NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM SCIENCE COLLABORATIVE

Sustaining Coastal Landscapes and Community Benefits: Developing an Interdisciplinary Model for Enhancing the Impact of NERRS Science

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Headwaters of the Merriland River, Branch Brook and Little River Watershed
Photo Credit C. Feurt

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Sustaining Coastal Landscapes and Community Benefits: Developing an Interdisciplinary Model for Enhancing the Impact of NERRS Science

Abstract

Riparian buffers and wetlands are a nexus for complex land use challenges where tradeoffs for ecosystem services must be evaluated. Coveted by developers and home owners, people and property in these areas are vulnerable to flooding, shoreline erosion and sea level rise. Natural buffers have water quality value for their ability to effectively filter nonpoint source pollution and are the last line of defense for stormwater runoff to estuaries. Ecologists recognize and value riparian habitats and fringing marshes for their complex roles in nutrient cycling and biodiversity. Thus far, however, this recognition and associated ecological data in the NERR system have been inadequately linked to social science approaches required to characterize and quantify tradeoffs in ecosystem service benefits, and methods to translate these results for effective policy guidance. This project developed an innovative model for interdisciplinary research to build capacity within the NERR system. The aim being to enhance the impact of NERRS science by applying an ecosystem based management approach to address complex land use challenges and facilitate dialogue and policy deliberation about ecosystem service tradeoffs.

Integrating ecosystem service tradeoffs into policy design can overcome barriers to effective management. Evaluation of ecosystem service tradeoffs requires rigorous coordination of social and ecological science to quantify changes in ecosystem services and assess how these changes affect society's well-being (Weinstein et al. 2007; Weinstein 2005, 2007; US EPA 2009). Ecosystem structure and function can be modeled using ecological methods, while economic methods are required to define and value associated ecosystem services. Although the sensitivity of ecosystem services to changes in riparian land use is unquestioned, the quantification of associated spatially-explicit human benefits and tradeoffs, as well as the use of resulting information to guide policy, is often hindered by methodological gaps between economic approaches though which ecosystem services are defined and valued and ecological paradigms through which ecosystem processes are modeled (Boyd and Banzhaf 2006; Johnston et al. 2010b; Wainger et al. 2010). Within this context, the National Estuarine Research Reserve System (NERRS) is uniquely positioned to test, implement and evaluate the application of EBM frameworks that integrate quantitative information on ecosystem service values and tradeoffs at a scale appropriate to improve decision-making. Over three decades of ecological research and monitoring, strong linkages to community education, a diverse and evolving suite of land stewardship practices and stakeholder engagement and training have generated rich collaborative networks anchored by the NERRS. Within these networks, coordinated social and natural science research methodologies can be rapidly and effectively deployed and linked to existing robust ecological frameworks and data. Rich ecological data like the System Wide Monitoring Program (SWMP) and related reserve-specific ecological data have yet to be broadly applied by the scientific, management and education communities to promote effective protection and conservation of estuarine habitats and ecosystem services. This project addressed gaps in the application and integration of socio-economic approaches to improve the impact of NERRS science on decision-making for riparian and wetland area management, including policy processes and decisions influencing land use, habitat and nonpoint source pollution.

Coastal Management Context and Decision-Making Arena

Ongoing land use changes in watersheds in and around the Wells NERR[1] exemplify common stressors to sustainable coastal ecosystems (Wells NERR 2006; Weinstein et al. 2007, Weinstein 2008, 2009; Coles et al. 2004).[2] Processes provided by these threatened systems support myriad ecosystem services, defined as the outputs of natural systems that provide benefits to society (Millennium Assessment 2005; US EPA 2009; Wainger et al. 2010). Many of these depend critically on the integrity and properties of riparian areas (Johnston et al. 2002a,b, 2005; Opaluch et al. 1999),[3] including aesthetic and cultural services related to scenery, wildlife, or other valued characteristics (Johnston et al. 2002a, 2005; Lupi et al. 2002; Zedler and Kercher 2005).

As the variety and intensity of development-related impacts on coastal New England's riparian areas grow, there have been numerous recommendations to move toward a more comprehensive, spatial, ecosystem-based approach to management that (1) accounts for multiple stressors, (2) considers the health of functioning ecosystems, and (3) accounts for spatially-explicit tradeoffs related to different ecosystem uses, users, and values (Holland et al. 2010). Ecosystem-based management (EBM) offers an interdisciplinary organizing framework for riparian area management that can better account for tradeoffs in ecosystem services and human benefits. Despite its promise, however, EBM presents numerous challenges (Feurt 2007; DeLauer 2009; Holland et al. 2010). Among the most critical are those related to the quantification and communication of tradeoffs between the services provided by natural ecosystems and otherwise beneficial human activities that degrade ecosystem structure and function, and integration of this information within stakeholder processes to guide policy (Feurt 2007; DeLauer 2009; Wainger et al. 2010).

In the absence of informed management able to promote sustainable tradeoffs, human actions typically trend towards a degradation of ecosystems that ultimately diminishes human welfare (Ehrlich and Ehrlich 2008; Turner and Daily 2008). Entities engaged in activities that degrade riparian ecosystem functions are often distinct from those who bear associated costs of degraded ecosystems, and may be unaware of their impacts. This manifestation of the "externality" problem in economics may be due to a lack of information on the presence or value of affected services, heterogeneous preferences among groups, differences between the locations at which impacts occur, and the fact that many ecosystem service values are not realized through markets (Bockstael et al. 2000; Freeman 2003; Johnston et al. 2005b; Robbins 2007; Troy and Grove 2008).

As a result of these and other impediments, residents, managers and stakeholder groups often engage in riparian and other land use decisions that are not in the long-term best interest of

[1] These include the Webhannet and Merriland River, Ranch Brook and Little River (MBLR).

[2] In the Wells NERR, housing growth over the past 25 years has been more than double the growth in population, with a 10-year growth rate of nearly 50% (Smith 2006), mirroring similar changes in other Estuarine Reserves nationwide.

[3] These include services related to (1) groundwater filtering and biogeochemical processing; (2) habitat provision; (3) prevention of flooding and erosion; (4) retention of toxics and pathogens; (5) production and primary export in aquatic food chains; (6) carbon sequestration (Howe 1987; Engelhardt and Ritchie 2001; Mitsch and Gosselink 1993; Wharton et al. 1982; Novitzki et al. 2001; Weller 1994; Sather and Smith 1994; Zedler and Kercher 2005).

the public, because they do not have the information required to accurately consider tradeoffs between the benefits/costs of development and associated losses of ecosystem services (Holland et al. 2010; Wainger et al. 2010). This lack of information persists despite the rich ecological data available within NERRS and elsewhere, because these data have been thus far poorly linked to (1) social science models required to characterize and quantify tradeoffs in ecosystem service benefits (Wainger et al. 2010; Johnston et al. 2010), and (2) methods to translate results for effective policy guidance (DeLauer 2009; McGuigan et al 2009; DeLauer et al 2010). The outcomes of this project provide information on ecosystem service tradeoffs and values in a concrete, useful format, available for use by Wells NERR in coordination with the Wells NERR stakeholder network to promote sustainable management of riparian land use and habitat (Adamowicz et al. 1998; Bateman et al. 2002; Bennett and Blamey 2001; Louviere et al. 2000; Johnston et al. 1999; 2001; 2002a,b,c,d; 2003a,c,d; 2005a,b; 2010a). Coordinated ecological/economic models and associated communication activities are built on data that include:

(1) spatially-explicit land use data for the Merriland River, Branch Brook, and Little River Watershed (MBLR),

(2) data on biogeophysical processes, water quality and habitat from Wells NERR monitoring and research,

(3) survey data on area households' characteristics, attitudes, knowledge and resource uses/activities,

(4) results from survey-based choice experiments characterizing households' preferences and values for specific ecosystem services and related tradeoffs, revealed through choices over multiattribute policy alternatives and

(5) descriptions of the mental models used by stakeholders to understand and evaluate the values of riparian buffers and their choices to manage them.

Results can be used to Integrate Ecosystem Service Tradeoffs into Policy Design to Overcome Management Barriers

Evaluation of ecosystem service tradeoffs requires rigorous coordination of social and ecological science to quantify changes in ecosystem services and assess how these changes affect society's well-being (Weinstein et al. 2007; Weinstein 2005, 2007; US EPA 2009). Ecosystem structure and function can be modeled using ecological methods, while economic methods are required to define and value associated ecosystem services. Although the sensitivity of ecosystem services to changes in riparian land use is unquestioned, the quantification of associated spatially-explicit human benefits and tradeoffs, as well as the use of resulting information to guide policy, is often hindered by methodological gaps between economic approaches though which ecosystem services are defined and valued and ecological paradigms through which ecosystem processes are modeled (Boyd and Banzhaf 2006; Johnston et al. 2010b; Wainger et al. 2010). Despite widespread recognition of ecosystem services, only rarely does management integrate quantitative, systematic information on these services and their economic value. Strategies and frameworks for improving linkages among disciplines and among researchers, managers and policy makers exist but are infrequently applied at the local scale where land use policy is crafted and decisions made (ORRAP Task Force 2007; Roux et al. 2006; Daniels & Walker 2001; Karl et al. 2007; NRC 2009; Brody 2003; Cash et al. 2002). This project provides a model for overcoming these interdisciplinary barriers using an integrated approach applied at a local scale where land use decision making is most relevant.

Within this context, the National Estuarine Research Reserve System (NERRS) is uniquely positioned to test, implement and evaluate the application of EBM frameworks that integrate quantitative information on ecosystem service values and tradeoffs at a scale appropriate to improve decision-making. Over three decades of ecological research and monitoring, strong linkages to community education, a diverse and evolving suite of land stewardship practices and stakeholder engagement and training have generated rich collaborative networks anchored by the NERRS. Within these networks, coordinated social and natural science research methodologies can be rapidly and effectively deployed and linked to existing robust ecological frameworks and data. This includes rich ecological data from the System Wide Monitoring Program (SWMP) and related reserve-specific ecological data collection efforts that have yet to be broadly applied by the scientific, management and education communities to promote effective protection and conservation of estuarine habitats and ecosystem services. This project drew from these strengths to begin to address gaps in the application and integration of socio-economic approaches to improve the impact of NERRS science on decision-making for riparian and wetland area management, including policy processes, communication strategies and decisions influencing land use, habitat and nonpoint source pollution.

Results provide concrete, practical information on ecosystem service values and tradeoffs associated with management of riparian land use and habitat. This can give policymakers and stakeholders understanding that can be applied to develop policies that are supported and accepted. Quantification of ecosystem service values associated with specific policy changes can be used by NERRS and its stakeholders with information crucial for appropriate policy design and for identifying often overlooked social and economic benefits of policies to enhance ecosystem services. Project results, for example, can be used to forecast the types of management that well-informed local residents are most likely to support, based on tradeoffs involving regulations, human uses, monetary costs, and effects on riparian ecosystem services. Results may also be used to estimate public support for different management alternatives based on outcomes, households' willingness to pay for particular ecosystem services, and the information needed by residents to consider tradeoffs. Results also characterize heterogeneity in benefits and costs of riparian area management, both spatially and across groups (Campbell et al. 2009; Johnston et al. 2002d, 2005b). This will allow those engaged in policy deliberations to consider not only total ecosystem service benefits and tradeoffs, but also who is affected and where.

The project results emphasize ecosystem service benefits to residents that (1) are likely to be most significant, based on qualitative research and information from prior research, and; (2) show a high degree of sensitivity to policy decisions, based on available ecological information. Preliminary interactions with Wells NERR stakeholders and area residents suggested these services as most important: (1) aesthetics and recreational use; (2) habitat and wildlife; (3) groundwater filtering, biogeochemical processing and water quality; (4) land preservation and development; and (5) flooding prevention. Research results provided validation and quantification of these preliminary ideas.

Results Connect to Priorities of the Wells NERR Stakeholder Network

The Wells NERR has a unique role and responsibility in ensuring that research, data, and science translation and synthesis to non-scientists is communicated in such a way that stakeholders and decision-makers are motivated and able to make informed decisions regarding riparian management. The NERR is strongly linked to a rich Gulf of Maine-wide stakeholder network of municipal, state and federal agencies, NGOs, academic institutions, policy makers and community groups (hereafter referred to as Wells NERR stakeholders).[4] The need for economic information on the consequences of riparian land use decisions, restoration priorities and conservation planning has been identified as a top priority among Wells NERR stakeholders.[5] Municipal decisions about land use, land trust decisions about conservation priorities, and state/federal prioritization of restoration funding require economic information to inform tradeoffs and clarify consequences, particularly related to ecosystem service tradeoffs and implications for sustainable human benefits. Moreover, the state of Maine, Gulf of Maine Region, and NERRS have all identified the need for increased use of social science to achieve EBM objectives, particularly when coordinated with natural science data and methods (Brookings 2006; GOMC 2006; NERRS 2009).

This project tested interdisciplinary methods (described in the following sections) of using NERRS ecological data and science expertise to evaluate social and economic tradeoffs associated with coastal resource management, specifically emphasizing ecosystem service tradeoffs and values associated with the management of riparian land use and habitat. These methods, specifically the design of the choice experiment, the communication audit and mental models research integrated and tested social science-based tools within stakeholder and policymaker networks. The decision-making context focused on coastal management problems related to land use change, habitat change and restoration and nonpoint source pollution. The challenges associated with integration of biophysical and social science research methods were of interest to the NERRS. Project outcomes dealing with these challenges were shared through meetings, workshops and trainings targeted to NERRS/NOAA audiences.

Results were a direct result of the composition and structure of the research team and the stakeholder network engaged in the project

Three interconnected spheres of stakeholders were engaged and contributed to the outcomes produced by this project. The sphere of the Wells NERR Science Collaborative

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[4] These include land trusts and conservation organizations from southern Maine; regional and municipal stakeholders from surrounding communities; state, federal and regional land use outreach and planning organizations; and other organizations including the Maine Geological Survey, Maine Association of Conservation Commissions, Maine Coastal Program, Maine NEMO, Maine Sea Grant, Maine Drinking Water Program, Maine Department of Inland Fisheries and Wildlife, Southern Maine Regional Planning Commission, Mt A to the Sea Conservation Initiative Partners, Rachel Carson National Wildlife Refuge, University of New England Center for Sustainable Communities, Laudholm Trust, Maine DEP. Piscataqua Region Estuaries Partnership.

[5] Looking Back, Moving Forward Workshop, 2008: 60 land trusts and conservation organizations from southern Maine; The Sanford Conservation Plan Process, 2008-2009: 20 regional and municipal stakeholders; The Summit at the Summit Working Group, 2009: 16 state, federal and regional land use outreach and planning organizations. Source Water Collaborative, 2009-2010: 20 ME & NH municipal, state and federal water managers. NERRS/NERRA Annual Conferences, 2008 7 2009: social science working group.

Team included all sectors of the Reserve – research, SWMP, GIS, education, stewardship, Coastal Training and the Wells NERR nonprofit partner, Laudholm Trust.

The second sphere was the Interdisciplinary Research Team representing researchers from the Wells NERR, Clark University and NOAA's Office for Coastal Management. This team included quantitative and qualitative researchers drawing from their expertise within the disciplines of ecology, geology, economics, communication and policy.

The third sphere of the Wells NERR Stakeholder Network included federal, state and municipal government officials, land trusts, NGOs, citizen groups and academic researchers from outside the project team. This group also included the participants in focus groups, stakeholder interviews and the over 1,000 residents of the watershed who completed the choice experiment and subsequently became members of Laudholm Trust for one year.[6]

<u>Participants in each sphere of the project are identified below:</u>

Wells NERR Science Collaborative Team
Dr. Christine Feurt (Science Integrator/Collaborative Lead), Dr. Kristin Wilson, Dr. Michele Dionne, Tin Smith, Suzanne Kahn, Jeremy Miller, Jake Aman, Sue Bickford, Annie Cox, Mike Mahoney, Chris Peter

Titles: Coastal Training Program (CTP) Coordinator, Research Director (2013-2015), Research Director (2009 –2012) Stewardship Coordinator, Education Director, Research Associate, Research Associate, GIS Specialist, CTP Associate, CTP Associate, Research Consultant (UNH)

Interdisciplinary Research Team
This interdisciplinary team designed and conducted economics, ecological, policy and communication research in collaboration with stakeholders.

Co-Principal Investigator Dr. Christine Feurt, CTP Coordinator, Wells NERR & Director Center for Sustainable Communities University of New England
Co-Principal Investigator: Dr. Robert Johnston, Director, George Perkins Marsh Institute and Professor, Department of Economics Clark University
Dr. Verna DeLauer, Research Scientist, George Perkins Marsh Institute, Clark University & Franklin Pierce University
Dr. Michelle Dionne, Research Director, Wells NERR
Mr. Ben Holland, PhD student, George Perkins Marsh Institute, Clark University
Mr. Peter Wiley, Economist, NOAA Office for Coastal Management
Dr. Kristin Wilson, Research Director, Wells NERR

[6] As an incentive to complete the 20 page *Choices for Our Land and Water Survey* participants were offered a one year free membership ($20 value) in Laudholm Trust, the non-profit partner of the Wells NERR. This group received all member benefits and invitations to special events at the Reserve during the year following the survey.

Wells NERR Stakeholder Network

Many of these organizations participated in the development of the initial proposal and stayed engaged throughout the project. The original group of 18 organizations expanded to 24 organizations during the course of the project. Representative members of the network interacted with the Wells NERR or Interdisciplinary Research Team to provide feedback on research design, progress, interpretation of results and incorporation of results in conservation, management and planning.

1. Maine Association of Conservation Commissions
2. Maine Geological Survey
3. Maine Coastal Program
4. Maine Nonpoint Education for Municipal Officials (NEMO)
5. Maine Sea Grant
6. Maine Drinking Water Program
7. Maine Department of Inland Fisheries and Wildlife, Beginning with Habitat
8. Maine Department of Environmental Protection
9. Maine Department of Marine Resources
10. Southern Maine Regional Planning Commission
11. Mt A to the Sea Conservation Initiative
12. Rachel Carson National Wildlife Refuge
13. University of New England
14. Laudholm Trust
15. Piscataqua Region Estuaries Partnership
16. Town of Wells, Planning Department
17. Town of Sanford, Planning Department
18. Town of Kennebunk, Conservation and Open Space Planning Committee & Planning Department
19. Kennebunk, Kennebunkport and Wells Water District
20. U Maine Sustainability Solutions Initiative
21. New England Sustainability Consortium (NEST) UNE, U Maine and UNH, EPSCoR
22. Maine Aquatic Resources Management Strategy (ARMS) Group
23. Mousam Kennebunk Rivers Alliance
24. U Maine & UNE EPSCoR, Sustainable Ecological Aquaculture Network (SEANET)

Sustaining Coastal Landscapes and Community Benefits
Interdisciplinary Research Summary

Interdisciplinary research and stakeholder engagement during the development of the research proposal and throughout the five years of the project were guided by the four objectives below. The summary of research findings in this section includes an overview of methods, results and outcomes for each aspect of the research. Ecological, economic, communication and policy aspects are summarized in this section.

Overall Project Objectives (excerpt from project proposal May 2009)

I. Develop a user-inspired, transdisciplinary model to guide sustainable riparian management in the Wells NERR and surrounding watersheds, grounded in geo-spatially explicit quantification of ecological/economic tradeoffs in ecosystem services and values.
II. Coordinate social science and cognitive theory, principles of effective communication, local motivations for stewardship/conservation, and approaches for social learning to:
    a. Identify specific stakeholders most influential in affecting decisions, management and policy change affecting Wells NERR riparian areas addressed in Objective I.
    b. Evaluate Wells NERR communication approaches to these identified stakeholders/stakeholder groups to assess the degree to which messages are in alignment with values and priorities identified in Objective I;
    c. Develop high impact, science-based communication strategies and decision support tools—based on the ecological/economic results of Objective I—to inform integrated management of riparian area land use, habitat and nonpoint source pollution in watersheds draining into the Wells NERR region.
III. Engage Wells NERR stakeholders, the Science Collaborative Team and the Project Research Team within a collaborative learning process to build long-term institutional and regional capacity for improved riparian management through a community of practice. Collaborative learning will be grounded in coordinated science, communication and decision support outputs of Objectives I and II.
IV. Based on results of prior objectives, develop transferable templates for application of developed methods to guide policy development and stakeholder interactions in other Estuarine Reserves. Integrate with NERRS/NOAA to assist in broader adoption.

Ecological Assessment of Riparian Buffers in the Little River Watershed

Prepared by Kristin Wilson, Ph.D.
Research Director, Wells National Estuarine Research Reserve
August 2014

Introduction

The goal of the ecological component of this study was to assess the health, or biotic integrity, of riparian areas of the Merriland River, Branch Brook, and Little River (MBLR) watershed. Biotic integrity can be defined as "the ability to support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to those of natural habitats within a region" (Karr and Dudley, 1981). Biological integrity is critical because it in turn determines the kinds and quality of ecosystem services that riparian waters and upland buffers provide for people living in the surrounding watershed (Brauman et al., 2007). Some of those ecosystem services include: clean drinking water, fish to catch for food or sport, safe and clean spots to swim, recreate or forage for wild edibles, erosion control, flood protection, and groundwater recharge, among others. Human activities, like changing land use, can alter the biological integrity of a system, shifting it along a gradient toward a threshold, over which the system slips from healthy to unhealthy (Fig 1; Karr, 1999). Vegetated, riparian buffers enhance stream biodiversity and water quality by regulating inputs of light, organic matter, sediment and nutrients (Sweeney et al., 2004). The delivery of these ecosystem services is spatially explicit, however (Sweeney et al., 2004) and may affect their associated societal value (Brauman et al., 2007). To assess biological integrity, the Wells Reserve measured a suite of biophysical and ecological attributes of riparian habitats of the MBLR watershed over the 3-year period from 2011-2013. This approach recognizes that multi-metric approaches are needed to fully understand the biological integrity of a system and contributions to ecosystem services provisioning (Karr, 1999; Luck et al., 2009).

Methods

MBLR Watershed

The MBLR watershed drains 30.4 mi^2 across the southern Maine towns of Sanford, Kennebunk, and Wells (Dionne et al., 2006). The headwaters of Branch Brook and the Merriland River begin in sandy glacial outwash near the Sanford Municipal Airport, and flow southeast, eventually coming together to form the Little River, which passes through the United States Fish & Wildlife Services Rachel Carson National Wildlife Refuge, the Wells National Estuarine Research Reserve, and a large back-barrier salt marsh before emptying into the Gulf of Maine at

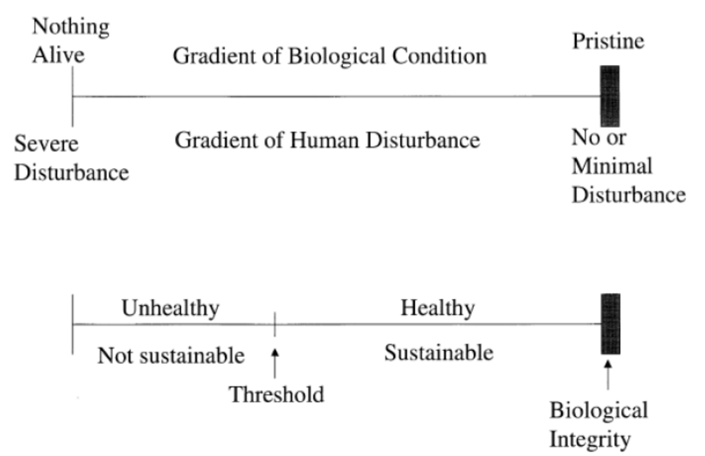

Fig. 1 At one end of a continuum of human influence on biological condition, severe disturbance eliminates all life; at the other end of the gradient are pristine, or minimally disturbed, living systems (top). A parallel gradient (bottom), from integrity towards nothing alive, passes through healthy, or sustainable, condition or activities. Below a threshold defined by specific criteria (see text), the conditions or activities are no longer healthy or sustainable in terms of supporting living systems.

Figure 1. From Karr (1999).

two popular swimming beaches, Laudholm Beach and Crescent Surf Beach (Fig 2). Branch Brook is underlain by 15-30 m thick sand and gravel deposits which overtop the Presumpscot Formation, a glacial marine clay deposited during the last deglaciation, around 15,000 BP (Kelley et al., 2010). Baseflow is primarily groundwater driven (D'Amore, 1983). The Merriland River is underlain by glacial till, stratified sand and gravel, and the Presumpscot Formation (Kuo, 1999). The MBLR watershed is more than 84% forested with less than 6% characterized as developed land (remaining 10% is 2% water, and 8% hay, pasture, and mowed land; Fig 2; Holden, 1997). Large portions of the watershed are protected as undeveloped forestland, either through the State or conservation easements on private lands. Significant portions of the Branch Brook watershed are protected because it serves as an important drinking water source for the Kennebunk, Kennebunkport, and Wells Water District which serves those three towns as well as Arundel, Biddeford, and York (Dionne et al., 2006).

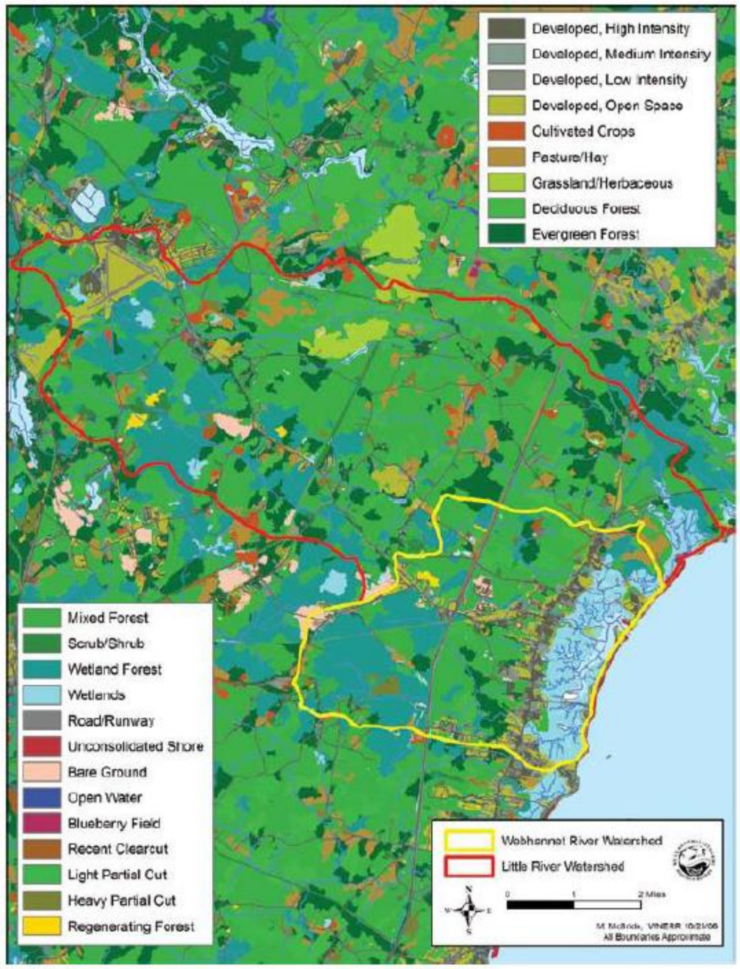

Fig 2. Land cover map of watersheds entering the Wells National Estuarine Research Reserve, with the Merriland River-Branch-Brook-Little River watershed outlined in red. Map is based on Landsat imagery from 1999-2001 (data from the Maine Office of GIS and the Maine Land Cover Database). Figure 5-1 in Dionne et al. 2006.

Site Selection and Access

We used Google Earth then ground-truthed sites to select 10 stream reaches, 5 each, along the Merriland River and Branch Brook (Fig 3). Reaches met the following criteria: (1) both main stem and tributaries were represented, (2) paired sites could be identified within the same reach that had both forested and open riparian buffers and were separated by at least 76 m, and (3) land-owner permission was granted for site access. In total, 17 different private landowners in the towns of Sanford, Kennebunk and Wells granted access to their lands over the three-year study. Forested buffers were defined as those that were nearly 100% vegetated by forest or other natural vegetation within a 100 m circular buffer of the study site, while open sites were those that had some development within the 100 m buffer and were cleared, at least in part, up to the stream edge (Fig 4a).

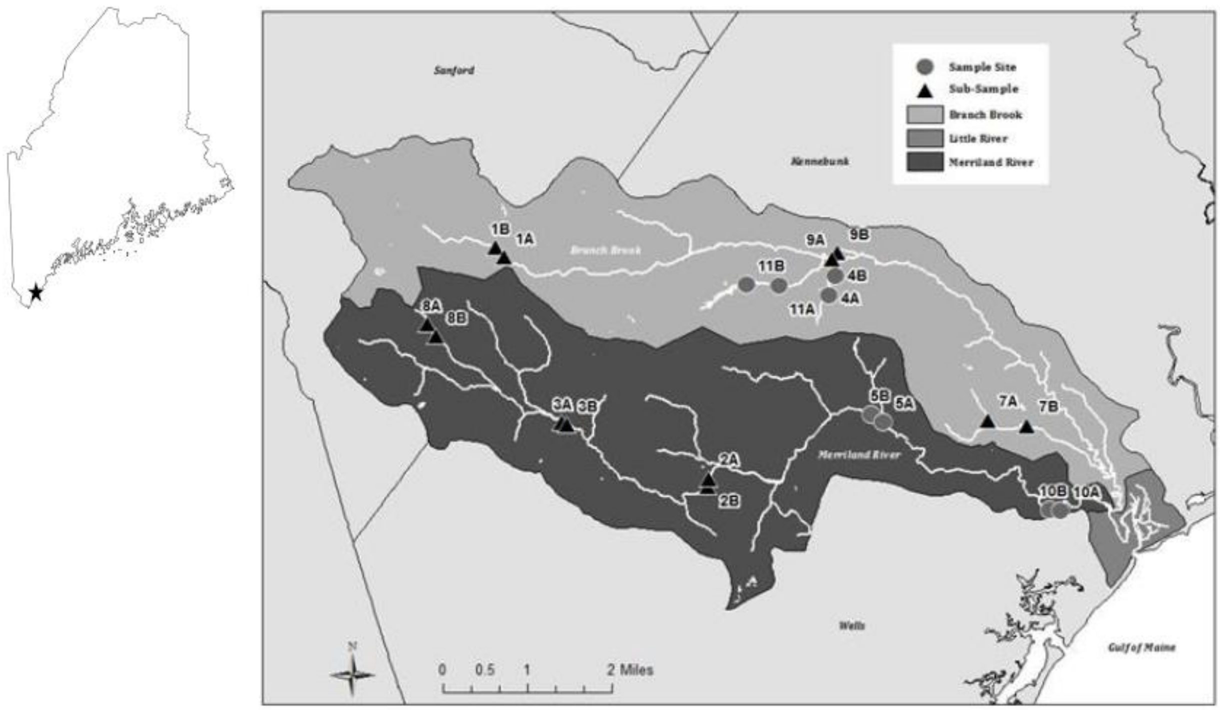

Figure 3. Map of the study area showing the Merriland River, Branch Brook, and Little River watersheds and study locations. A =forested sites and B = open sites.

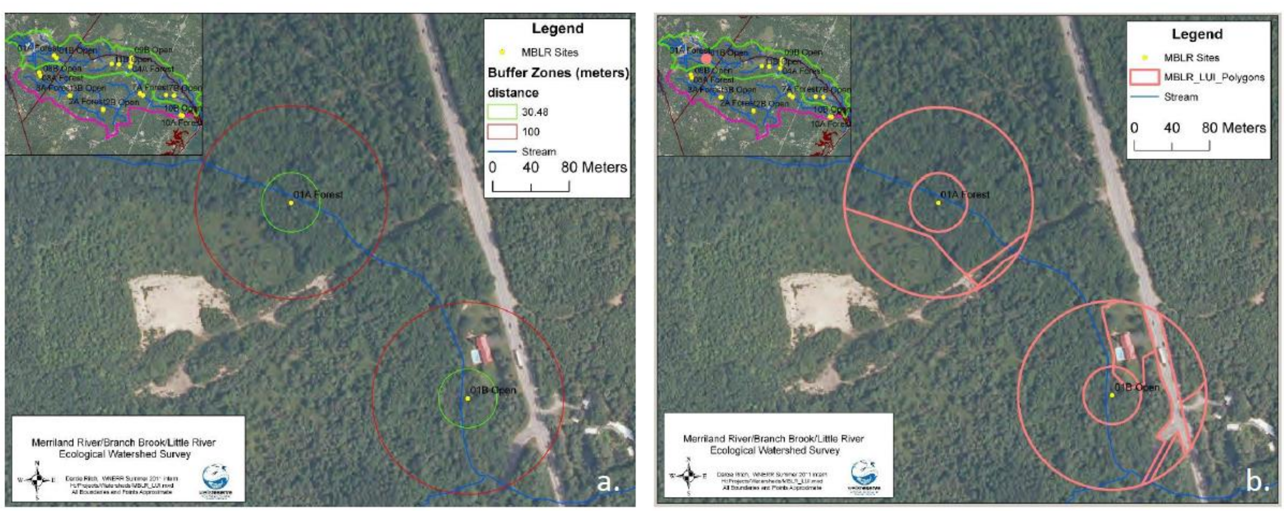

Figure 4. (a) Comparison of forested and open buffers with the 100 m buffer shown in red. (b) Example of how the land-use index was calculated using screen-digitized polygons and averaged scores of land-use classes within the 35 m and 100 m buffers.

Biophysical and Ecological Methods

To assess physical stream conditions at each site, in 2011, 2012, and 2013 we recorded water quality parameters (water temperature, pH, specific conductance, dissolved oxygen, and turbidity) at 15-minute intervals using YSI 6600 data sondes adapted for horizontal deployment for shallow water depths. We also quantified percent aquatic vegetative cover, stream bed percent cover, substrates, stream width and depth, stream gradient, velocity, discharge, in-stream large woody debris, bank condition, spawning gravel areas and the locations of pools/riffles/runs and pool quality using United States Department of Agriculture, Forest Service stream sampling protocols. To quantify buffer quality, we recorded stream bank percent vegetated cover, air temperature, canopy cover, and soil nutrients (NO^{3-} and NH^{4+} using buried, streamside resin bags). To supplement field observations, we calculated a land use index (LUI) for each site using aerial photographs to screen digitize polygons which were assigned land cover classes that were averaged for 35 m and 100 m buffers to further characterize riparian habitat (after Carlisle, 2002; Fig 4b, Appendix A). To characterize biotic communities in stream reaches, we measured epibenthic algae using unglazed ceramic tiles (after Barbour et al., 1999), identified macroinvertebrates to family using rock collection bags (after Davies and Tsomides, 2002; Fig 5a, b), and electroshocked fish to determine composition, abundance, and biomass (Fig 5c). We used the RBP II Index of Biotic Integrity (IBI) to analyze macroinvertebrate data (an analysis commonly used for New England streams; Shelton, 2004) and two different indices to assess fish community structure: the modified index of well-being (Ohio Environmental Protection Agency, 1987) and the cold water index of biotic integrity (Langdon, 2001). Biotic indices, univariate and multivariate tests including PRIMER, were used to compare biophysical conditions and ecological communities between buffer types and streams across years.

Figure 5. (a) Field deployment of a rock bag used to sample macroinvertebrates. (b) Macroinvertebrates found included dragonflies, water beetles, and dobsonflies. (c) Interns and staff of the Wells National Estuarine Research Reserve, electroshocking for fish.

Preliminary results from the ecological data in year one were used to inform focus group meetings and survey development to link measureable (and realistic) ecological outcomes to ecosystem services that were valued by area residents. Specifically, the ecological parameters included in the economic model included: (1) condition of the riparian landscape measured using the land use index, (2) impacts of nutrient loading (using nutrient data) on the ecological condition of proximate water bodies, and (3) fish assemblage and abundance effects.

Results & Discussion

Comparison of River Systems

Both Branch Brook and the Merriland River provide high quality stream habitat. Waters provide cool, average summertime temperatures (17-19˚C), are high in dissolved oxygen (84-97% saturation; 8-9 mg/L) and have no indication of chronic pollution indicators (normal ranges for pH, turbidity, and specific conductance). Analyses of the macroinvertebrate IBI scores further suggest that water quality in both systems is good. On average and compared to the Merriland River, Branch Brook has faster flowing water (0.14 ± 0.03 m/s vs. 0.05 ± 0.01 m/s; *F-ratio 5.30, p = 0.028*), more large woody debris (9.47 ± 1.38 pieces/reach vs. 2.71 ± 0.55 pieces/reach; *F-ratio 19.18, p = <0.001*), more sandy substrates (60 ± 4% vs. 26 ± 6%; *F-ratio 16.85, p = < 0.001*) and lower macroinvertebrate IBI scores (25.17 ± 1.97 vs 28.67 ± 1.19; *F-ratio 4.58, p = 0.041*; Appendix B).

Both systems support diverse fish communities. Overall, 13 different species were observed in both systems, including one invasive species (chain pickerel), two state listed species of concern (Eastern brook trout and the American eel), and three diadromous species (Eastern brook trout, American eel, and sea lamprey). Averaged across years, the Merriland River had: (1) significantly fewer fish, (2) significantly fewer Eastern brook trout, (3) significantly lower modified index of well-being scores, and (4) significantly lower cold water index of biological integrity (CWIBI) scores, than Branch Brook (Fig 6; Appendix C). CWIBI scores indicate that Branch Brook provides "very good" stream habitat for cold water species, while score ranges for the Merriland River are in the "poor" to "fair" range (Langdon, 2001).

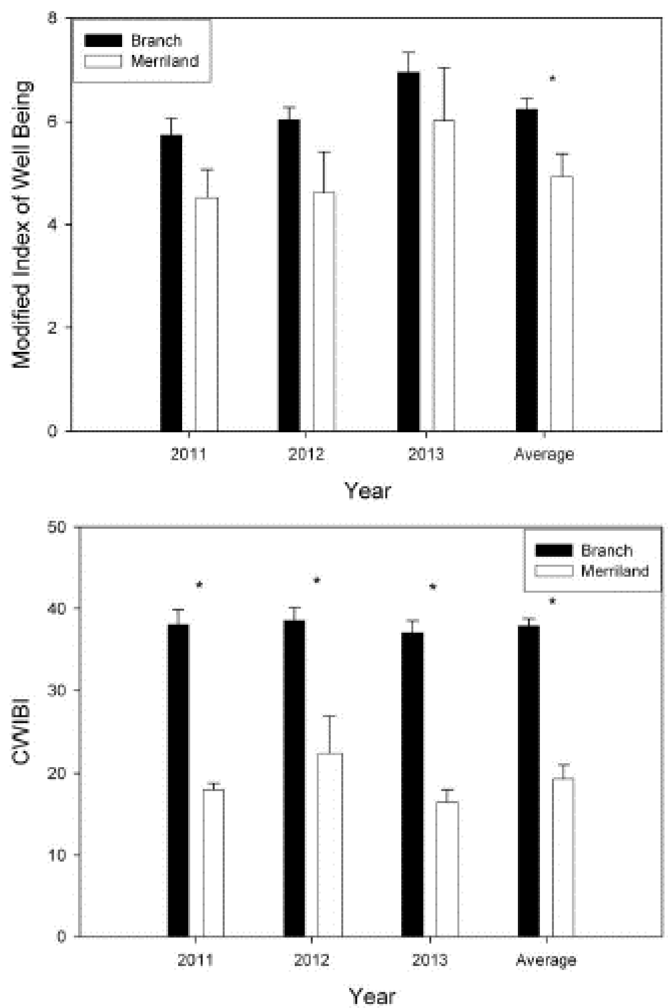

Figure 6. Scores for the Modified Index of Well Being and the Cold Water Index of Biotic Integrity that compares fish communities of Branch Brook (black) and the Merriland River (white). Branch Brook scores consistently higher than the Merriland (asterisk denotes significance at the p =0.05 level).

The driver for the difference in scores between systems is the number of brook trout (Fig 7). Branch Brook supports many more brook trout of all sizes than the Merriland River, including both young of year (YOY) and adult fish (Fig 7). Further analyses of average dissimilarity measures between systems indicate that in addition to Eastern brook trout, the American eel contributes the second most to differences in fish communities between rivers (a larger component of the Merriland River; Appendix D).

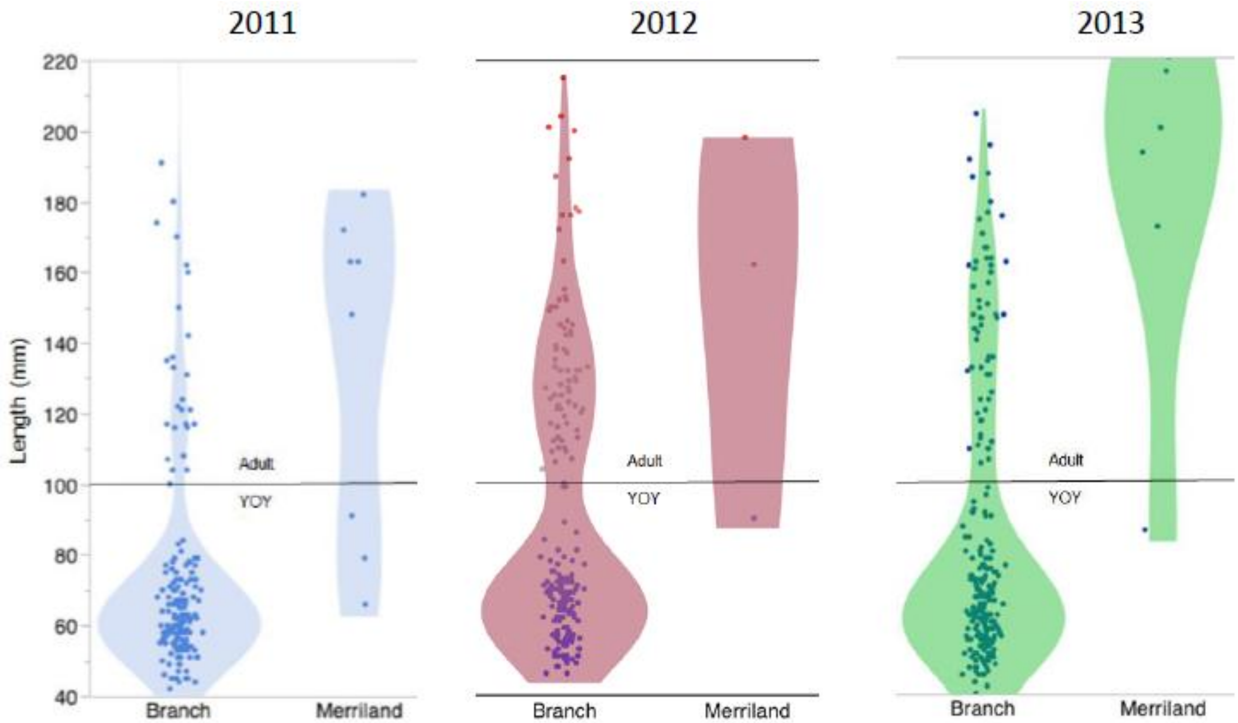

Figure 7. In all years, Branch Brook supports many more Eastern brook trout of all size ranges than the Merriland River, where each dot represents a fish and the horizontal line indicates the division between young of year (YOY) fish and adults based on size.

Comparison of Buffer Types: Forested versus Open

Analyses by buffer types indicate there were no measureable differences in any water quality, stream habitat, or biotic metric measured (Appendix E). These data suggest that differences in buffer quality are not as important as between stream differences in this southern Maine watershed. This result was surprising, but it is important to remember that riparian buffer condition exists along a continuum, that >84% of the MBLR watershed is forested (Holden, 1997), and that average LUI scores were greater than 59 at all sites (most were greater than 85; Table 1). In a 2007 review, Brauman et al. found that in general, land cover effects on hydrologic process are not observed until at least 20% of the watershed is converted from natural vegetation to other land cover types. This likely explains why no differences were found between forested and open sites in this study and suggests this watershed is at a critical point in space and time. In fact, additional analyses reveal that system wide, fish biomass is significantly and positively correlated with the amount of canopy cover (Fig 8a) and significantly and negatively correlated with the amount of fine sediments present in these rivers (Fig 8b).

These results suggest that if fish are valued by residents of the MBLR watershed, then there are conservation actions like planting trees in riparian areas to increase canopy cover or sediment erosion reduction measures like silt fencing that can be put in place to increase fish biomass.

Table 1. Average land-use index scores by site reveal high values at most sites, where 100 indicates complete natural vegetation.

Site	Average LUI Score
1A	93.86
1B	87.59
2A	94.78
2B	90.19
3A	92.42
3B	93.09
4A	92.81
4B	86.16
5A	94.83
5B	79.57
7A	93.65
7B	89.33
8A	91.96
8B	94.17
9A	91.54
9B	78.71
10A	95.00
10B	59.19
11A	89.00
11B	87.18

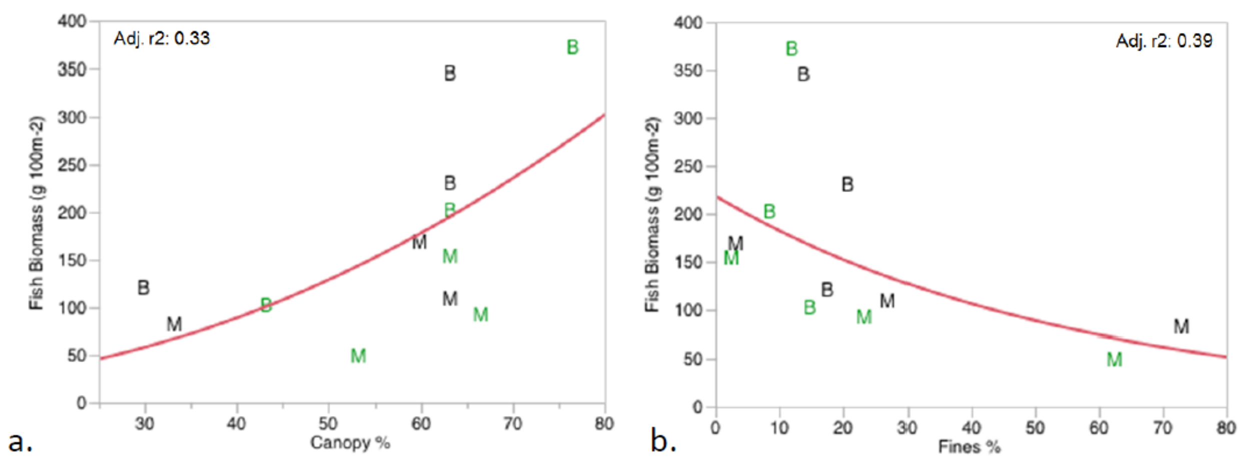

Figure 8. In both the Merriland River (M) and Branch Brook (B) for both open (black font) and forested (green font) sites, fish biomass is significantly positively correlated with percent canopy cover (a) and significantly and negatively correlated with the percentage of fine sediments in the system (b).

Lessons Learned

From an ecological perspective, this study provides new ecological information and important context for watersheds feeding into the Wells NERR. It is an exciting example of how authentic, site-specific ecological data can contribute to economic analyses that inform interpretations of residents' valuation of riparian habitats and their mental models of this ecotone.

This project would have benefitted from more in-person, whole-team data synthesis sessions, particularly toward the "end" of the project. It feels as though we just started seeing how these pieces fit together as the project came to a close. It seems like there are many logical extensions of this work. I am particularly excited to think about how both the mental modelling piece and the economic analyses may help re-frame the science stories I tell from this project. I hope to keep working with and learning from these new colleagues moving forward.

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Note

This synthesis prepared in 2014, was compiled by Kristin Wilson and incorporates earlier syntheses, summaries, progress reports, and notes from present and past Wells NERR staff and contractors who have worked on this project, principally including: Michele Dionne, Chris Peter, Hannah Wilhelm, Jake Aman, Tin Smith, Jeremy Miller, and Darcie Ritch.

Appendix A. Land use bins and weights used to calculate the land-use index scores for each site.

CATEGORY	DEFINITION	BIN	BIN_weight
Cropland	Intensive agriculture	Agriculture	4
Pasture	Extensive agriculture	Agriculture	3
Forest	Forest	Natural	1
Wetland	Nonforested freshwater wetland	Natural	1
Mining	Sand, gravel & rock	Disturbed Open	3
Open Land	Abandoned agriculture, power lines, areas of no vegetation	Maintained Open	2
Participation	Golf, tennis, Recreation Playgrounds, skiing	Maintained Open	2
Spectator	Stadiums, racetracks, Recreation Fairgrounds, drive-ins	Urban	4
Water Based	Beaches, marinas Recreation Swimming pools	Maintained Open	2
Residential	Multi-family	Residential High	5
Residential	Smaller than ¼ acre lots	Residential High	4
Residential	¼ – ½ acre lots	Residential High	4
Residential	Larger than ½+ acre lots	Residential Low	3
Salt Wetland	Salt marsh	Natural	1
Commercial	General urban, shopping center	Urban	5
Industrial	Light & heavy industry	Urban	5
Urban Open	Parks, cemeteries, public & institutional greenspace, also vacant undeveloped land	Maintained Open	2
Transportation	Airports, docks, divided highway Freight storage, railroads	Urban	5
Waste Disposal	Landfills, sewage lagoons	Urban	5
Water	Fresh water, coastal embayment	Natural	1
Woody Perennial	Orchard, nursery, cranberry bog	Agriculture	3

Appendix B. Statistics for habitat characterization comparing Branch Brook and the Merriland River by year and averaged across years. LWD = large woody debris.

Habitat Characteristics 2011-13	Branch	SE	Merriland	SE	F ratio	p value
Avg. Velocity (m s^{-1})	0.14	0.03	0.05	0.01	5.30	0.028
Discharge ($m^3 s^{-1}$)	0.17	0.05	0.07	0.03	2.23	0.146
Avg. Channel Width (m)	5.89	0.60	7.26	0.79	1.74	0.197
Avg. Depth (m)	0.21	0.05	0.25	0.06	0.22	0.639
Resident Fish Spawning Area (m^2)	42.32	9.29	28.41	10.57	0.61	0.441
Anadromous Spawning Area (m^2)	5.65	5.65	12.60	10.23	--	--
Num. LWD $reach^{-1}$	9.47	1.38	2.71	0.55	19.18	<0.001
Pool Area (m^2)	231.23	33.72	657.24	338.70	0.05	0.825
Num. Pools $reach^{-1}$	3.94	0.43	2.11	0.55	6.35	0.017
Num. Riffle $reach^{-1}$	2.06	0.49	1.67	0.41	0.68	0.418
Undercut Banks (%)	73.53	10.60	36.11	11.29	--	--
Stream Bed						
Bedrock (rel. %)	0.00	0.00	3.14	1.73	--	--
Boulders (rel. %)	1.35	0.62	10.81	3.81	--	--
Rubble (rel. %)	2.71	0.74	15.28	4.66	--	--
Gravel (rel. %)	21.01	3.97	12.65	2.46	2.94	0.097
Sand (rel. %)	60.14	4.43	26.06	6.45	16.85	<0.001
Fines (rel. %)	14.78	2.24	32.05	7.19	0.31	0.583
Total Aquatic Veg (%)	7.22	2.26	21.67	5.32	5.91	0.021
Buffer Vegetation						
Canopy %	56.67	4.12	56.67	3.23	0.00	1.000
Trees (rel. %)	17.25	2.74	21.28	1.68	2.32	0.139
Shrubs (rel. %)	9.50	2.33	9.29	2.36	0.00	0.957
Grasses (rel. %)	10.24	3.79	8.30	2.00	0.60	0.444

Appendix C. Fish statistics comparing Branch Brook and the Merriland River by year and averaged across years. Miwb = modified index of well being, CWIBI = cold water index of well-being, and BT = brook trout.

Fish Metrics	Branch	SE	Merriland	SE	F ratio	p vaule
2011						
Miwb	5.73	0.33	4.52	0.55	3.64	0.086
CWIBI	38.00	1.84	18.00	0.77	100.00	<0.001
Species Richness (spp. $reach^{-1}$)	2.67	0.49	3.50	0.50	1.41	0.263
Fish Density (# $100m^{-2}$)	25.43	7.47	9.26	2.33	3.23	0.102
BT Density (# $100m^{-2}$)	23.01	7.38	0.81	0.13	28.57	<0.001
Fish Biomass (g $100m^{-2}$)	143.75	38.88	142.47	22.73	0.00	0.978
2012						
Miwb	6.03	0.24	4.62	0.79	2.93	0.118
CWIBI	38.50	1.63	22.50	4.30	12.13	0.006
Species Richness (spp. $reach^{-1}$)	2.83	0.48	3.17	0.54	0.21	0.655
Fish Density (# $100m^{-2}$)	28.68	10.01	5.47	1.52	8.96	0.014
BT Density (# $100m^{-2}$)	24.63	8.46	0.91	0.54	30.58	<0.001
Fish Biomass (g $100m^{-2}$)	248.89	63.16	79.35	22.13	6.42	0.029
2013						
Miwb	6.95	0.38	6.01	1.03	0.99	0.35
CWIBI	37.00	1.48	16.50	1.50	86.76	<0.001
Species Richness (spp. $reach^{-1}$)	3.83	0.54	4.25	1.11	0.14	0.717
Fish Density (# $100m^{-2}$)	35.45	12.94	6.27	2.80	10.88	0.011
BT Density (# $100m^{-2}$)	25.24	9.17	0.72	0.13	28.86	<0.001
Fish Biomass (g $100m^{-2}$)	292.65	63.94	123.52	22.04	4.28	0.073
Average						
Miwb	6.24	0.21	4.93	0.44	6.62	0.016
CWIBI	37.83	0.91	19.31	1.71	97.53	<0.001
Species Richness (spp. $reach^{-1}$)	3.11	0.30	3.56	0.38	1.20	0.283
Fish Density (# $100m^{-2}$)	29.85	5.72	7.09	1.25	22.04	<0.001
BT Density (# $100m^{-2}$)	24.30	4.54	0.82	0.20	86.88	<0.001
Fish Biomass (g $100m^{-2}$)	228.43	34.20	114.06	14.21	9.23	0.005

Appendix D. Analysis of dissimilarity between Branch Brook and the Merriland River show that Eastern brook trout and the American eel contribute the most to what makes these system different in terms of their fish communities.

Species	Fish Density (# 100m^{-2}) Branch	Merriland	Contribution to Dissimilarity %	Cumulative Contribution %
	2011 - Avg. Dissimilarity = 59.20			
Salvelinus fontinalis	23.01	0.81	52.86	52.86
Anguilla rostrata	2.00	6.66	21.05	73.90
Catostomus commersonii	0.11	1.32	9.57	83.48
Esox niger	0.00	0.32	6.71	90.19
Notropis cornutus	0.09	0.00	3.36	93.55
Ameiurus nebulosus	0.21	0.00	2.92	96.47
Lepomis gibbosus	0.00	0.07	1.56	98.03
Salmo trutta	0.00	0.04	0.98	99.02
Unknown	0.00	0.04	0.98	100.00
	2012 - Avg. Dissimilarity = 67.38			
Salvelinus fontinalis	24.63	0.91	53.21	53.21
Anguilla rostrata	3.05	3.20	17.74	70.95
Catostomus commersonii	0.12	0.54	7.68	78.63
Esox niger	0.00	0.36	7.24	85.87
Semotilus corporalis	0.52	0.11	4.26	90.13
Lepomis gibbosus	0.00	0.34	4.05	94.18
Cyprinidae spp.	0.16	0.00	2.70	96.88
Ameiurus nebulosus	0.10	0.00	1.56	98.44
Pungitius pungitius	0.10	0.00	1.56	100.00
	2013 - Avg. Dissimilarity = 66.31			
Salvelinus fontinalis	25.24	0.71	44.87	44.87
Anguilla rostrata	2.11	2.56	10.87	55.74
Lepomis gibbosus	4.28	0.55	10.21	65.95
Semotilus atromaculatus	0.21	1.47	8.82	74.77
Cyprinidae spp.	2.55	0.00	6.71	81.48
Catostomus commersonii	0.55	0.38	5.90	87.38
Semotilus corporalis	0.00	0.54	4.87	92.25
Pungitius pungitius	0.37	0.00	4.26	96.51
Petromyzon marinus	0.13	0.00	2.30	98.82
Esox niger	0.00	0.05	1.18	100.00

Appendix E. Statistical results for all study parameters comparing forested versus open buffers.

	Forested	SE	Open	SE	F ratio	p value
2011						
Temperature (°C)	18.62	0.83	18.92	0.75	0.07	0.795
Diss. Oxygen (% sat)	88.47	6.03	84.12	6.12	0.26	0.624
Diss. Oxygen (mg L^{-1})	8.30	0.64	7.78	0.66	0.31	0.587
Spec. Cond. (mS cm^{-1})	0.08	0.01	0.07	0.01	0.66	0.429
pH	6.57	0.13	6.66	0.13	0.26	0.619
$NO3^-$ (mg L^{-1})	1.75	0.35	1.95	0.39	0.16	0.697
Turbidity (NTU)	3.40	0.74	16.71	4.95	10.81	0.004
2012						
Temperature (°C)	18.50	0.74	19.13	0.81	0.33	0.574
Diss. Oxygen (% sat)	92.53	2.51	89.42	4.09	0.42	0.530
Diss. Oxygen (mg L^{-1})	8.83	0.28	8.56	0.51	0.22	0.649
Spec. Cond. (mS cm^{-1})	0.07	0.01	0.04	0.01	3.83	0.066
pH	6.77	0.11	6.73	0.12	0.07	0.788
$NO3^-$ (mg L^{-1})	1.46	0.48	1.18	0.54	1.12	0.289
Turbidity (NTU)	2.13	0.39	1.86	0.30	0.14	0.714
2013						
Temperature (°C)	18.33	0.49	18.40	0.58	0.01	0.932
Diss. Oxygen (% sat)	98.82	4.17	92.65	4.19	1.09	0.321
Diss. Oxygen (mg L^{-1})	9.88	0.55	9.12	0.60	0.89	0.369
Spec. Cond. (mS cm^{-1})	0.08	0.02	0.07	0.01	0.49	0.495
pH	6.27	0.12	6.06	0.13	1.43	0.248
$NO3^-$ (mg L^{-1})	--	--	--	--	--	--
Turbidity (NTU)	49.48	45.94	25.38	21.84	0.01	0.928
Average						
Temperature (°C)	18.48	0.39	18.83	0.41	0.32	0.575
Diss. Oxygen (% sat)	93.27	2.64	88.73	2.78	1.41	0.244
Diss. Oxygen (mg L^{-1})	9.00	0.32	8.49	0.35	1.31	0.262
Spec. Cond. (mS cm^{-1})	0.08	0.01	0.06	0.01	3.69	0.060
pH	6.54	0.08	6.50	0.09	0.29	0.592
$NO3^-$ (mg L^{-1})	1.60	0.29	1.57	0.34	0.26	0.617
Turbidity (NTU)	18.34	15.33	14.28	6.95	1.67	0.201

Habitat Characteristics 2011-13	Forested	SE	Open	SE	F ratio	p value
Avg. Velocity (m s^{-1})	0.09	0.03	0.10	0.03	0.72	0.404
Discharge ($m^3 s^{-1}$)	0.09	0.03	0.15	0.05	0.88	0.355
Avg. Channel Width (m)	6.28	0.69	6.87	0.74	0.31	0.582
Avg. Depth (m)	0.21	0.05	0.25	0.06	0.24	0.631
Resident Fish Spawning Area (m^2)	35.91	10.59	36.18	9.35	0.01	0.929
Anadromous Spawning Area (m^2)	10.94	10.20	7.31	5.80	--	--
Num. LWD $reach^{-1}$	5.93	1.45	6.82	1.40	0.08	0.787
Pool Area (m^2)	638.44	340.28	250.03	31.15	0.08	0.779
Num. Pools $reach^{-1}$	2.78	0.42	3.28	0.64	0.40	0.534
Num. Riffle $reach^{-1}$	2.00	0.41	1.72	0.50	0.31	0.581
Undercut Banks (%)	55.56	12.05	52.94	11.72	--	--
Stream Bed						
Bedrock (rel. %)	2.86	1.73	0.29	0.29	--	--
Boulders (rel. %)	5.61	2.71	6.86	3.36	--	--
Rubble (rel. %)	8.67	3.61	9.72	3.92	--	--
Gravel (rel. %)	16.95	3.14	16.46	3.70	0.02	0.903
Sand (rel. %)	45.15	7.29	39.93	6.57	0.24	0.631
Fines (rel. %)	20.76	5.24	26.74	6.39	0.33	0.570
Total Aquatic Veg (%)	20.00	5.36	8.89	2.67	3.08	0.089
Buffer Vegetation						
Canopy %	61.11	3.01	52.22	4.01	2.81	0.104
Trees (rel. %)	20.68	2.33	17.88	2.20	0.93	0.343
Shrubs (rel. %)	9.07	2.35	9.73	2.35	0.01	0.920
Grasses (rel. %)	9.64	3.47	8.82	2.34	0.10	0.753

Macroinvertebrate Metrics	Forested	SE	Open	SE	F ratio	p value
IBI	19.50	3.17	21.50	2.94	0.21	0.654
IBI % Reference	0.39	0.05	0.42	0.05	0.19	0.675
FBI	4.50	0.44	4.54	0.39	0.01	0.946
% Contribution of Dominant Taxon	51.87	7.46	47.97	4.99	0.19	0.673
EPT : Chironomidae Abundance	0.44	0.08	0.50	0.11	0.19	0.669
Taxa Richness (spp. $reach^{-1}$)	9.67	2.11	10.83	2.14	0.15	0.706
Total abundance (# bag^{-1})	25.58	9.90	19.81	4.89	0.27	0.612
EPT Index	5.00	0.82	5.50	1.28	0.11	0.749
2012						
IBI	27.50	1.20	31.00	1.67	2.88	0.120
IBI % Reference	0.52	0.02	0.59	0.03	3.18	0.105
FBI	4.86	0.29	4.77	0.22	0.07	0.792
% Contribution of Dominant Taxon	62.16	6.51	48.38	7.37	1.96	0.192
EPT : Chironomidae Abundance	0.39	0.12	0.46	0.08	0.23	0.640
Taxa Richness (spp. $reach^{-1}$)	17.33	1.84	20.17	1.14	1.72	0.219
Total abundance (# bag^{-1})	117.89	24.95	99.42	16.97	0.38	0.554
EPT Index	9.67	1.09	10.83	0.87	0.70	0.422
2013						
IBI	30.50	2.50	31.50	1.28	0.13	0.729
IBI % Reference	0.57	0.04	0.58	0.02	0.05	0.827
FBI	4.66	0.26	4.94	0.23	0.65	0.438
% Contribution of Dominant Taxon	53.38	6.57	58.01	5.94	0.27	0.613
EPT : Chironomidae Abundance	0.41	0.09	0.34	0.07	0.34	0.572
Taxa Richness (spp. $reach^{-1}$)	18.83	0.79	20.33	1.02	1.35	0.273
Total abundance (# bag^{-1})	102.42	32.24	109.45	21.97	0.03	0.861
EPT Index	8.67	0.33	9.50	0.76	1.00	0.341
Average						
IBI	25.83	1.73	28.00	1.59	1.37	0.251
IBI % Reference	0.49	0.03	0.53	0.03	1.31	0.261
FBI	4.68	0.19	4.75	0.16	0.08	0.773
% Contribution of Dominant Taxon	55.80	3.88	51.45	3.53	0.67	0.421
EPT : Chironomidae Abundance	0.41	0.05	0.43	0.05	0.08	0.785
Taxa Richness (spp. $reach^{-1}$)	15.28	1.33	17.11	1.35	1.97	0.171
Total abundance (# bag^{-1})	81.96	16.38	76.22	13.13	0.12	0.736
EPT Index	7.78	0.65	8.61	0.77	1.28	0.270

Fish Metrics	Forested	SE	Open	SE	F ratio	p value
2011						
Miwb	5.73	0.41	5.53	0.57	1.37	0.269
CWIBI	28.00	5.12	28.00	4.22	0.00	1.000
Species Richness (spp. $reach^{-1}$)	2.67	0.45	3.17	0.60	0.05	0.828
Fish Density (# $100m^{-1}$)	25.43	8.05	17.29	4.75	0.21	0.661
BT Density (# $100m^{-1}$)	13.72	8.66	10.11	5.24	0.00	0.956
Fish Biomass (g $100m^{-2}$)	143.75	21.63	176.57	33.36	2.83	0.123
2012						
Miwb	5.62	0.54	5.03	0.48	0.40	0.541
CWIBI	28.00	5.98	33.00	2.90	0.57	0.460
Species Richness (spp. $reach^{-1}$)	3.17	0.54	2.83	0.48	0.21	0.656
Fish Density (# $100m^{-1}$)	22.11	11.59	12.04	3.45	0.06	0.813
BT Density (# $100m^{-1}$)	17.29	10.29	8.25	3.75	0.00	0.974
Fish Biomass (g $100m^{-2}$)	186.42	66.97	141.81	51.67	0.28	0.609
2013						
Miwb	6.19	0.76	6.95	0.55	0.65	0.442
CWIBI	28.80	4.61	28.80	5.82	0.00	1.000
Species Richness (spp. $reach^{-1}$)	3.60	0.87	4.40	0.60	0.57	0.471
Fish Density (# $100m^{-1}$)	28.40	17.98	19.15	4.91	0.03	0.866
BT Density (# $100m^{-1}$)	19.97	12.58	10.89	5.46	0.05	0.837
Fish Biomass (g $100m^{-2}$)	216.31	74.67	233.68	65.13	0.03	0.866
Average						
Miwb	5.47	0.31	5.77	0.42	0.45	0.509
CWIBI	28.24	2.90	30.00	2.39	0.24	0.629
Species Richness (spp. $reach^{-1}$)	3.24	0.34	3.41	0.34	0.19	0.666
Fish Density (# $100m^{-1}$)	22.30	6.85	15.98	2.48	0.04	0.852
BT Density (# $100m^{-1}$)	16.82	5.66	9.68	2.62	0.01	0.936
Fish Biomass (g $100m^{-2}$)	168.12	32.89	181.10	28.54	0.09	0.766

Economics: Quantifying Preferences and Values for Aquatic Ecosystem Services

Prepared by Robert Johnston Ph.D., Director George Perkins Marsh Institute and Department of Economics Clark University

August 2014

The economics component of the project coordinated with the ecological and engagement components to (1) identify and disentangle the unique contributions of different ecosystem services to human well-being, (2) quantify changes in these services resulting from alternative policy interventions, (3) estimate valid and consistent economic values, and (4) evaluate implications for policy development. Results demonstrate the different ways that riparian land contributes to aquatic ecosystem services valued by the public and the coordinated use of economic and ecological models to estimate these values. These include results quantifying households' preferences and willingness to pay (WTP) for ecosystem service outcomes of riparian land restoration in the Merriland, Branch Brook, and Little River (MBLR) watershed.

The transdisciplinary approach is grounded in an ecological-economic model linking ecosystem services influenced by riparian land restoration to benefits realized by area residents. The value of these services is reflected in WTP, or the maximum amount that households would be willing to pay (e.g., in a bond payment) to obtain increases in particular ecosystem services, rather than go without. The resulting data enabled estimation of the WTP of area residents for options that would restore between 0 and 500 acres of riparian land in the watershed, along with associated changes in recreational fish abundance, swimming safety, river ecology, and riparian development restrictions. Results also enable prediction of public voting patterns for riparian land conservation proposals in the MBLR watershed, and allow the identification of policy options with the greatest predicted public benefit.

Economic preferences, values and tradeoffs are estimated using an application of discrete choice experiments coupled with the targeted ecological data and modeling detailed above. Discrete choice experiments present survey respondents with voting-type choices between multi-attribute policy options, in this case for riparian area conservation in the MBLR watershed. Each option is described by indicators of ecosystem services developed and refined in prior research phases. That is, surveyed households are presented with policy choices, similar to public referenda, that allow them to choose among riparian land restoration policies with different effects on quantities, qualities and uses of ecosystem services (as quantified and forecast by ecological models and data, summarized above), along with attributes of the policy process required to provide those outcomes. Households' observed choices (or votes) over many sets of options enables the estimation of economic preferences, tradeoffs and values.

The model and choice experiments were developed and tested over more than 3 years in a collaborative process involving scientists and other experts from the Wells National Estuarine Research Reserve. This included in-depth coordination between ecologists and economists to develop the coupled economic and ecological models and data underlying the choice experiment, along with meetings with managers and stakeholders. Nine focus groups were used to inform survey development and test questionnaire designs. Survey language, graphics and maps were pretested carefully to ensure respondent comprehension. Particular attention was given to the presentation and interpretation of ecological information, including the amount and type of information required by individuals in able to provide meaningful survey responses. Based on input from this extensive pretesting, the survey provided information (1) describing the status of riparian land in the study area, (2) characterizing affected ecological systems and linkages, (3) describing restoration outcomes, and (4) providing definitions, derivations and interpretations of attributes used in survey scenarios. Information was conveyed via a combination of text, graphics including Geographic Information System (GIS) maps, and photographs, all of which were subject to careful pretesting. This information was followed by a sequence of voting questions through which respondents expressed their preferences and values for ecosystem services. Three independent survey treatments were developed and tested, each enabling different sets of hypotheses to be tested regarding the value of aquatic ecosystem services in the MBLR watershed. This included a survey treatment explicitly quantifying the effect of explicit spatial information (i.e., the location of each respondent's household relative to affected riparian land) on respondents' support for riparian land conservation.

The model underlying the choice experiment begins with a standard random utility specification in which household h chooses among three policy options, ($k = A, B, N$) for ecosystem service restoration. These include two multi-attribute riparian land restoration options (A, B) and a status quo (N) option with no restoration and zero household cost. Each policy option is characterized by a vector of attributes, $\mathbf{X} = [X_1 \ldots X_J]$, representing policy outcomes. These include quantified changes in ecosystem services. Here, we define $X_1 \ldots X_{J-1}$ as variables representing ecological or regulatory outcomes of restoration (i.e., effects on ecosystem services or development regulations) and X_J as a variable representing unavoidable household cost.

Within all choice experiment variants, choice options were characterized by four ecological attributes that described changes in ecosystem services, two attributes characterizing development restrictions/enforcement, and one attribute characterizing unavoidable annual cost to the household. Ecological attributes in the choice model were selected based on a conceptual model that coordinated ecological science with findings from focus groups (Johnston et al. 2012). The initial direct effect of riparian land restoration (or conservation) is to increase the number of riparian acres with natural vegetation. This is communicated by the attribute *Riparian Land Condition*. The status quo and attribute values for this variable were projected using GIS raster maps showing conditions and changes in riparian land development and clearing within the study area. The predicted consequences of this restoration include (1) changes in the ecological condition of area rivers (*River Condition*), calculated using an aquatic biotic index following Johnston et al. (2011); (2) changes in the relative abundance of recreational fish (*Recreational Fish*), quantified using MBLR sampling data on brown trout; and (3) changes in the safety of water quality for swimming at area beaches (*Safe Swimming*), characterized using data on water quality testing available from the Maine Healthy Beaches Program. In addition to these ecological outcomes, policy attributes characterized the minimum width of the riparian area in the MBLR Watershed within which development would be restricted (*Development Setbacks*), and whether enforcement and inspections would be increased to prevent illegal development and clearing on riparian land (*Enforcement*). Household cost (*Cost*) was characterized as an increase in taxes and fees required to implement each restoration plan.

Choice options (the policy scenarios over which respondents voted) represented each ecological attribute in relative terms with regard to upper and lower reference conditions (i.e., best and worst possible in the watershed) as defined in survey materials. Relative scores represented percent progress toward the upper reference condition (100%), starting from the lower reference condition (0%). Scenarios also presented the cardinal basis for these relative scores where applicable. The final composite policy options considered by each household were developed using an experimental design that mixed and matched different outcomes for each of the attributes listed above (e.g., *Riparian Land Condition*, *River Condition*, etc.). The experimental design minimized D-error for a choice model covariance matrix with both main effects and selected two-way interactions. The final design included 72 unique choice questions divided into 24 booklets (three choice questions per booklet). A sample choice question is illustrated by Figure 1.

The experimental design allows respondents to consider a wide range of possible outcomes, in which ecological outcomes are uncorrelated. Ecological systems are typically characterized by correlation among many processes and outcomes. In the context of riparian land restoration, for example, increases in natural vegetation (*Riparian Land Condition*) are expected to be correlated with other ecological outcomes including the ecological condition of area rivers (*River Condition*) and the relative abundance of recreational fish (*Recreational Fish*). Were the choice experiment survey scenarios to incorporate the same expected correlations, it would be difficult to determine which attribute(s) caused respondents to vote for one scenario over another. For example, if large improvements in riparian land vegetation always accompany large positive effects on recreational fish abundance and large positive effects on ecosystem condition within survey scenarios, it would be difficult to estimate the relative influence of each effect on respondents' choices and values.

The experimental design used in the stated preference survey breaks this correlation, allowing different attributes to vary independently. This enables different respondents to view many different hypothetical but feasible policy proposals (or choice options), each with different combinations of *Riparian Land Condition*, *River Condition*, *Recreational Fish*, *Safe Swimming*, *Development Setbacks*, *Enforcement* and *Cost*. While some of the resulting scenarios might be unlikely in actual aquatic systems, they are not ecologically impossible. By breaking the correlation between these attributes that is normally present in ecosystems, the choice experiment design allows the independent effect of each attribute on choices to be estimated. This allows the value of each ecosystem service to be estimated, independent of all other effects.

The resulting mail surveys were implemented from December 2013 through January 2014. Surveys were mailed to 3,816 randomly-selected households of Kennebunk, Sanford and Wells—the three towns that overlap the MBLR watershed. Survey implementation followed Dillman et al. (2009), with multiple follow-up mailings to increase response rates. Of the 3,472 deliverable surveys (344 surveys were returned as undeliverable), 1,126 were returned, for a net response rate of 32.4%. Response rates were 35.1% in Wells, 27.2% in Sanford, and 34.9% in Kennebunk. Figure 2 shows the location of mailed (black dots) and returned (colored dots) surveys, across all survey variants, within the sampled area.

Results and Findings

The data are analyzed using a discrete choice model that predicts respondents' votes as a function of policy outcomes (ecological and regulatory) and household cost. Based on each respondent's observed choices, the model predicts the relative importance given to each attribute. By comparing the relative importance given to changes in an ecosystem service to the relative importance given to program cost, it is possible to calculate each household's willingness to trade off money (the cost of a program to the household) for increases in specific ecosystem services. This is the definition of economic value, or WTP.

Results indicate that residents of the three towns have positive economic values (WTP) associated with improvements in all ecological outcomes. These WTP values may be interpreted as the maximum amount that the average area household would be willing to pay, per year (e.g., as part of a local bond referendum) to obtain ecosystem service improvements. Residents also have positive values for increases in development setbacks and for increased enforcement. That is, the average area resident would prefer to see larger setbacks and more enforcement of riparian land development restrictions, holding all else constant.

Table 1 illustrates estimated per household values associated with ecosystem services flowing from riparian land conservation in the MBLR watershed. All values are measured per household, per unit change, per year.[7] For ecological outcomes, the highest economic values (per percentage point increase) are associated with acres of riparian land with natural vegetation. This is followed, in order, by improvements to: swimming safety (the % of tests that show area beaches safe to swim), river ecology, and recreational fish abundance.

Table 1. Economic Value of Riparian Restoration Outcomes and Regulations (Willingness to Pay per Household, per Unit Change, per Year).

Attribute (ecosystem services or regulatory methods)	**Description and Units**	**Marginal Value (willingness to pay per unit change, per household, per year)**

[7] For example, holding other effects constant, the average household in the MBLR watershed is willing to pay $2.05 per year for each additional 1% of riparian land in MBLR watershed (each additional 47 acres) covered by natural vegetation, compared to current levels.

Land Condition	The percentage of riparian land in the MBLR watershed covered by natural vegetation, quantified using GIS land cover data layers for the watershed. Presented as a percentage of the reference condition. Range 0-100%. Each percentage point change is equivalent to an additional 47 acres of naturally vegetated land.	$2.05
River Condition	A 100-point index of aquatic ecological condition, reflecting the similarity of the restored area to the most undisturbed watershed area possible in south coastal Maine. Index components include the mass and variety of different macroinvertebrates distinguished by pollution tolerance. Presented as a percentage of the reference condition for the watershed. Range 0-100%.	$1.28
Recreational Fish	Average abundance of recreational fish within the MBLR watershed. Measured as the number of brook trout per 1000 square feet of river. Presented as a percentage of the reference value for the region (30 fish per 1000 square feet), defined as the highest average level sampled in any area of the Watershed. Range 0-100%. Each percentage point change is equivalent to an additional 0.3 fish per 1000 square feet.	$1.15
Swim Safety	The percentage of days during which water quality tests show safe levels of bacteria colony forming formations in samples at area beaches (Laudholm, Drakes Island, Crescent Surf, and Parson Beach). Calculated using data provided by Maine Healthy Beach Initiative. Range 0-100%. Each percentage point change is equivalent to an additional 0.3 days per month of safe swimming.	$2.02
Setbacks	The minimum width of the riparian area where development is restricted around rivers, in feet. Range 100-200 feet.	$0.14
Enforcement	Binary (0 or 1) variable indicating whether enforcement is increased to prevent illegal development or clearing on riparian land. This could	$17.31

	include inspections on private land if violations are suspected. A value of 1 indicates increased enforcement activity.	

Implications and Policy Relevance

Project results provide numerous insights into public preferences and values that are directly relevant to policy and management in south coastal Maine. For example, results reveal heretofore unexpected degrees of support for development restrictions and enforcement designed to protect natural riparian land. Contrary to common expectations voiced to project investigators at the outset of the project, the average resident of the MBLR watershed *supports* greater development restrictions and enforcement, holding all else constant. These results suggest that there are widespread misperceptions concerning the degree to which residents support regulatory changes designed to protect riparian lands. Results of the project help dispel these misconceptions, and can hence promote better-informed policy and management choices.

Results in Table 1 can also be used to calculate the total change in ecosystem service values resulting from proposed riparian restoration or conservation programs. Consider, for example, a program that would restore natural vegetation to an additional 5% (235 acres) of riparian land in the MBLR watershed. Based on ecological data reported above, each 1% increase in riparian land tree canopy cover is associated with a 2.47% increase in brook trout (recreational fish) abundance. According to these patterns, the additional 235 acres of naturally vegetated riparian land is expected to enhance recreational fish populations by $5\%\times2.47 = 12.35\%$. From Table 1, the total value of these ecosystem service improvements is equivalent to $(5\times\$2.05) + (12.35\times\$1.15) = \$24.45$ per household, per year. This value may be interpreted as the maximum amount that area households would be willing to pay, per year, to support a bond issue that would achieve these benefits.

The model can also be used to predict the results of public votes (Johnston 2006). For example, assume that the program described above were offered to Kennebunk, Sanford and Wells voters at an average household cost of $20 per year (e.g., in additional property tax payments to support a local bond). Model results predict that 71.5% of residents would support this proposal, if given the opportunity to vote. Results may also be used to distinguish voting patterns and values across different population groups—for example residents who live in or out of the MBLR watershed, or those who live in different towns (e.g., values of Sanford versus Wells residents). Such results provide a concrete and transparent perspective on the degree to which different types of residents, in different areas, support and value programs that would provide different types of ecosystem services related to riparian land conservation. These results are directly tied to ecosystem properties and services quantified by the ecological research described above, providing a direct link from riparian land to ecosystem services to human values.

These results are based on a random sample of Kennebunk, Sanford and Wells voters. Hence, they provide a more representative perspective on public values than is revealed by the small, self-selected and more vocal set of area residents who attend public meetings, are active in advocacy groups, or engage in other activities that influence public policy decisions. As a result, results that reveal actual public values can be surprising to policymakers and other stakeholders, who may infer public values from a small but very vocal set of residents. By providing a more representative perspective, the ecosystem service value results summarized here can help policymakers develop policies that more accurately reflect the true values of all residents.

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QUESTION 5

OPTION A and **OPTION B** are possible protection options for the area surrounding the Merriland, Branch Brook, and Little River. The current situation is the status quo with **NO NEW PROTECTION**.

Given a choice between the three, how would you vote?

Method or Effect of Protection	In 5-10 years under the Current Situation	In 5-10 years under Option A	In 5-10 years under Option B
Riparian Land Condition	**85%** 4000 out of 4700 riparian acres covered by natural vegetation	**87%** 4100 out of 4700 riparian acres covered by natural vegetation	**90%** 4200 out of 4700 riparian acres covered by natural vegetation
River Ecology	**55%** of best possible (100%) ecological condition	**75%** of best possible (100%) ecological condition	**75%** of best possible (100%) ecological condition
Recreational Fish	**55%** 17 out of 30 possible fish per 1000 sq. feet	**65%** 20 out of 30 possible fish per 1000 sq. feet	**65%** 20 out of 30 possible fish per 1000 sq. feet
Safe Swimming	**85%** of beach tests meet safe swimming guidelines	**90%** of beach tests meet safe swimming guidelines	**90%** of beach tests meet safe swimming guidelines
Development Setback	**100 feet** required between development and rivers; 25 feet for streams	**100 feet** required between development and rivers; 25 feet for streams	**200 feet** required between development and rivers; 125 feet for streams
Enforcement	**No Change** in enforcement and inspections	**No Change** in enforcement and inspections	**No Change** in enforcement and inspections
$ Cost to your Household per Year	**$0** Increase in Annual Taxes or Fees	**$45** Increase in Annual Taxes or Fees	**$30** Increase in Annual Taxes or Fees
HOW WOULD YOU VOTE? (CHOOSE ONLY ONE) I vote for	☐ **NO NEW PROTECTION**	☐ I vote for **OPTION A**	☐ I vote for **OPTION B**

38717

12

Figure 1. Example Choice Experiment Question

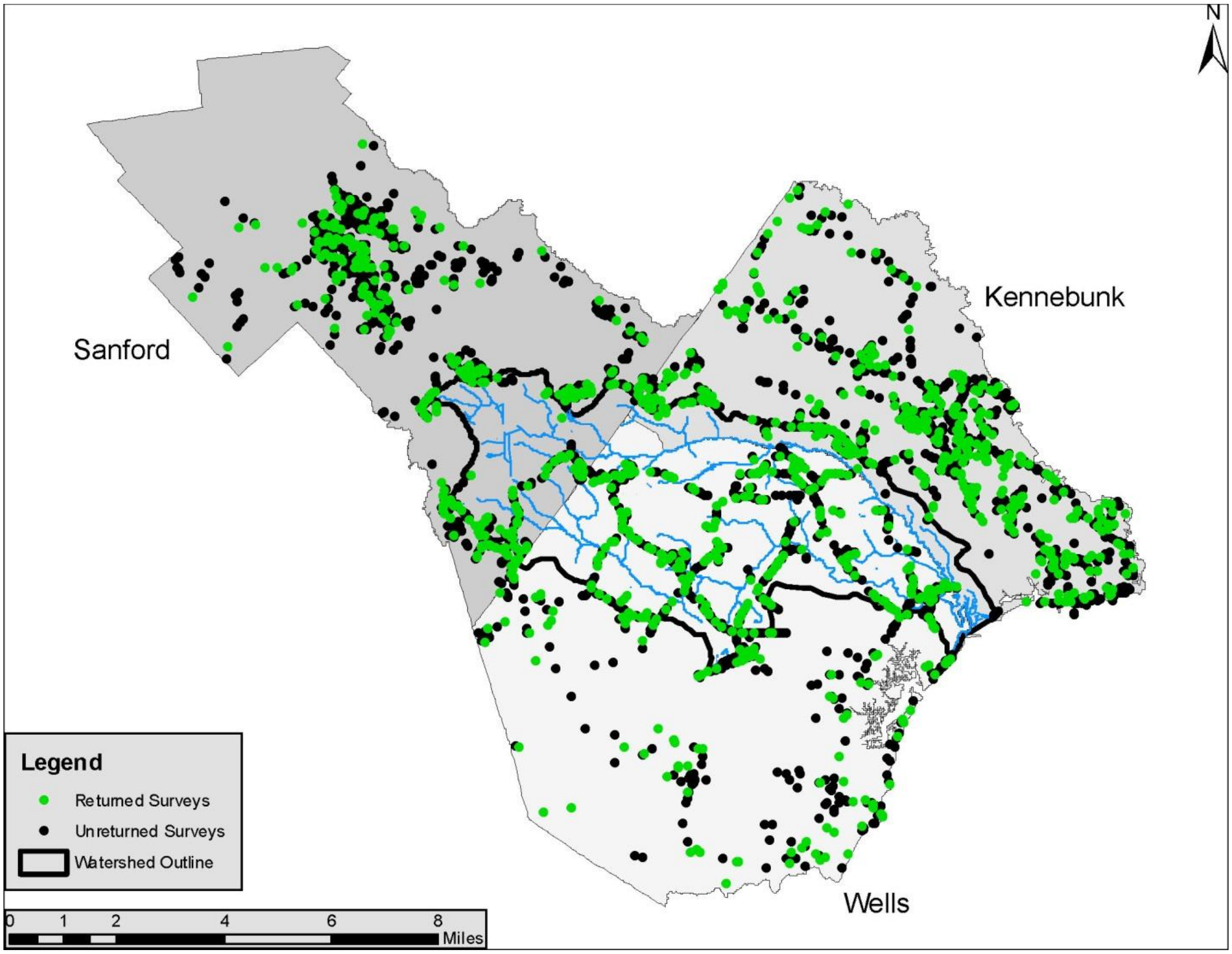

Figure 2. Location of Returned and Unreturned Surveys

Appendix to Economics Research Summary[8]

Ecosystem Services and Riparian Land Management in the Merriland, Branch Brook and Little River Watershed

Quantifying Values and Tradeoffs

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[8] This summary of the results of the Choices for Our Land and Water survey is targeted to managers and policy makers whose decisions and work focus on riparian buffer management, conservation and policy. This document was distributed to key stakeholders in the project and is available on the Wells Reserve website.

Executive Summary

Management of the riparian land (or shore land) that borders New England's rivers and streams can require difficult choices. These often involve tradeoffs between the demand for development on this land and the protection of the valued services that naturally vegetated riparian land provides to the public—often called *ecosystem services*. People value these and other ecosystem services in the same way that they value goods and services purchased in markets. However, traditional economic assessments often overlook the economic benefits provided by ecosystem services. This leads to decisions that harm the public, because they overlook the economic value provided by the protection and restoration of natural systems. Quantifying the economic value of ecosystem services can help ensure that development and conservation decisions balance all benefits and costs.

This report summarizes an analysis of ecosystem service values provided by protection and restoration of riparian land in the Merriland, Branch Brook and Little River (MBLR) watershed in south coastal Maine. These results are drawn from *Choices for Our Land and Water: A Survey of Kennebunk, Sanford and Wells Residents*, conducted through a collaboration of Clark University and the Wells National Estuarine Research Reserve, and funded by the National Estuarine Research Reserve Science Collaborative. The survey evaluated the attitudes and preferences of community residents towards actions that would conserve and restore riparian land. It also included systematic voting (or choice experiment) questions that enable the economic value of local ecosystem services to be quantified. Results show the type of economic value that riparian land provides to the public, and the tradeoffs that the public would be willing to accept.

Survey development engaged a diverse set of residents, stakeholders, policy experts and public officials from Kennebunk, Sanford and Wells over three years of careful design and pretesting. The process included meetings with state and federal natural resource managers, town planners, scientists, and stakeholder groups; nine focus groups with community residents; and extensive pretesting. The survey was implemented by mail from December 2013 through January 2014. It was mailed to a sample of 3,816 randomly selected MBLR residents split evenly across the three sampled towns (Kennebunk, Sanford and Wells), with systematic follow-up mailings to increase response rates. Out of 3,472 deliverable surveys, 1,126 were returned for an average response rate of 32.4%. Response rates were 27.0% in Sanford, 34.9% in Kennebunk and 35.1% in Wells.

Survey results demonstrate the types of economic value provided by natural riparian lands in the MBLR Watershed, and the extent to which local residents are willing to pay for programs that would enhance these valued natural resources and the ecosystem services they provide. These results are based on a random sample of Kennebunk, Sanford and Wells voters. Hence, they provide a more representative perspective on public values than is revealed by the small, self-selected and more vocal set of area residents who attend public meetings, are active in advocacy groups, or engage in other activities that influence public policy decisions. By providing a more representative perspective, the ecosystem service value results summarized here can help policymakers develop policies that more accurately reflect the values of all residents.

Some key findings of the study include:

- Residents of Kennebunk, Sanford and Wells place very high importance on environmental protection. The importance placed on environmental and ecosystem service protection is greater than that placed on the protection of landowner rights and prevention of tax increases.
- Residents hold considerable value for ecosystem services provided by riparian land. The value that people hold for riparian land restoration depends on how much land is restored, the effects on ecosystem services, and how restoration is accomplished. For example, residents are willing to pay for improvements in riparian land condition itself, as well as for improvements in the condition of local rivers, recreational fisheries, and swimming safety of local beaches that can result from the restoration of this land.
- All else equal, residents prefer management alternatives that *increase* restrictions on the development of riparian land (by increasing setback requirements) and that increase enforcement and inspections of these and other development restrictions. Residents prefer stronger regulation of development on riparian lands.
- Residents will support programs that restore and protect riparian land in the MBLR Watershed and associated ecosystem services, even if implementing these programs requires increases in the taxes and fees paid by their households.

The results of this study do not indicate what types of riparian land protection or restoration alternatives are right or wrong. Rather, the results predict which riparian land protection or restoration alternatives would be strongly supported by area residents because they are perceived as providing the greatest value. When combined with information on the projected ecological outcomes of riparian land management and the associated costs, results such as these can help identify management alternatives that best support the long term goals and values of residents, and generate the greatest sustainable economic value.

1.0 Introduction—What Ecosystem Services Are Provided By Riparian Land?
Management of the riparian land (or shore land) that borders New England's rivers and streams can require difficult choices. These often involve tradeoffs between the demand for development on this land and the protection of the valued services that naturally vegetated riparian land provides to the public—often called *ecosystem services*. Riparian lands provide many valued ecosystem services. For example, naturally forested riparian land on river banks can filter out pollutants and sediments before they reach the water (leading to cleaner and clearer water); prevent the erosion and collapse of river banks; improve habitat for fish and wildlife; enhance local aesthetics; improve the environmental health of river systems; and prevent flooding of homes and property. Figure 1 illustrates some of the main ecosystem services provided by riparian land.

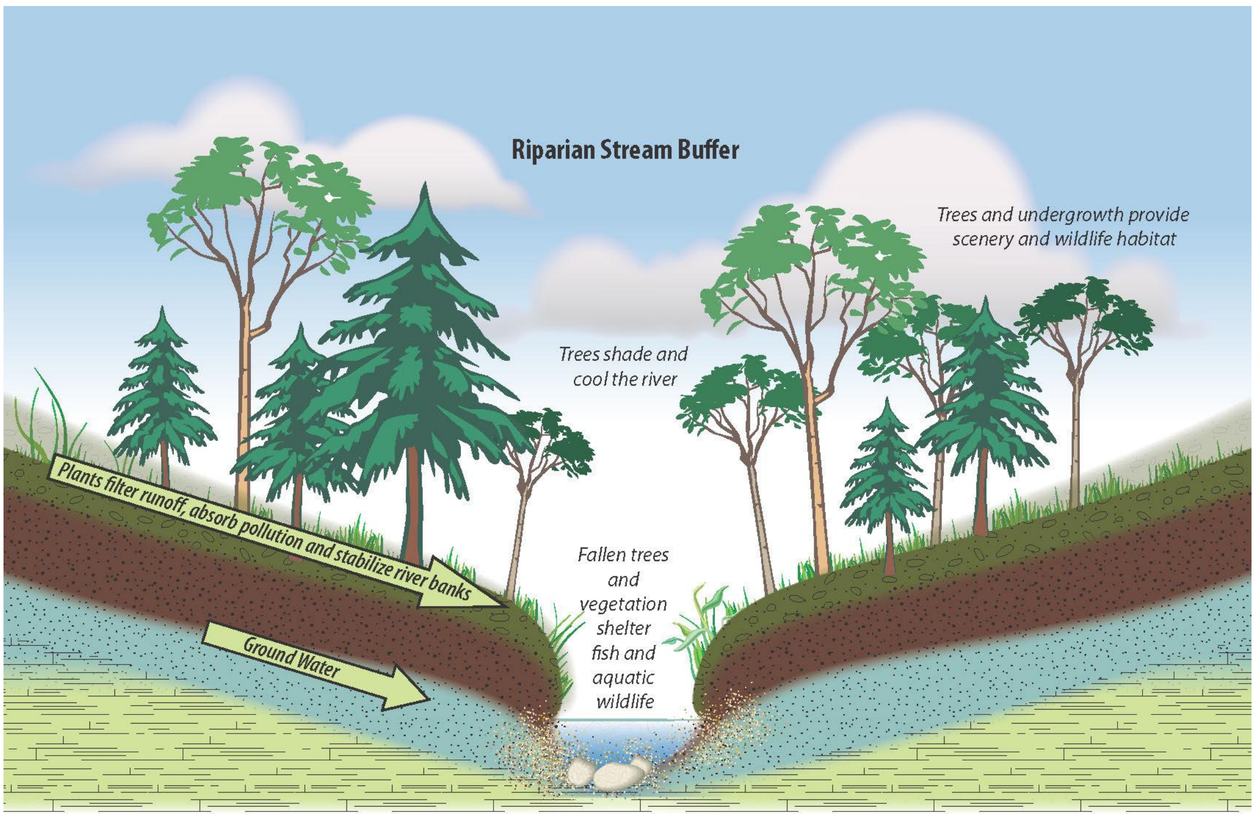

Figure 1. Natural Services of Riparian Land

People value ecosystem services like these in the same way that they value goods and services purchased in markets. In some cases ecosystem services are similar or identical to market goods and services (e.g., a fish caught in a local river may be nearly identical to a fish purchased in a market). In most cases, however, ecosystem services are not bought and sold. Because of this, traditional economic assessments (looking only at market transactions, jobs, income, etc.) overlook the economic benefits provided by these services. This can lead to decisions that harm the public, because they overlook the economic value provided by the protection and restoration of natural systems. Development of riparian land often benefits a very small group of people, for example homeowners who clear trees to obtain an improved view of the water. However, cutting down trees on riparian land can increase the flow of pollution and sediment into local rivers, diminishing the water quality valued by thousands of residents and visitors. Quantifying the economic value of ecosystem services can help ensure that development and conservation decisions balance all benefits and costs to all affected people.

1.1 Context for the Study

This study evaluates the public's willingness to pay for ecosystem services that could be provided by riparian land management the Merriland, Branch Brook and Little River (MBLR) watershed. This small coastal watershed in south coastal Maine has importance beyond the three municipalities where it originates, flows and connects to the ocean. For example, the Branch Brook provides drinking water during peak times for up to 75,000 people in portions of seven communities. The watershed also flows to one of the two focus estuaries of the Wells National Estuarine Research Reserve and through significant habitats of the Rachel Carson National Wildlife Refuge.

1.2 Riparian Land in the MBLR Watershed

Many scientists consider riparian land within about 300 feet of the water to be most important for ecosystem services. Today, there are roughly 4,700 acres of this land bordering freshwater rivers and streams in the MBLR Watershed in Kennebunk, Sanford and Wells, Maine (Figure 2). About 4,300 of these acres are covered by trees and other natural vegetation. The remaining acres have been developed or cleared. Currently, natural riparian land is being lost to development at a rate of about 5% (approximately 235 acres) every ten years. Without new action, this loss is likely to continue. Yet the conservation of riparian land requires tradeoffs. Many different actions are possible, yet available funds are rarely sufficient to protect all sites and resources. Protection of riparian land may also require restrictions on the development or clearing of private land. Thus, difficult choices must be made. Quantifying economic benefits and costs can help illustrate the consequences of these choices for the public.

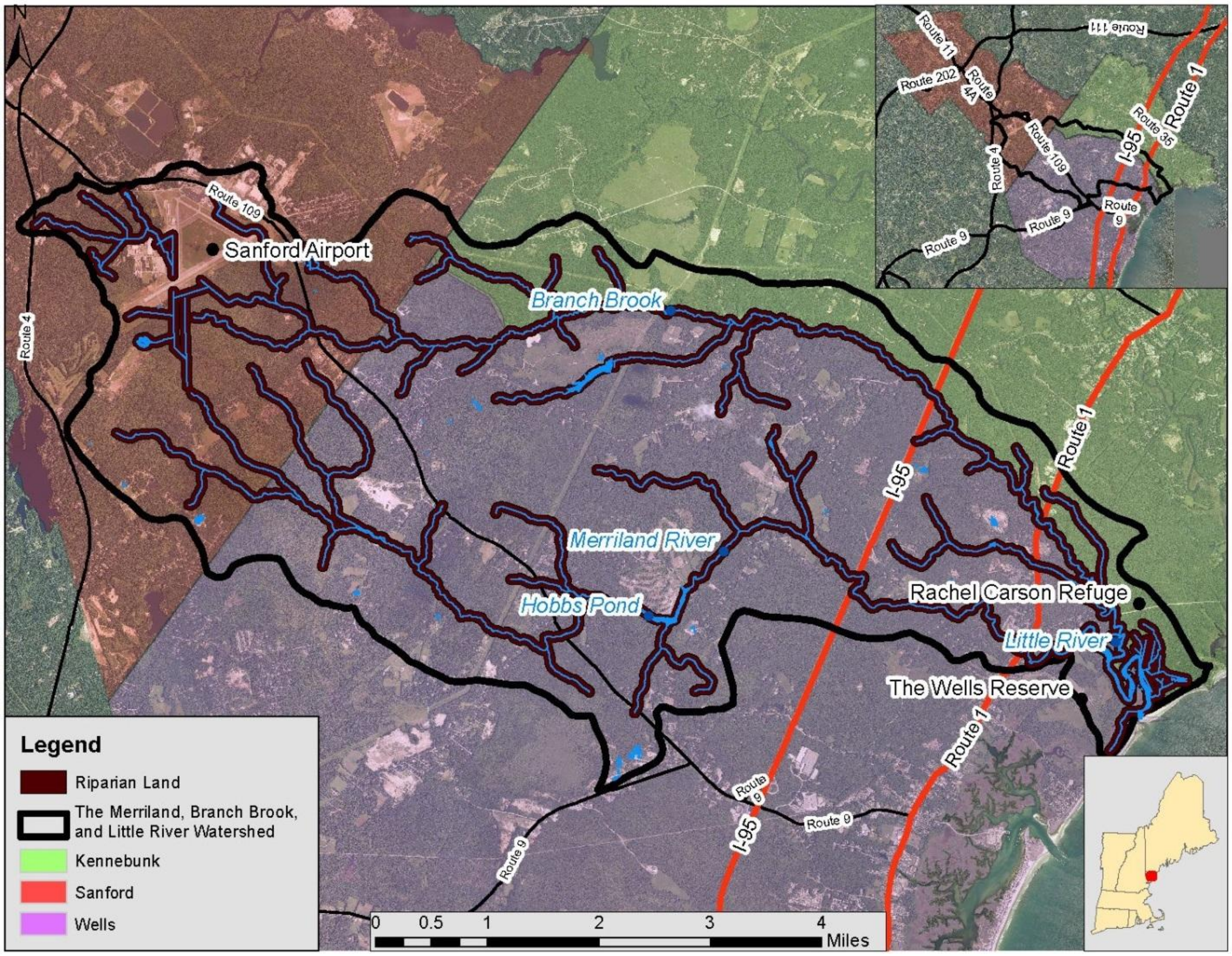

Figure 2. The Merriland, Branch Brook and Little River (MBLR) Watershed

1.3 The Goal of This Report

This report summarizes an analysis of ecosystem service values provided by protection and restoration of riparian land in the MBLR Watershed in south coastal Maine. These results are drawn from *Choices for Our Land and Water: A Survey of Kennebunk, Sanford and Wells Residents*, conducted through a collaboration of Clark University and the Wells National Estuarine Research Reserve, and funded by the National Estuarine Research Reserve Science Collaborative. This survey evaluated the attitudes and preferences of community residents towards actions that would conserve and restore riparian land. It also included systematic voting (or choice experiment) questions that enable the economic value of local ecosystem services to be quantified.[9] Results show the type of economic value that riparian land provides to the public, and the tradeoffs that the public would be willing to accept.

2.0 Survey Design

[9] For a discussion of the choice experiment approach, see Bateman, I. J., R. T. Carson, B. Day, M. Hanemann, N. Hanley, T. Hett, M. Jones-Lee, G. Loomes, S. Mourato, E. Özdemiroglu, D. W. Pearce, R. Sugden, and J. Swanson. 2002. Economic Valuation with Stated Preference Techniques: A Manual. Cheltenham, UK: Edward Elgar.

Survey development engaged a diverse set of residents, stakeholders, policy experts and public officials from Kennebunk, Sanford and Wells over three years of careful design and pretesting. The process included meetings with state and federal natural resource managers, town planners, scientists, and stakeholder groups; nine focus groups with community residents[10]; and extensive pretesting. This survey development ensured that information in the survey was accurate and that the survey could be easily understood and answered by the public.

The goal of the survey was to understand residents' (a) attitudes concerning development, the rights of property owners, and conservation of riparian land, (b) values for the ecosystem services provided by riparian land, and (c) tradeoffs they would be willing to make to protect riparian land and the ecosystem services it provides. The survey included a wide range of attitudinal questions, along with referendum-style voting questions that enabled residents to vote for or against different types of hypothetical but realistic development and conservation alternatives for the MBLR Watershed. Results provide insight into the way that residents value riparian land in the MBLR watershed compared to other priorities such as the protection of landowner rights, and the specific types of tradeoffs they would be willing to accept in order to retain the services provided by riparian land in the watershed.

3.0 Survey Implementation and Response

The survey was implemented by mail from December 2013 through January 2014. It was mailed to a sample of 3,816 randomly selected MBLR residents split evenly across the three sampled towns (Kennebunk, Sanford and Wells), with systematic follow-up mailings to increase response rates. Out of 3,472 deliverable surveys, 1,126 were returned for an average response rate of 32.4%. Response rates were 27.0% in Sanford, 34.9% in Kennebunk and 35.1% in Wells. This is a high rate of return for a mail survey, and suggests the relevance of the topic to the public. Figure 3 shows the approximate home locations of those residents who did and did not return a completed survey.[11] The demographic characteristics of those who responded to the survey are shown in Appendix I.

[10] Within these focus groups, groups of randomly selected residents of Kennebunk, Sanford and Wells met with a moderator to freely discuss their perceptions, opinions, beliefs and attitudes related to the development and riparian land in the MBLR Watershed, and the types of policies they would support. Focus groups were also used to obtain feedback on preliminary drafts of the survey instrument.

[11] These locations are perturbed, or moved slightly to prevent identification of specific home addresses.

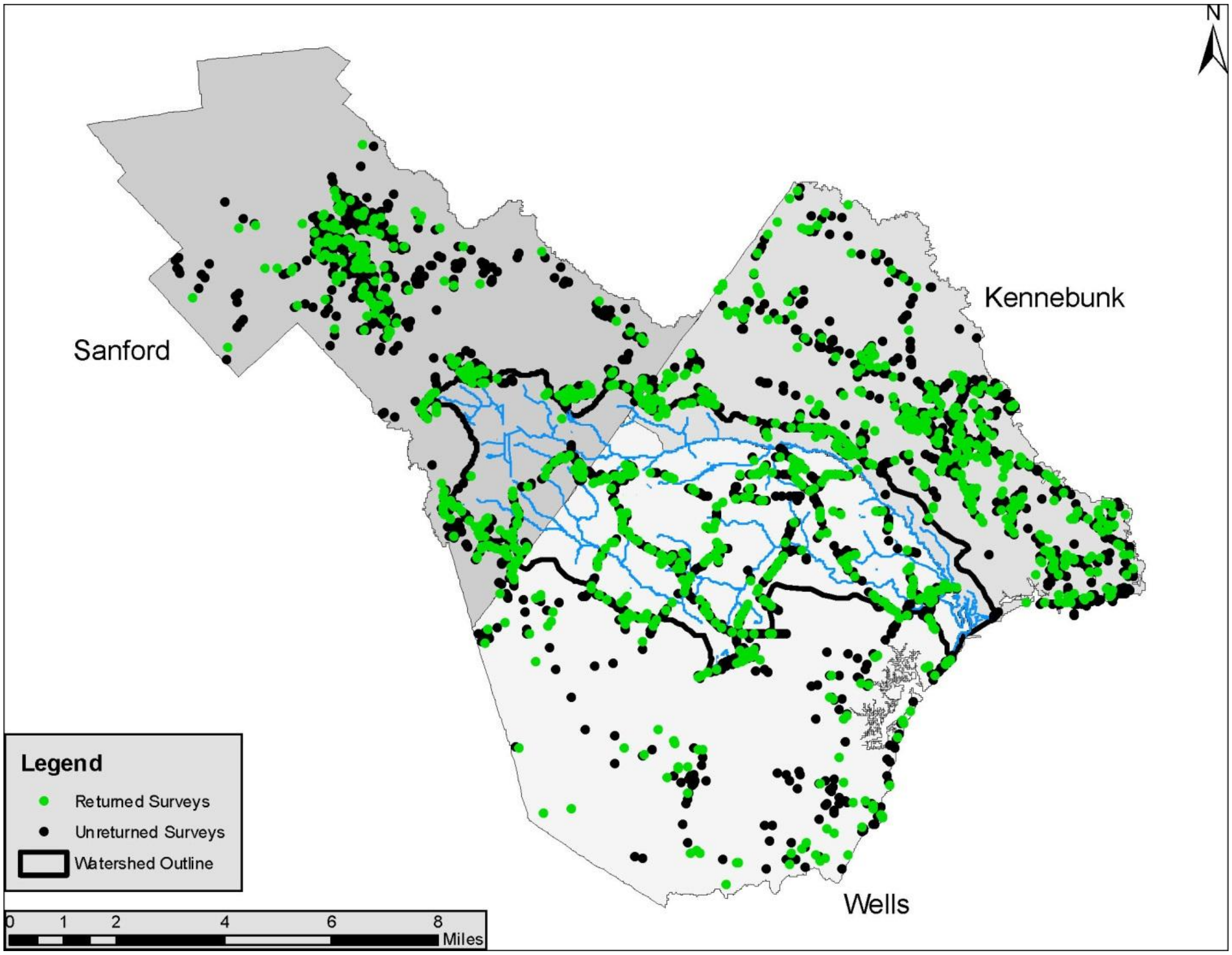

Figure 3. Approximate Location of Survey Respondents

4.0 Residents' Attitudes Concerning Development and Riparian Land

The first section of the survey asked respondents to indicate the importance of statements related to development, property rights and the protection of riparian land in the watershed. These statements were rated on a scale of 1 to 5, where 1 = Not at all important and 5 = Very important. Because these statements were rated independently, the responses cannot be used to quantify tradeoffs (e.g., how much of one outcome respondents would be willing to give up in exchange for increases in others). However, they provide insight into the extent to which residents care about different types of priorities.

4.1 Protecting the Environment

Survey responses show the high importance placed on environmental protection. This was greater than the importance placed on all other priorities, including the protection of landowner rights and prevention of tax increases. Over 85% of respondents indicated that it was "very important" that water quality is protected in lakes rivers and streams—the highest possible importance category (Figure 4). Only 1% of respondents indicated that this was less than moderately important. Similarly, over 72% of respondents indicated that it was “very important” to protect the local environment (Figure 5). Only 1% indicated that it was less than moderately important.

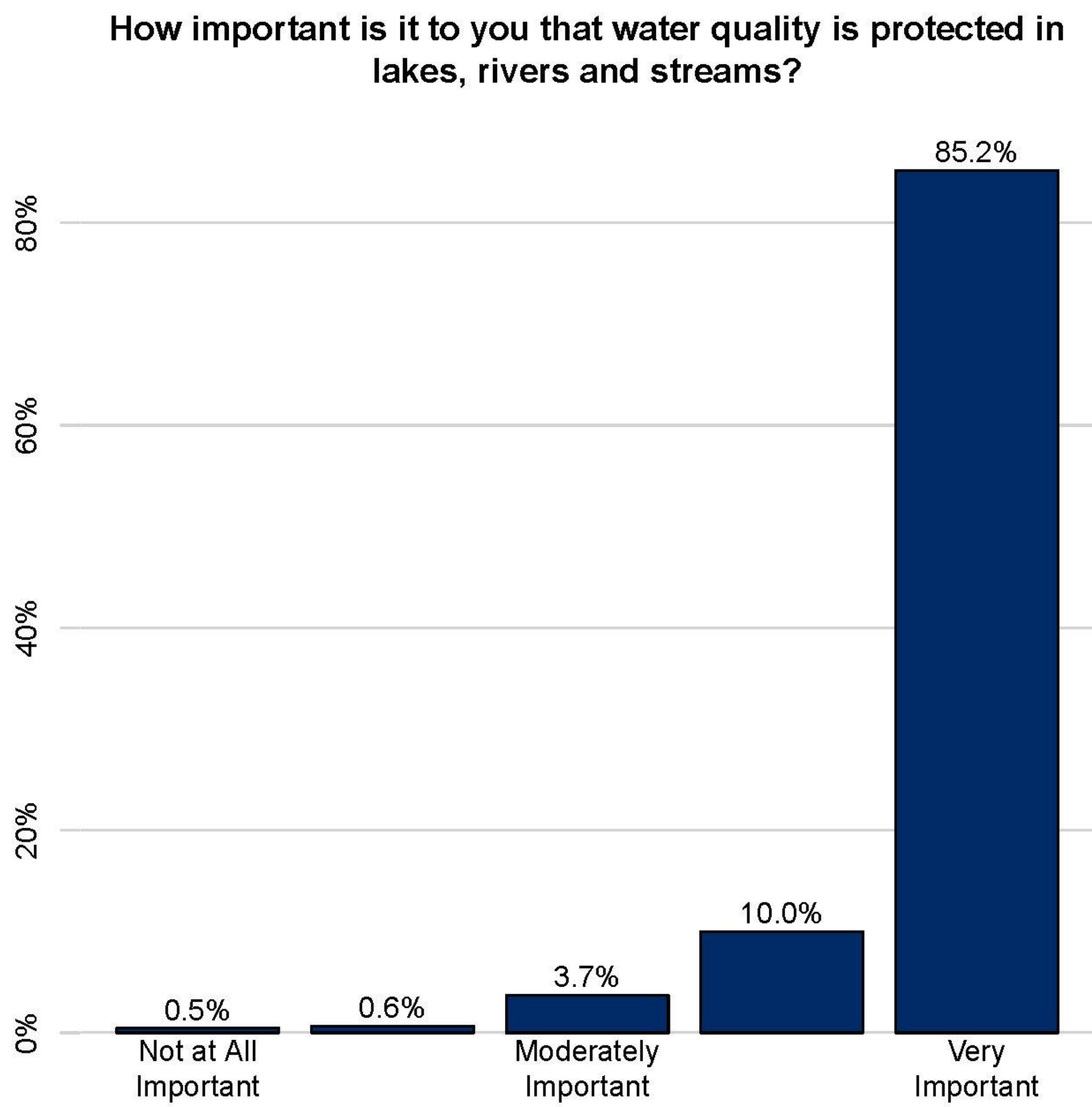

Figure 4. Importance of Water Quality Protection

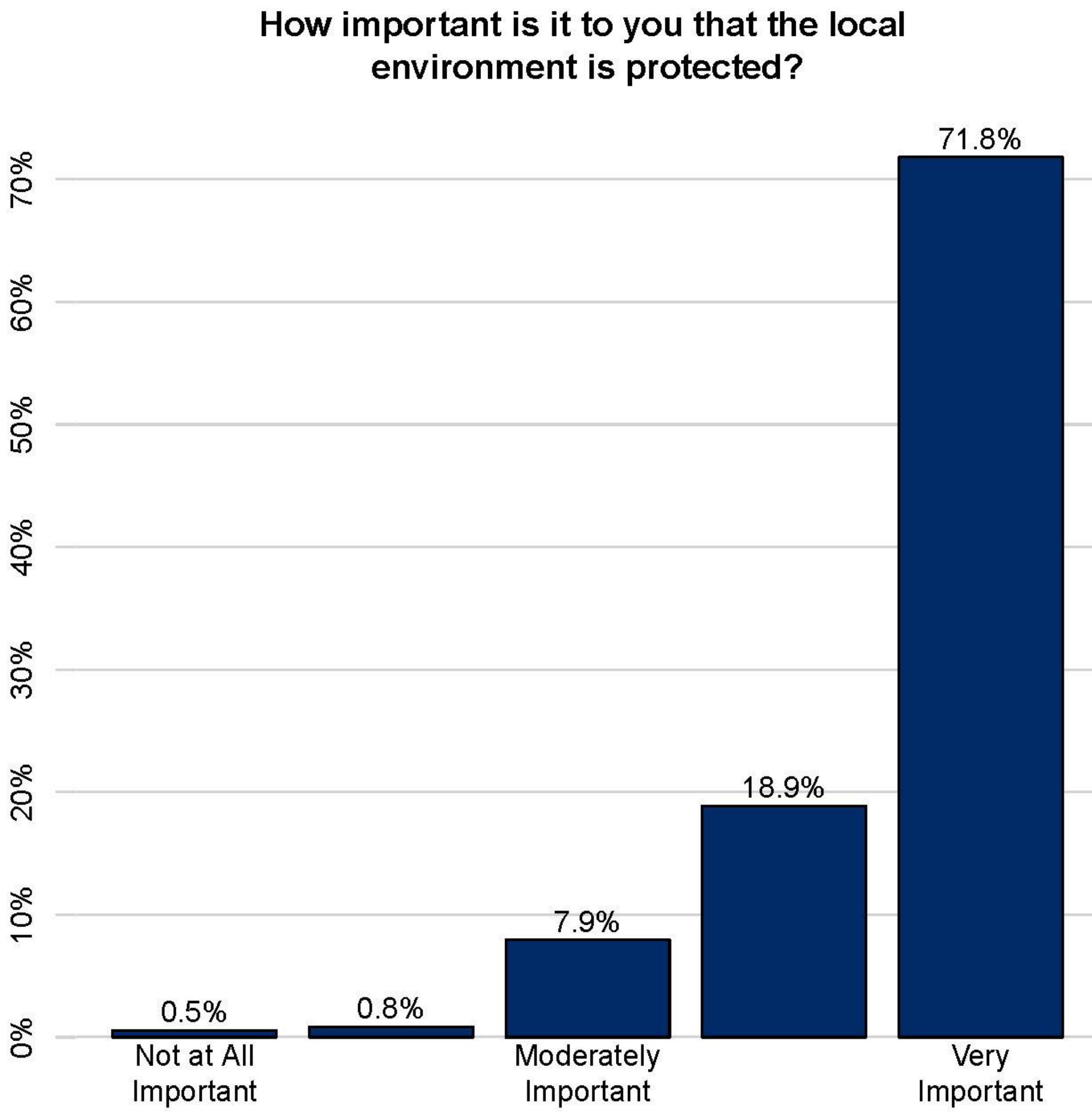

Figure 5. Importance of Environmental Protection

4.2 Respecting the Rights of Private Landowners

Some approaches to protect the natural environment require limiting the actions of private landowners, such as restricting development within a certain distance of rivers and streams. Survey respondents had mixed feelings regarding the importance of respecting landowners' rights, and most did not consider it to be a high priority. Less than 35% of respondents stated that it was "very important" that government respects the right of private landowners to develop their land, whereas 43% indicated that this was of moderate importance or less (Figure 6). Similarly, only 33% of respondents indicated it was "very important" that existing uses of private land are grandfathered, so that they are not subject to new restrictions. Approximately 47% stated that grandfathering existing land uses was of moderate importance or less (Figure 7).

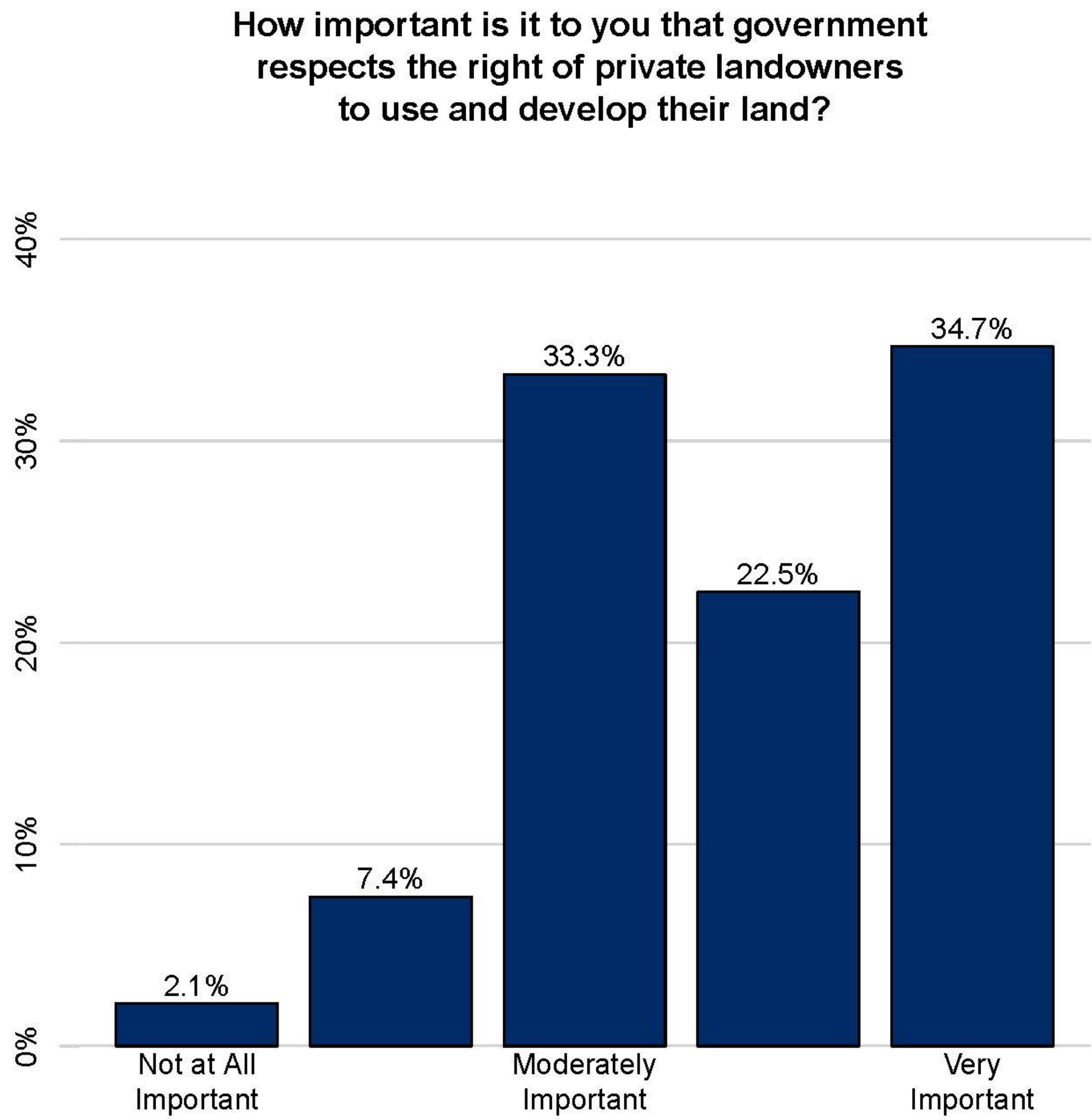

Figure 6. Importance of Landowner Rights

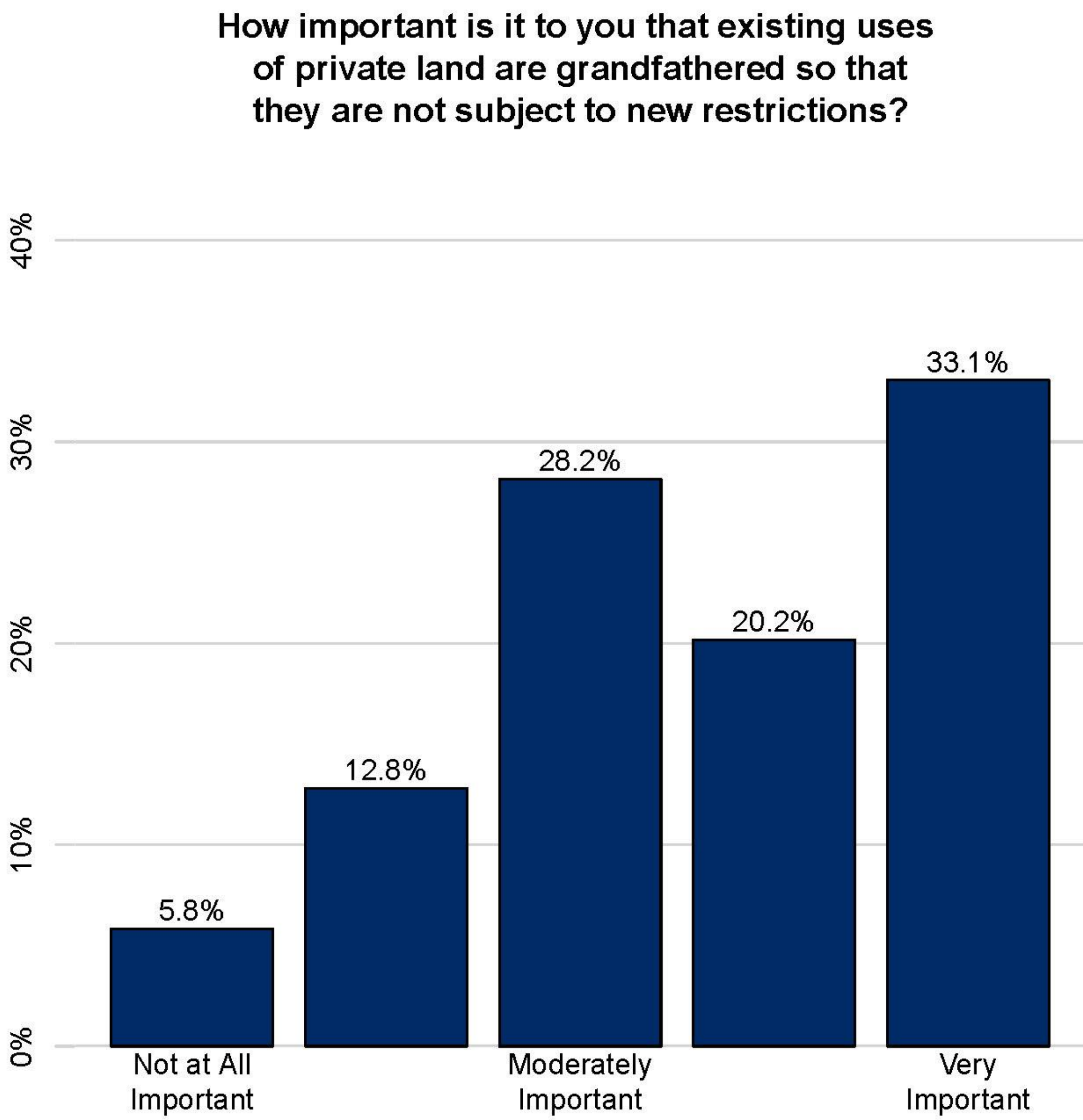

Figure 7. Importance of Grandfathering Land Uses

4.3 Fairness and Effectiveness of Land Use Regulations

In contrast to protecting the rights of landowners (which had only moderate importance on average), the fairness and effectiveness of land use regulations was considered to be very important. Approximately 65% of respondents considered it “very important” that existing regulations are enforced fairly and effectively (Figure 8). Only 2% of respondents considered this to be less than moderately important.

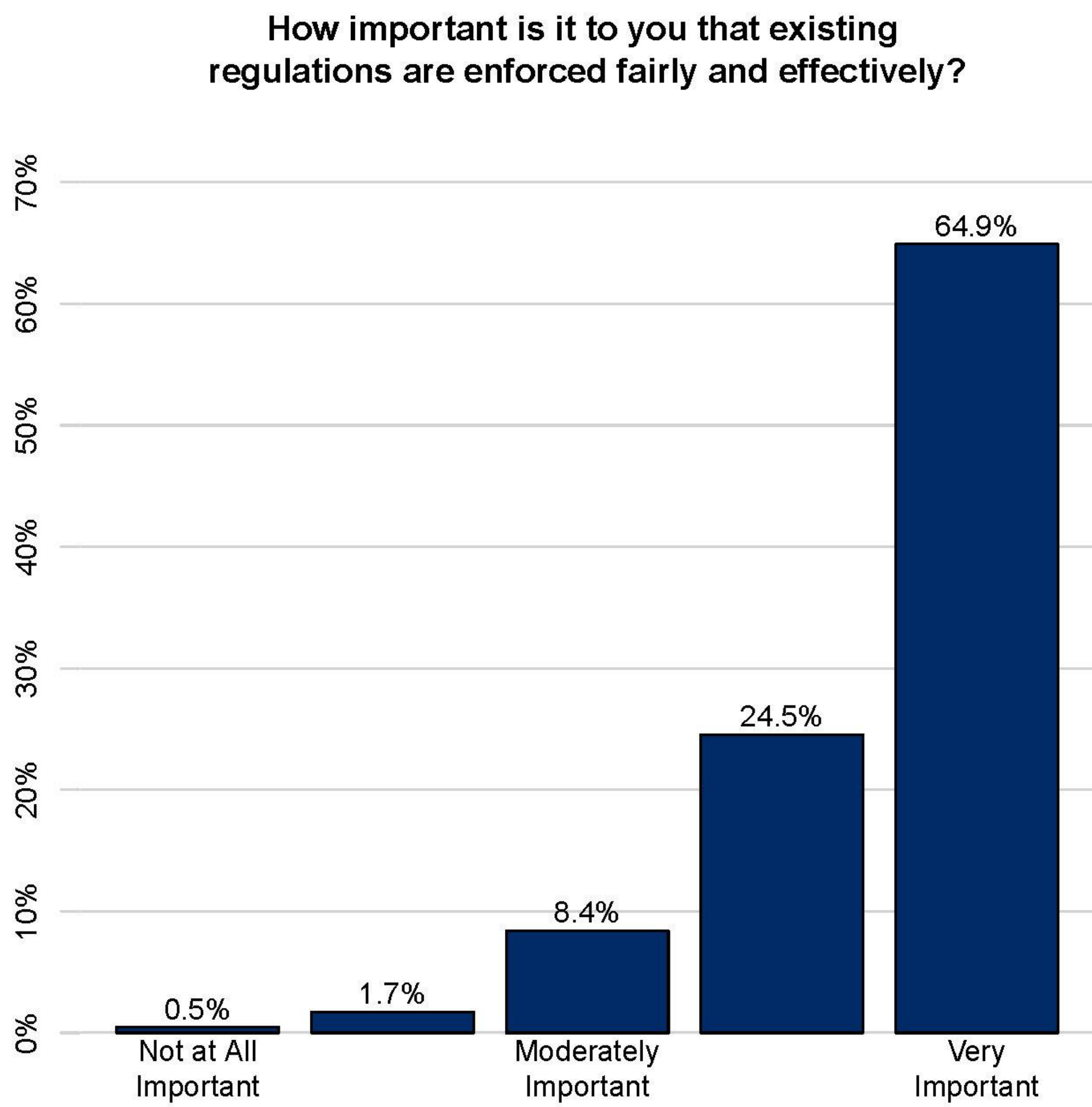

Figure 8. Importance of Fair and Effective Enforcement

4.4 Preventing Tax Increases

Actions to restore and protect riparian land can be costly, and one way to fund programs is through public taxes and fees. It is often believed that preventing tax increases is a top priority of many people. Results of the survey reject that common wisdom. Although preventing tax increases is very important to some people, it is less important on average than many other priorities. Only 44% of respondents considered it “very important” that taxes and fees paid by their households do not increase (in order to protect natural riparian land). Approximately 37% of respondents stated that preventing tax increases was moderately important or less (Figure 9).

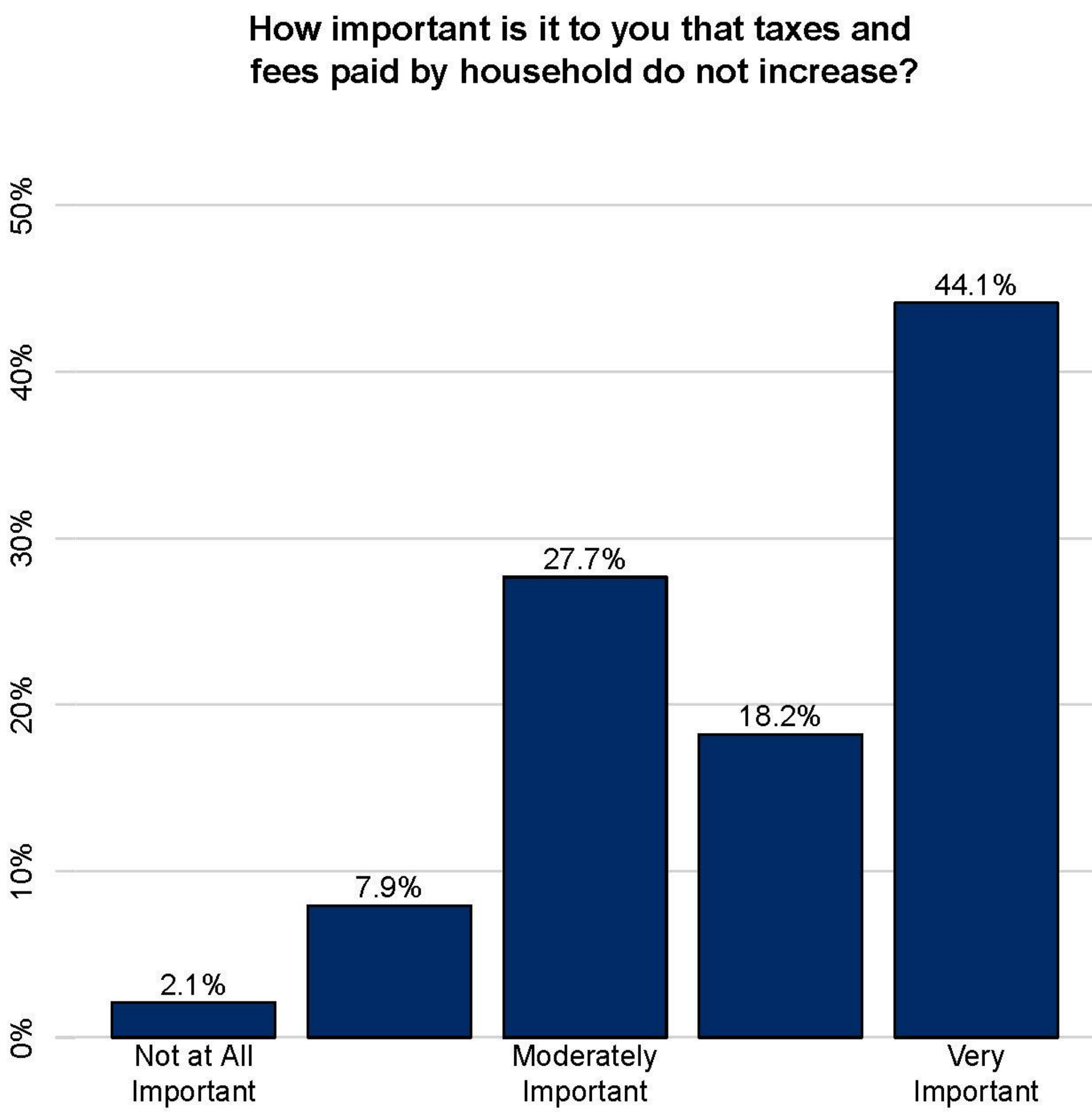

Figure 9. Importance of Preventing Tax Increases

4.5 Do Residents Support Greater Development Restrictions in General?

Survey results show that residents support the increased use of development setbacks (when development is required to be a certain minimum distance from the water) and land inspections to protect riparian land in the MBLR Watershed. As shown by Figure 10, over 73% of respondents indicated that they "support greater use of development setbacks and land inspections to limit future development on riparian land." Only 13% of respondents did not support greater use of these tools (the remaining 14% were unsure).

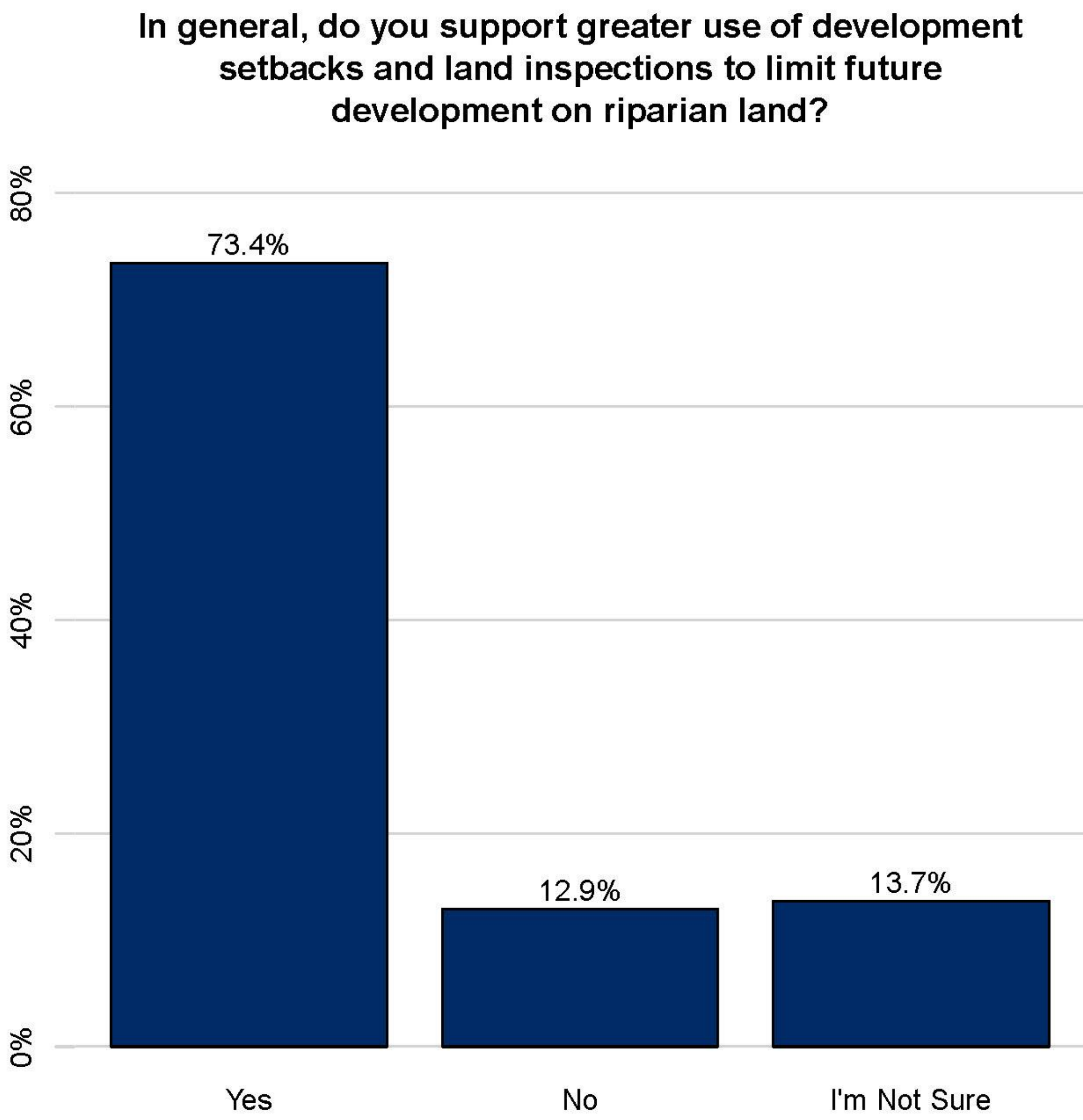

Figure 10. General Support for Development Setbacks and Inspections

5.0 Quantifying Ecosystem Service Values

One of the primary goals of the survey was to evaluate the types of tradeoffs that would be supported by Kennebunk, Sanford and Wells residents, when considering different ways to protect and restore riparian land in the MBLR Watershed. One of these tradeoffs is respondents' willingness to give up money (e.g., accept increased taxes or fees) to obtain different types of riparian land protection programs, with different effects. This is interpreted as residents' willingness to pay (WTP), and may be used to quantify their values for the ecosystem services delivered under each plan.[12]

For example, assume that a person would vote "yes" for a program that would increase her tax bill by $100, in return for a specific set of ecosystem service improvements. That positive vote indicates that the person values the environmental improvements by at least $100—otherwise they would not support the program. This is the same way that market purchases reveal economic values, by showing the monetary tradeoffs that people are willing to make. By modeling how residents would vote for or against different possible programs to protect riparian land—with different costs and effects on ecosystem services—it is possible to calculate the value of ecosystem services to those residents.

To evaluate the tradeoffs supported by Kennebunk, Sanford and Wells residents, surveyed households were asked to choose among different types of programs to protect and restore riparian land in the MBLR Watershed, within referendum-style voting questions called choice experiments. Each voting choice was described in terms of projected effects on natural riparian land, the condition of local rivers, abundance of recreational fish in those rivers, the safety of water at local beaches for swimming, development restrictions and inspections, and annual household costs. Each of these voting questions asked the respondent to choose between two hypothetical but feasible protection programs with different effects and costs, and a "business as usual" alternative with no additional cost (i.e., Option A versus Option B versus Neither [N], or A-B-N). Seventy-two hypothetical A-B-N choices were developed, and divided randomly among surveys sent to different households. Each of these questions illustrated a different set of riparian land protection programs. Each household was asked to answer three of the seventy-two A-B-N choices. The combined votes of all households over all of these hypothetical A-B-N choices were used to calculate the tradeoffs households were willing to make, based on their observed votes. This rigorous, systematic design helps to ensure the validity of results.

Possible effects of each hypothetical riparian land management program over the next 10 years ("Comparing Protection Options"—Figure 11) used as a basis for the A-B-N choices were derived from scenarios for the MBLR Watershed. These were developed in coordination with scientists at the Wells National Estuarine Research Reserve, based on available ecological data collected from local watersheds specifically for this study. Within each question, each alternative (A, B or N) shows a possible outcome of riparian land protection and/or restoration in the watershed. The initial effect of riparian land programs is to increase the number of naturally vegetated riparian acres, described by the attribute *Riparian Land Condition*. The predicted consequences include (1) changes in the ecological condition of area rivers (*River Condition*), calculated using an aquatic biotic index; (2) changes in the relative abundance of recreational fish (*Recreational Fish*), quantified using MBLR sampling data on brook trout; and (3) changes in the safety of water quality for swimming at area beaches (*Safe Swimming*), characterized using data

[12] More generally, willingness to pay is defined as the maximum amount of money that a person (or group) would be willing to give up in exchange for a specified quantity of a good or service, rather than go without. It is the measure most commonly used by economists to quantify value.

on water quality testing from the Maine Healthy Beaches Program. In addition to these ecological outcomes, some of the presented programs would change the minimum width of the riparian area in the MBLR Watershed within which development would be restricted (*Development Setbacks*), and whether enforcement and inspections would be increased to prevent illegal development and clearing on riparian land (*Enforcement*). Annual household cost (*Cost*) was characterized as an unavoidable increase in taxes and fees required to implement each restoration plan.

COMPARING PROTECTION OPTIONS

The upcoming questions will ask you to compare different ways of protecting riparian land in Kennebunk, Sanford and Wells, and vote for the ones you prefer. You may also vote to reject the proposed programs and retain the status quo. **Effects of each option will be described by the following effects, as estimated by scientists:**

Effect	What it Means
Natural Riparian Land	The amount of riparian land covered by natural vegetation. Currently about 91% of the land is in natural condition. With no action **85%** of riparian land in the area (4000 acres) will remain in natural condition in 5-10 years.
River Ecology	Average ecological condition of area rivers, measured by the diversity of small organisms (dragonflies, mayflies, etc.) that live there. A score of 100% is the best possible condition in the area. A score of 0% means nothing lives in the water. With no action, the ecological condition in area rivers will be **55%** in 5-10 years. The score today is about 60%.
Recreational Fish	The number of recreational fish in area rivers, measured by scientific sampling of brook trout. A score of 100% would mean that area rivers contain the maximum number of trout possible (30 trout per 1000 sq. feet). Today there are about 19 trout per 1000 sq. feet. With no action, scientists predict there will be an average of 17 trout per 1000 sq. feet (**55%** of the most possible) in 5-10 years.
Safe Swimming	The percentage of days in which government tests show that area beaches (Laudholm, Drakes Island, Crescent Surf, and Parson) are safe for swimming. 100% means that all tests show water safe for swimming. With no action, scientists predict **85%** of tests will show water safe for swimming in 5-10 years.
Development Setback	The minimum width of the riparian area where development is restricted. Currently development and clearing is restricted within a minimum distance of **100 feet from rivers** and **25 feet from streams**. This distance is larger in some areas and for some types of development. Existing (legal) development would be grandfathered if setbacks change.
Enforcement	Whether enforcement is increased to prevent illegal development or clearing on riparian land. This could include inspections on private land if violations are suspected. Currently, inspections can only occur when a violation has been reported or as part of permitting.
$ **Cost to your Household per Year**	How much the policy will cost your household in unavoidable annual taxes and fees. These are guaranteed to only be spent on the protection option that is indicated.

7

Figure 11. Effects and Costs of Riparian Land Management Included in Choice Questions

Figure 12 shows an example of the type of A-B-N choices included in the survey. The annual household costs presented in each A-B-N choice are hypothetical. Some programs include higher costs and others include lower costs, to evaluate how changes in these costs affect residents' votes for or against different types of programs.

YOU WILL BE ASKED TO VOTE

After considering the current situation and possible protection effects and methods, which do you prefer? You will be given choices and asked to vote for the option you prefer by checking the appropriate box. **Questions will look similar to the sample below.**

SAMPLE QUESTION:

Method or Effect of Protection	In 5-10 years under the Current Situation	In 5-10 years under Option A	In 5-10 years under Option B
Riparian Land Condition	**85%** 4000 out of 4700 riparian acres covered by natural vegetation	**87%** 4100 out of 4700 riparian acres covered by natural vegetation	**95%** 4500 out of 4700 riparian acres covered by natural vegetation
River Ecology	**55%** of best possible (100%) ecological condition	**85%** of best possible (100%) ecological condition	**85%** of best possible (100%) ecological condition
Recreational Fish	**55%** 17 out of 30 possible fish per 1000 sq. feet	**75%** 23 out of 30 possible fish per 1000 sq. feet	**55%** 17 out of 30 possible fish per 1000 sq. feet
Safe Swimming	**85%** of beach tests meet safe swimming guidelines	**95%** of beach tests meet safe swimming guidelines	**85%** of beach tests meet safe swimming guidelines
Development Setback	**100 feet** required between development and rivers; 25 feet for streams	**150 feet** required between development and rivers; 75 feet for streams	**100 feet** required between development and rivers; 25 feet for streams
Enforcement	**No Change** in enforcement and inspections	**No Change** in enforcement and inspections	**Increased** enforcement and inspections
$ Cost to your Household per Year	**$0** Increase in Annual Taxes or Fees	**$45** Increase in Annual Taxes or Fees	**$5** Increase in Annual Taxes or Fees
HOW WOULD YOU VOTE? (CHOOSE ONLY ONE) I vote for	X NO NEW PROTECTION	X I vote for OPTION A	X I vote for OPTION B

	If you prefer **No New Action** Check Here	If you prefer **Option A** Check Here	If you prefer **Option B** Check Here

8

Figure 12. Example Choice Question

Prior to each choice, the survey presented information on the situation in the MBLR Watershed, as well as the different types of riparian land protection actions that could be used. Maps and graphics were included to illustrate the effects of these actions. All materials were subjected to extensive pretesting and revision over the three year survey development process. This process ensured that survey information and questions were clear and easily understood, and that questions addressed outcomes that were important to community residents.

5.1 Ecosystem Service Values and Riparian Land Protection

The choices of Kennebunk, Sanford and Wells residents show strong support for riparian land protection and/or restoration, even if it requires new taxes and fees. The choices also demonstrate the value of different types of protection outcomes (e.g., changes in ecosystem services).

Table 1 shows the value of each protection outcome and method (described in Figure 10) to an average household in the survey sample, based on observed votes. These may be interpreted as the amount that an average household would be willing to pay per year, in additional and reoccurring town taxes and fees, to obtain each of these outcomes. These are average values for each respondent household and reflect a WTP per year, *in perpetuity*. These results show that the value placed on riparian land protection depends on what is protected and how.

Table 1. Economic Value of Riparian Land Protection Outcomes

Outcome	**Description of Outcome** (All effects are within the MBLR Watershed)	**Value per Household, per Year** (Additional taxes/fees that each household would be willing to pay, per year)
Riparian Land Condition	The number of riparian acres with natural vegetation.	**$0.044** per additional acre with natural vegetation.
River Condition	The average ecological condition of area rivers, measured using a 100-point aquatic biotic index.	**$1.280** per point increase in the biotic index
Recreational Fish	The average number of brook trout per 1000 square feet of river.	**$3.833** per additional fish, per 1000 square feet of river
Swim Safety	The percentage of days during which government tests show that area beaches (Laudholm, Drakes Island, Crescent Surf and Parson) are safe for swimming.	**$2.020** per percentage point increase in safe swimming days
Setbacks	The minimum width of the riparian area where	**$0.140** per foot of **increased** development

	development is restricted, in feet.	setbacks.
Enforcement	Whether enforcement is increased to prevent illegal development or clearing on riparian land.	**$17.310** for increased enforcement and inspections, compared to the status quo

These results can be used to calculate residents' total value for different types of ecosystem service changes, and also to illustrate the tradeoffs that residents are willing to make. For example, increasing the number of brook trout in MBLR rivers by 1 fish per 1000 square feet (which as a value of $3.83 per household, per year) would have the same value to residents as restoring natural vegetation on 87.88 acres of riparian land (value = 87.89 × $0.04 ≈ $3.83 per household, per year). The same value would be provided by a program that increased the percentage of safe swimming days by 1.90 (value = 1.90 × $2.02 ≈ $3.83 per household, per year). Results such as these can be used to calculate the type of programs that would be most valued by residents of the area, and how to best design programs to meet residents' priorities.

Results also show that increases in minimum development restrictions (setbacks) and enforcement are *positively* valued by local residents—residents are more likely to support riparian land protection programs if those programs involve stronger restrictions on development, holding all else constant. This finding contradicts "common wisdom" that Maine residents would not support development restrictions to obtain improved environmental outcomes.

These results can also be used to quantify the combined value of riparian land protection or restoration to Kennebunk, Sanford and Wells residents. For example, consider a hypothetical riparian land protection and restoration plan that would lead to the following projected outcomes within the MBLR Watershed: (1) restore natural vegetation on 200 acres of currently cleared riparian land, (2) increase the ecological condition of rivers by 5 points on the 100 point aquatic biotic scale, (3) increase the average number of brook trout by 3 fish per 1000 square feet of river, (4) have no effect on the safety of local beaches for swimming, (5) make no change in required development setbacks, (6) increase enforcement and inspections of development restrictions on private land. Table 2 shows the total value of this plan, both to each household (on average) and to the three communities as a whole.

Table 2. Illustrative Economic Value of a Hypothetical Riparian Restoration Plan in the MBLR Watershed

(A) Projected Outcome	**(B) Additional Taxes/Fees that Each Household would be Willing to Pay – See Table 1**	**(C) Total Value per Household, Per Year (= A×B)**
Restore natural vegetation on 200 acres of riparian land	$0.044 per acre	$8.72
Increase ecological condition of rivers by 5 points on aquatic biotic index	$1.28 per point	$6.40
Increase the average number of brook trout by 3 fish per 1000 square feet of river	$3.833 per fish	$11.50
No effect on the safety of local beaches for swimming	$2.02 per percentage point increase in safe swimming days	$0.00
No change in required development setbacks	$0.140 per foot	$0.00
Increase enforcement and inspections	$17.31 for increased enforcement and inspections	$17.31
Total Plan Value per Household Per Year The amount that an average household would be willing to pay in additional taxes and fees, per year and in perpetuity, to obtain these combined outcomes		**$43.93** per household, per year (Equivalent to a total value of **$760,443 per year**, in perpetuity, when multiplied by all 17,309 households of Kennebunk, Sanford and Wells.)[13,14]

The illustrative scenario in Table 2 is just one of many examples that can be developed using the choice experiment results. As shown by Tables 1 and 2, residents of Kennebunk, Sanford and Wells receive considerable value from the potential outcomes of riparian land restoration, as reflected in their WTP. If given a choice, residents would vote to support programs (such as local bond issues) that would generate increased ecosystem services from riparian land in the MBLR watershed, even if those programs required additional taxes and fees. For example, assume that the program described above were offered to Kennebunk, Sanford and Wells voters at an average household cost of $20 per year (e.g., in additional property tax payments to support a local bond). Model results predict that 73.7% of residents would vote ‘yes’ for this proposal. This support reflects the personal value that the ecosystem services of riparian land provide to residents. Of course, residents’ willingness to support any public program depends on a

[13] As of the 2010 Census there were 4,120 households in Wells, 4,689 in Kennebunk and 8,500 in Sanford.
[14] For example, over 20 years, this would imply that Kennebunk, Sanford and Wells residents would be willing to pay a total of $15.2 million in additional taxes and fees (20 × $760,443), in order to obtain these outcomes. This reflects the value they receive.

variety of other factors as well, including whether a program is viewed as feasible and whether funds are guaranteed to be spent for the intended purposes. Residents are also willing to accept greater restrictions on the use of private lands, and indeed are more likely to vote for programs that include more strict regulation of development in the riparian zone, and additional enforcement.

The survey also included questions to evaluate the validity of these results, and how respondents felt about the survey. The vast majority of respondents viewed the survey instrument favorably. Most indicated that the information and questions were easy to understand, that survey content was fair and balanced and that they were confident about their answers. For example, 76% of respondents agreed or strongly agreed that they felt confident in their survey answers, and 83% of respondents agreed or strongly agreed that they would vote the same way in a binding referendum.

5.2 Are these Real Economic Values?

These values are derived from a survey instrument and not a real binding vote. If given an actual choice (say, in a real binding vote), would people *really* pay these amounts? Although there is concern among some economists that surveys such as this can generate inflated value estimates, comparisons to actual binding referenda show that well-designed surveys such as this accurately predict people's votes and values.[15] Hence, while there is some degree of uncertainty in all scientific measurements (including measurements of economic value), the results provided here provide strong evidence that Kennebunk, Sanford and Wells residents receive considerable value from the ecosystem services of riparian land, and would vote for programs that enhance these services.

6.0 Conclusion

Quantifying the ecosystem service values and tradeoffs associated with environmental management alternatives can provide information crucial for policy design and to identify the often overlooked benefits of policies that enhance ecosystem sustainability. Results of the survey *Choices for Our Land and Water: A Survey of Kennebunk, Sanford and Wells Residents* demonstrate the types of economic value provided by natural riparian lands in the Merriland, Branch Brook and Little River Watershed, and the extent to which local residents are willing to pay for programs that would enhance these valued natural resources and the ecosystem services that they provide. These results are based on a random sample of Kennebunk, Sanford and Wells residents. Hence, they provide a more representative perspective on public values than is revealed by the small, self-selected and more vocal set of area residents who attend public meetings, are active in advocacy groups, or engage in other activities that influence public policy decisions. By providing a more representative perspective, the ecosystem service value results summarized here can help policymakers develop policies that more accurately reflect the values of all residents, not just a select few.

Some key findings of the study include:

[15] Johnston, R.J. 2006. Is Hypothetical Bias Universal? Validating Contingent Valuation Responses Using a Binding Public Referendum. Journal of Environmental Economics and Management 52(1): 469-481.

- Residents of Kennebunk, Sanford and Wells place high importance on environmental protection. The importance placed on environmental and ecosystem service protection is greater than that placed on the protection of landowner rights and prevention of tax increases.
- Residents hold considerable value for ecosystem services provided by riparian land. The value that people hold for riparian land restoration depends on how much land is restored, the effects on ecosystem services, and how restoration is accomplished. Residents are willing to pay for improvements in riparian land condition itself, as well as for improvements in the condition of local rivers, recreational fisheries, and swimming safety of local beaches that can result from the restoration of this land.
- All else equal, residents prefer management alternatives that *increase* restrictions on the development of riparian land (by increasing setback requirements) and that increase enforcement and inspections of these and other development restrictions. Residents prefer stronger regulation of development on riparian lands.
- Residents will support programs that restore and protect riparian land in the MBLR Watershed and associated ecosystem services, even if implementing these programs requires increases in the taxes and fees paid by their households.

The results of this study do not indicate what types of riparian land protection or restoration alternatives are right or wrong. Rather, the results predict which riparian land protection or restoration alternatives would be strongly supported by area residents because they are perceived as providing the greatest value. When combined with information on the projected ecological outcomes of riparian land management and the associated costs, results such as these can help identify management alternatives that best support the long term goals and values of residents, and generate the greatest sustainable economic value.

Appendix I. Demographic Profile of Respondents

The survey was mailed to a random sample of residents in Kennebunk, Sanford and Wells, including all residents of the MBLR watershed. The following summarizes the characteristics of those who responded. These results suggest that responses were received from a wide range of demographic groups, but the sample was of somewhat greater age, income and education than the general population. Females were more likely to respond than males.

Selected Socio-demographic Characteristics of the Survey Sample (Survey Responses)

What is your gender?

Male	Female
40%	60%

What is your age?

20~29	30~39	40~49	50~59	60~69	70~80	More than 80
2%	8%	14%	28%	26%	17%	6%

Do you live in the Merriland, Branch Brook and Little River Watershed?

Yes	No	Not Sure
55%	32%	13%

What is the highest level of education you have completed?

Less than high school	High school/GED	Some college	2~Year College	4~Year college	Graduate Degree (MS, PHD, etc.)
1%	17%	19%	14%	31%	19%

How long have you been a Maine resident?

Less than 5	5-19	20-34	35-49	50-65	More than 65
6%	23%	26%	19%	18%	9%

What category best describes your total household annual income?

Less than $10,000	$10,000 ~ $19,999	$20,000 ~ $39,999	$40,000 ~ $59,999	$60,000 ~ $79,999	$80,000 ~ $99,999	$100,000 ~ $249,999	$250,000 or more
2%	7%	18%	19%	17%	13%	20%	3%

Of the final survey sample, 33.7% of returned surveys were from Kennebunk residents, 33.1% were from Sanford residents, and 33.2% were from Wells residents.

Appendix II. Technical Details of the Choice Model and Results

Table A.1 shows the statistical results underlying the value estimates provided in Table 1. The random utility model for the choice experiment was estimated using mixed logit with Halton draws, allowing for correlations across multiple responses from each respondent. The model predicts the choices (or votes) that were made by each survey respondent, as a function of the attributes of the riparian land protection plans they considered. The final specification was chosen after the estimation of preliminary models with varying specifications of fixed and random coefficients. Coefficients on an alternative specific constant for the status quo (*ASC*), *Recreational Fish*, *Safe Swimming*, *Development Setbacks*, and *Enforcement* are specified as random with a normal distribution. The coefficient on *Cost* (sign-reversed) is random with a bounded triangular distribution, ensuring positive marginal utility of income. The coefficients on *Riparian Land Condition* and *River Condition* are specified as non-random. The model is statistically significant at $p<0.0001$, with all coefficient estimates on fixed and random parameters statistically significant at $p<0.01$. Willingness to pay estimates reported in Tables 1 and 2 are calculated from these results. Very similar results are derived from other specifications of the model (i.e., the results are statistically robust).

Table A.1. Mixed Logit Model Results

Chi squared [13 d.f.] 1174.99325
Significance level .00000
McFadden Pseudo R-squared .2411012
Number of obs.= 2218

	Coefficient	Standard Error	z	Prob. |z|>Z*	95% Confidence Interval	
Random parameters in utility functions						
NEITHER	-3.26424***	0.51291	-6.36	0.0000	-4.26952	-2.25896
FISH_PCT	0.04075***	0.00596	6.84	0.0000	.02907	0.05243
SWIM_PCT	0.07220***	0.01322	5.46	0.0000	.04629	0.09811
SETBACK_	0.00541***	0.00182	2.98	0.0029	.00185	0.00897
ENFORCE	0.64542***	0.11486	5.62	0.0000	.42031	0.87054
NEG_COST	0.04932***	0.00504	9.80	0.0000	.03945	0.05919
Nonrandom parameters in utility functions						
LAND_PCT	0.07392***	0.01680	4.40	0.0000	.04099	0.10685
WATER_PC	0.04546***	0.00566	8.03	0.0000	.03436	0.05656
Distns. of RPs. Std.Devs or limits of triangular						
NsNE	6.70172***	0.67433	9.94	0.0000	5.38006	8.02337
NsFISH_P	0.03404*	0.01758	1.94	0.0529	-.00042	0.06849
NsSWIM_P	0.05711	0.03967	1.44	0.1499	-.02063	0.13486
NsSETBAC	0.02565***	0.00370	6.94	0.0000	.01840	0.03289
NsENFORC	1.07711***	0.25742	4.18	0.0000	.57258	1.58165
TsNEG_CO	0.04932***	0.00504	9.80	0.0000	.03945	0.05919

Communication Audit and Mental Mapping Research Summary

Prepared By Verna DeLauer Ph.D., Franklin Pierce University & Clark University

April 2015

Introduction: If natural resource managers are to influence positive beliefs and behaviors toward riparian ecosystem services and shoreland protection then a clearer picture of how adults make meaning of these systems and themselves within them is critical (DeLauer 2013). Understanding adult beliefs, perceptions and values increases the opportunity for the Wells National Estuarine Research Reserve science to make the greatest impact with stakeholders and residents. The goals of the communications/mental modeling research stream were to evaluate current communication messages among the Wells Reserve and its partner stakeholders, capture Reserve staff and stakeholder beliefs about shoreland protection, test to see if those same beliefs were prevalent among residents within the Merriland, Branch Brook, and Little River (MBLR) watershed, and reevaluate communication messages and strategies to improve mutual understanding. The overarching research question was: *How should the Wells Reserve and its partner stakeholders communicate messages about shoreland protection and riparian buffers more effectively to build trusting relationships with residents, improve attitudes and change beliefs?*

Methods: A mental model methodology was adapted from Morgan et al's (2002) work on risk communication and included three data collection techniques: communication audit, mental modeling interviews and a confirmatory questionnaire. First, a communication audit of the Wells Reserve and four other environmental organizations in the MBLR watershed was conducted. A communications audit is an inventory of communication efforts of an organization (Brooks et al 2010). This includes capturing key audiences, messages, techniques, available resources, and program evaluation (Downs and Adrian 2004). The goal of an audit is to identify effective communications and engagement practices, areas of improvement and resource needs. This audit provided baseline information about the ways the Reserve and stakeholders were communicating about shoreland protection and how might the research results improve how they communicate or what they communicate. Workshops and presentations by experts to landowners were the most common engagement methods. Messaging focused on land conservation, viewsheds and how land use affects water quality. Time, financial and staff resources were lacking to increase outreach efforts, evaluate them, and conduct social science research.

Mental modeling interviews were conducted after the communications audit. Mental models, also called cognitive models or mapping, are used in a variety of contexts to assess ways in which people comprehend complex and uncertain environmental issues (CRED 2009; Welp et al. 2006; Morgan et al. 2002). They depict a person's beliefs about a concept, idea or system, including a representation of how a person interprets and relates disparate pieces of information and experiences.

Purposive and snowball sampling techniques were used to acquire a representative sample of 22 individuals of stakeholders, including municipal officials, developers and realtors, engineers, state officials and NGO staff. The first step in the mental modeling process was to conduct in-depth, open-ended interviews with this representative sample. The goal of these interviews was to capture patterns of beliefs one has about shoreland protection and riparian buffers. These interviews began with very open-ended questions such as, "Tell me what you know about buffers." Then questions such as, "You mentioned XX. Can you give me an example?" were asked to provoke participants to elaborate on their beliefs. As widely held or different beliefs became apparent, these patterns and divergences were further explored.

In qualitative research, data coding and analysis happen simultaneously. This involved identifying themes within the data and iteratively testing and retesting them to prove or disprove their salience. NVivo, a qualitative data analysis program, was used to organize the data and perform queries to explore latent connections in the data. Kohen's Kappa statistic was used to ensure greater than 80% inter-rater reliability between two coders. This process resulted in three themes that described common patterns of inference and belief held by stakeholders: 1. Change perception about regulation; 2. Specifically target new and seasonal residents; and, 3. Communicate with more empathy when working with landowners.

Using these data, individual mental models were created first to explore individual cognitive processes.
Next aggregate mental models were created using a program called Vensim to visually depict the beliefs stakeholders' collectively held about these three themes. The cognitive linkages illustrated in the final models showed shared frames of meaning among 50% or more stakeholders. An example is given at the end of this section.

Using the mental model findings, a set of confirmatory questions were added to the project's choice experiment survey to confirm whether the patterns of inference and belief found among stakeholders' mental models were also present among a large population of residents, i.e. n = 1,126.

Mental Model Findings

How should the Wells Reserve and its partner stakeholders communicate messages about shoreland protection and riparian buffers more effectively to build trusting relationships with residents, improve attitudes and change beliefs?

There were three collective beliefs that stood out among Wells staff and its stakeholder partners.

1. Perception about regulation must change so that landowners believe regulators are interested in the natural resources on *their* properties and are evaluating them on a case-by-case basis.
2. One's identity as a "Mainer" only assumes an interest in environmental custodianship if you are a long-time resident; new and seasonal residents are

mainly interested in ownership. An effort must be made to target new and seasonal residents with messages that encourage environmental custodianship.

3. To more fully engage landowners, they must be communicated to with empathy so that they believe that their property rights are being considered equally to environmental protection.

Likert scale questions were created related to these three beliefs to test agreement among residents.

1. To maintain a high quality of life in Maine, it is important to balance development with preservation and conservation.
2. I have heard of the Shoreland Protection Act.
3. I understand the goals of the Shoreland Protection Act.
4. There is sound scientific research that supports current zoning regulations on riparian land.
5. I consider myself a custodian of the land.
6. Regulations are needed to protect shoreland and clean water in York County.
7. It is equally important to protect private property rights and clean water. The long-term protection of the environment is more important than the right of an individual property owner to develop his/her property.

Mental Model Themes	Shoreland Regulation	Identity & Custodianship among new/seasonal residents	Environmental & Personal Balance
Survey Result	Over 50% of residents were not secure in their understanding of shoreland protection regulations	Over 50% of residents considered themselves custodians of the land regardless of years of residency	Nearly 90% of respondents agreed that private property rights were just as important as environmental protection
Communication Recommendation	Target younger audience; messaging about type of regulation	Strengthen messages about owners of one’s land to custodians of one’s land.	Messaging about the relationship between protecting one’s home and the natural resources on one’s property.
Survey Result	As one’s income increased, support of regulation decreased.		Interest in private property rights decreased as one’s affluence and education increased.
Communication	Further research on		Further research on

Recommendation	perception of regulation & of one's rights		perception of one's rights & of govt. to protect one's rights

Survey Results and Implications by Theme: A correlation matrix was used to identify potential relationships between individual questions and between individual questions and demographic attributes such as age, income, education, and years of residency in Maine. Chi Square analyses were conducted to further test significance.

Theme 1: Shoreland Regulation: Over 50% of respondents were not secure in their understanding of the Shoreland Protection Act though as age increased, understanding of the act increased. *Communication Tip*: The Reserve could target communications about shoreland regulations to a younger audience who may not currently own land but may do so in the future.

Despite an average knowledge and understanding of the Act, nearly 90% of respondents believed that shoreland regulations were important. *Communication Tip*: The Reserve could conduct further research to learn how residents were making sense of the idea of regulation or they could more strategically define regulation, using the Shoreland Protection Act as one example.

Those who were interested in environmental protection also favored regulation. However, as one's income increased, support of regulation decreased. *Communication Tip*: Further research would be needed to understand why regulation is not as important to more affluent residents. Becoming a steward and taking personal responsibility might be more powerful messages to this audience than a message about following regulations.

Results also indicated that there might not be a clear understanding of the science underlying the Shoreland Protection Act. *Communication Tip*: If the Reserve wanted to increase the impact of their science, more education about their research projects and how they would be useful to residents would be needed.

Theme 2: Targeting new/seasonal residents: Over half of respondents considered themselves custodians of the land. There were not any significant relationships between this and length of residency, age, education, or income. *Communication Tip:* The Reserve could recruit residents involved in stewardship activities to help educate and inform other residents. The Reserve could work with municipal officials to strengthen their messages about community stewardship and changing mindsets from owners of one's land to custodianship of one's land.

Theme 3: Recognizing the balance between private property rights and environmental protection: Nearly 90% of respondents agreed that private property rights were just as important as environmental protection yet these were negatively correlated, as interest in private property rights increased, interest in environmental protection decreased. *Communication Tip:* The Reserve could use messaging that showed a significant relationship between protecting one's home and the natural resources on one's property or in one's community.

Similarly to regulation, interest in private property rights decreased as one's affluence increased. *Communication Tip:* More research could be conducted to understand how residents of different socio-economic means perceive private property rights, e.g. do less affluent residents feel their rights are more vulnerable therefore they are more protective of them and possibly see regulation as one way of protecting their rights.

In addition to income, as one's education increased one's interest in private property rights decreased. *Communication Tip:* More research could be conducted to understand whether there are particular educational experiences that contribute to this decreased sense of importance on rights, e.g. do more educated residents feel their rights are less vulnerable to political decisions because they better understand the political process?

Overall, results indicate that the Reserve and its partners could be more strategic in their communication strategies. The mental model results are applicable to the Reserve and its stakeholder partners because they identify common patterns of inference and belief and can be useful toward more strategic collaboration with one another, particularly those who are trying to communicate with similar audiences. The results also suggest the need for much more targeted and nuanced types of communication. The confirmatory questionnaire results could be applicable to the Reserve, its stakeholder partners and other Reserves around the country trying to gain more support of regulation, more interest in stewardship programs, and more balanced discussions about the many trade-offs involved in natural resource decision-making. Some of the recommendations call for further research and the communication audit showed that education and outreach resources were already tight. Inter-organizational collaboration could be useful. This research stream was able to use the existing choice experiment survey to administer a confirmatory questionnaire to a broader population while not expending additional resources. Interdisciplinary collaboration has the potential to be cost effective and mutually supportive.

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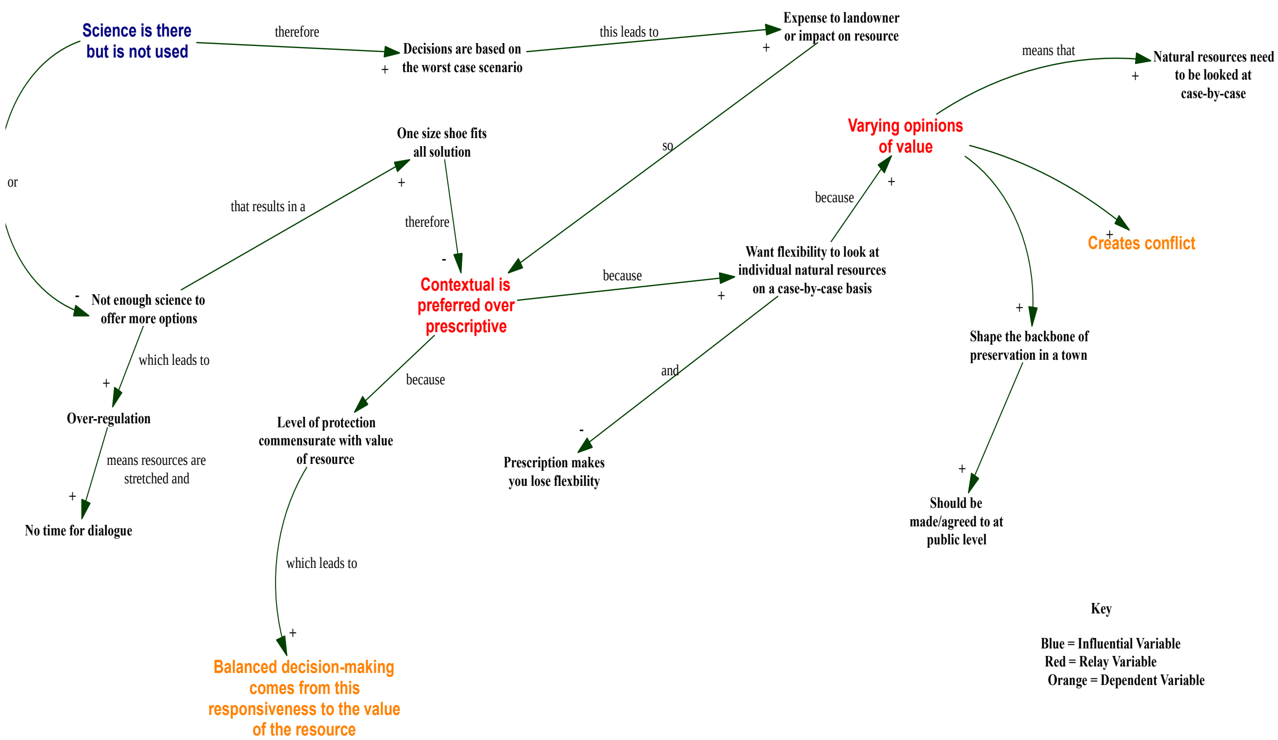
Mental Model Example from Shoreland Regulation Theme.



Appendix to Communications Audit and Mental Modeling
Handout Prepared for Ecosystem Valuation in the NERRS Summit April 2015

Sustaining Coastal Landscapes – Communication Audit and Mental Mapping

By Dr. Verna DeLauer, Franklin Pierce University & Clark University
Member of Research Team for Wells NERR Science Collaborative Project
"Sustaining Coastal Landscapes and Community Benefits:
Developing an Interdisciplinary Model for Enhancing the Impact of NERRS Science"

Introduction: If natural resource managers are to influence positive beliefs and behaviors toward riparian ecosystem services and shoreland protection then a clearer picture of how adults make meaning of these systems and themselves within them is critical (DeLauer 2013). Understanding adult beliefs, perceptions and values increases the opportunity for the Wells National Estuarine Research Reserve science to make the greatest impact with residents. The goal of the communications/mental mapping research was two-fold: to understand the collective beliefs about riparian buffers among Reserve staff and their stakeholder partners (e.g. municipal and state government, not-for-profit organizations) and based on those beliefs, to identify which communication and engagement strategies should be collectively prioritized.

Communication Audit: First, a communication audit of the Wells Reserve was conducted. A communications audit is an inventory of communication efforts of an organization (Brooks et al 2010). This includes capturing key audiences, messages, techniques, available resources, and program evaluation (Downs and Adrian 2004). For example, the Wells National Estuarine Research Reserve does not currently have an overarching communication vision. Rather, limited resources are spent promoting Reserve programs and events to attract visitors. The Reserve has specific targeted audiences such as town planners, the planning board, selectmen and landowners. They are interested in connecting with these particular audiences about land use as it relates to riparian ecosystem services.

Geographically, the Reserve staff is focused on messaging relevant to southern Maine. They want to communicate that clean water is a product of a natural landscape and requires greater attention to land conservation, proper riparian buffers and non-point source pollution. The tourism industry in particular causes tension for the Reserve and other environmentally-oriented organizations in Maine because of the economic benefits tourism brings to the State and the environmental impacts tourism has on pristine beaches, lakes and ponds.

The Reserve uses a variety of mechanisms to communicate these messages about clean water and land protection. Workshops, Coastal Training Program events and Rotary events are a few examples. Reserve staff also participates in watershed planning efforts in the region. They try to capitalize on existing opportunities to reach landowners and town planners. The Coastal Training Program, which is situated at the Reserve, is an important resource and support for communications staff. Other community organizations are also important in building and maintaining a network of partners. Reserve staff uses other organizations' newsletters, for example, to communicate with their targeted audiences.

At present, there are limited resources for thorough, ongoing evaluation of their communication efforts. They do evaluate some of their workshops but do not have an evaluation plan in place for their other work. Overall, due to very little, if any, financial resources, communications staff takes advantages of opportunities to reach targeted audiences. Because of the lack of resources, communication planning is opportunistic rather than an integral process to further the NERRS mission.

Mental Mapping: Mental mapping interviews were conducted after the communications audit. Mental maps are used in a variety of contexts to assess ways in which people comprehend complex and uncertain environmental issues (CRED 2009; Welp et al. 2006; Morgan et al. 2002). Mental mapping was a useful methodology to understand how Reserve staff and stakeholder partners comprehend the complexity of riparian buffers. Purposive and snowball sampling techniques were used to acquire a representative sample of 22 individuals, including Reserve staff, municipal officials, developers and realtors, engineers, state officials and NGO staff. The first step in the mental mapping process was to conduct in-depth, open-ended interviews with this representative sample. The goal of these interviews was to capture patterns of beliefs one has about shoreland protection and riparian buffers. These interviews began with very open-ended questions such as, "Tell me what you know about buffers." Then questions such as, "You mentioned XX. Can you give me an example?" were asked to provoke participants to elaborate on their beliefs. As widely held or different beliefs became apparent, these patterns and divergences were further explored.

In qualitative research, data coding and analysis happen simultaneously. This involved identifying themes within the data and iteratively testing and retesting them to prove or disprove their salience. NVivo, a qualitative data analysis program, was used to organize the data and perform queries to explore latent connections in the data. Kohen's Kappa statistic was used to ensure greater than 80% inter-rater reliability between two coders. We mapped what the research participants believed to be true about York County residents and riparian buffers. Using these data, individual mental models were created first to explore individual cognitive processes. Next aggregate mental models were created using a program called Vensim to visually depict the collective beliefs held about these three themes.

Mental Mapping Results: There were three collective beliefs that stood out among Wells staff and its stakeholder partners.

1. Perception about regulation must change so that landowners believe regulators are interested in the natural resources on *their* properties and are evaluating them on a case-by-case basis.
2. One's identity as a "Mainer" only assumes an interest in environmental custodianship if you are a long-time resident; new and seasonal residents are

mainly interested in ownership. An effort must be made to target new and seasonal residents with messages that encourage environmental custodianship.

3. To more fully engage landowners, they must be communicated to with empathy so that they believe that their property rights are being considered *equally* to environmental protection.

Survey: To explore the relevance of the mental mapping results to residents, seven questions were added to an existing survey that was administered to nearly 1200 residents within the watershed. A correlation matrix was used to identify potential relationships between individual questions and between individual questions and demographic attributes such as age, income, education, and years of residency in Maine. Chi Square analyses were conducted to further test significance.

What Reserve staff and stakeholder partners believed	**How residents responded**
Residents see regulation as negative.	Over 50% of (particularly younger) residents did not understand shoreland protection regulations. Residents with higher incomes felt more mistrust for regulation than those with lower incomes.
Long-time residents care about environmental protection more than new/seasonal residents	There was no correlation between length or type of residency and caring about environmental protection
Residents believe individual rights *and* environmental protection must be balanced.	90% of residents, particularly those with lower income and less formal education believe private property rights are *as* important as environmental protection

Strategies for Achieving Communication Goals: First and foremost, it is important for the Reserve and the stakeholders who participated in this research to discuss results and generate a collective plan for better educating and communicating with residents about riparian buffers. The communication audit for the Reserve identified the challenges they face in fully addressing their communication needs. The collective mental mapping results identified the communication priorities among the Reserve and its partners. The survey results tested the relevance of the mental maps with a larger population. Based on these results, the following strategies are recommended:

1. Target communications about shoreland regulations to a younger audience who may not currently own land but may do so in the future.

2. Further research is needed to understand why regulation is not as important to more affluent residents. Becoming a steward and taking personal responsibility might be more powerful messages for this audience rather than messaging about rules and regulations.

3. Specifically communicate the usefulness of the Reserve's research to residents, e.g. how is a particular research project or outcome beneficial to a specific segment of the population.

4. Recruit residents involved in stewardship activities (particularly long-term residents) to help educate and inform other residents. The Reserve could work with municipal officials to strengthen their messages about community stewardship.

5. Use messaging that shows an integral relationship between protecting one's home and the natural resources on one's property or in one's community.

6. Further research is needed to understand why less affluent and less educated residents are particularly interested in protecting the balance between their property rights and environmental protection.

7. Communicate with landowners in ways that promote protection of riparian ecosystem services while simultaneously honoring their property rights.

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Connecting Place-based Ecosystem Services Research with National Priorities

Prepared by Peter Wiley
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August 2014

One of the most important outcomes of this project is the contributions it makes to NERRS and NOAA level needs for specific information about ecosystem service values, how they are applied, and examples of comprehensive and appropriate methodology and approach.

NOAA and Ecosystem Services

For some time, NOAA has been interested in expanding the agency's ability to estimate and apply ecosystem services in a variety of management contexts. Although there are many examples of ecosystem services research in NOAA, they are largely inconsistent, disjointed, and not well supported. One of the reasons for this has been the historic lack of a consistent platform with which to conduct this kind of research (fisheries research notwithstanding). The NERRS has great potential to provide a consistent platform with a diversity of geographic, habitat and stakeholder contexts.

Use of information on the economic value of coastal and ocean resources at NOAA is not a new idea. This work has been ongoing for some time in support of fisheries management, natural resource damage assessment, and sanctuaries management. What has been missing is an explicit connection between economic value and ecosystem condition and function. The trend toward integrating ecological and economic parameters in the estimation of values has been going up in recent years but there is still considerable confusion as to what constitutes ecosystem services research. Specifically, ecosystem services valuation work that does not include, or has weaknesses in either the ecological or economic side remains common.

This project provides a clear example, which includes significant ecological and economic research, as well as an iterative process by which the economists and ecologists had regular communication regarding relative needs, and how the work could best be integrated. Additionally, the stakeholder engagement, and communication aspects of this project provided further clear examples of what is required for an ecosystem services project to be effectively carried out and applied.

The project team has regularly interacted with NOAA staff in order to assure that the lessons learned in the conduct of the project would benefit existing and future NOAA efforts. The interaction included the Office of the Chief Economist, the Ecosystem Services Working Group, the Ecosystem Research Agenda Committee, as well as numerous other staff who conduct or manage ecosystem services work.

In order to manage coastal and ocean resources from an informed perspective, NOAA must have consistent and comprehensive information about the relative benefits and costs of its management actions. This information will depend heavily on the agency's capacity to conduct ecosystem services research as is illustrated in the results of this project.

NERRS as a "Living Laboratory" for research on ecosystem service valuation

The NERRS, with its established monitoring program and its role in individual communities, have a unique potential to take advantage of this context to explore the significant potential for utilizing ecosystem services research in a variety of management and decision frameworks.

Through work with local coastal managers, planners and decision-makers, NERRS staff has the connections with their local networks and an understanding of the information needs to make informed decisions. NERRS staff also has access to the System Wide Monitoring Program, a rich repository of water quality monitoring data that can serve as the foundation for the ecological data needed to conduct ecosystem services work.

The results of this project can be used to explicitly identify what is needed in terms of these data and to identify the remaining gaps. The economic components of this work are one area that will need to be enhanced to expand this work. In partnership with NERRA, NOAA is currently exploring the best way to approach this work, including the establishment of a socioeconomic observing system that could be a regular source of socioeconomic data to complement the SWMP data.

The approach, data needs, and interdisciplinary interactions in this project have, and will continue to serve as a model for how this program might be developed.
It also applies a collaborative approach to increase the likelihood that results will be directly applied to address coastal area management challenges in the Wells NERR and surrounding coastal areas. The work is directly responsive to goals of the NERRS Strategic Plan, including "demonstrate and facilitate the development of sound science and best practices for improved local and regional coastal resource management" (NERRS 2006). It explicitly addresses Goal 4 of the NERRS Research and Monitoring Plan (2006-2011), to ensure that scientific, coastal management and education communities, as well as the general public, use data, products, tools, and techniques generated at the NERRS.

Developing an Interdisciplinary Model for Enhancing the Impact of NERRS Science

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Director Center for Sustainable Communities, University of New England
July 2015

> *Estuaries, where rivers meet the sea, are among the nation's most biologically rich and economically important ecosystems. They are also one of the most vulnerable – situated on the front lines of natural and human-induced change. The interconnection between the health of estuaries and society's economic and recreational well-being is increasingly evident, and coastal conservation is being driven by both ecological and societal needs. The National Estuarine Research Reserve System, a network of 28 protected areas along America's coasts, responds to these needs by providing platforms for learning and teaching, applying research to management, and practicing coastal stewardship. Each reserve in the national system serves as a place-based living laboratory and classroom where program development, research techniques, and management approaches can be piloted and applied to issues of local, regional, and national importance*
>
> Introduction to NERRS Strategic Plan, 2011

This Reserve Initiated Project Enhanced Capacity within the NERRS

The National Estuarine Research Reserve System (NERRS) protects over 1.3 million acres of salt and fresh water estuaries. These estuaries have been selected for inclusion in the system as representative examples from distinct bio-geographical regions of the US including Puerto Rico. The concept for the system was established by the Coastal Zone Management Act of 1972. Reserves are managed as a state-federal partnership where NOAA is the federal partner. State partners can be agencies, universities or designated partnerships. Each Reserve implements a site specific management plan consisting of research, education, training and stewardship programs.

This project engaged all aspects of the NERR system in collaborative interdisciplinary research aligned with national goals articulated in the NERRS Strategic Plan and in response to coastal management issues identified as important to local Wells NERR stakeholders. As part of one of the stakeholder workshops developed for this project, a mental model narrative of "Collaborative Research" was developed. This mental model narrative was used during the *Bridging the Gulfs* workshop at the Wells NERR,

> Collaborative Research is an approach to addressing a research question or testing a research hypothesis that includes people who have a stake in or connection to the research. Collaborative research is an adaptable

> approach that can engage stakeholders in a single phase of a research project or in multiple aspects of the research. Stakeholders and researchers can work together to identify the research question, determine methods of data collection, make sense of research findings and evaluate applications of research findings. There is evidence to support the concept that engaging stakeholders in the research project increases the application of research findings to solve societal problems. Collaborative research methods have been used in social sciences for decades, especially in anthropology. Collaborative research methods are becoming increasingly important in interdisciplinary research practices associated with adaptive ecosystem management, coupled human and natural systems research, research on social ecological systems and resilience, and sustainability science.

Collaborative research was a relatively new concept for the NERRS in 2010 when the NERRS Science Collaborative released their first RFP. This project was developed in response to that RFP addressing the requirements and criteria specifically articulated therein. Because the proposal was initiated by a Reserve, the proposal design was strongly aligned with the goals and objectives of the NERRS. Proposals emanated from a University owe allegiance and compliance first to their University's Office of Sponsored Research. NERRS strategic goals and priorities are of secondary importance and are highlighted in a proposal primarily in the limiting context of an individual RFP.

The Reserve system is guided by a Strategic Plan developed collaboratively by members of the system and NOAA (NERRS/NOAA, 2011). This project was designed to specifically address key elements of the NERRS Strategic Plan, which was developed as the project began. Alignment of this project with multiple goals of the NERRS Strategic Plan is highlighted below.

> NERRS Priorities addressed by *Sustaining Coastal Landscapes and Community Benefits*
>
> **Protected Places Goal**: Estuaries and coastal watersheds are better protected and managed by implementing place-based approaches at Reserves.
>
> *Objective*: Develop, demonstrate, and evaluate tools and practices at reserves that advance progress on habitat protection, water quality, and climate change impacts.
>
> *Priority Strategy Used*: Implement engagement programs to promote estuarine resource stewardship.
>
> **Science Goal**: NERRS scientific investigations improve understanding and inform decisions affecting estuaries and coastal watersheds.

Objectives: Characterize coastal watersheds and estuary ecosystems and quantify ecosystem services to support ecosystem-based management of natural and built communities.

Increase social science research and use of social information to foster coastal stewards that value and protect estuaries.

Priority Strategies Used:
Lead Reserve-based collaborative projects that connect scientists with intended users from problem definition through implementation.

Develop and implement strategies that build reserve capacity to conduct and use social science to address coastal management issues

People Goal: NERRS education and training increases participants' environmental literacy and ability to make science-based decisions related to estuaries and coastal watersheds.

Objective: Improve the capacity and skills of coastal decision makers to use and apply science-based information in decisions that affect estuaries and coastal watersheds.

Priority Strategies Used:
Include relevant estuarine research and data in reserve professional training and education programs.

Expand training for coastal decision makers focused on climate change, habitat protection, and water quality issues.

A Suite of Six Training and Outreach Approaches Engaged the NERRS with the Project

I. *Working Together to Get Things Done* Training 2012
Collaborative Learning Training developed in partnership with Wells NERR CTP and the NERRS Science Collaborative. During the period from January – August 2012 eight trainings were delivered at: Elkhorn Slough NERR, Waquoit Bay NERR, Rookery Bay NERR, Grand Bay/Weeks Bay NERR, Tijuana River NERR, Padilla Bay NERR, Old Woman Creek NERR, and North Carolina NERR. 250 participants attended the two day training at all sites. While these trainings were not funded as part of this grant they did contribute to goals of increased used of collaborative research methods in the NERRS and provided valuable insights into national challenges faced by Reserve stakeholders attempting to implement collaborative approaches. This focused interaction with the NERRS staff provided useful information that was used to adapt the findings of this project for dissemination to the system as part of subsequent meetings and

trainings. This training was offered in 2013 at the Narragansett Bay NERR and was adapted to a one day and half day training workshop for national conferences sponsored by EPA and A Community for Ecosystem Services (ACES). This training is available for all Reserves and can be scheduled through the Wells NERR Coastal Training Program. Materials for this training will be available on the Wells Reserve website beginning September 2015. Resource materials include a participant and facilitator workbook, process agenda, Collaborative Learning Guide, Cultural Models Primer and workshop power point slides.

II. Qualitative Methods On-line Course 2013 Archived on Wells NERR website at, http://www.wellsreserve.org/blog/664-nerrs_online_qualitative_research_course

Designed following a needs assessment of Coastal Training Program (CTP) Coordinators, this three part seminar style on-line course provided CTP Coordinators with an overview of qualitative research methods relevant to their work. Resources for this course include videos of the seminars, course assignments and key literature resources.

III. Webinars: Qualitative Methods & Ecosystem Service Valuation 2012 & 2015
Dr. Verna DeLauer presented a preliminary webinar before the on line course. The information in this webinar was incorporated into the on line course.

Dr. Robert Johnston presented a webinar entitled *Ecosystem Service Valuation – An Economist's Perspective* in July 2015. This presentation was a repeat of Dr. Johnston's presentation at the Ecosystem Services Summit at the Wells NERR in April 2015. The webinar was recording and will be archived on the Wells NERR website and made available with other resources from the Ecosystem Services Summit. This webinar provided an overview for people considering conducting an ecosystem services valuation, using a decision-making framework to guide the design of such studies.

IV. *Bridging the Gulfs* 2014 Wells NERR; 2015 Mission Aransas NERR. Funded by a NERRS Science Collaborative Transfer Grant to share lessons learned from a suite of collaborative research projects. A description of the Mission Aransas course appears below. A Wells NERR website of resources from the trainings is under development and should be available in September 2015.

Interdisciplinary Methods for Stakeholder Engagement and Collaborative Research

Lessons from the National Estuarine Research Reserve System (NERRS)

January 14 – 15, 2015

Mission Aransas National Estuarine Research Reserve, Texas

Workshop Goal: *to build awareness, capacity and skills to enable coastal management and research communities to use expert interdisciplinary practices to* *engage stakeholders in developing and implementing collaborative research projects that link science to coastal management and policy.*

Overview

Collaborative research is one method for "bridging the gulf" between science and policy. The NERRS Science Collaborative (NSC) projects use interdisciplinary methods for understanding stakeholder priorities and motivations for engaging in collaborative projects with researchers. For the past five years, developing and applying methods for stakeholder engagement in collaborative research that facilitates the use of science in decision-making has been a national focus for the NSC projects. The Wells, Maine and Mission-Aransas, Texas NERRs projects used different methods to understand and engage stakeholders and researchers in their projects. The *Bridging the Gulfs* training shares those methods more broadly with the NERRS and their partners through two trainings – one delivered at the Wells NERR in the Gulf of Maine (September 2014) and one delivered at the Mission-Aransas NERR in the Gulf of Mexico. Reserve staff, coastal managers and researchers in each region are the audience for the trainings. The trainings transfer collaborative research methodologies between Texas and Maine as well as engaging other reserves and their partners in a discussion of lessons learned about collaborative research best practices that can be adopted across the NERRS and within the coastal management community.

Both the Wells NERR and Mission-Aransas NERR projects have expanded upon the framework provided by Collaborative Learning to explicitly assess stakeholder understanding, foster the development of shared knowledge and move diverse stakeholder groups toward mutually agreed upon improvements in management and policy. In addition to the Maine and Texas examples, the Chesapeake Bay Maryland NERR has adapted Collaborative Learning in a project focusing on marsh and human community resilience to sea level rise that will be included in the training. The *Bridging the Gulfs* training builds competencies in particular collaborative research methodologies including: conducting mediated modeling, mental modeling and resilience practice. Evaluation of additional practices will be shared among participants at both trainings to develop a *Bridging the Gulfs Best Practices Primer* for the NERRS and key partners. We hope this *Primer* will inform the next generation of NERRS Science Collaborative projects and will be a resource for groups engaged in collaborative research.

Bridging the Gulf Objectives

1. Participants will have a clear understanding of the interdisciplinary methods used by NSC projects in Wells, Mission-Aransas and Chesapeake Bay Maryland NERRs and evaluate how those methods might be adapted to their work.
2. Participants will provide examples from their work of methods used to foster stakeholder engagement and collaborative research in coastal management.

3. Participants will learn how the concept of boundary spanning and the role of boundary spanners *bridge the gulf* between science and management, and will evaluate the boundary spanning concept for its relevance to their own work.
4. Drawing from their experience, participants will identify common barriers to stakeholder engagement and the effective translation of science to decision-making that could be addressed using methods identified during the training.
5. Drawing from experience, presentations, small group work and facilitated discussions, participants will contribute to the development of a Primer of best practices for stakeholder engagement in collaborative research.
6. Participants will experience and evaluate a Collaborative Learning event as a method designed to model stakeholder engagement that generates collective findings to make progress on shared goals.

V. Ecosystem Services Summit At the Wells NERR 2015

This Summit was funded as part of the original grant to bring participants from across the NERRS together to learn about the findings of the project. Objectives of the workshop are listed below. These included furthering the conversation across the system for using an ecosystem services approach to support the mission of the NERRS. Results of the Summit are currently being analyzed and will be posted on the Wells NERR website with other resources from the Summit in September 2015. Results of the Summit will be shared during the NERRS/NERRA Annual Conference in October 2015.

Valuing Ecosystem Services in the NERRS
A Summit at the Wells NERR
April 30-May 1, 2015

Objectives for the Summit

- Build upon current ecosystem services work in the NERRS to adapt an ecosystem services approach more broadly to accomplish the mission of the system and contribute to NOAA priorities.
- Explore the economic, ecological, engagement and communication elements of ecosystem services work in the NERRS with economists, ecologists, NERRS and NOAA staff.
- Understand the research and capability requirements for conducting ecosystem services research that contributes to coastal management efforts to build resilience in coastal communities.
- Building upon reserve specific system models developed at the 2015 NERRS Program Managers' Meeting; develop a more detailed strategy for conducting ecosystem services research at specific reserves.
- Understand the common needs for valuing ecosystem services across the NERRS and explore the potential for cross-reserve collaboration.

Agenda Day 1: Thursday April 30, 2015

Time	Topics and Objectives	Responsibility
8:30	**Registration and Breakfast** *Objectives:* Participant list is finalized and brains are fueled and caffeinated	**Cox** **Wiley**
9:00	**Welcome and Introductions** *Objectives:* Participants understand objectives for the summit and review the agenda. Through individual introductions, participants identify what comes to mind for them about ecosystem services through an introductory activity "Ecosystem services are _______(one word) because ______________ (a few words)" 30 seconds each person	**Miller** facilitate **Cox** record on flip chart **Nick** record on computer **Wiley, Miller, Cox,** provide examples
9:40	**Ecosystem Services 101** *Objectives*: Participants understand the definition of ecosystem services and the elements that are part of the framework of an ecosystem service approach	**Wiley**
10:00	**Break and Gallery Walk** *Objectives of Gallery Walk:* participants use flip charts around the room to record coastal management issues they face that would benefit from an ecosystem services approach	**Miller and Cox**
10:15	**Ecosystem Services Work Currently Underway in the NERRS** *Objectives:* Participants can identify diverse examples of projects in the NERRS where an ecosystem services approach was used and describe the coastal management issue, the role the NERR played in the project, the ecosystem services, and key stakeholders for each project. Each presenter speaks for 10 minutes using about 10 slides. Describe: The coastal management issue and objective of the project The role the Reserve played in the project The ecosystem services focused on Key stakeholders The outcome of the project resulting from use of an ecosystem service approach If the application of the approach is in progress speak to	**Goodrich** *Tijuana River NERR, CA* **Swanson** *Mission Aransas NERR, TX* **Washburn** *Lake Superior NERR, WI* **Riley** *Great Bay NERR, NH*

	that time frame.	
11:30	**Valuing Ecosystems Services – An Economist's Perspective** *Objectives:* Participants will understand • The definition of economic value from an economist's perspective. • The methods that economists use to determine value • The reasons for conducting an ecosystem service valuation • The basic elements of an ecosystem service valuation • What a NERRS manager needs to know to develop or evaluate a proposal to conduct ecosystem service valuation work at a Reserve	**Johnston** *George Perkins Marsh Institute Clark University*
12:30	**Lunch**	
1:30	**Discussion of NERRS ideas for Ecosystem Services Work** *Objectives:* NERRS participants share ideas and pose questions for ecosystem services work in discussion with Dr. Robert Johnston	**Participants & Johnston**
2:00	**Learning from Ecosystem Services Work in Contexts outside the NERRS** *Objectives:* Participants will identify diverse approaches to applying an ecosystem services approach in projects outside the NERRS. Participants will understand • The management issue addressed • The methods used in the Ecosystem Services approach • The management and/or policy implications of the project Each presenter speaks for 10 minutes using about 10 slides.	**Nadeau** *Eastern Research Group, Inc.* **Yoskowitz** *NOAA* **Logsdon** *University of Michigan / Graham Sustainability Institute*
3:00	**Break**	
3:15	**Promising Ideas for advancing an ecosystem services approach in the NERRS Small Group Breakout** *Objectives:* Working individually and in small groups participants identify promising ideas for ways that an ecosystem service approach can be applied at their	**Feurt** **Miller** **Facilitators**

	reserve and broadly in the NERRS	
4:00	**Idea Sharing and Facilitated Discussion** *Objectives:* Participants share ideas developed	**Feurt** **Miller** **Participants**
4:20	***Most Promising Ideas Listening Walk*** Objectives: Participants discuss and listen to ideas for applying an ecosystem services approach in the NERRS. Participants process concepts from the day's training more deeply through reflection and listening.	**Feurt** **Participants**
5:30	**Lobster Dinner**	**Gulf of Maine**

Agenda Day 2: Friday, May 1, 2015

Time	Topic and Objectives	Responsibility
8:30	**Breakfast** *Objectives:* Brains are fueled and caffeinated	**Cox** **Nick**
9:00	**Morning Refresher and Reflection** *Objectives*: Participants review key concepts from day 1 to identify burning questions, and "now that I've slept on it" reflections	**Miller** **Feurt**
9:30	**Most Promising Ideas for Advancing an Ecosystem Services Approach in the NERRS: Targeted Breakout Sessions** *Objectives:* Participants self-organize into targeted breakout groups to develop strategies for moving ideas to action using the Ideas to Actions Worksheet. • Research and Monitoring Applications • Education, CTP, Outreach and Communication Applications • Stewardship, Mapping and GIS Applications • Emerging crosscutting ideas	**Facilitators:** **Miller** **Cox** **Feurt** **Participants** Each targeted breakout group will have a note taker and reporter
10:30	**Break**	
10:45	**Moving from ideas to actions that advance an ecosystem services approach in the NERRS: Targeted Breakout Sessions report out to group.** *Objectives:* Participants report ideas from breakout to full group to identify synergies, realistically assess capacity, boldly address barriers and link ideas to NERRS Strategy Documents.	**Reporter from each group**

11:45	**Lunch**	
12:45	**Charting the Path from Actions to Outcomes & Measures of Progress** *Objectives:* Participants reconvene in groups to complete the final worksheet linking ideas to outcomes and measures of progress including identification of: • Funding strategies for ecosystem services work. What can be done using current resources? What are some sources for funding innovative approaches? • How does an ecosystem services approach contribute to achieving the goals and objectives of the NERRS Strategic Plan/NOAA priorities? • What does an ecosystem services approach mean to the current work of each sector and to NERRS initiatives in place such as CTP, Sentinel Sites, SWMP and TOTE?	**Facilitators** **Participants**
2:00	**Break**	
2:15	**The Way Forward - Building the capacity for an ecosystem services approach in the NERRS** *Objectives:* Participants review action items developed during the Summit and prioritize next steps from an individual and system-wide perspective including mechanisms for distributing the results of the Summit to the System.	**Feurt** **Miller**
3:15	**Evaluations and Award Ceremony** *Objectives:* Participants will complete a written evaluation and assessment of the progress made at the Summit. Participants will receive formal professional recognition for their participation in the Summit and the opportunity to receive valuable prizes.	**Feurt** **Cox** **Miller**
3:30	**Adjourn & Safe Travels Home**	

VI. Annual Meeting Presentations, Sessions and Trainings (2011 – 2014)

During NERRS/NERRA Annual Meetings from 2011-2014 findings and methods used during the project were shared with participants from all sectors. This information was shared and used to refine the project to address the needs of the system. Feedback from the Annual Meetings inspired the transfer projects, on line course and webinars providing additional support and capacity building for the system.

The Wells NERR Stakeholder Network Participated Actively in the Project

The Wells NERR Stakeholder Network is described on page 7 of this report. Members of this network were engaged in the development of the proposal, contributed to focus groups for the mental models and economic portion of the research and provided input into the design and methodology of the ecological research. The ecosystem service valuation survey, Choice for our Land and Water was developed in collaboration with the Stakeholder Network. This three year process required focus group interaction with every day citizens like those who would complete the survey as well as the professionals in the Stakeholder Network. Rigorous inspection and critique of the survey design by members of the network resulted in a survey that was understandable by participants and accurate in terms of ecological messaging.

The stakeholder network was enriched through the Choices for Our Land and Water survey process. The Wells Reserve non-profit partner Laudholm Trust offered one year free membership in Laudholm Trust for people completing the survey who were not already members. Over 1,000 new members became part of the Wells NERR "family" during 2014 and 2015. Special events during the year presented the results of the research for all aspects of the project.

During the final meeting with the Stakeholder Network to share final results ideas about how the findings would be used by the stakeholders were collected. One key finding from this meeting is that the complexity of the findings for ecosystem service valuation and mental models required additional synthesis for use by stakeholders. These ideas are being explored for potential use in a transfer project to carry the work forward.

The project has been shared beyond the Stakeholder Network at local and regional conferences. Findings will be shared in November 2015 with the Maine Watershed Roundtable, a statewide network of water professionals. The project has also been shared with Maine's George Mitchell Sustainability Institute at the Maine Water and Sustainability Conference in 2014 and 2015. The potential to share findings and develop communication and outreach materials from this project is just beginning.

Retrospective Questions Posed by the NERRS Science Collaborative
Prepared by Christine Feurt Ph.D.

1. What did you find challenging or unexpected about this project? This could include any aspect of the project—the integration of collaboration and applied science, physical, social, political, technical barriers, project management, communication, duration, resources etc.

   This project was designed as a three year project. After five years of work as a team, we could tackle a new project and complete the work in three years, but this initial project required five years. Collaborative interdisciplinary research, engaging a new team of researchers and stakeholders, is time and effort intensive.

The demands of rigorous disciplinary research are embedded within a paradigm shifting framework of interdisciplinarity and stakeholder engagement. Even from the writer's perspective as a specialist in collaborative processes, the demands of interdisciplinary, stakeholder engaged research are under appreciated, underfunded and yet remain the most powerful component of any project focusing on solutions to complex coastal management issues. This project accomplished planned objectives in the five years with additional support from the NERRS Science Collaborative through transfer project funds. These transfer funds were critical to accomplishing the level of impact that this project has had on the NERR system.

2. How did collaboration with intended users impact the applied science components of the project?

   This question is thoroughly addressed in the individual sections of each element of the project above.

3. Did you have all the skill sets on the team that you needed? If not, please identify the missing skill sets and how you adapted to the gap.

   Our team was fortunate to have the right balance of expertise.

4. Did your budget include sufficient resources to execute the project? If not, what kinds of expenses would you include in a budget for this project if you were developing it today?

   Transfer funds during the course of the project made a difference. We had a large portion of the budget dedicated to engagement and communication, 40% I believe. This was critically important.

5. What do you know now that you wish you had known when you started?

   I would be up front with collaborators from outside institutions about the time required to participate on conference calls, on-site meetings, and meetings with stakeholders. Our team gave considerable time to this interaction.

6. If additional resources and time were available, how would you proceed from this point?

   Our team shared the feeling that we were just beginning our work together. We generated findings in ecology, communication and economics that were integrated and connected to stakeholders. We have results of that work and are poised to engage stakeholders in the use and application of that work. Future work would focus on the knowledge to action aspects of coastal management using our findings. This boundary work (Clark, et al 2010) would build upon the relationships we have developed as a research team, the relationship with the national network of Research Reserves and the managers and policy makers at multiple scales who would benefit from the methods developed. What we have learned about building capacity for integrating different sources of knowledge and understanding the role of mental models in fostering effective action are key aspects of the research that can be shared and applied across contexts of ecosystem science.

While this project developed from the ecosystem management approach, the approaches used are in alignment with social ecological systems approaches used in sustainability science. The Wells NERR Coastal Training Program shares with many CTPs a commitment to bridging the gulfs separating science and its application to management and policy. The Collaborative Learning approach used in this project worked well due to the adaptability of the approach to the demands of diverse situations. The Wells Reserve research team anticipates continued work within our local Stakeholder Network and nationally within the NERR system using this project as a foundation.

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