Buffer Options for the Bay: Economic Valuation of Water Quality Ecosystem Services in New Hampshire's Great Bay Watershed

Dana Marie Bauer and Robert J. Johnston

George Perkins Marsh Institute
Clark University
dbauer@clarku.edu and rjohnston@clarku.edu

June 2017

Table of Contents

Executive Summary

Land that borders New Hampshire's rivers, streams, and estuaries provides many ecosystem services including water purification, wave and storm surge protection, and wildlife habitat. Management of these lands can be challenging as residential development, agriculture, and other intensive land uses can impede the generation of these services, leading to management tradeoffs. Traditional economic assessments sometimes ignore the value of ecosystem goods and services, because these services are not bought and sold through formal markets. Nonetheless, these services have economic value that can be quantified. Non-market valuation quantifies the benefits and costs associated with the goods and services provided by nature in order to improve decision making regarding their use and conservation. Benefit transfer is an economic valuation method that uses results from preexisting primary research studies at one or more "study" sites to predict economic values at other non-studied "management or policy" sites. Benefit transfer is often used when the necessary time or funding resources are not available to conduct an original primary study at the site(s) expected to be impacted by future management activities or policy interventions. This report describes the generation of a water quality benefit transfer function using meta-analysis techniques, details the step-by-step process used to apply this transfer function including the calculation of a water quality index (WQI), and presents value forecasts for a suite of buffer-related water quality change scenarios.

This analysis was commissioned by Buffer Options for the Bay (BOB), a grant-sponsored collaboration of public, academic, and nonprofit organizations dedicated to enhancing the capacity of New Hampshire stakeholders to make informed decisions that make best use of buffer lands to protect water quality, guard against storm surge and sea level rise, and sustain fish and wildlife in the Great Bay region. The project defines buffers as naturally vegetated segments of land directly upslope of a water resource, such as a lake, stream, river, pond, estuary, or other wetland type.

This analysis is intended to be a resource for the organizations involved in the BOB project and others engaged in helping communities and individuals with decisions related to buffer management and policy. The team also has conducted analyses of the biophysical and social scientific literature that underpins buffer management, a buffer-focused GIS analysis of the Great Bay region, and an assessment of the barriers and opportunities related to buffer management in four communities in the Exeter/Squamscott subwatershed.

The results of these analyses are captured in individual reports, available at www.bufferoptionsnh.org/reports. They also have been integrated into an online framework intended to inform discussions around buffer management in the region, open the door to new and needed research; and encourage strategic investment. Finally, the team created a collective action plan to encourage collaboration among outreach professionals as they work with towns on advancing effective buffer policy and practice at the community level.

The meta-regression analysis in this report used 140 observations from 51 primary stated preference valuation studies published between 1985 and 2013 that estimate per household willingness to pay (WTP) for water quality changes in US water bodies that affect a variety of ecosystem services including aquatic life support, recreational uses, and non-use values. WTP reflects the amount of money that households would be willing to give up—for example in taxes and fees—in order to obtain a specified gain in ecosystem services (or to prevent a loss), rather than go without. The estimated benefit transfer function explains household WTP using information on the geographic region and focal water body, the baseline focal water body condition and evaluated water quality change, the affected human populations, and potential substitute resources and complementary land uses.

The benefit transfer function was applied to a suite of water-quality change scenarios that focus on three water body resources within the Great Bay watershed: the Great Bay Estuary itself (not including tributaries), and the freshwater and tidal portions of the Exeter-Squamscott River. The choice of the Exeter-Squamscott River was driven by the appeal of coordinating this economic analysis with work being done by the project team's Community Assessment group. For the Great Bay Estuary, we estimated WTP for water quality improvements at three different socio-economic scales: residents in N.H. towns immediately adjacent to the bay, residents of N.H. towns within the entire Great Bay watershed (approximated by Rockingham and Strafford counties), and all residents of the state of N.H.. For the freshwater and tidal portions of the Exeter-Squamscott River, we evaluate willingness to pay for residents in towns adjacent to the upper or lower portion of the river, respectively. Because information on specific policy-driven changes in buffer quantity, quality, and location (as well as the associated changes to water quality) was not available for this project, we investigated a range of potential water quality improvements: 3, 5, 7, and 9-point increases on a 100-point water quality index (WQI) beyond current conditions. We also investigated a set of policy scenarios that considered the potential ramifications of a "do nothing" buffer policy that would lead to a reduction or degradation in the existing supply of vegetative buffers and a subsequent reduction in water quality. For these hypothetical scenarios, we forecast annual household WTP to maintain water quality at its current level rather than allowing it to fall below the minimum WQI threshold required for swimming.

The benefit transfer produces a wide range of willingness to pay forecasts for water quality improvements in New Hampshire's Great Bay watershed, with results varying as expected over the 50 unique scenarios. Annual household WTP increases as the size of the water quality improvement increases for all focal water bodies. For the Exeter-Squamscott River subwatershed, values range from $39 to $54 per household per year for households in adjacent communities. While the baseline water quality is better and the size of the improved water body is larger in the Exeter River, median household income is higher in communities along the Squamscott River. Thus, despite differences in scenario parameters, tradeoffs among those parameters can result in similar WTP forecasts. Annual household WTP is greater ($62-$85) for improvements to the entire Great Bay versus the smaller Exeter-Squamscott regions, despite the baseline water quality being better and median household income being lower, due to the larger size of the improved water body and also due to the relative lack of a substitute for the Great Bay within New Hampshire. As the market area for the Great Bay increases from adjacent towns to surrounding counties to the entire state of N.H., annual household WTP, reflecting a pattern in which people who live farther away, value improvements to the Great Bay less than those living closer, *ceteris paribus*. Results from the "Maintain Swimmable" scenarios, which forecast willingness to pay to maintain water quality at its current baseline level rather than allowing it to fall below 70 on the 100-point WQI, are also intuitive. Households are willing to pay more to maintain a higher baseline water quality level across all water bodies.

WTP aggregated over an entire market area (or population) can vary due to differences in per household WTP, or due to differences in the number of households in the market area. For example, despite comparable household WTP measures, regional WTP values aggregated across all households in the adjacent communities for the three-town Squamscott River region ($300-600K) are lower than values for the larger seven-town Exeter River region (~$1 million) due to the larger number of households in the Exeter region. Aggregated values for the seven communities immediately adjacent to the Great Bay ($1.5-2.8 million) exceed those of the Exeter-Squamscott region, due to both larger household values and the larger number of households. Further, despite lower household WTP values for the larger market regions, the much larger number of households in the two counties and the entire state results in dramatically higher aggregate regional WTP values.

While we elected to include statewide scenarios in our analysis to show how WTP values can change over larger market areas, it is unclear whether any statewide buffer policy would focus on the Great Bay estuary alone. It is more likely that a statewide buffer policy would be implemented across all water bodies in the state. Thus, the more relevant aggregate WTP comparison would be among adjacent communities ($1.5-2.8 million) and the two counties that encompass the entire watershed ($9.5-17.1 million). The larger two-county values would be useful for funding buffer policies or management activities that impact the Great Bay and all its tributaries, while the small adjacent community values would be more appropriate for small bay shoreline projects.

Interpretation of all the forecasted (i.e., transferred) values should be handled with caution. Results are not exact, but rather approximations of public values for water quality improvements that can be used to guide resource management and policy decision making. It is important to recognize that the values are representative of what households would be willing to pay for particular water quality improvements, but there is no guarantee that those funds would actually be sufficient to support the level of buffer restoration or other activities that actually improves water quality by the desired amount. Of course, the opposite could be true as well—funds equaling aggregated WTP might support management activities that exceed the desired level of water quality improvement. That is, WTP reflects the *value* of an improvement to people, not the *cost* of obtaining those improvements.

Quantitatively linking the change in the quantity or quality of buffers that would result from a specific management action to a direct consequential change in the WQI is challenging and beyond the scope of this analysis. As such, this economic analysis forecasts values for water quality improvements directly, and then systematically explores a range of modest changes in water quality from the WQI baseline for each focal resource. The role and potential contribution of buffers in driving changes in water quality of this magnitude can then be explained after the fact, lessening potential criticism that our modeled scenarios are based on too many biophysical assumptions (e.g., that a buffer of a particular type and location would lead to a particular water quality improvement). The WQI information provided can point practitioners to particular pollutants and could be a good place to start when identifying potential buffer actions, however, it is ultimately necessary to integrate the economic valuation results presented here with the results of biophysical water quality modeling scenarios in order to make well-informed decisions.

Finally, this economic valuation does not inform the decision maker regarding which set of management activities to engage in; that is, there is no cost analysis of buffer management. This analysis quantifies benefits only. A full cost-benefit analysis is often required to determine whether the benefits of specific management actions exceed the costs, although in some cases it may be obvious that the benefits reported here will outweigh the costs without conducting a formal cost analysis.

1. Introduction

The overall goal of the Buffer Options for the Bay project is to enhance stakeholder capacity to make informed decisions related to the protection and restoration of riparian buffers surrounding New Hampshire's Great Bay. To this end, the project conducted an integrated assessment that combines, interprets, and communicates science-based information. This information is focused on regulatory and non-regulatory options for protecting and restoring buffer zones around the Great Bay, and addressing the challenges necessary to do so. This report describes the methods and results of the economic ecosystem service valuation component of the project.

Traditional economic assessments sometimes ignore the value of ecosystem goods and services, because these services are not bought and sold through formal markets. Nonetheless, these services have economic value that can be quantified. Valuation is often conducted in order to improve decision making regarding the use and conservation of natural assets, and typically quantifies willingness to pay (WTP) for well-defined measures of losses or gains in specified ecosystem services (or the assets that provide them). Benefit transfer is an economic valuation method that uses results from preexisting primary research studies at one or more "study" sites to predict economic values at other non-studied "management or policy" sites (Johnston and Wainger 2015). Benefit transfer is often used when the necessary time or funding resources are not available for an original primary study at the site(s) expected to be impacted by future management activities or policy interventions. Benefit transfer may be conducted using multiple different approaches (Johnston et al. 2015). The benefit transfer method used here involves two major steps: the use of meta-analysis techniques to generate a flexible, transferable benefit function from previous studies that estimate WTP for a quality change of interest, and the application of this benefit transfer function to multiple management scenarios. A scenario definition includes descriptions of the focal resource, the level of improvement in that resource, and the market area, which identifies the human population affected by the change in quality.

In the analysis reported here, we focus on the economic values associated with water quality improvements resulting from the protection or restoration of vegetated buffers within New Hampshire's Great Bay ecosystem. The focal resource could be the entire Great Bay, a portion of the bay, a particular tributary that leads into the bay, or a group of water bodies. The level of water quality improvement is typically determined by combining socio-economic and biophysical modeling or expert knowledge that relates a new buffer policy or set of management activities to changes in buffers (e.g., size, quality, and location) to changes in water quality. The market area could include just those communities adjacent to the water body of interest, communities in a particular county or group of counties, or the entire state of New Hampshire.

This report describes the generation of a water quality benefit transfer function using meta-analysis techniques, details the step-by-step process used to apply this transfer function with sufficient detail such that the function can also be used after the Buffer Options for the Bay project ends, and presents economic value forecasts for a suite of buffer-related water quality change scenarios based on three focal resources (Great Bay Estuary, Squamscott River, and Exeter River) and three affected populations (adjacent communities, watershed communities, and the entire state of New Hampshire). Because information on policy-driven changes in water quality was not available, we selected a range of water quality improvements to investigate.

2. Water Quality Benefit Transfer Function

When conducted using meta-analysis (as done here), the generation of transferable benefit functions from existing economic valuation studies involves three main steps: data synthesis, metadata construction, and meta-regression model specification and estimation (Johnston et al. 2015). The process begins with the selection, screening, and coding of primary economic valuation studies conducted over different sites and populations, each providing one or more estimates of positive or negative economic values associated with changes in environmental quality. Here, the metadata were drawn from primary stated preference valuation studies that estimate per household willingness to pay (WTP) for water quality changes in US water bodies that affect a variety of ecosystem services including aquatic life support, recreational uses (e.g., fishing, boating, and swimming), and nonuse values (e.g., biodiversity). The metadata selection excluded revealed preference studies, as they do not include nonuse values, and studies focusing primarily on drinking water supplies, as these tend to be very different from studies that focus more broadly on use and nonuse values. Studies were screened to ensure that necessary data (e.g., identification of the improved water body, the specific water quality change being valued, and details of the sampled population) was provided and that the WTP measure used could be linked to water quality changes measured on a standard 100-point Water Quality Index (WQI) that relates water quality pollutant concentrations to water body suitability for human uses.[1] These primary study selection restrictions allowed observations from multiple studies to be combined into a single meta-dataset suitable for analysis using standard statistical regression techniques. The final metadata included 140 observations (i.e., WTP estimates) from 51 stated preference studies published between 1985 and 2013 (Table 1), noting that multiple observations can result from a single study because of variations in key valuation characteristics including the spatial extent of the water quality change, the sampled populations, the number and type of water bodies affected, or the specific affected recreational uses.

The dependent variable used in our meta-regression model is the natural log of per household WTP for water quality improvements. Independent variables expected to explain variation in household WTP (and included in the model) characterize (1) the geographic region and focal resource, (2) the sampled and affected populations, (3) the baseline focal resource condition and evaluated water quality change, (4) potential substitute resources and complementary land uses, and (5) the primary study methodology and year (Table 2). While the primary studies provided values for most independent variables, additional development of the metadata was required. This included calculations of spatial metrics using GIS techniques, lookup of census data, and translations of verbal descriptions (e.g., “swimmable”) or ordinal rankings (e.g., poor/fair/good) of water quality into the 100-point WQI, was required. In addition, all monetary values were adjusted to 2007 US dollars, once again to enable standard regression techniques.[2]

---

[1] Details of the Water Quality Index (WQI) and its use in benefit transfers are provided in section 3.
[2] The full metadata development process is described in Johnston et al. (2016).

Three meta-regression model specifications were estimated based on the following general form:

$$\ln(WTP) = \text{intercept} + \Sigma\ \text{coefficient}_i * \textit{independent-variable}_i$$

(1)

The three models differ by which composite variable is used to express the relationship between geospatial scale (the size of the water body or surrounding land area) and market area (the size of

Table 1. Primary Studies in Metadata (mean WTP is per household per year in 2007 USD).

Reference†	Obs.	State(s)	Water Body Type(s)	Mean WTP
Aiken (1985)	1	CO	River and lake	193.18
Anderson and Edwards (1986)	1	RI	Salt pond/marsh	180.71
Banzhaf et al. (2006)	2	NY	Lake	57.47
Banzhaf et al. (2011)	1	VA, WV, TN, NC, GA	River/stream	31.30
Bockstael et al. (1988)	1	DC, MD, VA	Estuary	149.03
Bockstael et al. (1989)	2	MD	Estuary	158.30
Borisova et al. (2008)	3	WV, VA	River/stream	44.94
Cameron and Huppert (1989)	1	CA	Estuary	49.53
Carson et al. (1994)	2	CA	Estuary	59.40
Clonts and Malone (1990)	3	AL	River/stream	103.20
Collins and Rosenberger (2007)	1	WV	River/stream	18.19
Collins et al. (2009)	7	WV	River/stream	120.52
Corrigan et al. (2009)	1	IA	Lake	123.30
Croke et al. (1986)	9	IL	River/stream	77.47
De Zoysa (1995)	1	OH	River/stream	70.18
Desvousges et al. (1987)	12	PA	River/stream	59.19
Downstream Strategies (2008)	2	PA	River/stream	12.74
Farber and Griner (2000)	6	PA	River/stream	76.16
Hayes et al. (1992)	2	RI	Estuary	397.44
Herriges and Shogren (1996)	2	IA	Lake	134.55
Hite (2002)	2	MS	River/stream	60.08
Huang et al. (1997)	2	NC	Estuary	258.65
Irvin et al. (2007)	4	OH	All freshwater	21.67
Johnston et al. (1999)	1	RI	River/stream	180.95
Kaoru (1993)	1	MA	Salt pond/marsh	218.61
Lant and Roberts (1990)	3	IA, IL	River/stream	143.93
Lant and Tobin. (1989)	9	IA, IL	River/stream	55.63
Lichtkoppler and Blaine (1999)	1	OH	River and lake	41.93
Lindsey (1994)	8	MD	Estuary	66.80
Lipton (2004)	1	MD	Estuary	63.98
Londoño Cadavid and Ando (2013)	2	IL	River/stream	38.68
Loomis (1996)	1	WA	River/stream	93.07
Lyke (1993)	2	WI	River and lake	78.75
Matthews et al. (1999)	2	MN	River/stream	21.73
Opaluch et al. (1998)	1	NY	Estuary	138.47
Roberts and Leitch (1997)	1	MN, SD	Lake	8.35
Rowe et al. (1985)	1	CO	River/stream	134.59
Sanders et al. (1990)	4	CO	River/stream	160.69
Schulze et al. (1995)	2	MT	River/stream	20.84
Shrestha and Alavalapati (2004)	2	FL	River and lake	156.46
Stumborg et al. (2001)	2	WI	Lake	84.29
Sutherland and Walsh (1985)	1	MT	River and lake	146.03
Takatsuka (2004)	4	TN	River/stream	286.88
Wattage (1993)	3	IA	River/stream	53.89
Welle (1986)	6	MN	Lake	167.28
Welle and Hodgson (2011)	3	MN	Lake	145.10

Table 1. (continued) Primary Studies in Metadata (mean WTP is per household per year in 2007 USD).

Wey (1990)	2	RI	Salt pond/marsh	147.26
Whitehead and Groothuis (1992)	3	NC	River/stream	41.01
Whitehead (2006)	3	NC	River/stream	187.18
Whitehead et al. (1995)	2	NC	Estuary	95.44
Whittington et al. (1994)	1	TX	Estuary	194.72

†See Appendix D for full citations.

the population affected by the water quality change) and their combined effect on household WTP. Two of the variables, *Ln_AreaRatio1* and *Ln_AreaRatio2*, divide the size of the market area (i.e., the area of the towns, counties, or states where the affected population lives) by the size of the counties that intersect the focal water body or the size of the watershed(s) that surround the focal water body, respectively. The third composite variable (*Ln_RelativeSize*) divides the size of the focal resource, calculated as shoreline length, by the size of the market area. Economic theory provides no intuition as to which composite variable would best explain variation in household WTP, so three separate regression models were estimated.

A trans-log specification, in which the dependent variable and the continuous independent variables (e.g., water quality change, household income, and spatial metrics) appear as natural logs, was used because of its ability to capture curvature in the valuation function and because it constrains the value of WTP to zero as values of those independent variables approach zero.[3] The three specifications described above were tested against a restricted model that omits all three spatial composite variables. The models were estimated using an unweighted generalized least squares (GLS) random-effects procedure with robust standard errors that accounts for cross-sectional correlation among multiple observations from the same primary study.

Regression results are reported in Table 3. Wald chi-square tests reject the null hypothesis that the restricted model is the same as the three unrestricted models, indicating that the spatial composite variables add significant explanatory power. Of the 23 explanatory variables, the majority are statistically significant at the $p < 0.10$ level and most of those, including the three spatial composite variables, are significant at the $p < 0.01$ level. The signs of statistically significant parameter estimates match what one would expect based on economic theory or intuition. For example, household WTP is positively related to the size of the water quality improvement, median household income, the proportion of the focal resource type within an entire state that is improved, and one-time lump-sum (versus annual) payments, while it is negatively related to the proportion of agriculture land in intersecting counties (a non-complementary land use), an affected population of only non-users, and median (versus mean) WTP. All three spatial composite variables are of the appropriate sign. The positive sign on *Ln_RelativeSize* can be interpreted as follows. Starting with the numerator, the larger the size of the improved water body, the higher is per household WTP, *ceteris paribus*. That is, a household is willing to pay more for a similar increase in water quality in a larger lake than in a smaller lake because water quality has been improved over a larger geographical area. Thus, the effect of a larger number in the numerator is positive. Now consider the effect of the

[3] Other advantages of the trans-log functional form are discussed by Johnston et al. 2005.

denominator. The larger the market area (or the area over which people were sampled by each original study in the metadata), the longer the average distance between a given household and the focal water body. People farther away from water bodies are generally willing to pay less to improve those water bodies, compared to otherwise identical people who live closer to the same water bodies. Thus, the larger the market area, the lower the household WTP, *ceteris paribus*. However, because market area is in the *denominator* of the composite variable, larger market areas make the composite variable smaller (an inverse relationship). Thus, the overall effect of relative size on household WTP is positive. Similar logic can be used for the other spatial composite variables, but the sign is negative because market area is in the numerator rather than the denominator.[4]

Table 2. Meta-Analysis Variable Descriptions and Mean Metadata Values.

Variable	Description	Mean
Ln_BaseQuality	Natural log of the baseline water quality from which improvements would occur, specified on the 100-point water quality index.	3.589
Ln_QualityChg	Natural log of the change in water quality, specified on the 100-point water quality index.	2.907
Ln_Income	Natural log of median household income (in 2007 USD) for the market area based on historical U.S. Census data.	10.745
Non_Users	Binary variable indicating that the survey was implemented over a population of nonusers only.	0.086
Swim_Use	Binary variable indicating that changes in swimming uses are specifically noted in the survey.	0.264
Boat_Use	Binary variable indicating that changes in boating uses are specifically noted in the survey.	0.114
Game_Fish	Binary variable indicating that changes in game fishing uses are specifically noted in the survey.	0.057
River	Binary variable indicating that the focal resource is a river or multiple rivers.	0.686
Multi_Body	Binary variable indicating the focal resource includes multiple water body types (e.g., rivers *and* estuaries).	0.078
Ln_PropAgLand	Natural log of the proportion of the land area in all counties that intersect the improved focal resource that is agricultural land based on the National Land Cover Database (NLCD).	-1.433

[4] More details of the entire benefit transfer function generation process can be found in Johnston et al. 2016.

Table 2 (continued) Meta-Analysis Variable Descriptions and Mean Metadata Values.

Variable	Description	Mean
Ln_RelativeSize	Natural log of the total shoreline length (in kilometers) of the improved focal resource divided by the size of the market area (in square kilometers). For a river, shoreline length is given by the two times the length of the river. For a bay, shoreline length is the perimeter of the bay, not including tributaries.	-1.198
ProportionChg	Proportion of water bodies of the same hydrological type as the improved focal resource, within affected state(s). For rivers, this is measured as the length of the improved river divided by the length of all rivers of the same or lower order (*PropChgRiver*). For bays and estuaries, this is defined as the shoreline length of the water body as a proportion of all analogous (e.g., coastal) shoreline lengths (*PropChgBay*). *ProportionChg* is defined as the maximum of *PropChgRiver* or *PropChgBay*.	0.188
Northeast_US	Binary variable indicating that the survey included respondents from the USDA Northeast region.	0.071
Central_US	Binary variable indicating that the survey included respondents from the USDA Midwest or Mountain Plains region.	0.336
Southern_US	Binary variable indicating that the survey included respondents from the USDA Southeast or Southwest.	0.157
MedianWTP	Binary variable indicating that the study's WTP measure is the median rather than the mean.	0.071
LumpSum	Binary variable indicating that payments were to occur on something other than an annual basis over an extended or indefinite period of time.	0.186
Ln_StudyYear	Natural log of the year in which the primary study was conducted (converted to an index by subtracting 1980, before making the log transformation).	2.212
ChoiceExp	Binary variable with a value of one for studies that are choice experiments.	0.107
Thesis	Binary variable with a value of one for studies developed as thesis projects or dissertations.	0.144
Voluntary	Binary variable indicating that WTP was estimated using a payment vehicle described as voluntary.	0.086

Table 2 (continued) Meta-Analysis Variable Descriptions and Mean Metadata Values.

Variable	Description	Mean
NonParametric	Binary variable indicating that WTP was estimated using non-parametric methods.	0.429
NonReviewed	Binary variable indicating that the study was not published in a peer-reviewed journal.	0.236

Table 3. Benefit Transfer Function Coefficients and Standard Errors (SE).

Variable	Model 1	(SE)	Model 2	(SE)	Model 3	(SE)
Ln_BaseQuality	-0.068	(0.122)	-0.064	(0.123)	-0.046	(0.125)
Ln_QualityChg	0.282	(0.106)***	0.281	(0.106)***	0.293	(0.108)***
Ln_Income	0.679	(0.373)*	0.628	(0.375)*	0.618	(0.386)
Non_Users	-0.440	(0.122)***	-0.455	(0.121)***	-0.473	(0.000)***
Swim_Use	-0.395	(0.221)*	-0.391	(0.220)*	-0.385	(0.220)*
Boat_Use	-0.318	(0.171)*	-0.314	(0.183)*	-0.363	(0.171)**
Game_Fish	0.342	(0.194)*	0.303	(0.207)	0.315	(0.206)
River	-0.192	(0.133)	-0.226	(0.128)*	-0.207	(0.129)
Multi_Body	-0.532	(0.140)***	-0.525	(0.145)***	-0.538	(0.132)***
Ln_PropAgLand	-0.347	(0.093)***	-0.351	(0.095)***	-0.337	(0.092)***
Ln_AreaRatio1	-0.072	(0.026)***	------	------	------	------
Ln_AreaRatio2	------	------	------	------	-0.059	(0.022)***
Ln_RelativeSize	------	------	0.052	(0.019)***	------	------
ProportionChg	0.693	(0.194)***	0.525	(0.189)***	0.638	(0.188)***
Northeast_US	0.542	(0.245)**	0.549	(0.249)**	0.530	(0.257)**
Central_US	0.606	(0.108)***	0.601	(0.112)***	0.565	(0.106)***
Southern_US	1.399	(0.133)***	1.366	(0.127)***	1.345	(0.131)***
MedianWTP	-0.288	(0.225)	-0.264	(0.239)	-0.305	(0.220)
LumpSum	0.777	(0.137)***	0.727	(0.136)***	0.747	(0.134)***
Ln_StudyYear	-0.477	(0.080)***	-0.478	(0.080)***	-0.469	(0.080)***

Table 3. Benefit Transfer Function Coefficients and Standard Errors (SE).

Variable	Model 1	(SE)	Model 2	(SE)	Model 3	(SE)
ChoiceExp	0.489	(0.198)**	0.487	(0.210)**	0.469	(0.206)**
Thesis	0.609	(0.196)***	0.557	(0.195)**	0.584	(0.194)***
Voluntary	-1.315	(0.228)***	-1.296	(0.209)***	-1.275	(0.223)***
OutlierBids	-0.421	(0.120)***	-0.429	(0.120)***	-0.428	(0.117)***
NonParametric	-0.499	(0.129)***	-0.477	(0.126)***	-0.516	(0.128)***
NonReviewed	-0.656	(0.165)***	-0.679	(0.171)***	-0.619	(0.172)***
Intercept	-3.030	(4.269)	-2.281	(4.225)	-2.369	(4.256)
R^2	0.63		0.63		0.63	
σ_ε	0.541		0.541		0.541	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

3. Economic Valuation and the Benefit Transfer Process

The goal of many benefit transfers is to forecast economic values (e.g., household WTP estimates) for specific management activities or policies that have the potential to lead to changes in one or more ecosystem services. In this section, we present a suite of water quality change scenarios and describe the process by which we applied the benefit transfer function estimated in the previous section. We include a description of external data requirements and intermediate calculations, and end the section with a detailed illustration for one scenario.

Scenario Descriptions

Each unique scenario is defined by descriptions of the focal resource, the level of improvement in the quality of that resource, and the market area (i.e., affected human population). For this project, we investigate water-quality change scenarios that focus on three focal water body resources within the Great Bay watershed: the Great Bay Estuary itself, not including tributaries (Figure 1), and the freshwater and tidal portions of one subwatershed, that associated with the Exeter-Squamscott River (Figure 2). The choice of the Exeter-Squamscott River was driven by the appeal of coordinating this economic analysis with work being done by the Buffers Options for the Bay project's Community Assessment group.

For the Great Bay Estuary, we evaluate water quality improvements at three different socio-economic scales (i.e., market areas): (i) residents in N.H. towns immediately adjacent to the bay (Figure 1), (ii) residents of N.H. towns within the entire Great Bay watershed (Figure 3), and (iii) all residents of the state of N.H. While we acknowledge that several towns in Maine are part of the Great Bay watershed and that those residents would have positive WTP for water quality improvements, we focus this analysis on New Hampshire residents only. For the freshwater and tidal portions of the Exeter-Squamscott River, we evaluate willingness to pay for residents in towns adjacent to the upper or lower portion of the river, respectively (Figure 2).

Because biophysical information on specific policy-driven changes in buffer quantity, quality, and location (as well as the associated changes to water quality) was not available for this project, we investigated a range of potential water quality improvements: 3, 5, 7, and 9-point increases on a 100-point water quality index beyond current (i.e., baseline) conditions. We also investigated a set of policy scenarios that consider the potential ramifications of a "do nothing" buffer policy that would lead to a reduction or degradation in the existing supply of vegetated buffers and a subsequent reduction in water quality. For these hypothetical scenarios, we forecast annual household willingness to pay to maintain water quality at its current level rather than allowing it to fall below the minimum WQI threshold required for swimming. We refer to these scenarios as "maintain swimmable" water quality.

The combination of five distinct water body market areas (i.e., affected populations) and five distinct water quality changes results in 25 unique scenarios. For each of these, we conduct sensitivity analysis utilizing minimum and maximum estimates for the current (i.e., baseline) water quality conditions, giving us a total of 50 unique scenarios.

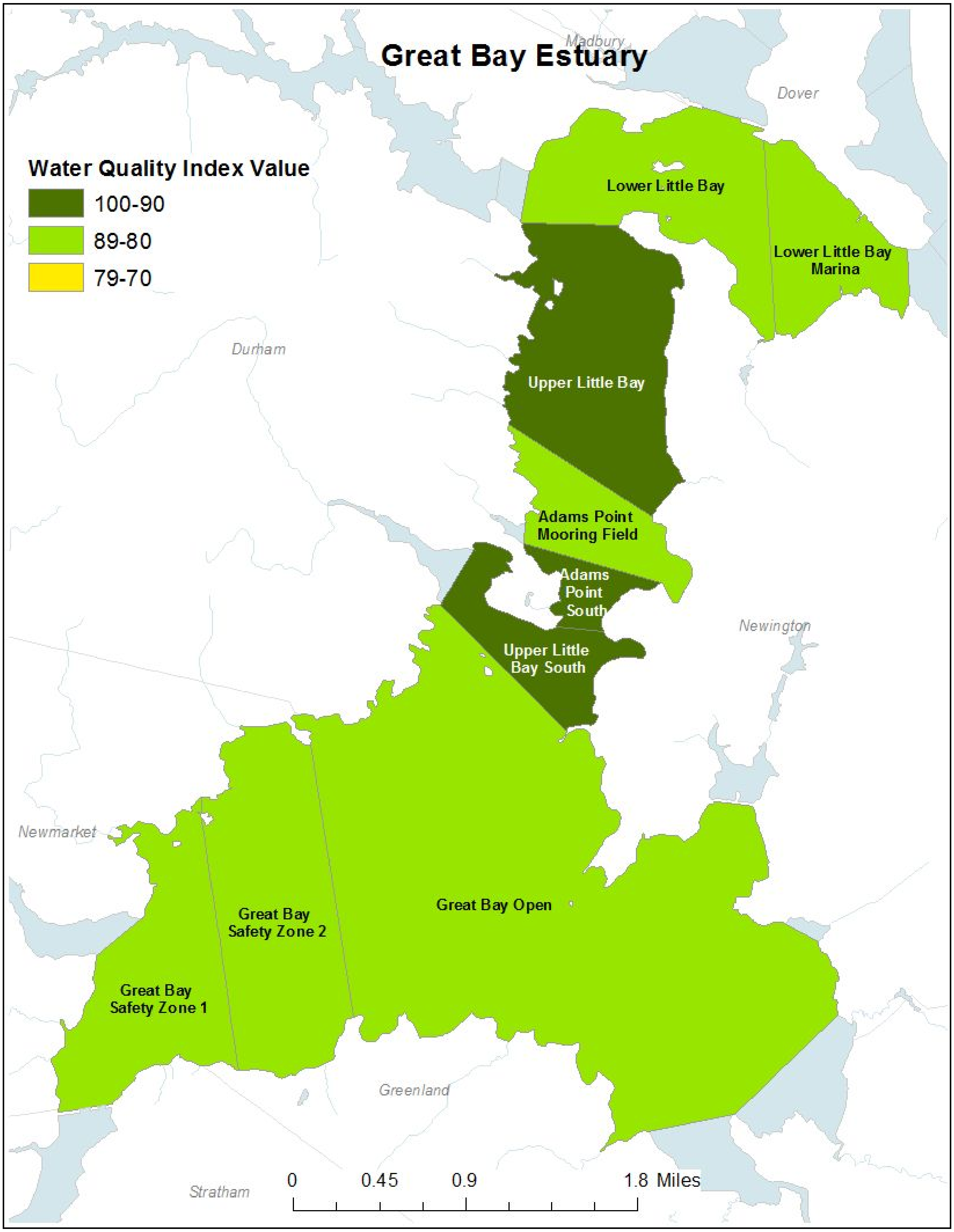


Figure 1. Great Bay Estuary Major Assessment Units and Baseline Water Quality (Table 6). Water Quality Index (WQI) values are calculated using Equation 3.

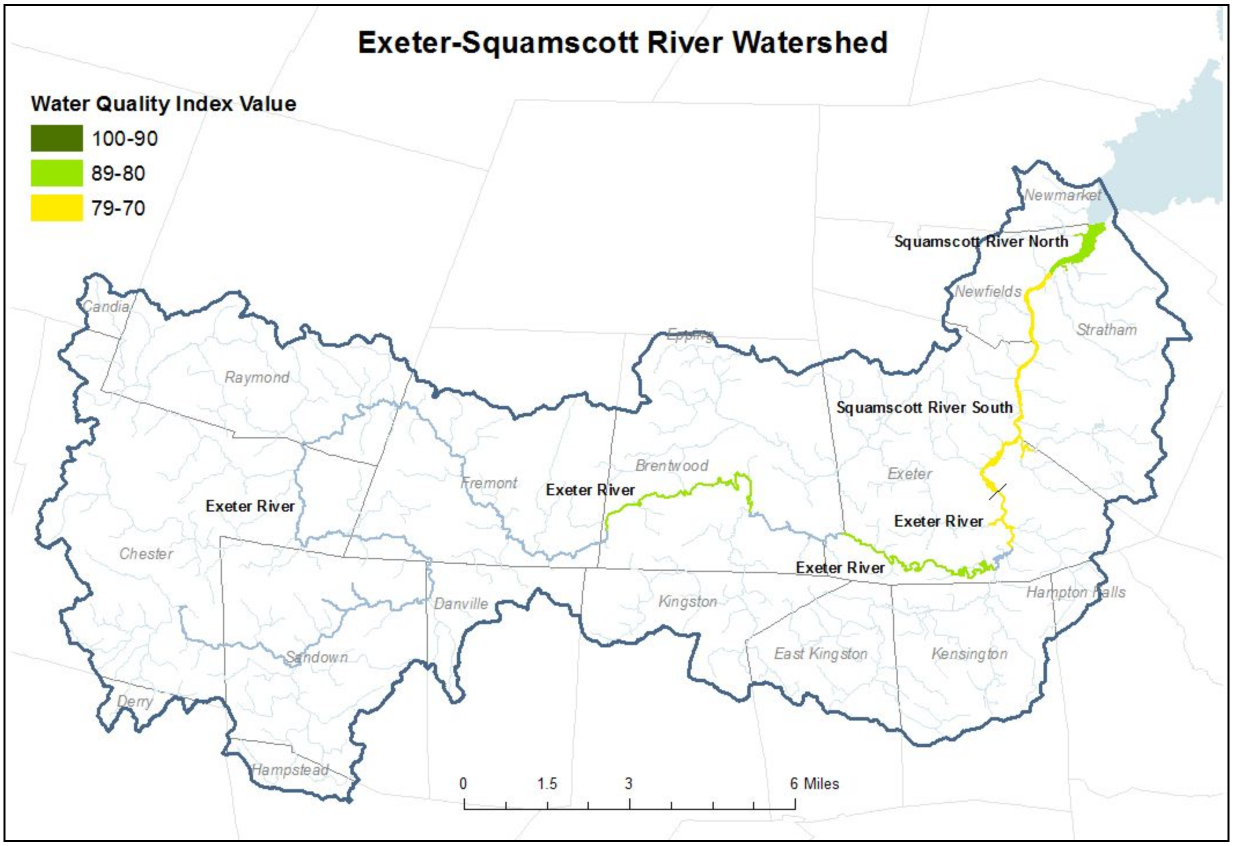


Figure 2. Exeter-Squamscott River Watershed, a sub-watershed in the southern portion of the Great Bay watershed (Hydrologic Unit Code 0106000308). The Exeter River is the freshwater portion of the river from the headwaters to the Exeter town center (indicated by hash mark across river) while the Squamscott River is the tidal portion of the river from the Exeter town center to the Great Bay. Baseline water quality shown for select river segments (Table 6). Water Quality Index (WQI) values are calculated using Equation 3.

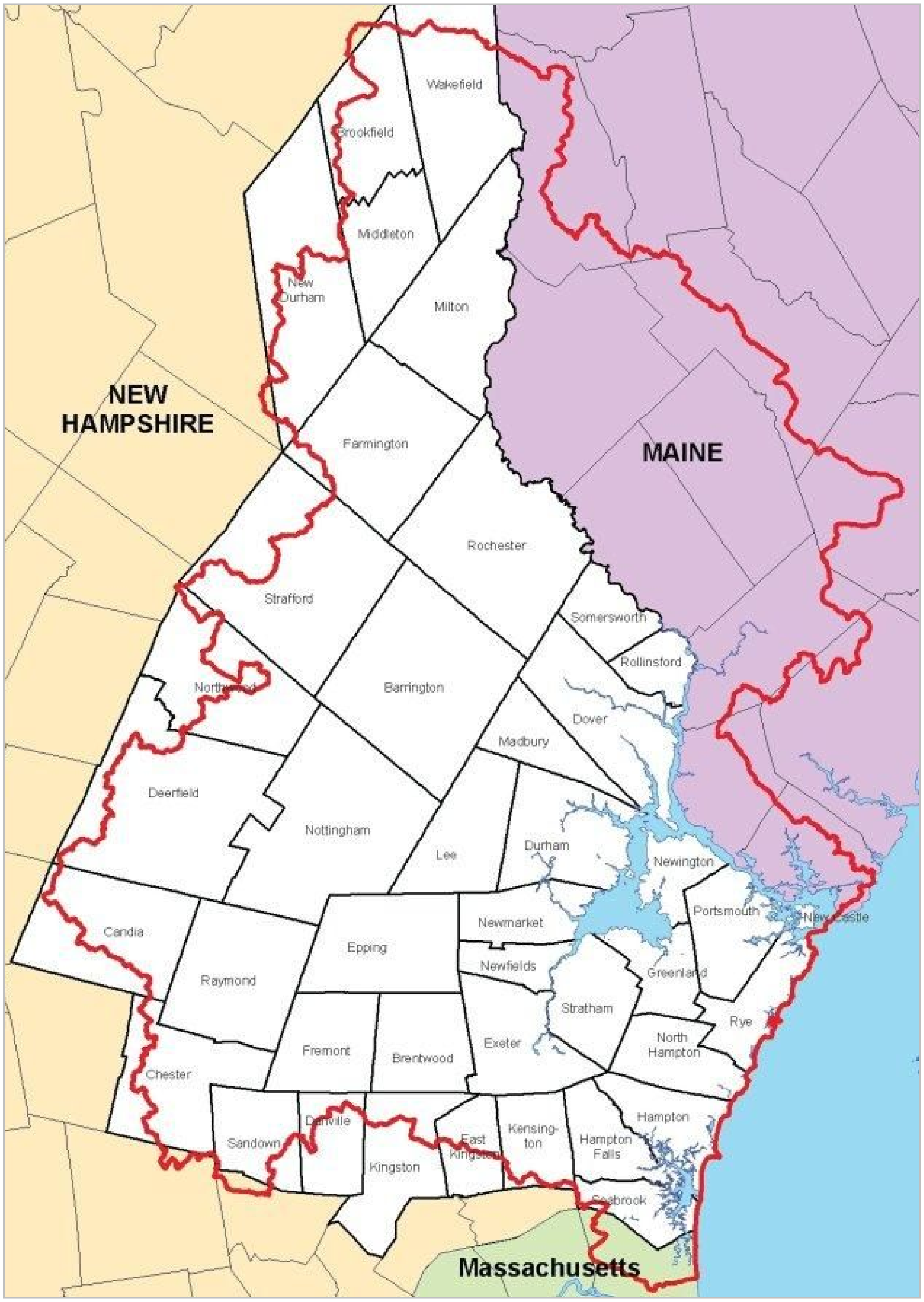


Figure 3. New Hampshire communities in the Great Bay watershed.
(Source: http://info.nhpr.org/sites/default/files/gbmap081610.jpg; downloaded 8/24/16)

Data Requirements and Sources

For each scenario, the benefit transfer process requires values (or levels) to be chosen for each independent variable (Table 2) that are then plugged into Equation 1. Where possible, these variable levels are typically chosen to reflect current conditions at the policy site—or the site for which value estimates are desired. Selecting variable levels in this way enables the resulting WTP estimates to be tailored to specific conditions at the policy site. Some of these values require intermediate calculations using external data such as spatial landscape (GIS) metrics, population census data, and a set of baseline water quality data, while other values are selected based on anticipated policy or management activity contributions or economic fundamentals.

For the geospatial variables (*Ln_PropAgLand*, *Ln_AreaRatio1*, *Ln_AreaRatio2*, *Ln_RelativeSize*, and *ProportionChg*), values of the underlying components (e.g., shoreline length, watershed area, town area, county area, and agricultural land area) are generated using spatial GIS techniques. Benefit transfers are then calculated based on the variable definitions provided in Table 2. For example, *Ln_RelativeSize* is calculated by dividing the shoreline length of the focal resource (river or bay) by the size of the market area and then taking the natural log of the result. Potential sources for raw data include the National Hydrography Dataset (http://www.horizon-systems.com/NHDPlus/NHDPlusV2_home.php), the Hydrologic Unit Code Watershed Boundary Dataset (http://water.usgs.gov/GIS/huc.html), the National Land Cover Database (NLCD) (http://www.mrlc.gov), the NOAA Global Self-Consistent, Hierarchical, High-resolution Geography Database (GSHHD); http://www.ngdc.noaa.gov/mgg/shorelines/shorelines.html), and US Census (http://www.census.gov/geo/maps-data/data/tiger.html).[5]

For the affected population(s), median household income (*Ln_Income*) and number of households for selected towns, counties, and states can be obtained directly from US Census data. We used 2015 households and median household income from the 2011-2015 American Community Survey 5-year Estimates (https://www.census.gov/programs-surveys/acs/). Median household income for the Great Bay watershed was approximated using a household weighted average for Rockingham and Strafford counties. Median household income for groups of communities (e.g., communities adjacent to the Exeter River) were calculated as a household-weighted average across the communities. Because the meta-regression analysis used 2007 US dollars in its estimation process, it is necessary to convert income values from 2015 USD to 2007 USD using the following equation and values for the average monthly Consumer Price Index (CPI) from U.S. Bureau of Labor Statistics (https://www.bls.gov/cpi/):

$$\text{Median Household Income}_{2007} = \text{Median Household Income}_{2015} * (CPI_{2007}/CPI_{2015}) \quad (2)$$[6]

Values for the remaining variables (except baseline water quality) are selected based on the scenario definition. Because none of the scenarios involved multiple geographically distinct water body types, we set *Multi_Body* = 0. The Squamscott and Exeter scenarios include a river,

[5] Geospatial and household data values used in scenarios can be found in Appendix B.
[6] Average monthly CPI values for 2007 and 2015 are 207.342 and 237.017, respectively.

so *River* = 1. In all scenarios, we were interested in forecasting WTP for both users and nonusers (*Non_Users* = 0) in New Hampshire (*Northeast_US* = 1) and the three recreational uses (*Swim_Use* = 1, *Boat_Use* = 1, *Game_Fish* = 1). For the primary study variables, we chose an annual, mandatory, mean payment (*LumpSum* = 0, *Voluntary* = 0, *MedianWTP* = 0), and selected values as if the study occurred in 2017 (*StudyYear* = 2017), omitted outlier bids (*OutlierBids* = 0), and was peer reviewed (*NonReviewed* = 0). We used the mean value of the metadata for the remaining variables.

For the baseline water quality variable (*Ln_BaseQuality*), it is necessary to calculate the value of a 100-point water quality index (WQI) for the focal water body. The WQI provides a single number for describing general water quality that can be related to the suitability of a water body for various human uses (e.g., swimming, fishing, or boating) or to the presence of particular aquatic species. As such, the WQI links specific water quality pollutant levels (e.g., fecal coliform concentrations) to particular human use and non-use benefits. Our analysis uses the WQI methodology and classification of United State Environmental Protection Agency (USEPA) (2009), adapted from the Oregon Water Quality Index of Cude (2001), because of its national scope and support of rivers, streams, *and* estuaries.

Implementing the WQI for a particular water body entails three steps: (1) obtaining pollutant data for the water body of interest, (2) transforming these data into sub index values, and (3) combining the subindex values into an aggregate water quality index. The specific water quality pollutants used by the WQI, along with their required units of measure and associated WQI subindex weights, are shown in Table 4. Pollutant data was obtained from the New Hampshire Department of Environmental Services (NHDES). These data were averaged across all sampling periods and monitoring stations for several NHDES Water Quality Assessment Units in each our three focal water bodies (Table 6) to produce WQI pollutant parameter values for each pollutant subindex.[7] We elected to investigate water quality in each Assessment Unit rather than averaging pollutant data across the entire water body in order to produce a range of water quality values that could then be assessed in sensitivity analyses. These pollutant parameter values were then transformed into the corresponding subindex values using the information in Table 5, which is derived from USEPA (2009, Tables 10-1 and 10-3 and Appendix F). There are six water quality subindices in each WQI, however, note that the WQI for freshwater rivers and streams includes biochemical oxygen demand (BOD), while the WQI for estuaries includes chlorophyll-*a* (ChA). Finally, the subindex values and subindex weights were used to calculate the WQI for each major water body using the following (weighted geometric mean) equation:

$$WQI = \prod_{i=1}^{6} Q_i^{W_i} \tag{3}$$

where Q_i is the calculated water quality subindex for parameter i and W_i is the weight of the ith parameter from Table 4. Calculated baseline WQI values for each water quality assessment unit are shown in the last column of Table 6.

[7] Average pollutant concentration values for each assessment unit used in our scenarios are listed in Appendix C.

Table 4. Water Quality Index (WQI) Pollutants, Concentration Units, and Index Weights.

Pollutant	Unit	Freshwater WQI Weight	Estuarine WQI Weight
Dissolved Oxygen (DO)	Mg/L	0.24	0.26
Fecal Coliform (FC)	colonies/100mL	0.22	0.25
Total Nitrogen (TN)	Mg/L	0.14	0.15
Total Phosphorous (TP)	Mg/L	0.14	0.15
Total Suspended Solids (TSS)	Mg/L	0.11	0.11
Biochemical Oxygen Demand (BOD)	Mg/L	0.15	---
Chlorophyll-*a* (ChA)	µg/L	---	0.08

Table 5. Water Quality Index Parameter-Subindex Transformation Equations.

Parameter	Value	Subindex
DO	DO ≤ 3.3	10
	3.3 < DO < 10.5	$-80.29 + 31.88*DO - 1.401*DO^2$
	10.5 ≤ DO	100
FC	FC ≤ 50	98
	50 < FC ≤ 1600	98 * exp(-0.00099178*(FC – 50))
	1600 < FC	10
TN	TN ≤ 3	100 * exp(-0.4605*TN)
	3 < TN	10
TP	TP ≤ 0.25	$100 - 299.5*TP - 0.1384*TP^2$
	0.25 < TP	10
TSS	TSS ≤ 28	100
	28 < TSS ≤ 168	158.48 * exp(-0.0164*TSS)
	168 < TSS	10
BOD	BOD ≤ 8	100 * exp(-0.1993*BOD)
	8 < BOD	10
ChA	ChA ≤ 40	100 * exp(-0.05605*ChA)
	40 < ChA	10

Table 6. Major Water Bodies Used in Scenarios and Baseline Water Quality.

Water Body	NHDES Assessment Unit (ID)	Type	Baseline WQI
Exeter River*	Exeter River – Brentwood (NHRIV600030803-05)	River/Stream	85
Exeter River*	Exeter River – Exeter (NHRIV600030805-02)	River/Stream	84
Exeter River*	Exeter River – Exeter Dam (NHIMP600030805-04)**	Impoundment	77
Squamscott River	Squamscott River South (NHEST600030806-01-01)	Estuary	71
Squamscott River	Squamscott River North (NHEST600030806-01-02)	Estuary	86
Great Bay	Great Bay Safety Zone 1 (NHEST600030904-02)	Estuary	87
Great Bay	Great Bay Safety Zone 2 (NHEST600030904-03)	Estuary	85
Great Bay	Great Bay Open (NHEST600030904-04-05)	Estuary	89
Great Bay	Adams Point South (NHEST600030904-04-06)	Estuary	92
Great Bay	Upper Little Bay South (NHEST600030904-06-12)	Estuary	93
Great Bay	Adams Point Mooring Field (NHEST600030904-06-10)	Estuary	84
Great Bay	Upper Little Bay (NHEST600030904-06-19)	Estuary	91
Great Bay	Lower Little Bay (NHEST600030904-06-18)	Estuary	88
Great Bay	Lower Little Bay Marina (NHEST600030904-06-14)	Estuary	89

* Water quality data was limited for much of the Exeter River. The "Brentwood" assessment unit was the farthest upstream unit that contained a relatively complete set of pollutant data.

** Beginning in 2016, impoundment area NHIMP600030805-04 behind the Exeter River dam became part of river area NHRIV600030805-32.

Table 7. Water Quality Classifications (USEPA 2009).

WQI Value	Water Quality Classification
95	Drinking without treatment
70	Swimming
50	Game fishing (food)
45	Rough fishing (non-food)
25	Boating

The WQI can be used to describe general water quality and is useful for making comparisons among water bodies at a given time, assessing changes in water quality for a particular water body over time, or assisting with management decision making. A water quality classification system can facilitate this process. USEPA's (2009) water quality classification identifies the minimum WQI value on a 100-point scale required for particular human uses (Table 7). These classes were originally determined by assessing the minimum threshold level of each WQI pollutant that would be required to be met for each human use. However, there is no guarantee that a specific occurrence of this value means that the water body supports the particular use. For example, a WQI value of 70 is the minimum value necessary for swimming (i.e., contact recreation). However, a WQI value of 70 does not guarantee that a particular water body is of good enough quality for swimming as it possible that one of the index pollutants relatively less important for swimming (e.g., dissolved oxygen) is above its minimum threshold while another index pollutant relatively more important for swimming (chlorophyll-*a*) is below its minimum threshold. Another consideration is the importance of pollutants that are omitted from the WQI. For example, relatively high concentrations of mercury in the water body would prohibit fish consumption even if the value of the WQI, which does not include mercury, was very high. In fact, mercury levels are high throughout the Great Bay watershed. Thus, the water quality classifications in Table 4 can "aid in the assessment of water quality for general recreational uses" but they "cannot determine the quality of water for specific uses" (Cude 2001, p. 126).

Water quality varies among our study's assessment units (Table 6, Figures 2 and 3). While none of the water bodies investigated here are suitable for drinking without treatment (i.e., all have a WQI < 95), the nine assessment units of the Great Bay (an area-weighted WQI of 88), the northern portion of the Squamscott River (section closest to the bay), and most of the Exeter River are suitable for boating, fishing and swimming uses (Tables 6 and 7). Thus, it appears as though the Great Bay itself has been able to assimilate or dilute pollutant loads from contributing rivers. In contrast, the southern portion of the Squamscott River (closer to Exeter town center) and the portion of the Exeter River behind the Exeter dam are barely suitable for swimming (based on WQI scores) and may be focal areas for future policy or management interventions. What is most noticeable about the water quality pollutants in Squamscott River South is the high level of chlorophyll-a, 42.8μg/L (Appendix C). In comparison, other values throughout the study region range from 1.5μg/L in the Lower Little Bay Marina to 8.1μg/L in Squamscott River North. Fecal coliform levels in Squamscott River South are also the highest in the study region (Appendix C).

Benefit Transfer Illustration

Once all the levels for the independent variables are chosen for a given scenario, they can be plugged into Equation 1, which gives a value for ln (WTP), or the natural log of per household WTP. To obtain an estimate of mean per household WTP, it is necessary to use the following exponential transformation:

$$WTP = \exp(\ln WTP + \sigma_{\varepsilon}^{2}/2) \qquad (3)$$

where σ_{ε} is the model error variance from Table 3. Note that the value of WTP that comes out of this analysis is in 2007 US dollars and can be converted to current dollars using values from the CPI similar to the process used to convert median household income from 2015 USD to 2007 USD in Equation 2.

The benefit transfer process described in the previous sections is illustrated in Table 8 for the Squamscott River 9-point WQI increase scenario, using Model 2 of the benefit transfer function (Table 3) and the lower bound of baseline water quality for the river (Table 6). Communities in this region include Exeter, Newfields, and Stratham, with a median household income of $86,305 (Appendix B). Given these conditions, the benefit transfer projects annual household WTP = $53.73 (2016 USD). This reflects the amount of money that an average household in these communities would be willing to pay, in order to increase water quality from its current WQI level of 71 to 80. When aggregated across all households in the three adjacent communities, the result is a total WTP of $4.64 million per year. All subsequent analyses also use Model 2 of the benefit transfer function.

Table 8. Illustrating the benefit transfer process for a 9-point increase on the 100-point water quality index (WQI) in the Squamscott River (baseline WQI is 71).

Variable	(A) Model Coefficients	(B) Selected Values	Data Source	(C) Product (A) * (B)
Ln_BaseQuality	-0.064	4.260	NHDES	-0.273
Ln_QualityChg	0.281	3.185	Scenario	0.617
Ln_Income	0.628	11.232	U.S. Census	7.054
Non_Users	-0.455	0	Scenario	0.000
Swim_Use	-0.391	1	Scenario	-0.391
Boat_Use	-0.314	1	Scenario	-0.314
Game_Fish	0.303	1	Scenario	0.303
River	-0.226	1	Scenario	-0.226
Multi_Body	-0.525	0	Scenario	0.000
Ln_PropAgLand	-0.351	-2.795	GIS calculated	0.981
Ln_RelativeSize	0.052	-1.704	GIS calculated	-0.089
ProportionChg	0.525	0.008	GIS calculated	0.004
Northeast_US	0.549	1	Scenario	0.549
Central_US	0.601	0	Scenario	0.000
Southern_US	1.366	0	Scenario	0.000
MedianWTP	-0.264	0	Scenario	0.000
LumpSum	0.727	0	Scenario	0.000
Ln_StudyYear	-0.478	3.611	Scenario	-1.726
ChoiceExp	0.487	0.107	Metadata	0.052
Thesis	0.557	0.114	Metadata	0.063
Voluntary	-1.296	0	Scenario	0.000
OutlierBids	-0.429	1	Scenario	-0.429
NonParametric	-0.477	0.429	Metadata	-0.205
NonReviewed	-0.679	0	Scenario	0.000
Intercept	-2.281	1		-2.281

Calculation	Data	Result	Value
sum of column (C)		lnWTP	3.691
$\exp(\ln WTP + \sigma_\varepsilon^2/2)$	$\sigma_\varepsilon = 0.541$	Household WTP_{2007}	46.41
$(CPI_{2016}/CPI_{2007})*WTP_{07}$	$CPI_{2007} = 207.342$ $CPI_{2016} = 240.007$	**Household WTP_{2016}**	53.73
WTP * #Households	#Households = 9637	**Regionwide WTP**	4,636,788

5. Water Quality Values for New Hampshire's Great Bay

The benefit transfer produces a wide range of willingness to pay forecasts for water quality improvements in New Hampshire's Great Bay watershed, with results varying as expected over the 50 unique scenarios (Figures 4 through 6, Table 9). As shown by these scenarios, multiple factors can cause WTP to either increase or decrease. For example, annual household WTP increases as the size of the water quality improvement increases (e.g., from a 3-point increase to a 9-point increase) for all focal water bodies (Figure 4). For the Exeter-Squamscott River, WTP values range from \$39 to \$54 per household per year, for households in adjacent communities along both freshwater and tidal areas of the river. While the baseline water quality is better and the size of the improved water body (i.e., the length of the river) is larger in the Exeter (freshwater) portion of the river, median household income is higher in the Squamscott (tidal) portion (Table 6, Appendix B). Thus, despite differences in scenario parameters, tradeoffs among those parameters can result in similar WTP forecasts. Annual household WTP is greater (\$62-\$85) for improvements to the entire Great Bay versus the smaller Exeter-Squamscott regions (Figure 4), despite baseline water quality being better and median household income being lower. This is due to the larger size of the improved water body and also due to the relative lack of a substitute for the Great Bay within New Hampshire (Table 6, Appendix B). As the market area for the Great Bay increases from adjacent towns to surrounding counties to the entire state of N.H., annual per household WTP decreases. This reflects a pattern in which people who live farther away value improvements to the Great Bay less than those living closer, *ceteris paribus* (Figure 4). Sensitivity analysis comparing the upper and lower bounds on the calculated baseline WQI indicate household WTP values and trends are robust to variations in baseline water quality throughout the Great Bay watershed (Appendix A, Table A1).

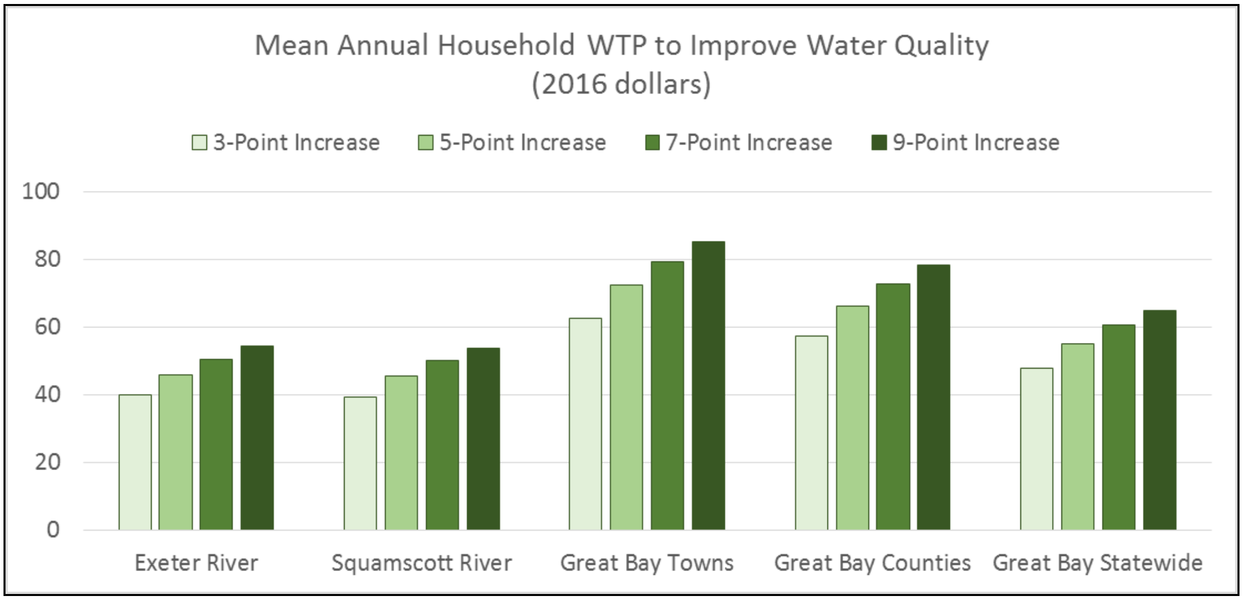


Figure 4. Willingness to pay (per household per year) for 3, 5, 7, and 9-point increases in water quality on the 100-point water quality index (WQI) for three water bodies using the minimum baseline WQI index value for each water body from Table 5. Three market regions (adjacent towns, two counties, and all of N.H.) were assessed for the Great Bay.

Results from the "Maintain Swimmable" scenarios, which forecast willingness to pay to maintain water quality at its current baseline level rather than allowing it to fall below 70 on the 100-point WQI, are also intuitive (Figure 5). Recall that 70 is the minimum threshold value on the WQI that indicates swimming (i.e., direct contact recreation) is an allowable use. In these scenarios, we are considering the potential degradation that could occur without any buffer policy or management interventions. That is, these scenarios represent WTP for damage avoidance. Households are willing to pay more to maintain a higher baseline water quality level (Maximum WQI versus Minimum WQI) across all water bodies, which is best illustrated by the Squamscott River scenarios where the difference between the minimum and maximum baseline of 15 points on the 100-point WQI scale leads to a *difference* in WTP of $35 per household per year. The previous trends associated with larger water bodies (bay versus river) and larger market areas (state versus counties versus adjacent communities) still hold.

WTP aggregated over an entire market area (or population) can vary due to differences in per household WTP, or due to differences in the number of households in the market area. Despite comparable household WTP measures, regional WTP values aggregated across all households in the adjacent communities for the three-town Squamscott (tidal) region are much lower than values for the larger seven-town Exeter (freshwater) region due to the larger number of households in the Exeter region (Figure 6A, Table 9). Aggregated values for the seven communities immediately adjacent to the Great Bay exceed those of the Exeter-Squamscott River, due to both larger household WTP values (because of the larger water body) and the larger number of households (Figure 6A, Table 9). Further, despite lower per household WTP values for the larger market regions, the much larger number of households in the two counties and the entire state results in dramatically higher aggregate regional WTP values (Figure 6B, Table 9). A full set of benefit transfer results, including a comparative analysis of Models 1 and 3, can be found in Appendix A. General trends among the three transfer functions are similar.

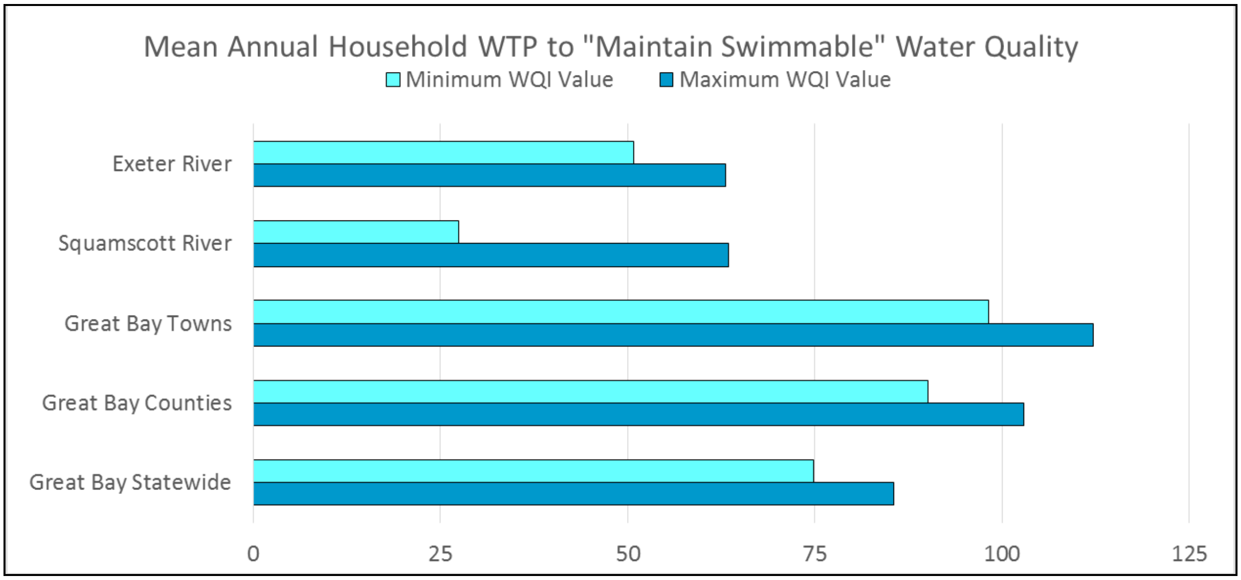
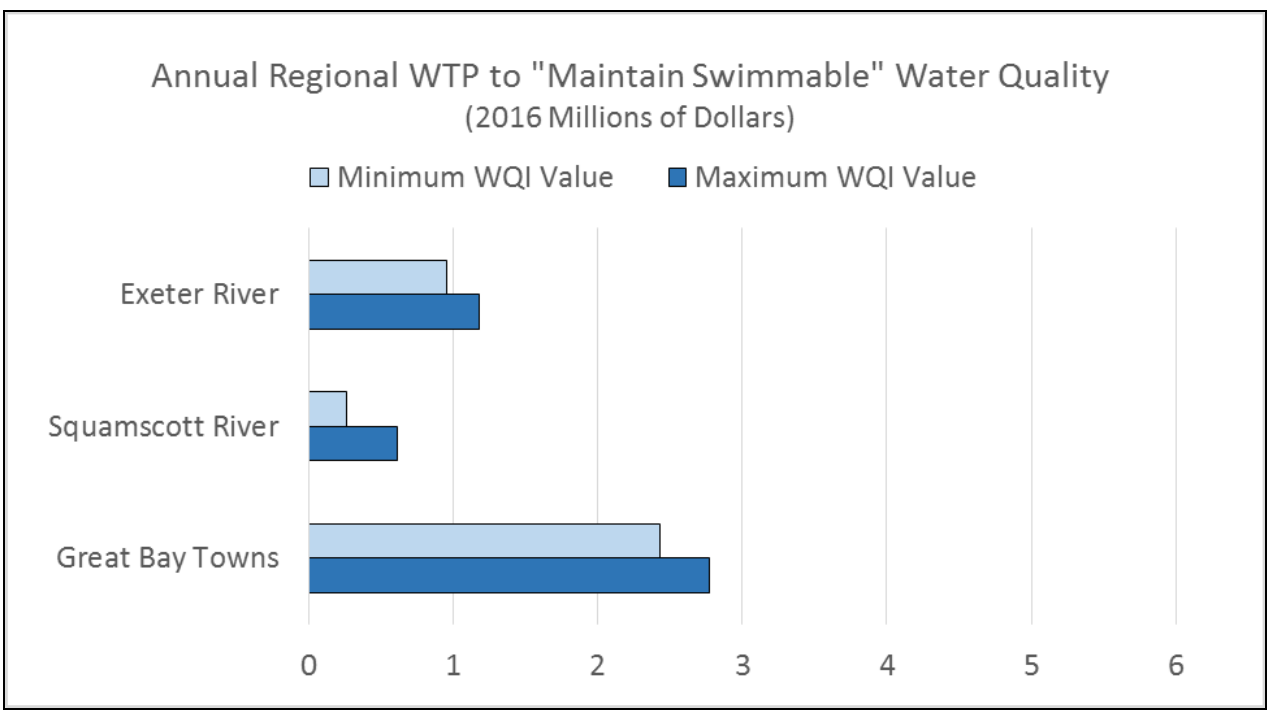


Figure 5. Willingness to pay (per household per year) to maintain water quality at its current baseline level rather than allowing it to fall below 70 on the 100-point water quality index. Three market regions (adjacent towns, two counties, and all of N.H.) were assessed for the Great Bay.

(A)



(B)

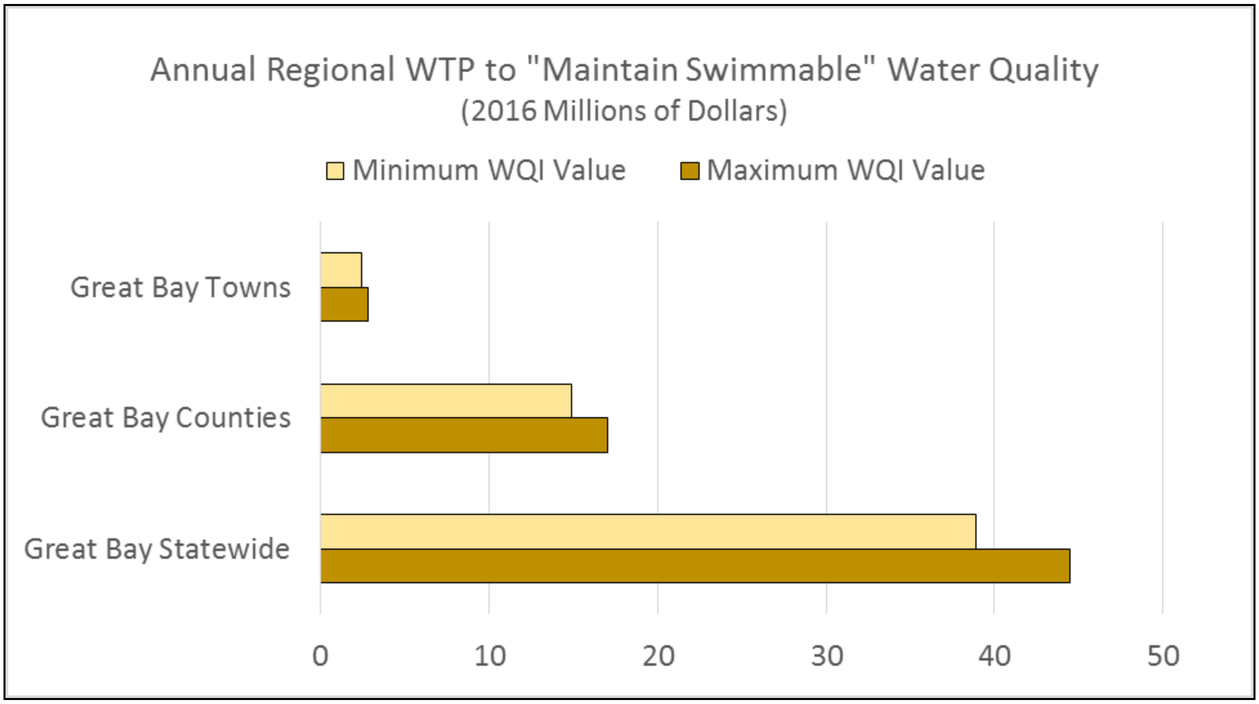


Figure 6. Regional willingness to pay to maintain water quality at its current baseline level rather than allowing it to fall below 70 on the 100-point water quality index. **(A)** Adjacent communities for three water bodies. **(B)** Three market regions for the Great Bay.

Table 9. Annual Regional Willingness to Pay ($ millions) to "Maintain Swimmable" or to Improve Water Quality from the Current Baseline Water Quality Index (WQI) Value.*

Region	Maintain Swimmable	3-point	5-point	7-point	9-point
Exeter River Min	0.95	0.75	0.86	0.95	1.02
Exeter River Max	1.18	0.74	0.86	0.94	1.01
Squamscott River Min	0.27	0.38	0.44	0.48	0.52
Squamscott River Max	0.61	0.38	0.43	0.48	0.51
Great Bay Towns Min	2.43	1.55	1.79	1.97	2.11
Great Bay Towns Max	2.77	1.54	1.78	1.95	2.10
Great Bay Counties Min	14.92	9.52	10.99	12.08	12.97
Great Bay Counties Max	17.05	9.46	10.92	12.01	12.89
Great Bay Statewide Min	38.93	24.85	28.69	31.53	33.84
Great Bay Statewide Max	44.49	24.70	28.51	31.34	33.63

* All values are in 2016 dollars. Swimmable = maintaining water quality at the current baseline level rather than allowing it to fall below 70 on the 100-point WQI.

Using Willingness to Pay (WTP) Values in Decision Making

Results from the benefit transfer approximate WTP estimates that would emerge from a primary stated preference survey conducted over the same market area (e.g., town, county, state). Often these surveys are written such that WTP is elicited from respondents using a referendum question. These questions ask whether surveyed households (respondents) would vote for or against a policy that would improve ecosystem services in a particular way (in a particular region), given a specified cost (e.g., in increases taxes or fees) that varies across different households receiving the survey. Households' votes at different costs illustrate their willingness to exchange money for specified ecosystem service improvements—this is the basis of WTP estimation.

To illustrate how one could use the WTP values described in the previous section and reported in Table 9 and Appendix A, consider the situation of the southern portion of the Squamscott River, which currently has the lowest average water quality in this project's study area. The results of the benefit transfer indicate that residents of the surrounding communities (Exeter, Newfields, and Stratham) would be willing to pay an aggregate amount of $518,000 per year for a 9-point water quality improvement from the current baseline WQI value of 71 to a WQI value of 80. This result implies that the three towns would be able to generate a water quality improvement fund of $518,000 per year through a referendum process. Recall that the Squamscott River's relatively poor water quality is due to high levels of chlorophyll-*a* and fecal coliform compared to other water bodies in the study region. Thus, the three towns could use these funds to target mitigation activities on reducing one or both of these two pollutants. For example, one way of increasing the WQI value to 80 would be to reduce chlorophyll-*a* concentrations from the current level of 43µg/L to 14µg/L; another way would be to reduce chlorophyll-*a* concentrations to 24µg/L while also reducing fecal coliform concentrations from the current level of 233 colonies/100ml to 50 colonies/100ml.

While we elected to include statewide scenarios in our analysis to show how WTP values can change over larger market areas (i.e., larger market areas produce lower household WTP, but much higher aggregate regional WTP), it is unclear whether any statewide buffer policy would focus on the Great Bay estuary alone. It is more likely that a statewide buffer policy would be implemented across all water bodies in the state. Thus, the more relevant aggregate WTP comparison would be among adjacent communities ($1.5-2.8 million) and the two counties that encompass the entire watershed ($9.5-17.1 million). The larger two-county values would be useful for funding buffer polices or management activities that impact the Great Bay and all its tributaries, while the small adjacent community values would be more appropriate for small bay shoreline projects.

It is also important to keep in mind that the WQI is a measure of general water quality, but the human use classifications (e.g., swimming, fishing, boating) cannot be used literally in specific situations. Mercury is prevalent throughout the Great Bay watershed and, thus, practitioners should rely on the NHDES water quality assessment reports (303(d) list) rather than WQI values for human use decisions in specific water bodies.

Interpretation of all the forecasted (i.e., transferred) values should be handled with caution. Results are not exact, but rather approximations of public values for water quality improvements that can be used to guide resource management and policy decision making. It is important to recognize that the values are representative of what households would be willing to pay for particular water quality improvements, but there is no guarantee that those funds would actually be sufficient to support the level of buffer restoration or other activities that actually improves water quality by the desired amount. Consider the Squamscott River case presented above. The economic analysis presented here does not determine whether $518,000 worth of management activities each year would actually achieve a 9-point water quality increase and then maintain that level of water quality into the future. Of course, the opposite could be true as well—funds equaling aggregated WTP might support management activities that exceed the desired level of water quality improvement. That is, WTP reflects the *value* of an improvement to people, not the *cost* of obtaining those improvements.

Quantitatively linking the change in the quantity or quality of buffers that would result from a specific management action to a direct consequential change in the WQI is challenging and beyond the scope of this analysis. As such, this economic analysis forecasts values for water quality improvements directly, and then systematically explores a range of modest changes in water quality from the WQI baseline for each focal resource. The role and potential contribution of buffers in driving changes in water quality of this magnitude can then be explained after the fact, lessoning potential criticism that our modeled scenarios are based on too many biophysical assumptions (e.g., that a buffer of a particular type and location would lead to a particular water quality improvement). The WQI information provided can point practitioners to particular pollutants and could be a good place to start when identifying potential buffer actions, however, it is ultimately necessary to integrate the economic valuation results presented here with the results of biophysical water quality modeling scenarios in order to make well-informed decisions.

Finally, this economic valuation does not inform the decision maker regarding which set of management activities to engage in; that is, there is no cost analysis of buffer management. This analysis quantifies benefits only. A full cost-benefit analysis is often required to determine whether the benefits of specific management actions exceed the costs, although in some cases it may be obvious that the benefits reported here will outweigh the costs without conducting a formal cost analysis.

6. Conclusions

This report describes the generation of a water quality benefit transfer function using meta-analysis techniques, explains the step-by-step process to apply this transfer function to specific management or policy settings (with sufficient detail such that the benefit transfer function can also be used by stakeholders after the Buffer Options for the Bay project ends), and presents economic value forecasts for selected water quality scenarios for the Great Bay. Economic values for water quality improvements in the Great Bay watershed are substantial, ranging from the hundreds of thousands of dollars for small affected populations immediately adjacent to the Exeter-Squamscott River, up to $34 million when values are aggregated over all New Hampshire residents. Even higher economic values exist for maintaining water quality at its current level rather than allowing it to fall below 70 on the WQI, the minimum threshold for swimming uses. The goal of the Buffer Options for the Bay project is "to enhance stakeholder capacity to make informed decisions related to the protection and restoration of buffers around New Hampshire's Great Bay." This report provides economic WTP values for water quality improvements and damage avoidance that can be combined with information from biophysical, hydrological modeling and cost assessments to facilitate well-informed buffer management that recognizes both the costs and benefits of potential actions.

Acknowledgements

The authors would like to thank David Patrick and Peter Steckler of the New Hampshire Chapter of The Nature Conservancy, Matt Wood of the New Hampshire Department of Environmental Services, and Abigail Kaminski of the Marsh Institute at Clark University for assistance with acquiring water quality data and generating spatial GIS data and maps.

References

Cude, C.G. 2001. Oregon Water Quality Index: A Tool for Evaluating Water Quality Management Effectiveness. *Journal of the American Water Resources Association* 37(1):125-137.

Johnston, R.J., E.Y. Besedin, R. Iovanna, C.J. Miller, R.F. Wardwell, and M.H. Ranson. 2005. Systematic variation in willingness to pay for aquatic resource improvements and implications for benefit transfer: A meta-analysis. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 53(2-3):221-248.

Johnston, R.J., and L.A. Wainger. 2015. Benefit Transfer for Ecosystem Service Valuation: An Introduction to Theory and Methods. Chapter 12 in R.J. Johnston et al. (eds.) *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*. Dordrecht, The Netherlands: Springer.

Johnston, R.J., J. Rolfe, R.S. Rosenberger, and R. Brouwer. 2015. Introduction to Benefit Transfer Methods. Chapter 2 in R.J. Johnston et al. (eds.) *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*. Dordrecht, The Netherlands: Springer.

Johnston, R.J., E. Besedin, and R. Stapler. 2016. Enhanced Geospatial Data for Meta-Analysis and Environmental Benefit Transfer: An Application to Water Quality Improvements. *Environmental and Resource Economics* doi:10.1007/s10640-016-0021-7.

USEPA. 2009. Nonmarket Benefits from Water Quality Improvements. Chapter 10 in *Environmental Impact and Benefits Assessment for Final Effluent Guidelines and Standards for the Construction and Development Category*. Report EPA-821-R-09-012.

Appendix A. WTP Comparison across Benefit Transfer Functions.

Table A1. Annual Household WTP Using Three Benefit Transfer Functions.*

Model 1	**Swimmable**	**3-point**	**5-point**	**7-point**	**9-point**
Exeter River Min	52.98	41.59	48.04	52.82	56.70
Exeter River Max	65.84	41.31	47.71	52.46	56.32
Squamscott River Min	32.14	46.16	53.31	58.61	62.92
Squamscott River Max	74.47	45.54	52.59	57.83	62.08
Great Bay Towns Min	118.29	75.34	87.01	95.67	102.70
Great Bay Towns Max	135.24	74.84	86.44	95.04	102.02
Great Bay Counties Min	104.04	66.26	76.53	84.15	90.33
Great Bay Counties Max	118.95	65.82	76.02	83.59	89.73
Great Bay Statewide Min	82.29	52.41	60.53	66.55	71.44
Great Bay Statewide Max	94.08	52.06	60.13	66.11	70.97

Model 2	**Swimmable**	**3-point**	**5-point**	**7-point**	**9-point**
Exeter River Min	50.83	39.95	46.12	50.69	54.40
Exeter River Max	63.12	39.70	45.83	50.37	54.06
Squamscott River Min	27.51	39.46	45.55	50.06	53.73
Squamscott River Max	63.55	38.96	44.97	49.43	53.05
Great Bay Towns Min	98.20	62.69	72.36	79.54	85.36
Great Bay Towns Max	112.22	62.30	71.91	79.04	84.83
Great Bay Counties Min	90.12	57.53	66.41	73.00	78.34
Great Bay Counties Max	102.98	57.17	66.00	72.54	77.85
Great Bay Statewide Min	74.83	47.77	55.14	60.61	65.05
Great Bay Statewide Max	85.51	47.47	54.80	60.23	64.64

Model 3	**Swimmable**	**3-point**	**5-point**	**7-point**	**9-point**
Exeter River Min	46.06	35.91	41.71	46.03	49.54
Exeter River Max	57.73	35.74	41.52	45.82	49.32
Squamscott River Min	26.85	39.12	45.43	50.14	53.97
Squamscott River Max	64.28	38.76	45.02	49.68	53.48
Great Bay Towns Min	106.65	67.05	77.87	85.94	92.50
Great Bay Towns Max	122.57	66.74	77.52	85.55	92.09
Great Bay Counties Min	96.30	60.54	70.31	77.60	83.53
Great Bay Counties Max	110.67	60.27	70.00	77.25	83.15
Great Bay Statewide Min	78.87	49.58	57.59	63.55	68.41
Great Bay Statewide Max	90.65	49.36	57.33	63.27	68.10

* All values are in 2016 dollars. Swimmable = maintaining water quality at the current baseline level rather than allowing it to fall below 70 on the 100-point WQI.

Table A2. Annual Regional WTP ($ millions) Using Three Benefit Transfer Functions.*

Model 1	Swimmable	3-point	5-point	7-point	9-point
Exeter River Min	0.99	0.78	0.90	0.99	1.06
Exeter River Max	1.23	0.77	0.89	0.98	1.05
Squamscott River Min	0.31	0.44	0.51	0.56	0.61
Squamscott River Max	0.72	0.44	0.51	0.56	0.60
Great Bay Towns Min	2.92	1.86	2.15	2.36	2.54
Great Bay Towns Max	3.34	1.85	2.14	2.35	2.52
Great Bay Counties Min	17.22	10.97	12.67	13.93	14.95
Great Bay Counties Max	19.69	10.89	12.58	13.84	14.85
Great Bay Statewide Min	42.81	27.27	31.49	34.62	37.17
Great Bay Statewide Max	48.94	27.09	31.28	34.40	36.92

Model 2	Swimmable	3-point	5-point	7-point	9-point
Exeter River Min	0.95	0.75	0.86	0.95	1.02
Exeter River Max	1.18	0.74	0.86	0.94	1.01
Squamscott River Min	0.27	0.38	0.44	0.48	0.52
Squamscott River Max	0.61	0.38	0.43	0.48	0.51
Great Bay Towns Min	2.43	1.55	1.79	1.97	2.11
Great Bay Towns Max	2.77	1.54	1.78	1.95	2.10
Great Bay Counties Min	14.92	9.52	10.99	12.08	12.97
Great Bay Counties Max	17.05	9.46	10.92	12.01	12.89
Great Bay Statewide Min	38.93	24.85	28.69	31.53	33.84
Great Bay Statewide Max	44.49	24.70	28.51	31.34	33.63

Model 3	Swimmable	3-point	5-point	7-point	9-point
Exeter River Min	0.86	0.67	0.78	0.86	0.93
Exeter River Max	1.08	0.67	0.78	0.86	0.92
Squamscott River Min	0.26	0.38	0.44	0.48	0.52
Squamscott River Max	0.62	0.37	0.43	0.48	0.52
Great Bay Towns Min	2.64	1.66	1.92	2.12	2.29
Great Bay Towns Max	3.03	1.65	1.92	2.11	2.28
Great Bay Counties Min	15.94	10.02	11.64	12.84	13.82
Great Bay Counties Max	18.32	9.97	11.59	12.79	13.76
Great Bay Statewide Min	41.03	25.80	29.96	33.06	35.59
Great Bay Statewide Max	47.16	25.68	29.83	32.92	35.43

* All values are in 2016 millions of dollars. Swimmable = maintaining water quality at the current baseline level rather than allowing it to fall below 70 on the 100-point WQI.

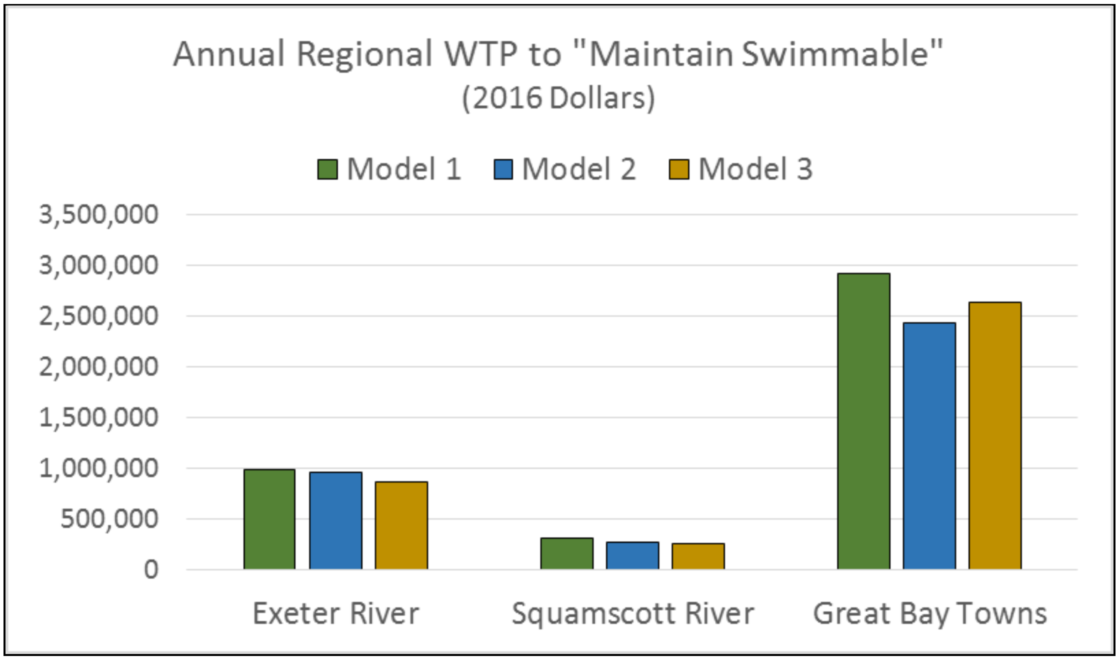


Figure A1. Annual regional willingness to pay to maintain water quality at its current baseline level rather than allowing it to fall below 70 on the 100-point water quality index comparing three models of the benefit transfer function given in Table 3.

Appendix B. Geospatial and Socioeconomic Data Values Used in Benefit Transfer Scenarios.

Variable	**Units**	**Exeter River**	**Squamscott River**	**Great Bay Towns**	**Great Bay Counties**	**Great Bay Statewide**
Market Area Towns/Counties		Brentwood, Chester, Danville, Exeter, Fremont, Raymond, and Sandown	Exeter, Newfields, and Stratham	Dover, Durham, Greenland, Newfields, Newington, Newmarket, and Stratham	Rockingham and Strafford	All N.H. towns
Number of Households	households	18,705	9,637	24,713	165,514	520,251
Household-weighted Median Income	2015 USD	80,724	86,305	71,668	75,329	66,799
Adjusted Median Income	2007 USD	70,617	75,499	62,695	65,898	58,436
Focal River Length	kilometers	65.3	10.1	N/A	N/A	N/A
Focal Shore Length	kilometers	130.6	20.2	61.3	61.3	61.3
Other River Length	kilometers	1191	1191	N/A	N/A	N/A
Other Shore Length	kilometers	2382	2382	24.7	24.7	24.7
Market Area	square-km	353	111	302	2873	24040
County Area	square-km	1882	1882	2873	2873	2873
County Ag Land Area	square-km	115	115	181	181	181
HUC 10 Area	square-km	331	331	1172	1172	1172
HUC 10 Ag Land Area	square-km	38	38	95	95	95

Appendix C. Average Water Quality Pollutant Concentrations Used in WQI Calculations.

	Dissolved Oxygen	Fecal Coliform	Total Nitrogen	Total Phosphorus	BOD or Chloroph yl l-*a*
Exeter River – Brentwood* (NHRIV600030803-05)	7.5956	85.1235	0.5907	0.0203	10.0000
Exeter River – Exeter* (NHRIV600030805-02)	7.4133	112.7144	0.4470	0.0332	
Exeter River – Exeter Dam* (NHIMP600030805-04)	7.5909	149.5000	1.8361	0.0309	3.7324
Squamscott River South (NHEST600030806-01-01)	8.8743	232.5371	0.5978	0.0918	
Squamscott River North (NHEST600030806-01-02)	9.0676	155.5208	0.4869	0.0539	29.3676
Great Bay Safety Zone 1 (NHEST600030904-02)	8.6573	117.8089	0.3621	0.0864	27.2530
Great Bay Safety Zone 2 (NHEST600030904-03)	8.8782	59.7002	0.2662	0.1590	21.5867
Great Bay Open (NHEST600030904-04-05)	8.4627	49.4913	0.2428	0.0957	15.1462
Adams Point South (NHEST600030904-04-06)	8.5143	22.6361	0.0825	0.0470	9.0000
Upper Little Bay South (NHEST600030904-06-12)	9.0559	29.9169	0.2904	0.0316	15.9371
Adams Point Mooring Field (NHEST600030904-06-10)	7.7900	88.0622	0.3346	0.1196	22.2467
Upper Little Bay (NHEST600030904-06-19)	8.2305	34.5966	0.2803	0.0410	12.9626
Lower Little Bay (NHEST600030904-06-18)	8.1745	22.8302	0.6939	0.0558	12.5542
Lower Little Bay Marina (NHEST600030904-06-14)	7.6321	68.5747	0.2330	0.0200	7.8233

* Data for the Exeter River was limited. BOD was only available for the Exeter Dam, but used for all units. E. coli counts were used
in lieu of fecal coliform.

Appendix D. Primary Studies Used in Meta-Regression Analysis.

Aiken RA (1985) Public benefits of environmental protection in Colorado. Master's thesis, Colorado State University.

Anderson GD, Edwards SF (1986) Protecting Rhode Island's coastal salt ponds: an economic assessment of downzoning. Coast Zone Manag 14(1/2):67–91.

Banzhaf HS, Burtraw D, Chung S, Evans DA, Krupnik A, Siikamaki J (2011) Valuation of ecosystem services in the southern Appalachian Mountains. Paper presented at the annual meeting of the Association of Environmental and Resource Economists (AERE).

Banzhaf HS, Burtraw D, Evans D, Krupnick A (2006) Valuation of natural resource improvements in the Adirondacks. Land Econ 82(3):445–464.

Bockstael NE, McConnell KE, Strand IE (1989) Measuring the benefits of improvements in water quality: the Chesapeake Bay. Mar Resour Econ 6(1):1–18.

Bockstael NE, McConnell KE, Strand IE (1988) Benefits from improvements in Chesapeake Baywater quality. Department of Agricultural and Resource Economics. University of Maryland.

Borisova T, Collins A, D'Souza G, Benson M, Wolfe ML, Benham B (2008) A benefit-cost analysis of total maximum daily load implementation. J Am Water Resour Assoc 44(4):1009–1023.

Cameron TA, Huppert DD (1989) OLS versus ML estimation of non-market resource values with payment card interval data. J Environ Econ Manag 17:230–246.

Carson RT, Hanemann WM, Kopp RJ, Krosnick JA, Mitchell RC, Presser S, Ruud PA, Smith VK (1994) Prospective interim lost use value due to DDT and PCB contamination in the Southern California Bight. Volume 2. Report to the National Oceanic and Atmospheric Administration, Produced by Natural Resources Damage Assessment Inc., LA Jolla, CA.

Clonts HA, Malone JW (1990) Preservation attitudes and consumer surplus in free flowing rivers. In: Vining J (ed) Social science and natural resource recreation management. Westview Press, Boulder, pp 301–317

Collins AR, Rosenberger RS, Fletcher JJ (2009) Valuing the restoration of acidic streams in the Appalachian Region: a stated choice method. In: Thurstone HW, HeberlingMT, Schrecongost A (eds) Environmental economics for watershed restoration. CRC/Taylor Francis, Boca Raton, pp 29–52.

Collins AR, Rosenberger RS (2007) Protest adjustments in the valuation of watershed restoration using payment card data. Agric Resour Econ Rev 36(2):321–335.

Corrigan JR, KlingCL, Zhao J (2009) Willingness to pay and the cost of commitment: an empirical specification and test. Environ Resour Econ 40:285–298.

Croke K, Fabian RG, Brenniman G (1986–1987) Estimating the value of improved water quality in an urban river system. J Environ Syst 16(1):13–24.

De Zoysa ADN (1995) A benefit evaluation of programs to enhance groundwater quality, surface water quality and wetland habitat in Northwest Ohio. Dissertation, Ohio State University.

Desvousges WH, Smith VK, Fisher A (1987) Option price estimates for water quality improvements: a contingent valuation study for the Monongahela River. J Environ Econ Manag 14:248–267.

Downstream Strategies LLC (2008) An economic benefit analysis for abandoned mine drainage remediation in the west branch Susquehanna River Watershed. Pennsylvania, Prepared for Trout Unlimited.

Farber S, Griner B (2000) Using conjoint analysis to value ecosystem change. Environ Sci Technol 34(8):1407–1412.

Hayes KM, Tyrell TJ, Anderson G (1992) Estimating the benefits of water quality improvements in the Upper Narragansett Bay. Mar Resour Econ 7:75–85.

Herriges JA, Shogren JF (1996) Starting point bias in dichotomous choice valuation with follow up questioning. J Environ Econ Manag 30(1):112–131.

Hite D (2002) Willingness to pay for water quality improvements: the case of precision application technology. Department of Agricultural Economics and Rural Sociology, Auburn University, Auburn, AL.

Huang JC, Haab TC, Whitehead JC (1997) Willingness to pay for quality improvements: should revealed and stated preference data be combined? J Environ Econ Manag 34(3):240–255.

Irvin S, Haab T, Hitzhusen FJ (2007) Estimating willingness to pay for additional protection of Ohio surface waters: contingent valuation of water quality. In: Hitzhusen FJ (ed) Economic valuation of river systems. Edward Elgar, Cheltenham, pp 35–51.

Johnston SK Swallow, Weaver TF (1999) Estimating willingness to pay and resource tradeoffs with different payment mechanisms: an evaluation of a funding guarantee for watershed management. J Environ Econ Manag 38:97–120.

Kaoru Y (1993) Differentiating use and nonuse values for coastal pond water quality improvements. Environ Resour Econ 3:487–494.

Lant CL, Roberts RS (1990) Greenbelts in the cornbelt: riparian wetlands, intrinsic values, and market failure. Environ Plan 22:1375–1388.

Lant CL, Tobin GA (1989) The economic value of riparian corridors in cornbelt floodplains: a research framework. Prof Geogr 41:337–349.

Lichtkoppler FR, Blaine TW (1999) Environmental awareness and attitudes of Ashtabula County voters concerning the Ashtabula River area of concern: 1996–1997. J Gt Lakes Resour 25:500–514.

Lindsey G (1994) Market models, protest bids, and outliers in contingent valuation. J Water Resour Plan Manag 12:121–129.

Lipton D (2004) The value of improved water quality to Chesapeake Bay boaters. Mar Resour Econ 19:265–270.

Londoño Cadavid C, Ando AW (2013) Valuing preferences over stormwater management outcomes including improved hydrologic function. Water Resour Res 49:4114–4125.

Loomis JB (1996) How large is the extent of the market for public goods: evidence from a nationwide contingent valuation survey. Appl Econ 28(7):779–782.

Lyke AJ (1993) Discrete choice models to value changes in environmental quality: a Great Lakes case study. Dissertation submitted to the Graduate School of the University of Wisconsin, Madison.

Matthews LG, Homans FR, Easter KW (1999) Reducing phosphorous pollution in the Minnesota River: how much is it worth? Department of Applied Economics, University of Minnesota, Staff Paper.

Opaluch JJ, Grigalunas T, Mazzotta MJ, Diamantides J, Johnston R (1998) Resource and recreational economic values for the Peconic Estuary. Report prepared for Peconic Estuary Program, Suffolk County Department of Health Services, Riverhead, NY, by Economic Analysis Inc., Peace Dale, Rhode Island.

Roberts LA, Leitch JA (1997) Economic valuation of some wetland outputs of Mud Lake. Agricultural Economics Report No. 381, Department of Agricultural Economics, North Dakota Agricultural Experiment Station, North Dakota State University.

Rowe RD, Schulze WD, Hurd B, Orr D (1985) Economic assessment of damage related to the Eagle Mine facility. Energy and Resource Consultants Inc, Boulder.

Sanders LB, Walsh RG, Loomis JB (1990) Toward empirical estimation of the total value of protecting rivers. Water Resour Res 26(7):1345–1357.

Schulze WD, Rowe RD, Breffle WS, Boyce RR, McClelland GH (1995) Contingent valuation of natural resource damages due to injuries to the Upper Clark Fork River Basin. State of Montana, Natural Resource Damage Litigation Program. Prepared by: RCG/Hagler Bailly, Boulder, CO.

Shrestha RK, Alavalapati JRR (2004) Valuing environmental benefits of silvopasture practice: a case study of the Lake Okeechobee watershed in Florida. Ecol Econ 49:349–359.

Stumborg BE, Baerenklau KA, Bishop RC (2001) Nonpoint source pollution and present values: a contingent valuation of Lake Mendota. Rev Agric Econ 23(1):120–132.

Sutherland RJ, Walsh RG (1985) Effect of distance on the preservation value of water quality. Land Econ 61(3):282–290.

Takatsuka Y (2004) Comparison of the contingent valuation method and the stated choice model for measuring benefits of ecosystem management: a case study of the Clinch River Valley, Tennessee. Ph.D. dissertation, University of Tennessee.

Wattage PM (1993) Measuring the benefits of water resource protection from agricultural contamination: results from a contingent valuation study. Dissertation, Forestry, Iowa State University.

Welle PG (1986) Potential economic impacts of acid deposition: a contingent valuation study of Minnesota. Dissertation, University of Wisconsin-Madison.

Welle PG, Hodgson JB (2011) Property owner's willingness to pay for water quality improvements: contingent valuation estimates in two central Minnesota Watersheds. J Appl Bus Econ 12(1):81–94.

Wey KA (1990) Social welfare analysis of congestion and water quality of Great Salt Pond, Block Island, Rhode Island. Dissertation, University of Rhode Island.

Whitehead JC (2006) Improving willingness to pay estimates for quality improvements through joint estimation with quality perceptions. South Econ J 73(1):100–111.

Whitehead JC, Groothuis PA (1992) Economic benefits of improved water quality: a case study of North Carolina's Tar-Pamlico River. Rivers 3:170–178.

Whitehead JC, Blomquist GC, Hoban TJ, Clifford WB (1995) Assessing the validity and reliability of contingent values: a comparison of on-site users, off-site users, and nonusers. J Environ Econ Manag 29:238–251.

Whittington D, Cassidy G, Amaral D, McClelland E, Wang H, Poulos C (1994) The economic value of improving the environmental quality of Galveston Bay. Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill. GBNEP-38, 6/94.