Willingness-to-Pay for Water Quality Improvements in the Androscoggin River: Enhancing Geospatial Validity in Benefit Transfers

Emma Glidden-Lyon, Candidate for Master of Environmental Management, 2015
Dr. Thomas Holmes, Adviser
April 24, 2015

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University

Abstract: Geospatial variables have been omitted from most meta-regression models evaluating water quality improvements, undermining the validity of these studies' estimations of willingness-to-pay (WTP). This paper takes a recent analysis demonstrating the importance of geospatial variables and applies it to water quality improvements in the Androscoggin River. The Androscoggin River has seen dramatic improvements in water quality since the 1970s but still struggles in certain reaches to meet the minimum state attainment standards. This paper estimates WTP for the historic improvements as well as WTP for additional future changes by applying a new meta-regression model created by Johnston et al. (in review). Johnston et al.'s paper increases the validity of WTP estimations by including three significant geospatial variables: scale of the affected resource; size of the market area; and availability of substitutes (in review). The empirical analysis here also finds that exclusion of the geospatial variables has a large impact on the WTP estimates, with overestimates when the geospatial scale of the market area to the region or affected water body to market area is relatively small and underestimates when these ratios of these variables are relatively large. The results also indicate that there is positive WTP per household for the historic water quality improvements in the Androscoggin River and for possible future water improvements.

Acknowledgements: I would like to thank Dr. Robert Johnston, who generously provided access to his paper and a significant amount of his time, for all of his assistance in this paper. I also owe a debt to Dr. Thomas Holmes, my adviser on this work for the past year and a half and without whom this project would not have happened.

Mike Auger, Executive Director of the Androscoggin Land Trust, was willing to talk to me about growing up along the Androscoggin and provided me with context for the dramatic changes that have occurred along the river and the amazing recreational resource it has become. The staff at the Maine Department of Environmental Protection quickly and generously helped me navigate the public water quality data that played an important role in this work.

Finally, I would like to thank my parents, William Glidden and Katharine Lyon, my sister, Sophie Glidden-Lyon, my grandmother, Jane Burton, and my partner, Derek Birkner, who inspired me to go to the Nicholas School and then made sure I got there.

Introduction

The passage of the Clean Water Act in 1972 as amendments to the Federal Water Pollution Control Act ushered in a decade of ambitious efforts to improve the water quality of the nation's rivers and streams. Since initial passage of the law and subsequent additional amendments, severely degraded waterways have seen a resurgence in their role as sources for wildlife, recreation, and desirable quality of life attributes.

Measurements of the value of these improvements have been calculated various ways, but an important tool for estimating the recreational added value has been contingent valuations studies. This paper uses a recent study that includes for the first time spatial attributes to measure the mean willingness-to-pay (WTP) per household value of past and future water quality improvements of the Androscoggin River—one of the rivers that acted as a motivator for the creation of the modern Clean Water Act.

Background

Clean Water Act: While water quality standards had been a feature of federal law since 1965, the legislation that preceded the Clean Water Act of 1972 was cumbersome and did not result in effective management of pollutants in the nation's waterways (CRS, 2014). Among the changes brought about by the 1972 amendments were to give the Environmental Protection Agency (EPA) the authority to set wastewater standards for industry and to make it illegal for pollutants to be discharged by a point source into navigable waters without a permit (EPA, 2014). The amendments also set goals of zero discharge of pollutants by 1985 and fishable and swimmable water bodies by mid-1983 (CRS, 2014). To achieve this, industries had to install best practice control technology by July 1, 1977 and best available technology by March 31, 1989 (CRS, 2014). While the Act continues to court controversy, an examination of the effects of the law two decades after passage found declining releases of toxic chemicals in to waterways and improved water quality in water bodies where the pollutants were primarily from point sources (Adler et al., 1993).

Androscoggin River: The 1972 amendments came out of frustration with the existing regulations and concern with the lack of improvement in rivers like the Androscoggin (Blomquist, 1997). Large rivers like the Androscoggin were crucial to the establishment of industries in the region, which relied on the power and transportation the water bodies provided. As these industries developed, however, the water quality of the rivers swiftly declined. While the Great Depression slowed the production and economic growth in the Androscoggin region temporarily, the resulting improvement in water quality did not last. In 1941, an unusually dry winter and hot summer led to an environmental crisis when the sulfite-heavy water, a waste product from the river's paper mills, began noticeably affecting the surrounding communities. In *Evolution of a Valley: The Androscoggin Story*, Page Helm Jones writes that

> "Jewelers, for example, nearly went berserk keeping their stocks of silverware saleable because the sulfite-laden air turned silver and other metals black overnight. If you were driving from Augusta to Lewiston, you began to smell it at North Monmouth, twenty miles from the city, and it increased in intensity as the road approached the river. House painted white turned black and blistered in great ugly patches, and by the time you had reached the city limits, you had to put up your car windows despite the heat and try not to breathe through your nose" (1975, p. 146).

Despite efforts by the state, the issue grew, and by the 1960s, the Androscoggin River was one of the most polluted water ways in the country with dissolved oxygen levels frequently reaching zero during the summer months (Watts, 2003-2005).

International Paper Company's Chisholm Mill at Livermore Falls on the Androscoggin River 06/1973 (Steinhacker, 1973)

Through a combination of industry initiatives and federal and state regulatory efforts, however, the Androscoggin River water quality slowly began to recover in the 1940s with additional significant advances in the 1970s and 1980s. Today, the entire length river is used as a recreational resource, and water quality has improved dramatically enough to allow for boating throughout the river and fishing, and swimming in many of the river's reaches.

Regional Economy: The industries located along the Androscoggin have historically been the primary economic engine of the mill towns and cities located along the banks. These New Hampshire and Maine towns relied on the river from their beginnings, and in the early 1960s, Berlin, Gorham, Rumford, Jay, Livermore Falls, Lewiston, Lisbon Falls, Lisbon Village, and Topsham all had operating paper mills. Many other towns were directly reliant on these mills as major employers. Over the next five decades, however, six of these mills would close, leaving only paper mills in Gorham, Rumford, and Jay in operation today.

Statewide, manufacturing jobs declined by 53% from their peak in the late 1970s to 2011 (Center for Workforce Research and Information, 2012), and this effect was even more pronounced in the towns that lost a mill (Fig. 1). As manufacturing jobs left the state, service-providing industries increased almost fourfold (Center for Workforce Research and Information, 2012).

Fig 1. Lewiston's Bates Mill closed in 1990. (Center for Workforce Research and Information, 2015a)

While the current overall employment rates in the counties that the Androscoggin River runs through are roughly in the middle of Maine's unemployment distribution (Center for Workforce Research and Information, 2015b), these shifts in employment have had a lasting and unevenly distributed effect on the region. While this economic shift is outside the scope of this paper, it provides important context for the contribution to improved water quality in the Androscoggin that came from mill closures.

Willingness-to-Pay and Stated Preference: The studies included in Johnston et al. estimate use and nonuse values via stated preference methods. Use values are created by actual engagement with a resource resulting in the use of a good or service. This can be indirect use, but it contrasts with non-use value, which can only be captured using state preference methods, and are defined as the values that are not associated with any use of the resource at all. Non-use values include existence values but not the values associated with potential future use for the resource.

In a stated preference model, WTP for a change in environmental quality is elicited using survey methods. This contrasts with revealed preference models that rely on observations of actual expenditures, such as recreational travel costs or home purchases, to estimate WTP. While revealed preference methods are often preferred as a more reliable measure of value, it is not always possible because of a lack of relationship between a market and the environmental good to be measured (Champ et al., 2003). Instead, economists have come to rely in part on stated preference approaches such as contingent valuation and choice experiments. While stated preference models like contingent valuation have faced criticism, studies have shown that, when designed appropriately, contingent valuation models can produce WTP estimates of similar magnitude as revealed preference models (Champ, et al., 2003).

Benefit Transfer: Often because of restrictions in time and resource availability, an original stated preference study cannot be completed, and researchers and policy makers must rely on a benefit transfer from an existing study or group of studies. There are two primary methods of preforming a benefit transfer. In the first, the WTP estimation from a single existing study is taken an applied to the new policy site. In the second, a meta-regression model is developed that statistically explains the variation in a vector of WTP estimates using a vector of explanatory variables, and can be used to compute WTP for environmental quality changes at a policy site by inserting values for the explanatory variables at the policy site into the statistical model (Champ et al., 2003). The meta-regression approach is based on the assumption that there exists a true model that explains the relationship between WTP and the independent variables (Champ et al., 2003). The individual studies in the meta-regression are then assumed to be independent draws of that true model and the meta-regression creates an approximation of the true model (Champ et al., 2003). The meta-regression model can then be better tailored to a policy site.

Transferring an entire demand, benefit, or WTP function is considered to be a more valid and consistent method than transferring only a single WTP value from a comparable study area to the policy site. Research has also indicated that transferring a value function from a multi-regression model may also provide increased accuracy and validity (Champ et al., 2003). A multi-regression model may better explain variation across studies and describe the effects these variations have on outcomes (Champ et al., 2003). Significant error can occur when a meta-regression model transfer is misapplied, however, so any estimations must be checked against the realities of the policy site and any pre-existing values that can act as benchmarks (Champ et al., 2003). Meta-regression is the approach taken in this paper.

Empirical Analysis: The primary basis for the empirical analysis included here is Johnston et al.'s "Enhanced Geospatial Data for Meta-Analysis and Environmental Benefit Transfer" (in review). In this paper, Robert J. Johnston and his co-authors, Elena Y. Besedin and Ryan Stapler, include spatial variables into a meta-analysis of WTP values for water quality improvement in a recreational context.[1] To do this, the authors include variables in their meta-regression model to address market extent, geospatial scale, and substitute availability (Johnston et al., in review). These variables come from the well-established relationship between WTP and geospatial scale including the importance of the size of the resource, the scale of change, and distance decay of WTP. These relationships are all supported in literature and economic theory, but are often only measured at a simplified or binary level in benefit transfers (Johnston et al, in review). This runs the risk of masking the effect of complicated geospatial scale issues on WTP estimations. Johnston et al. found that these variables are almost universally omitted in previous meta-regression models, and their own analysis found that stated preference is sensitive to these

[1] It does not include the value of improved water quality in terms of infrastructure spending, tourist dollars, health benefits, or any other possible benefit provided by better water quality.

measures (Johnston et al., in review). The inclusion of these variables potentially allows for a more reliable and accurate estimation of WTP for water quality improvements.

Despite potential limitations and the need for additional exploration of these models, the inclusion of geospatial variables is an innovative approach to improving value estimations. As the paper points out, it is common sense that market area, geospatial scale, and substitute availability would all affect stated preference (Johnston et al., in review). This is shown with the three model specifications run by Johnston et al with combinations of inclusion or exclusion of geospatial variables that finds that omission of the variables has a statistically significant effect on the estimation (Johnston et al., in review).

Methods

Meta-regression model: To estimate the value of the improvements in water quality on the Androscoggin River over the past four decades, this paper relies on Johnston et al.'s meta-regression model (in review). This model allows for cross-sectional correlation between observations the dependent and explanatory variables (Johnston et al., in review). The studies included in the model contain both mean and median measures of central tendency for the dependent variable:

$$\ln(\bar{y}_{js}) = \beta_0 + \bar{x}_{js}\beta_{js} + \ln(\bar{x}_{js})\beta_{js} + \varepsilon_{js}$$

where $\bar{y}_{js}$ is the WTP per household for observation *s* in study *j*; the variable $\bar{x}_{js}$ is the vector of independent variables; β is the vector of parameters; $\ln(\bar{x}_{js})$ is the additional vector of log transformed variables with β , the associated coefficients; and ε_{js} represents the error term (Johnston et al., in review). A table with the variables and summary statistics can be found in Appendix A.

The error term is made up of two components: a systematic, normally distributed, study-level random effects error and a standard *iid* estimation level error (Johnston et al., in review). Johnston et al. also cluster by study to address correlation within studies and estimate the model using an unweighted GLS random-effects model with robust standard errors (Johnston et al., in review).

As the computed WTP value is in logarithmic form, computation of the antilog is required. The antilog WTP value provides an estimate of the median WTP, and computation of the mean WTP requires multiplication by a bias correction term. Without correcting for this bias, the error term is incorrectly dropped from the resulting prediction for $\bar{y}_{js}$ (Newman, 1992). In a regression with logged terms, the mean of ε_{js} is zero, as it would be in linear regression models (Newman, 1992). When the antilog is taken, however, the mean will not remain zero and the error term must be retained in the model (Newman, 1992). To account for log transformation bias, it is necessary to include one-half of the variance of the error term in the computation of mean WTP per household.

Independent variables and parameters: Johnston et al.'s multi-regression model includes twenty-seven independent variables. Many of these represent characteristics of the primary studies the meta-regression model is built upon, with the means of each reported. The analysis done in this paper utilizes parameters chosen based on the best recommended practices for function transfers in order to best fit the meta-regression model to the policy site (Champ et al., 2003). For example, the dummy variable for river is set to 1 to reflect that the policy site is a river. A full description of these variables and their parameters can be found in Appendix A.

The summary statistics of the parameters included in Johnston et al.'s model were also compared to those of the policy site, with specific attention paid to the base level of water quality and the amount of change in the water quality. In both instances, estimations of these variables for the Androscoggin River fell within the range included in the original multi-regression model.

Geospatial variables: The geospatial variables needed for the meta-regression model (market area, geospatial scale, and substitute availability) were calculated using the same methods as those in Johnston et al. (in review). The three primary geospatial variables measured substitute availability (*sub_frac)*, the relative size of the market area (*ln_ar_ratio)*, and the relative size of the affected water body (*ln_rel_size)*.

Multiple variations of these variables were created for this paper in order to measure the effects of an average change in water quality throughout the whole river and the effects of the average change in water quality in the river reaches closest to Lewiston and Auburn (LA). The data came from geospatial databases, including the National Hydrography Dataset, the Hydrologic Unit Code Watershed Boundary Dataset, the National Land Cover Database, and the U.S. Census. [2]

Substitute availability was calculated as the length of the affected river reach in proportion to all river reaches of the same order throughout the state (Johnston et al., in review). In the case of Maine, all of the Androscoggin reaches were classified as Order 5 river reaches in the National Hydrography Dataset and were compared to the other Order 5 reaches throughout the states (see Appendix B). This was done for both the whole river and the partial LA section.

The relative size of the market area was measured by computing the size of the sampled area in square kilometers and dividing it by the total area of all counties that intersect the affected water body. To calculate the sample area, multiple scenarios were created in ArcMap that centered on the major towns along the Androscoggin and buffered out on the 2013 Census block group map by 5, 10, 20, and 30 miles. These are referred to as buffers throughout the rest of the paper. For the equations run to estimate WTP per household for the water quality improvements in the LA river section, the buffering was only done on Lewiston and Auburn. The county selection was also adjusted for the calculations done for the smaller section of river.

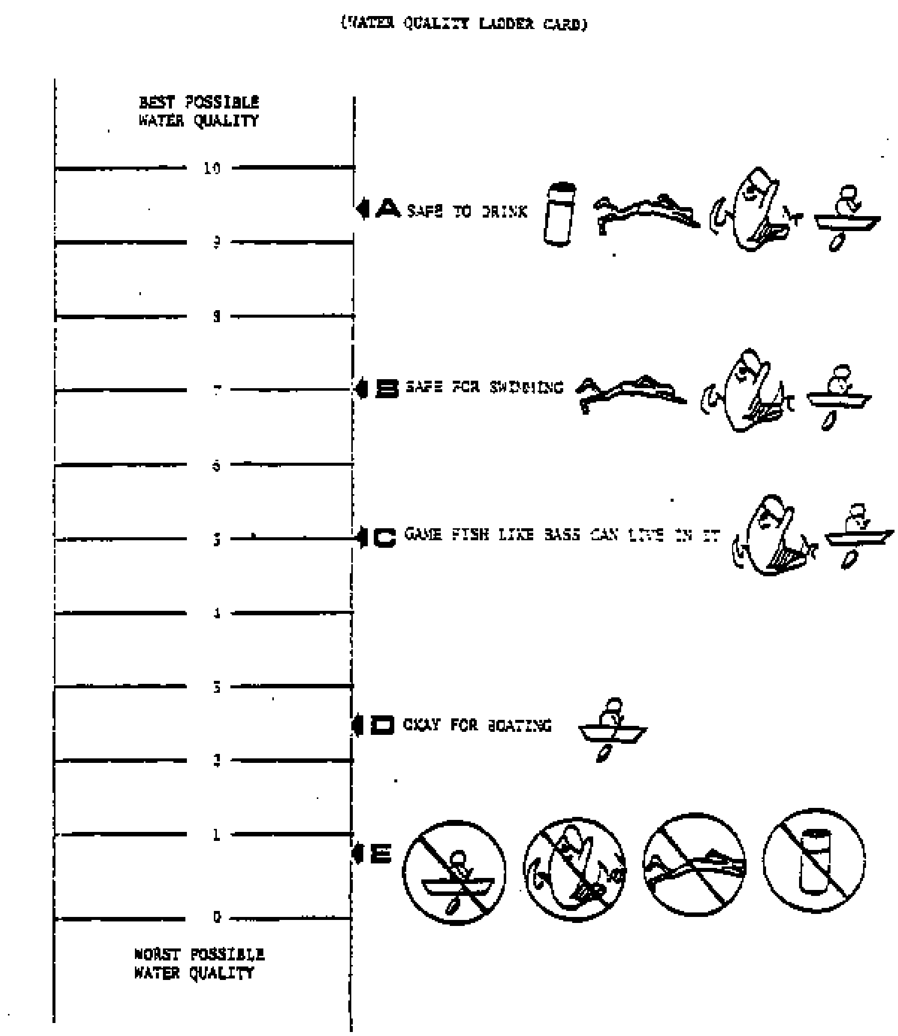
The relative size of the affected water body was calculated as the size of the affected water body in kilometers and including both shorelines relative to the size of the sampled area in square kilometers. This was measured using the National Hydrography Dataset. Again, the sample area differed depending on whether the equation was estimating a WTP per household for the whole river or for only the LA section.

---

[2] In all calculations, the only state considered is Maine. While the river originates in New Hampshire and sees some effect from industry in the state, the majority of the river containments are felt in Maine. Other calculations made using the geospatial layers included the proportion of agriculture land in the counties intersecting the river.

Measures of water quality: Johnston et al. include two measures of water quality in the multi-regression model: one representing the base water quality and one representing the improvement (in review). These are both measured using the Water Quality Index (WQI), which is a 100-point index (Johnston et al., in review). Many of the original studies included either a value for the water quality that used the WQI or a more granular version known as the Water Quality Ladder (WQL). For those studies that included neither, the authors used descriptive information to estimate the baseline and the improvement (Johnston et al., in review).

The WQL is a ten point scale that categorizing water quality along a range from unsuitable for boating, game fishing, swimming, or drinking to suitable for all those activities (National Center for Environmental Economics). The ladder is most useful in survey situations because it allows for respondents to quickly grasp existing water quality and the magnitude of change (National Center for Environmental Economics). The ten point scale can then be converted to the 100-point WQI index by multiplying the ladder score by ten (Johnston et al., in review).



Water Quality Ladder (National Center for Environmental Economics)

The WQL provides a very basic understanding of water quality, however, and does not always accurately reflect the ways water is currently used by a population versus how it should or could be used. For example, in the Maine water classification system, one of the lower quality classes includes the descriptive standard of usable for water treatment plants, even when swimming or fishing are not recommended activities (Maine Revised Statutes, Title 38, Chapter 3, Subchapter 1, Article 4-A) . The WQI, in contrast, is based on direct measures of water quality and allows for a more refined estimation.[3] This paper uses the WQI variables and weights used by the EPA (Table 1). The estimation, however, may not reflect the public perception or actual uses of the water body depending on the type of pollution present.

Factor	Biological Oxygen Demand	Dissolved Oxygen	Fecal Coliform/E.coli	Total Suspended Solids	Nitrogen	Phosphorous
Weight	.15	.18	.23	.10	.14	.14

Table 1. Weights assigned to the variables used in the EPA's WQI calculation (Walsh and Wheeler, 2012)

In order to provide as an accurate an estimation as possible, this paper runs two specifications based on the differing water quality measures: 1) the first utilizes the WQL with estimations of water quality levels based on state records, public accounts, and state water quality measurements; and 2) the second calculates WQI values for the baseline based on state data from 1960 and more recent data collected by the state in 2010.[4]

	Whole River WQ Estimate Using WQI[5]	Whole River WQ Estimate Using WQL
1960	58.23	50.00
2010	79.51	70.00
Future	80.00[6]	80.00

Table 2. Water Quality Values Estimated for the Entire Androscoggin

	Lewiston/Auburn WQ Estimate Using WQI	Lewiston/Auburn WQ Estimate Using WQL
1960	58.08	30.00
2010	78.77	70.00
Future	80.00	80.00

Table 3. Water Quality Values Estimated for the LA Stretch

Results

Multiple scenarios were developed to test the three models created by Johnston et al., and each was run twice—once using the WQL to estimate the water quality variables and once using the WQI as the estimator. The WTP per household results of these scenarios are included here: 1) the minimum, maximum, and mean WTP for historic water quality change estimated for all models run on the LA stretch of the river and the whole river (Table 4), and 2) the minimum, maximum, and mean WTP for future water quality change estimated for all models run on the LA stretch of the river and the whole river (Table 5). There model estimations were run: 1) Unrestricted 1, which includes the relative size of the market area and the substitute availability;

[3] The WQI is a weighted calculation that uses temperature change, pH, dissolved oxygen, turbidity, fecal coliform or E.coli, biochemical oxygen, total phosphates, nitrates, and total suspended solids. Not all of these pieces of data have been measured and recorded by the state so the estimation of WQI could be further refined in future research. As a result of the limitations, this paper relies on the weighting formula developed by the U.S. Environmental Protection Agency in 2003 (Walsh and Wheeler, 2012).

[4] WQL estimates err on the side of usability in order to provide a conservative estimate of willingness-to-pay.

[5] Full water quality data for the EPA's WQI variables was not available for any of the years so the most complete years were selected.

[6] Future water quality for all models is set at 80.00 on the WQI, or 10 points above the minimum standard for swimming as described by the WQL.

2) Unrestricted 2, which includes the relative size of the affected stretches of the river and the substitute availability; and 3) Restricted, which includes none of the three geospatial variables. Only the results of the two unrestricted models are discussed in Tables 4 and 5.

Willingness-to-Pay: As anticipated, the benefit transfer WTP per household results varied depending on the size of the market area (as measured by the geospatial buffer), which geospatial variables were included, the baseline water quality, and the amount of change in water quality that occurred. The range in WTP values for the LA section is similar in both the historic and future improvement estimations but the same is not true for the variance in the estimations of WTP for the whole river. For the whole river estimations, there is a much greater range when estimating the WTP for future change than there is when estimating the WTP for historic water quality improvements. This is likely the result of differences in amount of water quality improvement predicted by the WQL method and the WQI method. The WQI indicates a relatively high level of water quality in 2010 for both the entire river length and the LA section, but this quality level is not reflected with the WQL assessment of the LA river section.

Historic	**Lewiston/Auburn Section**	**Whole River**
Minimum	$46.69	$73.69
Maximum	$78.75	$93.00
Mean	$62.75	$86.70

Table 4. WTP per household for Historic Improvement in Water Quality[7]

Future	**Lewiston/Auburn Section**	**Whole River**
Minimum	$19.87	$24.20
Maximum	$50.46	$80.62
Mean	$34.31	$48.64

Table 5. WTP per household for Future Improvement in Water Quality

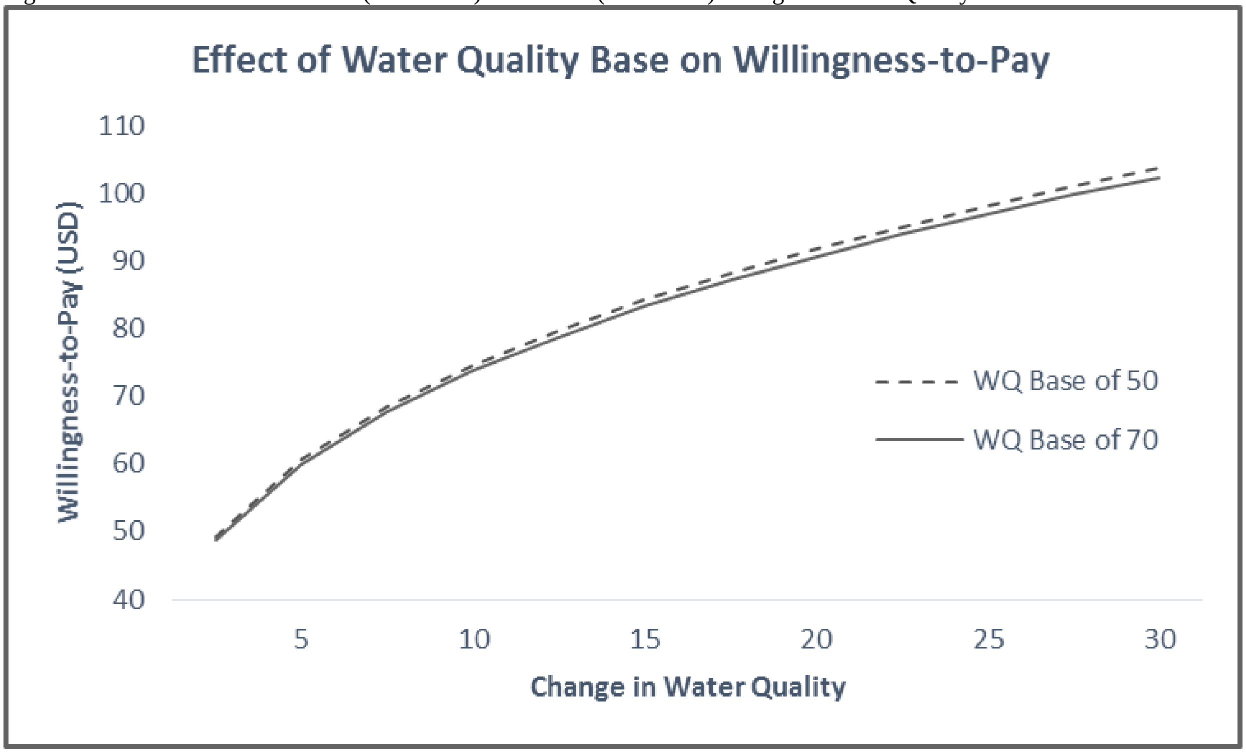
As the buffer increased, the WTP per household values decreased, which is unsurprising given the economic understanding of distance decay. The final effect of the combination of the water quality variables was not consistent throughout the models, as the baseline value is negatively correlated with WTP while the amount of change is positively correlated. In the historic change that occurred in the LA sections, this meant that the WTP per household values estimated using the WQI were smaller than those estimated using the WQL. The reverse was true for the historic change that occurred throughout the entire river. This difference is the result of the historic water quality base of the entire river was very similar whether estimated by the WQL or the WQI, while the LA section historic base water quality was very different depending on which method was used to estimate the value.

In all scenarios the WTP for future improvements in water quality was less than the WTP for the historic change. The WTP per unit of water quality change for the historic improvement appears, however, to be less than the same value for the future improvement. This is because each of these estimations exists on their own curve created by their specified equations.

[7] Both Table 4 and Table 5 report the estimates from the models using geospatial variables (Unrestricted Model 1 and 2)

Together, these multiple specifications create a family of curves, which is the result of the differing base levels of water quality. The baseline for water quality is negatively correlated with the WTP estimate, and as the baseline quality of the Androscoggin improves, the WTP per household for the same amount of change is lower than it would have been if the change had occurred with a more degraded level of water quality.

Fig. 2. The WTP Curves for Historic (Base of 50) and Future (Base of 70) Changes in Water Quality



As can be seen in Fig. 2, both the historic and future WTP curves increase at a decreasing rate, but the historic curve, with its lower base, provides higher relative estimations of WTP per household than the curve for future improvements in water quality.

Implications

Nonmarket Valuation Methodology: In the models run by Johnston et al., the authors found that, when compared to the unrestricted models, the omission of the geospatial variables had a statistically significant effect on the restricted model ($p<0.0001$) (in review). Johnston et al., also found that the exclusion of the geospatial variables underestimated WTP per household by as much as 181% and overestimated WTP per household by as much as 52% (in review). The impact of the geospatial variables on the WTP per household estimates can also be seen in the benefit transfer done in this paper.

For the scenarios developed around the LA stretch of water, the exclusion of geospatial variables underestimates WTP per household by as a much as 7% and overestimates it by as much as 26%. For the scenarios developed for the change in the entire river, the exclusion of geospatial variables underestimates WTP per household by as much as 48% and overestimates it by as much as 1%.[8] The effect on underestimations of WTP is amplified as the length of the affected river makes up a larger proportion of the market area or as the market area makes up a larger proportion of the intersecting counties. This relationship is reversed for the effect on overestimations.

The addition of the geospatial variables significantly changed the WTP per household estimations in the majority of the scenarios run for this paper. The geospatial variables explain a part of the WTP per household for water quality improvements that are otherwise not included in the estimation. While this effect depends somewhat on the relative size of the geospatial variable to its contextual geographic space, the inclusion of these variables enhances the validity of the final WTP per household estimation. This corresponds with Johnston et al.'s findings and offers a clear lesson for future benefit transfers on the importance of geospatial scale in estimating WTP per household. This paper demonstrates that this is especially true as the relative size of the water body and the market area increase.

Androscoggin River Policy: The complete set of results from the various scenarios is included in the index, but results from two of the models in particular can help inform policy decision-making regarding the Androscoggin River. The LA model with a 10 mile buffers estimates WTP per household for the water quality improvement of the section of the Androscoggin that runs from just above Gulf Island Pond, the primary area of nonattainment along the Androscoggin, down to Lisbon Falls. The buffer also represents the market area for the model, measuring the geographic area for where the change in water quality is relevant and providing the household income information for the model.

This stretch of river is under a TMDL for nonattainment of dissolved oxygen and phosphorous levels, among other variables, and the paper mills, primary dam, and major upstream municipalities must all meet additional Clean Water Act load level standards. Using the 10 mile buffers allows for the inclusion of the entire cities of Lewiston and Auburn, as well as smaller nearby towns, in the market area calculation.

LA 10 mile	Historic WQ Change of 20.69 points (WQI)	Historic WQ Change of 40 points (WQL)	Future WQ Change of 1.23 points (WQI)	Future WQ Change of 20 points (WQL)
Unrestricted 1 (ln_ar_ratio)	$56.02 (-1%)	$69.87 (-2%)	$23.85 (-15%)	$44.78 (-4%)
Unrestricted 2 (ln_rel_size)	$57.17 (1%)	$71.02 (0%)	$24.50 (-13%)	$45.79 (-2%)
Restricted	$56.64	$71.21	$28.14	$46.73

Table 6. WTP per household for Water Quality Improvements for LA river segment with 10-mile buffer (percent difference from the restricted model in parentheses)

[8] The difference in the effect of the geospatial variables on the WTP estimate between this analysis and Johnston et al.'s is likely the result of the policy site's geospatial variables being closer to the mean values in the original study, while Johnston et al.'s effect is estimated on the minimum and maximum extremes for these variables.

In this scenario, it becomes clear that while there is WTP per household for the historic and future improvements, excluding the geospatial variables from the analysis generally results in an overestimation of the value of the improvement.[9] This is especially relevant for the future improvement estimations. While historically the whole river has seen a dramatic improvement in water quality, a primary focus of current efforts is on this shorter stretch. WQI is more reliable in this scenario because of the relatively complete water quality data collected in 2010, and indicates that there is a very small amount of water quality improvement needed to place the stretch of river firmly in to the swimmable category. In this future scenario measured by WQI there is also the greatest likelihood of overestimation if geospatial variables are not included. This WTP per household is reduced further if the market area is increased to include more households, although an aggregate value of the WTP may increase overall.

The second model that is informative for understanding the policy context of the water quality improvements in the Androscoggin River is one that looks at the average overall change in water quality for the whole river using a 10-mile buffer.

River 10 mile	Historic WQ Change of 21.28 points (WQI)	Historic WQ Change of 20 points (WQL)	Future WQ Change of .49 points (WQI)	Future WQ Change of 10 points (WQL)
Unrestricted 1 (ln_ar_ratio)	$93.00 (36%)	$91.79 (33%)	$29.75 (9%)	$73.71 (31%)
Unrestricted 2 (ln_rel_size)	$88.85 (29%)	$87.65 (27%)	$28.67 (5%)	$70.57 (25%)
Restricted	$68.61	$68.77	$27.20	$56.25

Table 7. WTP per household for Water Quality Improvements for LA river segment with 10-mile buffer (percent difference from the restricted model in parentheses)

Given that the historic change occurred throughout the river, this model provides insight into how to value the improvement that occurred from 1960 to 2010. The WTP per household is now significantly undervalued if the geospatial variables are absent. The Androscoggin River is a large resource in the region, and a 10-mile buffer represents a community relatively close to the river with the associated higher WTP for this geographic proximity. Both the relative size of the market area and the river mean that this undervaluation is unsurprising.

The WTP per household for this greater change is also significantly larger than the previously estimated WTP for future improvement in the LA stretch of the river. Using the minimum values calculated with geospatial variables, there is a WTP per household of $87.65 for the historic 20 point improvement throughout the entire Androscoggin and a $23.85 WTP per household for the 1.23 point water quality improvement that might be desired in the LA region.

As previously discussed, the much larger WTP per unit of water quality improvement found for future change is the artifact of the different base water quality curves that are represented and the nature of those curves. The value of the changes in water quality increase at a decreasing rate, so

[9] The exception is the WTP in Unrestricted Model 2 in the historical change estimated using the WQI.

the historic change (the larger absolute amount of change) occurs as the curve is flattening, while the smaller, future change occurs as the curve is still increasing at an increasing rate. The policy implications, however, are still intriguing. The historic and future WTP values are estimations produced by two different equations, but there still seems to be a large amount of WTP for a relatively small amount of water quality improvement that could occur in the LA section of the Androscoggin River.

Conclusions

This paper and its development illustrate the challenges and advantages of a practical application of benefit transfer methodology to a specific, ongoing policy debate. Johnston et al.'s work created a strong foundation of data and econometrics that allowed for easy replication. Specifically, the sources of data used for most of the variables are publically available, relatively reliable, and regularly updated. This allowed for a seamless transfer of the methods used by Johnston et al.'s meta-analysis to the policy site of the Androscoggin River. Explicit, detailed information about the data sources and how they are used to calculate the variables is critical for the success of any application of a benefit transfer.

The transfer of a meta-regression model becomes more challenging when variables depend on a level of subject or qualitative evaluation. Within the model, both the sample area and water quality variables played a critical role in the final WTP per household estimation and required judgement calls by the researcher. This paper addresses that issue by developing numerous scenarios of different sample areas and using multiple tools to estimate water quality. With additional resources, expert elicitation could have provided valuable information to further develop these variables.

Despite these limitations, the results offer a clear indication of the importance of geospatial variables in benefit transfer. In almost all of the scenarios run for this paper, excluding the geospatial variables altered the estimation of WTP per household significantly. Going forward, more benefit transfers should include variables representing these geospatial factors of the relative size of the market area, the relative size of the affected water body, and substitute availability.

The results are also a first step at estimating a value for the water quality improvements that the Androscoggin River has seen and the improvements that might still occur. Again, expert elicitation on the appropriate size of the market area, as well as more precise measurement of water quality could further improve this valuation. Ultimately, the aggregate value of willingness-to-pay, calculated by multiplying the WTP per household value by the number of households in the market area for each specification, could be combined with additional values for the water quality improvement, including for health and drinking water benefits, and compared with the estimated costs of the clean-up—both in the past and the future.

References

Adler, R., Jessica C. Landman, and Diane M. Cameron. (1993). *The Clean Water Act 20 years later*. Washington, D.C.: Island Press.

Blomquist, R. F. (1997). To Stir Up Public Interest": Edmund S. Muskie and the U.S. Senate Special Subcommittee's Water Pollution Investigation and Legislative Activities, 196366-a Case Study in Early Congressional Environmental Policy Development. *Vol.22, no.1, 1 p.1997, 22*(1), 1-1.

Center for Workforce Research and Information. (2012). Manufacturing Jobs: Trends, Issues, and Outlook. Augusta, Maine: Maine Department of Labor.

Center for Workforce Research and Information. (2015a). Nonfarm Payroll Job Estimates. Retrieved April 24, 2015, from http://www.maine.gov/labor/cwri/ces.html#tables

Center for Workforce Research and Information. (2015b). Unemployment and Labor Force. Retrieved April 24, 2015, from http://www.maine.gov/labor/cwri/laus.html

Copeland, C. (2014). Clean Water Act: A Summary of the Law. Washington, DC: Congressional Research Service.

Environmental Protection Agency. (2015). Summary of the Clean Water Act. Retrieved April 24, 2015, from http://www2.epa.gov/laws-regulations/summary-clean-water-act

Johnston, R., Elena Y. Besedin, and Ryan Stapler. (in review). Enhanced Geospatial Validity for Meta-Analysis and Benefit Transfer: An Application to Water Quality Improvements. *George Perkins Marsh Institute and Department of Economics, Clark University*.

Jones, P. H. (1975). *Evolution of a Valley*. Canaan, New Hampshire: Phoenix Publishing.

National Center for Environmental Economics. Water Pollution Ladder and Value Levels. Retrieved April 24, 2015, from http://yosemite.epa.gov/ee/epa/eed.nsf/dcee735e22c76aef85257662005f4116/13735032f8deb12f85257662007490c3!OpenDocument

Newman, M. C. (1993). Regression analysis of log-transformed data: Statistical bias and its correction. *Environmental Toxicology and Chemistry, 12*(6), 1129-1133. doi: 10.1002/etc.5620120618

Steinhacker, C. (1973). International Paper Company's Chisholm Mill at Livermore Falls on the Androscoggin River Washington, DC: National Archives.

Walsh, P. a. W. W. (2012). Water Quality Index Aggregation and Cost Benefit Analysis. Washington, DC: National Center for Environmental Economics.

Water Classification Program, Title 38, Chapter 3, Subchapter 1, Article 4-A) Stat. (2005).

Watts, D. (2003-2005). Androscoggin Watershed.

Appendix A. Independent Variables and Statistics

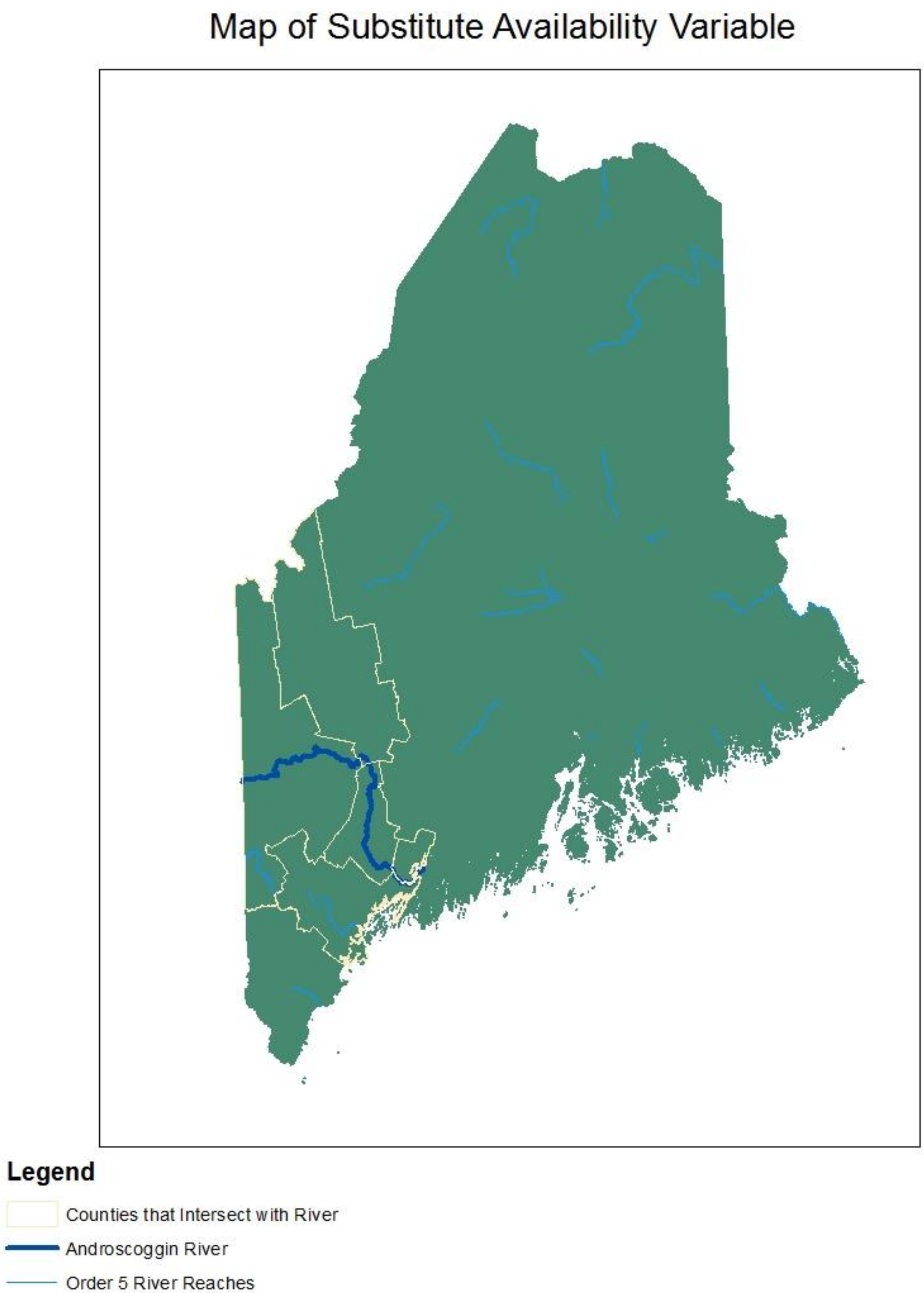
Variable Name	**Description**	**Mean**	**Std. Dev.**	**Policy Site Value**
ce	binary variable with a value of one for studies that are choice experiments (default is any non-choice experiment method)	0.11	0.31	0.11
thesis	binary variable with a value of one for studies developed as thesis projects or dissertations (default is studies not developed as theses)	0.11	0.32	0.11
lnyear	natural log of the year in which the study was conducted (converted to an index by subtracting 1980, before making the log transformation)	2.21	0.93	3.56
volunt	binary variable indicating that WTP was estimated using a payment vehicle described as voluntary (default is a binding and mandatory payment vehicle)	0.09	0.28	0.09
outlier_bids	binary variable indicating that outlier bids were excluded when estimating WTP (default is studies using parametric methods)	0.19	0.40	0.19
nonparam	binary variable indicating that WTP was estimated using non-parametric methods (default is studies using parametric methods)	0.43	0.50	0.43
non_reviewed	binary variable indicating that the study was not published in a peer-reviewed journal (default is studies published in peer reviewed journals)	0.24	0.43	0.24
lump_sum	binary variable indicating that payments were to occur on something other than an annual basis over an extended or indefinite period of time (default is payments on an annual basis over more than 5 years)	0.19	0.39	0.00
wtp_median	binary variable indicating that the study's WTP measure is the median (default is mean WTP)	0.07	0.26	0.07
northeast	binary variable indicating that the survey included respondents from the USDA Northeast region (default is respondents from the Mid-Atlantic, West, or multiple regions)	0.07	0.26	1.00
central	binary variable indicating that the survey included respondents from the USDA Midwest or Mountain Plains regions (default is respondents from the Mid-Atlantic, West, or multiple regions)	0.36	0.48	0.00

south	binary variable indicating that the survey included respondents from the USDA Southeast or Southwest regions (default is respondents from the Mid-Atlantic, West, or multiple regions)	0.16	0.37	0.00
nonusers	binary variable indicating that the survey was implemented over a population of nonusers (default is a survey of any population that includes users)	0.09	0.28	0.00
lnincome	natural log of median income (in 2007$) for the sample area of each study based on historical U.S. Census data	10.75	0.17	varied
multi_bod	binary variable that takes on a value of 1 if the studied system includes multiple water body types and zero otherwise	0.08	0.27	0.00
river	binary variable that takes on a value of 1 if the studied system includes rivers and zero otherwise	0.69	0.47	1.00
swim_use	binary variable identifying studies in which changes in swimming uses are specifically noted in the survey	0.26	0.44	0.26
gamefish	binary variable identifying studies in which changes in game fishing uses are specifically noted in the survey (default is surveys that do not describe effects on game fishing)	0.06	0.23	0.06
boat_use	binary variable identifying studies in which changes in boating uses are specifically noted in the survey (default is surveys that do not describe effects on boating)	0.11	0.32	0.11
ln_ar_agr	natural log of the proportion of the affected resource area which is agricultural based on NLCD (coded as planted/cultivated). Affected resource area includes all counties that intersect the affected resource	-1.43	0.90	varied
ln_ar_ratio	natural log of the size of the sampled area (in square kilometers) divided by the total area of all counties that intersect the affected water resource	-1.13	2.61	varied
ln_rel_size	index of the size of the affected water body (defined by total shoreline length in kilometers) relative to the size of the sampled area in square kilometers (sa_area). For a river, shoreline (assuming a left and right shoreline) is = river_length*2 and ln_rel_size = log(shoreline / sa_area)	-1.20	3.42	varied

sub_frac	proportion of water bodies of the same hydrological type affected by the water quality change, within affected state. For rivers, this is measured as the length of the affected river reaches as a proportion of all reaches of the same order	0.19	0.29	varied
lnquality_ch	natural log of the change in mean water quality valued by the study, specified on the 100-point water quality index (McClelland 1974; Mitchell and Carson 1989)	2.91	0.69	varied
lnbase	natural log of the baseline water quality from which improvements would occur, specified on the 100-point water quality index	3.59	0.67	varied
intercept	constant			1.00
error u	0			0.00
error e	0.541			0.00

Adapted from Johnston et al. (in review)

Appendix B. Example of Map for Geospatial Variables (full dataset available upon request)



Appendix C. Water Quality Values

Year	WQI from Partial Data for Entire River	WQL Estimated for Entire River
1956	56.52	
1957	55.73	
1958	57.95	
1959	58.98	
1960	58.23	50.00
1961	58.33	
-		
1965	63.80	
1976	70.94	
2003	76.99	
2010	79.51	70.00
Future?		80

Year	WQI from Partial Data for LA Stretches	WQL Estimated for LA Stretches
1956	55.04	
1957	55.66	
1958	56.22	
1959	58.58	
1960	58.08	30.00
1961	58.30	
-		
1965	-	
1976	68.83	
2003	-	
2010	78.77	70.00
Future?		80

Appendix D. Complete set of results

LA 5 mile	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$78.75	6%	$63.14	7%	$50.46	4%	$26.87	-8%
Unrestricted 2 (ln_rel_size)	$78.15	6%	$62.91	7%	$50.39	4%	$26.96	-8%
Restricted	$73.99		$58.85		$48.56		$29.24	
LA 10 mile	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$69.87	-2%	$56.02	-1%	$44.78	-4%	$23.85	-15%
Unrestricted 2 (ln_rel_size)	$71.02	0%	$57.17	1%	$45.79	-2%	$24.50	-13%
Restricted	$71.21		$56.64		$46.73		$28.14	
LA 30 mile	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$58.24	-15%	$46.69	-14%	$37.32	-17%	$19.87	-26%
Unrestricted 2 (ln_rel_size)	$61.55	-10%	$49.55	-9%	$39.69	-11%	$21.23	-21%
Restricted	$68.13		$54.19		$44.71		$26.93	

River 5 mile	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$100.40	45%	$101.72	48%	$80.62	43%	$32.54	19%
Unrestricted 2 (ln_rel_size)	$93.73	36%	$95.01	38%	$75.47	34%	$30.66	12%
Restricted	$69.05		$68.90		$56.48		$27.31	
River 10 mile	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$91.79	33%	$93.00	36%	$73.71	31%	$29.75	9%
Unrestricted 2 (ln_rel_size)	$87.65	27%	$88.85	29%	$70.57	25%	$28.67	5%
Restricted	$68.77		$68.61		$56.25		$27.20	
River 20 mile	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$84.75	25%	$85.87	27%	$68.06	23%	$27.47	3%
Unrestricted 2 (ln_rel_size)	$82.39	22%	$83.52	24%	$66.34	20%	$26.95	1%
Restricted	$67.75		$67.60		$55.42		$26.79	

River 30 mile	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$74.60	21%	$75.58	23%	$59.90	18%	$24.17	-1%
Unrestricted 2 (ln_rel_size)	$73.69	19%	$74.69	21%	$59.33	17%	$24.10	-1%
Restricted	$61.83		$61.69		$50.57		$24.45	
Small Section in 10 mi River context	Historic with WQL	% diff	Historic with WQI	% diff	Future with WQL	% diff	Future with WQI	% diff
Unrestricted 1 (ln_ar_ratio)	$56.18	-12%	$45.05	-11%	$36.00	-14%	$19.17	-24%
Unrestricted 2 (ln_rel_size)	$58.88	-7%	$47.39	-6%	$37.96	-9%	$20.31	-19%
Restricted	$63.57		$50.56		$41.72		$25.12	