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Article

The Value of Forest Conservation for Water Quality Protection

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Abstract: Forests protect water quality by reducing soil erosion, sedimentation, and pollution; yet there is little information about the economic value of conserving forests for water quality protection in much of the United States. To assess this value, we conducted a meta-analysis of willingness-to-pay (WTP) for protecting unimpaired waters, and econometrically determined several significant drivers of WTP: type of conservation instrument (tool), aquatic resource type, geographic context, spatial scale, time, and household income. Using a benefit transfer to two highly forested sites, we illustrate the importance of these factors on WTP for water quality protection programs, forest conservation and policy design.

Keywords: benefit transfer; conservation easement; ecosystem services and goods; forest conservation policies; water quality; willingness-to-pay

1. Introduction

Water quality remains a serious public policy challenge in the United States (US). In 2012, 54% of rivers and streams and 69% of lakes, reservoirs, and ponds assessed in the US were identified as having threatened or impaired water quality [1]. Anthropogenic non-point source nutrient pollution, for example from intensively managed land uses and urban development, is a leading cause of water impairment in the US [2]. These increasing land use changes and loss of forests and other ecosystems are expected to lead to further impairment of water quality without significant policy intervention [3,4].

Forested watersheds provide 80 percent of US freshwater resources [5]. Conserving forests (e.g., public land acquisition, conservation easements, and landowner incentives or assistance programs) and improving forest management practices can protect water quality by reducing sedimentation and nutrient pollution input to water bodies [6,7]. Replacing these forest ecosystem services with engineered infrastructure can be extremely expensive. For example, the US Environmental Protection Agency (EPA) estimated that during 2000–2019, it would cost as much as an additional $271 billion and $263 billion to meet Clean Water and Drinking Water standards, respectively [8]. Conserving forests can therefore be considered a relatively cost-effective approach to help meet these standards by protecting water quality, thus reducing water treatment costs [9,10]. A study of 27 US drinking water utilities found that a 10% increase in forest land area in water recharge zones reduced chemical and treatment costs by 20% on average [10].

There are a number of popular forest conservation policy mechanisms, including regulations, incentive payments, extension education, public land ownership, and easements [3]. Recent studies have assessed forest landowners' willingness to participate in such programs [11,12] however relatively little is known about public preferences for these alternative policies.

Conserving forests from conversion to more intensive land uses has been linked to improved water quality [13,14]. Here, we employ data on public support for water quality protection to infer the value of forests for water quality protection, and assess the role of several factors thought to influence this support. Studies assessing public support for specific policies typically estimate the public's willingness-to-pay (WTP) for these directly [13], or for the underlying ecosystem goods and services they provide [14]. We present the results of a meta-analysis of WTP studies that focus on water quality protection and program design with an emphasis on the benefits of forest conservation. Econometric model results indicate that a number of factors significantly influence WTP for water quality protection programs: geographical region (e.g., Southern US), program scale (e.g., watershed-wide), water body type (e.g., river), and conservation tool (e.g., easement). Results of the meta-analysis are applied to two example highly forested policy sites using a benefit transfer (BT) approach to illustrate the influence of these variables on water quality policy support. The results inform our understanding of the economic value of water quality protection and the important role that policy context plays in public support for forest conservation programs.

2. Conceptual Approach

2.1. Benefits of Forest Conservation

Forest ecosystems play significant water provisioning and regulating roles by filtering, retaining and storing water. The filtering function—retention and removal of excess nutrients—is mainly performed by the vegetation cover and soil biota [6]. As a result, forests can buffer aquatic ecosystems from nutrient export effects, such as nitrogen [15] and phosphorous [16], that impair water quality, such as: (1) increased eutrophication of water bodies that leads to algal blooms and fish kills; (2) low water visibility and excessive bacterial growth that threatens water users, and creates invasive species problems [17,18]; and (3) reduced recreational and aesthetic values [19]. Conserving forest land generally reduces alteration of aquatic ecosystems [20]. However, the impact of forest cover on water quality depends heavily on forest land use practices. Anthropogenic influences and management practices on forest lands, such as roads, logging, land clearing, urbanization, and even recreation, are also known to alter ecosystem structure and function and lead to increased nutrient loading and other water pollution problems [2,21], In general, the function and structure of a particular ecosystem will affect the attributes of its water yield and quality, thus, all land uses provide hydrologic services, although to differing degrees. For example, lands that are managed for multiple uses to maintain some amount of forest cover provide greater water resource protection services compared to lands under intensive agriculture and urban development. In this study, we broadly characterize the term "forests" as natural areas, riparian areas or mixed-use lands that have forest cover.

The ecosystem services and goods provided by forests and water bodies include benefits in the form of direct use (e.g., irrigation, timber, and recreation), indirect use (e.g., flood protection and nutrient cycling), and nonuse values (e.g., aesthetics, endangered species protection) [22,23]. The presence of indirect and non-use values requires the use of nonmarket valuation techniques, such as contingent valuation, to assess the importance of the impacts on these systems [24].

2.2. Valuing Water Quality

Maintaining the function and structure of forests through conservation programs and policies can be an important water quality protection tool [25–28]. Indeed, the relatively low cost of *ex ante* forest conservation *versus ex post* water quality treatment has made forest conservation popular with policy makers [3]. Despite this, there are relatively few studies that adequately describe the forest conservation—water quality link in a valuation context. In the body of valuation literature addressing water quality issues, many studies focus on WTP to *improve* water quality in already polluted aquatic systems, for example [13,29–34]. Such studies would be appropriate for assessing afforestation efforts (*i.e.*, WTP to improve water quality through increased forest cover), but they are not compatible for assessing conservation efforts (e.g., WTP to prevent reductions in forest cover). By comparison there are relatively few studies that assess the value of protecting unimpaired waters [25,35–41] and even fewer valuation studies that focus on the role of forest conservation in protecting unimpaired waters [36,39–41].

When valuing forest conservation efforts, some economic studies focus exclusively on the water quality protection benefits [27,28,39,41] while other studies present water quality protection as part of a bundle of co-benefits along with conservation of green spaces, recreation opportunities, wildlife habitat preservation, and environmental education [25,37,38,40,42]. Other economic valuation studies that measure WTP to protect water quality propose the use of nonspecific "environmental programs" and do not disclose if the program intends to use specific forest conservation tools [27,32,35,43–47]. These studies focus on valuing the benefits or outcomes of resource protection and WTP to protect water quality independent of detailed information regarding the policy process or make vague references to policy implementation techniques [27,44,47–49]. In a few cases the primary purpose of a valuation study is not to directly provide policy makers with information on measures of discrete welfare outcomes to different management alternatives, but to empirically test different stated preference methods or the effect of biophysical factors on WTP [50,51].

Valuation studies that omit information about the proposed program and potential co-benefits may limit the respondent from making an informed WTP decision and can mask existing systematic preferences useful for developing effective water protection programs and policies [49]. Econometric analyses of disparate studies—meta-analysis—is a method that has been commonly used to address a set of related research hypotheses [52–57]. Here, we apply that approach to assess the role of available information on program type, along with a number of other factors, on WTP for water quality protection. The results are expected to elucidate the public's preferences for environmental policies, programs, and priorities for forest conservation and water quality protection.

2.3. Meta-Analysis and Benefit Transfer Methods

To assess WTP for unimpaired aquatic systems in Florida we conducted a meta-analysis of existing economic studies related to WTP for water quality programs. Using the results of the meta-analysis we conducted a BT of econometrically-estimated WTP values to two locations: one watershed in Florida and another in the state of Minnesota for comparison; two highly forested states with extensive areas of water bodies. Meta-analysis is a statistical method for analyzing results from existing studies with a set of related research hypotheses and has widespread use in several areas including health sciences, psychology, education, marketing and social sciences [58]. As such, it has been applied in economics as a way to synthesize numerous studies that placed economic values on environmental goods and service [57,59–61].

When using econometric techniques, the results of a meta-analysis can be used to predict estimates of value constructs (*i.e.*, influential factors, or drivers) across time and space while controlling for differences in study methods. Value estimates from a set of related studies serve as the dependent variable in a regression model and characteristics of the individual studies serve as the independent variables. We specify a conceptual meta-analysis model as:

$$y_i = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_k x_{ki} + \varepsilon_i \tag{1}$$

where y_i is the per-capita value estimate from study i, β_0 is an intercept term, $\beta_{j=1\ldots k}$ are estimated coefficients, and $x_{j=1\ldots k}$ specify study attributes, such as site characteristics and valuation approach, and ε_i specifies between study variation [58].

A common application of meta-analyses is in benefits transfer (BT)—calibrating and applying the benefit function or point estimate generated at one set of locations ("study sites") to another ("policy site") [53,62]. BT can be generally described in two ways: (1) by direct transfer of unit-value estimates; and (2) by the transfer of a benefit function [53,55]. Unit-value transfer is done by applying a single statistic (usually an average from one or more study sites) to the policy site and may or may not account for differences between the study sites and the policy site. An example of a benefit function transfer would be through the use of a meta-analysis of previous studies and quantitatively calculating a variable mean or coefficient based on relevant characteristics of the research methods and study site (e.g., biophysical and socioeconomic variables). Given the importance of socioeconomic variables and methodological approaches (e.g., type of stated preference method) on value estimation [42,63–65], the benefit function approach is preferred to the unit-value transfer approach.

The benefit estimates are then forecast based on the characteristics of the policy site. The general form of a benefits transfer function based on a meta-analysis is:

$$(\text{Value}) = \beta_0 + \Sigma(\beta_j)\,(L_{jl}) \quad (2)$$

where value is the estimated value of the policy site, β_0 is the estimated equation intercept, β_j is the estimated coefficient for variable *j* and Lj_l is the adjustment level assigned to variable *j* so it will match the characteristics of the policy site *l* [66].

In the field of forest resource and environmental valuation, meta-analyses and the BT approach have focused on a range of environmental issues, including the economic benefits of endangered species [42], outdoor recreation [57,64,65], wetland ecosystem services [56,63], forest product certification [54], non-timber forest benefits [60], and water quality improvements [48,67]. The focus of this study is the value of protecting unimpaired aquatic systems, where the policy action (e.g., forest conservation) would help dampen an increase in pollution due to factors like population growth [68] or increased mining activity [44,51]. Valuing unimpaired aquatic systems is important in establishing a baseline for understanding the potential economic benefits of preventing nutrient pollution as well as support for various kinds of forest-related water resource protection programs [22]. This study is novel; our search of the economics literature found no other meta-analysis for protection of unimpaired aquatic systems.

2.3.1. Meta-Analysis Variable Selection

In our meta-analysis, value estimates from a set of related studies serve as the dependent variable in a regression model, and characteristics of the individual studies serve as the independent variables. Site characteristics, study and methodology attributes, and socioeconomic variables are typically included in meta-analyses of economic values [63,69]. Site characteristics provide a description of the resource (e.g., lake) [48,56,63], the geographic scale of the protection program [48,63,67] and the study area [48,64,65].

Study and method attributes characterize such features as the year in which a study was conducted, elicitation format and survey response rates. Year is often negatively correlated with WTP, which is partially explained by improved methods [42,48,70]. Elicitation format has also been found to influence estimated values [42,63,71] and is often measured using contingent valuation (CV) which captures the elicited demand, or WTP, for an ecosystem service by posing a series of hypothetical alternatives to the respondent [22]. This stated preference method is intended to capture changes in total value, including direct use, indirect use, and nonuse values, whereas revealed preference methods, such as travel cost and hedonic pricing, capture only use values because they rely on observed behavior (e.g., existing market data) [23]. The survey study size is useful as a measure of heteroskedasticity among observations when variance or a standard error is not reported [58]. Experts [58] stress the importance of incorporating knowledge of variances or samples sizes in meta-analyses as a "best-practice guideline". The assumption is that surveys with a higher sample size and response rate are "strong" studies because they may have a lower variance or standard error and therefore provide better estimates of WTP [56]; however, several meta-analysis studies show mixed results for this use of response rates [42,48,63].

Socioeconomic characteristics of respondents such as sex, race, age, and income have been found to influence WTP [54,67]. Although these characteristics are not always available in CV studies, information can be gathered from ancillary, study relevant data sources and incorporated in the meta-analysis [28,48,67]. Income is commonly found to be positively correlated with WTP for water resources which are considered a normal or necessary good [72].

While the variables described above are commonly included in a meta-analysis of WTP studies, others are less frequently included such as variables that describe specific attributes about the proposed program or policy [49]. Including program design attributes in a meta-analysis is important because individuals may not hold similar preferences for the different program mechanisms proposed in each study, even if the programs produce similar benefits (e.g., similar levels of water quality). This might be important if a respondent holds strong views about how environmental resources should be managed (e.g., anthropocentric *versus* biocentric views) and who should manage them (e.g., trust in government, views on the appropriate role of government involvement, private property rights, *etc*.). Trust among stakeholders has been found to be an important feature in building resilience in social-ecological systems [73], and trust in government has been used to predict general attitudes towards forest use fees and WTP for US National Forest recreation passes, and was significantly associated with perceived risks, benefits and agency competency [74,75]. Similarly, biocentric and anthropocentric value orientations have been significant in explaining intended WTP for a wetlands restoration program [76] and biocentric orientation has been correlated with support for programs on public lands [77].

3. Data Collection and Analysis

From our literature review of WTP studies, we retained those that met the following criteria for our meta-analysis: (1) the subject of the study was an unimpaired freshwater resource (*i.e.*, already "fair" or "good" as defined by the levels of use support by the EPA [78]); (2) the study estimated annual household or individual WTP; (3) it was conducted in the US; and (4) it used a stated preference approach to capture economic value (e.g., contingent valuation). Applying these criteria to our search produced 43 observations from the academic and gray literature (see Table 1). Studies that produced multiple observations reported the results of multiple methodological approaches (*i.e.*, multiple elicitation methods and statistical analyses per study). Also, results reported as WTP per household were divided by 2.5, the average number of individuals per household in the US, to arrive at individual WTP [79]. Individual characteristics and information provided by each study were used to develop the independent variables used in our meta-analysis (see Table 2) and were selected based on parameters used in other similar analyses [42,48,80]. We found only five forest-related studies relevant to the topics of WTP, forests and water resource protection. To supplement these, we included studies where the process used to protect water resources (e.g., forest conservation) was not stated. We also included select studies that focused on comparable land uses (*i.e.*, riparian zones, green space, agriculture, and wetlands) that used similar implementation processes (e.g., land acquisition) and provided similar water quality protection benefits.

Table 1. Summary of studies estimating willingness-to-pay (WTP) for protection of unimpaired water bodies.

Study	Observations Per Study [a]	Conservation Tool	Water Body Type [b]	Scale	Valuation Methodology	US State	WTP Per-Capita Per-Year [c,d]
Aiken (1984) [35]	4	Not specified	River/stream	Statewide	Iterative bidding and open ended	Colorado	13.43–31.02
Blaine *et al.* (2003) [25]	1	Easement	All water resources	Watershed	Dichotomous choice	Ohio	11.06
Blaine and Smith (2006) [36]	2	Easement	River/stream	Watershed	Other	Ohio	7.59–13.18
Blaine and Lichtkoppler (2004) [37]	1	Easement	Wetland	Watershed	Dichotomous choice	Ohio	17.53
Carman *et al.* (1992) [38]	1	Acquisition	Wetland/estuary	Watershed	Open ended	Oregon	2.87
Cho *et al.* (2005) [39]	2	Easement	All water resources	Watershed	Dichotomous choice	North Carolina	4.95–9.85
Condon (2007) [41]	2	Acquisition and Easement	All water resources	Watershed	Attribute based choice experiment	Florida	17.07–20.37
Cooksey and Theodore (1995) [40]	1	Easement	All water resources	Watershed	Other	New Hampshire	18.60
Giraud *et al.* (2001) [43]	3	Not specified	River/stream	Watershed	Dichotomous choice	Colorado	237.77
Greenley *et al.* (1981) [44]	5	Not specified	River/stream	Watershed	Dichotomous choice	Colorado	8.38–59.34
Hanemann *et al.* (1991) [50]	2	Not specified	Wetland/estuary	Watershed	Dichotomous choice	California	82.32–139.32
Holmes *et al.* (2004) [27]	3	Not specified	River/stream	Single site	Dichotomous choice	North Carolina	12.74–25.12

Table 1. *Cont.*

Study	Observations Per Study [a]	Conservation Tool	Water Body Type [b]	Scale	Valuation Methodology	US State	WTP Per-Capita Per-Year [c,d]
Mannesto *et al.* (1991) [45]	2	Not specified	Wetland/estuary	Single site	Payment card	California	29.43–54.24
Petrolia (2011) [46]	2	Not specified	Wetland/estuary	Watershed	Dichotomous choice	Louisiana	221.11–266.48
Sanders *et al.* (1990) [32]	4	Not specified	River/stream	Watershed	Open ended	Colorado	14.15–32.08
Shrestha and Alavalapati (2004) [28]	2	Land owner incentives	Lake	Single site	Other	Florida	14.84–34.92
Sutherland and Walsh (1985) [51]	4	Not specified	River/stream	Watershed	Open ended	Montana	6.05–21.64
Whitehead (1990) [47]	2	Not specified	Wetland/estuary	Single site	Other	Kentucky	4.05–8.78

[a] Multiple WTP estimates from a single study were available due to in-study variation in such factors as elicitation methods and statistical analysis; [b] Water body type can include: river/stream, lakes, wetlands/estuaries or all water resources combined; [c] All values were adjusted for inflation to the 2010 US dollar value according to the Consumer Price Index; [d] Studies with household WTP values were divided by 2.5 to calculate annual individual WTP based on the average number of individuals per US household [79].

Table 2. Meta-analysis model variables and descriptions.

Variable Category	Level	Description	Mean (SE)
Willingness to pay (dependent)	Ln_WTP	Natural log of per-capita willingness-to-pay to maintain or protect water resources, in 2010 US Dollars.	3.01 (0.710)
Survey method	CV_OE	1 if WTP was estimated using an open ended survey instrument; 0 otherwise (e.g., payment card, iterative bidding, dichotomous choice, or attribute based choice experiment).	0.166 (0.241)
Year	YR_INDX	Index of year the study was conducted (1970 baseline).	24.67 (6.080)
Weighting	RR_COFF	Weighting variable, calculated as response rate divided by sample size.	0.186 (0.174)
Median household income	INCOME	Median household income of respondents as reported by the original study or calculated from US Census data (2010 dollars).	50,605 (5,074)
Region	SOUTH	1 if study was conducted in the southern region of the US (Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana and Florida); 0 otherwise.	0.333 (0.304)
Resource	RIVER	1 if protected resource is a river; 0 otherwise.	0.388 (0.315)
Scale	WT_SHD	1 if resource protection is within a watershed; 0 otherwise.	0.722 (0.289)
Scale	SGL_SITE	1 if resource protection at a single site; 0 otherwise.	0.221 (0.268)
Program	PRG_AE	1 if the proposed water quality protection program uses acquisition or easement type strategies implemented by a government agency; 0 otherwise.	0.389 (0.315)

3.1. Study Characteristics

The most commonly reported study characteristics included type of survey methodology, year, and response rate. Stated preference survey methodologies included open ended CV, payment card, dichotomous choice, iterative bidding, and attribute choice experiment; and most of the studies used mail surveys (Table 1). The implementation dates for the studies ranged from 1976 to 2010. Sample sizes and response rates were also reported in every study, and ranged from 90 to 3000 respondents, with response rates from 19% to 100%. Recall that sample size is a useful proxy for study quality since many WTP studies fail to report standard error or standard deviation [58].

3.2. Site Characteristics

Site characteristics described in each study included geographical location, type of freshwater resource, and the spatial scale of the water protection program. Most of the studies were conducted in the Western US, but six were conducted in southeastern states and four in northeastern and midwestern states. Types of resources valued in each study were coded as stream or river, lake, wetland, and all surface water resources combined. Seven of the studies focused on valuing streams and rivers, six valued wetlands and four valued all water resources combined; only one study elicited values associated only with lakes. The spatial scale of the proposed water protection program ranged widely. Four of the proposed programs focused on a single site, such as a single lake or wetland, one proposed a statewide program and the remaining studies proposed programs with a spatial scale somewhere in-between such as a region within the state or a watershed (Table 1).

3.3. Socio-Economic Characteristics

Nine of the studies used in this analysis reported socio-economic data about the respondents. Of these studies two included information about the respondent's ethnicity, gender, or age, but the remaining studies only reported median annual household income (Table 1). To estimate income not reported in the remaining studies, we used annual household income values at the county level from the US Census Bureau [79]. Income values for all studies were standardized to 2010 US Dollars. Unfortunately, accurate information about other relevant social demographics was not available from sources outside of the original study, which limited the scope of our analysis.

3.4. Program/Policy Attributes

Of the 18 studies in our meta-analysis, seven proposed land acquisition or easement programs, one proposed a cost-share program for land owners, and 10 proposed the use of non-specific "environmental programs" where respondents were not informed how water quality protection objectives would be achieved (Table 1). Those that revealed the underlying water quality protection process to the respondent stated that its goal was to preserve the ecosystem structure and function of forested lands, mixed land use areas, green space, riparian areas, and other important lands to protect in-stream water quality.

3.5. Econometric Model and Analysis

Using a meta-analysis approach, we determine several statistically significant drivers of WTP, and we explore how the processes and outcomes of a water quality protection program affect an individual's welfare and WTP. We specify an empirical model of WTP:

$$\begin{aligned}\text{lnWTP} = \beta_0 + \beta_1\,\text{CV\_OE} + \beta_2\,\text{YR\_INDX} + \beta_3\,\text{RR\_COFF} + \beta_4\,\text{INCOME} + \beta_5\,\text{SOUTH} \\ + \beta_6\,\text{RIVER} + \beta_7\,\text{WT\_SHD} + \beta_8\,\text{SGL\_SITE} + \beta_9\,\text{PRG\_AE} + \varepsilon\end{aligned} \quad (3)$$

where lnWTP is the natural log of an individual's annual WTP ([48,61] or the effect size; β_0 is intercept or the estimated overall effect size; $\beta_{1\ldots9}$ are coefficients for the study and methodology attributes (*i.e.*, survey methodology, year index, response weighting), socio-economic characteristics (*i.e.*, annual household income) and site characteristics (*i.e.*, region, resource, scale, program) of each study, and ε is an error term (see Table 2). The response weighting variable is a proxy for study quality, and is the ratio of response rate to sample size for each study [58].

Our empirical model was parameterized using a stepwise hierarchical approach with NCSS Statistical System's multiple regression function (Software version 07.1.12), and different variable levels within each variable category were systematically compared against a corresponding reference level to calculate a regression coefficient (see Tables 2 and 3). We tested for normality using Shapiro-Wilk's test ($p < 0.10$) and multicollinearity using eigenvalues.

Table 3. Regression Model Results for Individual lnWTP.

Variable Category	Level [a]	Coefficient (SE)
Intercept	Intercept	−0.883 (0.886)
Survey Method	CV_OE	−0.591 ** (0.220)
Year	YR_INDX	0.091 *** (0.012)
Weighting	RR_COFF	0.897 ** (0.388)
Median household income	INCOME	0.058 *** (0.000)
Region	SOUTH	−0.414 * (0.259)
Resource	RIVER	−1.072 *** (0.209)
Scale	WT_SHD	0.821 ** (0.340)
Scale	SGL_SITE	−1.294 *** (0.415)
Program	PRG_AE	−2.990 *** (0.209)
Sample size		43
R^2 adjusted		0.8847
Standard error		0.246
F-statistic (degrees of freedom)		28.136 * (9)

[a] Levels within each variable category were systematically compared against a corresponding reference variable to calculate a regression coefficient; *** Significant at $p < 0.01$; ** Significant at $p < 0.05$; * Significant at $p < 0.1$.

4. Results

4.1. Meta-Analysis

Our econometric model revealed statistically significant relationships and drivers that influence WTP for protecting water quality. Coefficients of all variables except *Region* were significant at $p < 0.05$, and at least 88% of the variation in WTP was systematically correlated with model variables (Table 3), suggesting good predictive power [81].

We found that WTP is negatively influenced by the open-ended CV method, while response weighting—a proxy for survey quality—has a positive influence on WTP. The study year also has a positive influence on WTP, suggesting that respondents were WTP a greater percentage of their income each year towards protecting water quality. As expected, median household income has a positive influence on WTP, increasing approximately \$3.00 for every \$10,000 increase in income when adjusting for the natural log of WTP. *Region* was the only variable significant at $p < 0.10$ but not at $p < 0.05$, and WTP estimated for SOUTH was significantly lower compared to all other non-southern states. While this variable carries a low presumption of being different from the null hypothesis ($p < 0.10$) it suggests that regional differences may exist.

For variable category *Resource*, expected WTP for RIVER was significantly lower than for all other resources. Compared to the *Scale* reference level (statewide) WTP for watershed was significantly higher and single site was significantly lower. Finally, for variable category *Program*, WTP for acquisition or easement by a government agency was significantly lower than the reference variable indicating that respondent preferences are different for programs that used land acquisition or easements compared to non-specific environmental programs.

4.2. Benefit Transfer

We applied the results of our empirical model as a BT to two highly forested, yet disparate policy sites in terms of geographic region, scale, resource, and program type to represent a range of WTP values. The first policy site was the lower Suwannee River Watershed located throughout five counties in north central Florida. This site has been referred to as "one of the most pristine and undeveloped river systems" in the US [82]. The second policy site was the state of Minnesota, US that has approximately 11,842 lakes greater than 25 hectares in size and known for extensive lake related use and nonuse values [83]. Attributes of the WTP model were adjusted to run four program scenarios for both policy sites: (1) River protection or (2) Protection of all water resources; and (3) programs that use acquisition or easements strategies or (4) non-specified environmental programs. The Lower Suwannee site included model variables *Region* = SOUTH and *Scale* = WT_SHD and the Minnesota site included model variables *Region* = Reference and *Scale* = ST_WD. For example, Equation (4) shows the application of the empirical model to the Suwannee River policy site for water quality protection programs that use acquisition or easement strategies to protect rivers:

$$\begin{gathered}\ln\mathrm{WTP} = \mathrm{CV\_OE}\ \textit{coefficient}\ (\text{mean value}) + \mathrm{YR\_INDX}\ \textit{coefficient}\ (\text{mean value}) + \\ \mathrm{INCOME}\ \textit{coefficient}\ (\text{median household income}) + \mathrm{SOUTH}\ \textit{coefficient} + \mathrm{RIVER} \\ \textit{coefficient} + \mathrm{WT\_SHD}\ \textit{coefficient} + \mathrm{PRG\_AE}\ \textit{coefficient}\end{gathered} \tag{4}$$

Systematic variation associated with study variables *Survey method* and *Year* was removed by multiplying the coefficient by the mean reported value. The coefficient for income in the Lower Suwannee was multiplied by the mean annual household income (2010 US Dollars) for Dixie ($26,082), Levy ($26,959), Gilchrist ($30,328), Lafayette ($30,651), and Suwanee ($29,963) counties [79]. Site variables, *Region*, *Resource*, *Scale*, and *Program* were also adjusted accordingly and the predicted lnWTP from Equation 4 was transformed to WTP using Equation (5):

$$\text{WTP} = e^{(x+MSE/2)} \quad (5)$$

where x is the predicted lnWTP from Equation 4 and MSE is the regression mean square error. The transformed individual WTP value was then multiplied by 2.5 to calculate annual household WTP based on the average number of individuals per US household [79] and applied to the policy site based on a conservative determination of standing (*i.e.*, whose values matter to the analysis?) (e.g., [84]). For the Lower Suwannee River Watershed, we aggregate WTP by the number of households (46,000) in the five-county watershed, but we recognize that the benefits of watershed protection extend beyond this region. Analogous calculations were performed for the Minnesota policy site with standing limited to the state level.

Results from the model indicate that, to protect water quality in the Suwannee River, annual per-household WTP for programs that use acquisition or easements was $2.29 (95% confidence interval $2.10–$2.50) and total annual WTP was $105,340 (see Table 4). Annual per-household WTP for non-specific programs to protect water quality in the Lower Suwannee was $43.79 (range $39.98–$47.97) and total annual WTP was $2,014,340. In Minnesota, per-household WTP for programs that use acquisition or easements was $14.66 (95% C.I. $13.39–$16.06) and total annual WTP was $31,102,216 (see Table 4). Annual per-household WTP for non-specific programs to protect water quality in lakes was $290.00 (95% C.I. $264.72–$317.70) and total annual WTP was $615,255,300. The BT estimates at both sites reveal that WTP for non-specific programs is considerably higher compared to WTP for acquisition and easement type programs. The BT also found that WTP is higher for lakes, wetlands and all water resources compared to streams and rivers alone (see Table 4).

Table 4. Benefit transfer WTP for water quality protection: lower Suwannee River, Florida, and state of Minnesota (US).

Policy Site	Resource	Program	Annual Household WTP [a]	CI (95%)	Population	Total Annual WTP
Lower Suwannee River Watershed, Florida (US)	Streams and rivers	Acquisition/ Easement	$2.29	($2.10–$2.50)	46,000	$105,340
		Non-specific program	$43.79	($39.98–$47.97)	46,000	$2,014,340
	Wetlands, lakes and all water resources	Acquisition/ Easement	$6.51	($5.95–$7.13)	46,000	$299,460
		Non-specific program	$127.79	($116.65–$139.99)	46,000	$5,878,340
State of Minnesota (US)	Streams and rivers	Acquisition/ Easement	$5.08	($4.65–$5.56)	2,121,570	$10,777,576
		Non-specific program	$99.31	($90.66–$108.79)	2,121,570	$210,693,117
	Wetlands, lakes and all water resources	Acquisition/ Easement	$14.66	($13.39–$16.06)	2,121,570	$31,102,216
		Non-specific program	$290.00	($264.72–$317.70)	2,121,570	$615,255,300

[a] 2010 US dollars; assuming median annual household income is $35,371 (Suwannee River Watershed) and $56,554 (Minnesota).

5. Discussion

5.1. Systematic Variation in Study Variables

In this analysis, the systematic variation associated with study variables was consistent with results found in other studies. The negative slope associated with *survey method* is consistent with studies that have shown that dichotomous choice values equal or exceed those of the open-ended method [71] and that iterative bidding and payment cards elicit higher values compared to dichotomous choice methods [85].

The increase in WTP associated with *Year* suggests that, after accounting for inflation and increases in income there may be a growing demand for protecting water quality from pollution, perhaps due to increased visitor numbers and expenditures by tourists [86,87]. Contingent Valuation methods have been found to provide a consistent and reliable measure of total value [88,89]; therefore a general trend in increasing WTP to prevent water pollution appears to be reasonable, perhaps due to pressures from population growth and demand for clean water.

Variable category *Weighting*, had a positive slope suggesting that studies classified as strong (high number of respondents and a high response rate) are associated with a higher WTP. This result is not dissimilar to other meta-analyses that have had mixed results on the sign associated with response rate [42,48,63]. However we note that one meta-analysis [56] found on average, weak, and strong studies do not yield statistically different WTP values.

5.2. Systematic Variation in Income and Site Variables

We found that an increase in income was significantly related with an increase in WTP ($p < 0.01$). If we assume that WTP is an adequate proxy for quantity demanded, then this finding suggests that water quality is either a normal or luxury good (see, e.g., [90]). The negative slope associated with SOUTH signifies that individuals in the southern region of the US have a lower average WTP (after accounting for other factors like income) to protect water quality compared to other regions (Table 3). The p-value for this variable was relatively high ($p < 0.10$) so we are only moderately confident that there may be differences, however, this is an interesting contrast to a meta-analysis by Johnston *et al*. [48], which found that WTP to improve water quality in already polluted waters was higher in the Southeast than the Western and Midwestern US.

The negative slope associated with RIVER indicates that WTP to protect rivers is less than for other water bodies. Ref. [48] also found that WTP for rivers was lower when compared to lakes and saltwater estuaries; however, another meta-analysis of recreational values by [28] produced mixed results in WTP among lakes and rivers. Intuitively, one could consider that rivers may provide fewer perceived benefits than other freshwater resources. For example, lakes may offer better swimming and fishing benefits than rivers, and wetlands may offer better water purification services and wildlife habitat [91].

Spatial scale also influenced WTP, with WTP increasing with scale from a single site to a watershed, but decreasing slightly from watershed to statewide. While we are not certain of the underlying cause of this result, we propose two competing influences: increasing returns to scale and declining instrumental value with distance. It is possible that respondents view single site programs to be too limited in scale focusing on one resource or place, but statewide programs diffuse the benefits of the program too broadly. Information about a distant resource may be limited and the individual might assume that a change in a resource outside of their immediate vicinity would not greatly affect their wellbeing. When respondents have better information and greater held values (*i.e.*, sense of place) towards a particular region they are likely to assign a higher WTP value [80]. Evidence of systematic variation in scale and/or scope can also be found in other recent meta-analysis literature [48,63,92] and this finding is consistent with improved valuation study design [93]. Indeed, not finding sensitivity to scale or scope would be cause for concern [94]; especially in regards to the perceived water quality benefits of property-specific *versus* watershed-level best management practices and policies.

5.3. Systematic Variation in Program Variables

The negative slope associated with government programs that use land acquisition or easements suggest that the respondent's level of utility decreased when information about the proposed program was revealed (Table 3). Studies, such as [49], found similar results for different types of agricultural land preservation programs with public agency implementation. The authors also concluded that systematic preferences for land preservation policy process attributes may emerge if they appear to influence utility and serve as proxies for unobserved land use outcomes. In our study context, these preferences may be guided by already established attitudes and beliefs about how forests should be used and who should manage them. For example, hunters and birdwatchers may be concerned that conservation easements will not provide public access as compared to public land acquisition [95]. Alternately, respondents may maintain a systematic preference for government involvement in land preservation, or believe that certain policy strategies represent an inappropriate use of public authority [49]. However, in the absence of this information, many respondents may have assumed that the process used to implement the program would not reduce their utility, leading to WTP overestimates. The results of this analysis suggest that valuation studies that do not specify key aspects of the proposed program, such as implementation process and implementing organization, may not fully capture important preferences and produce misleading WTP estimates.

5.4. Benefit Transfer

We highlight the importance of site characteristics and program attributes with the two BT examples: (1) the Lower Suwannee River watershed; and (2) the state of Minnesota. These examples provide helpful estimates of WTP for forest-based water quality protection programs, and emphasize the role that program type, scale, and region in affecting WTP. Recognizing what factors significantly influence WTP can provide useful guidance regarding the general magnitudes of value, as well as a more accurate estimation of the dollar values associated with water quality protection programs. Accounting for these systematic preferences can help policy makers avoid greatly over- or under-estimating the benefits associated with water protection programs when conducting a cost-benefit analysis.

6. Conclusions

This study presented a meta-analysis to estimate systematic components of WTP to protect water quality in unimpaired aquatic systems, which can be used to infer the value of conserving forests for water quality protection. Model results facilitate identification of systematic components of WTP and reveal factors that might otherwise not be evident when examining specific and individual stated preference valuation results. Our findings indicate several factors affecting WTP that may be useful to policy makers and valuation practitioners interested in forest conservation polices, including program type (e.g., easement), scale (e.g., statewide), target resource (e.g., lakes), geographic region (e.g., Southern US), study method (e.g., open-ended CV), and time (with WTP to protect water quality increasing over time). Importantly, our finding on program type suggests that providing limited information about the proposed program in the valuation survey, such as the use of forest conservation, can affect WTP estimates, perhaps because absent the information respondents make incorrect assumptions about how the program will affect their individual utility and preferences for the program are not fully captured. An important implication of this study is that decision-makers should use context-appropriate WTP values to inform policy choices, and that program type is important contextual information for respondents.

Although our model performed well, we acknowledge that the results are based on a relatively small sample size (n = 43) and that there is an inherent limitation in the meta-analysis and BT approaches—sensitivity to information availability. That is, the approaches only work well when the underlying studies include enough variables of interest to be appropriate for transfer to the policy sites [55]. It is possible that we have omitted important variables such as the amount of forest cover in each study that were not observed at our study sites but would influence WTP in meaningful ways at our policy sites. Variation in the quality of information from underlying studies is another concern with these approaches [96]. We also acknowledge that several studies have been critical of contingent valuation [97] despite its use in more than 7500 academic publications from more than 130 countries [98] and its approval by US federal courts for use in natural resource valuation and damage assessments.

Data limitations also precluded us from examining other important policy alternatives. Further research is warranted on the influence of program design attributes such as incentives, education programs, and assistance on WTP to protect water quality, and how the WTP for these programs compares to WTP for acquisition and easement strategies, as well as non-specified programs. Unfortunately, there are relatively few valuation studies that focus on the role of forest conservation to reduce pollution [36,39,41] compared to those that focus on WTP to improve water quality in polluted aquatic systems [13,29–33]. We also see a need for identifying how information about the proposed program type may lead to WTP estimates that are more representative of actual WTP, and whether providing this information can reduce unexplained variation in econometric models of WTP.

Quantifying WTP values for unimpaired water bodies—those that are not already impaired—provides an important baseline for understanding the potential economic benefits of preventing nutrient pollution and support for various kinds of water resource protection through the use of forest conservation programs and best management practices [22,41,86]. We highlight both the application of our results and the importance of policy context with two benefit transfer examples, and show the dramatic differences in expected WTP given changes in the policy context. Finally, our study provides a better understanding of the priorities individuals assign to forest conservation and water resource protection strategies; and indeed our results demonstrated a positive WTP for water quality protection and forest conservation.

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Author Contributions

Melissa Kreye and Damian Adams identified the research questions and designed the study. Melissa Kreye collected the data and performed the analyses with guidance from co-authors. All co-authors assisted with writing and revising successive drafts.

Conflicts of Interest

The authors declare no conflict of interest.

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