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Valuing Changes in Aquatic Biodiversity and Recreation with a Nationwide Survey

Chris Moore[ab], Bryan Parthum[a], Matt Massey[a],

Stephen Newbold[c], and David Smith[a]

[a] National Center for Environmental Economics, U.S. Environmental Protection Agency
[b] Corresponding author: moore.chris@epa.gov
[c] Department of Economics, University of Wyoming

ABSTRACT: The existing body of literature on the total economic benefits from surface water quality improvements is robust and provides valuable information for benefit cost analysis of Clean Water Act regulations. However, there are some important elements of benefit transfer that are best informed by study designs that are uncommon or absent from relevant valuation studies. In this paper, we present the results of a national stated preference survey that was designed to collect data on those elements. The policy scenarios presented in the repeated dichotomous choice questions describe improvements to local and distant aquatic resources, providing data that will inform decisions on the extent of market and distance decay in benefit transfer studies. The attributes in the choice scenarios capture distinct sources of value that may respond differently to new water quality standards, providing a more general benefits function than one that relies on a single composite index. Lastly, we demonstrate the importance of capturing preference heterogeneity and correlation among individual preferences when estimating willingness to pay and how it is impacted by the spatial features of surface water quality improvements.

KEYWORDS: Clean Water Act, stated preference, willingness to pay, discrete choice experiment, preference heterogeneity, water pollution, recreation, biodiversity

JEL CODES: H41; Q28; Q51

1 Introduction

The US Environmental Protection Agency (EPA) has been performing benefit cost analyses (BCA) on Clean Water Act (CWA) regulations for over 40 years. As the state of the art in nonmarket valuation has improved, so have the methods used to estimate the social welfare benefits of CWA regulations. Early BCAs were characterized by benefit transfers that relied on qualitative definitions of water quality for national impacts, supplemented with more detailed regional case studies (e.g., 1982 Iron and Steel Manufacturing effluent guidelines; 1987 Organic Chemicals, Plastics, and Synthetic Fibers rule; see Griffiths et al. 2012). Beginning with the 1998 Pulp and Paper rule, EPA began valuing recreation impacts and applying a rule-of-thumb based on Fisher and Raucher (1984), that assumed nonuse values were 50% of the recreation value. Through the early 2000s, BCAs for CWA regulations relied upon benefit transfer from a handful of contingent valuation and recreation demand studies. Supported in part by $10.5 million in EPA research grants, nonmarket valuation methods for water quality have vastly improved (Moore et al. 2023), best practices have been established and updated (Johnston et al. 2017a), and the number of studies has continued to grow. The proliferation of high-quality research in this area motivated another update to EPA's water quality valuation approach. The economic analysis for the 2009 Construction and Development rule (US EPA 2009) relied on a meta-analysis of water quality valuation studies, allowing the agency to perform a functional benefit transfer and tailor the results more closely to the specific improvements expected under the rule. The meta-analytic transfer approach has been used to analyze nearly all significant CWA regulations since, with occasional updates to reflect methodological advances and to incorporate new studies (e.g., Johnston et al. 2017b; Newbold et al. 2018; Moeltner et al. 2023).

Methodological improvements notwithstanding, the quality of meta-analytic transfers is limited by the body of literature on which they are estimated. Within the 59 studies used for the most recent application of the meta-analysis, 15 out of the 48 contiguous states are not represented (US EPA 2024). Further, only seven of the studies sample populations outside a single state and few of those sample populations outside the watershed that is the focus of the primary study. The partial coverage and narrow spatial scope of most water quality valuation studies limits our understanding of important features of benefit transfer, including preferences of the affected population and how willingness to pay (WTP) changes with distance from the improved resource. Several previous valuation studies found that the spatial extent of WTP for environmental improvements is of first-order importance in BCA and can often dominate the decisions regarding estimation of household WTP (Smith 1993; Loomis 2000; Ian J. Bateman et al. 2006a; Corona et al. 2020). In addition to market extent for environmental improvements, there is some empirical support for a WTP gradient that declines with distance from the improved resource (Hanley et al. 2003; Johnston et al. 2019). Only studies that sample households sufficiently far from the improved resource can identify distance decay and extent of market, and such studies are uncommon in surface water quality valuation.

An additional challenge in transferring WTP values to national regulations is standardizing the water quality attributes valued in the primary studies. The valuation studies that underly EPA's most recent application of meta-analytic transfer (US EPA 2024) estimated WTP for changes in a variety of environmental endpoints including the index of biotic integrity (IBI), algae levels in lakes, and water clarity, among others. To overcome disparities among studies, the baseline and post-policy attribute levels in the primary studies were converted to values on a common water quality index (WQI) before the meta-data were used to estimate the benefit transfer function. EPA's freshwater WQI compiles numerous water quality measures into a single score ranging from 10 to 100. While the underlying water quality measures impact various ecosystem services, EPA's WQI is primarily used to convey the suitability of lakes, rivers, and streams for recreational uses, with thresholds for boating, fishing, and contact recreation (Griffiths et al. 2012). While necessary to create a conformable valuation dataset from 59 studies, expressing water quality changes with a single index implicitly assumes that all aquatic ecosystem services are proportionately impacted and equivalently valued by the affected population. Lupi et al. (2023) find evidence that aggregating multiple sources of value into a single index can significantly impact WTP estimates compared to scenarios in which those ecosystem service changes are presented separately.

We report results from a national stated preference (SP) study designed to address the meta-analysis challenges described above and provide an alternative valuation approach for CWA regulations or other policies that would lead to widespread changes in surface water quality across the US. The sample was drawn from a nationally representative sample frame to ensure all 48 contiguous states are represented in proportion to their populations. The choice scenarios presented improvements in recreation experiences and aquatic biodiversity as distinct attributes to decouple two primary determinants of household WTP. The amount of surface waters improved in each of the choice scenarios also varies so we can ensure the estimated valuation function satisfies adding up with respect to quantity, a feature Newbold et al. (2018) show to have a significant impact on theoretical validity. Finally, the distances between the respondents' homes and the location of the water quality improvements vary across choice scenarios allowing an examination of distance decay, extent of market, and how they differ for recreation and biodiversity improvements.

We estimate household marginal WTP with two specifications of the random parameters logit model. In one specification, the coefficients are assumed to have independent distributions. While assuming individual preferences for attributes are uncorrelated simplifies estimation because off-diagonal elements of the covariance matrix are zero, it imposes unrealistic restrictions on preferences and may bias estimates. We generalize the model in the second specification to allow correlations among all preference parameters. Both models are estimated in WTP-space to avoid numerical issues that arise when WTP is a ratio of two random coefficients (Train and Weeks 2005). Both specifications produce statistically significant WTP values for water quality attributes that are consistent with our priors based on economic theory. We find that estimating the full covariance matrix improves model fit and mitigates apparent attenuation bias in the uncorrelated model.

The results of our preferred model show that marginal WTP for aquatic biodiversity in local watersheds is greater than WTP for recreational improvements. We find statistically significant distance decay for both water quality attributes and a market extent for biodiversity improvements that is 44% greater than the extent for recreation improvements. Taken together, these results imply that decoupling water recreation endpoints from aquatic ecosystem health can provide more informative benefit estimates than approaches that combine them into a single composite indicator. In Section 2 we describe the study design and summarize the survey data in Section 3. Section 4 presents the econometric model used in estimation and Section 5 reports the results. Section 6 concludes with a discussion of our results and potential implications for benefit cost analysis of CWA regulations.

2 Study Design

An identification strategy to answer our research questions requires variation across two water quality metrics, the spatial attributes of the policy scenarios, and costs incurred by households under the policy alternative. These survey design decisions were informed by focus groups held in Washington DC, Chicago, and Phoenix. Section 2.1 describes how the outcome of those focus groups and current best practices for SP studies shaped our survey design. Section 2.2 describes our sampling plan to collect responses from a nationally representative sample of households.

2.1 Survey Design

The introduction to the survey informed respondents that the survey is being conducted by the US Environmental Protection Agency, which improved consequentiality in focus group testing. The introduction also describes, in general terms, the policies they will be asked to consider. Specific management practices required by those policies, such as improving wastewater treatment and storm water management, are described later in the survey.[1]

The survey employed a repeated dichotomous choice format, with each survey containing six choice scenarios. Multiple valuation questions provide increased estimation efficiency for a given sample size and an opportunity for respondents to become familiar with the choice tasks (Johnston et al. 2017a). On the other hand, such a design introduces risks of sequencing effects and violating incentive compatibility. To address the former, the survey included prenotification screens on which respondents were shown each policy region they would encounter on their survey along with the baseline conditions and spatial attributes of each. Bateman et al. (2004) find that providing respondents with advance notification of the choice sets mitigates sequencing effects and improves responsiveness to scope. To mitigate threats to incentive compatibility, each of the first five choice scenarios were followed by a reminder to consider each policy as if it were the only one available and not to add up the water quality improvements or costs across questions. Vossler et al. (2012) show that under certain conditions repeated dichotomous choice questions can be incentive compatible and that reminders to treat questions independently can help to achieve those conditions.

Given the prevalence of the recreation-based water quality ladder (WQL; Vaughan and Russell 1982) and its continuous analogue, the water quality index (WQI), in the stated preference literature (e.g., Carson and Mitchell 1993; Lupi et al. 2023; Bateman et al. 2006b), we began our focus group research with a prior toward using a similar measure to represent the recreation aspects of water quality. The *Recreation Score* that we use on this survey is a 0-100 score, with threshold values indicating that waterbodies are either unsuitable, suitable, or good for boating, fishing, and swimming (Figure 1).

[1] Screenshots of an example survey are available in the supplementary material.

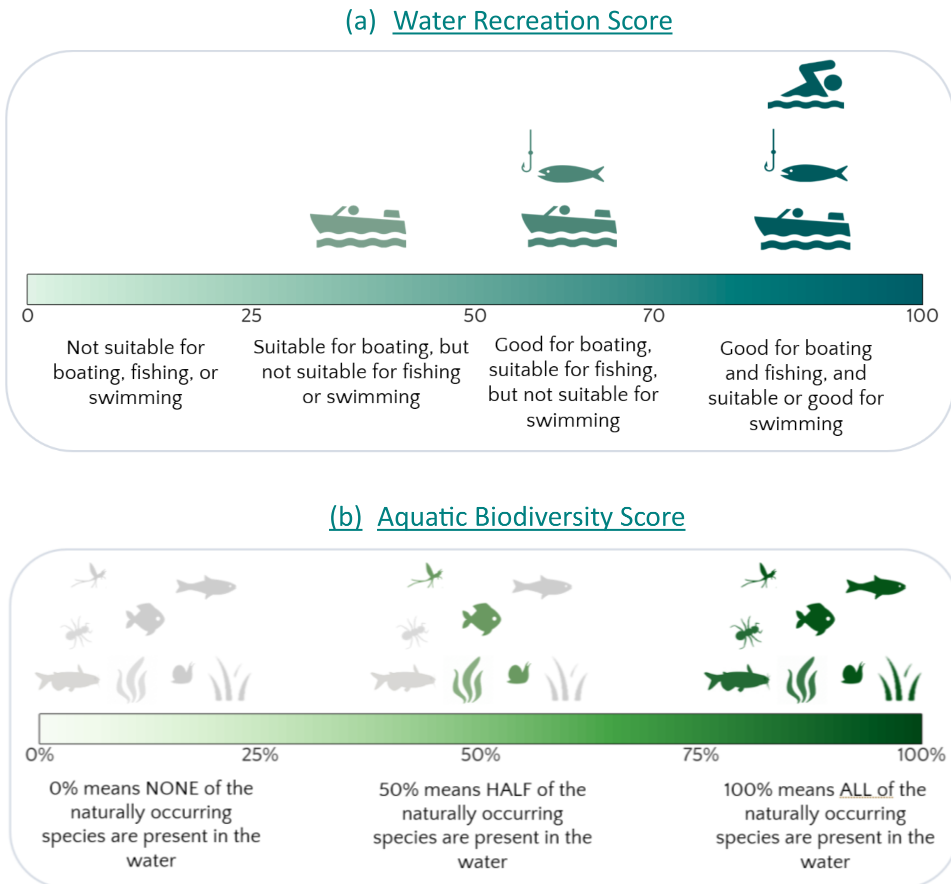

Figure 1. *Illustrations of the Water Recreation Score and the Aquatic Biodiversity Score*. The survey included text and visual descriptions of the water quality attributes. The Water Recreation Score scale is marked with threshold values at which water quality becomes suitable for select activities and shows that further increases in the score would improve the quality of those experiences from suitable to good. The text descriptions of the water quality attributes emphasized that the two scores could change independently because management practices and pollutants impact them differently.

A greater challenge, and one with less precedent on which to base focus group testing, is choosing a metric to capture sources of value other than recreation. These include tangible ecosystem services like source water for drinking water (Keeler et al. 2012), and intangible nonuse values like bequest and existence value. Given our focus on CWA regulations, as opposed to those under the Safe Drinking Water Act, we deliberately excluded drinking water impacts from the outcomes of the policy scenarios described on the survey. So while it may be difficult, or impossible, to decompose an estimate of total WTP into distinct use and nonuse values (Cummings and Harrison 1995), our intent was to develop an indicator of water quality that credibly captures value other than those generated by recreation. Lupi et al. (2023) designed a SP survey that expressed water quality using a Wildlife Score, a Contact Recreation Score, and a Recreational Fishing Score. Lupi et al. describe the Wildlife Score as "measuring the ability of a waterbody to support healthy and diverse populations of aquatic plants and animals." Vossler et al. (2023) expressed changes in water quality using a biological condition gradient (BCG) that classifies waterbodies into one of six categories, each reflecting a level of anthropogenic stress on the ecosystem. Our focus group discussions led to indicators of ecosystem health and biodiversity but found problems with general scores and multimeric indices because participants found it difficult to relate changes in the numeric index to tangible changes in the ecosystem (Hill et al. 2023). The *Aquatic Biodiversity Score* that we used to complement the Recreation Score expresses the percentage of aquatic macroinvertebrates present in a water body relative to the number that would be found under the best possible conditions for similar resources (Figure 1). We based this metric on the "observed to expected ratio" that is collected and reported as part of the National Aquatic Resources Survey (US EPA 2013). A large share of focus group participants preferred this metric because changes in the numerical value mapped directly to tangible changes they could understand and simultaneously served as a general indication of ecosystem integrity.

The study design achieved variation in the spatial attributes using *policy regions.* Each choice scenario references a region of the US where the hypothetical policy will be implemented. Outside of the policy region there are no changes in water quality. To reinforce the spatial boundaries on the water quality changes, the survey describes watersheds and shows a map of the 18 major watersheds of the contiguous US (2-digit hydrological units or HUC2s, Figure S1.1). Three of the six valuation questions on each survey referenced policy regions that contained the respondent's address. Of those three regions, one was their home watershed, one was their home watershed plus two adjoining watersheds, and the third was their home watershed plus five adjoining watersheds. The other three choice scenarios referenced policy regions that did not contain the respondent's home, but also comprised one, three, and six adjoining watersheds. Creating sets of 3 and 6 adjacent HUC2s from the 18 across the contiguous US results in 83 and 1050 unique sets, respectively. However, not all sets are reasonable in terms of watershed policy which could lead to scenario rejection by respondents. To address the plausibility of various sets of 3 and 6 HUC2s, we establish selection criteria based on the convexity of the set.[2] That is, if HUC2s were paired together in such a way that made the overall set less compact, and therefore less plausible in the context of watershed policies, the set was discarded. We required each set of 3 and 6 HUC2s to have a convex hull score of at least 0.6. This resulted in 45 unique sets of 3 HUC2s, and 461 unique sets of 6 HUC2s. We then had three reviewers examine the remaining sets and use subjective review criteria to select 29 3-HUC2

[2] The convex hull score is the ratio of the area of the HUC2 set to the area of the minimum convex polygon (MCP) that can encloses the set's geometry. A set's score falls within the range of [0,1] and a score closer to 1 indicates a more compact set. Specifically, $Convex\ hull\ score = \frac{Area_{set}}{Area_{MCP}}$. We use the *sf* package in R to calculate the scores (Pebesma 2018)

policy regions and 141 6-HUC2 policy regions as plausible in the context of watershed policy (see Figure S1.2 for examples of accepted and discarded policy regions). In combination with the 18 single 1-HUC2 policy regions, a total of 188 policy regions populated the design space. Policy regions were randomly assigned within the constraints described above and all were randomly ordered on each survey. If a respondent's address is outside the policy region, they were given the geodesic distance, in miles, from the centroid of their zip code to the nearest part of the region. The information in each choice scenario also included the surface area (square miles) of lakes, rivers, and streams in the policy region. See Figure 2 for an example choice scenario.

Policy Features	No Policy	With Policy
Average Water Recreation Score ?	71	78 (7-point improvement)
Average Aquatic Biodiversity Score ?	70%	75% (5% improvement)
Square miles of lakes, rivers, and streams affected	0 square miles	3,744 square miles (14% of US total)
Distance to nearest part of policy region	0 miles	0 miles
Increase in your annual taxes for 5 years	$0	$270 per year
Vote Here	Vote No Policy ○	Vote for Policy ○

Figure 2. *Example dichotomous choice question from the survey.* The question screens included a map of the policy region where improvements would occur and a table showing the water quality attribute levels under baseline and policy scenarios, the spatial characteristics of the policy region, and the cost of the policy to the respondent's household.

Payment vehicles in SP choice scenarios should be realistic, credible, familiar, and binding for all respondents to satisfy incentive compatibility (Johnston et al. 2017a). When the sample frame contains households throughout the contiguous US there are few payment vehicles that meet all criteria. Not all households pay utility bills or income tax. Sales tax and cost of living increases can be mitigated by changing purchasing behavior. This survey described the payments in the form of, "increases in federal, state, and local taxes" for five years. Recognizing that tax increases could trigger scenario rejection, the survey included debriefing questions to probe this issue and screen the data before estimation.

We used the *Ngene* software package to develop a D-optimal design for the recreation, biodiversity, and cost attributes, assuming utility is linear in those attributes, while imposing some constraints to ensure balance. Prior distributions on the coefficients were estimated using pretest data. The final experimental design for the water quality and policy attributes is summarized in Table 1.

Table 1. *Experimental design*

Attribute	Description		Mean	Values or Range
Baseline Recreation Score	Numeric score 0-100 that conveys the average suitability of for boating, fishing, and swimming.		65.0	35-92
Improvement in Recreation Score	Change in recreation score under policy.		3.8	0,1 ,3, 5, 7
Baseline Biodiversity Score	The average percent of aquatic macro-invertebrates species found in waterbodies relative to the best possible conditions.		69.5	35-93
Improvement in Biodiversity Score	Change in biodiversity score under policy.		3.9	0,1 ,3, 5, 7
Surface Area (square miles)	Total surface area of all lakes rivers and streams in a policy region.	1-HUC2 Regions	1,681	95-4,975
		3-HUC2 Regions	5,019	758-5,019
		6-HUC2 Regions	10,693	1,903-19,766
Distance (miles)	Geodesic distance from the centroid of the respondent's zip code to the nearest edge of the policy region.		285	0-2,540
Cost of Policy Scenario	Increase in annual federal, state, and local taxes for the next five years.		$345	$20-$1,145

A description of each policy attribute and summary statistics for the experimental design. Mean values are provided for each attribute. Ranges are provided for the continuous attributes and a list of values are provided for the discrete attributes.

2.2 Sampling

A nationally representative sample is critical to address our primary research questions and for applicability to CWA regulatory analysis. Further, a national sample frame provides data from regions of the US that are underrepresented in the water quality valuation literature. The sample for this study was drawn from the Ipsos KnowledgePanel probability-based panel, targeting a representative sample of households located in the 48 contiguous states of the US and Washington, DC. Drawing our sample from an existing panel provides several advantages over other sample frames. For example, KnowledgePanel collects extensive demographic data from all panel members, making it unnecessary to include demographic questions on the survey, conserving valuable survey space and time. Sampling from an existing panel also allowed us to easily customize each survey and provide household-specific information about the choice scenarios.

3 Data Summary

Of the 10,216 panelists invited to participate in our study, 64.3% completed a survey, resulting in an initial sample of 6,567 respondents. Figure 3 contains a map showing respondent locations by zip code. Table 2 provides a demographic summary of our sample and a comparison to the adult population according to the March supplement of the 2023 Current Population Survey (CPS). Through raking, the weighted sample percentages match the population percentages in all respects.

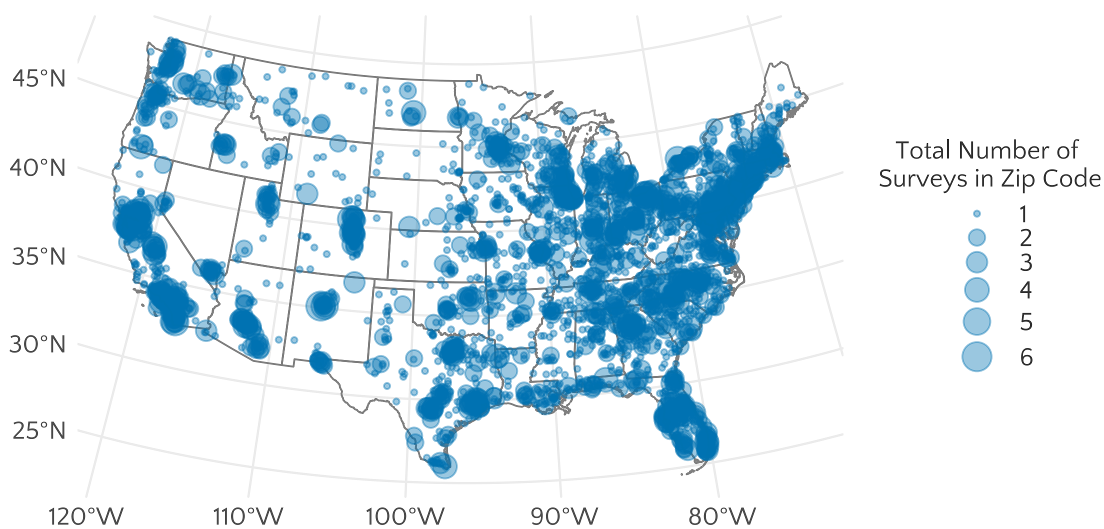

Figure 3. *Location of survey respondents by zip code.* The maximum number of survey respondents from the same zip code was 6, and the average is 1.3 across 4,763 unique zip codes covering all 48 states in the Continental US, plus the District of Columbia.

__Table 2.__ Demographic comparison of sample to population

	Unweighted Sample Percentage	Population Percentage
Respondent Location		
Northeast	17.7	17.4
Midwest	21.9	20.5
South	37.6	38.6
West	22.9	23.6
Metropolitan Areas	86.5	86.6
Race		
White non-Hispanic	68.5	61.3
Black non-Hispanic	10.8	12.1
Hispanic	13.0	17.5
Other non-Hispanic	7.8	9.2
Gender		
Female	49.9	51.0
Annual Income		
Less than $25,000	9.6	11.1
$25,000 - $49,999	15.0	15.4
$50,000 - $74,999	15.4	15.4
$75,000 - $99,999	13.7	13.0
$100,000 - $150,000	20.2	18.9
More than $150,000	25.9	26.3
Education		
Less than high school	5.4	9.4
High school or GED	25.2	28.8
Associate's degree or some college	27.6	26.4
Bachelor's degree or higher	41.9	35.4

Demographic characteristics of respondent households are very similar to the population. Race, gender, and income distributions match closely while the sample underrepresents respondents without a high school degree and includes a higher percentage of people with a college degree.

The survey collected data on respondents' behaviors and attitudes that may influence their responses to the stated preference questions. 13% of our sample purchased a fishing license in 2023 compared with 12.9% of the adult population.[3] Slightly more than half of our sample, 54.9%, reported taking a recreational trip to a lake, river, or stream in their home watershed over the past 12 months. After answering the choice scenario questions, respondents were asked whether each of the attributes had a large, moderate, some, little, or no effect on their choices. Figure 4 shows the distributions of those

[3] See Fishing Licenses, Holders, and Costs by Apportionment Year, Retrieved 8/22/2025, From https://us-east-1.quicksight.aws.amazon.com/sn/accounts/329180516311/dashboards/602cf050-6e11-4da5-9917-7229fd08648b/sheets/602cf050-6e11-4da5-9917-7229fd08648b_6af87d82-d05b-429c-8723-8ce03fa38df3

responses. Improving recreational experiences appears to have the strongest effect on respondents' choices overall, while the distribution for improving aquatic biodiversity suggests highly heterogeneous preferences. The distance from home and amount of water in the policy regions have similar distributions that show generally large effects. Responses on the effect of the cost attribute raise some concern about the consequentiality of the payment vehicle.

Figure 3. *Distribution of categorical responses to debriefing questions.* Respondents were asked to indicate how much of an effect each of the policy attributes had on their responses to the dichotomous choice questions. The Water Recreation Score had the largest share of "large" and "moderate" responses. The Aquatic Biodiversity Score and cost attributes had the largest shares of "little" and "none" responses.

To mitigate concerns about lack of consequentiality, scenario rejection, and hypothetical bias, we screened the data before estimation using a combination of responses to debriefing questions and the choice scenarios in a manner similar to Moore et al. (2018). The screening criteria require all omitted choice scenario responses to be consistent with the bias we aim to mitigate. For example, if a respondent disagreed with the statement, *"I voted as if my household would actually face the costs shown,"* but voted for the status quo option in at least one instance, their responses would not be screened from the data. We also dropped respondents who completed the survey in less than five minutes, which was about 2% of our sample. Table 3 contains each screening prompt and the number of respondents who were dropped for each.

Table 3. *Data screening criteria and results*

Debriefing Response	Choice Scenario Responses	Screened Respondents
Agreed with "It is important to improve water quality no matter how high the cost"	Policy Option	54
Agreed with "I want better water quality, but I shouldn't have to pay additional taxes to get it."	Status Quo	116
Disagreed with "I voted as if my household would actually face the costs shown."	Policy Option	45
Total, including those screened for completing survey in less than 5 minutes		317 (5.2% of sample)

Three of the criteria for screening surveys from the sample relied on a combination of responses to debriefing questions and responses to the dichotomous questions. A fourth criterion identified "speeders" that completed the survey in less than 5 minutes.

4 Estimation

To analyze the repeated dichotomous choice responses, we adopt the random utility framework in which choice probabilities are a function of utility differences between the status quo and policy alternatives (Hanley et al. 1998; Hanemann 1984). We begin by specifying utility as a function of the choice attributes and income or, equivalently, consumption of all market goods and services.

$$V_{ij0} = A_{ij}\left[\beta_R \ln(R_{ij}) + \beta_B \ln(B_{ij}) + \beta_{DR} \ln(R_{ij}) \cdot \ln(D_{ij}) + \beta_{DB} \ln(B_{ij}) \cdot \ln(D_{ij})\right] + \lambda M_i + \varepsilon_{ij0}. \quad (1)$$

Equation (1) represents utility in the baseline case where A_{ij} is the surface area of water in the policy region for individual *i* on choice occasion *j*, R_{ij} is the recreation score in that case, B_{ij} is the biodiversity score, D_{ij} is the distance from the individual's home to the nearest part of the policy region, M_i is individual *i*'s income, and ε_0 is a residual representing the unobserved portion of utility. β_R and β_B are the utility coefficients for the recreation and biodiversity scores, β_{DR} and β_{DB} are the coefficients for the distance interactions with those values, and λ is the marginal utility of income. We assume that utility derived from water quality scales linearly with the affected area. Linearity in A ensures a form of internal consistency with respect to the spatial (de-)composition of watershed policies: it guarantees that the benefits of any given water quality improvement in a watershed are the same whether it is accomplished with a single policy spanning the entire watershed or multiple policies that make the same improvements in each of its sub-watersheds.

Under the policy alternative, the utility function becomes,

$$V_{ijk} = \phi_{jk} + A_{ij}\left[\beta_R \ln(R'_{ijk}) + \beta_B \ln(B'_{ijk}) + \beta_{DR} \ln(R'_{ijk})\cdot\ln(D_{ij}) + \beta_{BR} \ln(B'_{ijk})\cdot\ln(D_{ij})\right] + \lambda(M_i - c_{ijk}) + \varepsilon_{ijk}.$$

(2)

In equation (2), ϕ_{jk} is the alternative specific constant (ASC) for policy case *k* in choice occasion *j, R'_{ijk}* and *B'_{ijk}* are the recreation and biodiversity scores in the policy case, and c_{ijk} is the cost of the policy. Differencing equations (1) and (2) and rearranging terms to make the expression linear in the utility coefficients yields,

$$\begin{aligned} V_{ijk} - V_{ij0} &= \phi_{jk} + \beta_R A_{ij} \ln(\frac{R'_{ijk}}{R_{ij}}) + \beta_B A_{ij} \ln(\frac{B'_{ijk}}{B_{ij}}) + \beta_{DR} \ln(D_{ij}) A_{ij} \ln(\frac{R'_{ijk}}{R_{ij}}) + \beta_{DB} \ln(D_{ij}) A_{ij} \ln(\frac{B'_{ijk}}{B_{ij}}) - \lambda c_{ijk} + \varepsilon_{ijk} - \varepsilon_{ij0} \\ &= \beta' x_{ijk} + \tilde{\varepsilon}_{ijk}, \end{aligned}$$

(3)

where, x_{ijk} is a vector of choice attributes and β is a vector of utility coefficients. Using equation (2) to solve for the marginal rate of substitution between the recreation score and income to derive marginal WTP results in the expression $A/R\cdot\left(\beta_R + \beta_{DR}\ln\left(D\right)\right)/\lambda$.[4] The same derivation for the marginal WTP for improvements in biodiversity yields $A/B\cdot\left(\beta_B + \beta_{DB}\ln\left(D\right)\right)/\lambda$.

Assuming the ε_{ijk} follow a type-I extreme value distribution allows the choice probabilities and utility coefficients to be estimated using the logit model so that the probability of individual *i* choosing alternative *k* on occasion *j* is given by,

$$P^L_{ijk} = \frac{\exp\left(\beta' x_{ijk}\right)}{\sum_h \exp\left(\beta' x_{ijh}\right)}\ . \qquad (4)$$

[4] In estimation, values for *Distance* were increased by 1 mile so that distances of zero for respondents' home regions were replaced with 1. When applied to the marginal WTP derivation, this causes the distance coefficient to be multiplied by ln(1) = 0, so the term drops out for home region calculations.

The logit model described thus far assumes homogeneous preferences across all individuals. When preferences are substantially heterogeneous, the standard logit model is a misspecification (Hess and Train 2017). The mixed logit model (McFadden and Train 2000; Revelt and Train 1988) is the most widely applied empirical model that accommodates preference heterogeneity in discrete choice data. The mixed logit model assumes that the utility coefficients follow continuous distributions chosen by the researcher. While this improves estimation, it introduces a complication for estimating WTP from the utility coefficients. Given that the WTP for an attribute involves the ratio of the attribute coefficient and the cost coefficient, using estimates from a mixed logit model produces a ratio of two random terms. Depending on the distribution chosen for the cost coefficient in the denominator, that can result in a distribution for WTP with undefined moments or heavily skewed distributions. Two alternatives that circumvent this numerical issue are common in the literature. One is to assume a fixed cost coefficient, implying that the marginal utility of income is constant across the population, which may not be a realistic assumption. The second is to estimate the model in WTP-space.

Train and Weeks (2005) show that by reformulating the utility function, the coefficients can express marginal WTP rather than marginal utilities. In this way, distributions can be specified for marginal WTP directly. With statistical software packages offering routines that estimate mixed logit models in WTP space, the approach has become more common and straightforward to implement.[5] When coefficients are estimated in WTP-space, the expressions for marginal WTP for recreation and biodiversity improvements become $A/R \cdot \left(\tilde{\beta}_R + \tilde{\beta}_{DR} \ln\left(D\right)\right)$ and $A/B \cdot \left(\tilde{\beta}_B + \tilde{\beta}_{DB} \ln\left(D\right)\right)$. Another feature of the estimation routine allows us to examine the impact of correlation among WTP coefficients on their distributions. Unlike models estimated in preference space, an uncorrelated model estimated in WTP-space automatically allows for scale heterogeneity (Hess and Train 2017). However, ignoring possible correlation among WTP coefficients can bias the estimated means and standard deviations (Mariel and Meyerhoff 2018).

5 Results

While there is wide agreement that discrete choice models estimated in WTP-space generate more plausible distributions of WTP, there is mixed evidence regarding how well the models fit the underlying data. In comparisons of goodness-of-fit, Trains and Weeks (2005), Sonnier (2007), and Hole and Kolstad

[5] Model estimation was performed using the Stata statistical software, version 18, and the user-written command *mixlogitwtp* (StataCorp 2023, Hole 2015)

(2012) found results that favored the preference-space approach. In this application, like Scarpa et al. (2008), we find that models estimated in WTP-space fit our data better. Results for the preference-space models are provided in the supplementary material, but we focus the remainder of our discussion on the WTP-space results.

Table 4 contains the estimated means for each coefficient from the two mixed logit models. While these models were estimated in WTP space, the values should not be interpreted as marginal WTP. The values reported in table 4 correspond to ratios of the attribute coefficients and the cost coefficient which require further manipulation to reflect marginal WTP given the indirect utility function in Equation 1. All coefficient means in the correlated and uncorrelated models are statistically significant at the 0.001 level. The chi-squared statistic from a likelihood ratio test comparing the two models is 322.98, which indicates that the null hypothesis of no cross-coefficent correlations can be rejected at the 0.001 level. This result is consistent with other empirical comparisons of correlated and uncorrelated mixed logit models that find better model fit in the correlated models (Mariel and Meyerhoff 2018; Scarpa et al. 2008; Hole and Kolstad 2012).

The coefficients on the distance interactions are negative, indicating that people are willing to pay less for improvements that occur in more distant policy regions. Interestingly, the coefficient on the distance-biodiversity interaction is larger than the coefficient on the distance-recreation interaction, suggesting that WTP for biodiversity declines more rapidly with distance than WTP for recreation. One objective of the survey design is to decouple value associated with recreation, including option and bequest values, and other sources of value. Our assumption is that respondents' WTP for aquatic biodiversity would consist primarily of existence value, though we cannot test that assumption empirically. Given that there is no utility theoretic reason for existence value to decline with distance, while there is for use values, this is a noteworthy result that we examine further in the context of marginal WTP below.

Table 4. *Estimated means of coefficient distributions*

	Uncorrelated MXL in WTP Space	Correlated MXL in WTP Space
$Policy\ ASC$	53.85***	75.58***
	(11.63)	(11.48)
$Area \times log(recreation)$	201.1***	236.3***
	(18.78)	(18.49)
$Area \times \log(biodiversity)$	365.3***	442.2***
	(23.92)	(25.61)
$Area \times \log(distance) \times \log(recreation)$	-24.85***	-48.15***
	(4.775)	(6.96)
$Area \times \log(distance) \times \log(biodiversity)$	-65.31***	-83.89***
	(5.746)	(7.239)
$Cost$ (log-normally distributed)	-5.466***	-5.327***
	(0.0391)	(0.0402)
Transformed $Cost$ (normally distributed)	-0.0042***	-0.0049***
	(0.00017)	(0.00020)
Log-likelihood	-18184.1	-18022.6
Pseudo R^2	0.213	0.220
AIC	36392.3	36099.3
BIC	36501.8	36345.7
Observations	68064	68064
Halton Draws	200	200
Iterations to Converge	22	104

Observations are the number of individuals N times choice occasions T times alternatives J: $N \times T \times J$. Standard deviations of the random parameters in the uncorrelated model and the Cholesky decomposition of the covariance matrix of the random parameters in the correlated model—what is estimated and reported when using the estimation command *mixlogitwtp* in Stata 18—can be found in the supplementary material (Table S1.1). We also present correlation coefficients of the random parameters in the correlated model (Figure S1.3). The coefficient on *Cost* is assumed to be distributed log-normal and reported as estimated—the transformed *Cost* coefficient was recovered using Stata's *nlcom* command (StataCorp 2023) and is also reported in the table where its mean equals $exp\left(\beta_{cost} + \frac{\sigma^2_{cost}}{2}\right)$. Standard errors are in parentheses where * p < 0.05, ** p < 0.01, and *** p < 0.001.

The results indicate that accounting for correlations among preference parameters improves the model fit, so it is worth noting that most coefficients in the uncorrelated model are substantially smaller in magnitude than the corresponding estimates from the correlated model. Few empirical studies examine the effects of ignoring correlation among parameters in mixed logit models and even fewer do so in WTP-space. Our results indicate that the estimated means in the uncorrelated model are attenuated which will result in lower marginal WTP for improvements in home watersheds and a more gradual distance decay.

Hole and Kolstad (2012) also compare correlated and uncorrelated models in WTP-space and find mixed results regarding their relative magnitude.[6]

Table 5 presents means and 95% confidence intervals for marginal WTP when the nearest improved waters are 0, 50, 100, and 250 miles away.[7] The calculations assume water surface area of 1,680 square miles, a water recreation score of 65, and an aquatic biodiversity score of 70, which are the average values for single-watershed policy regions in our design space (see Table 1). Panel A contains estimates of marginal WTP for recreation improvements. As expected, given the magnitudes of the coefficient means, the central estimate for local improvements from the fully correlated model is larger than the estimate from the from the uncorrelated model. With positive distances, however, the decay effect dominates and the WTP estimates from the correlated model decline faster. Most striking are the extent of market estimates which we find by setting marginal WTP equal to zero and solving for distance. Those values are given by the expressions $exp\,(-\frac{\beta_R}{\beta_D})$ and $exp\,(-\frac{\beta_B}{\beta_D})$ for recreation and biodiversity, respectively.[8] A common assumption is that the extent of market for recreation benefits roughly corresponds to the farthest one-way distance someone would travel for a single-day recreation trip. For example, McConnell and Strand (1994) assumed fishermen choose among fishing sites within 150 road miles of their homes; Parsons, Massey, and Tomasi (1999) assumed Delaware residents consider Maryland, Delaware, and New Jersey beaches up to 230 road miles from their homes; EPA commonly assumes that people within 100 geodesic miles of an environmental improvement accrue benefits (US EPA 2024). The coefficient distributions from the uncorrelated model imply a central estimate greater than 3,000 miles and an upper bound of 11,000 miles on the 95% confidence interval. Given that the 95% confidence interval includes zero, we conclude that the uncorrelated model provides weak evidence regarding the market extent for recreational benefits. In contrast, estimates from the fully correlated model generate a much narrower confidence interval. While we cannot infer that WTP for recreational improvements necessarily extends beyond the home policy region, the upper bound of the 95% confidence interval for market extent of recreational improvements is 309 miles.

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[6] In the supplementary material (S2), we provide a proof for a simplified case that, when preferences are positively correlated, a misspecified uncorrelated mixed logit model will bias the means of the preference parameter distributions toward zero.

[7] Confidence intervals were found using the delta method via Stata's *nlcom* command.

[8] For estimation purposes, distances were increased by 1 mile so that the natural logarithm of distance in the home region was zero. When calculating the marginal willingness to pay by distance and the extent of market we account for this.

Table 5. *Marginal willingness to pay, distance decay, and extent of market*

Panel A: Recreation	(1) Uncorrelated Random Parameters	(2) Correlated Random Parameters
0 Miles	5.20***	6.11***
	[4.25, 6.15]	[5.17, 7.05]
50 Miles	2.67***	1.21
	[1.87, 3.47]	[-0.11, 2.54]
100 Miles	2.23***	0.36
	[1.35, 3.12]	[-1.16, 1.88]
250 Miles	1.65**	-0.77
	[0.63, 2.67]	[-2.57, 1.03]
Extent of market (miles)	3,265	134
	[-4485, 11017]	[-40, 309]
Panel B: Biodiversity		
0 Miles	8.83***	10.70***
	[7.70, 9.97]	[9.48, 11.91]
50 Miles	2.62***	2.72***
	[1.73, 3.52]	[1.54, 3.89]
100 Miles	1.54**	1.33*
	[0.57, 2.52]	[0.01, 2.65]
250 Miles	0.11	-0.52
	[-1.02, 1.23]	[-2.06, 1.03]
Extent of market (miles)	267**	194**
	[74, 460]	[52, 336]
Observations	68064	68064

Observations are the number of individuals N times choice occasions T times alternatives J: $N \times T \times J$. 95% confidence intervals are presented in brackets and were recovered using the delta method in Stata's *nlcom* command where * p < 0.05, ** p < 0.01, and *** p < 0.001.

Panel B of Table 5 shows the marginal WTP estimates for improvements in biodiversity. Willingness to pay for local biodiversity improvements is significantly higher than the corresponding estimates for recreation. Comparing models, the fully correlated model produces higher estimates of WTP for local improvements in biodiversity that decline faster with distance than those from the uncorrelated model. Unlike the extent of market estimates for recreational improvements, the estimates from both models for biodiversity are statistically different from zero and similar in magnitude. If we assume that WTP for improvements in aquatic biodiversity is a proxy for existence value, there is little theoretical or empirical guidance regarding the extent of the market. However, both models produce estimates that indicate WTP for biodiversity improvements becomes negligible at distances within our design space (mean distance of 285 miles, see Table 1). Further, the fully correlated model produces results that are consistent with our prior that WTP for biodiversity extends farther from the household than WTP for recreation benefits, though there is substantial overlap in the 95% confidence intervals and the upper bounds are similar.

6 Discussion and Conclusions

This study was designed to address specific gaps in the literature that impede benefit cost analysis of CWA regulations. First, only two previous national surveys have estimated the total economic benefits of meeting surface water quality criteria (Carson and Mitchell 1993; Viscusi et al. 2008). The surveys were administered in 1983 and 2004 and employed study designs that are not consistent with contemporary guidance on stated preference. While synthesis of results across many studies via meta-analysis can increase the geographic coverage of data in the aggregate, there remain large parts of the US that are not represented in the relevant literature. To ensure preference data were collected from underrepresented parts of the US, this study surveyed a nationally representative sample using a probability-based internet panel.

A national sample will include respondents with different connections to and experiences with surface waters, and therefore different preferences for water quality improvements. We account for preference heterogeneity in our choice data with two random parameter logit models estimated in WTP-space. One model estimated a full covariance matrix for the random parameters. The other estimated only the own-variance elements of the matrix. The results revealed important differences between the fully correlated model and the uncorrelated model. A likelihood ratio test reveals that estimating the full covariance matrix for the random parameters improves model fit substantially, indicating that individual preferences across attributes are correlated. The implications for marginal WTP estimates could be meaningful in a policy context. The fully correlated model generates central WTP estimates for local improvements that are about 20% greater than the uncorrelated model, however the distance gradient is steeper.

The uncorrelated model does not provide useful information on market extent for recreation benefits. The correlated model, however, generates a central estimate of 135 miles and 95% confidence that WTP for recreation becomes negligible within 309 miles. These results are consistent with previous findings and the standard assumption of maximum driving distance for a single-day recreation trip. Recent studies by Vossler et al. (2023) and Johnston et al. (2023) explore the spatial dimensions of WTP for water quality improvements. While both studies find evidence that respondents are willing to pay more for local improvements than for improvements at greater distances from their homes, the study designs do not provide sufficient information to identify an extent of market for water quality benefits. Our results for the extent of the market for recreational benefits will complement the qualitative results of other studies and provide empirical support for an important feature of benefit cost analysis of CWA regulations.

Our survey asked respondents to distinguish between improvements in recreation experiences and increases in aquatic biodiversity. We do not claim that WTP for biodiversity perfectly corresponds to nonuse or existence value. However, decomposing total WTP into recreation and biodiversity components may have some practical advantages over a use and nonuse decomposition. A common method to isolate use value from nonuse value is to include questions about recreation behavior and estimate WTP for users separately from nonusers (e.g., Hanley et al. 2003; Johnston et al. 2005). However, users may also hold nonuse value for environmental endpoints that are distinct from those that provide use value. Similarly, responses from nonusers may reflect option values that are derived from endpoints associated with use values. By using different environmental endpoints as attributes in the choice experiment, we have developed a framework in which valuing recreation and biodiversity in a separable way provides the means for a more refined approach to benefits estimation than if all benefits were captured by a single measure of environmental quality. By interacting the biodiversity and recreation attributes with distance, we find that the central estimate for extent of the market for biodiversity benefits is about 44% greater than that for recreation benefits.

The findings of this study imply that a closer examination of some standard assumptions of meta-analytic benefit transfer for CWA regulations may be in order. First, it appears that the assumed extent of market for all water quality benefits of 100 miles may be too low. Second, the assumption that all water quality benefits can be captured with a single water quality metric, which implicitly assumes that all sources of value are proportionally affected by policy and equally valued by households, could obscure important differences in benefits across policy options. A review of the primary studies included in the meta-analysis and an assessment of whether the environmental endpoints in those studies can be valued in a separable way is worth exploring. Finally, we found that allowing for the most general structure for preference heterogeneity, while computationally challenging, has meaningful impacts on WTP estimates and their precision.

References

Bateman, I. J., M. A. Cole, S. Georgiou, and D. J. Hadley. 2006a. "Comparing Contingent Valuation and Contingent Ranking: A Case Study Considering the Benefits of Urban River Water Quality Improvements." *Journal of Environmental Management* 79 (3): 221–31. https://doi.org/10.1016/j.jenvman.2005.06.010.

Bateman, Ian J, Matthew Cole, Philip Cooper, Stavros Georgiou, David Hadley, and Gregory L Poe. 2004. "On Visible Choice Sets and Scope Sensitivity." *Journal of Environmental Economics and Management* 47 (1): 71–93. https://doi.org/10.1016/S0095-0696(03)00057-3.

Bateman, Ian J., Brett H. Day, Stavros Georgiou, and Iain Lake. 2006b. "The Aggregation of Environmental Benefit Values: Welfare Measures, Distance Decay and Total WTP." *Ecological Economics*, Environmental Benefits Transfer: Methods, Applications and New Directions, vol. 60 (2): 450–60. https://doi.org/10.1016/j.ecolecon.2006.04.003.

Carson, Richard T., and Robert Cameron Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water." *Water Resources Research* 29 (7): 2445–54. https://doi.org/10.1029/93WR00495.

Corona, Joel, Todd Doley, Charles Griffiths, et al. 2020. "An Integrated Assessment Model for Valuing Water Quality Changes in the United States." Articles. *Land Economics* 96 (4): 478–92. https://doi.org/10.3368/wple.96.4.478.

Cummings, Ronald G., and Glenn W. Harrison. 1995. "The Measurement and Decomposition of Nonuse Values: A Critical Review." *Environmental and Resource Economics* 5 (3): 225–47. https://doi.org/10.1007/BF00691518.

Fisher, Ann, and Robert Raucher. 1984. "Intrinsic Benefits of Improved Water Quality: Conceptual and Empirical Perspectives." *Advances in Applied Micro-Economics* 3: 37–66.

Griffiths, Charles, Heather Klemick, Matt Massey, et al. 2012. "U.S. Environmental Protection Agency Valuation of Surface Water Quality Improvements." *Review of Environmental Economics and Policy* 6 (1): 130–46. https://doi.org/10.1093/reep/rer025.

Hanemann, W. Michael. 1984. "Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses." *American Journal of Agricultural Economics* 66 (3): 332–41. https://doi.org/10.2307/1240800.

Hanley, Nick, Felix Schläpfer, and James Spurgeon. 2003. "Aggregating the Benefits of Environmental Improvements: Distance-Decay Functions for Use and Non-Use Values." *Journal of Environmental Management* 68 (3): 297–304. https://doi.org/10.1016/S0301-4797(03)00084-7.

Hanley, Nick, Robert E. Wright, and Vic Adamowicz. 1998. "Using Choice Experiments to Value the Environment." *Environmental and Resource Economics* 11 (3): 413–28. https://doi.org/10.1023/A:1008287310583.

Hess, Stephane, and Kenneth Train. 2017. "Correlation and Scale in Mixed Logit Models." *Journal of Choice Modelling* 23 (June): 1–8. https://doi.org/10.1016/j.jocm.2017.03.001.

Hill, Ryan A., Chris C. Moore, Jessie M. Doyle, Scott G. Leibowitz, Paul L. Ringold, and Brenda Rashleigh. 2023. "Estimating Biotic Integrity to Capture Existence Value of Freshwater Ecosystems." *Proceedings of the National Academy of Sciences* 120 (18): e2120259119. https://doi.org/10.1073/pnas.2120259119.

Hole, Arne Risa, and Julie Riise Kolstad. 2012. "Mixed Logit Estimation of Willingness to Pay Distributions: A Comparison of Models in Preference and WTP Space Using Data from a Health-Related Choice Experiment." *Empirical Economics* 42 (2): 445–69. https://doi.org/10.1007/s00181-011-0500-1.

Johnston, Robert J., Kevin J. Boyle, Wiktor (Vic) Adamowicz, et al. 2017a. "Contemporary Guidance for Stated Preference Studies." *Journal of the Association of Environmental and Resource Economists* 4 (2): 319–405. https://doi.org/10.1086/691697.

Johnston, Robert J., Elena Y. Besedin, and Ryan Stapler. 2017b. "Enhanced Geospatial Validity for Meta-Analysis and Environmental Benefit Transfer: An Application to Water Quality Improvements." *Environmental and Resource Economics* 68 (2): 343–75. https://doi.org/10.1007/s10640-016-0021-7.

Johnston, Robert J., Elena Y. Besedin, and Benedict M. Holland. 2019. "Modeling Distance Decay Within Valuation Meta-Analysis." *Environmental and Resource Economics* 72 (3): 657–90. https://doi.org/10.1007/s10640-018-0218-z.

Johnston, Robert J., Klaus Moeltner, Seth Peery, et al. 2023. "Spatial Dimensions of Water Quality Value in New England River Networks." *Proceedings of the National Academy of Sciences* 120 (18): e2120255119. https://doi.org/10.1073/pnas.2120255119.

Keeler, Bonnie L., Stephen Polasky, Kate A. Brauman, et al. 2012. "Linking Water Quality and Well-Being for Improved Assessment and Valuation of Ecosystem Services." *Proceedings of the National Academy of Sciences* 109 (45): 18619–24. https://doi.org/10.1073/pnas.1215991109.

Loomis, John B. 2000. "Vertically Summing Public Good Demand Curves: An Empirical Comparison of Economic versus Political Jurisdictions." *Land Economics* 76 (2): 312–21. https://doi.org/10.2307/3147231.

Lupi, Frank, Joseph A. Herriges, Hyunjung Kim, and R. Jan Stevenson. 2023. "Getting off the Ladder: Disentangling Water Quality Indices to Enhance the Valuation of Divergent Ecosystem Services*." *Proceedings of the National Academy of Sciences* 120 (18): e2120261120. https://doi.org/10.1073/pnas.2120261120.

Mariel, Petr, and Jürgen Meyerhoff. 2018. "A More Flexible Model or Simply More Effort? On the Use of Correlated Random Parameters in Applied Choice Studies." *Ecological Economics* 154 (December): 419–29. https://doi.org/10.1016/j.ecolecon.2018.08.020.

McFadden, Daniel, and Kenneth Train. 2000. “Mixed MNL Models for Discrete Response.” *Journal of Applied Econometrics* 15 (5): 447–70. https://doi.org/10.1002/1099-1255(200009/10)15:5%253C447::AID-JAE570%253E3.0.CO;2-1.

Moeltner, Klaus, Roshan Puri, Robert J. Johnston, Elena Besedin, Jessica A. Balukas, and Alyssa Le. 2023. “Locally-Weighted Meta-Regression and Benefit Transfer.” *Journal of Environmental Economics and Management* 121 (September): 102871. https://doi.org/10.1016/j.jeem.2023.102871.

Moore, Chris C., Joel Corona, Charles Griffiths, et al. 2023. “Measuring the Social Benefits of Water Quality Improvements to Support Regulatory Objectives: Progress and Future Directions.” *Proceedings of the National Academy of Sciences of the United States of America* 120 (18): e2120247120. https://doi.org/10.1073/pnas.2120247120.

Moore, Chris, Dennis Guignet, Chris Dockins, Kelly B. Maguire, and Nathalie B. Simon. 2018. “Valuing Ecological Improvements in the Chesapeake Bay and the Importance of Ancillary Benefits.” *Journal of Benefit-Cost Analysis* 9 (1): 1–26. https://doi.org/10.1017/bca.2017.9.

Newbold, Stephen C., Patrick J. Walsh, D. Matthew Massey, and Julie Hewitt. 2018. “Using Structural Restrictions to Achieve Theoretical Consistency in Benefit Transfers.” *Environmental and Resource Economics* 69 (3): 529–53. https://doi.org/10.1007/s10640-017-0209-5.

Revelt, David, and Kenneth Train. 1988. “Mixed Logit with Repeated Choices: Households’ Choices of Appliance Efficiency Level.” *The Review of Economics and Statistics* 80 (4): 647–57.

Scarpa, R., M. Thiene, and K. Train. 2008. “Utility in Willingness to Pay Space: A Tool to Address Confounding Random Scale Effects in Destination Choice to the Alps.” *American Journal of Agricultural Economics* 90 (4). https://doi.org/10.1111/j.1467-8276.2008.01155.x.

Smith, V. Kerry. 1993. “Nonmarket Valuation of Environmental Resources: An Interpretive Appraisal.” *Land Economics* 69 (1): 1–26. https://doi.org/10.2307/3146275.

Train, Kenneth, and Melvyn Weeks. 2005. “Discrete Choice Models in Preference Space and Willingness-to-Pay Space.” In *Applications of Simulation Methods in Environmental and Resource Economics*, edited by Riccardo Scarpa and Anna Alberini. Springer Netherlands. https://doi.org/10.1007/1-4020-3684-1_1.

US EPA. 2009. *Environmental Impact and Benefits Assessment for Final Effluent Guidelines and Standards for the Construction and Development Category - November 2009*. EPA-821-R-09-012. U.S. Environmental Protection Agency Office of Water. https://www.epa.gov/sites/default/files/2015-06/documents/cd_envir-benefits-assessment_2009.pdf.

US EPA, OW. 2013. “National Aquatic Resource Surveys.” Collections and Lists. August 29. United States. https://www.epa.gov/national-aquatic-resource-surveys.

US EPA. 2024. *Benefit and Cost Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. EPA-821-R-24-006. United States Environmental Protection Agency Office of Water.

Vaughan, William J., and Clifford S. Russell. 1982. “Valuing a Fishing Day: An Application of a Systematic Varying Parameter Model.” *Land Economics* 58 (4): 450–63.

Viscusi, W. Kip, Joel Huber, and Jason Bell. 2008. “The Economic Value of Water Quality.” *Environmental and Resource Economics* 41 (2): 169–87. https://doi.org/10.1007/s10640-007-9186-4.

Vossler, Christian A., Christine L. Dolph, Jacques C. Finlay, David A. Keiser, Catherine L. Kling, and Daniel J. Phaneuf. 2023. “Valuing Improvements in the Ecological Integrity of Local and Regional Waters Using the Biological Condition Gradient.” *Proceedings of the National Academy of Sciences* 120 (18): e2120251119. https://doi.org/10.1073/pnas.2120251119.

Vossler, Christian A., Maurice Doyon, and Daniel Rondeau. 2012. “Truth in Consequentiality: Theory and Field Evidence on Discrete Choice Experiments.” *American Economic Journal: Microeconomics* 4 (4): 145–71. https://doi.org/10.1257/mic.4.4.145.

Supplementary Material

S.1 Supplementary Tables and Figures

Table S1.1. *WTP-Space Random Parameter Standard Deviations and Cholesky Matrix*

	(1) Uncorrelated Model: Standard Deviations	(2) Correlated Model: Cholesky Decomposition of Covariance Matrix					
Policy ASC	**644.2*****	**-489.3*****					
Area·ln(Recreation)	**174.7*****	-27.43	**-170.2*****				
Area·ln(Biodiversity)	**346.8*****	**-228.2*****	**-265.3*****	**223.9*****			
Area·ln(Distance)·ln(Recreation)	**26.19*****	**-88.63*****	**-25.63*****	**-47.85*****	-10.82		
Area·ln(Distance)·ln(Biodiversity)	8.182	7.004	3.389	**-60.75*****	**8.872****	**-16.01***	
Cost	**1.070*****	0.0149	**0.958*****	**-0.421*****	**0.618*****	0.0192	0.104

While the standard errors estimated in the uncorrelated model (column (1)) are comparable to the diagonal elements in the Cholesky matrix of the correlated model, the off-diagonal elements are not directly interpretable in their magnitude and are presented as results of the model estimation procedure. Statistical significance of the coefficients are represented by asterisks where * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Table S1.2. *Preference-Space Model Results*

Mean	(1) Uncorrelated	(2) Correlated
Cost	0.00311***	0.00325***
	(0.0000825)	(0.0000859)
Policy ASC	0.0832*	0.152***
	(0.0395)	(0.0373)
Area·ln(Recreation)	0.699***	0.676***
	(0.0628)	(0.0636)
Area·ln(Biodiversity)	1.253***	1.303***
	(0.0875)	(0.0945)
Area·ln(Distance)·ln(Recreation)	-0.0962***	-0.153***
	(0.0177)	(0.0225)
Area·ln(Distance)·ln(Biodiversity)	-0.242***	-0.295***
	(0.0221)	(0.0250)
Observations	68064	68064
Pseudo R^2	0.208	0.211
AIC	36657.4	36512.4
BIC	36757.9	36704.1
Log lik.	-18317.7	-18235.2
Minutes to Converge	58.45	110.4

Table S1.3. *Preference-Space Random Parameter Standard Deviations and Cholesky Matrix*

	(1) Uncorrelated Model: Standard Deviations	(2) Correlated Model: Cholesky Decomposition of Covariance Matrix				
Policy ASC	**2.191*** **	**1.898*** **				
Area·ln(Recreation)	0.489	0.130	**-0.601*** **			
Area·ln(Biodiversity)	**-1.365*** **	**0.698*** **	**-1.178*** **	**-0.516* **		
Area·ln(Distance)·ln(Recreation)	**0.205** **	**0.200*** **	0.0387	**0.255*** **	-0.0629	
Area·ln(Distance)·ln(Biodiversity)	**0.217* **	0.0179	-0.0310	**0.270*** **	-0.0733	0.0352

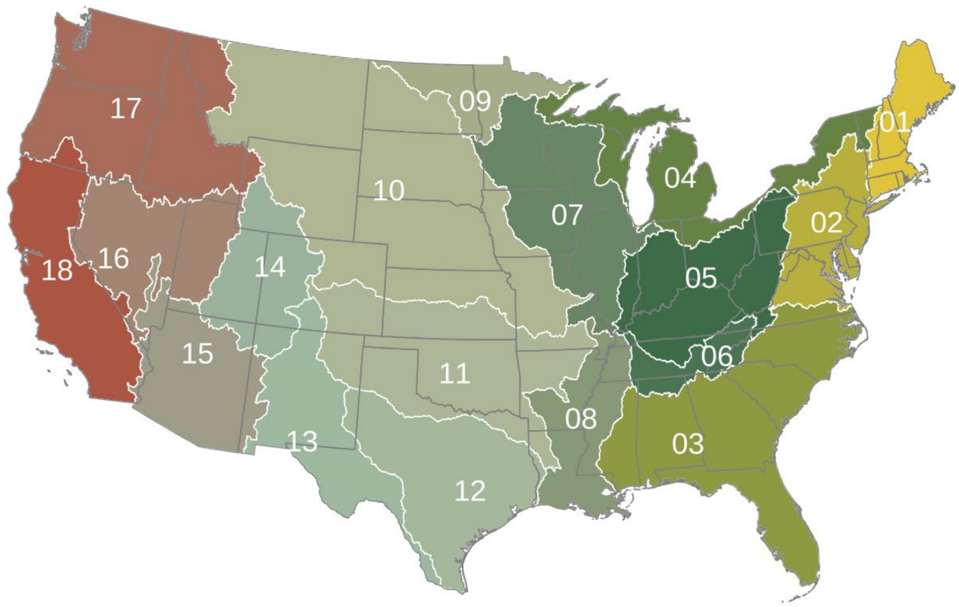
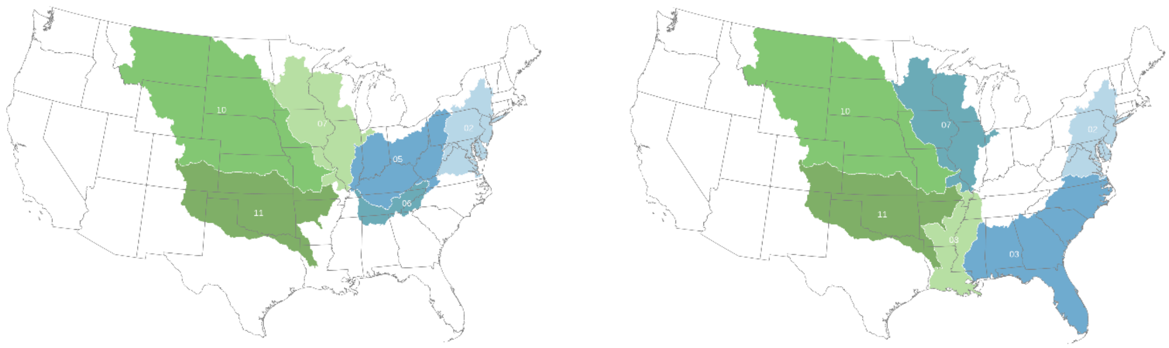


Figure S1.1. *HUC2s across the contiguous US.* There are 18 unique HUC2s across the contiguous US. The survey presents to respondents sets of 1, 3, and 6 for two scenarios: (1) three questions that include their home HUC2, and (2) three questions that does not contain their home HUC2. The numbering of the HUC2s, 1 through 18, is how the NHD identifies each HUC2.



Panel A: Plausible policy region

Panel B: Non-plausible policy region

Figure S1.2. *Example of a plausible and non-plausible policy region. While both these 6-HUC2 policy regions have a convex hull score above 0.6, the non-plausible policy region (right) was discarded during the final review from the three reviewers due to its peculiar shape which could lead to scenario rejection by respondents.*

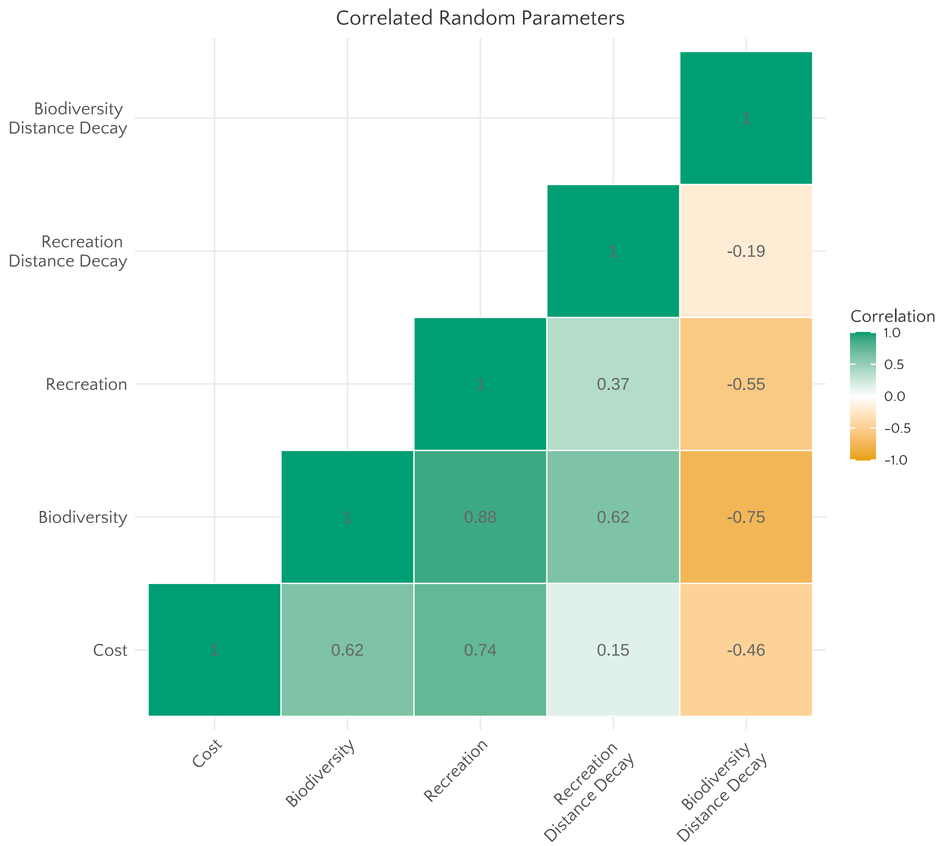


Figure S1.3. *Correlations between attribute coefficients in the fully correlated MXL model.* Correlations are drawn from the results of the Krinsky-Robb procedure using 10,000 simulations and collapsing across the second stage sampling uncertainty.

S.2 Demonstration of attenuation bias when correlation among preference parameters exists but model assumes no correlation

Consider the following highly simplified logit model with correlated preference parameters. There are two variables, x_1 and x_2. The preference parameters b_{1i} and b_{2i} are both either 0 or $2b$, with equal frequency in the population, and they are perfectly correlated:

$\Pr[b_{1i} = 0 \;\&\; b_{2i} = 0] = 0.5$ and $\Pr[b_{1i} = 2b \;\&\; b_{2i} = 2b] = 0.5$.

The true choice probability, accounting for preference parameter correlation, is

$$p = \frac{0.5}{1+e^{0}} + \frac{0.5}{1+e^{-2b(x_1+x_2)}}.$$

The misspecified choice probability, ignoring preference parameter correlation, is

$$\hat{p} = \frac{0.25}{1+e^{0}} + \frac{0.25}{1+e^{-2b(x_1+x_2)}} + \frac{0.25}{1+e^{-2bx_1}} + \frac{0.25}{1+e^{-2bx_2}}.$$

The log likelihood function for the misspecified model is

$$\hat{\ell} = y\ln(\hat{p}) + (1-y)\ln(1-\hat{p}),$$

where $y = 1$ indicates a "yes" response and $y = 0$ indicates a "no" response. The derivative of the log likelihood function with respect to b is

$$\frac{\partial\hat{\ell}}{\partial b} = \frac{y}{\hat{p}}\frac{\partial\hat{p}}{\partial b} + \frac{1-y}{1-\hat{p}}\left(-\frac{\partial\hat{p}}{\partial b}\right) = \left(\frac{y}{\hat{p}} - \frac{1-y}{1-\hat{p}}\right)\frac{\partial\hat{p}}{\partial b} = \frac{y-\hat{p}}{\hat{p}(1-\hat{p})}\frac{\partial\hat{p}}{\partial b}.$$

Since $\mathbb{E}[y] = p$, $\partial\hat{p}/\partial b > 0$, and $\hat{p}(1-\hat{p}) > 0$, the expected derivative will be negative—and so the misspecified model will underestimate b—when $\hat{p} > p$. Comparing the true and misspecified choice probabilities above, we find that $\hat{p} > p$ if and only if

$$\frac{0.5}{1+e^{-2bx_1}} + \frac{0.5}{1+e^{-2bx_2}} > p.$$

Define $A = e^{-2bx_1}$ and $B = e^{-2bx_2}$, so we can rewrite the above expression as

$$\frac{1}{1+A} + \frac{1}{1+B} > \frac{1}{2} + \frac{1}{1+AB}.$$

After some algebra, we can rearrange the above expression to give the following condition:

$$\underbrace{A + B + AB(AB - A - B)}_{C} < 1.$$

When all attributes are “goods,” we have $b > 0$, $x_1 > 0$, and $x_2 > 0$. These conditions imply $0 < A < 1$ and $0 < B < 1$. When $A = 0$ and $B = 0$, $C = 0$ so the condition holds. When $A = 1$ and $B = 1$, $C = 1$ so the condition holds weakly. $\partial C/\partial A = 1 + (2A(B-1) - B)B > 0$. $\partial C/\partial B$ is analogous, and so is also positive. Therefore, C must approach 1 from below monotonically as A or B or both increase from 0 to 1, so the condition always holds and the misspecified model underestimates b.

To prove attenuation rather than just downward bias, we must show that the expected derivative of the misspecified log likelihood function computed at $b = 0$ is positive. This will be true if $\hat{p}$ computed at $b = 0$, which is 0.5, is less than p, i.e.,

$$0.5 < \frac{0.5}{1 + e^0} + \frac{0.5}{1 + e^{-2b(x_1 + x_2)}}.$$

The first fraction on the right-hand side is 0.25 and the second fraction will be greater than 0.25 for all positive values of b, x_1, and x_2. Therefore, the misspecified model will produce an estimate of b that is biased down but greater than zero, i.e., the estimate will be attenuated.

Now suppose that the preference parameters are perfectly negatively correlated:

$\Pr[b_{1i} = 2b \,\&\, b_{2i} = 0] = 0.5$ and $\Pr[b_{1i} = 0 \,\&\, b_{2i} = 2b] = 0.5$.

The true choice probability, accounting for preference parameter correlation, is

$$p = \frac{0.5}{1 + e^{-2bx_1}} + \frac{0.5}{1 + e^{-2bx_2}}.$$

The misspecified choice probability, ignoring preference parameter correlation, is the same as before:

$$\hat{p} = \frac{0.25}{1 + e^0} + \frac{0.25}{1 + e^{-2b(x_1 + x_2)}} + \frac{0.25}{1 + e^{-2bx_1}} + \frac{0.25}{1 + e^{-2bx_2}}.$$

Using logic directly analogous to that in the case of positive correlation above, the expected derivative of the log likelihood function will be positive—and so the misspecified model will overestimate b—when $\hat{p} < p$. Comparing the true and misspecified choice probabilities, we find that $\hat{p} < p$ if and only if

$$\frac{1}{1 + e^{-2bx_1}} + \frac{1}{1 + e^{-2bx_2}} > \frac{1}{1 + e^0} + \frac{1}{1 + e^{-2b(x_1 + x_2)}}.$$

Using the same definitions as earlier, $A = e^{-2bx_1}$ and $B = e^{-2bx_2}$, we can rewrite the above expression as

$$\frac{1}{1 + A} + \frac{1}{1 + B} > \frac{1}{2} + \frac{1}{1 + AB}.$$

This is the same condition we found under the assumption of perfect positive correlation, so this expression will always be true for the same reasons given earlier. Therefore, if the preference parameters are perfectly negatively correlated, the misspecified model will overestimate b.

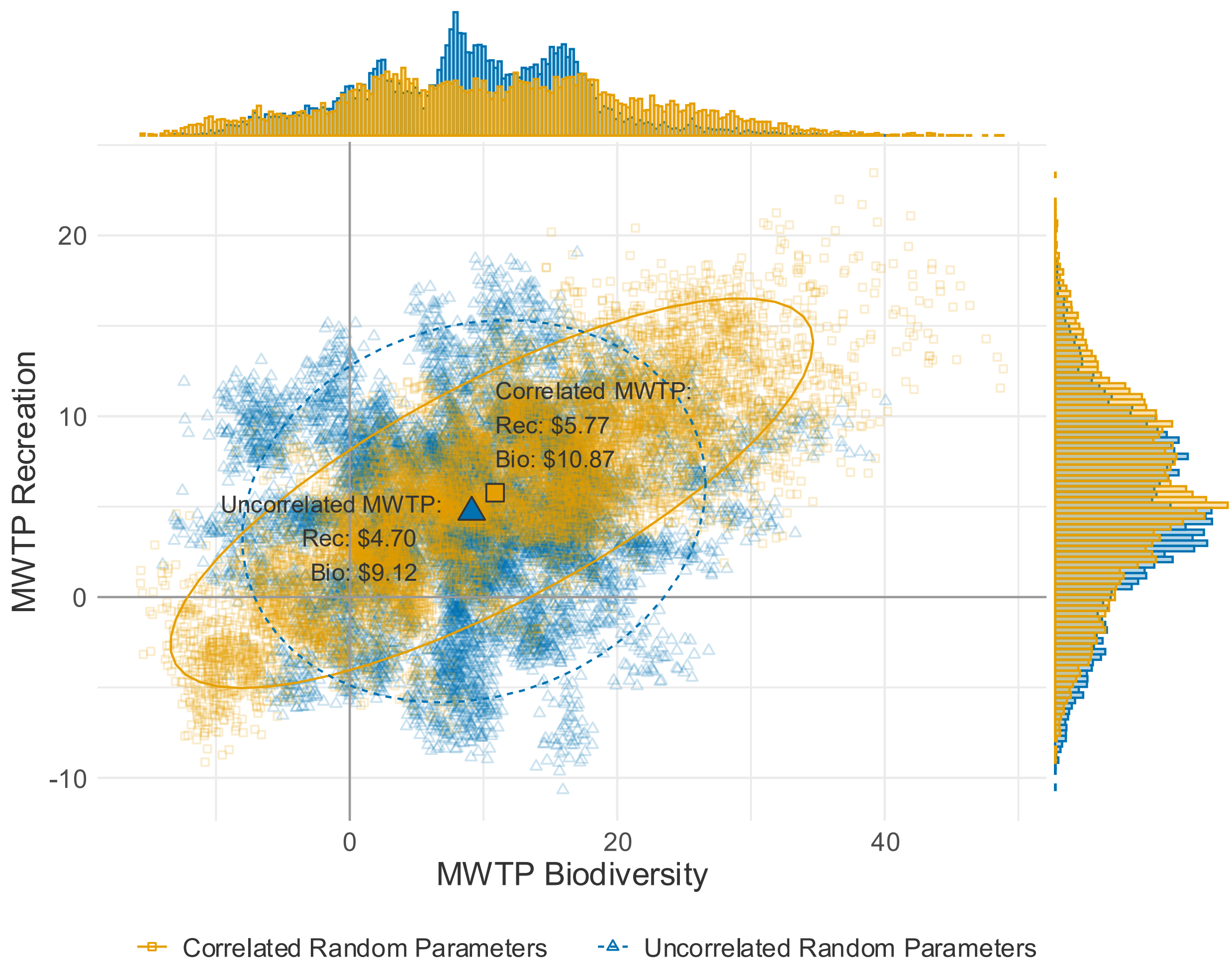


Figure S2.1. *An empirical presentation of attenuation bias on MWTP.* We recover a distribution of MWTP for both attributes under both a correlated and uncorrelated parameter specification, drawn from the results of the Krinsky-Robb procedure using 10,000 simulations. The resulting mean MWTP, taken across the 10,000 point estimates, suggests attenuation in the mean MWTP under the misspecified model that assumes no correlation between Recreation and Biodiversity, while the estimation correlation coefficient between the two is 0.88 (Fig. S1.3)—a strong and positive underlying correlation—consistent with the proof presented here in section S2.

S.3 Survey Screenshots

KnowledgePanel®

Need help?

Please enter a valid US Postal code.

What zip code do you currently live in?

1001

>>

KnowledgePanel®

Need help?

EPA United States Environmental Protection Agency

A survey on water quality in lakes, rivers, and streams

No personally identifiable information will be associated with your responses. The reports prepared from this study will summarize our findings and will not report individual responses.

This collection of information is approved by OMB under the Paperwork Reduction Act, 44 U.S.C. 3501 et seq. (OMB Control No. 2090-0032). Responses to this collection of information are voluntary (40 CFR 9). An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. The public reporting and recordkeeping burden for this collection of information is estimated to be 20 minutes per response. Send comments on the Agency's need for this information, the accuracy of the provided burden estimates and any suggested methods for minimizing respondent burden to the Regulatory Support Division Director, U.S. Environmental Protection Agency (2821T), 1200 Pennsylvania Ave., NW, Washington, D.C. 20460. Include the OMB control number in any correspondence.

>>

KnowledgePanel®

Need help?

This survey is being conducted by the **US Environmental Protection Agency** to collect information that may inform decisions affecting water quality and your household expenses.

The survey will:

1. Describe the impacts of pollution in lakes, rivers, and streams in the U.S.
2. Ask you to vote for or against potential policies that would improve the quality of some lakes, rivers, and streams. If implemented, policies would also increase costs to your household.
3. Ask some additional questions about water quality and your household.

>>

KnowledgePanel®

Need help?

A watershed is an area of land where all water flows into one major waterbody.

Policies will only impact lakes, rivers, and streams, where those policies are implemented.

This map shows the major **Watersheds** of the continental US.

KnowledgePanel®

Need help?

Good water quality in freshwater lakes, rivers, and streams allows for a full range of uses and can support a rich community of plants and animals.

In this survey we will ask about policies that would affect water quality in two ways:

- **Water Recreation** – The suitability of waterbodies for boating, fishing, and swimming.
- **Aquatic Biodiversity –** The ability of waterbodies to support healthy and diverse populations of naturally occurring plants and animals.

The policies described in this survey will ***not*** affect the following:

- **Drinking water** - the quality of drinking water in homes, schools, and public places would not be impacted by these policies.
- **The Great Lakes** – water quality in the Great Lakes would be managed under a different set of policies.
- **Oceans and coastal waters –** the policies you will consider would only affect freshwater lakes, rivers, and streams.

When making policy decisions that affect water quality in lakes, rivers, and streams, how important do you think the following should be?

Keeping waters clean for recreation like boating, fishing, and swimming:

- ○ Not at all important
- ○ Somewhat important
- ○ Very Important

Supporting diverse populations of native wildlife:

- ○ Not at all important
- ○ Somewhat important

Very Important

Keeping the cost low for taxpayers and consumers:

Not at all important

Somewhat important

Very Important

>>

KnowledgePanel®

Need help?

Before you vote on the policies, we will describe some important features we want you to consider when making your decision.

Those policy features are:

1. The amount of water that would be affected
2. The type of improvements you should expect
3. The locations where the policies would be implemented
4. The cost of each policy to your household

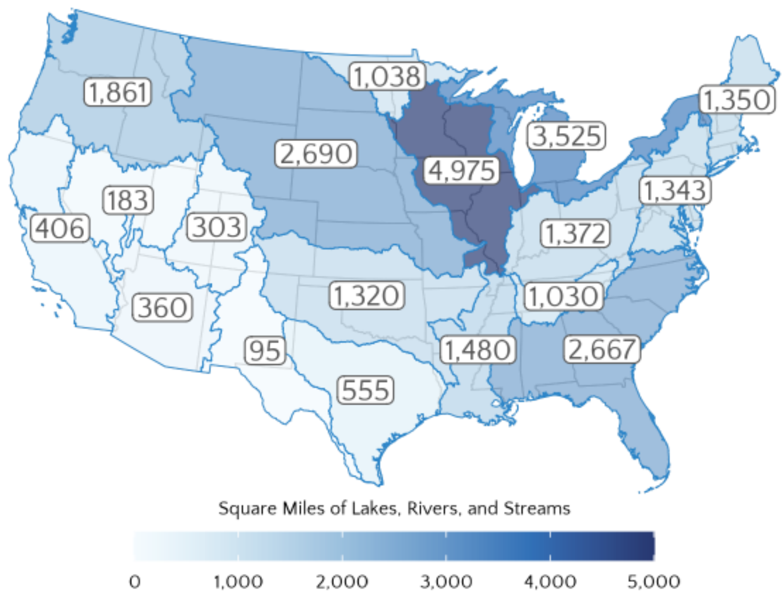
>>

KnowledgePanel®

Need help?

When describing policies, we will tell you the total square miles of lakes, rivers, and streams that could be improved by the policy.

This map shows the **Square Miles** of lakes, rivers, and streams, in each watershed.



KnowledgePanel®

Need help?

The **Water Recreation Score** is a measure of how suitable a lake, river, or stream is for different recreational activities.

As the score increases, waterbodies are suitable for more types of activities. The three activities this survey focuses on are:

- Swimming
- Fishing
- Boating

Have you ever gone boating in a lake, river, or stream?

- ◯ Yes
- ◯ No
- ◯ Not Sure

Have you ever gone fishing in a lake, river, or stream?

- ◯ Yes
- ◯ No

○ Not Sure

Have you ever gone swimming in a lake, river, or stream?

○ Yes

○ No

○ Not Sure

>>

KnowledgePanel®

Need help?

Water quality experts use a variety of scientific measurements to determine the **Water Recreation Score.**

Some of the measurements they use are:

- Fecal coliform - harmful bacteria from sewage
- Water clarity - how far below the surface we can see an object
- Algae growth - algae blooms can make some water recreation activities unpleasant or even dangerous

>>

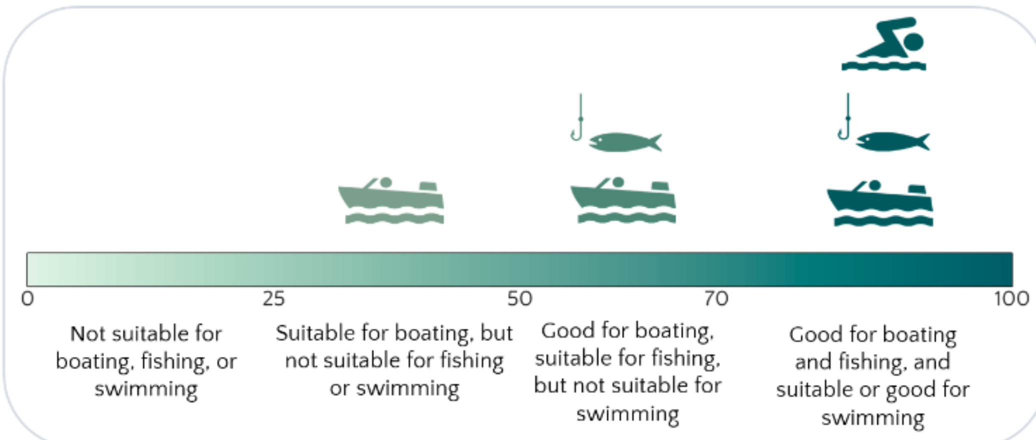
KnowledgePanel®

Need help?

The **Water Recreation Score** ranges from 0 to 100.

A waterbody can be *not suitable, suitable*, or *good* for a recreational activity.

- *Not Suitable* means that the minimum criteria for that activity are not met
- *Suitable* means that the waterbody meets the minimum criteria for that activity
- *Good* means that the waterbody exceeds the criteria for that activity and the experience is enhanced by good water quality



Would you consider swimming in a lake with a Water Recreation Score of **50** out of 100?

- ○ Yes
- ○ No
- ○ Not Sure

Would you consider swimming in a lake with a Water Recreation Score of **<u>70</u>** out of 100?

- ○ Yes
- ○ No
- ○ Not Sure

Would you consider swimming in a lake with a Water Recreation Score of **<u>90</u>** out of 100?

- ○ Yes
- ○ No
- ○ Not Sure

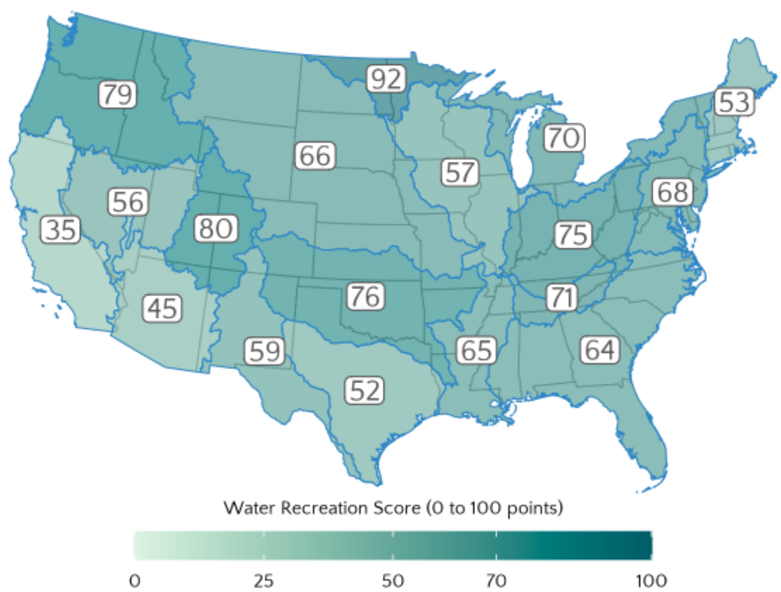
KnowledgePanel®

Need help?

When describing the policies, we will tell you the average score in the affected watersheds and how it would change under the new policy.

Individual lakes, rivers and streams may have scores that are higher or lower than the average in the watershed.

This map shows the average **Water Recreation Score** for each watershed.



KnowledgePanel®

Need help?

Did you purchase a freshwater or saltwater fishing license in your home state in 2023?

Please only answer Yes if you are certain that you purchased a fishing license last year.

- ◯ Yes
- ◯ No

Note: A fishing license is not always required to fish legally. For example, you may fish on private property and on public property during certain days of the year without purchasing a license.

>>

KnowledgePanel®

Need help?

Scientists use an **Aquatic Biodiversity Score** to measure the overall ecological health of a lake, river, or stream.

This score compares the number of different species that live in a water body to the number that would be expected to live there under the best possible conditions.

Scientists estimate the aquatic biodiversity score by counting the number of aquatic invertebrates that live in the water such as insects, worms, and snails.

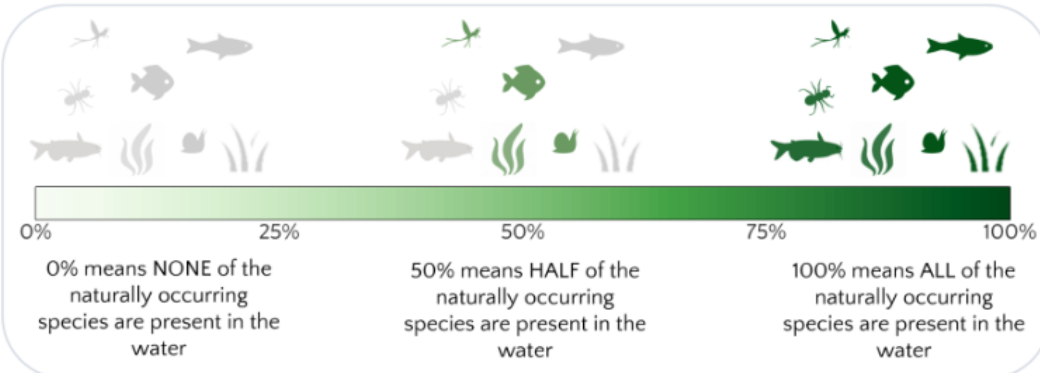
This measure is closely related to the biodiversity of a broad range of aquatic life, including plants, amphibians, fish, and shellfish.

>>

KnowledgePanel®

Need help?

The ***Aquatic Biodiversity Score*** ranges from 0% to 100%, as shown below.



Think about a lake, river, or stream that is close to your home. Do you think the aquatic biodiversity score in that waterbody is:

- ◯ Between 0% and 25%
- ◯ Between 25% and 50%
- ◯ Between 50% and 75%
- ◯ Between 75% and 100%
- ◯ Not Sure

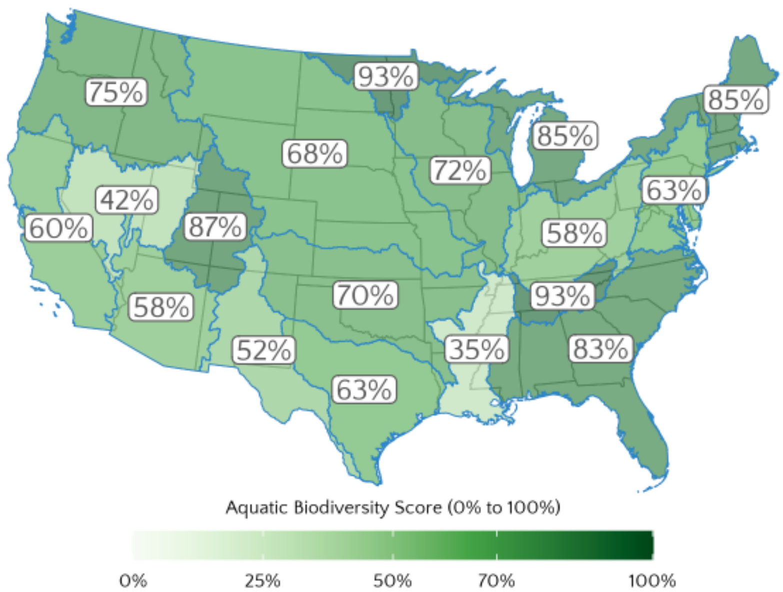
KnowledgePanel®

Need help?

When describing the policies, we will tell you the average score in the affected watersheds and how it would change under the new policy.

Individual lakes, rivers and streams may have scores that are higher or lower than the average in the watershed.

This map shows the average **Aquatic Biodiversity Score** for each watershed.



KnowledgePanel®

Need help?

Next, we will show you the 6 regions where the policies you will vote on would be implemented.

The policy regions will include one or more watersheds.

The policies will only improve water quality in the indicated regions.

>>

KnowledgePanel®

Need help?

Policy Region #1 out of 6

There are **1,030** square miles of lakes, rivers, and streams in this Policy Region (**4**% of US total).

The average Water Recreation Score is **71** out of 100.

The average Aquatic Biodiversity Score is 93%.

The nearest part of this Policy Region is about **574** miles from your home.
Your zip code is marked with a ★.

>>

KnowledgePanel®

Need help?

Policy Region #1 out of 6

During the past 12 months, have you taken a recreation trip to a freshwater lake, river, or stream in this Policy Region? Activities could include swimming, fishing, boating, hiking, viewing nature, etc.

- ○ Yes
- ○ No

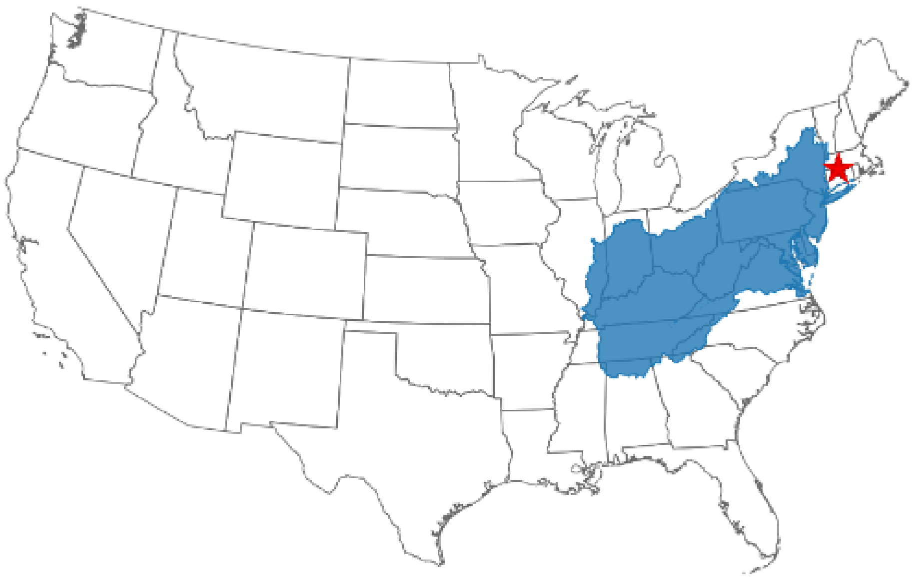
How likely are you to take a recreation trip to a freshwater lake, river, or stream in this Policy Region over the next 12 months?

- ○ Very likely
- ○ Maybe
- ○ Unlikely
- ○ Very unlikely

KnowledgePanel®

Need help?

Policy Region #2 out of 6



There are **3,744** square miles of lakes, rivers, and streams in this Policy Region (**14**% of US total).

The average Water Recreation Score is **71** out of 100. ?

The average Aquatic Biodiversity Score is **70**%. ?

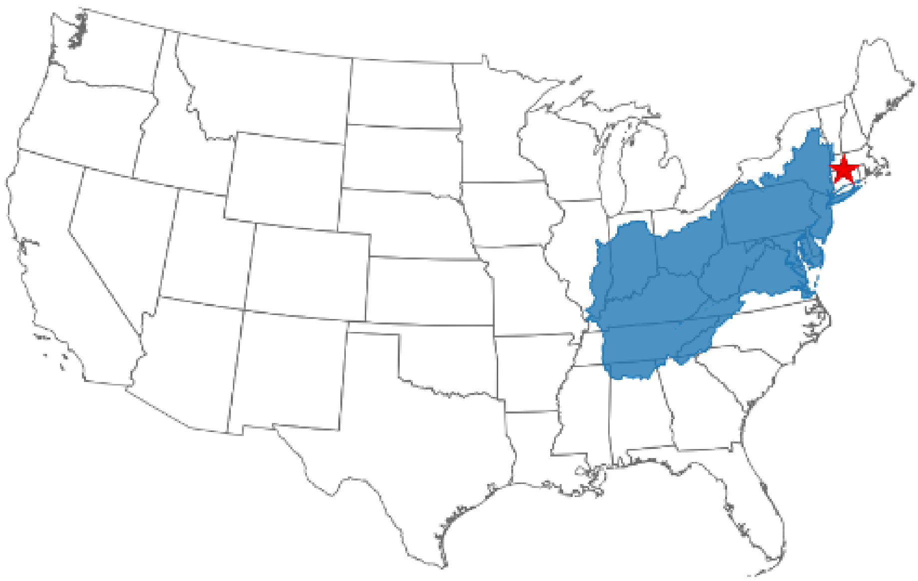
The nearest part of this Policy Region is about **40** miles from your home.
Your zip code is marked with a ★.

>>

KnowledgePanel®

Need help?

Policy Region #2 out of 6



During the past 12 months, have you taken a recreation trip to a freshwater lake, river, or stream in this Policy Region? Activities could include swimming, fishing, boating, hiking, viewing nature, etc.

- ◯ Yes
- ◯ No

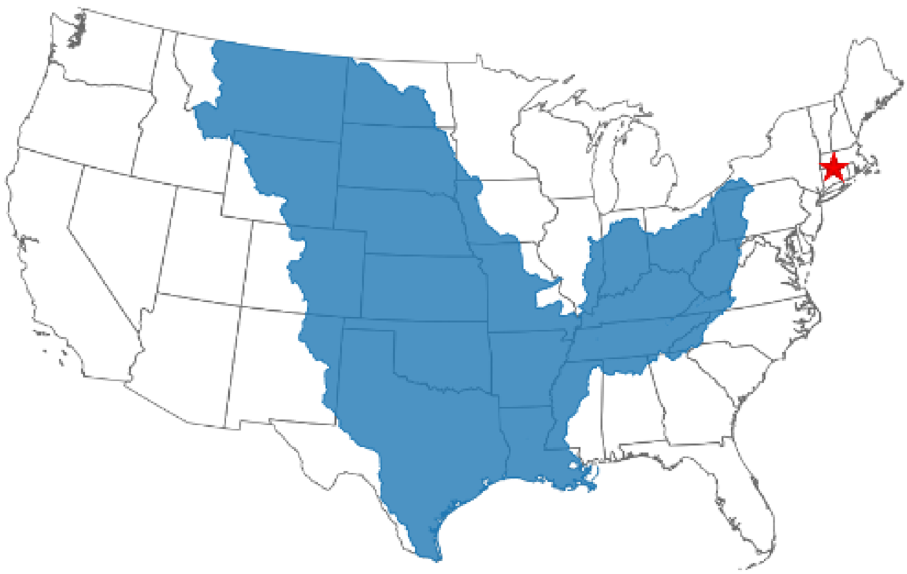
How likely are you to take a recreation trip to a freshwater lake, river, or stream in this Policy Region over the next 12 months?

- ◯ Very likely
- ◯ Maybe
- ◯ Unlikely
- ◯ Very unlikely

KnowledgePanel®

Need help?

Policy Region #3 out of 6



There are **8,447** square miles of lakes, rivers, and streams in this Policy Region (**32**% of US total).

The average Water Recreation Score is **68** out of 100.

The average Aquatic Biodiversity Score is **64**%.

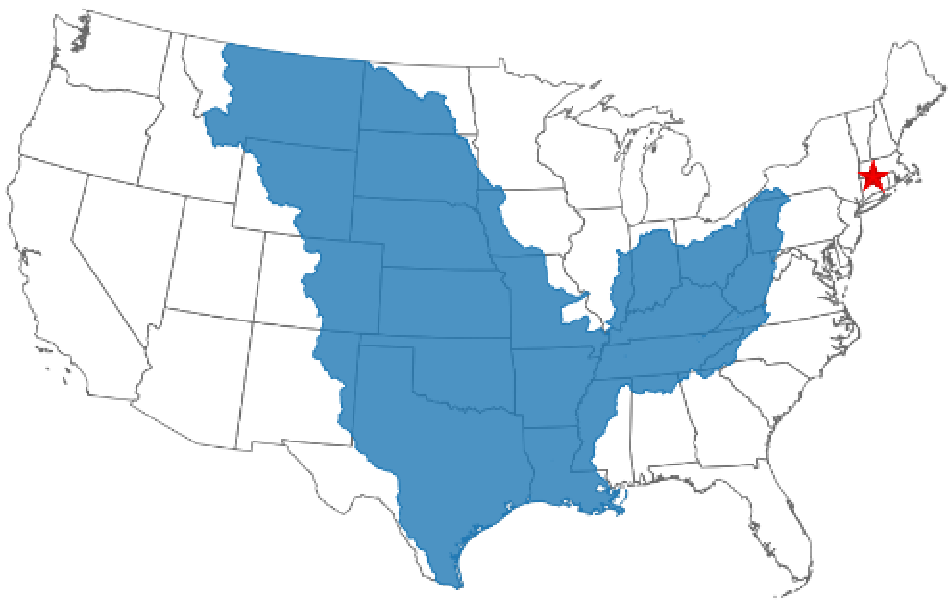
The nearest part of this Policy Region is about **267** miles from your home.
Your zip code is marked with a ★.

>>

KnowledgePanel®

Need help?

Policy Region #3 out of 6



During the past 12 months, have you taken a recreation trip to a freshwater lake, river, or stream in this Policy Region? Activities could include swimming, fishing, boating, hiking, viewing nature, etc.

- ◯ Yes
- ◯ No

How likely are you to take a recreation trip to a freshwater lake, river, or stream in this Policy Region over the next 12 months?

- ◯ Very likely
- ◯ Maybe
- ◯ Unlikely
- ◯ Very unlikely

>>

KnowledgePanel®

Need help?

Policy Region #4 out of 6

There are **1,350** square miles of lakes, rivers, and streams in this Policy Region (**5%** of US total).

The average Water Recreation Score is **53** out of 100.

The average Aquatic Biodiversity Score is **85%**.

The nearest part of this Policy Region is about **0** miles from your home.
Your zip code is marked with a ★.

>>

KnowledgePanel®

Need help?

Policy Region #4 out of 6

During the past 12 months, have you taken a recreation trip to a freshwater lake, river, or stream in this Policy Region? Activities could include swimming, fishing, boating, hiking, viewing nature, etc.

- ◯ Yes
- ◯ No

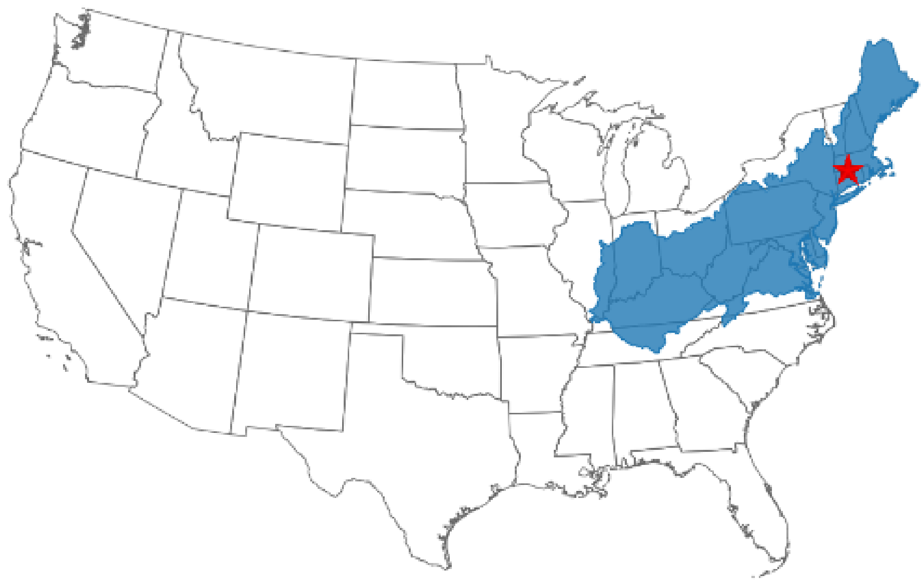
How likely are you to take a recreation trip to a freshwater lake, river, or stream in this Policy Region over the next 12 months?

- ◯ Very likely
- ◯ Maybe
- ◯ Unlikely
- ◯ Very unlikely

KnowledgePanel®

Need help?

Policy Region #5 out of 6



There are **4,065** square miles of lakes, rivers, and streams in this Policy Region (**15**% of US total).

The average Water Recreation Score is **65** out of 100.

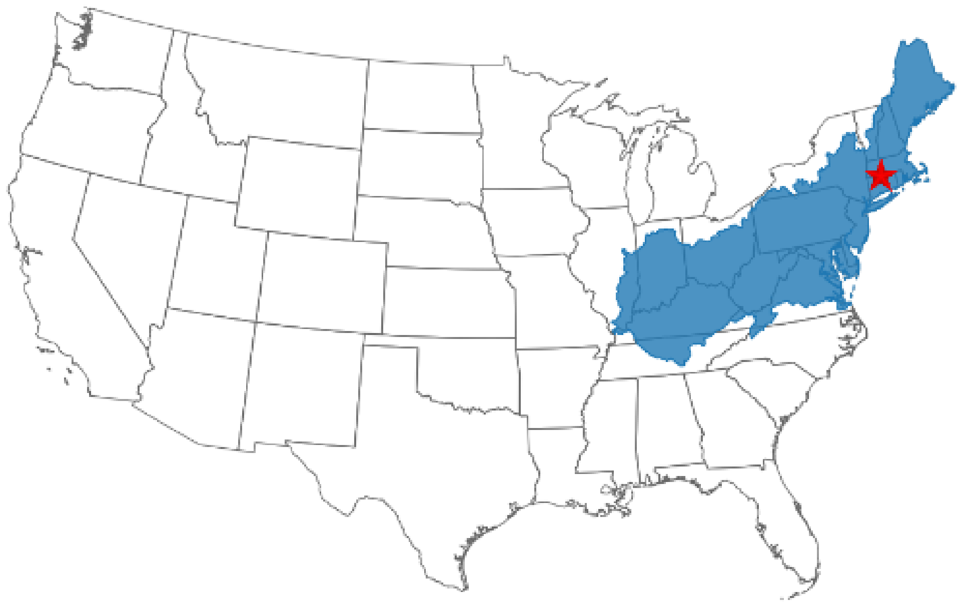
The average Aquatic Biodiversity Score is 69%.

The nearest part of this Policy Region is about **0** miles from your home.
Your zip code is marked with a ★.

KnowledgePanel®

Need help?

Policy Region #5 out of 6



During the past 12 months, have you taken a recreation trip to a freshwater lake, river, or stream in this Policy Region? Activities could include swimming, fishing, boating, hiking, viewing nature, etc.

- ◯ Yes
- ◯ No

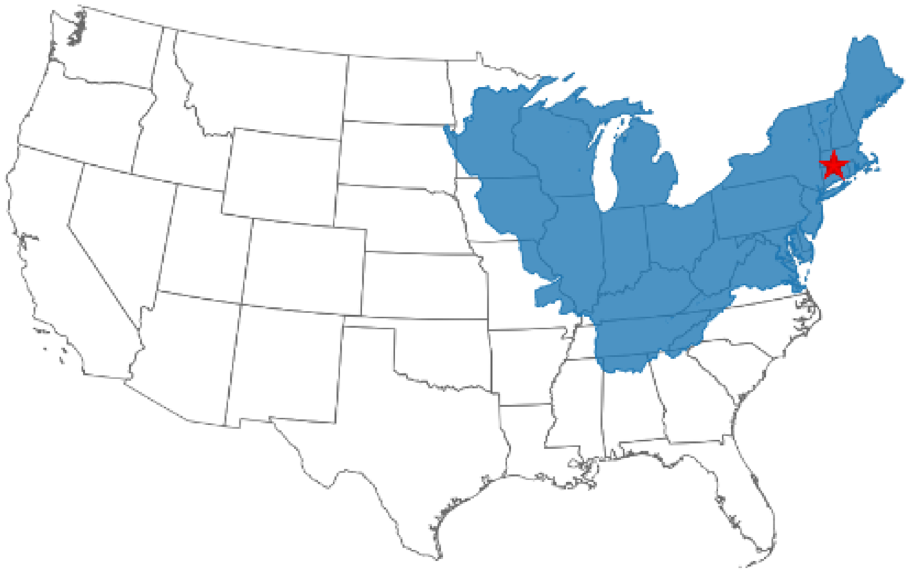
How likely are you to take a recreation trip to a freshwater lake, river, or stream in this Policy Region over the next 12 months?

- ◯ Very likely
- ◯ Maybe
- ◯ Unlikely
- ◯ Very unlikely

KnowledgePanel®

Need help?

Policy Region #6 out of 6



There are **13,594** square miles of lakes, rivers, and streams in this Policy Region (**51**% of US total).

The average Water Recreation Score is **64** out of 100. ❓

The average Aquatic Biodiversity Score is **76**%. ❓

The nearest part of this Policy Region is about **0** miles from your home.
Your zip code is marked with a ★.

>>

KnowledgePanel®

Need help?

Policy Region #6 out of 6

During the past 12 months, have you taken a recreation trip to a freshwater lake, river, or stream in this Policy Region? Activities could include swimming, fishing, boating, hiking, viewing nature, etc.

◯ Yes

◯ No

How likely are you to take a recreation trip to a freshwater lake, river, or stream in this Policy Region over the next 12 months?

◯ Very likely

◯ Maybe

◯ Unlikely

◯ Very unlikely

KnowledgePanel®

Need help?

Policies to meet water quality standards require different sources to reduce the amount of pollution they release into lakes, rivers, and streams.

Some examples are:

- More thorough treatment of sewage before releasing into waterways.
- Changing the way rainfall is handled around paved and developed areas.
- Stricter limits on pollution that industrial sources release into waterways.
- Reducing the amount of fertilizer, soil, and animal waste that runs off farmland.

These policies would have an immediate impact on water quality and improvements would be permanent.

>>

KnowledgePanel®

Need help?

If implemented, a policy would be paid for by increases in your federal, state and local taxes. The increases would last for **5 years** and would end after that time. The tax increase would begin in 2024 and end in 2028.

These additional tax payments would be used to:

- Pay for the up-front costs of the new practices such as purchasing and installing equipment and new construction.
- Pay into a fund that would be used to maintain improvements into the future even after the tax ends.

These additional taxes and the fund they go into would only be used to meet the new water quality requirements and would be prohibited from being used for anything else.

>>

KnowledgePanel®

Need help?

Your responses to this survey may inform policy decisions that, if implemented, will improve the quality of some lakes, rivers, and streams and increase costs to your household.

Remember, paying for water quality improvements will reduce the amount of money you have to spend on things like:

- Food and clothes
- Vacations
- Entertainment and recreation
- Donations to charitable organizations
- Resolving other environmental problems that you care about

Please keep these other expenses in mind when voting for or against a policy.

You will now be asked to consider six potential water quality policies.

>>

KnowledgePanel®

Need help?

Voting Instructions

A map showing where the policy would improve water quality.

Policy Region

The table describes conditions with and without the policy.

The **No Policy** column describes current conditions and will always have **zero cost**.

The **With Policy** column describes conditions under the policy and the increase in your household's taxes.

Policy Features	No Policy	With Policy
Water Recreation Score	66	69 (3-point improvement)
Aquatic Biodiversity Score	69%	72% (3% improvement)
Square miles of rivers, lakes, and streams affected	0 square miles	7,490 square miles (26% of US total)
Distance to nearest part of policy region	526 miles	526 miles
Increase in your annual taxes for 5 years	$0	$250 per year

Vote Here — No Policy ☐ — This Policy ☐

Click on the **No Policy** box or the **With Policy** box to cast your vote before advancing to the next screen.

>>

KnowledgePanel®

Need help?

! We would like to have your answer to this question.

Review the information below and then vote for "No Policy" or "This Policy" at the bottom of the screen.

Policy Region

Policy Features	No Policy	With Policy
Average Water Recreation Score ?	71	78 (7-point improvement)
Average Aquatic Biodiversity Score ?	70%	75% (5% improvement)
Square miles of lakes, rivers, and streams affected	0 square miles	3,744 square miles (14% of US total)
Distance to nearest part of policy region	40 miles	40 miles
Increase in your annual taxes for 5 years	$0	$270 per year

Vote Here

No Policy ○

With Policy ○

>>

KnowledgePanel®

Need help?

The next questions asks you to vote on a different policy.

Please disregard the previous question and now imagine the next policy is the only one available.

Do not add up water quality improvements or costs across different questions.

>>

KnowledgePanel®

Need help?

! We would like to have your answer to this question.

Review the information below and then vote for “No Policy” or “This Policy” at the bottom of the screen.

Policy Region

Policy Features	No Policy	With Policy
Average Water Recreation Score ?	68	69 (1-point improvement)
Average Aquatic Biodiversity Score ?	64%	71% (7% improvement)
Square miles of lakes, rivers, and streams affected	0 square miles	8,447 square miles (32% of US total)
Distance to nearest part of policy region	267 miles	267 miles
Increase in your annual taxes for 5 years	$0	$545 per year

per year

Vote Here

No Policy	With Policy
◯	◯

>>

KnowledgePanel®

Need help?

The next questions asks you to vote on a different policy.

Please disregard the previous question and now imagine the next policy is the only one available.

Do not add up water quality improvements or costs across different questions.

>>

KnowledgePanel®

Need help?

! We would like to have your answer to this question.

Review the information below and then vote for “No Policy” or “This Policy” at the bottom of the screen.

Policy Region

Policy Features	No Policy	With Policy
Average Water Recreation Score ?	64	64 (0-point improvement)
Average Aquatic Biodiversity Score ?	76%	79% (3% improvement)
Square miles of lakes, rivers, and streams affected	0 square miles	13,594 square miles (51% of US total)
Distance to nearest part of policy region	0 miles	0 miles
Increase in your annual taxes for 5 years	$0	$720 per year

Vote Here

	No Policy	With Policy
	◯	◯

>>

KnowledgePanel®

Need help?

The next questions asks you to vote on a different policy.

Please disregard the previous question and now imagine the next policy is the only one available.

Do not add up water quality improvements or costs across different questions.

>>

KnowledgePanel®

Need help?

We would like to have your answer to this question.

Review the information below and then vote for "No Policy" or "This Policy" at the bottom of the screen.

Policy Region

Policy Features	No Policy	With Policy
Average Water Recreation Score ?	65	70 (5-point improvement)
Average Aquatic Biodiversity Score ?	69%	76% (7% improvement)
Square miles of lakes, rivers, and streams affected	0 square miles	4,065 square miles (15% of US total)
Distance to nearest part of policy region	0 miles	0 miles
Increase in your annual taxes for 5 years	$0	$920 per year

Vote Here

	No Policy	With Policy
	◯	◯

>>

KnowledgePanel®

Need help?

The next questions asks you to vote on a different policy.

Please disregard the previous question and now imagine the next policy is the only one available.

Do not add up water quality improvements or costs across different questions.

>>

KnowledgePanel®

Need help?

! We would like to have your answer to this question.

Review the information below and then vote for "No Policy" or "This Policy" at the bottom of the screen.

Policy Region

Policy Features	No Policy	With Policy
Average Water Recreation Score ?	71	74 (3-point improvement)
Average Aquatic Biodiversity Score ?	93%	96% (3% improvement)
Square miles of lakes, rivers, and streams affected	0 square miles	1,030 square miles (4% of US total)
Distance to nearest part of policy region	574 miles	574 miles
Increase in your annual taxes for 5 years	$0	$95 per year

Vote Here

No Policy ○ With Policy ○

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Need help?

The next questions asks you to vote on a different policy.

Please disregard the previous question and now imagine the next policy is the only one available.

Do not add up water quality improvements or costs across different questions.

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Need help?

! We would like to have your answer to this question.

Review the information below and then vote for "No Policy" or "This Policy" at the bottom of the screen.

Policy Region

Policy Features	No Policy	With Policy
Average Water Recreation Score ?	71	78 (7-point improvement)
Average Aquatic Biodiversity Score ?	70%	75% (5% improvement)
Square miles of lakes, rivers, and streams affected	0 square miles	3,744 square miles (14% of US total)
Distance to nearest part of policy region	40 miles	40 miles
Increase in your annual taxes for 5 years	$0	$270 per year

Vote Here

	No Policy	With Policy
	◯	◯

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Need help?

Thinking about how you answered all the voting questions, please rate how much you agree or disagree with the following statements.

The data collected with this survey will be used to inform policy that would increase my taxes if implemented.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

It is important to improve water quality, no matter how high the costs.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

I voted as if the policies would actually achieve the improvements in water quality shown.

- ○ Strongly disagree
- ○ Somewhat disagree

- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I don't care much about water recreation or aquatic biodiversity, but I strongly support improving the environment in general.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I want better water quality, but my household should not have to pay additional taxes to get it.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I am certain that I voted the same way I would if given the same choices in reality.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I voted as if my household would actually face the costs shown.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I am against any more regulations or government spending.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree

○ Strongly agree

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Need help?

When choosing whether to vote for the policies or not, how much did each of the following policy features affect your votes?

Improvements in the Aquatic Biodiversity Score

- ◯ Large effect on my vote
- ◯ Moderate effect on my vote
- ◯ Some effect on my vote
- ◯ Little effect on my vote
- ◯ No effect on my vote

The cost to my household

- ◯ Large effect on my vote
- ◯ Moderate effect on my vote
- ◯ Some effect on my vote
- ◯ Little effect on my vote
- ◯ No effect on my vote

Distance of the policy region from your home

- ◯ Large effect on my vote
- ◯ Moderate effect on my vote

- Some effect on my vote
- Little effect on my vote
- No effect on my vote

The square miles of lakes, rivers, and streams (or % of U.S. total) in the policy region

- Large effect on my vote
- Moderate effect on my vote
- Some effect on my vote
- Little effect on my vote
- No effect on my vote

Improvements in the Water Recreation Score

- Large effect on my vote
- Moderate effect on my vote
- Some effect on my vote
- Little effect on my vote
- No effect on my vote

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Need help?

When choosing whether to vote for the policies or not, how much did each of the following affect your votes?

Improving the environment for others.

- ◯ Large effect on my vote
- ◯ Moderate effect on my vote
- ◯ Some effect on my vote
- ◯ Little effect on my vote
- ◯ No effect on my vote

The well-being of aquatic wildlife and plants.

- ◯ Large effect on my vote
- ◯ Moderate effect on my vote
- ◯ Some effect on my vote
- ◯ Little effect on my vote
- ◯ No effect on my vote

Trips I may take to visit lakes, rivers, or streams in the future.

- ◯ Large effect on my vote
- ◯ Moderate effect on my vote

○ Some effect on my vote

○ Little effect on my vote

○ No effect on my vote

Impacts on the economy and jobs.

○ Large effect on my vote

○ Moderate effect on my vote

○ Some effect on my vote

○ Little effect on my vote

○ No effect on my vote

Preserving the environment for future generations.

○ Large effect on my vote

○ Moderate effect on my vote

○ Some effect on my vote

○ Little effect on my vote

○ No effect on my vote

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