A National Study Valuing Ecological and Recreational Improvements in Water Quality

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Disclaimer

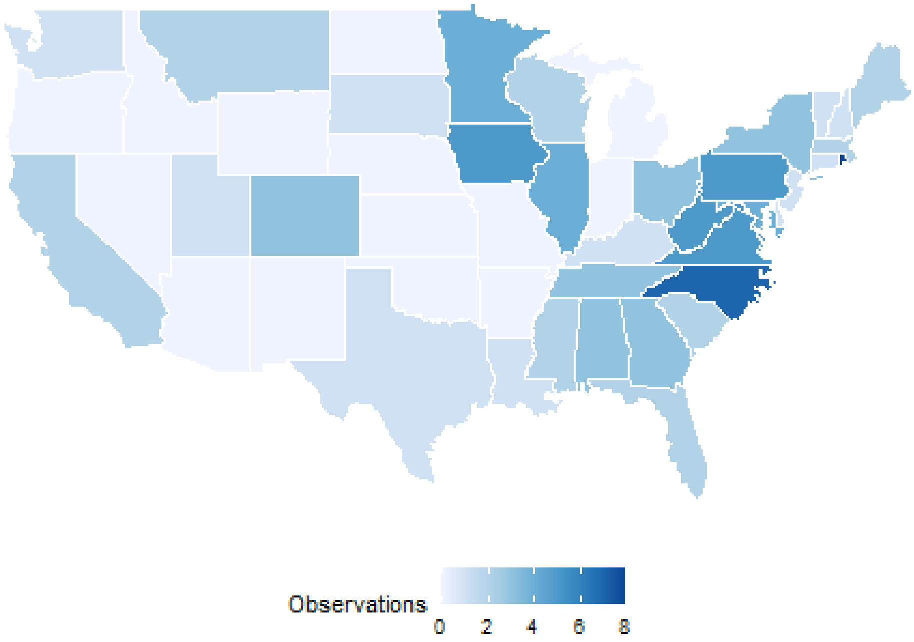
The views expressed are those of the authors and do not necessarily represent those of the U.S. Environmental Protection Agency (EPA). Although the research described in this paper may have been funded entirely or in part by the EPA, it has not been subjected to the Agency's required peer and policy review. No official Agency endorsement should be inferred. All errors are our own.

Results are preliminary and should not be cited

Project Summary

- National stated preference (SP) study to estimate economic benefits of surface water quality improvements
- Motivated by limitations of existing literature from which we can transfer values for regulatory analysis
  - Collective spatial coverage
  - Spatial scope of individual studies
  - Water quality attributes
- Electronic survey administered to probability-based internet panel targeting 6,000 completes
- Data were collected in Spring 2024

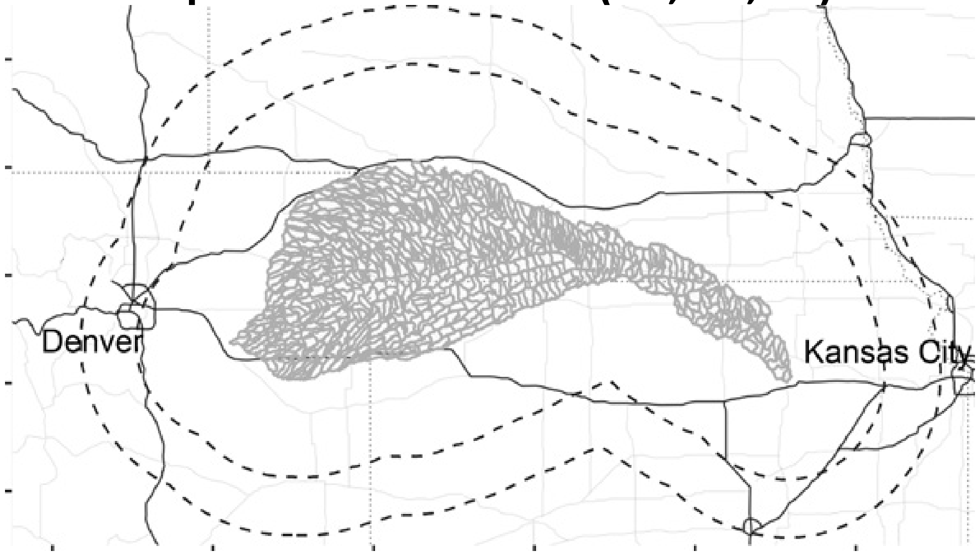
Count of Studies in Meta-Analysis by State



Primary Research Questions

- Spatial dimensions of willingness to pay (WTP) for water quality improvements
  - Extent of market
  - Distance decay
- How WTP differs between recreation and other sources of value along those spatial dimensions
  - WTP for recreation should be related to distance from household
  - Theoretical implications for existence value are unclear
- How WTP changes with the scope of the policy, i.e., the amount of water improved (we will not address this question today)

Republican River Basin (CO, NE, KS)



Extent of Market	Total Benefits
100km	$27.6 million
160km	$105 million

Source: Corona et al. 2020

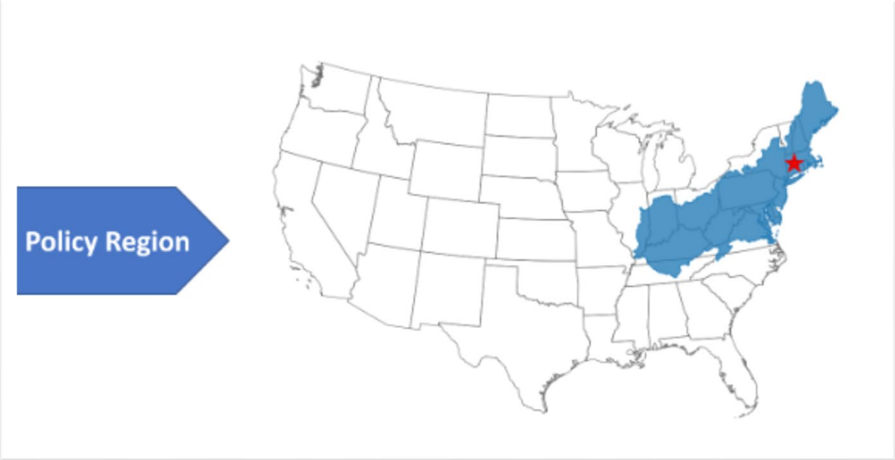
Experimental Design

To answer these questions, we need to:

1. Express changes in quality of recreation and other sources of value separately
2. Vary the distance of the improved waters from the respondents' locations
3. Vary the amount of water improved across policy scenarios
4. Vary the cost to households across policy scenarios

Each survey included 6 choice scenarios referencing different "policy regions"

- Three regions included the respondent's home
- The other three questions referenced remote regions
- Policy regions were made up of either one, two, or three contiguous HUC2s



Choice Attributes

- Water Recreation Score
  0-100: Boatable, Fishable, Swimmable

- Aquatic Biodiversity Score
  0%-100% of expected species found

- Surface area of water in policy region
  Square miles of lakes, rivers, and streams

- Linear distance to nearest part of region
  Zero for “home regions”

- Increase in annual taxes for 5 years

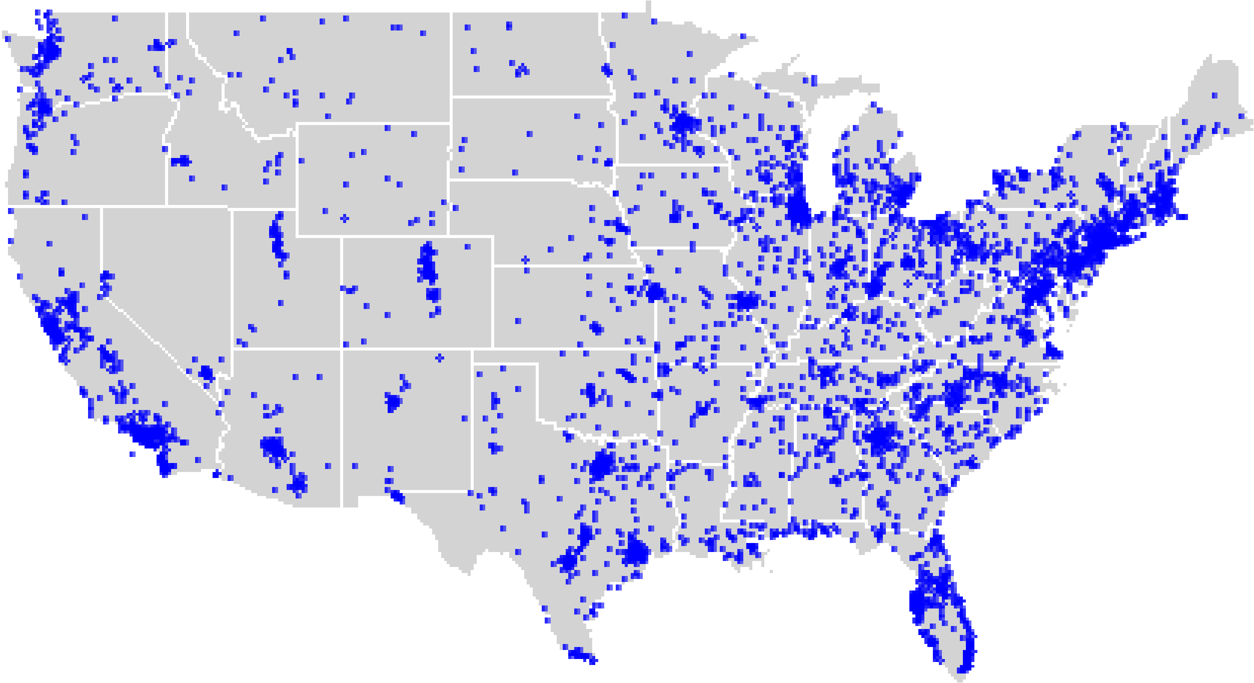
Policy Region

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

Data Summary

- 6,053 completed surveys collected through *KnowledgePanel* probability-based internet panel, maintained by Ipsos.
- 64.3% completion rate
- Sample weights calculated using
  - Age
  - Gender
  - Race/Ethnicity
  - Census Region-Metro Status
  - Education
  - Income
  - Fishing License Purchases

Respondent Locations



Random Utility Model

- Choice probabilities are a function of utility differences under status quo and policy scenarios

$$V(X_1, M - c \mid \phi, \beta, \lambda) - V(X_0, M \mid \beta, \lambda)$$

- Requires specifying indirect utility function that satisfies theoretical constraints

$$V_0 = A\left[\beta_R \ln(R) + \beta_B \ln(B) + \beta_{DR} \ln(R)\cdot\ln(D) + \beta_{BR} \ln(B)\cdot\ln(D)\right] + \lambda M + \varepsilon_0$$

Utility is scaled linearly by Area to satisfy adding up

Linear in parameters but Recreation and Biodiversity scores are log-transformed to reflect diminishing marginal utility

Interactions with logged Distance allow utility from environmental quality to vary with distance

Since the policy costs are small relative to total income, we can assume utility is linear in income

$$V_1 - V_0 = \phi + A\left[\beta_R \ln(\frac{R+\Delta R}{R}) + \beta_B \ln(\frac{B+\Delta B}{B}) + \beta_{DR} \ln(\frac{R+\Delta R}{R})\cdot\ln(D+1) + \beta_{BR} \ln(\frac{B+\Delta B}{B})\cdot\ln(D+1)\right] - \lambda c + \left(\varepsilon_1 - \varepsilon_0\right)$$

Estimation & Marginal WTP

- We estimate the model via mixed logit to allow for preference heterogeneity

$$\beta, \phi, \ln(\lambda) \sim MVN$$

We assume the attribute coefficients β and policy ASC ϕ are normally distributed over the population and allow full correlation.

We assume the marginal utility of income λ is log-normally distributed to ensure finite moments of the WTP distribution.

- Marginal WTP is the marginal rate of substitution between environmental *q*uality and inco*m*e

$$MWTP_q = \frac{\partial V}{\partial q} \Big/ \frac{\partial V}{\partial M}$$

$$MWTP_R = \frac{A\left(\beta_R + \beta_{DR} \cdot \ln(D)\right)}{-\lambda R}$$

$$MWTP_B = \frac{A\left(\beta_B + \beta_{DB} \cdot \ln(D)\right)}{-\lambda B}$$

- Unlike typical linear utility functions, MWTP is a function of Area, Distance, and baseline Recreation and Biodiversity scores

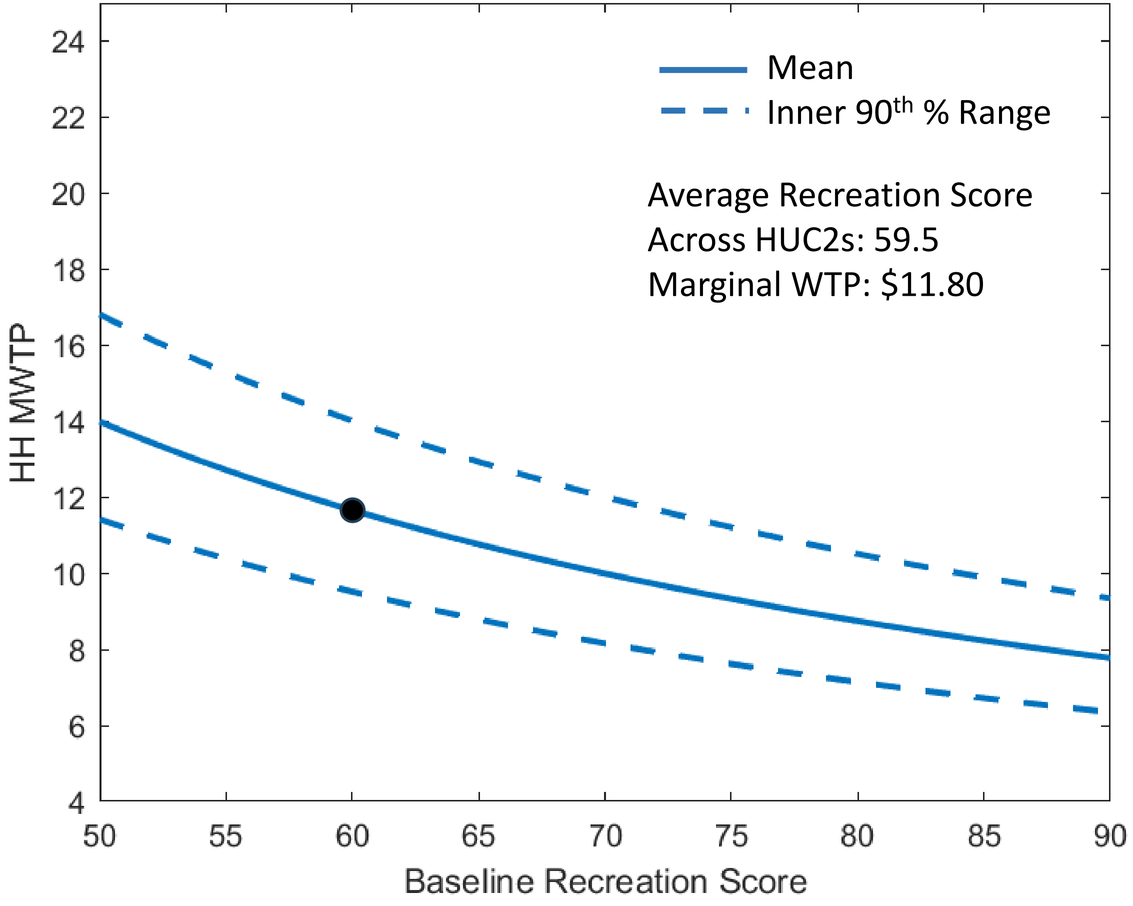
Mixed Logit Results

Variable	Coefficient Mean	Standard Deviation
Area-Scaled Recreation	1.468*** (0.146)	0.908** (0.337)
Area-Scaled Biodiversity	1.995*** (0.181)	1.758*** (0.244)
Recreation-Distance Interaction	-0.225*** (0.0319)	0.145 (0.153)
Biodiversity-Distance Interaction	-0.350*** (0.0374)	0.363*** (0.0879)
Policy Alternative Specific Constant	0.837*** (0.0752)	1.846*** (0.0751)
Annual Cost for 5 Years	-0.00413*** (0.0004)	0.00459*** (.0002)

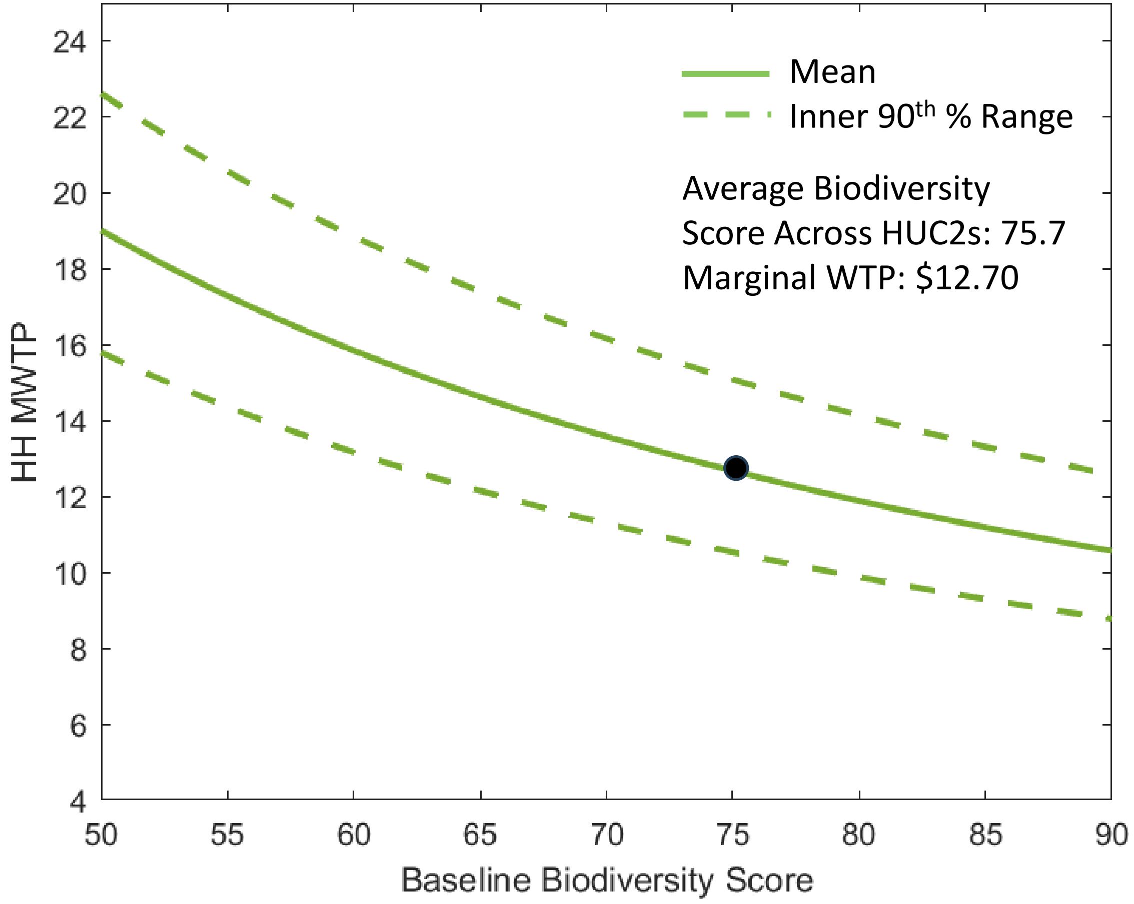
- Coefficient magnitudes suggest higher WTP for biodiversity in home regions, but it declines faster with distance than WTP for recreation.
- Positive and significant Policy ASC indicates tendency to choose policy alternative that is not explained by the model, but high SD estimate shows it's heterogeneous over the population.
- Recreation distance decay appears to be homogeneous over the population.

Household Marginal WTP

Mean of Marginal WTP for Recreation Improvement

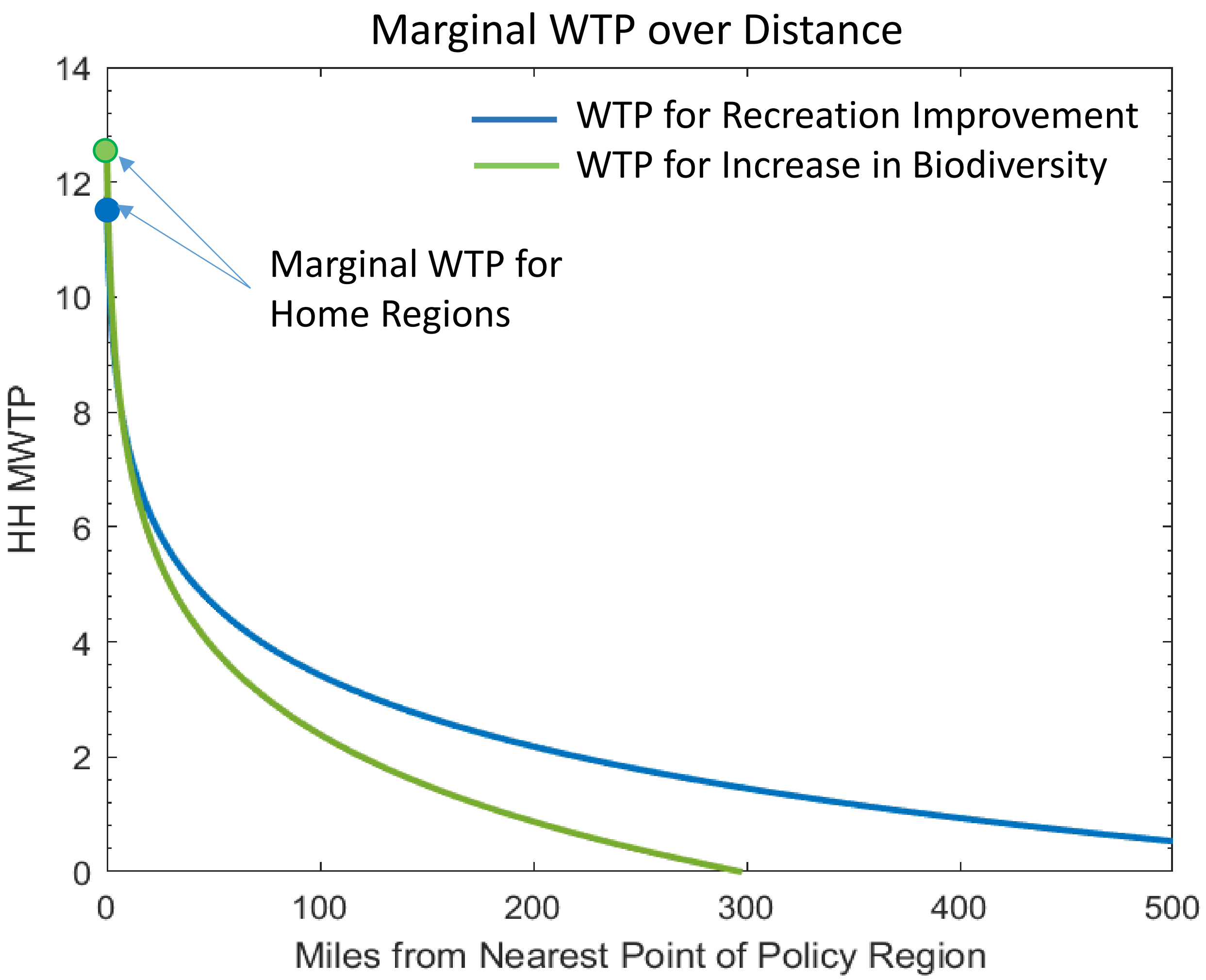


Mean of Marginal WTP for Increase in Biodiversity



- WTP values are for a home-region that contains 1,885 square miles of water (i.e., a single HUC2).
- WTP amounts are unadjusted from the five annual payments referenced in the question.

Extent of Market & Distance Decay



- Marginal WTP for biodiversity falls faster with distance than WTP for recreation
- The distance at which Marginal WTP reaches zero, or the "extent of market", is:

$$\text{Distance}_{MWTP=0} = \exp\left(-\frac{\beta_q}{\beta_{Dist}}\right)$$

Attribute	Extent of Market
Recreation	680 miles
Biodiversity	300 miles

Comparison with other WQ Valuation Studies

- Comparisons of household WTP across studies are complicated by different water quality metrics and treatments of spatial attributes.

Comparison Studies	Water Quality Change	Spatial Scope	Treatment of distance	Marginal WTP for a Local WQ Improvement	Marginal WTP for a Non-Local WQ Improvement
This study	1-point increase in two WQ indices	2-digit HUC	Miles from nearest point of policy region	$25	$6 at 100 miles
Vossler et al. (2023)	1-level improvement in BCG	4-digit HUC	Local vs non-local watersheds	$316	$165 outside home watershed
Johnston et al. (2023)	1-point increase in each of 3 water quality indices	2-digit HUC	10- and 25-mile radii from home	$46	Not estimated
Corona et al. (2020)	1-point improvement in WQI	4-digit HUC	62- and 100-mile radii from home	$4	Assumed $0
BenSPLASH estimate using Steam Electric ELG	1-point improvement in WQI	2-digit HUC	62- and 100-mile radii from home	$9	Assumed $0

Discussion

- Internet panel survey
  - Approved by OMB with pause in data collection for representativeness assessment
  - Using internet panel allowed household-level customization of surveys
- Extent of market & distance decay
  - Appears to be positive WTP beyond the 100-mile radius we use in our RIAs
  - Implied distance decay is sensitive to model specification and estimation approach
  - Estimation imposes restrictive form on effect of distance – more results to follow
- Difference between WTP for improvements in recreation and biodiversity
  - Marginal WTP for biodiversity is higher than recreation in home-regions but declines faster with distance
  - This is opposite of our expectations if biodiversity is a proxy for existence value
  - Can use data from auxiliary questions to explore this further

Appendix

Data Screening

- Dropped “speeders” who were in the fastest 2% of survey takers (less than 5.2 minutes)
- Combined choice behavior with debriefing responses to flag other respondents for protest responses, scenario rejection, or non-attendance to cost.

Debriefing Response	On all choice questions, chose…	Flagged Respondents
Strongly agreed with “It is important to improve water quality no matter how high the cost”	Policy Option	54
Strongly agreed with “I want better water quality, but I shouldn’t have to pay additional taxes to get it.”	Status Quo	116
Strongly disagreed with “I voted as if my household would actually face the costs shown.”	Policy Option	45
Total, including speeders		317 (5.2% of our sample)

Derivation of MWTP

$$V_0 = A\left[\beta_R \ln(R) + \beta_B \ln(B) + \beta_{DR} \ln(R)\cdot\ln(D) + \beta_{BR} \ln(B)\cdot\ln(D)\right] + \lambda M + \varepsilon_0$$

$$V_1 = \phi + A\left[\beta_R \ln(R+\Delta R) + \beta_B \ln(B+\Delta B) + \beta_{DR} \ln(R+\Delta R)\cdot\ln(D) + \beta_{BR} \ln(B+\Delta B)\cdot\ln(D)\right] + \lambda(M-c) + \varepsilon_1$$

$$V_1 - V_0 = \phi + A\left[\beta_R \ln(\frac{R+\Delta R}{R}) + \beta_B \ln(\frac{B+\Delta B}{B}) + \beta_{DR} \ln(\frac{R+\Delta R}{R})\cdot\ln(D) + \beta_{BR} \ln(\frac{B+\Delta B}{B})\cdot\ln(D)\right] - \lambda c + (\varepsilon_1 - \varepsilon_0)$$

$$= \phi + A\cdot\ln(\frac{R'}{R})\left[\beta_R + \beta_{DR}\ln(D)\right] + A\cdot\ln(\frac{B'}{B})\left[\beta_B + \beta_{BR}\ln(D)\right] - \lambda c + \varepsilon'$$

$$MWTP_q = \frac{\partial V}{\partial q} \Big/ \frac{\partial V}{\partial M}$$

$$MWTP_R = \frac{A(\beta_R + \beta_{DR}\cdot\ln(D))}{-\lambda R}$$

$$MWTP_B = \frac{A(\beta_B + \beta_{DB}\cdot\ln(D))}{-\lambda B}$$