Overlooked Benefits of Nutrient Reductions in the Mississippi River Basin

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Abstract

Improvements in local surface water quality in the Mississippi River Basin (MRB) can contribute to the regional environmental goals of reducing hypoxia in the Gulf of Mexico. To inform estimates of the benefits of water quality policy, we use a choice experiment survey in a typical sub-watershed of the MRB to estimate willingness to pay for local environmental improvements and helping to reduce hypoxia far downstream. We find that residents place large values on reduced local algal blooms, improved local fish populations and diversity, and meeting local commitments to help with the regional environmental problem.

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1 Introduction

Nutrient pollution and hydrological disruption cause water quality impairments throughout the Mississippi River Basin (MRB) and serious problems with widespread oxygen depletion called hypoxia in the Gulf of Mexico (U.S.EPA, 2008). The U.S. Environmental Protection Agency's 2008 Gulf Hypoxia Action Plan (GHP) tasked the 12 upstream states with the responsibility of reducing their transmission of nutrients such as nitrate-nitrogen and phosphorus by 45% by the year 2040. In an approach similar to the other states in the MRB, agencies in Illinois created the Illinois Nutrient Loss Reduction Strategy (INLRS) to coordinate efforts in that state to meet the nutrient reduction targets. The INLRS promotes voluntary efforts by farmers to reduce nutrient runoff into local waters, but a major policy change such as state subsidies will be needed to accomplish the 2040 goals (Coppess, 2016). State agencies and lawmakers are, therefore, interested in how much their own residents would support efforts to meet the INLRS targets. How much value do residents of the MRB gain from changes to water quality in their local watersheds, and to what extent do people in a state like Illinois value their local watershed's contribution to nonlocal improvements such as reducing the scale of the hypoxic dead zone in the Gulf of Mexico?

Integrated assessment of surface water quality policies and management actions can benefit from information about the total values of changes in water quality and the distribution of those values among different groups of people. A host of previous studies have shed light on the values people place on some dimensions of pollution reduction within the U.S. That work is surveyed in Bergstrom and Loomis (2017); meta-analyses of those studies have informed benefit transfer efforts to estimate aggregate benefits of water quality changes at the national level (Johnston et al., 2017; Moeltner, 2019). There is also a long line of research exploring the differences between use and nonuse values from local and nonlocal improvements in surface water quality in the U.S. (Greenley et al., 1981; Lant and Roberts, 1990; Carson and Mitchell, 1993; Johnston et al., 2003; Houtven et al., 2007) and recent work has emphasized the need to examine these relationships when considering the benefits from policies that reduce hypoxia in the Gulf of Mexico (Babcock and Kling, 2015; Keiser et al., 2019). This paper advances research on water quality valuation and integrated assessment with a choice experiment survey that estimates three conventional benefits of water quality improvements (improvements in local fish populations, fish diversity, and reductions in local algal blooms) and previously overlooked benefits (local contributions to reaching a regional nutrient reduction target) that arise from policies targeting hypoxia in the Gulf of Mexico.[1] We then illustrate how to use those values in a spatially disaggregate integrated assessment of a land-use management plan and explore two dimensions of value heterogeneity.

The bottom line of a benefit-cost analysis often aggregates benefits of environmental improvements to all people affected by the policy. However, many policy makers and interest groups are particularly concerned about the net impact of agricultural-environmental policies on rural residents (Gibbs, 2016; Farber, 2018), although evidence regarding preference heterogeneity between rural and urban areas is mixed. Some research shows that urban residents give more support for environmental policies than people in rural areas of the U.S. (Salka, 2001) and other research finds little difference between rural and urban residents

[1] Phaneuf (2002) estimates use values within a watershed for achieving total maximum daily load targets (nutrient reductions). We extend this analysis to estimate the local (within the watershed) benefits of contributing to regional, downstream (outside the watershed) nutrient reduction targets.

in their interests for environmental quality (Arcury and Christianson, 1993; Mobley, 2016). Racevskis and Lupi (2006) find rural residents in Michigan are less likely to support forest management efforts involving conservation, but conclude this is likely because those rural communities rely on forests products for production or exports. Melstrom et al. (2015) find that urban rivers and streams are less valued than rural rivers for recreational fishing, but do not estimate the differences in preferences between rural and urban recreationists themselves. We make a contribution to this discussion in the context of surface water quality by testing whether the values that people place on water quality improvements vary between people in rural areas and people in urban areas of the same watershed, located in the heart of the Mississippi River Basin (MRB).

Previous research in stated preference valuation shows that spatial dimensions matter in other important ways. First, willingness to pay (WTP) for an environmental improvement can vary widely across space (Johnston and Duke, 2007; Brouwer et al., 2010). In particular, people often have higher WTP when they are closer to the improvement (Sutherland and Walsh, 1985; Hanley et al., 2003; Czajkowski et al., 2017a; Glenk et al., 2019). Second, researchers have found that when estimating WTP for an environmental change that has a specific location within the landscape, the quality of responses from stated preference surveys depends on how clearly the survey describes the location of the change relative to the respondent (Schaafsma and Brouwer, 2013; Johnston et al., 2016). Our survey shows respondents exactly where they live relative to the proposed improvements. We also vary distance from the improvement experimentally across alternatives to identify how WTP varies with exogenously determined distance from the environmental good.

We find that people place positive and significant values on local water quality improvements and on helping to achieve basin-wide success in reducing hypoxia in the Gulf of Mexico. We do not find evidence of joint differences in preferences between rural and urban residents in the same watershed. We do, however, find that rural residents and people who are familiar with nutrient pollution problems place more value on moving away from the status quo conditions in the watershed regardless of the improvements a program produces. Finally, we demonstrate how these estimates can be used in spatially disaggregated integrated assessments, where benefit totals and distributions depend on spatial details of the improvements and the population that stands to gain.

2 Application

Freshwater systems throughout the U.S. Midwest have been severely altered due to decades of intensive agriculture production (Manifold and Swamp, 1998; Alexander et al., 2008). Tributaries located within the upper MRB carry excess nutrients, byproducts of intensive agriculture production, to the Mississippi River where they are eventually released into the northern Gulf of Mexico. An overabundance of these nutrients contributes to the large seasonal hypoxic dead zone off the cost of Louisiana and Texas (Diaz and Rosenberg, 2008; Rabalais et al., 2010; Rabotyagov et al., 2014).

This paper surveys people in the Upper Sangamon River Watershed (USRW) in central Illinois (Figure 1). This watershed is listed as a priority watershed due to its high levels of nitrate-nitrogen and phosphorus transmission within the MRB (U.S.EPA, 2008, 2013). The population in the study area is diverse and includes large swaths of rural landscape

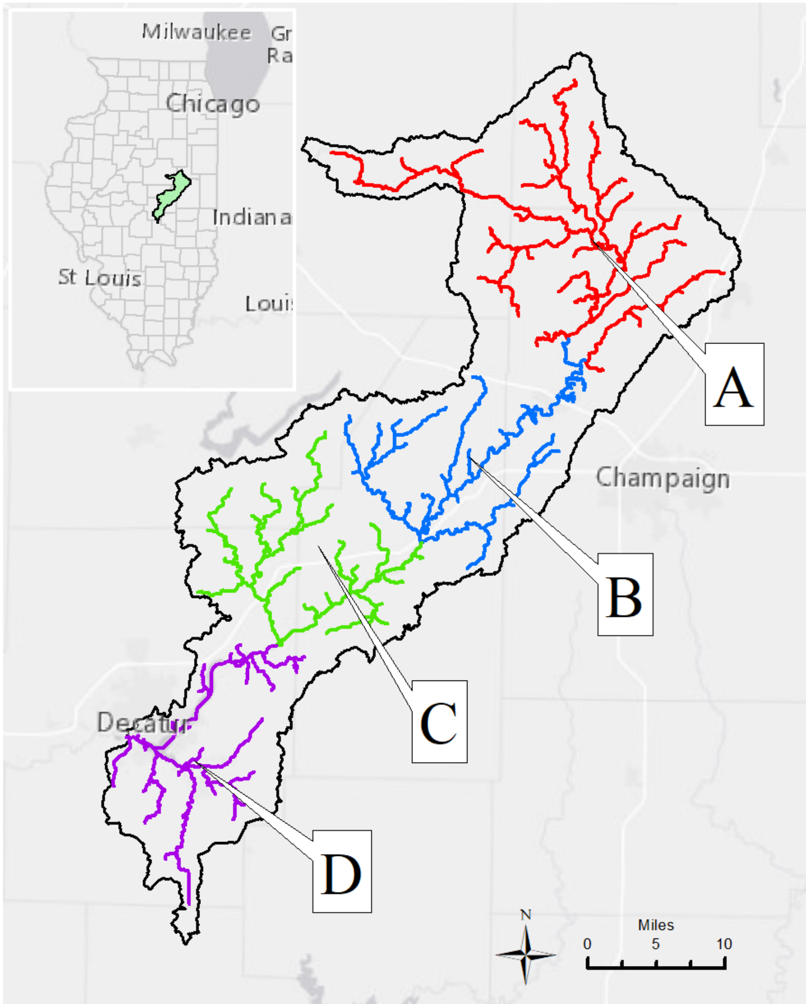


Figure 1: The Upper Sangamon River Watershed, located in central Illinois. It is listed as one of the EPA's prioritized watershed for high transmission of nutrients to the Gulf of Mexico. The four sections of river (A, B, C, D) are highlighted, and included as attributes on the choice card.

with several urban clusters. The characteristics of the USRW are representative of many watersheds in the MRB. This, this area provides an excellent setting for examining value differentials and policy-induced distributional effects across rural and urban populations in the MRB.

State agencies, Extension personnel, researchers at the University of Illinois, and people from groups like the Illinois Farm Bureau have been active communicating about the INLRS in the state, explaining the goals of the INLRS and how agricultural practices such as cover crops, reduced tillage, and riparian buffers can reduce nutrient loadings. It has been shown that stated preferences for environmental goods, and the underlying latent consequentiality of a survey, are more reliable when the policies that are being proposed include established practices—as is the case in our survey (Whitehead et al., 1995; LaRiviere et al., 2014; Czajkowski et al., 2015, 2017b; Needham and Hanley, 2020).

3 Choice experiment methodology

Choice experiment surveys are widely used to elicit preference for nonmarket environmental amenities such as water quality in rivers and streams. Using this platform allows us to model preferences in the random utility maximization (RUM) framework (McFadden, 1973). Preferences are characterized by estimating the probability a respondent chooses a scenario from a set of alternatives with varying levels of environmental quality (Hanley et al., 1998).

Each respondent began the survey by reading a consent form describing the purpose and nature of the survey and gave consent to continue with the survey. They were presented a background section that provided basic information about nutrient pollution problems in the MRB and the general nature of the improvements to be evaluated in the survey. After the respondent read the background section, they answered six choice questions and supplemental questions about personal characteristics.

We held a series of focus groups throughout the watershed with attendees from the general population. They were asked to take the survey and participate in a 30-minute follow-up discussion. In response to focus group feedback, we revised the survey to incorporate their suggestions regarding ambiguities in management mechanisms and wording of the attribute changes. We deployed the survey in a pre-test with 79 completed surveys (474 observations) and adjusted the levels of the cost attribute so that all levels were chosen with some frequency. Finally, we distributed the survey to a randomly selected group of respondents living within the watershed.

3.1 Consent and background

Several features of the survey were designed to increase respondent belief in consequentiality and prevent concern about agricultural regulation that might trigger protest responses. The consent form explained that "information from this survey will help policy makers, economists, and watershed managers choose how and how much to improve water quality in your area." The University of Illinois is regionally known to be connected to state policy makers and agricultural decision makers, supporting the claim that the survey will be consequential.

The background section of the survey tells respondents about the regional goal for nutrient loss reduction to reduce the size of the hypoxic zone and the nutrient pollution reduction target for Upper Sangamon River watershed's contribution to that goal. This section explains that the proposed environmental changes would come from changes in local agriculture such as expanded cover crops, reduced tillage, and riparian buffers; these voluntary and subsidized practices can reduce sediment and nutrient runoff from the surrounding area and are currently well-accepted and widely used by farmers throughout the region. The survey scenarios with water quality improvements from such changes in agricultural practices are within the range of future actions actually being discussed in the state, and thus not entirely hypothetical. In the survey background we explicitly state that an environmental change “will NOT result in a change in agricultural acreage or profits” to further prevent concern about the profitability of local agriculture from being confounded with the value people would gain from environmental improvements.[2]

3.2 Choice questions

A choice question is posed in a “card” that shows a set of scenarios and asks the respondent to choose the scenario they like most. In our survey, each scenario in a choice card has seven experimentally varied attributes. Four of those attributes relate to biophysical characteristics of water quality, two capture spatial heterogeneity, and one is the payment necessary to implement the proposed improvements. Table 1 summarizes each attribute, specifying the status quo and improved levels of each attribute. Our CE survey is tightly coupled to biophysical models of watershed improvements; the levels of the biophysical attributes were informed by the work of hydrological and ecological modelers in the USRW. Botero-Acosta et al. (2019) modeled predicted changes in nutrient levels throughout the USRW resulting from hypothetical changes in local agricultural practices. Andres et al. (2019) use these predicted changes in nutrient levels, climate, and data from 110 monitoring sites across the USRW, to model changes in aquatic biodiversity.

Three of the four biophysical attributes related to water quality are local and one is non-local. Number of fish species and population of fish (two independent attributes) are local quantitative measures summarizing the current average number of distinct species of fish (diversity) and populations of individual fish per 100 linear yards of river (density).

[2]The full survey text can be found in Appendix A.

Table 1: Survey Attributes and Levels

Attribute	Levels (SQ)	Description
Fish Species	(1), 2, 3, 5	Number of different recreational game fish species per 100 yards of river
Fish Population	(15), 30, 45, 150	Number of all fish (any species) per 100 yards of river
Algal Blooms (%)	(0), 25, 50, 75	Percent reduction in the frequency of local algal blooms
Nutrient Target (%)	(0), 50, 75, 100	Likelihood that nutrient runoff from this watershed is reduced by the target of "45 percent by 2040"
Location	A, B, C, D	The section of river where the improvements will be received
Distance	(varies)	The distance in miles from the respondent to the nearest point on the location attribute. This depends on where the respondent lives and which location is represented in the scenario.
Annual cost	(0), 5, 15, 30, 60	Payment vehicle: annual county fee (e.g. property tax)

Note: Status quo levels for each attribute are presented in parentheses. All attributes listed except for distance were included in the experiment design.

Dissanayake and Ando (2014) find that Illinois residents have positive value for both species diversity and faunal density in grassland birds; we test whether people value two such attributes of fish in inland streams. Local water quality improvement is captured as percent reductions in the frequency of occurrence of algal blooms in the local watershed including streams and ponds; that ranged from 0% to 75% reduction. The fourth nutrient-pollution attribute describes the likelihood that this watershed succeeds in meeting its targets for reductions in the level of nutrient transmission to the Gulf are met and ranges from 0% (definitely will not succeed) to 100% (certain to succeed).

Local water quality-related changes from a nutrient-loss reduction strategy are not uniform throughout a watershed, but rather depend on local details such as depth, flow rate, and shade. We partition the watershed into four equally sized sections. Each choice scenario alternative specified the section of the watershed in which water quality attributes improved. The location attribute varies as part of the experiment design; as a result, distance (measured as the distance from each respondent to the improved section of the watershed) also varies experimentally.

The final attribute in the choice scenarios is the household payment necessary to achieve the proposed improvements, cost. We use an increase in annual county fees as the payment vehicle, verifying with focus groups that this is a salient and credibly binding mechanism for payment. The survey states that the fee will be passed on to renters through an annual increase in rent charged by the landlord.[3] Figure 2 shows that all attribute levels were chosen with some frequency by respondents

We designed the survey to increase estimation efficiency while maintaining reliability in WTP estimates. In theory, choice experiments are only demand revealing if they are incentive compatible (Carson and Groves, 2007) and while a dichotomous choice design (one status quo and one alternative) is often argued to be incentive compatible, trichotomous choice (one status quo and two alternatives) is not. However, trichotomous choice increases the amount of information recovered from each survey response and some research shows that values are similar between the two mechanisms (Collins and Vossler, 2009). Thus, we include two alternatives along with the status quo on every choice card.

In stated preference research, hypothetical bias can influence estimates of WTP

[3] An example of a survey is in Appendix A.

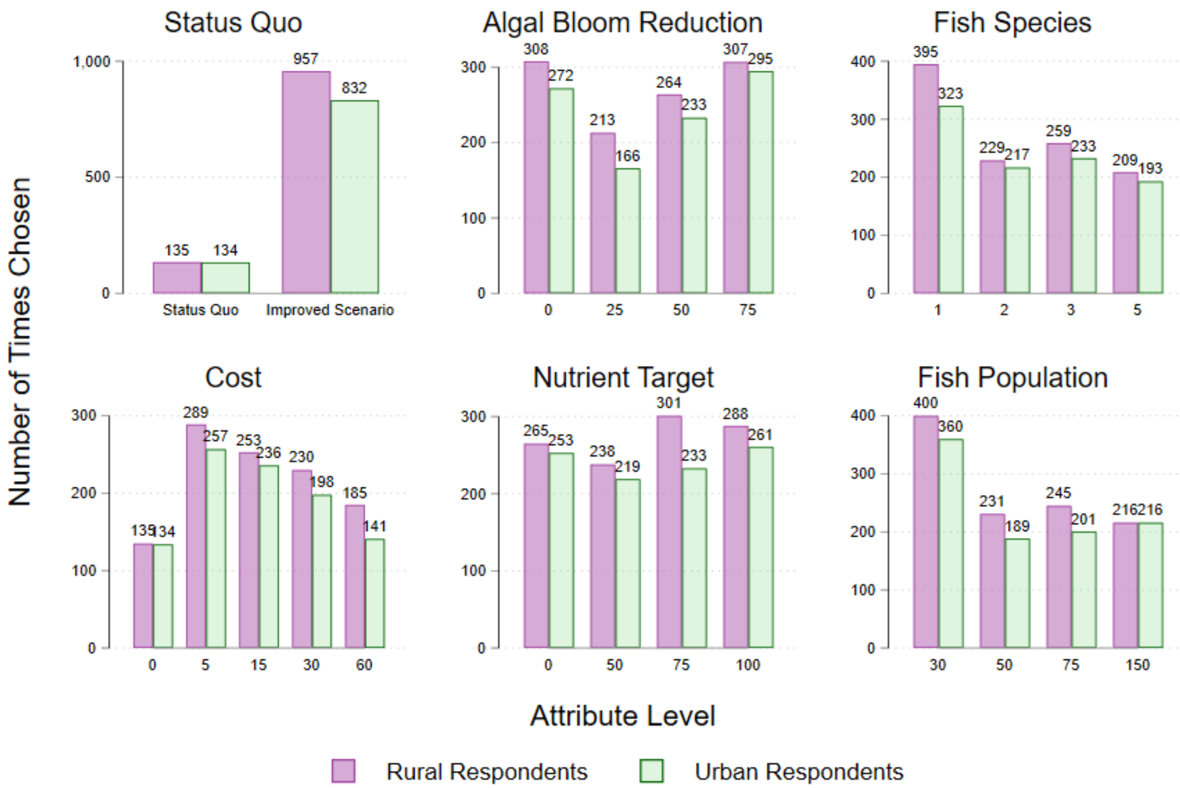


Figure 2: Frequency of attribute levels in the chosen alternative from each choice card. Status quo levels of each attribute are represented in the far-left column of each plot. Fish species and fish population are more represented by the status quo level than the other four attributes.

(Cummings et al., 1995; Cummings and Taylor, 1999), we include a modified cheap talk script in the information section of the survey and an opt-out reminder on each choice card to mitigate such bias (Ladenburg and Olsen, 2014).[4] After each choice card, we also include certainty questions asking how sure the respondent was of the selection they just made (Ready et al., 2010; Penn and Hu, 2020).[5]

[4]The cheap talk script included in the information section read: "Experience from previous similar surveys is that people often say they would be willing to pay more money for something than they actually would. For example, in one study, 80% of people said they would buy a product, but when a store actually stocked the product, only 43% of people actually bought the new product. It is important that you make each of your upcoming selections like you would if you were actually facing these exact choices in reality. Note that paying for environmental improvement means you would have less money available for other purchases."

[5]The question asked: "How confident are you in your answer?" With the range: "0 - not at all confident"; "1 - somewhat confident"; and "2 - very confident." Results and discussion are available in Appendix B).

3.3 Experimental design

We develop an optimal orthogonal choice matrix resulting in a D-efficient experiment design (Adamowicz et al., 1998b; Hensher et al., 2005; Street and Burgess, 2007; Ferrini and Scarpa, 2007). As recommended in Ferrini and Scarpa (2007), the design is optimized for main effects with zero priors ($\beta = 0$) to produce a reliable design when the true underlying data generating process is unknown and prior information on parameter values is not available. We produce 18 unique choice cards from the full factorial design, divided into three blocks of six choice cards. Respondents are randomly assigned one of the three blocks of six choice cards. The number of cards and alternatives are chosen to limit cognitive burden for the respondents while maintaining statistical power to estimate WTP (Swait and Adamowicz, 2001; Caussade et al., 2005).

After an initial design was created, we impose two additional conditions for the final design and re-run the design if the conditions are not met. The first condition is a no-free-lunch restriction (improvement in any attribute will come at a non-zero cost) and a welfare improving restriction (no improvement across all attributes cannot come at a cost). The second condition checks if any of the 18 resulting choice cards had an alternative that was strictly dominated by another alternative on the same card (e.g. a higher level of improvements at a lower cost). After seven iterations of the two-step procedure—each iteration consisting of many design iterations in the first step—all conditions are met.[6]

With the exception of location and distance, we allow the status quo level of each

[6]The design was generated in Stata using the package *dcreate* (Hole, 2015) with a wrapper that allows us to impose the additional conditions on the design.

attribute to be randomly included in the improved (non-status quo) scenarios. We include an alternative specific constant (ASC) in the experimental design (and regressions) to represent the status quo alternative on the choice card. The ASC captures preferences that the respondent may have for maintaining the status quo that are unobservable and not otherwise contained in our experimental design.

3.4 Individualized maps and choice card generation

Following recommendations highlighted in Johnston et al. (2016), each alternative on a choice card includes an individually geocoded map highlighting the section of river that would experience the improvements and a marker locating the respondent within the watershed relative to the proposed improvements. Each map is created for the individual respondent and geocoded using ArcPy integration in ArcGIS. Eight towns and city centers distributed throughout the watershed are geolocated to provide a "you are here" marker in each map. The total number of combinations of choice cards, alternatives, and geolocations results in 432 different individualized maps and 432 different levels for the distance attribute listed as an attribute on the choice card.

In order to accommodate the individualization of alternatives and choice cards, we create images of the choice cards by integrating the mail-merge capabilities of Microsoft Publisher, referencing an underlying matrix of all individualized combinations of the experiment design. The resulting pages of the document are then extracted by the survey protocol using Python to create an image for each page representing a choice card in the experiment. The 432 choice cards images are then stored online using Amazon Web Services and referenced in real-time while the respondent was taking the survey.

3.5 Other survey questions

We designed the survey instrument to test for potential preference heterogeneity between residents who identify as rural, and those who identify as urban. That characteristic was examined in two dimensions: 1) geographical affiliation; and 2) cultural affiliation. The first, geographical affiliation, is simply determined using the U.S. Census Bureau's classification of rural—a census block group area with less than 1,000 residents per square mile (Ratcliffe et al., 2016). Respondents who fit this designation are classified as living in a geographically rural area, all others are classified as living in an urban area. The second, cultural affiliation, is determined by the respondent's stated affiliation in the post-survey questionnaire. The question is phrased as: "Do you consider where you live to be rural?" Respondents in our sample overwhelmingly responded with a cultural affiliation that aligned with their geographical affiliation. Our design allows us to test the hypothesis that preferences for water quality are the same between those who live in a geographically and culturally rural area and those who live in a geographically and culturally urban area.

To understand other characteristics of the respondents in our survey sample, we ask two sets of personal questions. Three questions come before the choice questions and ask about the frequency with which people had seen algal blooms, how often respondents visit the river to go fishing, and how often they recreate nearby the river. A section after the choice questions contains common demographic and socioeconomic questions.

3.6 Survey administration

The survey was administered online using a Qualtrics panel of respondents through their survey interface, paired with additional JavaScript and HTML to incorporate the individualized choice cards.[7] Respondents were recruited from the 42 zip codes contained within the watershed. Once a respondent received an invitation to take the survey, they would arrive at the online interface where they were asked to enter their zip code. If the zip code was not one of the 42 qualifying, they would be screened and exited from the survey. The next step individualizing the CE was to ask respondents which of the eight locations (towns or city centers) they lived closest to. Their response would then cue the system to load a randomly ordered set of choice cards. Our final sample has complete responses from 343 individuals.

4 Econometric Framework

Following choice experiment methodology (Hanley et al., 1998), we assume that a respondent derives utility based on the observable characteristics contained within the choice card, and some characteristics unobservable to the researcher Specifically, U is the utility respondent i derives by choosing alternative j on choice card t:

$$U_{ijt} = -\alpha_i p_{jt} + \boldsymbol{\beta}_i' \boldsymbol{x}_{jt} + e_{ijt} \tag{1}$$

[7]The first wave of survey responses was collected from January, 2019, through February, 2019. A second collection period was administered January, 2020, through February, 2020.

where $\boldsymbol{x}$ is a vector of attributes, p is the price (cost) of the scenario, and e is the stochastic component capturing unobservable characteristics influencing the respondent's choice and is IID distributed extreme value. Included in $\boldsymbol{x}$ is an alternative specific constant (ASC) that is equal to 1 for the status quo alternative in each choice set, and 0 otherwise. β is the vector of preference coefficients, and α is the coefficient on cost. Both β and α are indexed to be respondent-specific when estimated using a random parameter logit model (Train, 1998).

The variance of error term also varies with each respondent such that: $Var(e_{ijt}) = k_i^2(\pi^2/6)$ where k is the scale parameter for respondent i. Variation in the error term can be attributable to scale heterogeneity or other forms of correlation between the model attributes, particularly so in panel (repeated choice occasion) settings such as ours (Swait and Louviere, 1993; Train and Weeks, 2005; Hess and Train, 2017). Dividing the preference parameters by the scale parameter where $\lambda_i = (\alpha_i/k_i)$ and $c_i = (\beta_i/k_i)$ results in a specification that has the same variance for all respondents:

$$U_{ijt} = -\lambda_i p_{jt} + \boldsymbol{c}_i' \boldsymbol{x}_{jt} + \varepsilon_{ijt} \tag{2}$$

where ε is IID type-one extreme value, now with a constant variance: $\pi^2/6$. With k in the denominator of each coefficient, allowing the coefficients to be independent (not correlated) would constrain the scale parameter to be constant for the sample while allowing the preference parameters to vary, or vice versa (Louviere et al., 2002). Equation 2 is the model in preference space (Train and Weeks, 2005). To avoid the postestimation difficulties in deriving empirical distributions of WTP (Train, 1998; Daly et al., 2012; Carson and Czajkowski, 2019), we choose to estimate our model in willingness to pay space directly (WTP-space) (Train and

Weeks, 2005; Scarpa et al., 2008).[8] This is a standard reparameterization of equation 2 such that $wtp_i = (c_i/\lambda_i)$; utility is then represented by:

$$U_{ijt} = -\lambda_i p_{jt} + \lambda_i \boldsymbol{wtp}_i' \boldsymbol{x}_{jt} + \varepsilon_{ijt}. \tag{3}$$

Equation 3 is the specification in WTP-space (Train and Weeks, 2005). We specify the vector of WTP parameters $\boldsymbol{wtp}$ to be distributed normal and the coefficient on cost, λ, is distributed log-normal as recommended by Train and Weeks (2005). We specify the distributions of the random parameters to be fully correlated, estimating a full covariance matrix and corresponding correlation coefficients for the random parameters in the model. We follow Thiene and Scarpa (2009) and estimate the model using maximum simulated likelihood. Halton draws were used in the maximum-likelihood simulation. The first N prime numbers were used to generate the draws, where N is equal to the number of random parameters in the model.[9]

To develop estimates of total WTP and its distribution throughout the watershed for hypothetical improvements in water quality, we allow for location-specific and individual-specific heterogeneity in estimates of MWTP by recovering the conditional individual specific means of the parameters in equation 3 (Greene et al., 2005; Meyerhoff et al., 2014). This is discussed in more detail in section 6 when we discuss the integrated assessment exercise.

[8] We also estimate our models using conventional preference-space specifications (Appendix B).

[9] All specifications and analyses are modeled using the *gmnl* package in R (Sarrias and Daziano, 2017).

5 Results

Our sample is evenly divided between people in rural (53%) and urban (47%) areas, and 56% of the sample own homes instead of renting.[10] Respondents are predominantly white (78%) and female (68%); the former is consistent with the actual demographics of the area. Our sample has broad representation of age, income, and education categories, and the distributions in our sample are similar to the U.S. Census demographics for this area. This is an area with little in-migration; half the people in our sample have lived in the area for more than 30 years, and only 10% have lived there for 10 years or fewer. The two sub-samples are mostly similar, except that urban respondents are more likely to hold a graduate degree and less likely to participate in recreational fishing and hiking.[11]

Figures 3 shows the distributions of answers to qualitative questions about familiarity with local algal blooms and water quality concerns described in the survey. Nearly 80% of the sample reported having at least some familiarity with the water quality issues discussed in the survey and about the same number of respondents reported experience with algal blooms in the rivers or connected bodies of water. Fewer than 20% of respondents report having fished in the USRW at all. However, nearly 50% reported having visited the river or walked trails near the river).[12]

Table 2 presents the main regression results, estimating equation 3 (WTP-space) for the full sample. The regression in Column 1 includes just the core model parameters. The

[10] Sample characteristics and comparison to the American Community Survey is in Appendix B.
[11] Sample differences between rural and urban respondents can be found in Appendix B.
[12] A summary of responses to visitation questions is in Appendix C

regression in Column 2 introduces an interaction term between the status quo dummy (ASC) and respondent characteristics.

All mean WTP coefficients in Column 1 are statistically significant at the 1% level or better. The coefficient on the status quo (no program) option is large and negative and suggests respondents strongly prefer having a water-quality improvement program than not. The coefficient on distance is also negative—people prefer a program focused on the river close to where they live. The coefficients on fish species and fish population are positive; people would be willing to pay nearly $5 per year to have an additional species of game fish in the river, and they separately place a positive value on the total number of individual fish in the river. The coefficients on algal blooms and nutrient target are positive. People would gain utility from reducing the frequency of these local problems in their watershed, with an average annual MWTP of $0.77 for a one percent reduction in the frequency of algal blooms. Respondents also place a large value on nutrient target, with an average annual MWTP of $0.95 for a one percentage point increase in the likelihood of achieving the watershed's nutrient loss target.

The large MWTP to move away from the status quo suggests that respondents have strong preferences for having a new program instead of the status quo regardless of the variable attributes in our choice scenarios. Column 2 explores two factors contributing to these preferences. Respondents who live in more rural areas of the watershed and respondents who were familiar with surface water issues in the area are willing to pay significantly more for moving away from the status quo. Rural residents are estimated to value this move from status quo $49 more than urban residents. Those who reported being familiar, very familiar,

Table 2: MWTP to Reduce Nutrient Transmission to the Gulf of Mexico

	(1) Full Sample		(2) ASC Heterogeneity	
	Mean MWTP	Std. Dev.	Mean MWTP	Std. Dev.
Distance (miles)	-0.67***	92.57***	-0.68***	1.22***
	(0.15)	(18.69)	(0.15)	(0.26)
Fish Species	4.73**	1.06***	4.72**	12.32***
	(1.48)	(0.26)	(1.55)	(2.14)
Fish Population	0.17**	6.58***	0.16**	0.38***
	(0.06)	(2.12)	(0.06)	(0.08)
Algal Blooms (%)	0.77***	0.35**	0.88***	0.96***
	(0.11)	(0.09)	(0.1)	(0.13)
Nutrient Target (%)	0.95***	0.85***	1.14***	0.89***
	(0.13)	(0.16)	(0.13)	(0.12)
Status Quo (No Program)	-69.49***	1.42***	-20.25	77.02***
	(14.78)	(0.23)	(13.48)	(21.19)
Status Quo × Rural			-48.79***	171.45***
			(14.33)	(26.29)
Status Quo × Aware of Water Issues			-65.82***	106.84***
			(16.34)	(21.01)
λ (cost coefficient)	-3.17***	0.85***	-2.71***	0.77***
	(0.32)	(0.13)	(0.42)	(0.12)
Observations (Respondents)	2058 (343)		2058 (343)	
Log-likelihood	-1717.19		-1717.77	
AIC	3506.38		3527.54	
McFadden ρ^2	0.15		0.15	

Note: Column 1 provides the results of the WTP-space model for the pooled (full) sample. Column 2 introduces an interaction between the Status Quo dummy and respondent characteristics. Correlation matrices of the random parameters can be found in the appendix (Table B.7). Standard errors in parentheses where $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

or very familiar and involved with watershed quality issues value this move from the status quo $66 more than those who were less aware. While preferences for the status quo may vary, the holistic set of preferences is consistent between urban and rural respondents in this watershed.[13]

[13] Regressions for the separate rural and urban sub-samples can be found in Appendix B. A likelihood ratio test of joint preference stability tests the fit of separate regressions for the two sub-samples against the constrained pooled sample. We fail to reject the null that MWTP are jointly similar across the two sub-samples.

6 Integrated Assessment Application

To illustrate how benefits from water quality improvements are distributed throughout the watershed, we recover the conditional individual-specific means of MWTP for every respondent in our sample (Greene et al., 2005). We use the primary specification in our analysis (Table 2, column 1) to recover conditional individual-specific means. For each zip code in our sample, we average the MWTP over the respondents who lived in that zip code. This gives us zip code level variation in the MWTP for each attribute.

Zip codes are considered rural if there are fewer than 1,000 residents per square mile, and urban otherwise (Ratcliffe et al., 2016; U.S.Census, 2019). This allows us to tally welfare changes separately for the rural and urban areas in the USRW. The distributions of MWTP in the rural and urban zip codes are as expected and have significant overlap.[14]

Policy simulations, or "state-of-the-world" experiments, simulate a change in the levels of the environmental attributes to recover an individual's total WTP for the suite of improvements over the status quo level (Holmes et al., 2017). For example, an individual's WTP for a change in attribute x_1 is their MWTP for x_1 multiplied by the change in x_1's level: $WTP_{x_1} = MWTP_{x_1} \times \Delta x_1$. If more than one attribute is changing, then the individual's WTP for changes in both attributes is the sum of their WTP for each attribute j that is changing:

$$WTP = \sum_j MWTP_{x_j} \times \Delta x_j. \tag{4}$$

[14] A full summary of the recovered conditional individual-specific means of the MWTP for each attribute can be found in Appendix C.

Because we have zip code specific MWTP for each attribute, we estimate changes in welfare for each zip code under different states of the world. Moreover, in zip code z over households N, the total WTP for improvements in a set of attributes indexed by j is:

$$WTP^z = \sum_n \sum_j (MWTP^z_{x_j} \times \Delta x^z_j)_n. \tag{5}$$

From equation 5, the total WTP in the watershed is simply the sum of WTP^z over all zip codes in the USRW.

Table 3 summarizes the results of our policy simulations. Panel A identifies the scenarios, Panel B considers benefits from only the environmental attributes in the model, and Panel C adds to Panel B by also including the benefits from moving away from the status quo—the MWTP associated with the ASC in our model. The first scenario models a 50% reduction in only the frequency of algal blooms in river section A. Scenario 2 models this same improvement except for river section C. This allows us to hold all other attributes constant to see how benefits might accrue differently depending on where the improvement takes place. Scenario 3 models a 75% likelihood that the watershed reaches it nutrient loss target of 45% by the year 2040. Scenario 4 introduces a more complete improvement scenario where river section A sees a 75% reduction in the frequency of algal blooms, sections A and B receive an additional 50 fish (population) per 100 yards of river, section A receives an additional 2 species of game fish per 100 yards of river, and a 100% likelihood of reaching the watershed's nutrient target.

Reducing the frequency of local algal blooms in just one of the four reaches of the

Table 3: Sample Integrated Assessment Value Estimates (total WTP)

Panel A: Scenarios	(1)	(2)	(3)	(4)
Algal Blooms	50% reduced Area A only	50% reduced Area C only	-	75% reduced Area A only
Nutrient Target	-	-	75% likelihood	100% likelihood
Fish Species	-	-	-	+2 species Area A only
Fish Population	-	-	-	+50 population Area A and B
Panel B: No ASC				
Annual Benefits	$1,057,497	$1,697,818	$4,406,411	$7,126,757
Rural Areas	$768,279	$985,443	$2,612,890	$4,512,142
Urban Areas	$289,218	$712,376	$1,793,521	$2,614,615
Per Household	$9.30	$14.93	$38.75	$62.67
Rural Areas	$13.51	$17.33	$45.95	$79.35
Urban Areas	$5.09	$12.53	$31.54	$45.98
Panel C: With ASC				
Annual Benefits	$3,648,648	$4,288,969	$6,997,562	$9,717,908
Rural Areas	$2,413,881	$2,631,044	$4,258,491	$6,157,744
Urban Areas	$1,234,768	$1,657,925	$2,739,071	$3,560,165
Per Household	$32.08	$37.71	$61.53	$85.45
Rural Areas	$42.45	$46.27	$74.89	$108.30
Urban Areas	$21.72	$29.16	$48.17	$62.61

Note: Benefits are estimated using equation 5. These are estimates of compensating variation for the improvements modeled in the IAM exercise. In aggregate, rural areas of the watershed stand to benefit nearly twice as much as the urban clusters. Rural areas of the watershed also tend to have a higher per household WTP for each scenario. This is largely because a majority of the improvements will be realized in more rural areas of the watershed.

watershed yields around $1 million to $1.6 million per year depending on the location of the improvement (Table 3, Panel B, columns 1 and 2). A 75% likelihood of reaching the nutrient target is worth $4.4 million per year (Table 3, Panel B, column 3). Finally, the most comprehensive scenario (Table 3, Panel B, column 4) yields benefits of around $7 million per year.

Table 3 also provides a summary of the average values per household for each of the scenarios. Household WTP's are calculated at the zip code level. We provide the average WTP for each scenario throughout the watershed as well as the average WTP in the rural and urban areas separately. Reducing algal blooms by 50% has an average value of $9 or $15 per year depending on where in the watershed it occurs, and the average value of a 75% change of the watershed doing its part for hypoxia reduction is $39 per year per household. The comprehensive scenario in column 4 produces average benefits of $63 per year per household.

To see where the benefits from the policy simulations accrue throughout the watershed, Figure 4 provides maps of both the total WTP (Panel A) and the per household WTP (Panel B) in each zip code. Benefits are most dense where population is most dense (Panel A). However, when we map benefits based on per household estimates, we see the distribution is often higher in the rural areas throughout the watershed (Panel B).[15] Rural areas tend to receive larger benefits because the river sections—and the corresponding improvements—are mostly in rural areas of the watershed.

7 Discussion

We have carried out a CE survey to estimate how much people in a sub-watershed of the Mississippi River Basin are willing to pay to improve local fish diversity and populations in their rivers, reduce the prevalence of local algal blooms, and ensure that their watershed does its part to hypoxia in the Gulf of Mexico. While current efforts in the MRB to reduce nutrients and sediment are driven by concern about water quality far away in the Gulf, we find that people in our study area would gain significant benefit from the local environmental

[15] Refinements could be made when modeling WTP throughout the watershed, or for use in transfer to similar watersheds, using spatial regression methods such as those discussed in Johnston et al. (2019) or DeValck and Rolfe (2018). However, the focus of this paper is to provide a proof of concept for estimating the distributional effects of policies related to water quality that span geographically and culturally diverse landscapes.

improvements that could result from reduced nutrient pollution and from helping to reduce environmental problems in the Gulf.

Much traditional research on water quality values has focused on generic measures of whether waters are boatable, fishable, and swimmable, and the resulting values can be quite small (Keiser et al., 2019). In contrast, we find that people would gain large value from reducing the frequency of local algal blooms, with respondents willing to pay nearly $40 per year to reduce the frequency of nearby algal blooms by 50%. Algal blooms are becoming more prevalent as climate change expands hot summer conditions; our result implies that economists and water quality modelers should pay increased attention to the impact of management and policies on those particularly harmful manifestations of nutrient pollution.

Residents of the central Midwest gain no use value from reducing hypoxia in the Gulf of Mexico. However, we find that people in our study area would gain utility from increasing the likelihood that their watershed reaches the target set for it under the Illinois Nutrient Loss Reduction Strategy; the average respondent would be willing to pay $48 to have even a 50% chance of the watershed's goal being met. This finding provides further compelling rationale for the work on nutrient loss in which government agencies, NGOs, and industry groups are all currently engaged.

Our estimates suggest that people in this landlocked part of the Midwest would gain large value from improving local game fish diversity and fish populations. This result seems to be capturing significant non-use values for having thriving river ecosystems in the region since only a small fraction of respondents reported engaging in local fishing. Most previous research on the value of fish species and populations comes from travel cost and recreational site-choice models that can only capture use values (Phaneuf et al., 2013; Melstrom et al., 2015). The large nonuse values we estimate in this study support the well-known claim that revealed preference estimates may not capture the full range of benefits from environmental improvements (Adamowicz et al., 1998a; Hanley and Czajkowski, 2019).

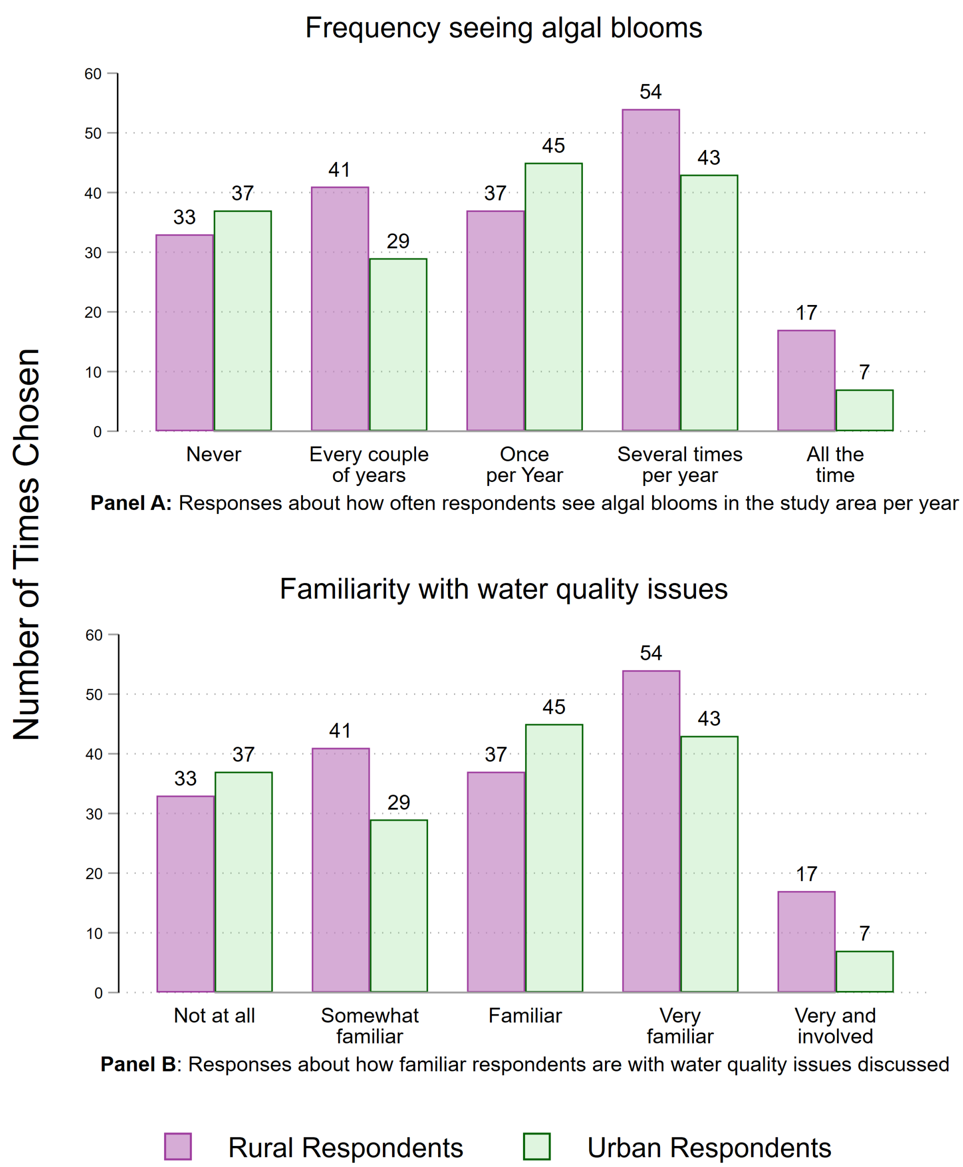
Economists, other social scientists, and policy makers have wondered if there is a rural-urban divide in the values people place on environmental improvements. In this case, we find that rural and urban preferences are similar. If anything, rural residents may place more value on a move away from the status quo towards environmental improvement. This finding implies that people in the rural areas that implement many of the changes needed to improve water quality may also have high willingness to pay for those improvements themselves.

Finally, the results from our simple simulations suggest that the total values water quality improvement could bring to a watershed like our study area are not trivial. For the USRW alone, total WTP for reaching a 75% likelihood of reaching nutrient reduction targets (scenario 3) is estimated at approximately $4.4 million dollars annually. And when modeled with improvements that will likely come as compliments for any policy targeting reductions in nutrient loss and transmission to the Gulf (scenario 4), total annual benefits within this small watershed are estimated to exceed $7 million dollars per year.

Debate over nutrient loss reduction strategies continues. To inform that debate, analysts should quantify the full range of costs and benefits and how costs and benefits are distributed among groups of people in the landscape. Our findings can play an important role in that effort. However, more work needs to be done in order to further uncover and understand the overlooked benefits of reductions in nutrient loss and transmission. Future research would do well to explore how values vary throughout the MRB for improving local fish habitat, avoiding local algal blooms, and solving regional environmental problems like hypoxia in the Gulf. Additional work is also needed to understand the factors driving people in our study to express such strong antipathy for a status quo that does nothing to address pervasive surface water pollution in the U.S.

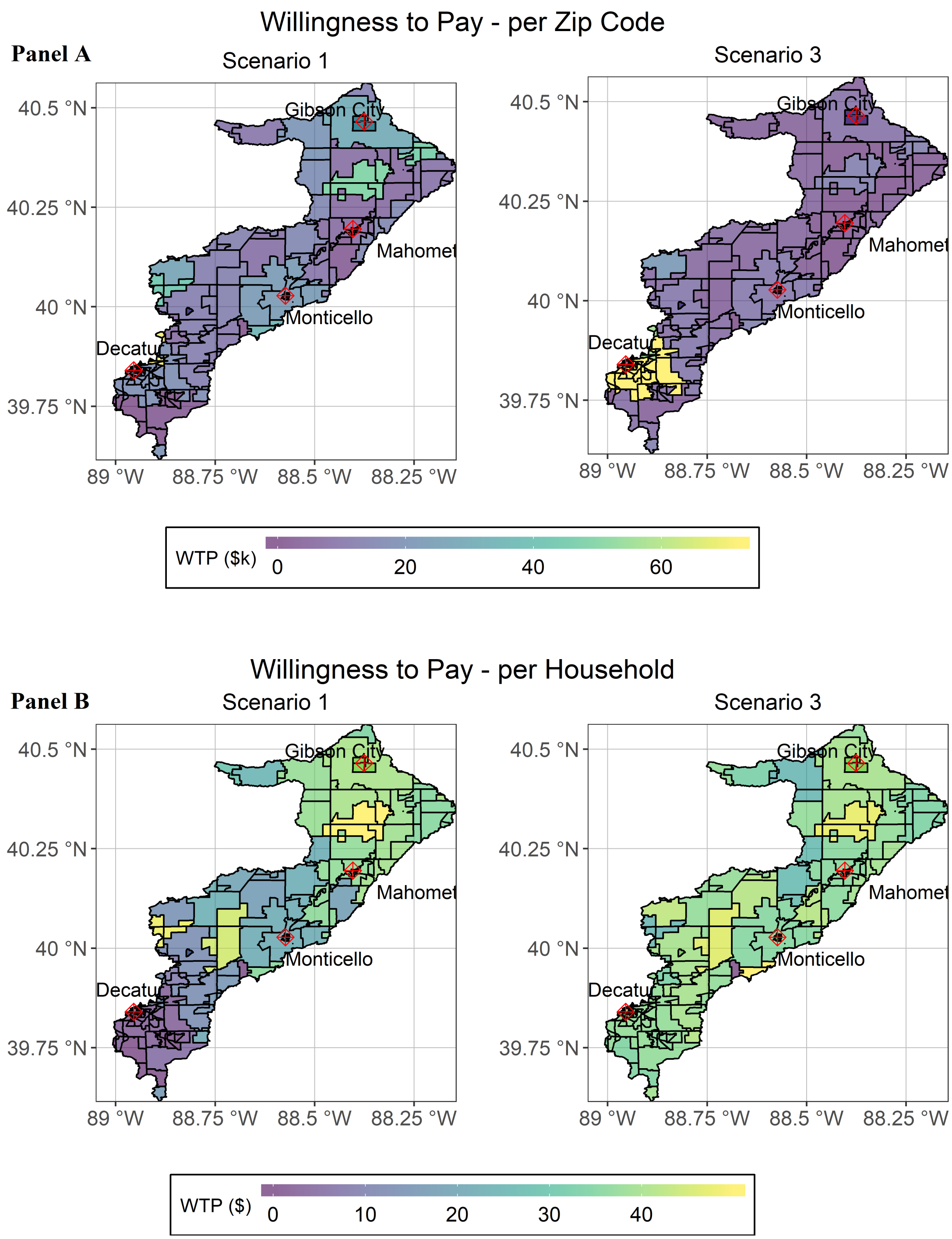
8 Figures

Figure 3: Responses to Questions about Surface Water Quality Awareness



Note: Responses to the post-survey questionnaire about how familiar respondents are to water quality issues in the watershed, and how frequently they experience algal blooms in or in nearby surface water the Upper Sangamon River. Algal blooms are quite frequently observed by respondents and is likely closely related to their awareness of water quality issues. Rural respondents reported more frequently seeing algal blooms and being more familiar with the water quality issues discussed in the survey.

Figure 4: Sample Integrated Assessment Value Estimates



Note: Spatial distribution of total WTP in each zip code throughout the watershed (Panel A) and per household MWTP (Panel B). Total benefits accrue in urban clusters where the population is dense. However, on a per household basis we see higher WTP in rural areas than in the urban clusters within the watershed.

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Appendix A The Survey

Water Quality in the Upper Sangamon River Survey

This survey will collect information for research being conducted at the University of Illinois. The research will study how people value changes to water quality in a nearby watershed resulting from changes in agriculture practices. You will not be asked to provide your name or address and your participation and answers to this survey will be completely anonymous.

Participation is voluntary and will take approximately 10 minutes

You should only complete this survey if you are over 18 years old. Please complete the survey to the best of your ability. You may choose not to answer specific questions or discontinue the survey at any time.

Your participation in this survey is very important. You might not benefit directly from participation, but the information from this survey will help policy makers, economists, and watershed managers choose how and how much to improve water quality in your area. We will be happy to provide you with a copy of the final report at your request.

Please keep this information for your records

You should keep this information for your future reference. If you have any questions about this survey research or its results please contact: watersurvey@illinois.edu

If you have any questions about your rights as a research subject, including questions, concerns, complaints, or to offer input, you may call the Office for the Protection of Research Subjects (OPRS) at 217-333-2670 or e-mail OPRS at irb@illinois.edu.

Instructions

This survey measures what people think about changes in local water quality due to local changes in agriculture practices. We are interested in how much you care about features such as: fish species and populations, local problems from water pollution like algal blooms, and the likelihood of reaching targets that have been set to reduce serious water quality problems in the Gulf of Mexico.

The survey has two sections:

1. **In section one** of the survey, you will be asked six questions. In each of those questions, we will ask you to choose between two possible future scenarios and the current situation ("No Change").

2. **In section two** of the survey, there will be some short questions about you so that we can understand what factors affect the way people feel about local water quality.

Remember that all your answers will be completely anonymous.

Background Information

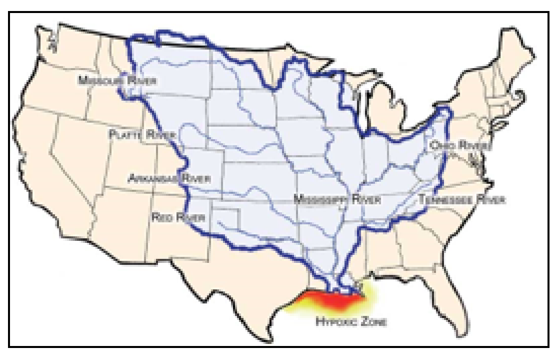
Rivers, streams, and lakes in the U.S. Midwest have been changed by things like farming. The soil and climate in the region provide a great environment for growing crops. However, rain runs off fields and carries bits of soil (sediment) and chemicals from fertilizer and plants (nutrients) into local waters. Runoff of nutrients and sediment causes local problems, reduced fish numbers and sudden growths of green algae that smell bad and can be toxic. Nutrient pollution also creates a big area that is starved of oxygen (the hypoxic zone) in the Gulf of Mexico.

Upper Sangamon River Basin

Locally, proposed changes that reduce nutrient runoff can improve rivers and lakes by providing clearer water and better habitat for fish. Improved water conditions can increase both the number of different **kinds** of fish (species) and **how many** fish there are (population). Some of these fish are game fish that are often fished for by recreational anglers, including bass, creel, and trout. Other types of fish are not directly interesting to people fishing, but they help support healthy homes in rivers and lakes for birds and other wild animals.

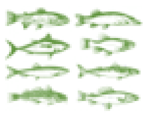
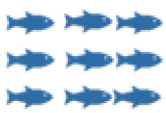
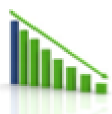
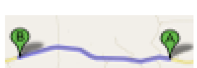
Hypoxia in the Gulf of Mexico

The nutrients and sediment that run off lands throughout the U.S. Midwest drain into the Gulf of Mexico. Once in the Gulf, these nutrients create a "dead zone" stretching thousands of square miles around the mouth of the Mississippi River. There are 12 states, including the state of Illinois, who have pledged to reduce the dead zone in the Gulf. Those states have agreed with the U.S. EPA to reduce nutrient flows from their lands by 45% by the year 2040.



Features of Water Quality Improvements

Depending on how it is done, changes in water quality can have different results. The features described below are of interest in this survey. Please read this carefully in order to answer the questions in the survey.

Species of Game Fish 	The number of different game fish species found in a typical 100 yards of river in the highlighted section of the river (100 yards is the length of a football field). A high number means you can expect to see many different kinds of game fish.
Population of All Fish 	The number of individual fish (from all species, game and non-game) found in a typical 100 yards of river in the highlighted section of the river. A high number means you can expect to see many individual fish. They may be all the same type, or they may be several different types.
Algal Blooms  Reduced	The percent reduction in the frequency of algal blooms in the highlighted section of the river. These are typically seen in the ponds and lakes connected to the river. A higher number means you will see fewer algal blooms. For example: 100 means 100 percent reduction so there are no algal blooms, 0 means the number of algal blooms stays exactly the same as it is now.
Nutrient Targets 	The likelihood that the Upper Sangamon River area succeeds in reaching its goal of reducing nearly half of the nutrients running down to the Gulf of Mexico by 2040. A higher number means the target is more likely to be reached. For example: 100 means the target is definitely reached; 0 means the target is definitely not reached.
Distance 	The distance in miles from you to the cleaned up section of the river. This feature depends on which section of river is cleaned up and where you live.
Annual Cost 	The amount of money that your household will have to pay every year to improve the water quality in the Upper Sangamon River. The money will be paid through an increase in annual county fees. If you are a renter, this will be passed on through rent charged by the landlord.

Current Experience

Before you answer the next questions, help us understand your current experience.

How often have you seen algal blooms in the rivers near you?

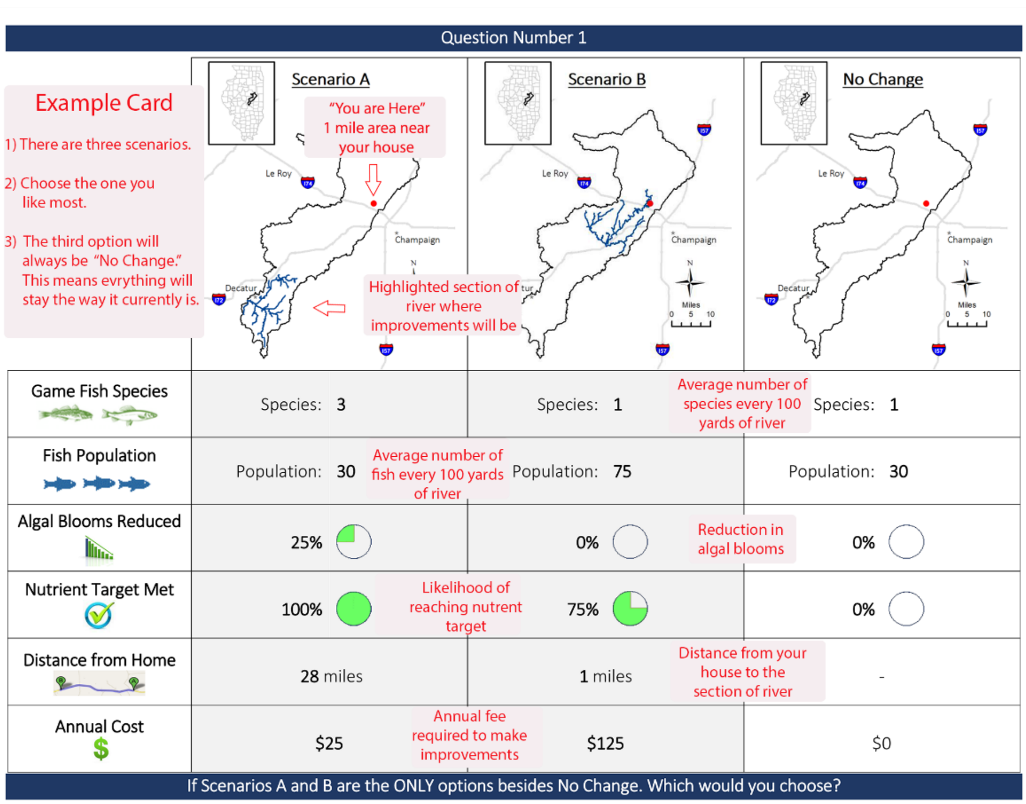
a) Never
b) Rarely, once every couple of years
c) Not often, once per year
d) Sometimes, several times a year
e) Very often

How many times in the last year have you gone fishing in the Upper Sangamon River?

a) 0
b) 1
c) 2
d) 3
e) 4
f) 5
g) more than 5

How many times in the last year have you participated in other recreation activities in the Upper Sangamon River Basin? (Boat, swim, bike, walk the trails, etc.)

a) 0
b) 1
c) 2
d) 3
e) 4
f) 5
g) more than 5



Things to Remember

For the purposes of this survey you should assume that every possible future scenario:

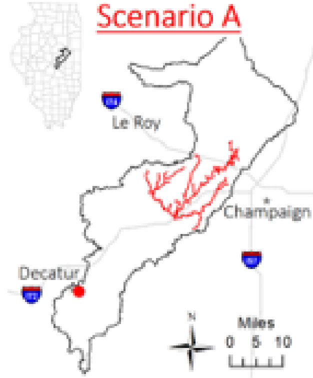
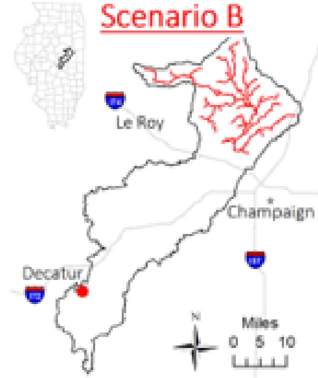
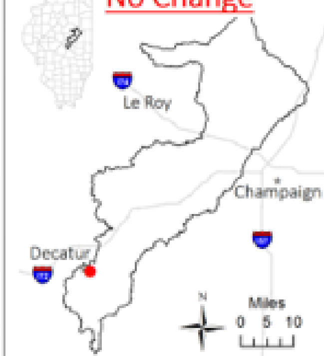
- will ONLY affect the highlighted area of the river
- will NOT result in additional changes such as fishing or visiting regulations
- will NOT result in a change in agricultural acreage or profits
- WILL be paid for by an annual increase in county fees

Experience from previous similar surveys is that people often say they would be willing to pay more money for something than they actually would. For example, in one study, 80% of people said they would buy a product, but when a store actually stocked the product, only 43% of people actually bought the new product. It is important that you make each of your upcoming selections like you would if you were **actually** facing these exact choices in reality. Note that paying for environmental improvement means you would have less money available for other purchases.

Ready, set, choose.

Remember, each of the six questions is separate and independent from the previous questions. For every question, Scenarios A and B are the ONLY options besides the "No Change." Which would you choose?

If scenarios A and B were the only options besides No Change, which would you choose?

	Scenario A	Scenario B	No Change
			
Game Fish Species	2	5	1
Fish Population	75	50	30
Algal Blooms Reduced	25%	0%	0%
Nutrient Target Met	75%	50%	0%
Distance from Home	23 miles	39 miles	-
Annual Cost	$5	$15	$0

If you are unsure about scenarios A or B, or would not actually spend the money, please choose No Change.

Almost Finished

Now we are going to ask a few quick questions about you, and then you will be finished.

1. Do you consider where you live to be rural?
    a. Yes
    b. No

2. Think about your household's total income each year. What category does it fall into?
    a. Less than $25,000 per year
    b. $25,000 - $34,999 per year
    c. $35,000 - $49,999 per year
    d. $50,000 - $74,999 per year
    e. $75,000 - $99,999 per year
    f. $100,000 - $149,999 per year
    g. $150,000 - $199,999 per year
    h. More than $200,000 per year

3. Do you own your home?
    a. Yes
    b. No

4. Do you or your family farm or do work related to agriculture?
    a. Yes
    b. No

5. What is your age group?
    a. 18-29 years old
    b. 30-44 years old
    c. 45-64 years old
    d. Over 65 years old

6. What is your gender?
    a. Female
    b. Male
    c. Other

7. What is your race?
    a. White
    b. African American
    c. Hispanic or Latino
    d. American Indian, or Alaska Native
    e. Other

8. What is your highest level of education?
    a. Less than high school
    b. High school / GED
    c. Some college
    d. Two-year college degree
    e. Four-year college degree
    f. Graduate degree

9. How many years have you lived in central Illinois?
    a. 0 to 5 years
    b. 5 to 10 years
    c. 10 to 20 years
    d. 20 to 30 years
    e. More than 30 years

10. How familiar are you with the water quality issues discussed in this survey?
    a. 0 – not familiar at all
    b. 1 – somewhat familiar
    c. 2 – familiar
    d. 3 – very familiar
    e. 4 – very familiar and involved

11. Do you ever go fishing in the Sangamon River?
    a. 0 - No, never
    b. 1 - Sometimes, once per year
    c. 2 - Yes, several times per year

12. Do you ever go hiking or recreating near the Sangamon River?
    a. 0 - No, never
    b. 1 - Sometimes, once per year
    c. 2 - Yes, several times per year

13. Please add any comments, questions, or concerns that you would like us to know about.

Appendix B Additional Tables

Table B.1: Summary Statistics

	(1) Respondents	(2) mean	(3) min	(4) max
Rural	343	0.53	0	1
Works in Agriculture	343	0.16	0	1
Male	343	0.32	0	1
White	343	0.78	0	1
Homeowner	343	0.56	0	1
Age				
18 - 29	343	0.25	0	1
30 - 44	343	0.33	0	1
45 - 64	343	0.3	0	1
> 65	343	0.12	0	1
Household income ($k)				
< $25,000	343	0.24	0	1
$25,000 - $34,999	343	0.16	0	1
$35,000 - $49,999	343	0.16	0	1
$50,000 - $74,999	343	0.2	0	1
$75,000 - $99,999	343	0.13	0	1
$100,000 - $149,999	343	0.07	0	1
$150,000 - $199,999	343	0.02	0	1
> $200,000	343	0.01	0	1
Education				
Less than high school	343	0.04	0	1
High school / GED	343	0.24	0	1
Some college	343	0.27	0	1
Two-year degree	343	0.11	0	1
Four-year degree	343	0.22	0	1
Graduate degree	343	0.12	0	1
Years of Residency				
0-5 years	343	0.06	0	1
5-10 years	343	0.04	0	1
10-20 years	343	0.17	0	1
20-30 years	343	0.2	0	1
> 30 years	343	0.53	0	1
Minutes to Complete	343	10.49	3.52	321.82

Note: Experience categories range from 0 (never go) to 5 (more than 5 times per year). Water Quality Issues relates to their current understanding of the water quality concerns in the watershed, and ranges from 0 (not aware of any) to 4 (very aware and involved). Algal Blooms refers to the respondent's current experience with algal blooms, and ranges from 0 (never see them) to 4 (very often, all the time).

Table B.2: Differences between Survey Respondents and U.S.Census (2019)

	(1) Respondents	(2) Census	(3) Difference
Works in Agriculture	0.15 (0.00)	0.05 (0.03)	-0.10*** (0.01)
Male	0.32 (0.00)	0.50 (0.04)	0.18*** (0.01)
White	0.77 (0.00)	0.94 (0.10)	0.16*** (0.02)
Homeowner	0.57 (0.00)	0.75 (0.16)	0.18*** (0.03)
Age			
18 - 29	0.22 (0.23)	0.18 (0.04)	-0.05 (0.04)
30 - 44	0.30 (0.31)	0.23 (0.04)	-0.07 (0.06)
45 - 64	0.36 (0.35)	0.38 (0.04)	0.02 (0.06)
> 65	0.12 (0.20)	0.21 (0.05)	0.09** (0.04)
Household income ($k)			
$<$ $25,000	0.06 (0.10)	0.12 (0.17)	0.07* (0.03)
$25,000 - $34,999	0.01 (0.03)	0.07 (0.03)	0.07*** (0.01)
$35,000 - $49,999	0.15 (0.24)	0.13 (0.08)	-0.02
$50,000 - $74,999	0.20 (0.31)	0.20 (0.06)	0.00 (0.06)
$75,000 - $99,999	0.22 (0.31)	0.18 (0.07)	-0.04 (0.06)
$100,000 - $149,999	0.18 (0.27)	0.17 (0.07)	-0.00 (0.05)
$150,000 - $199,999	0.18 (0.22)	0.07 (0.05)	-0.11*** (0.04)
$>$ $200,000	0.01 (0.02)	0.04 (0.04)	0.04*** (0.01)
Education			
Less than high school	0.22 (0.29)	0.06 (0.04)	-0.16*** (0.05)
High school/GED	0.12 (0.27)	0.35 (0.09)	0.23*** (0.05)
Some college	0.21 (0.22)	0.24 (0.04)	0.03 (0.04)
Two-year degree	0.08 (0.21)	0.09 (0.02)	0.01 (0.04)
Four-year degree	0.19 (0.20)	0.16 (0.07)	-0.03 (0.04)
Graduate degree	0.18 (0.33)	0.08 (0.07)	-0.10 (0.06)
Zip Codes	42	42	42

Standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01

Note: Comparisons are provided between the 2017 American Community Survey (ACS) 5-year zip code level data and the sample in the choice experiment. Averages are across the 42 zip codes in the study area. Our sample is largely representative of the region, with a few differences. Our sample is more likely to work in agriculture; however, this is likely because of the broad wording of the question where we asked respondents if they or their family performed work related to agriculture, and results are consistent with this. Our sample is more likely to be female, less likely to be white, and less likely to be a homeowner. The age of respondents is representative of the U.S. Census, with fewer above the age of 65. Our sample has similar income and education levels.

Table B.3: Differences between Respondents in Rural and Urban Areas

	(1) Rural	(2) Urban	(3) Difference
Works in Agriculture	0.19 (0.39)	0.12 (0.33)	-0.06 (0.04)
Male	0.32 (0.47)	0.32 (0.47)	-0.00 (0.05)
White	0.81 (0.40)	0.74 (0.44)	-0.07 (0.05)
Homeowner	0.60 (0.49)	0.52 (0.50)	-0.08 (0.05)
Age			
18 - 29	0.24 (0.43)	0.27 (0.44)	0.03 (0.05)
30 - 44	0.36 (0.48)	0.29 (0.46)	-0.07 (0.05)
45 - 64	0.28 (0.45)	0.32 (0.47)	0.04 (0.05)
> 65	0.12 (0.32)	0.12 (0.32)	0.00 (0.03)
Household income ($k)			
< $25,000	0.20 (0.40)	0.28 (0.45)	0.08* (0.05)
$25,000 - $34,999	0.19 (0.39)	0.14 (0.34)	-0.05 (0.04)
$35,000 - $49,999	0.17 (0.38)	0.16 (0.36)	-0.02 (0.04)
$50,000 - $74,999	0.19 (0.39)	0.20 (0.40)	0.02 (0.04)
$75,000 - $99,999	0.14 (0.35)	0.13 (0.34)	-0.01 (0.04)
$100,000 - $149,999	0.09 (0.29)	0.05 (0.22)	-0.04 (0.03)
$150,000 - $199,999	0.02 (0.13)	0.03 (0.17)	0.01 (0.02)
> $200,000	0.01 (0.10)	0.01 (0.11)	0.00 (0.01)
Education			
Less than high school	0.03 (0.18)	0.04 (0.21)	0.01 (0.02)
High school/GED	0.27 (0.44)	0.21 (0.41)	-0.06 (0.05)
Some college	0.31 (0.46)	0.22 (0.42)	-0.08* (0.05)
Two-year degree	0.08 (0.27)	0.14 (0.35)	0.07** (0.03)
Four-year degree	0.22 (0.42)	0.22 (0.42)	0.01 (0.05)
Graduate degree	0.09 (0.29)	0.16 (0.36)	0.06* (0.04)
Years of Residency			
0-5 years	0.04 (0.19)	0.09 (0.29)	0.06** (0.03)
5-10 years	0.04 (0.19)	0.04 (0.21)	0.01 (0.02)
10-20 years	0.15 (0.36)	0.18 (0.39)	0.03 (0.04)
20-30 years	0.25 (0.43)	0.15 (0.36)	-0.10** (0.04)
> 30 years	0.52 (0.50)	0.53 (0.50)	0.01 (0.05)
Experience			
Recreational Fishing	0.76 (1.36)	0.43 (1.08)	-0.32** (0.13)
Hiking/Biking Trails	1.34 (1.63)	1.03 (1.46)	-0.31* (0.17)
Water Quality Issues	1.90 (1.27)	1.71 (1.21)	-0.18 (0.13)
Algal Blooms	1.90 (1.27)	1.71 (1.21)	-0.18 (0.13)
Minutes to Complete	11.14 (24.32)	9.76 (7.42)	-1.38 (1.99)
Respondents	182	161	343

Standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01

Table B.4: Preferences-Space Models and Marginal Utilities

Mean Marg. Util.	(1) Full Sample	(2) ASC Het.	(3) Rural	(4) Urban
Distance (miles)	-0.0124***	-0.0134***	-0.0119**	-0.0135***
	(0.0026)	(0.0028)	(0.0038)	(0.0040)
Fish Species	0.0500	0.0495	0.0091	0.0908*
	(0.0271)	(0.0279)	(0.0395)	(0.0402)
Fish Population	0.0031**	0.0032**	0.0013	0.0048**
	(0.0010)	(0.0011)	(0.0014)	(0.0015)
Algal Blooms (%)	0.0143***	0.0149***	0.0125***	0.0171***
	(0.0015)	(0.0016)	(0.0021)	(0.0023)
Nutrient Target	0.0167***	0.0170***	0.0172***	0.0170***
	(0.0015)	(0.0016)	(0.0022)	(0.0022)
Cost	0.0163***	0.0165***	0.0150***	0.0191***
	(0.0021)	(0.0022)	(0.0029)	(0.0033)
Status Quo (No Program)	-0.7933***	-0.2811	-1.1083***	-0.4291
	(0.1980)	(0.2626)	(0.2755)	(0.2963)
Status Quo × Rural		-0.5295		
		(0.2880)		
Status Quo ×		-0.3753		
Aware of Water Issues		(0.2223)		
SD of Ran. Param.				
Distance (miles)	0.024***	0.027***	0.03***	1.50**
	(0.006)	(0.005)	(0.007)	(0.28)
Fish Species	0.160**	0.174**	0.225**	0.024*
	(0.055)	(0.06)	(0.09)	(0.009)
Fish Population	0.007***	0.007***	0.006*	0.009**
	(0.002)	(0.002)	(0.003)	(0.003)
Algal Blooms (%)	0.017**	0.017***	0.021***	0.012**
	(0.002)	(0.003)	(0.003)	(0.004)
Nutrient Target	0.016***	0.016***	0.017***	0.015***
	(0.002)	(0.12)	(0.003)	(0.003)
Status Quo (No Program)	1.70***	2.12***	1.300*	2.17***
	(0.32)	(0.43)	(0.54)	(0.47)
Status Quo × Rural		1.78***		
		(0.41)		
Status Quo ×		0.167		
Aware of Water Issues		(0.34)		
Obs. (Respondents)	2058 (343)	2058 (343)	1092 (182)	966 (161)
Log-likelihood	-1739.9212	-1730.2633	-913.4013	-807.9063
AIC	3535.8424	3550.5267	1882.8027	1671.8127
McFadden ρ^2	0.14	0.15	0.14	0.16
LR χ^2_{63}	37.23			

Standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01

Note: The likelihood ratio test in column 1 tests for joint similarities between rural and urban respondents (columns 3 and 4). We fail to reject that preferences are jointly the same. For all preference-space regressions, the coefficient on cost is assumed fixed. All other parameters are assumed to be distributed normal.

Table B.5: MWTP from Preference-Space Models

	(1) Full Sample	(2) ASC Heterogeneity	(3) Rural	(4) Urban
Distance (miles)	-0.76***	-0.82***	-0.80**	-0.71**
	(0.18)	(0.20)	(0.29)	(0.24)
Fish Species	3.06	3.00	0.61	4.77*
	(1.73)	(1.77)	(2.65)	(2.27)
Fish Population	0.19**	0.19**	0.09	0.25**
	(0.07)	(0.07)	(0.10)	(0.10)
Algal Blooms (%)	0.88***	0.90***	0.84***	0.90***
	(0.13)	(0.14)	(0.20)	(0.17)
Nutrient Target	1.02***	1.03***	1.15***	0.89***
	(0.15)	(0.15)	(0.25)	(0.17)
Status Quo (No Program)	-48.54***	-17.04	-74.06***	-22.52
	(11.95)	(15.75)	(19.88)	(15.16)
Status Quo × Rural		-32.10		
		(17.96)		
Status Quo × Aware of Water Issues		-22.75		
		(13.59)		

Standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01

Note: MWTP values are recovered from the preference-space model summarized here. Means and standard errors are estimated using the delta method in the *gmnl* package in R (Sarrias and Daziano, 2017). The coefficient on cost was assumed to be fixed for the population. This allowed us to derive meaningful distributions of MWTP by taking a simple ratio of the mean preference parameters. Results are comparable to the estimates in the WTP-space models in our main analysis (Table 2). However, the MWTP produced from the WTP-space models has a tighter distribution around the means with more precise estimates of the mean MWTP for each attribute.

Table B.6: Differences in MWTP Between Rural and Urban Respondents

	(1)	(2)	(3)
Mean MWTP Coefficients	Full Sample	Rural	Urban
Distance (miles)	-0.67***	-0.87***	-0.77***
	(0.15)	(0.23)	(0.21)
Fish Species	4.73**	2.65	5.62**
	(1.48)	(1.79)	(1.77)
Fish Population	0.17**	0.05	0.23**
	(0.06)	(0.07)	(0.08)
Algal Blooms (%)	0.77***	0.80***	0.77***
	(0.11)	(0.13)	(0.15)
Nutrient Target	0.95***	1.11***	0.79***
	(0.13)	(0.16)	(0.14)
Status Quo (No Program)	-69.49***	-50.92***	-10.53
	(14.78)	(12.93)	(12.22)
SD of Random Parameters			
Distance (miles)	92.57***	5.57	104.78***
	(18.69)	(15.47)	(21.48)
Fish Species	1.06***	1.16***	1.38***
	(0.26)	(0.34)	(0.32)
Fish Population	6.58***	10.47***	10.38***
	(2.12)	(2.79)	(1.96)
Algal Blooms (%)	0.35**	0.25*	0.50***
	(0.09)	(0.11)	(0.10)
Nutrient Target	0.85***	1.08***	0.67***
	(0.16)	(0.21)	(0.17)
Cost	0.85***	1.11***	0.85***
	(0.13)	(0.18)	(0.15)
Status Quo (No Program)	1.42***	1.28***	1.50***
	(0.23)	(0.18)	(0.28)
Observations (Respondents)	2058 (343)	1092 (182)	966 (161)
Log-likelihood	-1717.19	-899.63	-786.11
AIC	3506.38	1871.26	1644.22
McFadden ρ^2	0.15	0.16	0.16
LR χ^2_{63}	62.90		

Standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01

Note: Column 1 provides the results of the WTP-space model for the pooled (full) sample. Column 2 and 3 divide the sample into rural and urban respondents. The likelihood ratio test in column 1 tests for joint similarities between rural and urban respondents. We fail to reject that MWTP values are jointly the same.

Table B.7: Correlation Coefficients in Primary Models

Panel A: Full Sample							
	Status Q.	Distance	Fish Spe.	Fish Pop.	Algal	Nutrient	Cost
Status Q.	1						
Distance	0.006	1					
Fish Spe.	-0.631	0.489	1				
Fish Pop.	0.236	-0.103	-0.658	1			
Algal	-0.169	0.142	-0.392	0.792	1		
Nutrient	-0.541	0.486	0.304	0.067	0.526	1	
Cost	0.085	-0.078	-0.438	0.627	0.537	0.438	1
Panel B: Rural							
	Status Q.	Distance	Fish Spe.	Fish Pop.	Algal	Nutrient	Cost
Status Q.	1						
Distance	-0.591	1					
Fish Spe.	-0.253	-0.572	1				
Fish Pop.	-0.017	-0.054	-0.150	1			
Algal	-0.264	0.848	-0.691	0.238	1		
Nutrient	-0.202	0.463	-0.188	-0.006	0.614	1	
Cost	0.260	-0.018	-0.251	0.200	0.286	0.613	1
Panel C: Urban							
	Status Q.	Distance	Fish Spe.	Fish Pop.	Algal	Nutrient	Cost
Status Q.	1						
Distance	-0.390	1					
Fish Spe.	-0.222	-0.080	1				
Fish Pop.	-0.122	0.337	0.245	1			
Algal	0.047	0.376	-0.352	0.815	1		
Nutrient	-0.533	0.621	0.156	0.039	-0.111	1	
Cost	0.219	0.082	0.240	0.424	0.219	0.467	1

Note: Correlation coefficients are recovered from the primary model in Table 2 (Panel A) and the rural and urban samples in Table B.6. As expected, correlations between parameters are large for many of the attributes providing strong evidence that an attribute-correlated model is appropriate.

Table B.8: MWTP with Certainty Adjustments

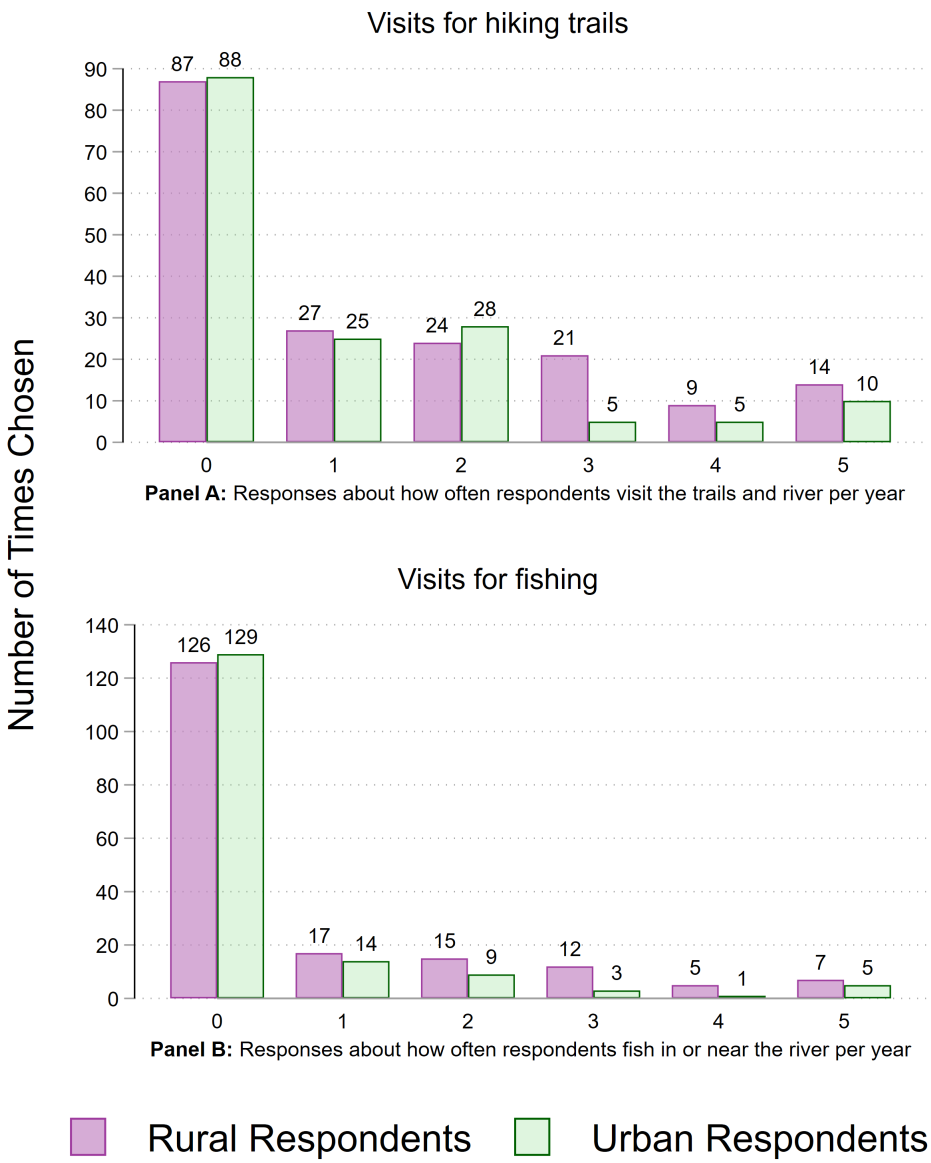
	(1) Full Sample	(2) Adjustment 1	(3) Adjustment 2
Distance (miles)	-0.67***	-0.76***	-0.67*
	(0.15)	(0.18)	(0.28)
Fish Species	4.73**	3.34	-7.61
	(1.48)	(1.89)	(4.78)
Fish Population	0.17**	0.14	0.09
	(0.06)	(0.07)	(0.13)
Algal Blooms (%)	0.77***	0.89***	0.75*
	(0.11)	(0.15)	(0.30)
Nutrient Target	0.95***	1.06***	0.63*
	(0.13)	(0.16)	(0.26)
Status Quo (No Program)	-69.49***	-8.90	196.67***
	(14.78)	(12.31)	(56.60)
Observations (Respondents)	2058 (343)	2058 (343)	2058 (343)
Log-likelihood	-1717.19	-1762.15	-1433.89
AIC	3506.38	3596.29	2939.78
McFadden ρ^2	0.15	0.13	0.29

Standard errors in parentheses *p<0.1; **p<0.05; ***p<0.01

Note: Column 1 presents the results from our primary specification (Table 2). Column 2 makes a certainty adjustment that recodes any "not very certain" follow-up questions to the status quo option. Column 3 makes a certainty adjustment that recodes any "not very certain" and "somewhat certain" follow-up questions to the status quo option. This can be interpreted as moving from less restrictive (column 1) to more restrictive (column 3). MWTP values become more noisy (larger standard errors) in columns 2 and 3. However, MWTP for improvements in Algal Blooms and reaching the Nutrient Target are still large and significant. The MWTP for distance is also robust to certainty adjustments. As discussed in Penn and Hu (2020), the most restrictive assumptions regarding certainty adjustments (column 3) are believed to underestimate the true MWTP—overcorrecting for hypothetical bias.

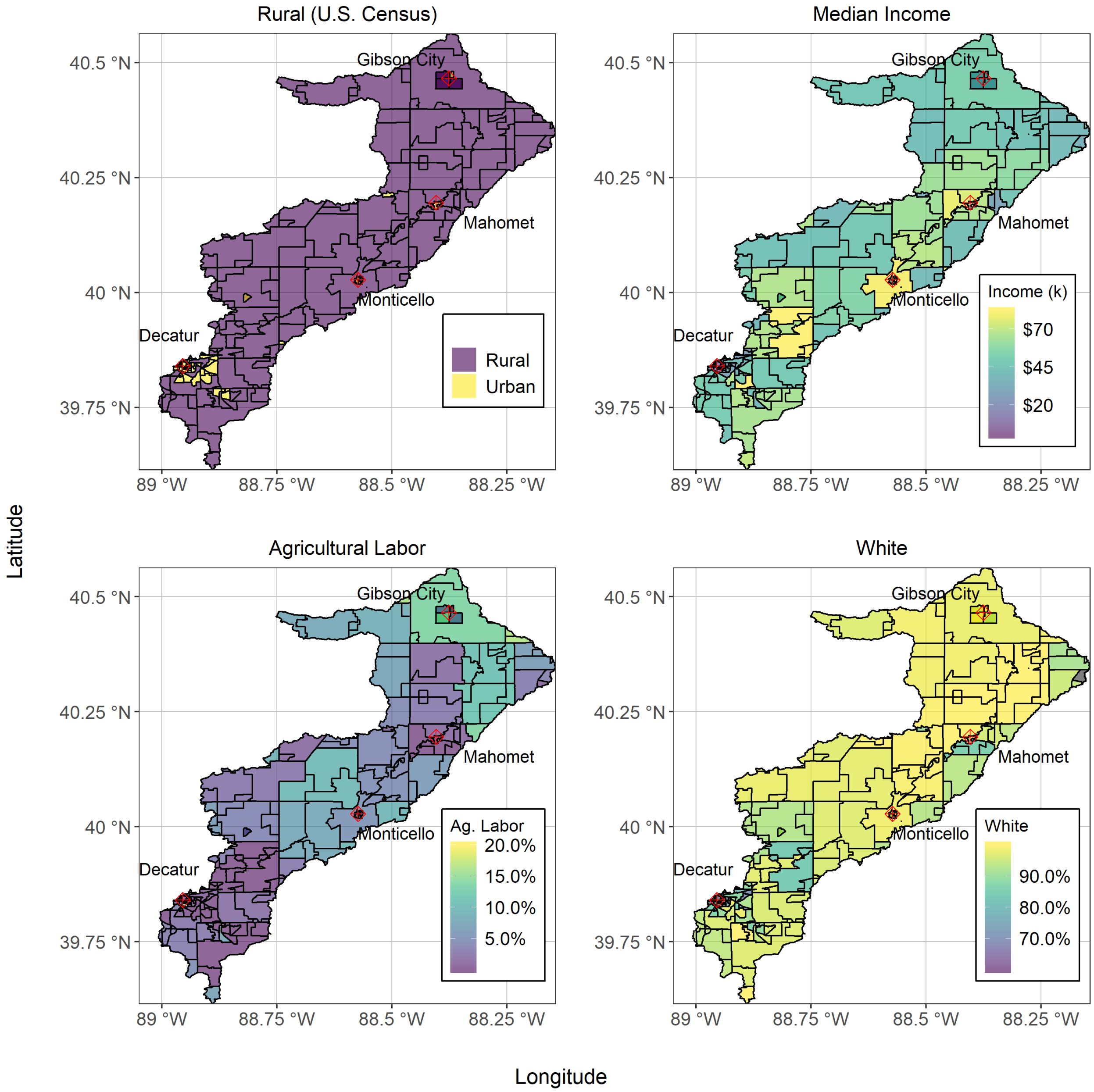
Appendix C Additional Figures

Figure C.1: Responses to Questions about Recreation



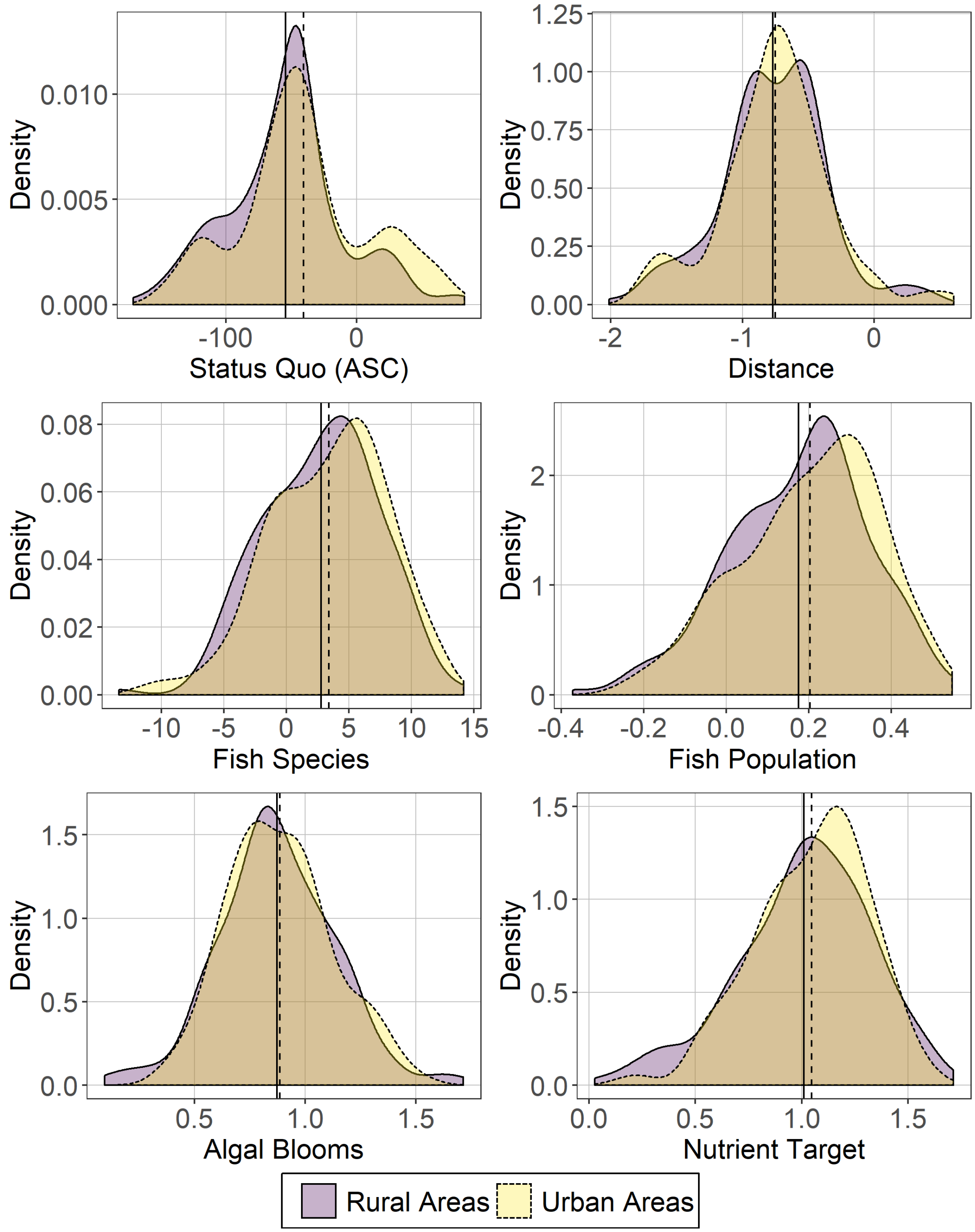
Note: Responses to the post-survey questionnaire about how frequently respondents visit the trails around the Upper Sangamon River each year, and if they participate in recreational fishing. Respondents rarely visit the trails, and even more rarely fish in the river or nearby water.

Figure C.2: Demographics and characteristics plots of the USRB



Note: Data from the American Community Survey (U.S.Census, 2019) are plotted within the watershed. Comparisons between these data and our sample are found in Table B.2.

Figure C.3: Conditional Individual-Specific Means of MWTP



Note: Conditional individual-specific means of MWTP are derived using the *gmnl* package in R (Sarrias and Daziano, 2017). These values are used in the IAM exercise to estimate the spatial distribution of benefits within the watershed.

Appendix D Miscellaneous Comments from Survey Respondents

- I appreciate your survey. I know central Illinois has had water issues for as long as I can remember so this survey gave me a lot not only think about but look into what is going on with our water. Thank you.
- Although this is a good cause—I do not trust the gov to collect the money & then actually use the money for what it is for.
- Working on a couple soil erosion projects on my land this year, so this was very interesting to me.
- Drinking water stinks and tastes like metal.
- I believe we do need to do whatever is necessary to keep our environment and waterways healthy, realizing there can be an impact to farming procedures. We need to find ways to keep the farms producing quality and wholesome foods and goods the farmers can afford, while at the same time making the environment safe for us, fish and wildlife. If it costs extra in local taxes, as long as that is where the money is spent, it is worth it.
- Algae blooms occurred before Europeans settled North America. How far back in earth's history are the EPA and Illinois going to achieve 0 blooms?
- We have the nastiest lake ever in the world and it sucks.
- I used to go hiking when I was younger in this area and I have family members that fish in the Sangamon river so I am concerned with these issues.
- I think the cost to provide water to a home in Decatur Illinois is outrageous because I don't believe it costs that much money in 1 month. I also think they should have a more realistic price instead of $150+ for 1 month and a family of 4.
- Some consideration needs to be directed to the use of chemicals and fertilizers used excessively by golf courses and home owners.
- I am concerned about how clean the water is.
- Thank you for caring.
- Save the fish!
- I would be glad to see improvement there. I use to fish everyday throughout the summer. Then for the last year I had to give it up for medical reasons but will be going a lot again starting this spring.
- I work 65 hours a week so I do not get out like I should.
- Thank you for looking into this matter.
- Would any of this help keeping stuff out of the aquifer?
- The water here isn't the greatest, but it's not too bad.
- I do not trust the Government to do anything right or to make sure the money that is collected goes to what it is supposed to be used for—they also have so many rules that we overpay by 1000%.
- I had no idea this was such a problem, but I will be looking into it. Thanks.

- River isn't deep enough to do anything near my house.
- This made me more concerned about the fish species that live in/or are imported into the area. If this were a real scenario, I'd be willing to educate myself further, and see how I could be part of a change.
- I'm more concerned about the Mahomet aquifer....whats up with that?
- Farmers should have to pay for the clean up of runoff or be forced to use organic farming methods.
- In Decatur, they've been cleaning the lake for the past couple of years. They are working diligently here to improve the water quality.
- I would honestly be willing to pay more for improvements if they weren't that expensive. Your scenarios were $5 or less per month which seems like a bargain for improvements.
- Thank you for informing me about these issue in my area.
- I have received emails in regard to the "drink-ability" of my water which comes from the Sangamon River. I would like to know more about this.
- Keep the Mohomet aquifer safe.
- The questions were easy to follow.
- I have noticed the water including Sangamon looking very green just in case that was a concern?
- One of the worst areas I can think of is at Crystal Lake Park in Urbana.
- This is a good survey. The water quality is the best I have ever encountered in Central Illinois.
- Most of our recreation is at Clinton lake and Moraine View. Unfortunately, I am not as well versed with Sangamon river issues but I do believe water purity and climate health are very important issues and would vote to for appropriate protections.