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Reducing Phosphorus Pollution in the Minnesota River: How Much is it Worth?

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Abstract

A mail survey was conducted in Minnesota in 1997 to estimate the value of reducing phosphorus levels in the Minnesota River by 40%. The general population survey of river basin residents was designed to gather information about respondents' use of the Minnesota River in addition to their valuation of a hypothetical water quality improvement program. An estimate of the value of a specific recreational site along the River, the Minnesota Valley National Wildlife Refuge, was also obtained.

Three distinct models were estimated in this research. The first was a contingent valuation model estimating the willingness to pay (WTP) for water quality improvements in the Minnesota River using only stated preference data. There were two different payment vehicles used in this question, an increase in the state income tax and a water bill surcharge. Respondents' annual mean willingness to pay for a 40% reduction in phosphorus was estimated to be $14.07 using this model and the tax vehicle, while the mean willingness to pay via the water bill surcharge was estimated to be $19.64 annually.

The second model utilized stated preference data from respondents along with responses about their actual visit behavior. A panel model was constructed using the responses to three separate questions concerning the value of a 40% reduction in phosphorus pollution and yielded an estimate of $38.88 per year. The final model used only data from the subset of respondents who had actually visited the Minnesota Valley National Wildlife Refuge. The recreational value of a typical trip to the Refuge was estimated to be $28.71 per individual.

Introduction

Recent attention given to water quality issues in Minnesota shows a strong public interest in improvements in water quality. In particular, the Minnesota River Assessment Project and statements made by former Governor Carlson, expressing his interest in making the Minnesota fishable and swimmable by 2002, put the water quality of the Minnesota River at the forefront of the local water quality agenda. This research is the first to estimate the willingness to pay for improvements in Minnesota River water quality. Since phosphorus has been identified as the limiting nutrient for algae growth in the Minnesota River, this study focused on the phosphorus pollution problem in the Basin. In addition, the recreational value of the Minnesota Valley National Wildlife Refuge is estimated since it is the recreational site on the River that would benefit most from phosphorus reduction.

The Minnesota River, Water Quality and Recreational Use

The Minnesota River flows 335 miles in the state through land that is primarily associated with agricultural activity.[1] The main pollutants of concern in the Minnesota River and its tributaries include sediments, phosphorus, nitrogen, bacteria, and oxygen demanding material. Nitrogen and phosphorus enrichment promotes algae growth which, when decomposing, uses up the available oxygen. Bacteria may cause a human health concern. Suspended solids reduce the amount of photosynthesis that occurs thus altering water temperature, and could possibly affect

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[1]This highly agricultural region of Minnesota is responsible for the production of 51% of the soybeans, 41% of the corn and 41% of the hogs produced in the state (Minnesota River Basin Agricultural Resources and Research). As a result, nonpoint sources of pollution are important in determining Minnesota River water quality.

aesthetic impressions of the River. Oxygen-demanding materials deplete dissolved oxygen in the water causing stress on aquatic life.

There are frequent documented violations of federal and state standards for bacteria, phosphorus, turbidity, and dissolved oxygen at monitoring stations along the Minnesota River or its tributaries. The EPA mandated a 40% reduction in biological oxygen demand, ammonia, and phosphorus in the Twin Cities metro area by July 1996.[2] The degraded water quality of the Minnesota River basin is believed to be the ultimate source of much of the phosphorus and oxygen demanding organic materials delivered to a widening of the Mississippi River on the Minnesota-Wisconsin border known as Lake Pepin, where severe eutrophication often occurs.

The Minnesota Valley National Wildlife Refuge in Bloomington is the largest single recreation area on the Minnesota River, extending for 34 river miles and 11,000 acres along the banks of the river between Jordan and Fort Snelling, with multiple access sites. Actual recreational use of the River in the Refuge is quite limited due in part to its current polluted state and the fact that there are many substitutes for water-based recreational activities nearby. Still, boaters and canoeists do use the River for recreation, and one can find anglers fishing off its banks. Other recreational activities in the Minnesota Valley National Wildlife Refuge include lake fishing, hunting, trapping, hiking, cross country skiing, snowshoeing, biking, horseback riding, and birdwatching. The Refuge has a Visitor's Center in Bloomington that offers educational exhibits on the ecology and wildlife of the Minnesota River valley, as well as an art gallery, an amphitheater and interpretive programs.

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[2]This reduction was not met by the 1996 deadline, nor has it been met on a continuous basis since the deadline.

Review of the Literature[3]

While economists often concentrate their research on market goods and services, it is also the case that individuals have preferences over things that are not readily tradable in the marketplace. The lack of price information about such goods is a complicating factor, though it does not necessarily prohibit one from studying preferences for goods such as natural resources and the environment.

One method used to reveal this underlying demand curve for environmental resources are those that associate consumption of a related market good to estimate the value of the nonmarket good or service. These techniques are categorized as revealed preference methods since consumer preferences are "revealed" through their consumption of a complementary good or service.[4] The travel cost methodology and hedonic price analysis are revealed preference methodologies that have been used for environmental valuation.

In contrast to revealed preference methods, the contingent valuation approach is based on stated preferences and does not use actual observed market behavior as the basis of benefit measurement. Contingent valuation is sometimes referred to as a "direct" approach to estimating willingness to pay since it involves directly asking individuals for their willingness to pay for some characteristic of the environment or natural resource in question. It is "contingent" valuation

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[3]For a more thorough review of the literature and greater detail on the empirical aspects of this study, see Mathews (1998).

[4]Mitchell and Carson (1989) use the term "observed market behavior" instead of revealed preference to classify these observed behavior-based methods of valuing public goods. They further break this category down into a "direct" subcategory, which includes referenda and simulated markets, and an "indirect" subcategory which includes household production and hedonic pricing methods (pp.74-75).

because it asks people how they would act if they were placed in certain possible situations. Despite much criticism[5], contingent valuation has been used extensively in measuring the benefits of a variety of public goods, especially environmental services. This is due in large part to the flexibility and applicability of the methodology, since contingent valuation can be tailored to study "virtually anything that can be made comprehensible to respondents."[6] The methodology has been authorized for use by the US Water Resources Council, the US Army Corps of Engineers, US Fish and Wildlife Service, and the US Environmental Protection Agency.[7] In Minnesota, the contingent valuation method has been used to estimate the economic benefits of reducing toxic air emissions and the value of improvements in drinking water quality, among other things.[8]

Both the revealed and stated preference methods have been used for environmental and natural resource valuation. Until recently, however, they have not been used in combination with one another but rather have been sometimes used to check each other's estimates of willingness to pay for environmental goods and services. The fundamental reason for combining the traditional revealed and stated preference methods is to improve the estimate of the total value of a resource or an environmental amenity. This methodology involves one jointly estimated model applied to a single sample of respondents.[9] Empirical examples of combining stated preference and revealed

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[5]Hausman (1993) provides a spirited critique of the contingent valuation method.

[6]Field (1994), p.151.

[7]Bishop, Champ, and Mullarkey (1995), p.629.

[8]Welle, Hagen, and Vincent (1992) and Cho (1997).

[9]The underlying philosophy is laid out in Cameron[b] (1992), p.1133, who states, "the social value of a resource is the sum of all individual values. We desire to acknowledge both the value accruing to users and the value accruing to nonusers. Although the

preference data are found in the literature of transportation research,[10] marketing research[11] and environmental valuation[12]

The Survey Instrument and Data Collection

The Survey Instrument

The actual survey instrument used in this study contained six sections. The first section included a description of the study and statement of the problem, along with a map depicting the Minnesota River. Also in this section was a statement which read, "*improving water quality in the Minnesota River will not solve all water quality problems in the River or in the state*" and an explicit reminder of other expenditures faced by policy makers. Statements such as this are included in order to remind respondents of the scope of the problem, and to help prevent an overestimation of their stated willingness to pay.[13]

The second section asked respondents a series of opinion questions, beginning with an explicit budget reminder question asking respondents to categorize their feelings on the amount of

individual values of nonusers may be small, there are potentially very large populations of nonusers for some resources. For policy or for litigation, whether or not you choose to recognize the aggregate 'value' accruing to nonusers of a resource can make all the difference in the world."

[10]Ben-Akiva & Morikawa (1990) and Morikawa, Ben-Akiva, & McFadden (1990).

[11]Eom & Smith (1994).

[12]Cameron[a (1992)] and Adamowicz, Louviere, and Williams (1994).

[13]Cummings, Brookshire, and Schulze (1994). Reminders of this sort may reduce the *context misspecification bias* that Mitchell and Carson categorize as *budget constraint bias* (Mitchell and Carson (1989), p.253-254).

money Minnesota is currently spending on certain issues such as improving education and reducing air pollution.[14] Again, reminders of one's opportunity costs were used in order to reduce the potential for an overestimate of the stated willingness to pay.[15]

Section three of the survey was the first of the contingent valuation sections, which asked about the respondents' willingness to pay for improvements in water quality of the river. This began with a description of a hypothetical water quality improvement program that would lead to a 40% reduction in phosphorus levels in the Minnesota River, and its hypothesized impacts. After the description, respondents were asked if they would vote *yes* or *no* for a referendum that if passed would increase their state income taxes to fund the program. If they responded *no*, there was a follow-up question designed to determine why they responded in such a manner.

Section four included questions asking respondents about their use of the Minnesota River as a recreation site. They were asked if they had visited the Minnesota Valley National Wildlife Refuge in the last 12 months and how often, what type of activity they typically engage in at the site, their round-trip distance from the site, and their expenses associated with their last trip to the Refuge. In section five respondents were asked if their visit behavior would change if water quality were improved in the Minnesota River. In the final section there were questions about the sociodemographic characteristics of the respondent.

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[14]This specific question was modeled after one used by Welle, Hagen, and Vincent (1992).

[15]Cummings (1994), p.12.

<u>Sample Selection and Data Collection</u>

Since those that do not currently use the Minnesota River for recreation or other purposes may also have a willingness to pay to maintain or improve water quality in the River, it was necessary to conduct a general population sample survey that included both users and nonusers. The sample population included individuals residing in the 37 counties of the Minnesota River basin, plus Ramsey county, since Ramsey was believed to be the home of many visitors to the Minnesota Valley National Wildlife Refuge. After two rounds of pre-testing, surveys were mailed to 1,044 households in April, 1997.[16] Two follow-up mailings were sent, and by June 461 completed surveys had been received from 44.2% of the sample.

A majority of respondents in the survey were male, married, and currently employed (Table 1). The average age was 50.2 years, and most had some education beyond high school. Roughly a third of respondent had at least one child under the age of 18 living in the household. The average reported annual household income was $49,615, calculated using the midpoint of each given intervals. The population of the city or town of the respondents' residence varied, with 109 (23.6%) living in towns of less than 10,000, 91 (19.7%) residing in towns between 10,000 and 25,000, 89 (19.3%) in cities of 25,000 to 50,000, and 172 (37.3%) living in cities of over 50,000.

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[16]The mailing list for the survey was generated by a survey sampling service that sampled randomly from local phone listings.

Table 1: Respondent Characteristics

Variable	Measure	Mean
Gender	Percent Male	69.2
Age	Years	50.2
Income	Household Average[a]	$49,614
Education Beyond H.S.	Percent	79.4
Marital Status	Percent Married	64.6
Children	Percent with Children	34.9
Employment	Percent Employed	68.8
N=461. [a]Calculated using the midpoint of given intervals.		

It is interesting to compare the demographic characteristics of the survey respondents with the characteristics of the area as a whole as found in 1990 census data. There is no major difference between the average reported household income of respondents ($49,614) and that reported in census data for the sample population ($48,445). This difference could be explained by the growth in income between 1990 and the time of the survey. In contrast, there are large differences in the education levels, age, and gender makeup of sample respondents. Levels of educational attainment are higher for a larger proportion of respondents than in the sample population, and the age distribution of respondents is older and respondents are more frequently male than in the sample population.

The percentage of respondents with a bachelor's degree or higher was 42.9 while the percentage in the sample population is 14.4.[17] There are several possible explanations for this

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[17]The percentage of respondents with a bachelor's degree or higher is used here for comparison with the statistics available for the sample population from the 1990 Census.

phenomenon. One is that the subject matter of the survey was not as interesting or not perceived to be as important to those in the survey sample without a bachelor's degree. Another possible explanation is that the survey questions were difficult to understand, leading those with less education to have a greater difficulty understanding the survey questions to the point where fewer of them responded.

The age distribution of respondents to the survey was different than that of the census population, in part because the cover letter asked that an adult in the household complete the survey. Thus those who completed the survey were older than the general population.[18] This can be better understood by looking at the opposite ends of the age spectrum: those under the age of 18 and those over the age of 65. For example, though 25.9% of the population was under the age of 18, none of the responses were attributed to that age group. In addition, 12.6% of the population was over the age of 65 but a much larger percentage of the responses, 21.9%, came from that group.

Over sixty-nine percent of the respondents to the survey were male (69.2%), while the percentage of males in the sample population is 48.2%. This gender difference could be due in part to the fact that phone listings were used to generate the sample and many listings are in the name of a male in the household. Thus a majority of survey letters were addressed to men and though the cover letter stated that any adult member of the household could respond to the

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For purposes of model estimation, however, the level of educational attainment is measured in a slightly different manner. It is based on whether respondents have had any education beyond high school.

[18] The specific breakdown of the age distribution of the population and of the respondents is found in Mathews (1998), p.63.

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survey, it may have been the case that more men completed the survey because it was addressed to them rather than passing it along to another (perhaps female) member of the household.

The Models Employed and Empirical Results

The Contingent Valuation WTP Models

The theorized relationship between a respondent's willingness to pay (WTP) for improved water quality and their level of income (INC), educational attainment (EDUC), age, gender (DMALE), willingness to pay taxes (DTAX), familiarity with pollution issues (DPFAM), and recreational use of the River (DUSER) may be summarized as follows:

WTP   =   f (EDUC, INC, AGE, DMALE, DTAX, DPFAM, DUSER)[19]   (1)

It is hypothesized that level of educational attainment will positively impact willingness to pay since those with higher levels of educational attainment will be more aware of environmental issues and their potential implications, and thus will be more willing to pay for improved water quality. Income is suspected to have a direct relationship with willingness to pay: the higher the level of income, the higher the willingness to pay for water quality improvements. Since environmental quality is a normal good, when incomes rise willingness to pay will increase. In essence, those with higher household income levels are likely to have a greater ability to pay for additional amenities such as improved water quality. Age is theorized to have an inverse

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[19]For each of the two payment vehicles used in the WTP questions, the income tax vehicle and a water bill surcharge, this relationship holds.

relationship with willingness to pay, since those respondents who are older may not be willing to pay for water quality improvements that they will not be able to enjoy in their lifetimes. The effect of gender on willingness to pay is uncertain, though previous work by Hamilton (1985) found that women were among those individuals with the highest concern about water contamination.

The indicator variable for the effect of an individual's opinion about paying more taxes is equal to one if they agreed with the statement, "I am against paying more taxes", zero otherwise. This implies an inverse relationship between the indicator variable, DTAX, and willingness to pay. If people are against paying more taxes, they will be less likely to state their willingness to pay for improved water quality when the vehicle used is increased taxes.

It is hypothesized that if a respondent is familiar with pollution issues, they will be more willing to pay for water quality improvements. If their awareness of pollution and water quality issues is high, individuals will likely have a greater understanding of the benefits from improving water quality. In addition, if they have visited the Minnesota Valley National Wildlife Refuge, it is should directly affect their willingness to pay. Recreational users of the River should have a greater awareness of the benefits of improving water quality that will lead them to be willing to pay more to realize those benefits.

Results of the CV WTP Model, Income Tax Vehicle

Estimation of the model was performed using LIMDEP's ordinary least squares regression for the available N = 461 observations (see Table 2). Mean estimated willingness to pay for a 40% reduction in phosphorus levels in the Minnesota River is found to be $14.07 using the

income tax vehicle question.[20] The F-ratio for testing joint significance of the regressors for this

model is 5.384, which is significant at the one percent level.

Table 2: Coefficient Estimates for WTP Regression, Tax Vehicle[21]

Variable	Coefficient	Std Error	t-ratio	Significant?
Constant	9.8579	2.816	3.501	yes
EDUC	5.2154	1.873	2.785	yes
INC	0.8639E-0	0.2774E-01	0.311	no
DTAX	-6.1972	1.809	-3.426	yes
DPFAM	-2.6019	3.105	-0.838	no
DUSER	4.774	1.626	2.937	yes
DMALE	0.19392	1.558	0.124	no
AGE	-0.655E-01	0.1399E-01	-0.468	no

The estimated parameters reflect the effect of a particular variable on the probability of

responding yes to the dichotomous choice WTP question. The significant variables are a

respondent's educational level, their response to the question regarding their willingness to pay

more taxes, and their visit behavior. These results imply that holding other factors constant, if an

individual had reported schooling beyond the high school level, they were more likely to respond

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[20]This estimate excludes those respondents who indicated a "protest" zero response to the WTP question. Those who indicated that they responded 'zero' to the WTP question because they didn't want to pay more taxes were labeled "protest" zero respondents since they appeared to be protesting the payment vehicle. If WTP is estimated with the inclusion of these protest zeros the estimate is $10.44.

[21]These results are derived from the estimation of 461 usable sample responses. Responses are deemed *significant* if the variable is statistically significant at the 5% level.

yes to the willingness to pay question. In addition, if an individual stated that they were against paying more taxes, then holding other factors constant, they were more likely to respond *no* to the willingness to pay questions on the survey. Again holding other factors constant, these results imply that visitors of the Minnesota Valley National Wildlife Refuge were more likely to respond *yes* to the willingness to pay questions than those respondents who had not visited the Refuge.

The estimated coefficients all reflect the hypothesized signs except for the indicator variable for familiarity with pollution issues, which suggested an inverse relationship with WTP rather than the expected direct relationship. In other words, those individuals who stated they were very familiar with environmental and water pollution issues in the state of Minnesota were less likely to respond *yes* to the willingness to pay question. One possible explanation for this unexpected result is that respondents' familiarity may have led them to form opinions about how to alleviate the pollution problems that the proposed program offered in the survey did not address. Alternatively, their familiarity with pollution issues could have led them to believe in the "polluter pays" principle, and thus be less likely to indicate individual willingness to pay for pollution control programs designed to clean up someone else's pollution. Since the DPFAM variable is not significant, an individual's familiarity with environmental issues does not appear to be an important factor in determining respondents' willingness to pay for water quality improvements, as was originally hypothesized.

Results of the CV WTP Model, Water Bill Vehicle

The second willingness to pay question on the survey was identical to the first except that the payment vehicle for the hypothetical water quality improvement program was a surcharge on

the household's water bill rather than a tax increase. The variables and hypothesized relationships found in equation 1 remain unchanged in this model, with the exception of the payment question.

Estimation of this model was performed using LIMDEP's ordinary least squares regression for the available 461 observations. Estimation results from this equation are shown in Table 3. Mean willingness to pay for a 40% reduction in phosphorus pollution in the Minnesota River when funded through a surcharge on respondent households' water bills was found to be $19.64.[22] The F-ratio for testing joint significance of the regressors for this model is 6.317, which is significant when tested at the one percent level.

The significant variables are the respondent's educational level, their opinion about paying more taxes, their visit behavior, and gender. As in the results for the WTP/tax vehicle estimation, the results imply that respondents who have had any schooling beyond high school had a higher willingness to pay for a 40% reduction in phosphorus pollution levels in the Minnesota River when other factors are held constant. Similarly, if an individual stated their opinion against paying additional taxes they were less willing to pay for the proposed water quality improvements. Again, similar to the previous estimation, these results imply that recreational users of the Minnesota Valley National Wildlife Refuge have a higher willingness to pay for water quality than nonusers of the Refuge.

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[22]This estimate reflects the exclusion of protest zero responses; the WTP estimate with protest zeros included is $10.83.

Table 3: Coefficient Estimates for WTP Regression, Water Bill Vehicle[23]

Variable	Coefficient	Std Error	t-ratio	Significant?
Constant	13.453	2.993	4.495	yes
EDUC	6.0478	1.991	3.038	yes
INC	0.02253	0.02948	0.764	no
DTAX	-7.2646	1.922	-3.779	yes
DPFAM	-2.0698	3.301	-0.627	no
DUSER	3.6509	1.728	2.113	yes
DMALE	-4.5182	1.656	2.729	yes
AGE	-0.00972	0.01487	-0.653	no

Interestingly, gender was a significant variable in this regression equation but it was not in the previous equation. It is not clear why gender would be a significant determinant of willingness to pay for water quality improvements paid for via a water bill surcharge and not for those improvements paid for via a tax increase. The coefficient of the gender indicator variable, in this regression, had the opposite sign to the regression with the tax vehicle. The inverse relationship implies that females had a higher willingness to pay than males. This result is similar to that found by Hamilton, which indicated that females were more likely to be concerned about water contamination.

The variables that were not found to significantly affect willingness to pay were income, familiarity with environmental and water pollution issues, and age. These results imply that the WTP estimate for a respondent with a higher income level is likely to be higher but not

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[23]These results are derived from the estimation of 461 usable sample responses. Responses are deemed *significant* if the variable is statistically significant at the 5% level.

significantly different from the WTP estimate for respondents at lower income levels.   Similarly, these parameter estimates reveal that the WTP estimate for those respondents who categorize themselves as very familiar with environmental issues is lower but not significantly different from the WTP estimates of the remainder of the respondents. Finally, the negative but not significant coefficient on the AGE variable indicates that older respondents have a lower but not significantly different WTP estimate than younger respondents.

The Panel Model

The general structure of the panel estimation follows Loomis (1997), who used a random effects probit model to allow for consistent modeling of actual trip decisions (at current trip costs), the intention to visit at higher trip costs (via a dichotomous choice contingent valuation question), and the intention to visit at hypothetical different quality levels in order to estimate the economic value of environmental quality changes.

Three (generic) types of questions were asked of respondents: "do you currently visit the Minnesota Valley National Wildlife Refuge?", "would you visit the Minnesota Valley National Wildlife Refuge if the water quality in the Minnesota River were higher?", and "would you visit the Minnesota Valley National Wildlife Refuge (MVNWR) if costs were higher?" Responses to the first type of question are revealed preference information while the responses to the second and third questions are stated preference data (contingent behavior and contingent valuation, respectively).

The theorized relationship between decisions to take trips to the MVNWR (R) and travel costs (TC) and water quality (Q) may be summarized as follows:

$$R = f(TC, Q). \tag{2}$$

Specifically, it is hypothesized that as travel costs increase individuals will take fewer trips since it will be more expensive for them to do so. As water quality improves it is expected that more trips to the MVNWR will be taken since the trip experience will be more pleasurable with a 40% reduction in phosphorus levels in the Minnesota River.

The responses to the three questions listed above were used in a system of three equations following the general structure of equation (2) to estimate the value of a 40% reduction in the amount of phosphorus in the Minnesota River. These equations are described as follows:

$$R_1 = TC1 + Q \tag{3}$$

$$R_2 = TC1 + Q \tag{4}$$

$$R_3 = TC_3 + Q \tag{5}$$

where R_1 = Indicator of current visit behavior; 1 if visitor, 0 otherwise

           R_2 = Indicator of visit behavior with water quality improvement; 1 if they would visit the MVNWR, 0 otherwise

           R_3 = Indicator of visit behavior with higher costs; 1 if they would visit the MVNWR, 0 otherwise

           TC_1 = Individual's reported travel cost to the MVNWR

$$TC_3 \quad = \quad \text{Individual's hypothetical increased travel cost to the MVNWR}$$

$$Q \quad = \quad \text{Indicator of water quality; 1 for current Minnesota River water quality, 0 otherwise}$$

Panel Estimation Results

Using the results from three responses from each of 451 survey respondents (for a total of 1383 observations), the panel model was estimated (see Table 4). The estimated parameters reflect the effect of the variables on the probability of responding *yes* to the dichotomous choice questions. Both the coefficients for travel cost and the indicator variable for water quality are significant at the one percent level, and the coefficients possess the hypothesized (negative) signs.

Table 4: Coefficient Estimates for the Panel Model

Variable	Coefficient	Std Error	t-ratio	Significant?
Travel Cost	-0.6086E-02	0.2190E-02	-2.779	yes
Quality	-0.23660	0.7191E-01	-3.290	yes
Rho	0.22010	0.6938E-01	3.172	yes

The negative coefficient on the water quality variable implies that at current water quality levels, individuals are less likely to visit the Minnesota Valley National Wildlife Refuge. A loose interpretation of the parameter estimate implies that at current quality, the probability of a respondent visiting the Refuge is 24% lower than under the proposed alternative of reducing phosphorus levels by 40%.

As expected, when travel costs rise, respondents are less likely to respond *yes* to the dichotomous choice questions asked on the survey. Specifically, the travel cost variable estimates

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reveal that as an individual's travel costs increase by $1, they are 0.6% less likely to visit the Refuge.

The Chi-squared statistic for testing the significance of the overall model (for testing the null hypothesis that all coefficients equal zero) was 24.246, which is significant at the one percent level. Rho, the estimated correlation coefficient between responses, was significant at the one percent level indicating that the errors from the panel equations were indeed correlated. This implies that statistical gains were realized by estimating the three equations as a panel rather than independently.

The panel estimation provides parameter estimates for the travel cost variable and the indicator variable for water quality, which can be used to estimate the mean and median WTP.[24] When calculated using the coefficient estimates obtained from the estimation of the panel model as reported in Table 4 above, mean WTP for improved water quality is estimated to be $38.88.

The Travel Cost Model

The last model that was estimated in this research is significantly different than the previous models. Specifically, the WTP models and the panel model were designed to estimate respondent willingness to pay for a 40% reduction in phosphorus levels in the Minnesota River, whereas the travel cost model is only capable of estimating the value of a recreational site, the Minnesota Valley National Wildlife Refuge (MVNWR).

The travel cost model uses data from the subset of respondents that had actually visited the Minnesota Valley National Wildlife Refuge. Their responses to survey questions about their

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[24]Hanemann (1984), p.335 and Hanemann (1989), p.1058.

visits are used to estimate the recreational value of the Refuge. The demand for recreational trips to the Refuge (Trips) are theorized to be a function of travel costs (TCOST), income (INC), age, and level of educational attainment (EDUC) which may be summarized as follows:

$$\text{Trips} = f(\text{TCOST, INC, AGE, EDUC}) \qquad (6)$$

Specifically, it is hypothesized that as travel costs increase respondents will take fewer trips to the MVNWR. Income is expected to have a direct relationship with trip demand: as income increases, more trips will be taken. The age influence on number of trips is uncertain. If older respondents have more time, they may take more trips. In contrast, younger respondents may be more inclined to visit because of the relatively cheap entertainment that a trip to the Refuge provides, or because they have children. Education is believed to have a direct relationship with the number of trips to the Refuge. Those respondents with education beyond high school are more likely to visit due to their greater awareness of the need for exercise that would make recreating at the Refuge more likely. Thus, the coefficient on the education variable is expected to be positive.

Results of Travel Cost Model Estimation

Poisson regression models are used to estimate models that contain variables that count the number of times that something has happened. In this case, the left-hand side of equation (6) counts the number of trips that were taken to the MVNWR. As a result, the travel cost model described above was estimated using LIMDEP's Poisson regression model for count data on the

100 user observations that were complete (see Table 5). The Chi-squared statistic for testing the significance of the overall model (for testing the null hypothesis that all coefficients equal zero) was 575.96, which is statistically significant at the one percent level.

Table 5: Coefficient Estimates for the Travel Cost Model

Variable	Coefficient	Std Error	t-ratio	Significant?
Constant	3.85180	0.25620	15.035	yes
Travel Cost	-0.017416	0.00518	-3.361	yes
Income	-0.0037276	0.00180	-2.071	yes
Age	-0.025698	0.00386	-6.653	yes
Education	-0.80398	0.14030	-5.731	yes

As expected, travel cost was found to inversely affect the number of trips. When an individual's travel costs increase by $1, the expected number of trips to the Refuge will decrease by 1.7%.

There was a significant relationship between income and number of visits, though the sign on the income coefficient was not positive as expected. The unexpected negative sign on the income variable indicates that as income increases, individuals are less likely to take trips to the Refuge. If income increases by $1000, individuals are expected to decrease the number of trips they take by 0.37%. This relationship could be explained by the fact that as income increases, people substitute other recreational opportunities for visits to the Refuge. If this is the case, then the Minnesota Valley National Wildlife Refuge is considered an inferior good. Alternatively, it may be the case that as income increases, an individual's time becomes more valuable. If this is

the case, then another possible explanation for the negative coefficient on the income variable is that as income rises, individuals' time costs of taking a trip to the Refuge increases and they are less likely to make a trip.

The age variable had a negative and significant coefficient, indicating that as age rose, individuals were significantly less likely to visit the Refuge. When age rose by one year, the number of trips taken by respondents deceased by 2.6%. One possible explanation for this relationship is that the older respondents are choosing to spend their free time in recreational sites other than the Refuge, or they simply recreate less often than younger individuals.

Education beyond high school also had a significant and negative relationship with trips to the Refuge. The negative impact of education was unexpected, but may be explained by the fact that those with some education beyond high school are more likely to have other recreational and entertainment opportunities available to them, so they will visit the Refuge less often. Or, as with the income coefficient, it may be the case that those respondents with education levels beyond high school place a higher value on their time. If respondents have high time costs, they will be less likely to make a trip.

The coefficient estimates described above and delineated in Table 5 can be used to estimate the consumer surplus (benefits) per trip to the Refuge.[25] The estimated benefit of a typical trip is $28.71 per individual per trip using the data from this model. This estimate should be viewed as a lower bound on the true estimate of consumer surplus for at least two reasons. First, the trip cost estimate did not incorporate the value of time. As long as visitors value their time at greater than zero, then the exclusion of time costs will lead to an underestimate of the true

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[25]Bockstael and Strand (1987), p.16.

costs of the trip. Ignoring the value of time in the travel cost model will bias the travel cost

estimate upward which will have the effect of biasing the benefit estimate downward.[26] Second,

the travel cost model assumes that those who do not visit the Refuge do not place any

recreational value on the site. If there are any nonvisitors who do value the Minnesota Valley

National Wildlife Refuge as a recreational site, then aggregate consumer surplus estimates derived

from the travel cost model will be lower than the true value.

Which Number Should Be Used?

The use of environmental valuation estimates such as those derived in this research are not

new to policy makers. They have been used in many different situations including natural

resource damage assessment and the weighing of benefits and costs of a policy change. However,

after considering the set of estimates one may wonder which number should be used. If a goal is

to weigh benefits and costs of a proposed policy change, then the precise benefit estimate used

may determine the feasibility of various policy options.

Table 6 summarizes the benefit estimates. There were three distinct models used to

estimate the value of the hypothetical water quality improvement program proposed in the survey-

-a 40% reduction in phosphorus levels in the Minnesota River--and each model produced a

different estimate. These range from $14.07 to $38.88 per household per year, with the CV

WTP/tax model providing the lowest WTP value, while the highest WTP value came from the

panel model that combined hypothetical (stated preference) and actual (revealed preference) data.

It is crucial to recognize that although these models were calculating the same non-market good--

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[26]Freeman (1993), p.449.

a reduction in phosphorus pollution in the Minnesota River--the estimates were calculated using slightly different data from the same survey. Specifically, the contingent valuation models used only hypothetical (stated preference) data, for two distinct payment vehicles (income tax increase and water bill surcharge), while the panel model used stated preference data combined with the revealed preference data to estimate the value of improved water quality.

The travel cost model used only revealed preference data from those who had visited the site to estimate the recreational value of the Minnesota Valley National Wildlife Refuge. A consumer surplus estimate of $28.71 per individual per trip was obtained from this model which is not comparable to the TWP estimates for the reduction in the phosphorous level in the river.

So which estimated value is appropriate? That will depend explicitly on which value is desired: an estimate of the value of reducing phosphorus pollution in the Minnesota River by 40%, or an estimate of the recreational value of the Minnesota Valley National Wildlife Refuge (MVNWR). For the reduction in phosphorous pollution, a value in the range of $14-20 per household per year is probably a realistically conservative figure. The total for the basin would, therefore, be between $14 and 20 million annually since there are slightly over 1 million households in the sample population.

Table 6: Summary of Estimated Benefit Values

Model	Benefit Estimate	Type of Data Used	Estimated Value
CV WTP, Tax Vehicle	WTP for water quality improvements[27]	Hypothetical[28]	$14.07[29]
CV WTP, Water Bill Vehicle	WTP for water quality improvements	Hypothetical	$19.64[30]
Panel Model	WTP for water quality improvements	Hypothetical and Actual	$38.88
Travel Cost Model	Recreational Value of MVNWR Site	Actual	$28.71

Are These Values the *True* Values?

It is important to recognize the possible shortcomings of the estimates calculated in this

research. The true willingness to pay for phosphorus reductions in the Minnesota River may be

higher than those estimated because the sample only included a subset of Minnesota counties, and

there may be others who would be willing to pay *more* for water quality improvements than those

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[27]Respondent willingness to pay for a 40% reduction in phosphorus pollution in the Minnesota River.

[28]This hypothetical data is also referred to as *stated preference* data and refers to that data which the respondent provides in response to a hypothetical scenario. Actual data is also known as *revealed preference* data; that is, the data gathered from respondents concerning their actual behavior.

[29]The $14.07 estimate excludes the zero WTP responses that have been labeled as "protest" zeros; with these protest zeros, WTP is $10.44.

[30]The $19.64 excludes protest zeros; with protest zeros, the WTP is $10.83.

sampled in this survey. One such group may be downstream users of the Mississippi River, or those who reside near or recreate in Lake Pepin, which has experienced algae blooms thought to be a result of phosphorus pollution in the Minnesota River. Alternatively, the true willingness to pay for phosphorus reductions in the Minnesota may be *lower* than those estimated here because those that were not sampled may have a willingness to pay for phosphorus reductions that is *less* than those included in this research. Unfortunately, without further sampling and estimation it is difficult to predict how close these estimates are to the true willingness to pay values.

Each of the models has limitations, and the welfare estimates derived from them should be used cautiously. The results should not be extended beyond the population sample area--those counties in the Minnesota River basin plus Ramsey county--for it is likely that models estimated from a different sample would not provide the same results. For example, residents in the Arrowhead region of Minnesota may have significantly different preferences for water quality in the Minnesota River and for the Minnesota Valley National Wildlife Refuge as a recreational site. If the values estimated in this research were used to represent the entire population of Minnesota, they would be inaccurate and misleading.

Implications of the Study

Over 60% of individuals surveyed responded *yes* to the willingness to pay questions, indicating broad support for the hypothetical program that proposed a 40% reduction in phosphorus pollution in the Minnesota River. At a minimum, this result indicates that a majority of respondents perceive that improving water quality in the Minnesota River is a worthwhile endeavor.

A large percentage (38%) of those respondents who did not currently visit the Minnesota Valley National Wildlife Refuge indicated that they *would* visit if phosphorus pollution in the Minnesota River were reduced by 40%. If these respondents do in fact change their visit behavior in response to a pollution reduction, then the recreational value of the Minnesota Valley National Wildlife Refuge will be increased. Assigning the average amount of consumer surplus received per typical trip to the Refuge calculated in the travel cost model, $28.71, and assuming that each of these 127 individuals would make one trip per year after the pollution reductions occur, the recreational value of the Refuge would increase by approximately $3,646 per year. Extrapolated to the sample population, the estimated increase in the recreational value of the Refuge is $11,052,976 per year.[31]

Summary and Conclusion

The benefits of reducing phosphorus pollution in the Minnesota River were estimated based on a 1997 survey asking residents in a subset of Minnesota counties about their willingness to pay for a hypothetical water quality improvement program that would reduce phosphorus levels by 40%. The estimated values ranged from $14.07 to $38.88 per household per year, as a result of differences in data and modeling approaches. *In other words, depending on how the question is phrased and how the response is modeled, the empirical estimates of the value of phosphorus reductions in the Minnesota River will vary.* The estimate that is most appropriate for policy use will depend on the policy under consideration.

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[31]This value is derived by calculating 38% of 1,013,123 households in the sample population, or 384,987 households, times one trip per year at the estimated value of $28.71 per trip.

This study provides an estimate of the benefits of improving water quality by reducing phosphorus pollution in the Minnesota River. However, in order for socially optimal water quality improvement programs to be designed and implemented it will be necessary to investigate the specific costs of improving water quality. Once estimates of both costs and benefits are obtained for various water quality improvement proposals, then informed decisions can and should be made about how best to achieve water quality improvements in the Minnesota River.

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