Valuing Ecosystem Service Benefits from Green Pollution Control Infrastructure: Evidence from Riparian Shading Programs in the Tualatin Watershed, Oregon

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Abstract: Scientific research and policy initiatives on using green infrastructure for pollution control are expanding. Potential cost-savings are often a prime motivation. However, environmental co-benefits may also ensue from such approaches. State of the science valuation methods, such as choice experiment surveys, are necessary to capture the full range and values of such benefits. We present a case study of this for the case of installing riparian shade corridors to meet temperature standards in an urban-rural fringe Oregon watershed. We use a primary survey, administered to a sample of 800 waste water treatment utility customers in the Tualatin river basin. Our findings shed light on the public's willingness to pay (WTP) for the additional ecosystem services generated by this green infrastructure approach. Our estimates show significant WTP for water quality, air quality and preservation of fish and wildlife highlighting that the public values the additional benefits. We also find that the WTP for these ecosystem services is influenced by perceived water quality conditions as well as the respondent's environmental attitudes. The results show that this green infrastructure program has substantial value beyond thermal pollution control. Indeed, by extrapolating the benefits to entire customer base suggests an attractive social benefit-cost ratio. This case analysis of a progressive ecosystem services management approach illuminates salient positive impacts of green infrastructure approaches beyond pollution control.

Keywords: Green infrastructure**,** Riparian shading, ecosystem services, choice experiment, tree-shade programs, Oregon

JEL Codes: Q25, Q56, Q51

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1. Introduction

Interest in using natural capital to control pollution and provide valuable ecosystem services is blossoming in science and policy arenas (Guerry et al 2015). Scholars argue that such green infrastructure approaches can help offset the pollution debt of expanding urban and exurban areas while fostering long-term resilience (Gomez-Baggethun and Barton 2013; Shaffler and Schwilling 2013). Some early evaluations, as for green flood plain protections, adopted a cost-effectiveness perspective and suggest the cost savings may not outweigh the program expenses (e.g., Kousky et al 2013). Although the cost-effectiveness insight is valuable, a broader analytical lens that captures the full set of socioeconomic and ecological effects is needed to evaluate green infrastructure investments (Vandermulen et al 2011). For example, researchers have documented that the presence of green street initiatives for stormwater control can affect the value of surrounding residential properties, sometimes in surprising ways (Netusil et al 2014). The bottom line is that an evaluation of the potential benefits of a green infrastructure project should include salient market and non-market effects and capture use and non-use values to compare against program cost.

Scholars note that the use of ecosystem service (ES) valuation to inform government policy lags advances in the science underpinning such valuation (Gerry et al 2015, Shaefer et al 2015). One reason for the discrepancy may be the lack of compelling cases that document the values in real settings. n this paper, we demonstrate an application of an inclusive ES benefit framework to a novel water pollution control effort in an exurban region southwest of Portland, Oregon (Porter et al 2014). High temperatures in rivers and streams in the area are a source of thermal pollution that can damage aquatic species, including some salmonids listed as endangered. Increases in water temperature caused by human activities, typically the use of water as coolants by power plants, sewage treatment plants and other factories, can lead to a decrease in the oxygen levels which can kill indigenous aquatic species, change the ecosystem composition and lead to invasion by thermophilic species (Kennish 1992, Laws 2000). Clean Water Services (CWS), the primary wastewater utility operating in the Tualatin River watershed has implemented a program of restoring riparian vegetation in the form of tree buffers along sections of the river to cool water temperatures to meet temperature regulatory standards. This green approach has been approved by Oregon's Department of Environmental Quality. Compared to building a thermal-fired chiller to achieve the temperature reductions, the buffers saved substantial costs, but also convey multiple environmental co-benefits (Porter et al 2014). Specifically, the riparian vegetation helps to improve the water quality by acting as filters, improve the quality of fish and wildlife within the area, improve the air quality, and provides hiking and fishing habitat. The public's values for these active and passive uses are currently not known and therefore are not systematically considered in CWS decision making about changes in the riparian shading program.

To fill this information gap, we use a choice experiment survey to understand the public's willingness to pay for the additional ecosystem services generated by these riparian plantings. The respondents were randomly selected from amongst CWS ratepayers from the Tualatin basin. We find significant willingness to pay for the water quality, air quality and preservation of the fish and wildlife in the Tualatin basin. We also find that respondents' willingness to pay for the ecosystem attributes is influenced by perceived current water quality as well as environmental attitudes. The results show that this program has value beyond the reduction of thermal pollution. Therefore, it is important that these values are taken into account when evaluating the effectiveness of the program and designing other green infrastructure projects for the area.

2. The Application

The Tualatin River travels some 83 miles and drains some 712 square miles in Northwestern Oregon including one the fastest growing areas of the State as well as some of its most productive agricultural lands. Clean Water Services (CWS), the water resource management utility for the Tualatin River watershed and urban Washington country, serves some 537,000 customers in urban Washington County and 12 local cities (Beaverton, Tigard, Tualatin, Hillsboro, King City, Forest Grove, Sherwood, Cornelius, Banks, Gaston, Durham, and North Plains). The CWS treats more than 64 million gallons of wastewater per day and is serviced by four award-winning wastewater treatment facilities that are subject to federal water quality regulation (Clean Water Services, 2014).

With increasing recognition of the negative impacts of thermal pollution in 2002, the US Environmental Protection Agency and Oregon Department of Environmental Quality determined that the wastewater discharged into the Tualatin River, though exceptionally clean, was too warm for salmon and trout and initiated a Total Maximum Daily Load (TMDL) for water temperature in the Tualatin. CWS was required to reduce their thermal loads by nearly 90%. To meet its federal and state regulatory obligations, CWS is required to maintain a National Pollution Discharge Elimination System (NPDES) permit. NPDES permits allow CWS to offset wastewater temperature discharge requirements by trading temperature credits within the Tualatin watershed. In 2004, CWS began implementing a shade credit program in order to reduce infrastructure costs and increase environmental benefits within the utility's district. The CWS Shade Credit Program constitutes of three riparian planting programs which combined have allowed CWS to meet 80% of its permit obligations. In addition, the program is a cost effective alternative to the waste water treatment plant and cooling system that would otherwise needed to have been constructed at an estimated cost of $150 million. The costs of the riparian program are small in comparison at approximately $4.3 million, allowing the cost savings to be invested into other projects that increase ecological benefits of the watershed (Roll et al, 2009).

In addition, the shade credit program is more beneficial than building and operating an industrial cooling plant for the overall health of the watershed because it addresses a host of additional issues like declining wildlife populations (by providing new habitat), increasing flooding (by slowing passage of water and absorbing more water), increasing runoff (with riparian buffers that reduce runoff) and other environmental benefits (Smith 2005). For example, such green infrastructure projects improve biodiversity, create additional carbon sinks, improve air quality, and improve water quality to name a few. Building a refrigeration facility to cool the water would not provide the additional benefits. Indeed, it would exacerbate some environmental costs such as greenhouse gas emissions. Placing dollar values on many of the benefits from the shade program is not easy. At the same time without values for these additional environmental services, the benefits of the CWS riparian shade credit program are undervalued. In addition, understanding consumer preferences towards these additional environmental services would inform future CWS watershed restoration projects and policies.

This study focuses on identifying the how the CWS ratepayers view these additional benefits and the amount they would be willing to pay to ensure the continuation of these natural benefits. Specifically we ask two research questions, (1) What is the public's willingness to pay for the additional ecosystem services generated by the riparian tree shade program? (2) How does the public's willingness to pay change based on socio-demographic variables? Choice experiments are well suited to evaluating values and preferences associated with different combinations and conditions of natural capital in a given region, therefore we use a choice experiment survey to provide new information on these salient values.

3. Methods

People value and are willing to pay for a variety of non-use or passive use benefits, including those provided by green infrastructure despite the absence of markets. For instance, think of charities one might contribute to but never actually use the services of their programs. Likewise, for environmental goods and services. The problem is if no monetary value is placed on these benefits, they are likely to be undervalued or ignored when making policy decisions (TEEB 2010). This is why it is important to use valuation methods that can uncover these otherwise hidden values. To be able to place values on these services, preferences must be stated not observed. There are two common stated preference techniques, contingent valuation and choice experiments.

3.1 Contingent valuation versus choice experiments

Contingent valuation (CV) has been historically the traditional stated preference method to elucidate passive use values for non-marketed ecosystem services for many years. This method relies on a survey technique that specifically asks respondents to state their perceived values, their willingness to pay, for a particular good or service or to answer a . This is in sharp contrast with a revealed preference approach such as travel cost or hedonic pricing methods, which extrapolates values for an environmental resource based on the observed expenditures by consumers of market goods, cost of traveling to a national park or the increase in housing values next to clean lakes, respectively.

Since many ecosystem services are considered non-use benefits, the CV methodology of simply asking respondent willingness to pay may seem appropriate. However, the CV method frames a single or a particular scenario. This may not always be appropriate, especially if the region or program being evaluated has multiple nnon-use benefits that can vary independently that need to be valued and where a detailed description would require complex information to be conveyed that is not appropriate in a survey being administered to the general population.

A choice experiment, on the other hand, does allow for multi-attribute valuation. Respondents are presented with a variety of choices similar to what they might see in an electronics store. Instead of the attributes that make up a blue-ray player, they are considering the benefits that are the result of a particular habitat or government programs. Each choice set the respondent considers has two or more alternatives from which to choose and each alternative has different levels associated with the benefit (i.e. high water quality vs. low water quality). There is a cost associated with each alternative. The respondent then chooses the combination of attributes that they feel suits their budget and personal values best.

Because choice experiment surveys pose choices to the respondent rather than explicitly asking their willingness to pay, not only can values for individual services be obtained, but values for scenario changes and tradeoffs between the services can be elicited as well (Adamowicz et al., 1998). It is a robust method that does not rely as much on the accuracy and completeness of the scenario description as does CV, but rather on the accurate representation of the choices being presented (Boxall et al., 1996). Since we are interested in understanding the value of multiple environmental benefits arising from the Shade Credit Program and these benefits can vary based on management practices we use a choice experiment survey for this survey.

3.2 Choice Experiment Survey

Choice experiments are a stated preference valuation tool used to determine someone's marginal willingness to pay (WTP) or willingness to accept (WTA) for goods, or characteristics of goods, when market data are not available for assessing these valuations. A choice experiment survey presents the respondent with choice scenarios where each choice scenario has alternatives with varied levels of different attributes of the good or policy being evaluated. The, respondents chooses one of the alternatives or a status quo option and the results from the choice experiment provide information about the value of individual features of the goods and policies being valued. Alpizar et al. (2003), Boxall et al. (1996), Hanley et al. (2001), Hensher et al. (2005), Hoyos (2010), and Louviere et al. (2000) provide reviews of the choice experiment methodology.

When conducting choice experiment surveys it is vital to ensure that relevant attributes and characteristics are presented to the respondent in an easily understandable form.

3.3 Selecting relevant ecosystem services and survey design

The ecosystem service benefits that arise from the Tree Shade Program are quite complex as they can be defined in multiple ways depending on the desired technical depth. This makes it difficult to frame "ecosystem services" in a way that will be most relevant to survey respondents who are not well versed in environmental concepts.

For instance, all the inputs that result in clean water (water quality) may be convoluted for the average respondent to grasp, i.e., pH, phosphorus and nitrate levels, and dissolved oxygen. However the result of good water quality is a concept that a respondent can easily understand. Good water quality means their kids can go swimming, that water is safe for drinking, etc. People can state their preferences for water quality and when prompted can choose their willingness to pay. These final environmental goods and services have been coined "ecological endpoints" (Boyd and Krupnick 2009, Olander 2015). Ecological endpoints are therefore the final goods and services of the environment. Estimating demand for a non-marketed good that is visible to people is easier to evaluate for willingness to pay than an unseen and scientifically complex input used as a measure of water quality (Millon and Scrogin 2003). Therefore we use ecological end-points in our survey instrument to inform the respondents about the benefits of the shading program.

An overarching principle to guide ecosystem service valuation is to engage key stakeholders in a transparent process to identify salient ecosystem services (Ervin 2018, Johnston 2018). To that end, in the beginning of this study we conducted informal focus groups, engaged in discussions with researchers and policy makers including personal from the Willamette Partnership and Clean water Services and then finally conducted formal focus groups. We then created a preliminary version of the survey and followed that up by conducting a trial survey using three classes at Portland State University and Portland Community College. We analyzed the data and presented the preliminary findings at a national conference. Through this process, based on the feedback from the participants of the trial survey, the feedback received from presentations of the work and further discussion with researchers we refined the survey instrument, in particular the list and descriptions of attributes. We then conducted another around of focus groups with CWS with a sample from the population of interest (CWS ratepayers). Facilitating stakeholder groups to identify salient attributes has been documented as a critical early step in ecosystem service projects (Inestia-Arandia, et al 2013; Ruckleshaus et al 2015). Through this process of interacting with key stakeholders, we identified four key attributes for the choice experiment; water quality, air quality, fish and wildlife, and cost.

The levels for each attribute are presented in Table 1. For water quality we use the levels from the EPA Water Quality Ladder, swimmable, fishable, and boatable. For air quality we used good, fair and poor. For fish and wildlife we indicated both levels and percentage indicating as High (90% of species), Medium (60% of species), Low (30% of species).

Attributes	Levels
Water quality refers to whether water is safe for drinking, swimming, fishing, or boating.	(1) Swimmable (good) (2) Fishable (fair) (3) Boatable (poor)
Air Quality refers to the amount of air pollutants that are present in the air.	(1) Good (2) Fair (3) Poor
Fish & Wildlife refers to the number of different types of life (fish, birds, vegetation, insects, amphibians, etc) that live in streams and wetlands.	(1) High (90% of species) (2) Medium (60% of species) (3) Low (30% of species)
Cost: Payment that goes to fund the maintenance or restoration projects.	(1) $0 (2) $25 a year (3) $50 a year (4) $75 a year (5) $100 a year

Table 1: Attributes used for Choice Experiment

The survey was designed and administered by DHM Research, a professional survey company that has done prior survey work for CWS. The respondents were selected from an online panel of CWS ratepayers. Each respondent answered 12 choice questions and each choice question has four riparian restoration options and a no restoration status quo option. Figure 1 shows an example of one choice question.

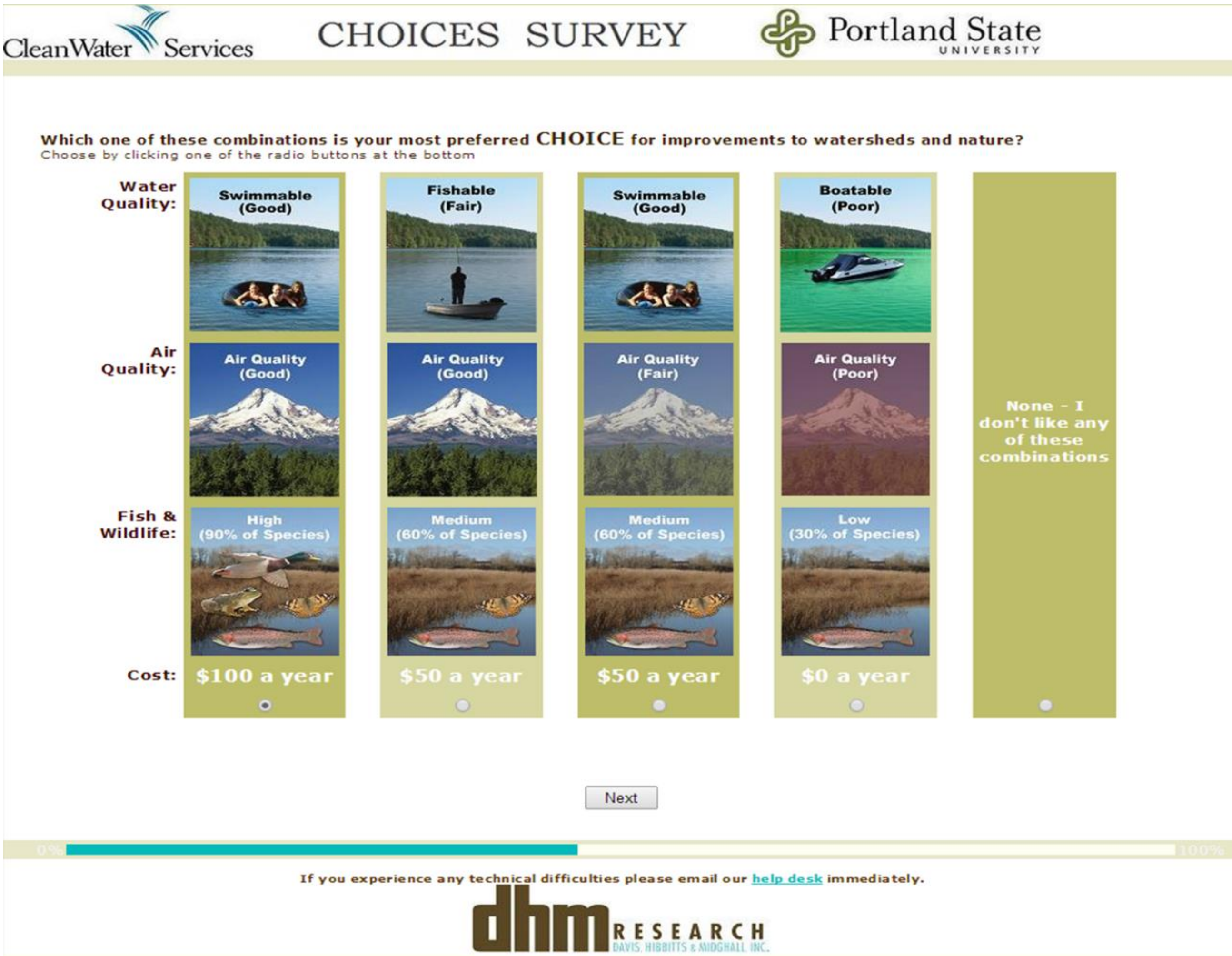

Figure 1: Sample Choice Question

4. Methods of Analysis

We follow the standard practice in the choice experiment literature and use a conditional logit and a mixed multinomial logit model to analyze the data. We use a linear random utility model (RUM) for the econometric specification. The general form of the conditional logit (CL) model includes attributes as a linear summation in the following general form:

$$V_i = \sum_{k=1}^{k} \beta_k X_{ki_1} + \beta_{price} X_{price} + \varepsilon_i \qquad (1)$$

With the specific attributes included in this choice survey, the model takes the form:

$$V_n = \beta_0 ASC + \beta_1 X_{Water\_Quality} + \beta_2 X_{Fish\ and\ Wildlife} + \beta_3 X_{Air\ Quality} + \beta_{Cost} X_{Cost} + \varepsilon_n \quad (2)$$

The alternative specific constant (ASC) term accounts for the fact that option A and option B are both improved restoration outcomes and therefore are closer substitutes with each other than with option C, the status quo option (Haaijer et al. 2001, Blaeij et al. 2007). The ASC term identifies the overall likelihood of choosing a combination of attributes (option A or option B) regardless of the levels of the specific attributes. The conditional logit model assumes that respondents all have homogeneous preferences and thus it provides a limited analysis of unobserved heterogeneity (β_i.in specification (2) estimates the mean value for the sample). In order to account for preference heterogeneity we also use a mixed multinomial logit (MMNL) model to analyze the data (Hensher et al. 2005, Carlsson et al. 2003, Train 2003).

For the MMNL model we use a linear random utility model for the main effects estimation.

$$V_{ni} = \beta_{0n} ASC + \beta_{1n} X_{Water\_Quality} + \beta_{2n} X_{Fish\ and\ Wildlife} + \beta_{3n} X_{Air\ Quality} + \beta_{Cost\ n} X_{Cost} + \varepsilon_{ni} \quad (3)$$

The coefficient estimates from the CL model and the MMNL model cannot be interpreted directly. Therefore, the average marginal WTP is calculated for a change in each attribute *i* by dividing the coefficient estimate for each attribute with the coefficient estimate for the payment term, as given in (3).

$$MWTP_i = -\frac{\beta_i}{\beta_{cost}} \quad . \quad (4)$$

The MMNL model does not explicitly identify the underlying factors, e.g., personal values (?), that lead to heterogeneous preferences. In addition to the above standard main effects specifications we also analyze the data using the specification that incorporates demographic interactions terms to better understand the heterogeneity in the sample.

$$V_{ni} = \beta_{0n} ASC + \beta_{1n} X_{Water\_Quality} + \beta_{2n} X_{Fish\ and\ Wildlife} + \beta_{3n} X_{Air\ Quality} + \beta_{Cost\ n} X_{Cost} + \beta_{kn} ASC * Z_{kn} + \varepsilon_{ni} \quad (5)$$

The Z variable represents socio-demographic interaction terms. Specifically, we test how beliefs about the quality of the environment, attitudes towards the environment, education and gender influence preferences.

5. Results

The results of the main effects specification using a CL, a MMNL with and interaction specification with attribute and cost interactions are provided in Table 2. The coefficients for all the attributes are significant and positive and respondents most preferred attributes were Water Quality, Fish and Wildlife and Air Quality in that order.

The MMNL model also provides information about the heterogeneity of preferences. In the main effects model the standard deviations for all the attributes are significant implying that that there is heterogeneity within the sample and significant variation among responses regarding these attributes and that a MMNL model should be used for the analysis.

To better interpret the results we calculate the marginal WTP for each of the attributes. The results are provided in Table 3 and Figure 2. The WTP for Water Quality is provided for an increase in one level on the EPA water quality ladder, for Fish and Wildlife for a 30% increase (increase in one level), and for Air Quality for an increase in one level (from poor to fair or fair to good). The results show that respondents recognize the external benefits from the Riparian Shading Program and are willing to pay for these benefits. In particular respondents are willing to pay on average \$62, \$50, and \$43 (over what period?) for increases (by one level) in Water Quality, Fish and Wildlife, and Air Quality.

Though the MMNL model indicates that there is significant heterogeneity in the preferences it does not identify the sources of heterogeneity. In an effort to better understand the heterogeneity we include two specifications with interactions terms, attribute interaction terms (Column 3) and cost interactions terms (Column 4). These results show two interesting patterns. First we find that respondents who perceive their current water quality is poor were willing to pay more for the improvement of water quality and air quality. This finding is consistent with the notion that water quality improvements deliver diminishing marginal benefits as would be expected of normal goods (correct Sahan?). Second we find, perhaps unsurprisingly, that respondents who care more for the environment are willing to pay for the benefits. The cost interaction terms show the robustness of these results.

	(1)	(2)	(3)	(4)
	Clogit: Main Effect	**Mixlogit: Main Effect**	**Mixlogit: Interaction with main attributes**	**Mixlogit: Interaction with Cost**
<u>Main Effects</u>				
Water Quality	0.910***	1.022***	0.739***	1.154***
	(0.0196)	(0.0303)	(0.0511)	(0.0321)
Fish & Wildlife	0.726***	0.814***	0.445***	0.896***
	(0.0176)	(0.0266)	(0.0453)	(0.0283)
Air Quality	0.634***	0.685***	0.496***	0.744***
	(0.0154)	(0.0233)	(0.0415)	(0.0251)
Cost	-0.0140***	-0.0172***	-0.0189***	-0.0560***
	(0.000436)	(0.000996)	(0.00100)	(0.00425)
ASC	-2.015***	-1.926***	-1.907***	-1.851***
	(0.0474)	(0.0988)	(0.0964)	(0.109)
Water quality*water pollution			-0.0355*	
			(0.0607)	
Fish & wildlife * water pollution			0.0753*	
			(0.0529)	
Air quality* water pollution			-0.0102	
			(0.0399)	
Water quality * Environmental Care			0.559***	
			(0.0582)	
Fish & Wildlife * Environmental Care			0.492***	
			(0.0515)	
Air quality * environmental care			0.305***	
			(0.0445)	
Cost * gender				-0.00616**
				(0.00222)
Cost * environmental care				0.0329***
				(0.00221)
Cost* water pollution				0.00514*
				(0.00218)
Cost * High education				0.00907*
				(0.00398)
Standard Deviations				
Water Quality		0.339***	-0.404***	0.280***
		(0.0324)	(0.0440)	(0.0426)
Fish & Wildlife		0.295***	0.313***	0.161**
		(0.0267)	(0.0281)	(0.0620)
Air Quality		0.280***	0.292***	0.186***

		(0.0249)	(0.0289)	(0.0337)
Cost		0.0137***	0.00503***	-0.0164***
		(0.000838)	(0.00143)	(0.00107)
ASC		1.270***	1.555***	1.884***
		(0.0680)	(0.120)	(0.104)
Water quality*water pollution				0.666***
				(0.0515)
Fish & wildlife * water pollution				0.574***
				(0.0536)
Air quality* water pollution				0.150*
				(0.0613)
Water quality * Environmental Care				0.592***
				(0.0390)
Fish & Wildlife * Environmental Care				0.351***
				(0.0354)
Cost * gender			0.0283***	
			(0.00245)	
Cost * environmental care			-0.0248***	
			(0.00164)	
Cost* water pollution			0.0327***	
			(0.00251)	
Cost * High education			-0.0163***	
			(0.00125)	
Observations	48420	48420	42180	42780
Adjusted R^2				
AIC	25188.0	23392.4	18806.2	19417.9
BIC	25232.0	23480.2	18961.9	19608.5
Log lik.	-12589.0	-11686.2	-9385.1	-9687.0
Chi-squared	5993.5	1805.7	2392.5	2269.6

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Estimation Results

	(1) WTP: Clogit ($)	(2) WTP: Mixlogit ($)
Water Quality	64.85***	59.55***
	(1.845)	(3.684)
Fish & Wildlife	51.75***	47.41***
	(1.922)	(3.099)
Air Quality	45.19***	39.94***
	(1.677)	(2.638)

Table 3: WTP Estimates

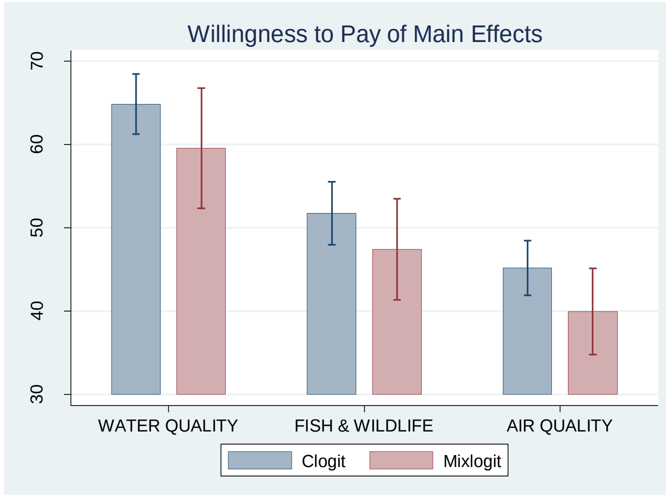

Figure 2: WTP Results from Maine Effects

6. Conclusions and Implications

In this study we use a choice experiment survey, conducted in Tualatin Oregon, to understand the willingness to pay for the additional ecosystem services generated from a Riparian Shading Program implemented by Clean Water Services, the water utility company for Tualatin Oregon. This innovative environmental management action was the first(?) step in developing a more holistic watershed restoration program of green infrastructure and natural capital. With increasing recognition of the negative impacts of thermal pollution the Oregon Department of Environmental Quality initiated a TMDL for water temperature in Oregon and CWS had to reduce their thermal loads by nearly 90%. Instead of building a water cooling plant that would cost over $150 million dollars CWS opted to use riparian shading to achieve the required thermal reductions and started a Riparian Shading Program in 2004. We analyze the CWS ratepayers WTP for the additional ecosystem service benefits generated from this riparian shading program.

We find that respondents are willing to pay on average $62, $50, and $43 for increases in Water Quality, Fish and Wildlife, and Air Quality. We find that the there is significant heterogeneity in the preferences for these attributes and we use two specifications with interactions to better understand the heterogeneity. We find that respondents that have attained a higher level of education are willing to pay more for improvement in the attributes in comparison to those with a lower level of education. We also find that respondents who believed that they currently had poor water quality were willing to pay more for the improvement of the quality of attributes in comparison to those who believed they had good quality water. Finally we find that respondents who claimed to care about the environment and natural resources were willing to pay more for the improvement of the quality of the attributes in comparison to those who did not care.

The results show that using riparian shading to achieve thermal pollution reduction has value beyond the reduction of thermal pollution. Therefore these values should be considered when future riparian shading programs are implemented and when the cost-effectiveness of the programs are evaluated. This study provides evidence that households are willing to pay for innovative programs focused on using natural capital to control pollution and provide valuable ecosystem services. CWS is currently moving towards a landscape level management to enhance overall ecosystem services using multiple forms of natural ecosystem infrastructure.

Figure 2: Multiple green infrastructure implemented by CWS

Specifically, CWS is considering simultaneously using riparian buffers and wetland enhancement activities and practices to improve irrigation efficiency. As next steps we hope to study the optimal targeting of these green infrastructure to maximize ecosystem service benefits.

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