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ANALYSIS

Contingent valuation, net marginal benefits, and the scale of riparian ecosystem restoration

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Abstract

A study was undertaken to estimate the benefits and costs of riparian restoration projects along the Little Tennessee River in western North Carolina. Restoration benefits were described in terms of five indicators of ecosystem services: abundance of game fish, water clarity, wildlife habitat, allowable water uses, and ecosystem naturalness. A sequence of dichotomous choice contingent valuation questions were presented to local residents to assess household willingness to pay increased county sales taxes for differing amounts of riparian restoration. Results showed that the benefits of ecosystem restoration were a non-linear function of restoration scale and the benefits of full restoration were super-additive. We estimated the costs of riparian restoration activities by collecting and analyzing data from 35 projects in the study area. After adjusting our estimated valuation function for socio-economic characteristics of the local population, the benefit/cost ratio for riparian restoration ranged from 4.03 (for 2 miles of restoration) to 15.65 (for 6 miles of restoration). Riparian restoration in this watershed is therefore an economically feasible investment of public funds at all measured spatial scales.

Keywords: Riparian restoration; Contingent valuation; Super-additivity; Complements in valuation

1. The need for marginal economic analysis of ecosystem restoration

Ecological systems provide an array of benefits to humans that are not generally accounted for in market transactions. Consequently, economic activities can degrade ecological systems and valuable ecosystem services may be underprovided or entirely lost. If ecosystems are resilient to changes caused by degradation, it may be possible to restore ecosystem services either to some pre-existing level or to a level that is commensurate with the demands of the current human population. However, because ecosystem restoration is still highly experimental and

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can be quite costly to implement, it is not immediately obvious which ecosystems deserve priority for restoration or, once specific ecosystems are chosen for restoration projects, just how far restoration activities should proceed.

During the past decade, the federal government has become increasingly concerned with protecting ecosystem integrity and federal funds have been provided for ecosystem restoration activities. Although policy decisions might be made on the basis of non-economic as well as economic criteria, analysis of the benefits and costs of restoration projects provides policy makers with information by which they can gauge the efficiency of public investments. The costing of restoration activities is conceptually straightforward, although the acquisition and analysis of such data is complicated by its relative scarcity. On the benefits side of the ledger, multiple human services are provided by riparian ecosystems, and the value of many services can only be measured using non-market valuation methods.

The existence of multiple, interconnected, non-market ecological services presents significant challenges to researchers seeking unbiased estimates of ecosystem values (Turner et al. 2002). Microeconomic analysis of the net benefits associated with marginal changes in ecosystem services, from a clearly defined baseline to a new condition resulting from the imposition of a policy, provides a conceptual foundation for empirical analysis (Balmford et al. 2002). However, ecosystem services are intrinsically connected and conventional valuation methods might produce piecemeal, incomplete estimates of the benefits of restoration (Bockstael et al. 2000).

The objectives of this study were to develop and test a general methodology for valuing the restoration of a set of ecosystem services and to compare the economic benefit of riparian ecosystem restoration with its cost. Based on detailed conversations with stream ecologists and local citizens, a set of relevant ecosystem services associated with riparian restoration was identified. During these conversations, it became apparent that the scale of restoration could be used as a summary measure for the provision of ecosystem services. That is, because the overall biological condition of a river basin is negatively linked to the degree of human influence (Karr and Chu 1999), the scale of restoration activities that mitigate human impacts provides a convenient meta-indicator that can be linked with the supply of ecosystem services. A contingent valuation survey was developed to estimate the benefits associated with the provision of different levels of ecosystem services, and data provided by the US Natural Resources Conservation Service were used to analyze the cost of restoration projects in the study watershed. This process allowed us to compare the costs and benefits of watershed restoration at different spatial scales.

2. History of the Little Tennessee River ecosystem

In this paper, we conduct a benefit–cost analysis of restoration activities along the Little Tennessee River (hereafter LTR) located in the southern Appalachian Mountains. The Little Tennessee River (LTR) originates in Rabun County, GA; it flows north into North Carolina before terminating at Fontana Dam, just south of the Great Smoky Mountains. The LTR basin contains about 100,000 ha of mountainous terrain of which 49% is part of the Nantahala National Forest, 37% is in privately held forest, and the remainder (14%) is developed.

Historically, the LTR watershed was within the homeland of the Cherokee Nation. After European settlement, the region supported logging, agriculture and mining industries. During the late 1940s, the Tennessee Valley Authority began to address the sediment loads in the LTR and grasses were planted on steep slopes to reduce soil erosion. Subsequently, land use shifted as farmers began increasing livestock production and many farmers cleared their land toward the riverbank to maximize output.

Most recently, tourism, recreation and the draw of living in an aesthetically pleasing environment has led to rapid population growth and an increase in the number of people who visit the area. In the last 20 years, the population in Macon County, NC (our study area), has doubled, leading to concerns about the future health of the watershed and the ecosystem services the watershed provides.

The majority (51%) of land within the watershed is privately owned and private land use decisions have had a major impact on ecosystem structure and function (Wear and Bolstad 1998). Non-point pollution from agricultural activities (such as watering cattle in streams) and development (housing and commercial development along streams and creeks) threaten the ecological integrity of the watershed. Economic activities have introduced increased levels of sediment, nutrients, fecal coliform bacteria, toxic chemicals, oil, grease, and road salt into the river system.

3. Prior riparian restoration activities and costs in the LTR watershed

A restoration program for the LTR watershed was initiated in 1995 and 59 projects had been completed by 2001. A total of 54 projects have set aside 45,118 ft, or 8.5 miles, of riparian buffer. This activity consists of planting trees and grasses to stabilize the riverbank. On 14 projects, fences were installed to prohibit livestock from entering the river. And on five projects, alternative water systems were developed for watering livestock.

Only 35 of the riparian buffer projects had sufficient cost data available to estimate project costs.[1] We estimated that riparian buffers without fencing cost, on average, $0.98/ft (based on data from 29 projects). With fencing, average costs were $3.13/ft (based on data from 6 projects).

Another restoration activity in the LTR watershed involved rebuilding eroding stream banks with revetments. Revetments consist of large tree branches or logs that are anchored to the stream bank with cables. Of the 54 projects, 45 landowners restored 15,321 ft (or 2.90 miles) of stream bank using revetments; 34 landowners used trees from their own property and the other projects brought in trees from off-site. Revetments are typically quite costly to construct. The average cost of revetments where on-site trees were available for construction was $15.50/ft. If on-site trees were not available, the average cost of revetments was $20.33/ft.

To permit comparison of the costs and benefits of restoration, it was necessary to make some assumptions about the typical mix of restoration activities to construct a representative scenario. Based on documented restoration data, it was assumed that, for every mile of riparian buffer that is established, 0.34 miles of revetment is installed (2.9 miles of revetment/8.5 miles of buffer). Using a weighted average cost estimate (on-site trees and without on-site trees) of $16.37/ft for constructing revetments, this translates into $5.56 per "representative" foot of restoration ($16.37*0.34). Next, it was assumed that fencing is installed for 46% of the length of riparian buffers (46% of the total length of riparian buffers was fenced in our project data). The average cost of establishing a riparian buffer in a "representative" restoration would then be $2.06/ft. The average cost per foot establishing a representative mix of restoration activities would be $7.62/ft (calculated as the sum $5.56 + $2.06).

Cost sharing is provided through the Natural Resources Conservation Service to landowners desiring to create riparian buffers (with or without fencing) or install revetments on their land. The NRCS program funds 75% of the cost while the landowners must provide the other 25%. If landowners contribute their own trees to a revetment project, then their cost share falls to 10% of that project. The private benefit to landowners who decide to enter into a project with the NRCS can be presumed to equal or exceed the dollar amount of their cost share agreement. Under the cost-share program, then, landowners must pay 25% of the cost, or $1.91/ft in our example. Thus, the public benefits must equal or exceed 75% of the cost, or $5.72/ft, for public investment in a representative mix of restoration activities to be economically feasible.

The upper LTR watershed is approximately 20 miles in length. Although approximately 8.5 miles along the river have received restoration treatments, many segments along the river still need to be restored. In consultation with local experts, it was determined that restoration of 6 additional miles of river would constitute complete restoration (not all stretches of the river require restoration).

4. Issues in the valuation of freshwater ecosystems

Economic valuation of ecosystems is complicated by the fact that ecosystems are characterized by

[1] All costs and benefits are standardized to the year 2000.

multiple, interdependent services that possibly exhibit complex dynamics and discontinuous change around critical thresholds (Limburg et al. 2002). Faced with this complexity, marginal economic valuation of ecosystems has typically proceeded via simplification. In a review of published research on the valuation of freshwater ecosystems from 1971 to 1997 (30 studies), Wilson and Carpenter (1999) found that most studies focused on a specific indicator of water quality such as water clarity or the frequency of noxious algal blooms. While these studies have made important contributions by demonstrating that freshwater ecosystems have economic value, particularly non-use value, they only provide partial benefit estimates because they are based on an incomplete list of potentially valuable services.

Turner (1999) defines Total Economic Value (TEV) as the sum of all use and non-use values provided by an ecosystem.[2] One approach, then, is to obtain values for each of the services provided by ecosystem protection or restoration. Recognizing the multi-dimensional nature of water quality, the US Environmental Protection Agency developed a six-dimensional characterization of the benefits provided by freshwater systems (USEPA, 1994): aquatic life support (providing habitat for fish and other aquatic organisms), fish consumption (fish do not pose a human health risk), drinking water supply (water is safe to drink with conventional treatment), primary contact recreation-swimming (no adverse health effects from occasional contact), secondary contact recreation (no adverse health effects from activities such as canoeing), and agricultural use (suitable for irrigation or watering livestock). Using this scheme, states are requested to report the percentage of lakes, rivers and streams that meet five levels of water quality, ranging from "good, fully supporting" to "poor, not attainable" for each of the water quality dimensions.

Magat et al. (2000) developed a study for valuing water quality based on a simplified version of the EPA monitoring structure. Using the method of paired comparisons, they found that swimmable water quality accounted for the greatest proportion of overall benefit, followed by quality of the aquatic environment, and finally by fishable water quality. They also noted that people were willing to pay a disproportionately high premium for water quality improvements in areas that they would never use, suggesting that non-use values are an important benefit provided by enhanced water quality.

An alternative, holistic approach to ecosystem valuation was reported by Loomis et al. (2000), who used the contingent valuation method to evaluate the benefits of restoring a portion of the Platte River watershed. The approach used in this paper described the current level of provision of four ecosystem services: dilution of wastewater, natural purification of water, erosion control, and habitat for fish and wildlife. Specific mechanisms for restoring ecosystem services were then described, followed by a referendum WTP question asking respondents whether or not they would vote in favor of a specific restoration program. Using estimated water leasing costs and farmland easement costs necessary to implement the program, benefit/cost ratios varied between 1.4:1 and 5.22:1 depending on whether those refusing to be interviewed had a zero value or not.

Zhongmin et al. (2003) estimated the benefits and costs of restoring ecosystem services in the Hei River basin in China using a holistic approach to valuation, similar to the method used by Loomis et al. (2000). Five ecosystem services were listed that ecosystem restoration could provide: control soil erosion and reduce sand storms, provide habitat for wildlife, natural purification of water, dilution of wastewater, and limit land salinization. Results of the in-person interviews indicated that over 90 percent of the respondents were willing to pay a positive amount for ecosystem restoration. However, the amount that the general public was willing to pay was found to be substantially less than the estimated costs of restoration.

The decision of whether to value a set of ecosystem services holistically, as is done using the contingent

[2] Use values associated with riverine ecosystems can include benefits arising from in-stream uses (such as fishing, swimming, or boating), withdrawal for drinking water or irrigation, enhanced aesthetics for nearby uses such as picnicking, consumptive activities such as hunting, and non-consumptive activities such as bird-watching. Restoration of riparian ecosystems can also enhance the well-being of the current generation by providing benefits for future generations (bequest values) and from the knowledge that a healthy ecosystem exists (existence value).

valuation method, or whether to focus valuation on trade-offs between specific services using an attribute-based stated preference method, depends on the goals of a study. If management actions can differentially affect the provision of individual ecosystem services, then information on value trade-offs between ecosystem services can be estimated using attribute-based methods (e.g., Holmes and Adamowicz 2003). However, if ecosystem services are highly correlated in production, then contingent valuation is probably more appropriate.[3]

5. Ecosystem valuation survey design

Hoehn et al. (2003) recognized that the economic value of freshwater ecosystems is derived from the services they provide, and stressed the importance of linking ecosystem science with ecosystem services in conducting stated choice experiments. For our study, conferred with a team of economists conferred with at team of ecologists from the USDA Forest Service Coweeta Hydrologic Laboratory to discuss the set of ecosystem services that have been impacted by land uses in the LTR watershed and the particular restoration activities that were being undertaken to address riparian ecosystem degradation. In these sessions, concern was expressed both about the current agricultural practice of watering cattle in the LTR and its tributaries and about the impact of residential and commercial development along streams in the river basin. Review and input on the relationships between ecosystem services and restoration activities in the LTR watershed were also obtained in focus group sessions with ecologists in the Institute of Ecology at the University of Georgia, and through discussions with the Little Tennessee River Association and members of the Macon County Soil and Water Conservation District.

Based on these conversations, several ecosystem services (and indicator variables for each service) were identified: (1) habitat for fish (abundance of game fish), (2) habitat for wildlife (wildlife habitat in buffer zones), (3) erosion control and water purification (water clarity), (4) recreational uses (allowable water uses), and (5) ecosystem integrity (index of ecosystem naturalness). Generalized categories representing the level of provision of each indicator were assigned to represent low, moderate or high levels of provision of these services. This technique is a modification of the "good–poor" categorical scale used by the USEPA (1994), and was used to obviate problems associated with characterizing an exact change in ecosystem services that could be expected to obtain from the implementation of specific riparian restoration activities.

Marginal ecosystem values may vary depending on the scale (scope) of ecosystem restoration. If a single restoration project is not effective in enhancing the overall level of ecosystem services, the derived economic benefits will probably be low. In contrast, the value of multiple projects that do in fact enhance the overall provision of ecosystem services may be greater than the sum of the benefits provided by individual projects valued in isolation. That is, if restoration projects are what Madden (1991) calls R-complements, then benefits might be "super-additive".[4]

This perspective is important to recognize because restoration projects are often conducted piecemeal, using the logic that some restoration is better than none, and that it is important to "start somewhere" with available funding. However, from an economic perspective, it is possible that, for geographically isolated projects, the costs of restoration exceed the benefits. This result becomes increasingly likely if restoration is expensive and if extensive restoration is required to change the overall level of services provided by an ecosystem.

To test the hypothesis that program scale has an impact on marginal economic benefits, it was necessary to link indicators of ecosystem services with

[3] Attribute-based stated preference methods rely on independent variation in attributes (e.g., ecosystem services) to estimate attribute values. Correlated attributes introduce the statistical problem of multicollinearity. For a discussion of this issue, see Holmes and Adamowicz (2003).

[4] A useful discussion of additivity effects and scale (scope) can be found in Hanemann (1994). In terms of the economic terminology defining scale effects, variation of the scale of restoration within-subjects is referred to as an internal scale (scope) test.

Table 1
Overview of hypothetical Little Tennessee River riparian restoration programs used in the iterative contingent valuation experiment

	Current situation	Program 1	Program 2	Program 3	Program 4
Indicator of ecosystem service	No small streams protected by BMPs + no new river restoration	All small streams protected by BMPs + no new river restoration	All small streams protected by BMPs + 2 miles of new river restoration	All small streams protected by BMPs + 4 miles of new river restoration	All small streams protected by BMPs + 6 miles of new river restoration
Game fish	Low	Low	Low	Low	High
Water clarity	Low	Low	Moderate	Moderate	High
Wildlife habitat in buffer zones	Low	Moderate	Moderate	High	High
Allowable water uses	Low	Moderate	Moderate	Moderate	High
Index of ecosystem naturalness	Low	Low	Moderate	High	High

scale (Table 1).[5] Indicator levels were also provided for the status quo scenario, and for a base program consisting of best management practices at construction sites and along private roads in order to prevent sediment from entering tributaries to the LTR.[6]

Respondents were asked to vote on four different programs. In consultation with local experts, it was determined that complete restoration could be accomplished by installing riparian restoration projects along an additional 6 miles of the riverbank. A base program mandating BMPs along tributaries of the LTR was designated, along with three alternative levels of river restoration (2, 4 and 6 miles of new restoration).

6. A computerized survey instrument

A computerized survey instrument was developed to facilitate communication of information about the sources of riparian ecosystem degradation in the LTR watershed, the various riparian restoration and protection activities that could be implemented to address the problem, and ecosystem services that would be enhanced by the watershed programs. This format allowed us to make extensive use of photographs and diagrams depicting restoration activities. Land use maps were included to depict land use change in the study area, and showed the proximity of economic development to the LTR and its tributaries. Although the use of a computerized instrument may eliminate the potential for bias that is sometimes induced by in-person surveys, it might discriminate against people who are less computer literate, such as older people or people with lower incomes.

The computerized instrument provided us with the opportunity to customize the bidding structure in the iterative referendum voting scenarios. Bid amounts for the 4-mile and 6-mile restoration programs were conditional on the response to the prior referendum question. A YES response to the 2-mile or 4-mile restoration referendum questions led to a higher bid amount for the subsequent program, whereas a NO response led to an identical bid amount for the subsequent program. All respondents were presented with bids for each of the four programs. The initial bids were randomly selected from the amounts \$1, \$5, \$10, \$50 or \$75. Bid amounts for the 6-mile restoration program ranged from \$1 (resulting from a string of prior NO responses) to \$500 (resulting from a string of prior YES responses).

The valuation questions asked the respondent to consider a vote to approve or reject specific man-

[5] The scientific basis for linking ecosystem services with scale of restoration is extremely limited and was therefore based on expert judgment. We let the overall provision of ecosystem services increase in a roughly linear fashion with scale up to 4 miles of restoration. That is, letting "low" = 1 point, "medium" = 2 points and "high" = 3 points, the marginal change in aggregate ecosystem services is constant up to 4 miles of restoration. However, at 6 miles of restoration, the change in aggregate ecosystem services doubles from the level provided at 4 miles of restoration.

[6] BMPs include activities such as construction of drop structures (e.g., weirs) to minimize soil movement down slopes. BMP activities would be paid for by the private sector.

Table 2
Descriptive statistics for Macon County, North Carolina

Data source	Median income ($)	Median Age (years)	Males per 100 females	Bachelor's degree or higher (%)	Property along LTR (%)
Sample	45,000	47	82	72	52
2000 Census	28,696	45.2	92.1	13.2	15[a]

[a] Based on the estimated number of households within 200 m of the LTR and its major tributaries using aerial photographs available at "terraserver-usa.com" and data on building density in the LTR Basin (Wear and Bolstad 1998).

agement programs for the Little Tennessee River watershed. The management program would be one of the alternative riparian ecosystem programs shown in Table 1. The scenarios stated that if the respondent agreed to support the program, payment would be collected through an increase in the local (county) sales tax that would be implemented over a 10-year period.[7] It was also stated that a restoration program would be implemented only if a majority of county residents voted in favor of it. Finally, respondents were asked to consider their current expenses before answering the referendum questions.

7. Citizen focus groups and valuation panels

Four focus group sessions were conducted in the study area to facilitate the development of the computerized survey instrument.[8] Two major concerns with the survey instrument emerged from the citizen focus group sessions. First, some people found it difficult to distinguish between the different programs, and recommended presenting a matrix showing the level of ecosystem services provided by each program. This structure, which facilitates a comparison of the ecosystem services across programs, was developed and used in the final survey (Table 1).[9] In addition, in order to familiarize respondents with the different programs, people were asked to rate, on a 1 to 7 scale, each of the programs prior to being asked the WTP questions.[10]

A second concern expressed in the focus groups was the construct of our payment vehicle. Initially, we included State income tax as the payment vehicle. After concern was expressed by focus group participants that State taxes should not be increased to support a local initiative, we altered our payment vehicle to represent an increase in the local sales tax.[11] It was noted that the county had recently passed an increase in the sales tax and that some people were reluctant to vote for further tax increases.

The citizen valuation panel was a non-probability sample made up of recruits from local civic organizations. Although we did not use a formal "quota" sample, where quotas are defined over specific socio-economic variables, an attempt was made to recruit a diverse set of citizens to make up the panel.[12] Then, once the valuation function was estimated, population values for stratification categories such age, gender, and income were inserted in the valuation function to predict WTP for the local population.

Each individual who participated in the final survey received a $40 incentive payment. The survey panels were held in the study area using

[7] The 10-year time frame was established based on the assumption that, once restoration activities were implemented, the flow of enhanced ecosystem services would continue unimpaired for 10 years.

[8] Focus group participants were provided with a $25 incentive for their time.

[9] For each WTP question, respondents were shown the level of ecosystem services associated with the status quo and with the restoration program they were voting on.

[10] Mean values for the desirability ratings for programs 1 through 4 were 3.07, 4.01, 4.82 and 5.75, respectively. These values increase monotonically, indicating that people were sensitive to the level of ecosystem services provided by each program.

[11] In the southern U.S. where the study area is located, local sales taxes must be approved in a public referendum and are a common and familiar means of financing local public goods and services.

[12] Harrison and Lesley (1996) state "If the goal of the sampling exercise is indeed to generate a good valuation function for the purpose of predicting population responses, then it does not follow that probability sampling is the best thing to do. Instead, one should try to ensure sample variation in all of the explanatory variables that will be used to predict the population mean, even if this means generating a greater number of responses for certain stratification categories than is found in the population" (p. 83).

computer labs at Franklin High School and Southwestern College. Ninety-six people completed the computerized interviews (this represents about 0.7% of the households in the County). A comparison of socio-economic characteristics of the sample and the County (based on the 2000 Census) showed that the income and education of the sample were higher than the values for the population (Table 2). This result is not uncommon for probability samples. It was found that the age and gender characteristics of our sample were quite close to the population values. Finally, our sample included a larger proportion of people who owned property along the LTR than occurs in the general population.

8. Statistical analysis

Binary responses to the referendum questions were analyzed using a random utility model. For each of the different programs shown in Table 1, respondents (*i*) were asked if they would vote to support the LTR watershed program at the stated bid amount. The probability of voting YES can be expressed as

$$\Pr[v(z^j, y - t_j) + \varepsilon_{ij} \geq v(z^0, y) + \varepsilon_{i0}] \quad (1)$$

where v is indirect utility, z^j is a vector of ecosystem services for program j, z^0 is a vector of ecosystem services for the status quo, y is income, t_j is the tax payment for program j and ε is a random error term. Eq. (1) can be re-written as:

$$\Pr[\Delta v \geq \varepsilon_{i0} - \varepsilon_{ij}] = \Pr[\Delta v \geq \eta]. \quad (2)$$

If it is assumed that η is normally distributed, Eq. (2) can be estimated using a probit model.

It is popular in the valuation literature to specify the WTP function as lognormally distributed. Similar to Bishop and Heberlein (1979), we used a logarithmic transformation of the bid amount in our statistical model. This model, which constrains WTP to be non-negative, can be shown to provide a utility-theoretic estimate of WTP (Hanemann and Kanninen 1999). If the random component of utility ε is randomly distributed, and if η and WTP are lognormal, then the probability of a YES vote is

$$\Pr[\text{vote yes}] = \Phi(\alpha - \mu \ln(\text{bid})) \quad (3)$$

where Φ is the normal cumulative distribution function, μ is the parameter estimate on the log-bid amount and α is either the estimated constant (if no other explanatory variables are included in the equation) or the "grand" constant, which is computed as the sum of the estimated constant plus the product of the other explanatory variables times their mean values.

Hanemann (1984) advocated the use of median WTP as a measure of economic welfare. While the mean WTP has been shown to be very sensitive to small changes in the right tail of the WTP distribution, the median is much more robust to these effects.[13] In addition, median WTP indicates the amount at which 50% of the sample would vote for a particular referendum. This is in keeping with our survey structure, where we reminded people that the conditions of a referendum would only take effect if at least one-half of the population voted in favor of it. Consequently, we use the median as a conservative estimate of WTP. As shown by Hanemann and Kanninen (1999) median WTP can be computed from the parameter estimates in Eq (3):

$$\text{WTP}^{\text{median}} = \exp\left(\frac{\alpha}{\mu}\right). \quad (4)$$

By including socio-economic characteristics in the model specification, WTP values for the sample can be estimated using sample means to compute the grand constant α in Eq. (4). Alternatively, WTP values for the population can be estimated by computing the grand mean using population values.

Ecosystem services may be a non-linear function of the scale of restoration activities (MILES). Thus, in order to estimate the response of WTP to changes in restoration scale, a quadratic form was used (MILES^2). Once the response surface is estimated, WTP for varying degrees of restoration can be computed. This is accomplished by adjusting the term representing the product of the parameter estimates on MILES and

[13] One concern in dichotomous choice CV studies has been the presence of "fat tails" in the WTP distribution. This effect might be due to the propensity for some respondents to answer YES to a WTP question irrespective of the price. The identification of yea-saying in dichotomous choice CV typically relies on split-samples (Holmes and Kramer 1995). Use of median, rather than mean, WTP acts to obviate this potential problem.

$MILES^2$ and the number of miles restored in the computation of the grand constant.

The iterative sequence of valuation questions used in our survey design suggested the use of a panel model to conduct the analysis. In particular, an error-components model was used to control for individual effects that might persist across iterations of the experiment and which contribute to the overall variance in responses. In an error-components model, the error term is comprised of a permanent component α_i that captures idiosyncratic behavior of the individual *i*, and a transitory random shock υ_{ij} (Hsiao 1986):

$$\varepsilon_{ij} = \alpha_i + \upsilon_{ij} \tag{5}$$

The idea behind Eq. (5) is that two identical individuals may differ systematically in their propensity to choose identical policy options due to idiosyncratic preferences. If the parameter α is treated as randomly distributed across the population, a random effects model can be estimated (Greene 2000). In this model, an idiosyncratic component in the error term introduces autocorrelation in the responses. The correlation coefficient ρ is equal to the ratio of the variance of the permanent component to overall variance:

$$\rho = \frac{\sigma_\alpha^2}{\sigma_\upsilon^2 + \sigma_\alpha^2} \tag{6}$$

where, in dichotomous choice models, it is typically assumed that $\sigma_v^2 = 1$. Thus, the value of ρ increases as the variance of the idiosyncratic component increases relative to the variance of the random component.

9. Statistical results

Standard and random effects versions of the statistical model were estimated (Table 3). A likelihood ratio test showed that the random effects model was statistically superior to the standard probit model (χ^2 statistic = 58.41, significant at > 0.01 level). The correlation coefficient (ρ) in the random effects model was significantly different than zero at greater than the 0.01 level and the magnitude of ρ suggests that preferences among respondents were heterogeneous after controlling for the effects of the explanatory variables.

Table 3
Parameter estimates from simple and random effects probit models of willingness to pay for local riparian restoration

Variables	Standard probit	Random effects probit
Constant	− 1.982 (1.444)	− 3.135 (3.774)
ln(Bid)	− 0.199*** (0.054)	− 0.539*** (0.150)
MILES	− 0.283*** (0.107)	− 0.454*** (0.171)
$MILES^2$	0.060*** (0.017)	0.098*** (0.027)
ln(Income)	0.178 (0.124)	0.322 (0.324)
Female	0.077 (0.149)	0.031 (0.395)
Age	0.011* (0.006)	0.021 (0.016)
College	0.402**	0.624 (0.482)
Property	− 0.591*** (0.145)	− 1.063*** (0.385)
ρ	–	0.641*** (0.087)
log Likelihood	− 229.396	− 200.192
McFadden R^2	0.11	0.22
Observations	384	384

Standard errors in parentheses.
* Significance at the 0.10 level.
** Significance at the 0.05 level.
*** Significance at the 0.01 level.

The sales tax parameter ln(BID) was negative and significant at the 0.01 level in both regression models. As anticipated, an increase in the sales tax amount decreased the probability of voting YES for riparian restoration. In the standard probit model, whether or not the respondent had a COLLEGE degree was positive and significant at the 0.02 level, AGE of the respondent was positive and significant at the 0.07 level, and log(INCOME) was positive and significant at the 0.15 level in explaining variation in the referenda votes. The statistical significance of these variables decreased in the random effects model.

The parameter estimate on the variable indicating whether or not respondents owned PROPERTY along the LTR or its tributaries was negative and significant at the 0.01 level in both model specifications. This result may reflect actual or anticipated expenditures for riparian restoration by people living along the LTR or its tributaries, or opportunity costs associated with land use restrictions in riparian buffers. Because restoration costs accrue to people participating in restoration programs, their WTP for new programs via higher sales taxes would presumably be less than WTP by people not facing those expenditures.

The scale of restoration, as measured by linear and quadratic terms describing MILES of restoration, was found to be statistically significant at the

0.01 level in both regression models. The WTP response surface, as a function of the scale of restoration, was therefore non-linear (Table 4). Respondents to our survey demonstrated a positive WTP amount for the implementation of Best Management Practices along tributaries to the LTR. A downward shift in WTP was observed for the program that would restore 2 additional miles of river (in addition to the BMP program). This finding is consistent with comments in the focus groups of some people who declared they favored total restoration of the watershed and disliked the idea of piecemeal, partial restoration. A small marginal increase in benefits was observed for the 4 mile restoration program. Notably, a very large increase in marginal benefits was observed for the 6-mile (total) restoration program, and suggests that riparian restoration projects are super-additive in valuation.[14]

Table 4
Annual economic benefits (median WTP), calculated at sample and population means, for riparian restoration in the Little Tennessee River watershed

Model used for calculation/ benefit category	Partial program (BMP only) [$]	Partial program (BMP + 2 miles) [$]	Partial program (BMP + 4 miles) [$]	Full program (BMP + 6 miles) [$]
Probit				
Per household benefits, sample means	5.66	1.09	2.30	53.76
Per household benefits, population means	3.62	0.69	1.47	34.34
County benefits, sample means	72,608	13,954	29,551	689,652
County benefits, population means	46,375	8912	18,875	440,486
Random effects probit				
Per household benefits, sample means	8.97	3.48	5.73	40.89
Per household benefits, population means	6.91	2.68	4.42	27.26
County benefits, sample means	115,092	44,672	73,539	524,559
County benefits, population means	88,659	34,412	56,649	349,705

10. Comparing benefits and costs of riparian ecosystem restoration

Annual median WTP values were estimated using the values for the socio-economic variables computed from our sample and using the population values for Macon County as reported in the 2000 Census (Table 4). In both statistical models, WTP values estimated using Census data were less than WTP values estimated using sample means. Population adjusted valuation functions derived from the statistically superior random effects model were used to compare ecosystem restoration benefits and costs.

Using the estimates reported in Table 4, present values for a 10-year stream of annual benefits were computed.[15] The present value of public benefits generated by full restoration (BMPs plus 6 miles of riparian restoration) was estimated to be $2,835,373. This is equivalent to benefits of $89.50/ft ($472,560/mile) of restoration, or a benefit/cost ratio of 15.65 (recall that the public cost associated with a representative mix of activities was estimated to be $5.72/ft). The present value of benefits generated by BMPs plus 2 miles (or 4 miles) of restoration was estimated to be $243,732 (or $401,645). This translates into benefits of $23.08/ft of restoration (or $19.02/ft of

[14] The proportions of people voting for programs 1 through 4 were 0.28, 0.34, 0.28, and 0.55, respectively. Note that the proportion of people voting for the 6-mile restoration program (0.55) was nearly double the proportion voting for the 4-mile restoration program (0.28). If benefits were linear in the level of ecosystem services, WTP should double between the 4-mile and 6-mile programs (see footnote 5). However, as is shown in (Table 4), per household WTP more than doubles—a result that is consistent with super-additivity. For example, household WTP computed using the statistically superior random effects probit model, and using population (rather than sample) means, increases from $4.42 to $27.26—approximately a 6-fold increase. Thus, WTP is super-additive in both miles of restoration and in ecosystem services.

[15] Recall that people were asked to vote on programs that would increase local sales tax by a given amount for the next 10 years. The discount rate used in the calculations was 0.05.

restoration), leading to benefit/cost ratios of 4.03 and 3.33, respectively.

The range of benefit/cost ratios in our study, 3.33–15.65, spans the estimate of 5.22 reported by Loomis et al. (2000) for restoring a 45-mile section of the Platte River. Although the household benefits of restoring the Platte River ($252/household/year) were larger than the household benefits of restoring the Little Tennessee River, the household benefits per mile were quite similar ($5.60/household/mile for Platte River restoration vs. $4.54/household/mile for full restoration of the LTR). The relatively high benefit/cost ratio estimated for full restoration of the LTR relative to the Platte River, therefore, appears to be due to the fact that the public share of restoration costs per mile were considerably lower for the LTR ($30,202/mile) relative to the Platte River ($298,444/mile).[16]

11. Conclusions

Scale is an important factor in conducting benefit/cost analyses of ecosystem restoration projects. In this study, respondents were willing to pay a premium for total restoration of the LTR ecosystem relative to more modest restoration levels, and the benefits of ecosystem restoration were super-additive in the sense that the value of total restoration was greater than the sum of benefits measured for partial restoration programs. In turn, this result showed a strong preference for programs that fully restored the level of ecosystem services.

Of particular interest, it was found that the benefits of partial restoration projects exceeded their costs. Thus, the philosophy held by some stream ecologists that partial restoration should proceed with available funds even if funding is not available for total restoration proved to be economically feasible in this case. This result is partially due to the relatively low costs associated with ecosystem restoration in this watershed.

Future research on the economics of ecosystem restoration is clearly needed. Among the greatest challenges facing ecological economists is the ability to discern and articulate the linkages between ecosystem science and the things that people value. In this study, a carefully developed characterization of a set of ecosystem services was developed, and ecosystem services were linked with the scale of restoration. Although this procedure facilitated the survey respondents' understanding of the issues, much remains to be done to improve methods for communicating complex ecological dynamics in the context of economic valuation studies.

Although the results here showed that respondents were sensitive to the (internal) scale of ecosystem restoration in a sequence of valuation questions, more rigorous (external) scale tests could be conducted by eliciting and comparing WTP values for different subsets of respondents faced with restoration choices at different spatial scales. In addition, it would be useful to investigate how WTP is affected by the number of restoration programs. Because the research reported here was based on restoration projects for a single watershed, it is not clear how the value of restoring a particular watershed might be influenced by the restoration of other ecosystems. It is possible that different ecosystems are valued as complements or substitutes, although very little is known about value interactions in ecosystem studies.[17]

Finally, human populations living in many different and diverse watersheds may benefit from riparian restoration activities. Future research needs to be conducted to discern within which watershed restoration activities could be justified using a benefit/cost criterion and what scale of restoration provides the greatest net social benefits.

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[16] The major restoration cost on the Platte River was the potential purchase of conservation reserve program farmland easements.

[17] For example, Hailu et al. (2000) found that multiple programs for protecting old-growth forests, prairie grasslands and mountain streams were perceived as complements by respondents.

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