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Valuing Forest Protection Programs to Maximize Economic Benefit

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Abstract

The hemlock woolly adelgid is an invasive insect that is infesting and destroying hemlock forests in the northeastern United States. Mitigation efforts are taking place on public lands throughout the affected area. This study examines one such effort in the southern Appalachian Mountains. Economic benefits from hemlock ecosystem services are estimated using contingent valuation and are shown to outweigh the costs of mitigation. The estimated benefit function is also used in an optimization routine to examine the current allocation of conservation resources. Results show that a reallocation of mitigation effort would result in large gains in net economic benefit.

Key Words: invasive species, hemlock woolly adelgid, ecosystem valuation, forest preservation.

Subject Areas: Economic Damages/Benefits, Forests, Benefit-Cost Analysis

1. Introduction

The tightening of public funds and the growing list of natural resource damages in the United States and elsewhere highlight the need for efficient allocation of conservation resources. The standard model for evaluating conservation projects in the US favors strategies that maximize the number of protected units within the allocated budget. Government conservation efforts such as the Environmental Quality Incentive Program (EQIP), the Conservation Reserve Program (CRP), and the Wildlife Habitat Incentive Program (WHIP) use the number of acres enrolled or the number of endangered species represented to evaluate individual projects.

Wu and Boggess (1999) show that using such resource conservation criteria rather than maximizing economic benefits can lead to highly inefficient allocations of conservation funds. In fact, maximizing the number of protected units subject to a budget constraint assumes that benefits are linearly increasing in these units. In reality, benefit functions can be highly nonlinear and may even reach a maximum before the budget constraint becomes binding.

Notable works in conservation optimization include Polasky, Camm, and Garber-Yonts (2001) and Ando, Camm, Polasky, and Solow (1998). These studies show that the integration of economic and biological data is necessary to choose an efficient network of biological reserve sites. To approximate biodiversity conservation, Polasky et al. maximize the number of terrestrial vertebrates found in the chosen sites subject to a budget constraint. Ando et al. also choose sites subject to a budget constraint but focus on the number of endangered species included. In each case the benefit metric is the number of species protected and is thus subject to the criticism of Wu and Boggess.

In this study we address the criticism of Wu and Boggess by estimating the economic value of ecosystem services that a network of preservation sites would provide. We use the empirical benefit function to show that the estimated net present value of the current conservation strategy is positive. Finally, we solve a static optimization routine for the network of conservation sites that provides the largest net economic benefit and show that substantial gains result from a reallocation of mitigation resources. This analysis is not spatially explicit and there is far less variation in ecosystem services than in Polasky et al. and Ando et al. These two simplifications make the estimation of economic benefits more straightforward without sacrificing policy relevance.

2. Background

The hemlock woolly adelgid (HWA) is an insect native to Asia where it is a common but largely harmless parasite of several hemlock species. However, by 1950 HWA had been introduced to forests in the eastern United States where hemlock species are susceptible to infestations. Infestations have now been found in 15 eastern states. It can take as few as four years for HWA to kill a mature hemlock, though some have survived infestation for a decade or more (McClure, Salom, Shields, 2003). In the absence of an aggressive mitigation strategy we can expect a 90% loss of hemlock resources in the eastern United States over the next 20 years (Jacobs, 2005).

2.1 Hemlock Forest Decline

Eastern hemlocks (*Tsuga canadensis*) are slow-growing, long-lived evergreens that reach 60 to 70 feet in height and may live for 800 years or more. The geographical range of eastern hemlock includes parts of Canada, extends from the east coast of the United States westward to the Great Lakes region and as far south as Georgia. The Carolina hemlock (*Tsuga caroliniana*) is a rare species that can only be found on the slopes of the southern Appalachian Mountains and is also being destroyed by HWA.

Hemlocks are an exceptional component of the natural scenery in mountain ranges along the east coast. In addition to providing a scenic background at outdoor recreation areas and along roads they provide shade at picnic areas, camp sites, and along hiking trails. They also shade mountain streams keeping water temperatures cool enough for sensitive species such as brook trout. It is important to remember that areas affected by HWA infestation will not simply lose hemlocks but that healthy hemlock stands will be replaced with standing dead trees for a number of years. This will significantly reduce aesthetic values, increase the risk of forest fires, and cause some recreation areas to close temporarily while dead trees are removed to avoid the danger of falling debris.

2.2 The Mitigation Effort

The purpose of this study is to estimate benefits from hemlock services and evaluate the mitigation plan being pursued on three federal lands in western North Carolina and eastern Tennessee. Great Smoky Mountains National Park, Nantahala National Forest, and Pisgah National Forest received a combined 15 million visits in 2006 (National Park Service; US Forest Service). Out of the nearly two million acres covered by these three lands 32,000 acres are hemlock-dominated forest.

Infestations have been recorded throughout the study area and extensive damage is already apparent at many popular recreation sites. While it is not possible to save all or even most of the hemlocks in the study area, a network of high-priority sites has been identified for preservation. Each site is about 125-acres of hemlock dominated forest and has been chosen for its high ecological value or high human-use value. Ecologically important sites were identified from either the North Carolina Natural Heritage Database or the Southern Appalachian Vegetation Database (Jacobs, 2005). Sites of high human-use value typically have a long history of outdoor recreation or education.

The mitigation strategy employs two forms of control simultaneously. Imidacloprid, a chemical insecticide, is injected into the soil at the base of the tree where the root system draws the chemical into the plant tissue of the stems and branches where the HWA feed. The insecticide will kill virtually all HWA feeding on that tree at the time of application and prevent reinfestation for up to three years. The risk of groundwater contamination limits the use of the insecticide to a small fraction of trees on each site. An average of 20 trees, covering about three of the 125 acres on a site, will receive chemical treatment (Jacobs, 2005).

Forest managers are also using a biological form of control. A number of predatory beetles found in the native range of HWA have been collected and observed in laboratory settings to assess their potential for biocontrol. Of the many species that were collected a few exhibit the potential to be effective control agents for HWA. In particular, the Japanese lady beetle (*Sasajiscymnus tsugae*) has been found to be a very effective predator of HWA (Cheah *et al*, 2004). Beetles are mass reared in laboratories on HWA-infested foliage collected from the field and released onto individual trees. A total of 1,500 to 2,500 beetles will be released on one to four trees at each preservation site from which they are expected to spread and colonize other nearby trees (Jacobs, 2005). A third form of control, spraying trees with insecticidal soap and oil, requires large equipment that is typically mounted on a truck so it is not a valid option for the vast majority of trees which are too far from roads for this type of treatment.

3. Valuation of Hemlock Decline

To evaluate the current mitigation strategy we estimate the economic benefit from hemlock services in the study area. The result is an empirical benefit function that can be used in a cost-benefit analysis and, as we show in Section 5, in an optimization routine to find a more efficient allocation of conservation resources.

3.1 Survey Design

A contingent valuation (CV) survey was administered to collect data on peoples' willingness to pay (WTP) to mitigate damages from HWA infestations. Contingent valuation was chosen over revealed preference and other stated preference methods for its ability to capture nonuse values of environmental goods (Brown, 2003). Given the severity of potential damage and the high profile of the study area, we believe nonuse values are a substantial fraction of total value. A sample of North Carolina residents was recruited via phone and asked to complete a web-based survey. Four-thousand, one-hundred and forty-four eligible people were contacted, 897 agreed to complete the survey, and 401 surveys were completed.

Choosing a CV response format often requires trading efficiency for precision. Formats that yield the most information, such as the open-ended format, tend to produce more biased responses. The single-bounded dichotomous choice format has been shown to be incentive compatible but reveals relatively little information. The payment card response format strikes a balance between efficiency and precision by providing more information than dichotomous choice and more reliable responses than the open-ended format (Brown, Champ, Bishop, McCollum 1996). We chose a payment card format for which respondents viewed a list of dollar amounts and were asked to indicate if they would be willing to pay each amount. The highest amount to which they answered in the affirmative and the lowest amount they refused reveal an interval that includes their WTP for the good in question.

Maintaining the distinction between ecologically important sites and human-use sites in the valuation exercise allows us to more accurately estimate benefits from the current mitigation strategy and gives us one dimension of variation over which we can conduct an optimization routine. An explanation of the treatment strategy and the two types of sites is given to each respondent before they answer the CV questions. Respondents are asked three valuation questions, each describing a different hypothetical treatment network defined by a combination of ecological and human-use sites. They are asked to use the payment card to indicate how much they would be willing to pay to support each treatment plan. Three versions of the survey were used to provide greater variation in the hypothetical treatment programs. With three questions on each survey, we collected WTP data on nine different combinations of ecological and human-use sites. Figure 1 contains one of the nine valuation questions asked. By varying the number of ecological and human-use sites we can estimate a WTP function that isolates the marginal contribution of each type of ecosystem service. Respondents are also asked a number of attitudinal questions that can be used to condition the WTP function. In particular, they are asked how important it is to protect hemlocks in different areas and for different reasons. Responses to these questions are summarized in the appendix.

[Figure 1]

3.2 Model Specification

We test two functional forms and a number of specifications for the WTP function. The semi-log functional form, in which a natural log transformation of the dependent variable is regressed on a linear function of explanatory variables, is common in valuation studies. The log transformation imposes a non-negativity condition on expected WTP and a log-normal distribution that is well-suited to the right-skewed distribution of bids we observe in CV studies.

We test a number of specifications for the right-hand side of the WTP function. Always present is a quadratic function of provision variables and dummy variables for residents of western North Carolina and categorical income variables (collectively referred to as 'demographic dummy variables'). Estimating a WTP function that is quadratic in provision allows us to assess the validity of our results through scope tests. A valid WTP function will be increasing in provision at a decreasing rate. The basic model that is nested in all other specifications is

$$y_{ij}^{*} = \beta_0 + \beta_1 Eco_{ij} + \beta_2 Use_{ij} + \beta_3 Eco_{ij}^2 + \beta_4 Use_{ij}^2 + \beta_5 Eco_{ij} Use_{ij} \quad (1)$$

$$+\beta_6 WNC_i + \beta_7 Income2_i + \ldots + \beta_{10} Income5_i + \varepsilon_{ij},$$

for $i = 1 \ldots N,\ j = 1,2,3.$

Recall, we only observe an interval for WTP so the value y_{ij}^{*} is the latent WTP value in the interval indicated by respondent *i* for question *j* or, in the case of the semi-log model, the logged transformation. Eco_{ij} and Use_{ij} are the number of ecologically important sites and human-use sites given in that question. *WNC* is a dummy variable used to identify respondents that are residents of western North Carolina. *Income2…Income5* are categorical dummy variables indicating which of the five income categories the i^{th} respondent indicated. Parameters on the income dummies should be interpreted as intercept shifts relative to the lowest income category, which has been omitted. The natural occurrence of hemlocks in North Carolina, with very few exceptions, is restricted to the western part of the state where elevation of the Appalachian Mountains keeps average temperatures lower. The dummy variable *WNC* is included in the WTP function to capture an intercept shift for respondents who live closer to the resource. A summary of the demographic variables is included in the appendix.

Responses to attitudinal questions are used to classify respondents as 'environmentalists' and 'recreationists'. The categories are neither mutually exclusive nor exhaustive. People who indicated environmental reasons as'extremely important' in their support for a mitigation program *and* hemlocks that provide primarily ecological services as 'extremely important' to protect are placed in the environmentalist category. Those who indicated recreational reasons as being 'extremely important' and hemlocks that provide human-use services as 'extremely important' to protect are categorized as recreationists. The result is two dummy variables for which a given individual could have a value of unity for one, both, or neither. Table 1 shows a cross-tabulation of the attitudinal dummy variables. Four specifications and two functional forms are tested in which the demographic and attitudinal dummy variables enter as intercept shifts or interact with the level provision terms.

[Table 1]

3.3 Estimation

We assume the errors are normally distributed with zero mean and variance σ^2 and independent over all *i, j* so that,

$$\varepsilon_k \sim N(0,\sigma^2), \text{ for } k = 1\ldots 3N. \qquad (2)$$

With each of the *N* respondents answering three questions there is likely to be correlation within responses. In this analysis we ignore that correlation and assume a strictly diagonal error covariance matrix. Analyzing payment card CV data, Cameron and

Huppert (1989) model each response's contribution to the likelihood function as the probability that the latent WTP value falls within the chosen interval. This is found by taking the integral of the conditional probability density function over the range of WTP indicated by the interval response. Appealing to the distributional assumptions embodied in (2), the likelihood function is

$$L(\beta,\sigma|X)=\prod_{k=1}^{3N}\left\{\int_{l_k}^{u_k}\frac{1}{\sigma\sqrt{2\pi}}\exp\left[-\frac{\left[y_k^*-x_k\beta\right]^2}{2\sigma^2}\right]dy_k^*\right\},\text{ for } k=1\ldots 3N \qquad (3)$$

where β is the vector of WTP parameters, X is the data matrix, u_k and l_k are the upper and lower bounds chosen in response to question k, y_k^* is the latent WTP value for question k, and x_k is the k^{th} row of the data matrix.

3.4 Results

Casual observation of the results shows that for every specification the semi-log model is superior to the linear counterpart. Parameters are more often of the expected sign and statistically significant under the semi-log form. As such, only the results of the semi-log models are reported here. The basic model of equation (1) was compared to other specifications that included dummy variables for the environmentalist and recreationist categories and models that interact the demographic and attitudinal dummy variables with level provision terms. None of the interactions are statistically significant and likelihood ratio tests fail to reject the null hypothesis that all of the parameters on the interactions are zero. To facilitate estimation and presentation of the results the squared and cross-product provision terms are scaled by 0.01.

[Table 2]

[Table 3]

Based on the results presented in Tables 2 and 3 the Attitudinal Dummy Variable model is the preferred specification. All coefficients have the expected sign and many are statistically significant. The coefficients on the level provision measures are positive and those on the squared terms are negative and of much smaller magnitude. This is indicative of WTP that is increasing at a decreasing rate over at least some of the provision space. The relative magnitudes of the coefficients on the categorical income variables indicates a WTP function that is generally increasing in income; the exception being respondents in the highest income category who tend to bid slightly lower than people in the second highest category. And though it is not statistically significant, the coefficient on the western North Carolina dummy indicates that, on average, people who live close to the affected area are willing to pay more to protect it. The coefficient on the environmentalist dummy is positive and significant indicating that people who feel strongly about protecting hemlocks for ecosystem services are willing to pay more for a conservation program. Overall the results are favorable and validate the results of the survey. We can now use these results to evaluate the current mitigation strategy and explore other allocations of conservation resources to increase net economic benefit.

4. Evaluating the Current Strategy

The valuation study was designed to distinguish between conservation sites that were chosen because they provide valuable ecological services and sites that are important for human-use. Characterizing the economic tradeoff between these two types of environmental services allows us to more accurately estimate benefits form the current mitigation strategy and explore other a conservation designs provide greater economic benefit while satisfying a budget constraint.

4.1 The Cost Function

In the general case costs of treatment could vary by the type of site and increase nonlinearly with the number of sites treated. However, based on the best information available neither appears to be true in this case. The costs of treatment are reported to be equal across sites and increase linearly with the number of sites treated with no fixed costs (Jacobs, 2005). So, in this case, average cost is equal to marginal cost and the cost function for treatment is simply

$$G\left(Eco,Use\right)=\alpha(Eco+Use), \qquad (4)$$

where α is the unit cost of administering chemical and biological treatment. The Environmental Assessment distributed for this specific mitigation program describes the costs for each type of treatment including equipment, labor, transportation, and the treatment media itself. It will cost $1,500 to treat an average of 20 trees with chemical insecticide on each conservation site. Biological control requires rearing the beetles in laboratories and manually placing them on infested trees. Between 1,500 and 2,500 beetles would be released on each site at a cost of $2,300 per site. Taken together the per-site cost of simultaneous biological and chemical treatment is α = $3,800. Treatments will be repeated each year so α is an annual cost, though it is unclear how long treatments will continue. When calculating net benefits we consider several time horizons for treatment.

4.2 The Benefit Function

Benefits are calculated for the sample frame only. While the mitigation strategy is sure to benefit people who do not live in North Carolina, it is not appropriate to apply estimated benefits beyond the sampled population. Census data is used to provide values for the demographic variables and number of households in North Carolina[1] thus weighting our results to the population. Benefits are calculated using the expected value of the WTP function evaluated at provision values provided by the current mitigation strategy. Assuming errors of the semi-log WTP function are normally distributed implies WTP values follow a log-normal distribution. Expected WTP for i^{th} household is calculated as

$$E\left(WTP_i\right) = \exp\left(\hat{\beta}\breve{x}_i' + \frac{\hat{\sigma}^2}{2}\right). \tag{5}$$

Where $\hat{\beta}$ is the row-vector of parameters from the Attitudinal Dummy model reported in Table 2 and $\breve{x}_k$ is the k^{th} row of the data matrix substituting the provision values with those from the current mitigation strategy. Respondents were asked about numbers of ecological and human-use sites ranging from zero to 100. The provision values used in benefit calculations are rescaled to represent this range[2].

Respondents were asked to provide the amount they would be willing to pay in additional annual taxes for each of the next three years to support the given mitigation strategy. Total estimated benefit is the present value of three annual payments.

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[1] The 2006 Census reports 3,132,013 households in North Carolina
[2] A total of 351 sites were considered for treatment. We assume this included an equal number of ecological and human-use sites. The current mitigation strategy includes 29 ecological sites and 130 human use sites. Rescaling these values to the 0-100 range results in 100(29/175.5) = 16.52 ecological sites and 100(130/175.5) = 74.07 human use sites.

Assuming the first payment will be made one year from present, total benefits for household *i* are calculated as

$$v_i = \frac{E(WTP_i)}{(1+r)} + \frac{E(WTP_i)}{(1+r)^2} + \frac{E(WTP_i)}{(1+r)^3}. \tag{6}$$

Where *r* is the interest rate used to discount future payments. The net benefit function for mitigation effort is

$$W = V\left(Eco, Use \mid \beta, \sigma\right) - \sum_{t=0}^{T} G(Eco, Use \mid \alpha) e^{-rt}. \tag{7}$$

Where *V* is the aggregated form of equation (6), weighted to the population, and *T* is the time horizon for control.

4.3 Evaluation of the Current Strategy

Using (5) to calculate the estimated WTP by a representative household for the current mitigation strategy, we find an annual value $17.42. Table 4 presents calculations for total household WTP using expression (6) and discount rates of 3, 5, and 7%.

[Table 4]

The treatment network includes 159 conservation sites. With the per-site treatment cost of $3,800 the total annual cost of treatment comes to $604,200. Dividing this cost among the more than 3 million households in North Carolina results in a negligible per-household figure. As a result, the household *net* benefits from the current strategy – even when we assume a ten-year time horizon for control – differ very little from the values in Table 4. Table 5 presents household net benefits assuming time horizons for control of two, four, six, and ten years at discount rates of 3, 5, and 7%. Based on our valuation of hemlock services in the treatment network and cost functions taken from Forest Service documents the benefits of the plan to mitigate damages from HWA in Great Smoky Mountains National Park and Pisgah and Nantahala National Forests far outweigh the costs and may warrant an expansion of the current program.

[Table 5]

5. Maximization of Economic Benefits

We have shown that the current mitigation program has a positive net present value and may be worthy of expansion. In this section we assume a per-period budget constraint and explore other allocations of conservation funds in order to maximize economic benefits. Specifically, we appeal to the distinction between ecological and human-use treatment sites by choosing the combination that leads to the largest net economic benefit subject to a budget constraint. We could not find information on the number of potential sites that fall into each category and thus concede that the combination that maximizes economic benefit may not be practical or even possible. However, given that economic benefit was not a part of the discussion in designing the current treatment network we are comfortable saying that improvements to the current strategy can be made in this regard.

Since the preferred model for benefits from hemlock services does not interact attitudinal or demographic variables with provision they will not affect the optimal allocation, only the resulting level of net benefits. As such, the attitudinal and demographic variables are combined with the constant term in the objective function. We use Lagrange's method for optimization so that

$$L = C + \hat{\beta}_1 Eco + \hat{\beta}_2 Use + \hat{\beta}_3 Eco^2 + \hat{\beta}_4 Use^2 + \hat{\beta}_5 EcoUse + \lambda\left(B - \alpha Eco - \alpha Use\right). \qquad (8)$$

Where C is a constant, λ is the Lagrange multiplier, *B* is the maximum expenditure per year, and α is the unit cost of treatment from expression (4). The first order conditions for a budget constrained optimum are

$$\frac{\partial L}{\partial Eco} = \beta_1 + 2\beta_3 Eco + \beta_5 Use - \lambda\alpha = 0, \qquad (9)$$

$$\frac{\partial L}{\partial Use} = \beta_2 + 2\beta_4 Use + \beta_5 Eco - \lambda\alpha = 0, \qquad (10)$$

$$\frac{\partial L}{\partial \lambda} = B - \alpha Eco - \alpha Use = 0. \qquad (11)$$

The per-site treatment cost of α = \$3,800 and 159 sites included in the network implies an annual budget of *B* = \$604,000. Using these figures, the conservation network that satisfies the first order conditions would contain approximately 78 ecologically important sites and 81 human-use sites. This is a considerable shift from the 29 ecological sites and 130 human use sites that make up the existing network. Table 6 compares net economic benefit from the current conservation network to the network that solves the optimization problem using a 5% discount rate. If such a choice of conservation sites is practical in other respects, the result would be a 38% gain in benefits. This result demonstrates the importance of economic analysis in the allocation of conservation resources.

[Table 6]

Conclusion

Using a stated preference approach to capture use and nonuse values for hemlock ecosystem services, we have shown that benefits from an ongoing effort to mitigate damages from invasive insects far exceed the costs. We have also shown that it is possible to increase the economic benefit from conservation efforts with a different allocation of resources. However, we are not suggesting that the solution to the economic optimization problem is necessarily superior to other allocations of conservation effort. We recognize that resource managers have a number of criteria to consider when developing the treatment network such as maintaining genetic diversity and strategically placing releases of biological control agents. However, one consideration that is conspicuously absent from the discussion of the network design is that of economic benefit.

Estimating economic benefits over a heterogeneous landscape can inform conservation decisions and result in a more efficient allocation of conservation resources. The efficiency of our solution would be improved with better data on costs and more variation in ecosystem services. However, adding dimensions to the characterization of ecosystem services can be problematic when relying on stated preference data. Asking people to consider more complicated tradeoffs between goods with which they are unfamiliar can place undue burden on survey respondents. Exploring the threshold of variation in ecosystem valuation may be a promising area of research.

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Table 1 Cross-Tabulation of 'Environmentalist' and 'Recreationist' Variables

Environmentalist	Recreationist		
	0	1	Total
0	193	11	204
1	130	67	197
Total	323	234	401

Table 2 Results from MLE of Candidate Models Using a Semi-Log Functional Form

	Basic Model		Attitudinal Dummies		Attitudinal Interaction		Demographic Interaction	
Variable	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error
Sigma	1.394	0.029	1.377	0.029	0.319	0.021	1.374	0.029
Constant	0.8714**	0.2833	0.6349*	0.2841	0.7486	0.2983	1.1031*	0.4338
Ecological Sites	0.0233**	0.0053	0.0235**	0.0053	0.0223**	0.0054	0.0196**	0.0063
Human-Use Sites	0.0080	0.0053	0.0086*	0.0053	0.0081	0.0054	0.0052	0.0064
Eco Sites Squared[3]	-0.0166**	0.0038	-0.0166**	0.0037	-0.0168**	0.0037	-0.0169**	0.0037
Use Sites Squared[3]	-0.0064*	0.0038	-0.0070*	0.0037	-0.0068*	0.0037	-0.0069*	0.0037
Eco × Use[3]	0.0041	0.0033	0.0040	0.0033	0.0040	0.0033	0.0040	0.0033
Western NC	0.1117	0.0817	0.1134	0.0808	0.1108	0.0807	-0.1316	0.2010
Income2	0.2548*	0.1541	0.2632*	0.1523	0.2543*	0.1523	0.0254	0.3992
Income3	0.7186**	0.1466	0.7003**	0.1449	0.6955**	0.1448	0.3156	0.3820
Income4	1.1933**	0.1598	1.2368**	0.1582	1.2340**	0.1580	0.7165*	0.4156
Income5	1.0915**	0.3329	1.1857**	0.3293	1.1968**	0.3292	0.5715	0.8147
Environmentalist	-	-	0.4280**	0.0861	0.2018	0.2164	0.4280**	0.0860
Recreationist	-	-	0.0221	0.1086	0.0258	0.2637	0.0223	0.1086
Eco Sites × Env	-	-	-	-	0.0033	0.0022	-	-
Eco Sites × Rec	-	-	-	-	-0.0015	0.0027	-	-
Use Sites × Env	-	-	-	-	0.0003	0.0022	-	-
Use Sites × Rec	-	-	-	-	0.0014	0.0028	-	-
Eco × WNC	-	-	-	-	-	-	0.0018	0.0021
Eco × Inc2	-	-	-	-	-	-	0.0035	0.0040
Eco × Inc3	-	-	-	-	-	-	0.0027	0.0038
Eco × Inc4	-	-	-	-	-	-	0.0051	0.0041
Eco × Inc5	-	-	-	-	-	-	0.0091	0.0083
Use × WNC	-	-	-	-	-	-	0.0022	0.0021
Use × Inc2	-	-	-	-	-	-	0.0003	0.0039
Use × Inc3	-	-	-	-	-	-	0.0035	0.0038
Use × Inc4	-	-	-	-	-	-	0.0033	0.0041
Use × Inc5	-	-	-	-	-	-	0.0010	0.0087
* Significant at the 0.1 level; ** Significant at the 0.01 level								

[3] Values are scaled by 0.01. Parameter estimates and standard errors should also be scaled by 0.01 for inference and benefit calculations.

Table 3 Likelihood Ratio Tests for Comparing Nested Models

Restricted Model	Basic Model	Attitudinal Dummies	Attitudinal Dummies
Unrestricted Model	Attitudinal Dummies	Attitudinal Interaction	Demographic Interaction
λ (df)	28.85* (2)	2.68 (4)	5.82 (10)
* Significant at the 0.001 level.			

Table 4 Household WTP for Current Mitigation Strategy

Discount Rate	0.03	0.05	0.07
Present Value of Three Annual Payments	$49.28	$49.28	$49.28

Table 5 Present Values of Per Household Net Benefits from the Current Mitigation Strategy

Years of Control \ Discount Rate	0.03	0.05	0.07
2	$48.91	$48.92	$48.93
6	$46.40	$46.46	$46.52
10	$44.07	$44.23	$44.36

Table 6 Net Benefits from Optimal and Current Conservation Networks

Years of Control	Current Strategy	Economic Optimum	Difference
2	$66.21	$107.03	38.34%
6	$63.32	$102.62	37.93%
10	$60.66	$98.53	37.56%

Figure 1 Example Contingent Valuation Question

18. Consider a program that would protect

all 100 of the ecologically important sites

and 50 of the 100 socially important sites.

In the table below indicate whether or not you would be willing to pay the listed amounts in increased annual taxes to support this treatment program. (Check "Willing to pay" or "Not willing to pay" for each amount.)

Appendix:

Summary of Responses to Attitudinal and Demographic Survey Questions

Reasons for Forest Protection

How important are the following reasons in the decision to protect hemlock forests? ('5' being extremely important and '1' being not at all important.)

	5	4	3	2	1
Providing wildlife habitat	281	88	23	4	1
Providing scenic views	137	141	91	22	3
Providing recreation opportunities	105	126	120	34	9
Providing timber	63	78	109	77	61
Preserving seed sources for the future	262	98	33	3	0

Impacts on Recreational Behavior

Do you agree that dead or dying hemlock trees would affect your recreation trips in the following ways? ('5' being strongly agree and '1' being strongly disagree.)

	5	4	3	2	1
Reduce the quality of hiking experiences	149	118	72	19	10
Improve the quality of fishing experiences	23	19	57	56	138
Reduce the quality of scenic views	214	108	30	11	13
Change the recreation sites I visit	48	69	123	45	64
Change the activities I engage in	54	60	114	42	77

Lands to Include in Conservation Plan

How important is it that hemlocks on the following lands be protected? ('5' being extremely important and '1' being not at all important.)	5	4	3	2	1
Great Smoky Mountains National Park	300	74	18	1	0
Pisgah and Nantahala National Forests	284	82	22	4	0
Other national parks and forests	263	100	25	4	1
State parks and forests	267	91	31	4	0
Privately owned lands used for timber	160	67	85	47	28
Forested lands in residential areas	194	88	78	23	8

Types of Landscapes to Protect

How important is it that hemlocks in the following areas be protected? ('5' being extremely important and '1' being not at all important.)	5	4	3	2	1
Along roads	185	127	61	19	2
Along hiking trails	238	121	28	7	1
Campgrounds and picnic areas	230	109	45	10	1
Wilderness areas	277	75	26	11	5
Designated conservation areas	297	67	27	4	1
Groves of old growth hemlocks	296	77	16	3	0

Control Methods

Do you believe these control methods should be used in the Great Smoky Mountains National Park and Pisgah and Nantahala National Forests?		
	Yes	No
Chemical insecticide	276	125
Insecticidal soaps and oils	171	230
Predatory Beetles	275	126
…In congressionally designated wilderness areas?		
Chemical insecticide	246	155
Insecticidal soaps and oils	163	238
Predatory Beetles	278	123

Summary of Sample Demographic Data

Category	Respondents with Affirmative Value	
Resident of Western North Carolina	201	50.1%
Income Category 1: Less than $14,999	38	9.5%
Income Category 2: $15,000 - $34,999	107	26.7%
Income Category 3: $35,000 - $74,999	165	41.1%
Income Category 4: $75,000 – $149,999	84	20.1%
Income Category 5: Greater than $150,000	7	1.8%