USING THE CONJOINT ANALYSIS TECHNIQUE FOR THE ESTIMATION OF PASSIVE USE VALUES OF FOREST HEALTH

MICHELLE A. HAEFELE AND JOHN B. LOOMIS*

ABSTRACT

Since management of forest health often involves trade-offs between forest characteristics, a multi-attribute analysis technique (conjoint) may be an appropriate tool. Conjoint allows estimating of the marginal economic value of one more unit of each attribute and thus provides the type of information useful for economic analyses of forest management trade-offs. This paper discusses the conjoint method and illustrates it with an application to forest health in the United States (U.S.) Within the range of our data, the conjoint method predicts household would pay $.54 (USD) for each acre reduction in the area infested with forest insects in the U.S. forests studied.

Keywords: Conjoint analysis, forest pests, marginal values, passive use values, willingness to pay.

~

INTRODUCTION

Forest health is an important resource issue facing land managers today. There is much discussion of how past fire suppression and overstocked stands have led to unhealthy forest conditions. While, disagreement exists as to the exact definition of forest health, it can be said to include protection from catastrophic insect and disease outbreaks, as well as the re-establishment of natural regulation systems. Both healthy forests, and the management of forest health have multiple attributes and the characteristics of public goods. They provide habitat for unique species, protect water quality, provide recreation settings, and deliver a host of non-use or passive use values such as bequest value to provide healthy forests to future generations. While no formal market exists for trading these amenities, including these non-market values can potentially improve forest management.

* Michelle A. Haefele and John B. Loomis, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO 80523, USA. Address correspondence to John B. Loomis. Phone (970) 491-2485; FAX (970) 491-2067. Email:jloomis@ceres.agsci.colostate.edu.

Acknowledgements: We would like to thank Eric Smith and Daniel McCollum of the U.S. Forest Service for support and assistance with this research.

JOURNAL OF FOREST ECONOMICS, ISSN 1104–6899. Manuscript received 2000-01-24. Revised manuscript accepted 2000-09-27.

The monetization of non-market values, such as those associated with forest health, has been pursued by economists for decades using the set of techniques broadly categorized into actual behavior based revealed preference (e.g. travel cost and hedonic methods) and stated preference (e.g. contingent valuation). Market researchers have used a stated preference technique called conjoint analysis to analyze market choices, and this technique has recently been applied to the estimation of preferences for non-market goods. Conjoint analysis is based on methods for analyzing complex decision making. These methods are based on a body of research called information integration theory (or IIT) (Louviere, 1988). This paper represents one of the first applications of conjoint analysis as a tool for estimating passive use values associated with protecting forest health.

CONJOINT ANALYSIS

Conjoint analysis is consistent with the Lancasterian view of consumers receiving utility from goods based on the type and levels of characteristics or attributes available from the goods. The levels of these attributes, and a consumer's knowledge about them will form the basis for the utility a consumer expects from a particular choice between goods. This utility is unobservable, but one assumption that is made in conjoint is that it is linearly related to a consumer's responses on a preference rating scale:

$$U_j = a + bR_j + e_j, \tag{1}$$

where U_j is the unknown utility of choice j, a and b are regression coefficients, R_j is the rating applied to choice j and e_j is the random error associated with the regression. The second assumption that must be made is that the consumer uses the rating scale as an approximate interval measure. Finally one must assume that the rating strategy of the consumer reveals his decision strategy.

The rating applied to each choice is based on a consumer's expected overall utility for that choice, which is in turn based on the part-worth utility associated with the level of each attribute of the choice. If a choice has three attributes, Equation 1 can be rewritten as:

$$U_{pqr} = C + u\left(A_{1p}\right) + u\left(A_{2q}\right) + u\left(A_{3r}\right), \tag{2}$$

where U_{pqr} is the overall utility associated with choice or good *pqr*, and $u(A_{1p})$, $u(A_{2q})$ and $u(A_{3r})$ are the part worth utilities associated with attributes 1, 2, and 3 at levels *p*, *q*, and *r*, respectively. Equation 2 assumes an additive form for the consumer's utility, although other forms can also be used to model the utility for the choice or good.

In a conjoint experiment, each choice presented to the respondent will have different levels of the attributes which are chosen by the researcher. The attributes used in an experiment must be chosen carefully in order to encompass the set of determinant attributes most likely to influence a consumer's preference.

The part worth or attribute values can be estimated by asking an individual to compare two bundles, each with different levels of the attributes. Two attributes in each bundle could (holding all other attributes constant) be varied in opposing directions to reach a point where the two bundles will be equivalent (that is, the individual will be indifferent between them). If a person is indifferent between two choices, the utility derived from each is assumed to be equivalent. The marginal rate of substitution between attributes can be derived from the ratio of the marginal utilities of each bundle. If one of the attributes is the cost of the good or bundle, then using the cost of each bundle, an indirect utility function can be derived that allows for monetary valuation. That is, varying the cost and another attribute to achieve equality between the two bundles, the marginal rate of substitution can be used to represent the marginal willingness to pay for the attribute. In this manner, a value can be estimated for each attribute by varying the level of the attribute and the cost of the option (Mackenzie, 1992). Using regression coefficients, one can calculate a marginal value (or willingness to pay) for each attribute using the negative ratio of the coefficient on the attribute over the coefficient on cost.

Since one cannot observe U_{pqr}, one can use a respondents rating for choice *pqr* and rewrite Equation 2 as:

$$R_{pqr} = D + u\left(A_{1p}\right) + u\left(A_{2q}\right) + u\left(A_{3r}\right) + e_{pqr}, \tag{3}$$

where R_{pqr} is the rating given to choice or bundle *pqr*, $u(A_{1p})$, $u(A_{2q})$, and $u(A_{3r})$ are as defined above, and e_{pqr} is the random component of the respondent's rating. Ratings are often used to assess consumer preferences in a conjoint experiment, but rankings and binary choice are also used. With ratings as the dependent variable in Equation (3), the attribute coefficients can be estimated using an ordered probit or ordered logit model.

The above example uses an additive model of utility, that is, it assumes that the attributes contribute to the overall utility of the choice in an additive manner. This means that responses to levels of one attribute are independent of responses to the levels of other attributes. When the number of attributes and / or levels is large, the number of possible combinations (or options) to be evaluated by the consumer becomes unwieldy quickly, especially if interactions are expected to be significant. According to Louviere (1988), the majority of variation in ratings can be explained using main effects or linear additive effects only. Thus it is appropriate to use a main effects experimental design which uses a subset of the possible combinations (Adamowicz *et. al,* 1998).

Conjoint analysis shares some features with the contingent valuation method. Within the contingent valuation method, there exist several question formats. Much debate has been carried on in the literature as to which question format best achieves the researcher's objective of inducing the respondent to reveal his or her true willingness to pay (or willingness to accept compensation) for a non-market good. It has been hypothesized that the more closely a researcher can come to emulating "real world" scenarios the more likely it is that a respondent will give a meaningful reply to a contingent valuation question. Consumers are most familiar with paying a pre-determined price for private goods, so a question which asks a respondent to "name your price" (such as open ended) may be unfamiliar that respondents making it difficult for them to give meaningful answers. A format such as dichotomous choice, which gives a respondent a "take it or leave it" choice, offering the public good for some specified price is more familiar, and may be easier for the respondent to grasp and answer.

Taking this emulation of the real world even further, a consumer who is considering making a purchase will usually have several “brands” to choose from. These different brands will have different attributes and/or levels of attributes. Among these attributes is the cost of the good. A consumer will weigh each brand and its set of attributes to determine which most fully meets his or her needs and budget constraint. If a public good is being offered to a consumer for “purchase” he or she may feel most comfortable if the choice involves trade-offs among different levels of attributes and cost. For example, a 200 acre park may cost each household ten dollars per year, a 100 acre park six dollars per year, and a 50 acre park only four dollars per year. A survey respondent is then asked to rank or rate each good (the park) at the postulated tax prices.

Conjoint analysis has been extensively applied to predict consumer (market) behavior. It has recently begun to be used to estimate values for non-market goods. Lareau & Rae (1989) used the technique to estimate willingness to pay to reduce diesel odors. Gan & Luzar (1993) applied conjoint methods to the problem of valuing waterfowl hunting. Revealed preferences and stated preferences (via conjoint analysis) for water based recreation were compared by Adamowicz *et al.* (1994). Stevens *et al.* (1997) examined the value of various groundwater protection programs using a conjoint technique. Finally, Zinkhan *et al.* (1994) offered an example of the use of conjoint analysis to estimate the multiple values associated with forest management and Garrod & Willis (1997) estimated non-use benefits associated with forest biodiversity.

Mackenzie (1992) used conjoint analysis to estimate the value of six attributes associated with waterfowl hunting trips. The attributes were varied in different combinations, which were described to the respondent as possible hunting trips. The respondent was asked to rate each trip on a scale of 1 to 10. The dependent variable in this experiment was the rating assigned to each trip and the levels of trip attributes are the explanatory variables in the regression. Using the negative ratio of the coefficient on each non-cost attribute (β_i) divided by the coefficient on the cost (β_{cost}) yields the marginal value or willingness to pay in (4):

$$MV_i = -\frac{\beta_i}{\beta_{\cos t}}. \quad (4)$$

Mackenzie concluded that the conjoint analysis technique can be a useful tool for estimating the value of individual attributes of a public good. This can be important when researchers attempt to value such things as whole ecosystems or forest management options which have multiple attributes. Further, the author concluded that the rating scale approach can account for preference intensities, which would not be accounted for in a discrete choice contingent valuation study. The rating scale model format can also account for respondent indifference or ambivalence. Mackenzie speculated that this ambivalence or indifference manifests itself in the form of non-response to more traditional non-market valuation surveys, leading to bias.

In all the applications above, marginal attribute values were calculated using Equation 4. While they are implicit prices, these marginal values may not reflect respondents' maximum willingness to pay for the change in each attribute holding utility constant (compensating variation). Roe *et al*. (1996) showed that by including an option that represents the status quo and examining the difference in ratings between the status quo and an alternative, conjoint analysis can yield estimates of compensating variation. This approach is followed in this paper.

The remainder of the paper is as follows. We describe our application of conjoint to forest health in the United States. We present our sampling and survey structure, followed by specification of the statistical model. We then report the empirical results to illustrate the applicability of conjoint analysis to measuring marginal passive use values for improving forest health.

Application of Conjoint Analysis to the Valuation of Forest Health

Forest health has aspects of a pure public good and is composed of multiple attributes. One aspect of forest health is the prevention or eradication of insect and disease infestations. Forest insects or diseases affect a variety of resources in different ways. An infestation of insects may reduce timber values, while at the same time increasing insect-eating bird populations and habitat for some wildlife. Pest management actions will obviously have different effects on these resources, and different levels of management will have different levels of impacts and different costs. Even pest management activities themselves involve a wide variety of activities each with different consequences or effects on attributes. Management to increase one or more attributes may lead to losses in the levels of other attributes.

Knowing public preferences regarding the trade-offs among various attributes or amenities of healthy forests can be useful to forest managers who must decide which actions to take on specific forest areas. Thus, conjoint analysis may be an appropriate tool to estimate the values of various attributes of management activities to protect or restore forest health. This is because conjoint analysis allows us to examine the disaggregated value of the alternative attributes of different public goods which can be produced from a given forest.

This paper presents the results of a conjoint study of alternative management programs for three different forest pest situations in the United States. The gypsy moth is an introduced pest, which has little effect on commercial timber, but does have a high impact on ornamental trees and trees in popular recreation areas (Doane & McManus, 1981; USDA Forest Service, 1995). The second scenario is the western spruce budworm. This insect is native to most fir stands in the western US, and has a large impact on commercial timber in the Pacific Northwest (Brookes et al., 1987; USDA Forest Service, 1989). The final scenario is the southern pine beetle, another native insect. This insect has impacts on commercial timber in the Southeast, and the problem is exacerbated by infestations in Wilderness areas where regulations make some control actions illegal (Thatcher *et al.*, 1981; USDA Forest Service, 1987).

SURVEY DESIGN

The three insect infestation scenarios were presented in a questionnaire mailed to 1200 households. The sample was concentrated equally in the three geographic regions most affected by the pests (the Northeastern United States, the Southeastern United States and the State of Oregon). The same questionnaire (with all three insect scenarios) was sent to each region.

Each forest pest management scenario contained a brief description of the insect, including its area of impact, and the effects of an uncontrolled infestation. Next was a description of three management options, the first of which was "no action." The next option was a moderate level of pest management and the third was intensive management. The three management options were then compared in a table showing the expected effects (e.g., level of attributes for each characteristic) over the next 15 years. These effects are: the area infested, changes in non-target insect populations, changes in insect-eating bird populations, water resource effects (streamflow changes and erosion), changes in recreation use and changes in commercial timber and the one-time cost to their household. The attributes used in the survey were derived from Environmental Impact Statements for proposed control programs for each of the scenarios. Levels were based on the expected levels for the alternatives examined in each EIS. The respondent was asked to rate (on a scale of 1 - 10) the three management options within that scenario. In order to provide sufficient variation in the levels of each attribute to estimate a coefficient on each, 6 versions of the survey were used. These survey versions were identical except for the levels of the attributes in the moderate and intensive management options. The "no action" option is constant for each version. For the specific levels used in each version, see Appendix A.

This questionnaire was developed using the assistance of professionals in the forest health field, including foresters and entomologists. These experts participated in devising the forest pest scenarios in order to ensure their realism and accuracy. Further, professionals working in the public land management sector were questioned about their information needs regarding public values for forest health management.

Next the survey instrument was refined using the input of a focus group of residents of Colorado. A pre-test was then conducted in the three survey regions to finalize the questionnaire. Participants for the pre-test were recruited via telephone. They were mailed the questionnaire booklet to review and answer. Then researchers called back at a pre-scheduled time for a de-briefing regarding their answers or concerns about the survey. Any questions which were unclear or difficult were refined and a final version was created.

SAMPLE DESIGN AND SURVEY RESPONSE RATE

The final survey was mailed to a random sample of 400 households in each of the three regions for a total of 1200 surveys. A variation of the Dillman total design method was used. After the initial mailing a reminder postcard was sent to all participants. A second mailing was sent about six weeks after the first mailing. Response rates were lower than usual, with an overall response of 32%. It is speculated that the complexity of the questionnaire, and the lack of a third mailing (due to budget constraints) contributed to the less than desirable response rate. Comparisons of the demographic characteristics of the sample to the population of the sampling areas indicates that our sample is slightly older and higher income than the general population. Despite these differences, for purposes of illustrating the applicability of conjoint methodology to measuring passive use values of forests, we believe this sample is adequate. These comparisons are presented in Tables 1 and 2.

STATISTICAL MODELING TECHNIQUE FOR CONJOINT ANALYSIS

The statistical analysis was conducted using the ordered probit model of the form:

$$P_i = \frac{1}{\sqrt{2\Pi}} \int_{-\infty}^{\alpha+\beta X_i} e^{-t^2/2} dt, \tag{5}$$

where P_i is the probability that a particular option receives a rating of "i", α is a regression constant, β_i is a vector of coefficients, X_i is a vector of independent variables and t is the standardized normal variable. This models is less restrictive than a tobit model (which assumes cardinality in the responses).

TABLE 1. COMPARISON OF SAMPLE DEMOGRAPHICS WITH POPULATION — AGE.

	Age Category	Percent of Sample	Percent of Population
Northeast	23-34	15.9	15.1
	35-44	23.2	15.9
	45-54	21.7	12.2
	55-64	10.1	8.8
	65+	28.9	13.9
Oregon	23-34	6.6	13.5
	35-44	18.9	16.6
	45-54	28.8	13.0
	55-64	17.7	8.1
	65+	26.6	13.9
Southeast	23-34	13.6	15.1
	35-44	15.2	15.4
	45-54	32.2	12.0
	55-64	16.9	8.4
	65+	22.0	12.4

Several possible variable specifications were examined, with different combinations of attributes included. Correlations among some of the attributes (sensible in some cases, such as streamflow and erosion) precluded the use of all of the attributes in one model. The final model used the following minimally correlated attributes as independent variables (names in *italics*): the number of forest acres expected to be infested by the pest within 15 years of implementation of the management program (*Acres*), the cost per household of the management program (*Cost*), expected changes in commercial timber harvests, expressed as a percentage change (*Timber*) and finally a dummy variable indicating whether the pest was introduced or native to the

TABLE 2. COMPARISON OF SAMPLE DEMPGRAHPICS WITH POPULATION — INCOME.

	Income Category	Percent of Sample	Percent of Population
Northeast	0–$14,999	6.4	18.7
	$15,000–$24,999	17.7	13.4
	$25,000–$34,999	14.5	13.3
	$35,000–$49,999	16.1	18.1
	$50,000–$74,999	24.6	18.7
	$75,000–$99,999	12.9	8.6
	$100,000 +	4.8	9.2
Oregon	0–$14,999	9.3	20.6
	$15,000–$24,999	12.7	17.0
	$25,000–$34,999	12.7	16.0
	$35,000–$49,999	20.1	19.8
	$50,000–$74,999	26.7	16.0
	$75,000–$99,999	11.6	5.5
	$100,000 +	5.8	5.2
Southeast	0–$14,999	5.3	25.7
	$15,000–$24,999	10.7	16.6
	$25,000–$34,999	7.1	14.9
	$35,000–$49,999	8.9	17.7
	$50,000–$74,999	42.9	14.9
	$75,000–$99,999	7.1	5.4
	$100,000 +	17.8	4.8

region (*Native*). Equation 5 shows the regression model

$$Ratings\ Difference = \beta_1 + \beta_2 Cost + \beta_3 Acres + \beta_4 Timber + \beta_5 Native. \tag{6}$$

RESULTS

Table 3 contains the coefficients, t-statistics and log likelihood function for the ordered probit model. The acres infested variable and cost variable are negative and statistically significant. This indicates that the levels of these variables are inversely related to the individual's rating and utility. The negative sign on the cost variable also indicates internal validity. That is, individuals apparently paid attention to the cost of each option and the higher the cost, the less they preferred it (the lower rating it received). The percent gain in commercial timber is positive and significant indicating this contribute's to the rating.

Marginal values were calculated for the various forest health management attributes using Equation (4). Because the marginal values are the ratio of random variables, we constructed confidence intervals around the marginal values (MV_i) via the method derived by Fieller (1932) and

TABLE 3. RESULTS OF ORDERED PROBIT REGRESSIONS.

	Coefficient	t-value
Constant	1.781 ***	13.530
Acres	–0.001344 ***	–4.221
Cost	–0.002481 ***	–2.782
Timber	0.01193 ***	3.441
Native	0.20063 *	1.680
Log likelihood:	–4168.404	
Chi-squared:	29.5281**	
Number of observations	1 488	

*, **, *** significant at a=0.10, 0.05, and 0.01 respectively.

TABLE 4. MARGINAL VALUES AND CONFIDENCE INTERVALS FOR FOREST ATTRIBUTES (USD).

Attribute	Marginal Value	90% Confidence Interval
Acres	–0.5417	–1.226, –0.312
Timber	4.8098	2.550, 10.761
Native	80.868	1.752, 239.8

used by Mackenzie (1992, 1993). Using Equation 4, the marginal value for attribute i is $-\beta_i$ / β_{cost}, we can express this as $\beta_i + \beta_{cost}MV_i = 0$. The confidence interval can then be estimated from the quadratic roots of:

$$\frac{\left(\beta_i + \beta_{\cos t}MV_i\right)}{\left(\alpha_i^2 + 2\alpha_i\alpha_{\cos t}MV_i + \alpha_{\cos t}^2 MV_i^2\right)^{0.5}} > t. \tag{7}$$

The results of this estimation are shown in Table 4.

The marginal values can be interpreted as either the loss in benefits from one more unit of a bad or the willingness to pay to avoid one more unit of a bad. For example, the marginal value on acres infested is $.54 (USD). Thus a household would have a reduction in benefits of 54 cents for each additional acre infested or it would pay 54 cents an acre to reduce forest infestation by one acre. It should be noted that economic theory would suggest that this marginal value for an acre of reduced infestation may not be constant for all levels of infestation. In other words a household may be willing to pay *more* per acre to control a high level of infestation, and perhaps *less* per acre to control a low level of infestation. This is a limitation of the linear conjoint model. Since reduction in forest infestation is a pure public good, each acre of infestation reduced simultaneously provides benefits to millions of households. Depending on the geographic extent of the passive use values and the population of the country, this value could be as high as several million dollars even for a small reduction (e.g. 100 acres) in a country with millions of households.

The confidence intervals for these marginal values do not include zero, indicating the marginal values are statistically different from zero. The upper and lower confidence interval estimates of the marginal values could be used for sensitivity analysis for management planning purposes.

CONCLUSIONS

Conjoint analysis has been used widely in market research, but less work has been done using conjoint analysis to estimate values for non-market goods. Further, most non-market research using conjoint analysis has been in the valuation of recreation amenities. There are very few applications of conjoint analysis to the valuation of non-use/ passive use values which are pure public goods. In our conjoint analysis it was found that households valued a reduction in the number of forest acres infested, even in regions far enough from home to make recreation use unlikely. This suggests that reduction in forest pest to increase forest health likely has passive use benefits such as existence and bequest values.

To date, economists have had only one tool (contingent valuation) to measure passive use values, and it has always been somewhat controversial. This study suggests that conjoint analysis can be added to the "toolbox" as a potential method for measuring passive use values. The conjoint technique to value multi-attribute forest management choices may be useful in two ways. First, estimating the marginal values of individual attributes of forest management actions may offer greater insight into the values held by people for their forests, and help determine the appropriate set of management alternatives to be implemented. Second, conjoint analysis technique is quite flexible and appears suited to estimate the values of a wide variety of non-market forest characteristics beyond those used in this paper. Thus the method appears to have promise for future applications in forest management decision-making.

REFERENCES

Adamowicz, W., Louvier, J. & Swait, J., 1998. *Introduction to Attribute-based State Choice Methods*. Final Report Submitted to the Resource Valuation Branch, Damage Assessmen Center, National Oceanic and Atmospheric Administration, US Department of Commerce.

Adamowicz, W., Louviere, J. & Williams, M., 1994. Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities. *Journal of Environmental Economics and Management*, 26, 271–292.

Alwin, D. F. & Krosnick, J. A., 1985. The Measurement of Values in Surveys: a Comparison of Ratings and Rankings. *Public Opinion Quarterly*, 49, 535-552.

Brookes, M. H., Campbell, R. W., Colbert, J. J., Mitchell, R. G. & Stark, R. W., 1987. *Western Spruce Budworm*. USDA Forest Service, Cooperative State Research Service, Technical Bulletin 1694.

Doane, C. C. & McManus, M. L. (eds), 1981. *The Gypsy Moth: Research Toward Integrated Pest Management*. United States Department of Agriculture, Expanded Gypsy Moth Research and Development Program. Forest Service Science and Education Administration and Animal and Plant Health Inspection Service. Technical Bulletin 1584. Washington DC.

Feather, N. T., 1973. The Measurement of Values: Effects of Different Assessment Procedures. *Australian Journal of Psychology*, 25 (3), 221–231.

Fieller, E. C., 1932. The Distribution of the Index in a Normal Bivariate Population. *Biometrika*, 24, 428–440.

Gan, C. & Luzar, E. J., 1993. A Conjoint Analysis of Waterfowl Hunting in Louisiana. *Journal of Agricultural and Applied Economics*, 25 (2), 36–45.

Garrod, G. D. & Willis, K. G., 1997. The Non-use Benefits of Enhancing Forest Biodiversity: a Contingent Ranking Study. *Ecological Economics*, 21, 45–61.

Lareau, T. J. & Rae, D. A., 1989. Valuing WTP for Diesel Odor Reductions: an Application of Contingent Ranking Technique. *Southern Economics Journal*, 55 (3), 728–742.

Louviere, J. J., 1988. *Analyzing Decision Making: Metric Conjoint Analysis*. Sage University Paper Series on Quantitative Applications in the Social Sciences, Series No. 07–067 (Beverly Hills, CA: Sage Publications).

MacDonald, H., McKenney, D. W. & Nealis, V., 1997. A Bug is a Bug is a Bug: Symbolic Responses to Contingent Valuation Questions about Forest Pest Control Programs? *Canadian Journal of Agricultural Economics*, 45, 145–163.

Mackenzie, J., 1992. Evaluating Recreation Trip Attributes and Travel Time via Conjoint Analysis. *Journal of Leisure Research*, 24 (2), 171–184.

Mackenzie, J., 1993. A Comparison of Contingent Preference Models. *American Journal of Agricultural Economics,* 75 (August), 593–603.

Mitchell, R. C. & Carson, R. T., 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method* (Washington D.C.: Resources for the Future).

Roe, B., Boyle, K. J. & Teisl, M. F., 1996. Using Conjoint Analysis to Derive Estimates of Compensating Variation. *Journal of Environmental Economics and Management*, 31, 145–159.

Rosenberger, R.S. & Smith, E. L., 1997. *Nonmarket Economic Impacts of Forest Insect Pests: a Literature Review*. General Technical Report PSW-GTR-164. Albany CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture.

Stevens, T. H., Barrett, C. & Willis, C. E., 1997. Conjoint Analysis of Groundwater Protection Programs. *Agricultural and Resource Economics Review*, 26 (3), 229–236.

Thatcher, R. C., Searcy, J. L., Coster, J. E., & Hertel, G. D. (eds), 1981. *The Southern Pine Beetle.* USDA Forest Service, Science and Education Administration. Technical Bulletin 1631.

USDA Forest Service, Souther Region, 1987. *Final Environmental Impact Statement for the Suppression of the Souther Pine Beetle.* Management Bulletin R8-MB 2.

USDA Forest Service, Forest Pest Management, Pacific Northwest Region, 1989. *Final Environmental Impact State: Management of Western Spruce Budworm in Oregon and Washington.*

USDA Forest Service and Animal and Plant Heath Inspection Service, 1995. *Gypsy Moth Management in the United States: A Cooperative Approach. Final Environmental Impact Statement.*

Zinkhan. C. F., Holmes, T. P. & Mercer, D. E., 1994. *Conjoint Analysis: a Pragmatic Approach for the Accounting of Multiple Benefits in Souther Forest Management*. Southeastern Center for Forest Economics Research, Research Triangle Park, NC. SCFER Working Paper No. 76.

APPENDIX A– QUESTIONNAIRE DESCRIPTION

Six treatments or versions of the questionnaire were developed. Attribute levels were varied in combinations which were designed to allow the researchers to examine main effects only. That is all possible unique combinations of “high” and “low” levels for each attribute are represented in the six versions described below. In the interest of a financially manageable project, we chose not to examine possible interactions among attributes since this would have increased the number of versions required to a level that would have been well outside the budge of the project. Presented below the levels used for each version of each scenario.

SCENARIO A – GYPSY MOTH

	Version 1		Version 2		Version 3	
Attribute	Moderate Management	Intensive Management	Moderate Management	Intensive Management	Moderate Management	Intensive Management
Acres Infested (millions)	426	200	426	425	426	200
Annual Cost / Household	$30	$80	$75	$80	$30	$125
Non-target Insects	–18%	–19%	–5%	–19%	–5%	–40%
Birds	+4%	–14%	–13%	–30%	–13%	–14%
Streamflow	+5%	+2.5%	+2.6%	+2.5%	+2.6%	No change
Erosion	+2.6%	+2.5%	+5%	+2.5%	+2.6%	+2.5%
Recreation Visitor Days	–5%	–4%	–9%	No change	–9%	No change
Timber	No change	No change	No change	No change	No change	No change

SCENARIO A – GYPSY MOTH (CONTINUED)

	Version 4		Version 5		Version 6	
Attribute	Moderate Management	Intensive management	Moderate Management	Intensive Management	Moderate Management	Intensive Management
Acres Infested (millions)	650	425	650	200	650	425
Annual Cost / Household	$75	$125	$30	$125	$75	$80
Non-target Insects	–18%	–19%	–18%	–40%	–5%	–40%
Birds	–13%	–14%	+4%	–30%	+4%	–30%
Streamflow	+5%	No change	+2.6%	+2.5%	+5%	No change
Erosion	+5%	No change	+5%	No change	+2.6%	No change
Recreation Visitor Days	–9%	–4%	–9%	–4%	–5%	No change
Timber	No change	No change	No change	No change	No change	No change

Scenario B – Western Spruce Budworm

	Version 1		Version 2		Version 3	
Attribute	Moderate Management	Intensive Management	Moderate Management	Intensive Management	Moderate Management	Intensive Management
Acres Infested (millions)	9	2	9	8	9	2
Annual Cost / Household	30	80	75	80	30	125
Non-target Insects	–1%	–30%	–14%	–30%	–14%	–15%
Birds	No change	–5%	–4%	–10%	–4%	–5%
Streamflow	+4%	+2%	+2.2%	+2%	+2.1%	No change
Erosion	+2.1%	+2%	+4%	+2%	+2.1%	+2%
Recreation Visitor Days	–7%	–6%	–7%	No change	–14%	No change
Timber	–8%	–5%	–8%	–7%	–19%	–7%

Scenario B – Western Spruce Budworm (continued)

	Version 4		Version 5		Version 6	
Attribute	Moderate Management	Intensive Management	Moderate Management	Intensive Management	Moderate Management	Intensive Management
Acres infested (millions)	14	8	14	2	14	8
Annual Cost / Household	75	125	30	125	75	80
Non-target Insects	–1%	–30%	–1%	–15%	–14%	–15%
Birds	–4%	–5%	No change	–10%	No change	–10%
Streamflow	+4%	No change	+2.1%	+2%	+4%	No change
Erosion	+4%	No change	+4%	No change	+2.1%	No change
Recreation Visitor Days	–14%	–6%	–14%	–6%	–7%	No change
Timber	–8%	–5%	–19%	–7%	–19%	–5%

SCENARIO C – SOUTHERN PINE BEETLE

	Version 1		Version 2		Version 3	
Attribute	Moderate Management	Intensive management	Moderate Management	Intensive management	Moderate Management	Intensive Management
Acres infested (millions)	8	1	8	7	9	2
Annual Cost / household	30	80	75	80	30	125
Non-target Insects	–5%	–20%	–12%	–20%	–14%	–15%
Birds	–6%	No change	–10%	–5%	–4%	–5%
Streamflow	+9%	+4%	+5%	+4%	+2.1%	No change
Erosion	+5%	+4%	+9%	+4%	+2.1%	+2%
Recreation Visitor Days	–8%	–7%	–8%	No change	–14%	No change
Timber	–18%	–5%	–18%	–17%	–19%	–7%

Scenario C – Southern Pine Beetle (continued)

	Version 4		Version 5		Version 6	
Attribute	Moderate Management	Intensive management	Moderate Management	Intensive management	Moderate Management	Intensive Management
Acres infested (millions)	14	8	14	2	14	8
Annual Cost / household	75	125	30	125	75	80
Non-target Insects	–1%	–30%	–1%	–15%	–14%	–15%
Birds	–4%	–5%	No change	–10%	No change	–10%
Streamflow	+4%	No change	+2.1%	+2%	+4%	No change
Erosion	+4%	No change	+4%	No change	+2.1%	No change
Recreation Visitor Days	–14%	–6%	–14%	–6%	–7%	No change
Timber	–8%	–5%	–19%	–7%	–19%	–5%