8. Model Estimation and Willingness to Pay

As explained at the outset, the overall goal of this project was to estimate the total values that the U.S. public places on the protection and restoration of degraded coral reefs of the MHI. We considered two problems: widespread, chronic degradation at the ecosystem level that has followed from the forces commonly referred to as "economic development" (e.g., overfishing, nonpoint source pollution) and much smaller, localized, but more traumatic injuries to the reefs (e.g., injuries from ship strikes, oil and toxic spills, urban pollution). This, in turn, required scenarios that individuals filling out our survey could understand and find plausible. No-fishing zones and ship strikes served this purpose. To be realistic, the scenarios were based on current scientific knowledge to the extent possible. We did not evaluate actual proposals to expand no-fishing zones around the MHI to 25% of the reefs or to establish a ship-strike damage repair program. These were merely tools or case studies to get at what really matters: the total values of substantial protection and restoration of large-scale ecosystems and more localized injuries to reefs.[1]

This chapter presents the final results. In the first section, data from application of the attribute-based questions and other questions in our survey are used to arrive at a final model to use in valuation. Then, later sections report value estimates at the household and aggregate levels.

8.1 Final Model and Variables

As described in Chapter 2, the Team applied an attribute-based approach using a stated choice format in which respondents provided a full ranking of four alternative programs, one of which was the status quo (the Current Program). There are several estimation techniques that economists can use to analyze such data.[2] For the final analysis, the Team used a rank-ordered probit model, which fits respondents' program choices into a utility-theoretic framework that is used to estimate WTP.[3]

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1. The phrase "substantial protection and restoration" implies an important caveat. Complete restoration to pristine conditions may not be technically feasible at this time and would be of limited policy relevance. No fishing zones would improve fish catches from 10% to 50% of historic levels and make the entire reef ecosystem healthier, support more marine life, improve the quality of recreation, and improve religious and cultural uses by native Hawaiians.

2. Appendix D, Section D.2, includes a review of these techniques.

3. In the Team's view, this is the most appropriate model for analyzing these ranked choices for two primary reasons. First, because three of the four alternatives in the choice set involve programs with a similar goal – to protect and/or repair coral reefs in the MHI - preferences for these alternatives are expected to be correlated.

As discussed in Appendix E, the model presented here only allows us to estimate WTP for the specific programs proposed. We are not able to estimate marginal WTP for varying levels of program attributes. This is due to the fact that we limited our program descriptions to scenarios that were deemed reasonable by our science advisors. The model presented here cannot extrapolate beyond the actual scenarios posed in the survey.

In analyzing stated choices, economists assume that the differences across respondents' choices are attributable to variation in both observed characteristics (e.g., respondents' demographic characteristics and/or responses to survey questions), as well as unobserved, random variation. Our model includes several variables to account for the variation in observed respondent characteristics. These include variables such as whether the respondent will visit Hawaii in the future, whether the respondent is an environmentalist, and the number of times a respondent has visited a coral reef, as well as demographic variables, such as income, education, marital status, and home ownership. To select these variables as the final model variables, we followed a process that began by considering the full set of variables that were significant in Section 7.2. We excluded attitudinal and management scenario variables because these variables might be "endogenous" variables, that is, variables that might be caused *by* respondents' program choices (or by an unobserved variable that is highly correlated) rather than simply causes *of* those choices. The model variables are defined and described in Tables 8.1 and 8.2,[4] and the estimation results of the rank-ordered probit model are presented in Table 8.3.[5, 6]

(See Appendix E, footnote 3, for more discussion of this issue.) Second, the fourth alternative in the choice set (the Full Program) is a combination program that is equal to the sum of the two individual programs (No-Fishing Zones Program plus Reef Repair Program). Thus, any unexplained variation in preferences for that program is likely to represent some combination of the unexplained variances for the individual programs. Therefore, the error variance for the combined program might be larger than the individual-program variances. In other words, the error terms might be heteroskedastic. (See Appendix E, footnote 4, for more discussion of this issue.) The rank-ordered probit model accommodates these issues by allowing for correlation and heteroskedasticity in the unexplained variances across alternatives. The rank-ordered probit model has been discussed in the literature for many years (Hajivassiliou and Ruud, 1994; Train, 2003) but has rarely been applied in practice due to its computational complexity. One recent paper that applies the rank-ordered probit model is Schechter (2010).

4. See Appendix F for a complete breakdown of the demographic variables: education, income, marital status, and home ownership. See Appendix H for a breakdown of responses to the other model variables.

5. The pooled dataset has 3,277 observations; 94 observations were dropped from the analysis because the respondents did not answer any part of the ranking sequence. If respondents answered the initial ranking question, Q10, but did not answer the follow-up ranking questions, Q13 or Q15, then all remaining alternatives in the choice set at the point of the nonresponse were treated as ties for that observation. This left 3,183 observations for our final analysis.

6. The model was estimated using the "asroprobit" command in Stata 10. See Appendix E, footnote 5, for details on the algorithm Stata used to estimate this model.

Table 8.1. Variables used in the rank-ordered probit model

	Variable definition
Alternative-specific variables	
Fish	A variable indicating the no-fishing zones program appeared in the chosen alternative
Reef	A variable indicating the reef repair program appeared in the chosen alternative
Cost	The cost to the household of the alternative
Individual-specific variables interacted with the no-fishing zones program	
Income X Fish	Equals the respondent's income divided by $1,000 interacted with alternatives that include the no-fishing zones program, 0 otherwise[a]
Education X Fish	Level of education interacted with alternatives that include the no-fishing zones program, 0 otherwise[b]
Married_own X Fish	A dummy variable that equals 1 if the respondent stated that he or she is married and owns a home interacted with alternatives that include the no-fishing zones program, 0 otherwise
Strong environmentalist X Fish	A dummy variable that equals 1 if the respondent said that he or she was at least a "strong environmentalist" interacted with alternatives that include the no-fishing zones program, 0 otherwise
Very strong environmentalist X Fish	A dummy variable that equals 1 if the respondent said that he or she was a "very strong environmentalist" interacted with alternatives that include the no-fishing zones program, 0 otherwise
Def_visit X Fish	A dummy variable that equals 1 if the respondent stated that he or she will "definitely" visit Hawaii in the next 10 years interacted with alternatives that include the no-fishing zones program, 0 otherwise
Times X Fish	Equal to the number of times the respondent has visited coral reefs interacted with alternatives that include the no-fishing zones program, 0 otherwise[c]
Individual-specific variables interacted with the reef repair program	
Income X Ship	Equals the respondent's income divided by $1,000 interacted with alternatives that include the reef repair program, 0 otherwise
Education X Ship	Level of education interacted with alternatives that include the reef repair program, 0 otherwise
Married_own X Ship	A dummy variable that equals 1 if the respondent stated that he or she is married and owns a home interacted with alternatives that include the reef repair program, 0 otherwise

Table 8.1. Variables used in the rank-ordered probit model (cont.)

	Variable definition
Strong environmentalist X Ship	A dummy variable that equals 1 if the respondent said that he or she was at least a "strong environmentalist" interacted with alternatives that include the reef repair program, 0 otherwise
Very strong environmentalist X Ship	A dummy variable that equals 1 if the respondent said that he or she was a "very strong environmentalist" interacted with alternatives that include the reef repair program, 0 otherwise
Def_visit X Ship	A dummy variable that equals 1 if the respondent stated that he or she will "definitely" visit Hawaii in the next 10 years interacted with alternatives that include the reef repair program, 0 otherwise
Times X Ship	Equal to the number of times the respondent has visited coral reefs interacted with alternatives that include the reef repair program, 0 otherwise

a. See Appendix D, footnote 2, for more information on how income categories were defined and how missing responses were imputed.
b. See Appendix F for a complete breakdown of the education variable. For modeling purposes, the education variable was re-centered around the median response of 10, or "some college." In other words, education, which ranged in levels from 1 to 14 in the original dataset (see Table 8.2), was reduced by 10 so that it ranged from –9 to 4 for the analysis. This means that, in the final model, respondents who have education levels at "high school graduate" or below have predicted WTPs that are below the "base" amounts, or the amounts predicted by the estimated program-specific constants. Those who are college graduates or above have predicted WTPs that are above these "base" amounts. This re-centering does not affect overall model results. It simply shifts the values between the education coefficients and the alternative-specific constants.
c. Fourteen respondents said they had visited coral reefs more than 100 times. For modeling purposes, these responses, which represent less than 1% of the data, were capped at 100.

Table 8.2. Summary of variables included in the final model (N = 3,277)

Variable	Mean	Standard deviation	Min	Max
Income	$64,196	$49,620	$2,500	$225,000
Education	10.14	1.86	1	14
Married_own	0.53	0.50	0	1
Strong environmentalist	0.17	0.38	0	1
Very strong environmentalist	0.03	0.17	0	1
Def_visit	0.30	0.46	0	1
Times	3.21	11.11	0	100

Table 8.3. Rank-ordered probit estimation results

Covariate	Coefficient	Standard error	z	P > |z|	95% confidence interval	
Cost	–0.002	0.000	–5.440	0.000	–0.003	–0.001
Fish	0.245	0.086	2.850	0.004	0.076	0.413
Ship	0.071	0.068	1.040	0.296	–0.062	0.204
Variables with the no-fishing zones program						
Income X Fish	0.002	0.001	2.280	0.023	0.000	0.003
Education X Fish	0.049	0.019	2.650	0.008	0.013	0.086
Married_own X Fish	–0.179	0.059	–3.030	0.002	–0.294	–0.063
Strong environmentalist X Fish	0.691	0.103	6.700	0.000	0.489	0.893
Very strong environmentalist X Fish	0.440	0.186	2.370	0.018	0.075	0.805
Def_visit X Fish	0.333	0.098	3.400	0.001	0.141	0.524
Times X Fish	0.007	0.002	2.760	0.006	0.002	0.012
Variables with the reef repair program						
Income X Ship	–0.000[a]	0.001	–0.210	0.834	–0.001	0.001
Education X Ship	–0.020	0.015	–1.310	0.189	–0.050	0.010
Married_own X Ship	–0.167	0.057	–2.940	0.003	–0.279	–0.056
Strong environmentalist X Ship	0.512	0.085	6.050	0.000	0.346	0.678
Very strong environmentalist X Ship	0.294	0.151	1.950	0.052	–0.002	0.591
Def_visit X Ship	0.333	0.103	3.240	0.001	0.131	0.534
Times X Ship	0.006	0.002	2.810	0.005	0.002	0.011
lnsigma 3[b]	–0.124	0.047	–2.630	0.008	–0.217	–0.032
lnsigma 4	0.512	0.041	12.610	0.000	0.433	0.592
atanhr3_2	0.862	0.074	11.590	0.000	0.716	1.008
atanhr4_2	1.304	0.086	15.110	0.000	1.135	1.473
atanhr4_3	1.159	0.083	14.010	0.000	0.997	1.321
sigma1	1.000 (base alternative)					
sigma2	1.000 (scale alternative)					
sigma3	0.883	0.042			0.805	0.969
sigma4	1.669	0.068			1.542	1.808

Table 8.3. Rank-ordered probit estimation results (cont.)

Covariate	Coefficient	Standard error	z	P > |z|	95% confidence interval	
rho3_2	0.697	0.038			0.615	0.765
rho4_2	0.863	0.022			0.813	0.900
rho4_3	0.821	0.027			0.760	0.867

Alternative = 1 is the alternative normalizing location.
Alternative = 2 is the alternative normalizing scale.
Log simulated-pseudolikelihood = –8,638.25.

a. The Income X Ship coefficient is –0.000129.
b. See Stata 10 manual [R] asroprobit for an explanation of model-specific variables.

In addition to the final model presented here, we conducted a number of exploratory studies to consider additional factors or alternative approaches that might have affected choice responses. We found that these other factors and approaches did not lead to results that differed significantly from our final model. To summarize, we conducted the following exploratory studies:

} The inclusion or exclusion of additional demographic covariates, as well as alternative specifications of the demographic covariates in the final model. Specifically, earlier runs of the model included variables for gender, age categories, and number of persons in the household, but these variables were found to be insignificant and were dropped from the final analysis to improve estimation efficiency. Estimation of average WTP is not significantly affected by the inclusion or exclusion of these additional covariates. We also estimated the model with a breakdown of the education variable into separate components so that different levels of educational attainment could have varying effects, but an LRT found that such a specification did not significantly improve model fit. Similarly, separating "married" and "own_home" into two separate variables did not significantly improve fit.

} Inclusion of separate coefficients representing the marginal utility of money income for different income groups. We found that different income groups might have, on average, different marginal values of money income and that models with separate parameters do not significantly change overall WTP estimation. To improve estimation efficiency, the final model includes one parameter representing the average marginal value of money income for the population. To estimate income effects, the model includes income as a covariate to explain program choices.

- Estimating alternative model specifications. Several alternative models that we considered are discussed in Appendix D. We found that it was important to include both correlation and heteroskedasticity in the final model to obtain the best fit.

- A study of how uncertainty affected responses. We found that excluding observations where the respondents were "not sure at all" of their responses did not give significantly different WTP results from those of our final model.

The model variables are summarized in Table 8.1. Three of the variables are specific to the alternative chosen (termed "alternative-specific") and seven are characteristics specific to the individual respondent (termed "individual-specific"). To generate variation across alternatives, which is necessary for estimation, the individual-specific variables were interacted with the alternative-specific program variables (No-Fishing Zones and Reef Repair). The result is that there are separate individual-specific variables for each program, for a total of 14 such variables. Each variable serves as a shifter that measures the propensity of individuals with those characteristics to choose that specific program over the status quo.

Summary statistics for the individual-specific variables are presented in Table 8.2.[7]

Results of the rank-ordered probit model are presented in Table 8.3 and discussed below.[8] A Wald test on the 17 final model covariates cannot reject their joint significance ($\chi^2_{(17)} = 263.44$, $p < 0.001$). The pseudo-simulated log-likelihood at model convergence is –8,638.25.

The results indicate that planning to visit Hawaii in the next 10 years, being a strong and/or very strong environmentalist, and the number of times the respondent has been to coral reefs all have positive and significant impacts on the probability of a respondent choosing both the No-Fishing Zones and the Reef Repair programs. Most of the demographic characteristics are statistically significant at the 95% level or above. For example, the coefficient on income interacted with the No-Fishing Zones Program is positive and significant at the 95% level. This implies that there are positive income effects for this program. On the other hand, the coefficient on income for the Reef Repair Program is insignificant, implying that there are no significant income effects for this program. This may be due to the fact that the Reef Repair Program was generally offered at a lower cost, requiring less of a burden on a household budget. Being married and owning a home have significantly negative effects on both programs. These characteristics are likely to be

7. See Appendix D, footnotes 1 and 2, for details about how categorical variables were defined and how item nonresponses were imputed.

8. The estimated correlation matrix indicates that there is a strong positive correlation among error terms across the program alternatives and that the estimated variance terms indicate that the variance for the fourth alternative – the "full program" – is significantly larger than for the other programs. Both of these findings confirm prior expectations. See Appendix E for more discussion.

correlated with a lower disposable income, so the signs on these variables are not unexpected. Educational level has a positive and significant impact on choice of the No-Fishing Zones Program and an insignificant effect on the Reef Repair Program. The indicator variable for the No-Fishing Zones Program is positive and significant, but the indicator variable for the Reef Repair Program is not significant, implying that there is no measurable propensity to choose the Reef Repair Program over the status quo separate from any propensity that is explained by the above-mentioned variables.

The coefficient on program cost is negative and significant at the 99% level, indicating that money spent by the respondent negatively affects his or her utility, as expected from economic theory.

8.2 Per Household Values

The model just presented was used to arrive at per household values for Hawaiian coral reef ecosystem protection and restoration – as exemplified by no-fishing zones – and repair of smaller, localized damage to Hawaiian coral reefs – as exemplified by repair of injuries for ship strikes.

Using the parameter estimates presented in Table 8.3, we estimated mean WTP per household for each program. See Appendix E for details on estimating these values. Estimated mean WTP for each scenario, including the "full" program, are presented in Table 8.4, along with their estimated standard errors and confidence intervals. Estimated mean WTP for substantial protection and restoration of degraded MHI ecosystems is $224.81 with a 95% confidence interval of $161.72- 287.89. Estimated mean WTP for restoration of reefs after localized injuries is $62.82 with a 95% confidence interval of $20.23–105.40; estimated mean WTP for achieving both goals combined is $287.62 with a 95% confidence interval of $193.46–381.78.[9]

Table 8.4. Mean WTP estimates (N = 3,183)

Program	Estimated WTP	Standard error	95% confidence interval	
Protection and restoration of degraded MHI ecosystems	$224.81	$32.19	$161.72	$287.89
Restoration after localized injuries	$62.82	$21.73	$20.23	$105.40
Achieving both goals	$287.62	$48.04	$193.46	$381.78

9. As discussed in Appendix E, footnote 2, these estimates are likely to be conservative estimates, This is due to the fact that our model does not explicitly account for substitution effects. Instead, any substitution effects, which, if significant, are expected to be negative, are averaged into the program coefficients, thus decreasing our final estimates.

8.3 Elasticities and Marginal Effects of Variables on WTP

The probit model presented in Table 8.3 allows us to explore how estimated WTP would vary, on average, with respect to the demographic and other characteristics that are significant predictors of WTP. Specifically, we can use the model estimates to predict income elasticities, as well as other variables' marginal impacts on WTP. This type of analysis allows us to better understand how WTP might vary across the U.S. population.

In Table 8.5 we present the income elasticities of WTP.[10]

Table 8.5. Income elasticity of WTP

Program	Elasticity	Standard error	95% confidence interval	
Protection and restoration of degraded MHI ecosystems	0.22	0.11	0.01	0.43
Full program	0.17	0.08	0.01	0.34

The elasticity of WTP with respect to income for the ecosystem protection and restoration is 0.22, which means that a 1% (or 10%) increase in average income (which, from Table 8.2, is $64,196 for the sample) would result in a 0.22% (2.2%) increase in WTP for that program. The elasticity of WTP for the combined program is 0.17. Both elasticity estimates are statistically significant at the 95% level. An elasticity was not estimated for restoration after localized injuries because income was not statistically significant in predicting WTP for that program.

Table 8.6 presents the marginal effects of the model variables on WTP.[11] The ecosystem protection and restoration has a "base" value of $122.48. Each level of educational attainment increases WTP, on average, by $24.63. Being married and owning a home decreases WTP, on average, by $89.38. Being an environmentalist and/or a very strong environmentalist increases WTP, on average, by $345.88 and $220.31, respectively. WTP is also increased, on average, by $3.37 for each time an individual took a trip to a coral reef. From Table 8.2, the number of times respondents visited coral reefs ranged from zero to 100, so this variable can increase WTP by as much as $337, on average, for individuals who have visited coral reefs as often as 100 times.

10. Equation E.12 in Appendix E presents an expression for the income elasticity of WTP.

11. Equation E.13 presents an expression for the marginal effects of discrete variables, such as "strong environmentalist" on WTP.

Table 8.6. Marginal effects of variables on WTP

Variables	Coefficient	Standard error	z	P > |z|	95% confidence interval	
Fish	122.48	34.95	3.50	0.00	53.98	190.98
Education X Fish	24.63	10.17	2.42	0.02	4.69	44.56
Married_own X Fish	–89.38	33.07	–2.70	0.01	–154.18	–24.57
Strong environmentalist X Fish	345.88	76.66	4.51	0.00	195.64	496.13
Very strong environmentalist X Fish	220.31	100.15	2.20	0.03	24.02	416.59
Def_visit X Fish	166.47	56.13	2.97	0.00	56.46	276.48
Times X Fish	3.37	1.33	2.54	0.01	0.77	5.97
Ship	35.41	30.95	1.14	0.25	–25.26	96.07
Education X Ship	–10.13	7.94	–1.27	0.20	–25.70	5.44
Married_own X Ship	–83.81	32.38	–2.59	0.01	–147.27	–20.34
Strong environmentalist X Ship	256.38	59.95	4.28	0.00	138.88	373.88
Very strong environmentalist X Ship	147.32	79.68	1.85	0.06	–8.85	303.50
Def_visit X Ship	166.49	57.47	2.90	0.00	53.84	279.14
Times X Ship	3.14	1.23	2.55	0.01	0.73	5.55

WTP for the restoration after a localized injury is increased significantly by being a strong and/or very strong environmentalist ($256.38 and $147.32, respectively), definitely planning to visit Hawaii in the next 10 years ($166.47), and the number of times an individual has been to a coral reef ($3.14 per time). WTP is significantly decreased, on average, by being married and owning a home (– $83.81).

8.4 Aggregating Annual Household WTP to the U.S. Population

The estimated mean household WTP for ecosystem protection and restoration is $224.81; mean household WTP for restoration after localized injuries is $62.82; and mean household WTP to achieve both goals is $287.62. The 2010 Census estimates that there were 116,716,292 households in the United States in 2010, the latest year estimates were available.[12] Using the mean household WTP estimates and the number of households in the United States, Table 8.7 presents the annual U.S. WTP for the three alternatives to the status quo.

12. This figure is based on the most recent estimates available from the 2010 Census.

Table 8.7. Estimated annual U.S. WTP

Program	Estimated WTP	95% confidence interval	
Protection and restoration of degraded MHI ecosystems	$26,238,989,605	$18,875,358,742	$33,601,453,304
Restoration after localized injuries	$7,332,117,463	$2,361,170,587	$12,301,897,177
Achieving both goals	$33,569,939,905	$22,579,933,850	$44,559,945,960

8.5 Validity Assessment

How credible are these results? In more technical terms, this question comes under the general heading of "validity assessment." WTP is very much like other concepts used in the social and behavioral sciences, such as human intelligence, competence in mathematics, creativity, and racial prejudice. In all such cases, real-world evidence has to be mustered to measure scientific constructs that cannot be observed directly because they exist in people's minds (Bishop, 2003). Scientists' inability to directly observe what they are trying to measure makes validity a pervasive issue throughout the social and behavioral sciences.

Validity assessments begin by considering the validity of the methods used. In essence, the question at this level is whether or not the methods used in a particular application are capable of producing valid estimates. It would make no sense to ask whether results from a specific application are valid if the overall methods used were deeply flawed. On the other hand, if the methods applied have an acceptable level of validity, then the next step in validity assessment is to ask whether those methods were correctly applied in the study in question.

What is known about the overall validity of methods used in our study? As explained in Chapter 2, the methods used here are a hybrid between conventional CV and attribute-based choice questions. Today, we are fortunate to have a very large base of scientific literature to draw on in considering the validity of CV. Since 1963, more than 6,000 papers and reports on CV have been published in the United States and many other countries, many of them in the peer-reviewed literature (Carson, Forthcoming). These studies provide a wealth of experience in applying the method and a large body of research on its validity. The result of this research is wide international acceptance of CV. In the United States, federal agencies such as OMB (2003) and U.S. EPA (2000) have approved the use of CV and developed guidelines on implementing it for policy analyses of environmental and natural resources issues. McCollum (2003) summarizes many instances where CV studies have influenced federal and state policies and regulations. See also Morgenstern (1997) and Bishop and Welsh (1999). A national panel of experts, NOAA's Blue Ribbon Panel on Contingent Valuation (NOAA, 1993), determined that if conducted properly, CV studies can provide valid results for natural resource damage assessments. Rules for damage assessment promulgated by the U.S. Department of Commerce (1996) and the U.S. Department of the Interior (1994) have explicitly authorized the use of CV in estimating damages from release of oil and chemicals into the environment.

This is not meant to imply that CV is free of controversy. An extended and, by and large, healthy scientific debate about the validity of the method continues. One branch of this literature dealing with so-called hypothetical bias deserves special mention since most work there is relatively recent and has been fairly influential. Studies on hypothetical bias have involved comparisons of hypothetical payments and actual payments, very often in laboratory experiments. List and Gallet (2001) and List and Shogren (2002) cite more than two dozen studies that compared hypothetical and real payments conducted before the year 2000, and Little and Berrens (2004) add to the list. More studies have been done since then (see, for example, Champ and Bishop, 2006; Johnston, 2006; Vossler and McKee, 2006; Christie, 2007; and Guzman and Kolstad, 2007). In most cases, average hypothetical WTP turned out to be larger than average values based on actual payments. List et al. (2004, p. 742) provide a succinct definition: “hypothetical bias is the difference between hypothetical and actual statements of value.”

The studies showing hypothetical bias have had one important feature in common. For respondents in their hypothetical treatments, survey designers have stressed that the valuation exercise was purely hypothetical. When researchers do that, the outcome has become predictable: if actual payments are taken as the standard for comparison, respondents to hypothetical questions will very often overvalue whatever is being offered.

Several remedies have been suggested for addressing hypothetical bias. To us, the most promising one involves making the valuation exercise “consequential.” Going back at least to Hoehn and Randall (1987) and Mitchell and Carson (1989), researchers on CV have stressed that the more realistic the valuation exercise is, the more likely are the results to be valid. If stressing that the exercise is hypothetical causes overvaluation, then the cure would seem to lie in encouraging respondents to believe that their expressions of WTP will affect whether or not the good they are valuing will be provided and how much they will actually pay. A growing body of literature has found that when CV exercises are consequential, hypothetical bias is eliminated, or at least greatly reduced. See Mitchell and Carson (1989), Champ and Brown (1997), Cummings and Taylor (1998), Vossler and Kerkvliet (2003), Vossler et al. (2003), Johnston (2006), Landry and List (2007), and Carson et al. (2008). Though it did not involve comparisons with actual payments, the recent paper by Herriges et al. (2010) also supports the proposition that making CV exercises consequential enhances validity.

Our study addressed the possibility of hypothetical bias by striving to make the valuation exercise consequential. After the programs were reviewed and just before the first choice question, the survey states:

> Each of these alternatives to the Current Program would cost your household additional federal taxes each year as shown in the bottom of the table.
>
> Remember, if you spend money for one of the programs that does more, that money won't be available for you to buy other things. If you do not want to do more and spend more to protect coral reefs in the Main Hawaiian Islands, you should check the Current Program as your most preferred program.

We stressed the same message when summarizing the cost attribute in each of the choice tables with the following words:

> Added federal taxes paid by your household each year.

Nothing was said anywhere in the survey that could be interpreted as implying the programs or taxes were hypothetical.

Less is known about the validity of values inferred from stated choice and ranking questions. This is partly because the attribute-based approach is relatively new and partly because tests of validity are probably harder to conduct for attribute-based exercises compared to simpler CV exercises. However, ABMs are close relatives of CV. In our hybrid approach, the stated choice format was used partly as a way to summarize the information that was presented earlier in the survey. In addition, we sought to capitalize on what many researchers consider a strong point of this sort of format, namely, that it encourages respondents to make detailed comparisons of alternatives on an attribute-by-attribute basis. Since we did not endeavor to vary or value individual attributes, as is normally done in full-fledged attribute-based choice studies, issues associated with the validity of marginal valuation of attributes did not arise. This aligns validity assessment of our study more closely with the CV literature than would be true had we conducted a full attribute-based study.

In sum, the validity of CV is a topic of continuing research and discussion, as is true of any evolving scientific tool. However, progress so far has led to its wide acceptance. Although our approach changed how the information was presented compared to a conventional CV exercise, the link between our study and the large CV literature should not matter much to the validity of the hybrid approach.

Having considered the validity of CV as a method, we turn next to the second part of the validity assessment, consideration of whether results of our application are valid. The quality and reliability of WTP estimates are functions of both the quality of the underlying survey and the quality of the econometric analysis (Smith, 2007). To enhance the validity of the work, we employed:

} A rigorous review process, including consultation with scientists to develop scientifically valid policy scenarios, and external peer reviews of the draft final report

} Extensive focus groups, one-on-one interviews, and pretests to develop comprehensible language and to inform the final bid design (see Chapter 3)

} Careful construction of the survey to ensure consequentiality and scenario acceptance (see Chapter 4)

} State-of-the-art sampling techniques to develop appropriate probability weights (see Chapter 5 and Appendix C)

} Construct validity analysis (Chapter 7) to test whether respondents' choices comport with expectations

} State-of-the-art econometric modeling techniques (Appendix E).

To some, a value of close to $300 per U.S. household per year for both programs may seem implausibly large. This is not an easy issue to address. After all, if we knew what reef restoration is worth, we would not have needed to do the study.

One way to consider questions of this kind is to see how our value estimates compare with values found in other nonmarket, ecosystem valuation studies. To do a complete review of all such studies would be a daunting task, requiring consideration of hundreds or even thousands of studies and careful weighing of their comparability to what we found. This would take us far beyond the scope of what was done here. However, even a brief review of the literature indicates there are many precedents in the literature for values per household that are comparable to ours. If we think in terms of orders of magnitude, many studies have value estimates in the hundreds of dollars per household per year.

Of greatest relevance would be total value studies involving the U.S. population. It turns out that such studies are rare, but there are some. To begin with a particularly stark example, Lee and Cameron's (2008) estimates of the mean WTP for an aggressive policy of climate change mitigation range from $151 to $353 per U.S. household *per month*, depending on how the money would be collected and how the costs of mitigation would be shared internationally. For comparison, Barrens et al. (2004) estimated several alternative values to U.S. residents of approval of the Kyoto Protocol under alternative assumptions. Their most conservative estimate is slightly less than $200 per U.S. household per year, but other values are much higher. For example, if all respondents are assumed to have positive values, the estimate goes up to slightly more than $800. Depending on assumptions and which of their subsamples is considered, their estimates run as high as $1,500 per household per year.

Studies with a more regional focus have also found values in the hundreds of dollars. Banzhaf et al. (2006) estimated the per household total economic value to New York state residents of ecological improvements in the Adirondack Park from reduced acid rain to be between \$48 and \$154 annually depending on assumptions, including the discount rate and whether their base case (improvements in 600 lakes plus other ecological impacts) or scope case (improvements in 900 lakes plus more ecological improvements) was considered. They also cited a 1992 unpublished paper by Haefele et al. (1992) that estimated the total economic value to those living within a 500-mile radius of Asheville, NC, of protecting high-elevation forests in the Southern Appalachian Mountains from acid rain damage. That study found average annual WTP per household of \$134.

Other studies that have addressed ecosystem values include Stevens et al. (2000), which valued ecosystem management ("defined as ecologically based, sustainable management that blends environmental, social, and economic values" (Stevens et al. 2000) using both CV and conjoint analysis. Subjects were private nonindustrial forest owners in Massachusetts. Values ranged from \$86 to \$285 per year, depending on the valuation approach taken and modeling assumptions. Loomis et al. (2000) surveyed area residents along the South Platte River in Colorado and asked them about their values for restoring the river's ecosystem through conservation easements. The average value was \$252 per household per year. Garber-Yonts et al. (2004) studied the value to Oregon residents of four different biodiversity programs in that state's Coast Range. Three of the four programs had estimated per household annual values that exceeded \$100 per year: increasing areas devoted old growth forests had an average value of \$380, an endangered species habitat program had an average value of \$250 per year, and increasing protected salmon habitat had an average value of \$144.

Nunes et al. (2001) surveyed 61 studies done between 1983 and 1999 that valued biodiversity using a variety of methods. Most of these studies were done in the United States. Many CV-based values exceeded \$100 per year. Furthermore, the authors stressed that "most studies lack a uniform, clear perspective on biodiversity as a distinct concept from biological resources. In fact, the empirical literature fails to apply economic valuation to the entire range of biodiversity benefits. Therefore, available economic valuation estimates should generally be regarded as providing a very incomplete perspective on, and at best lower bounds, to the unknown value of biodiversity changes" (Nunes et al. 2001, p. 203).

Some studies from Australia have found similar values for environmental programs (Oxford Economics, 2009). For example, Imber et al. (1991) considered WTP to avoid the damages to Kakadu National Park from mining. Converted to 2009 AUD,[13] the resulting annual per household estimates ranged from A\$86 to A\$210 (Oxford Economics, 2009, p. 50) depending on modeling assumptions. Jakobsson and Dragun (2001) investigated the value to Victoria residents

13. The exchange rate between Australian and U.S. dollars is currently very close to unity.

of preserving the endangered species of that province. In 2009 AUD, the average annual per household value was estimated to be A$164 (Oxford Economics, 2009, p. 50).

Two studies that consider the values for Australia's Great Barrier Reef have come to light. Rolfe and Windle (2010) examined the potential benefits (and costs) of improvements in ecosystem health of the Great Barrier Reef from reduced pollution, mostly from agriculture. They surveyed people from the watershed and from three Australian cities outside the watershed. Stated in terms of the marginal value of a 1% increase in the area of the reef in good ecological health, estimated values ranged from approximately 2010 A$20 to A$46 per household per year. They valued improvements in reef health of up to 9%, which clearly implies values in the hundreds of dollars per year for some of their policy scenarios. At the extreme, households within the watershed were estimated to have an annual value of more than A$400. Oxford Economics (2009, p. 49) drew on other studies to estimate that protection of the Great Barrier Reef was worth slightly less that 2009 A$60 per Australian household per year, but considered this estimate to be quite conservative for a number of reasons. Sensitivity testing indicated a "higher end" value of 2009 A$115 per household per year (Oxford Economics, 2009, p. 67).

Our purpose is not to suggest that CV studies always find value estimates in the hundreds of dollars per household per year. Many studies have estimated smaller values. But we would suggest that the mere fact that we found values for MHI reef restoration in the hundreds of dollars per year is not grounds for doubting the validity of our results. There are many studies that have estimated similar values.

One other concern sometimes arises when considering the magnitude of values from CV studies. Some may find aggregate values like those reported earlier in this chapter implausible compared to private goods. Could substantial protection and restoration of MHI coral reef ecosystems really be worth more than $26 billion per year? After all, given that there are 300,000 acres of reefs, this aggregate value averages out to more than $86,000 per acre. The temptation at this point is to begin to make comparisons with the economic benefits per acre from terrestrial, privately owned real estate. On closer inspection, however, this line of reasoning is not very helpful. Modern economics draws a sharp distinction between private and public goods. When private goods are produced – as happens on private land – the benefits from such lands are "excludable." For example, if one landowner produces pineapples on an acre of land on Oahu, only that landowner can profit from production. Public goods – passive use values from coral reef ecosystems – are non-excludable. One person's enjoyment of those benefits does not diminish the benefits that others can enjoy simultaneously. In our case, many of the benefits of coral reef restoration and protection are non-excludable and non-rival. That is, if degraded coral reefs are restored and protected, no one can be barred from the passive use values this would generate. And, one person's enjoyment of the passive use benefits does not interfere with another person's enjoyment. For these reasons, the economic benefits from protection and restoration can have much larger values per acre than would be true for private goods. Though this distinction is normally readily accepted in the classroom, it is often forgotten in the real world.

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