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Valuing Changes in the Quality of Coral Reef Ecosystems: A Stated Preference Study of SCUBA Diving in the Bonaire National Marine Park

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Abstract We estimated the economic value of changes in the quality of a coral reef ecosystem to SCUBA divers in the Caribbean using a stated preference mail survey. Our sampling frame was all divers with U.S. home addresses who purchased a tag required for diving in the Bonaire National Marine Park in 2001. Divers were asked how they might have altered their trip choice had the quality of the coral reef system been different from what they experienced. From these responses we inferred the value of three different levels of quality defined by visibility, species diversity, and percent coral cover. We used random utility theory and mixed logit to analyze the choice questions. Our sample size was 211, and our survey response rate was 75%. For modest changes in quality we estimated per person annual losses at \$45. For larger losses the value was \$192.

Keywords Coral reef · Marine protected area · Non-market valuation

1 Introduction

Coral reefs are widely regarded for their biological diversity and high ecological productivity. They support immense fisheries, offer recreational and research opportunities, provide coastal protection, and often serve to maintain the cultural traditions of millions of people (Allison et al. 1998; Moberg and Folke 1999; Spurgeon 1992). The decline of coral reef ecosystems throughout the world is widely recognized and well documented. In 2000, the Global Coral Reef Monitoring Network indicated that 27% of the world's reefs had been degraded

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beyond recovery and projected that 48% of the world's coral reefs may be lost by 2030 (Wilkinson 2000).

The purpose of this article is to estimate the potential economic loss to SCUBA divers associated with a hypothetical decline in the quality of the coral reef ecosystem in Bonaire National Marine Park. Bonaire is an island located in the Caribbean and is part of the Netherlands Antilles. The marine park in Bonaire is one of the finest diving areas in the world. The declines in quality we consider, while hypothetical, were designed to mimic the types of degradation that can occur in the absence of protection and are similar to those experienced in other diving areas. Our intention is to provide a set of estimates that may be useful in damage assessment and benefit-cost analyses of measures designed to protect coral reef ecosystems such as marine protected areas (MPAs), controls on land-based pollution, regulations on fishing activities near coral reefs, and so forth.

Our analysis is a stated preference (sp) study of 211 randomly drawn SCUBA divers who visited Bonaire in 2001 and reported U.S. home addresses. The divers were questioned about how they might have altered their trip choice had the quality of the coral reef system been different from what they actually experienced. From these responses we inferred the value of three different levels of quality defined by visibility, species diversity, and percent coral cover. The foundations for stated preference analysis in non-market valuation are presented in a number of good articles and books (egs. Adamowicz et al. 1999; Holmes and Adamowicz 2003; Louviere et al. 2000). Our survey design also drew heavily on Dillman (2007) and Champ (2003).

The following section, Section 2, is a brief review of the literature on valuing coral reefs and SCUBA diving. Section 3 is a brief description of Bonaire and its marine park. Section 4 lays out our study design and discusses the survey. Section 5 presents some descriptive statistics from the data set. Section 6 is our model. Section 7 is a presentation of results. And, Section 8 is our conclusion.

2 Literature on Coral Reef/Marine Protected Area Valuation in SCUBA Diving

This section presents a brief discussion of the current literature on valuing access and quality change in SCUBA diving at coral reef locations. Table 1 is a summary of selected studies. In 1991, prior to the implementation of the Bonaire Marine Park's SCUBA diving fee, Dixon conducted a survey of 79 divers to elicit reactions to the proposed fee (Dixon et al. 1993, 2000). He used an in-person survey and a convenience sample to test the feasibility of a fee for raising revenue. Using a dichotomous choice question with a $10 dive tag price followed by a payment card question with $20, $30, $50, and $100 options, Dixon et al. found that average annual willingnes to pay (WTP) for access was $27.40 (1991US$). Pendleton (1995) also presents an informative discussion of coral reef values and an application using Dixon's analysis.

A similar study was conducted at the Tubbataha Reef National Marine Park in the Philippines by Tongson and Dygico (2004). Because the reef is located well offshore, access is limited to divers on dive charter vessels. The authors conducted in-person interviews with a convenience sample of divers on several charter vessels and used a dichotomous choice elicitation question with fixed fees ranging from $25 to $75 (1999US$) per trip. The choice scenario and payment vehicle were not reported. Mean willingness to pay (WTP) for the 239 valid responses was $41.11 (1999US$) per trip, with the average trip including three days of SCUBA diving.

Table 1 Selected studies valuing access and quality change for diving at coral reef sites

Author(s)	Resource	Year of study	Value per diver in 'year of study dollars'
Dixon et al. (1993)	Bonaire Marine Park	1991	$27.40 mean annual WTP for access to scuba dive
Tongson and Dygico (2004)	Philippines Marine Park	1999	$41.11 mean WTP per live-a-board boat trip (avg. 3 dive days) for access to scuba dive
Spash (2000)	Jamaica Marine Park	Not reported	$25.89 mean annual donation for five years to trust fund to operate marine park to improve environmental quality from 60% to 100% of its potential
Spash (2000)	Hypothetical Curaçao Marine Park	Not reported	$25.21 mean annual donation for 5 years to trust fund to operate marine park to improve environmental quality from 35% to 75% of its potential
Lindsey and Holmes (2002)	Proposed Vietnam Marine Park	1999	$.51–1.48 mean WTP for daily access for any activity
Mathieu et al. (2003)	Six Seychelles Marine Parks	1998	$5.20–14.40 mean WTP for daily access for any activity (range is for different areas). $19.80 mean WTP for daily access to scuba dive.
Arin and Kramer (2002)	Hypothetical Philippines Marine Parks	1997	$3.40–5.50 mean WTP for daily access to scuba dive
Wielgus et al. (2003)	Eilat Coral Beach Nature Reserve in Israel	2001–2	$1–3 mean WTP per dive for moderate improvements in quality (many scenarios were considered)

The largest SCUBA diving valuation study to date was undertaken by Spash (2000) in Montego Bay, Jamaica and Curacao, Netherlands Antilles. In-person interviews of locals and tourists were conducted using open-ended elicitation questions. A total of 1,058 surveys were completed on Jamaica and another 1,152 on Curacao. In Jamaica, respondents were asked for an annual contribution for five years to a trust fund for the existing Montego Bay Marine Park. They were informed that the environment was currently at 75% of its quality potential. With their contributions, managers could fund initiatives to raise quality to 100%, while a decline to 60% of quality potential would occur without the trust fund. Mean WTP was $25.89 per year, and there was no statistically significant difference between locals' and tourists' WTP.

The policy scenario for the Curacao survey was similar, except that the MPA was hypothetical; Curacao had no MPA at the time of the study. The current state of the reef environment was described as being at 50% of its quality potential. Revenue from the trust fund would permit an increase to 75% of potential, while quality would decrease to 35% if nothing additional were done. Mean WTP was estimated to be $25.21 annually, again with no significant differences between locals and tourists. The respondents indicating intent to SCUBA dive or snorkel ranged from 6% of the local Jamaican's interviewed to 21% of the Curacao tourists, however a SCUBA diving sub-sample WTP is not reported.

Lindsey and Holmes (2002) estimated WTP for entrance to a proposed MPA in Nha Trang Bay, Vietnam. An in-person survey was administered by nine interviewers at four locations on three consecutive Sundays in June 1999. The non-random convenience sample yielded 571 completed surveys. The payment vehicle, a proposed entrance fee, allowed respondents to visit an aquarium located on an island surrounded by the MPA. Renting personal watercraft, fishing, swimming, snorkeling, and SCUBA diving were secondary activities permitted by visitors. The survey used a dichotomous choice question to screen for respondents with any positive WTP, and then presented a payment card with bids ranging from $.07 to $5.00 (1999US$). Vietnamese citizens comprised 89% of the respondents, and had a mean WTP of $.51 (1999US$) per day. Foreign tourists reported a mean WTP of $1.48 (1999US$). There is no indication of the number of respondents that intended to SCUBA dive or snorkel while in the MPA.

In June 1998, Mathieu et al. (2003) interviewed 300 tourists in the Seychelles. At the time of the study, there were six designated MPAs in the Seychelles, though one of these was a non-functioning park. The authors asked both MPA visitors and general tourists if they thought, "it is acceptable to be asked to pay a fee to enter a Marine Park", and followed with a payment card with bids ranging from $0 to $40 (1998US$). It appears that the entrance fee would be assessed daily. After eliminating 30 of the 300 responses as incomplete surveys, protest bids, or outliers, simple multiple linear regression and binary logistic models were used to investigate the determinants of WTP. The total sample mean WTP was estimated to be $12.20 (1998US$). Reported WTP was highly dependent on which, if any, of the six MPAs the respondent had visited. Mean WTP for the five active marine parks varied from $5.20 to $14.40. SCUBA divers had an average WTP of $19.80, significantly above the whole sample mean.

Arin and Kramer (2002) used a non-random, convenience sample to assess visitors' WTP for access to three hypothetical MPAs in the Philippines during the summer of 1997. The survey was administered to those planning to SCUBA dive or snorkel, and requested a per-day value for a two-tank, one-day boat trip. Their survey employed a payment card format question with $0, $1, $3, $5, and $10 options (1997US$). With sample sizes ranging from 37 to 46 divers per site, the authors estimate that mean daily WTP for access ranged from $3.40 to $5.50 (1998US$).

In an application most similar to ours Wielgus et al. (2003) estimate the economic value of coral reef damage at Eilat Coral Beach Nature Reserve in Israel. Using a stated preference choice model and videos to convey quality changes, Wielgus et al. estimate values for changes in a biological index as well as for changes in quality of water, coral cover, and diversity of species. Surveys were conducted at dive centers. Moderate changes in quality were valued in the range of $1 to $3 per dive.

Fig. 1 Bonaire Island in the Caribbean

3 Bonaire

Bonaire is located in the southern Caribbean approximately 80 km north of Venezuela (see Fig. 1). It is one of five islands that comprise the Netherlands Antilles. It is endowed with extensive fringing reefs on the leeward side of the island, and is one of the finest areas for snorkeling and SCUBA diving in the Caribbean. It has a population of 15,000 and is approximately 17 miles long. Tourism, focused on SCUBA diving, is the island's major economic sector.

The reefs of Bonaire are among the healthiest in the Caribbean with high levels of live coral cover and fish stocks (Wilkinson 2000). The pristine nature of the system is due in part to the conservation and management efforts of the Bonaire National Marine Park (BNMP). Established in 1979, the marine park surrounds the island from the high tide mark to a depth of 60 m. It is currently operated by the non-profit, non-governmental organization STINAPA Bonaire. The BNMP has jurisdiction over most activities in the 2,700-ha marine park.

In 1992, the park became the first fully self-funded marine protected area in the Caribbean by implementing a $10 user fee in the form of an annual SCUBA diving tag (personal communication with Elsmarie Beukenboom, STINAPA president, January 2002). All divers must display a current tag while diving in Bonaire, which permits unlimited dives anywhere in the BNMP for the calendar year. The fee is the primary source of revenue for the marine park. An informative description of the marine park's early history can be found in Dixon et al. (1993).

4 Study Design and Survey

As noted above, divers are required by law to display a tag while diving in the BNMP. The tag costs $10 and is valid for one year. When the tag is purchased the diver reports his or her

Table 2 Characteristics of Bonaire and Other Islands

Attribute	Level of environmental quality			
	Poor	Medium	Good	Bonaire
Coral cover	5%	20%	30%	35%
Species diversity	50 fish 10 corals	125 fish 25 corals	225 fish 40 corals	300 fish 45 corals
Visibility	20 feet	50 feet	75 feet	100 feet

address to the BNMP. This list of addresses forms an annual database from which we drew a random sample to survey. We confined our analysis to persons with US addresses—about 90% of the population of divers. Our sample was drawn in February 2002 for diving in 2001.

We pre-tested our survey on-site with 12 divers in January 2002. The pretest was self-administered and timed. It was essentially the same survey we hoped to mail. Respondents were asked how the survey could be made clearer, more neutral, easier, more interesting, and so forth. We also evaluated the results for consistency and plausibility. Only modest changes were made based on the pretest. In February, we mailed a revised version of the survey to 300 divers who had purchased a tag. (A total of 28,000 divers purchased tags in 2001.). We sent a reminder post card one week later, and a second survey after two weeks. Of the 300 surveys, 211 were completed and returned, 20 were returned by the post office as invalid addresses, and 69 were not returned. This is a 75% response rate of divers successfully contacted (211/280) and a 70% response rate of all divers in the initial draw (211/300).

The survey was in five parts. First, we asked some introductory questions. When did you visit Bonaire? Where did you stay while there? How long did you stay? And, so forth. Second, we provided the respondent with a list of dive sites and asked them to indicate where and how many times they had gone diving at each site. Third, we asked some questions about trip expenses. Fourth, we asked three stated preference (sp) questions that posed each person with a hypothetical choice of dive sites. Fifth, we asked a series of demographic questions—gender, income, and so forth. We estimate that it took five to ten minutes to complete the survey.

In the sp questions we asked each respondent to think about his or her recent trip to BNMP and to consider a hypothetical alternative site for diving. The alternative site differed from BNMP in three ways: percent coral cover, diversity of fish species underwater and visibility. A sample question along with the preamble is shown in Fig. 2. Each person was asked three versions of the stated preference question. A ‘no-trip’ option was offered in all cases. The alternative dive site in each case was of poorer quality than Bonaire. Table 2 shows the site quality at Bonaire and the quality of the three hypothetical islands. Respondents were told that the cost of the trip to the alternative site was the same as the cost of the trip to Bonaire and that, other than the three characteristics in the stated preference questions and the cost of the dive tag, the sites were the same. In each case the alternative island had no dive tag, while the dive tag price at Bonaire was varied from \$25 to \$500 randomly across respondents and across the three sp questions. Dive tag prices for Bonaire of \$50, \$100, \$150, \$200, and \$250 were each drawn 150 times (3 questions $\times$ 50 per question) and \$25 and \$500 were each drawn 75 times (3 questions $\times$ 25 per question). Again, the current dive tag price is \$10.

The simplicity of our design was intentional. The characteristics included three simple attributes widely considered to be of importance to divers and easily understood. Our on-site pretest indicated that the survey was easy to understand and that the characteristics made sense to people. The park administrator and a number of people in the pretest, without prompting, identified diving sites that they thought had quality corresponding to our *poor, medium*,

Now we are going to ask you three hypothetical questions. Each has the same format.

Suppose that prior to your most recent trip to Bonaire you were offered two dive vacations: one to Bonaire and another to a similar Caribbean Island. Assume that the cost of each vacation, excluding the dive tag, was the same as the cost of your recent Bonaire trip.

Suppose that the two destinations varied <u>only</u> by dive tag price, average coral cover, diversity of fish and coral species, and average visibility.

If the characteristics of each island varied as shown below …

Site Attribute	Options		
	Bonaire	Other Island	Neither
Dive Tag Price	$100	$0	Stay Home Or Take Some Other Dive or Non-Dive Vacation
Coral Cover	35%	5%	
Species Diversity	300 fish 45 corals	50 fish 10 corals	
Visibility	100 ft	20 ft	

….. which option would you choose? *(check <u>one</u>)*

- ▯ Bonaire
- ▯ Other Island
- ▯ Neither

Fig. 2 Stated preference question

and *good* scenarios in Table 2. We took this as evidence that the hypothetical alternative sites made sense to divers. The divers were told the characteristics corresponding to the Bonaire option were "based on actual estimates of the characteristics for the BNMP". We are confident that most everyone recognized this as being among the highest quality dive sites in the world. The *good-quality* option still offered the divers an exceptional diving experience, albeit of somewhat lower quality than BNMP. The *medium-quality* option is typical of many locations throughout the Caribbean and would be recognized as an average diving experience (Wilkinson 2000). The *poor-quality* option offered quality that we expected few would find attractive in a Caribbean trip.

We wanted to be sure that our range of sites and accompanying prices were such that Bonaire would likely be rejected in some cases and accepted in others. The pretest indicated a range of quality and price options that might accomplish this outcome. People in the pretest always accepted Bonaire at $25 versus the other sites, always rejected Bonaire at $250 and greater, and gave varied responses over the intermediate values. Finally, unlike most

Table 3 Sample characteristics

Mean individual characteristics	
Male divers	57.0%
Age (years)	44.6
Number of years diving	10.3
Number of lifetime dives	114
Household income	$101,800
Number of lifetime trips to Bonaire	2.08
Mean trip characteristics	
Per-person trip cost	$1,736
Length of trip (nights)	7.87
Primary purpose of trip was diving	92.3%
Number of dives on last trip to Bonaire	13.6

sp surveys we elected to offer all respondents the same three alternatives across the three questions. *This implies that our three attributes are perfectly collinear and that the attribute coefficients are not identified in our model.* The nature of coral reef degradation is such that it happens in a collinear way. By and large, when reefs decline in quality, coral cover, species count, and visibility all decline. No single attribute declines while the others stay stable. Most, perhaps all, practical policy questions involving benefit-cost analyses, damage assessments, climate change impacts, and so forth are likely to ask about collinear losses. While knowing the value of the decline in individual attributes may be of some interest we saw no practical reason to consider it. At the same time, it simplified the analysis. There was no need to consider optimal designs over the attributes or optimal assignment of questions across respondents. Our design implied that instead of valuing individual attributes we value declines in the overall quality of the coral reef system. The design allows us to value declines in quality at BNMP from current levels to *good-quality*, to *medium-quality*, and to *poor-quality*. Again, these are realistic events that might occur at BNMP or other locations.

5 Data and Descriptive Statistics

Table 3 shows the characteristics of the respondents in our sample. They are experienced divers. On average, they have been diving over 10 years and have taken over 100 dives. They are from a high economic stratum with an average income in 2001 of about $102,000. On average, their trip to Bonaire cost over $1,700 per person and the stay was about one week. Nearly everyone (92%) was visiting Bonaire for the primary purpose of diving.

Figure 3 shows the results for the three sp questions. The top frame pertains to the responses given to the sp question when the other Island option was *good-quality* (column 3 in Table 2). The middle frame pertains to the question using *medium-quality* (column 2 in Table 2) and the bottom frame pertains to *poor-quality* (column 1 in Table 2). Each frame shows the percent of divers selecting each alternative (Bonaire, Other Island, or Neither) at each tag price considered in the analysis. For example, the top frame shows that when the Other Island option was *good-quality* and the tag price at Bonaire was $25 about 90% of the respondents chose Bonaire, 10% chose the Other Island, and 0% chose Neither. When the price was raised to $50 about 70% of the respondents chose Bonaire, 26% chose the Other Island, and 4 % chose Neither. At $100 there was a noticeable swing with about 20% choosing Bonaire, 70%

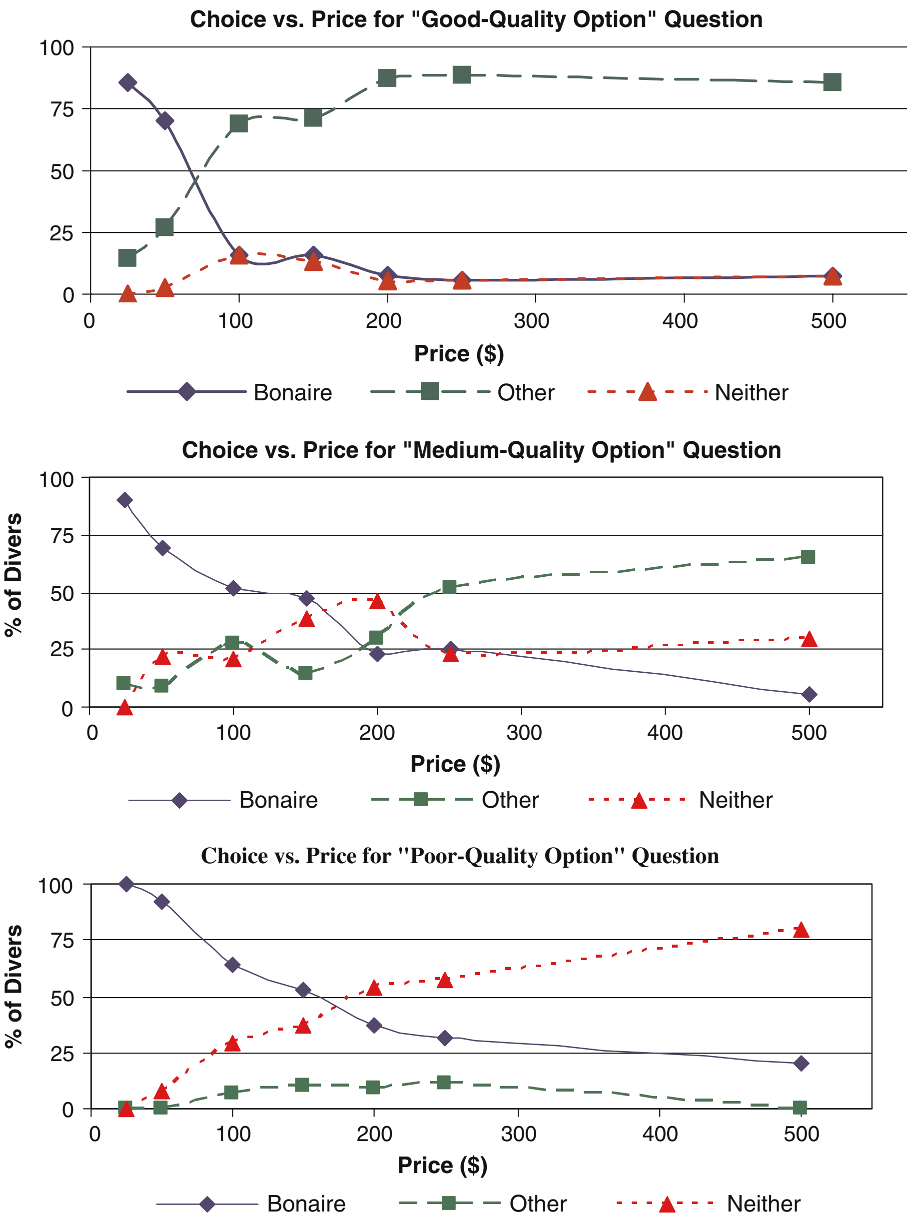

Fig. 3 Stated preference results

choosing the Other Island, and 10% choosing Neither. The split seemed to stabilize at a tag price of $200 and greater with 90% choosing the Other Island, 5% choosing Bonaire, and 5% choosing Neither. These results are understandable. The *good-quality* Other Island option gave the respondents an opportunity to visit an excellent substitute. At a moderately low tag price people shifted to the substitute and few selected Neither.

The middle frame in Fig. 3 pertains to responses for the choices when the Other Island option was *medium-quality*. In this case 90% chose Bonaire at $25, 10% chose the Other Island, and 0% chose Neither. As tag price at Bonaire rose the percent selecting Bonaire fell but not as rapidly as in the top frame with the *good-quality* option. Also, the number of respondents choosing Neither option increased. At $150, 50% of the respondents still selected Bonaire, 40% selected the Other Island, and 10% chose Neither. At $200 the split between the three options is fairly even. And, at $250 the Other Island is preferred over 50% of the time. The Other Island option and Neither track each other fairly closely.

The bottom frame shows the results for the *poor-quality* option where the Other Island offers a poor substitute to Bonaire. In this case, the fraction choosing Bonaire is 100% at a tag price of $25, 65% at $100, 50% at $150, and 30% at $250, and still 25% at $500. The Other Island, as expected, was rarely chosen.

Now, lets turn to our random utility model.

6 Choice Model and Valuation

6.1 Choice Model

Our experiment places respondents in three choice situations. In each situation a person faces three distinct alternatives: Bonaire, Other Island, or Neither.[1] Following random utility theory we assume that each alternative gives an individual some trip utility—U_b for Bonaire, U_o for Other Island, and U_n for Neither. The three utilities take the following form in our model

$$\begin{aligned} U_b &= \beta_0 + \beta_1 \cdot tp + \varepsilon_b \\ U_o^i &= \alpha_o^i + \varepsilon_o^i \quad (i = 1, 2, \text{ or } 3) \\ U_n &= \varepsilon_n \end{aligned} \tag{1}$$

The Other Island option, U_o^i, takes on one of three values for the three different choice questions. β_1 is the coefficient on the dive tag price (tp). Recall that the tag price ranged in value from $25 to $500 and applies only to Bonaire. The parameters $\beta_0, \alpha_o^1, \alpha_o^2,$ and α_o^3 are alternative specific constants. The parameters $\alpha_o^1, \alpha_o^2,$ and α_o^3 correspond to the different levels of quality (1 = *Good*, 2 = *Medium*, and 3 = *Poor*) we consider for the Other Island, and the alternative specific constant on the Neither option is normalized to zero.[2]

As mentioned earlier, the island characteristics (visibility, coral cover, and species diversity) are not included as separate arguments in the model because they are perfectly collinear across the three alternatives as shown in Table 2. Instead, the alternative specific constants infer relative values for the bundle of characteristics at each island. Again, this is realistic—when the coral environment declines the characteristics decline more or less proportionately.

We expect $\beta_1 < 0$ showing a dislike for higher tag prices. Similarly, we expect $\beta_0 > \alpha_o^1 > \alpha_o^2 > \alpha_o^3$—aligning the utility rankings with island quality. There is no prior expectation on the sign of the $\alpha_o^i{}'s$. Since the alternative specific constant on the Neither option is set to 0,

[1] The neither option included stay home, take another dive vacation, or take another non-dive vacation.

[2] We also estimated a few versions of the model using individual characteristics (such as age and experience). One included characteristics in the Neither utility as additional covariates and another interacted characteristics with the alternative specific constants on the Other Island utility. These models consistently showed little or no observed heterogeneity across the sample. We decided not to report these models since the results had negligible impact on the model and we were concerned that some of the arguments (like experience and number of past trips to Bonaire) were endogenous.

a $\alpha_o^i > 0$ indicates a preference ranking above the Neither option and a $\alpha_o^i < 0$ indicates a ranking below the Neither option.

We estimated the model using multinomial (fixed coefficient) and mixed (random coefficient) logit. Following much of the literature and for identification we assume the coefficient on tag price is fixed in the random coefficient model. For more discussion on the price coefficient and identification see Train and Weeks (2005). In our fixed coefficient logit model respondent m's likelihood of making the three choices observed in the survey data is

$$L_m^{FC}(\beta,\alpha) = \prod_{i=1}^{3} \frac{b_{mi} e^{\beta_0+\beta_1 tp_i} + o_{mi} e^{\alpha_o^i} + n_{mi}}{e^{\beta_0+\beta_1 tp_i} + e^{\alpha_o^i} + 1} \tag{2}$$

where $(\beta,\alpha) = (\beta_0, \beta_1, \alpha_o^1, \alpha_o^2, \alpha_o^3)$ and

$b_{mi} = 1$ if person m choose Bonaire on Choice i, and 0 Otherwise
$o_{mi} = 1$ if person m choose Other Island on Choice i, and 0 Otherwise
$n_{mi} = 1$ if person m choose Netiher Island on Choice i, and 0 Otherwise
$i = 1, 2, 3.$

The parameters were estimated using conventional maximum likelihood.

In the random coefficient form, the likelihood of observing the three choices is a multidimensional integral over $(\beta_0, \beta_1, \alpha_o^1, \alpha_o^2, \alpha_o^3)$

$$L_m^{RC_1}(\beta,\alpha) = \int \prod_{i=1}^{3} \frac{b_{mi} e^{\beta_0+\beta_1 tp_i} + o_{mi} e^{\alpha_o^i} + n_{mi}}{e^{\beta_0+\beta_1 tp_i} + e^{\alpha_o^i} + 1} \cdot f(\beta,\alpha) d\beta d\alpha, \tag{3}$$

where $f(\beta,\alpha)$ represents a multivariate normal distribution over $(\beta_0, \alpha_o^1, \alpha_o^2, \alpha_o^3)$ and β_1 is understood to be fixed.[3] This probability is approximated for each person in the sample using the simulated maximum likelihood estimation described in Train (2003, p. 148). We used 500 draws of each random coefficient using a Halton sequence. The results give estimated values of the means and standard deviations of $(\beta_0, \alpha_o^1, \alpha_o^2, \alpha_o^3)$. Random coefficients allows for a more general and realistic pattern of correlation across the error terms in our choice set and introduces unobserved heterogeneity into the model.

We also estimate a version of the model with random coefficients that accounts for the "non-independence in conditional errors" created by working with a sample of divers who have all chosen Bonaire (see Train and Wilson (2007)). This is a form of self-selection that implies a distribution of error terms in our sp experiment that deviates from the assumptions underlying the conventional logit model. Train and Wilson (2007) develop econometrics to account for this non-independence. They show that a standard mixed logit model that accounts for the initial revealed preference choice ('Bonaire' with tag price of 10 being implicitly preferred to 'Neither' by all respondents) along with the sp choices is sufficient to account for the self-selection. Their model also calls for a scaling of the sp parameters "to account for quixotic aspects of the sp task." This gives the following model

$$L_m^{RC_2}(\beta,\alpha) = \int \prod_{i=1}^{3} \frac{b_{mi} e^{\lambda(\beta_0+\beta_1 tp_i)} + o_{mi} e^{\lambda\alpha_o^i} + n_{mi}}{e^{\lambda(\beta_0+\beta_1 tp_i)} + e^{\lambda\alpha_o^i} + 1} \cdot \frac{e^{\beta_0+\beta_1\cdot 10}}{e^{\beta_0+\beta_1\cdot 10}+1} \cdot f(\beta,\alpha) d\beta d\alpha, \tag{4}$$

3 We also considered triangular distributions but found no significant difference in our behavioral model.

where the new term $\frac{e^{\beta_0+\beta_1 \cdot 10}}{e^{\beta_0+\beta_1 \cdot 10}+1}$ is the probability of choosing Bonaire over Neither conditioned on β. The parameter λ scales the sp coefficients.[4]

6.2 Valuation

To value changes in the quality of the coral reef ecosystem in the Bonaire National Marine Park, we simulated our estimated choice model. Each individual's expected utility of a dive vacation is given by $EU = E\{\max(U_b, U_n)\}$. EU is the expected value of the maximum of choosing Bonaire or Neither. The Other Island option is not included in the valuation simulation because it is not a choice in an individual's actual choice set. People will either go to Bonaire or they use their travel funds for another vacation or for other purposes.[5] We express utility in the form of an expected value because the utility is random from our perspective as researchers (see Hanemann (1999)).

In the valuation exercise, we compare each individual's expected utility of a dive vacation when the quality of the Bonaire coral reef system in its current condition with the expected utility of a dive vacation when its condition is deteriorated. We consider three deteriorated states—*good-quality, medium-quality*, and *poor-quality* as designated in the Other Island option but applied to Bonaire. The expected utility of a dive vacation with Bonaire in a deteriorated state is $EU^D = E\{\max(U_b^D, U_n)\}$. U_b^D is the new lower utility on a trip to Bonaire due to the decline in the quality of the coral reef system. With lower utility for a dive at Bonaire due to the quality decrease, the Neither option, giving U_n, has a greater likelihood of being the chosen alternative in $\max(U_b^D, U_n)$. An individual's decline in utility due deterioration of the coral reef system then is $EU^D - EU = E\{\max(U_b^D, U_n)\} - E\{\max(U_b, U_n)\}$. It is this decline (at three different levels) that we seek to monetize using the estimated choice model.

The expected maximum utility of a dive trip in our logit form is $EU = \ln\{\exp(\beta_0 + \beta_1 10) + \exp(0)\} + c$ where c is Euler's constant. This expression is the well-known log-sum used in logit models used in valuation (see Hanemann 1999). The form follows from the extreme value distribution assumed in these models. In our case it is a sum over two alternatives: $(\exp(\beta_0 + \beta_1 \cdot 10))$ for going to Bonaire and $(\exp(0))$ for going elsewhere. Tag price is set equal to 10. The expected utility of a dive trip when Bonaire is degraded has a similar form $EU^{D_i} = \ln\{\exp(\alpha_o^i + \beta_1 \cdot 10) + \exp(0)\} + c$ where the subscript i denotes the level of deterioration considered ($i = 1$ for deterioration to *good-quality*, $i = 2$ for deterioration to *medium-quality*, and $i = 3$ for deterioration to *poor-quality*).

The change in utility for a decline in quality then is $EU^{D_i} - EU$, and the compensating variation in the fixed parameter logit model is

$$cv_i = \left\{\ln\left[\exp(\alpha_o^i + \beta_1 \cdot 10) + 1\right] - \ln\left[\exp(\beta_0 + \beta_1 \cdot 10) + 1\right]\right\} / \beta_1. \tag{5}$$

Dividing by the coefficient on tag price, our marginal utility of income, monetizes the utility change. When the estimated coefficients are random, the compensating variation is also random. For this reason, in our random coefficients cases we report a mean simulated compensating variation

[4] We use Train and Wilson's equation (9) in estimation and, like their model, ours failed to converge over the scale parameter. Unlike theirs ours tended toward a smaller scale. The other parameters in the model remained reasonably stable over the iterations leaving the welfare results rather insensitive to the choice of scale. We report the model using a scale of .1.

[5] In this sense EU is not the expected utility of a dive vacation, it is really the expected utility of a choice occasion and choice need not involve a dive. Still, we like the terminology and will stay with it assuming many will substitute another dive vacation to replace Bonaire. This was clearly the case in our pretest.

$$\overline{cv}_i = \left\{ \sum_{j=1}^{2000} \left\{ \ln\left[\exp(\alpha_o^{ij} + \beta_1 \cdot 10) + 1\right] - \ln\left[\exp(\beta_0^j + \beta_1 \cdot 10) + 1\right] \right\} / \beta_1 \right\} /2000, \quad (6)$$

where j denotes one of 2000 draws from the estimated normal distributions for β_0^j and α_o^{ij} and i denotes the quality decline scenario. Recall that β_1 is fixed.

7 Results

The estimates are shown in Table 4. In all models the alternative specific constants work as expected. The mean coefficient on *Bonaire* is largest followed by *good-quality*, *medium-quality*, and *poor-quality*. The *medium-quality* option is close in ranking to the Neither option, which is normalized to zero. *The poor-quality* option ranks below Neither. These results are consistent with the results in Fig. 3. The coefficient on tag price, *tp*, is negative and significant as expected—also consistent with the story in Fig. 3. On average, individuals dislike higher dive tag prices. None of the estimated standard deviations (labeled 'dispersion' in the table) in random parameter logit models is significant and their sizes relative to the means suggests there is little unobserved heterogeneity. These results are consistent with our finding that there is little observed heterogeneity when individual characteristics are added to the model. In our random coefficients model that accounts for self-selection, we present the model results with the parameter using a scale of .1 (see footnote 4). The most significant changes observed in going from the fixed to random parameters logit model is a large increase in the mean value of the *poor-quality* alternative specific constant. There is a commensurate increase in its estimated standard deviation. The mean is still significantly different from the Bonaire mean but it is no longer statistically significantly different from 0.

The welfare losses for three hypothetical declines in the quality of the coral reef system in Bonaire are show in Table 5. The results show mean per person per trip values over our sample. All values are in 2002 dollars. Few people take more than one trip each year. The results are shown for all three models and are fairly stable across the models. The decline in quality to *good* gives a mean per person loss of about \$45. The decline to *medium-quality* is about \$142 per person and to *poor-quality* is about \$192 per person. Although *poor-quality* conditions are significantly worse than *medium-quality* conditions, the losses incurred when quality declines from *medium* to *poor* are attenuated by divers leaving Bonaire for another destination—notice a smaller incremental loss moving from *medium* to *poor* versus *good* to *medium*. Using a discount rate of .03 and assuming a population of users that is steady around 28,000, the corresponding total asset value of the loss at each level is about \$42 million, \$132 million, and \$179 million. If the number of divers grows at 2% annually, these asset values jump to \$126 million, \$398 million, and \$538 million.

8 Conclusions

We estimated the economic value of changes in the quality of the coral reef ecosystem using a stated preference mail survey of 211 divers drawn randomly from all U.S. divers who visited the Caribbean island of Bonaire in 2001. The sample was drawn from a list of divers who purchased a tag to dive on the island. Since the tag is required to dive and is presently rather cheap (\$10), the sample frame is near the entire population of divers. We excluded non-U.S.

Table 4 Fixed and random parameter logit model

Variable	Parameter	Fixed coefficient model[a]	Random coefficient model[a]	Random coefficient model w/self selection ($\lambda = .1$)[a]
Bonaire (β_0)	Mean	2.34 (11.2)	2.50 (6.70)	2.42 (9.40)
	Dispersion	–	.809 (.920)	.562 (1.29)
Good-quality (α_o^1)	Mean	1.77 (10.3)	1.89 (6.73)	1.83 (9.13)
	Dispersion	–	.005 (.011)	.004 (.009)
Medium-quality (α_o^2)	Mean	.177 (1.03)	.181 (1.03)	.182 (1.04)
	Dispersion	–	.023 (.030)	.016 (.021)
Poor-quality (α_o^3)	Mean	−1.88 (5.92)	−4.13 (1.11)	−4.05 (1.15)
	Dispersion		2.67 (.954)	2.59 (.978)
Tag price (β_1)	Mean	−.0113 (9.26)	−.0123 (5.39)	−.0118 (7.82)
	Dispersion	–	–	–
Log-likelihood		−494.6	−494.1	−494.9
Number of respondents	–	211	211	211
Number of choices[b]	–	607	607	818

[a] t-Statistics testing difference from 0 are shown in parenthesis next to the coefficient estimates

[b] Some respondents did not answer all 3 choice questions, hence the number of choices does not equal 3 times 211. In the self-selection model there are 818 choices—607 sp choices and 211 revealed preference choices of Bonaire over No Trip at a tag price of 10 by each respondent

Table 5 Mean per person annual welfare losses for decline in coral reef quality for three scenarios ($2002)

Scenario: decline in quality to the level[a]	Fixed coefficients model	Random coefficients model	Random coefficients model w/self selection ($\lambda = .1$)
Good	$44.06	$46.78	$45.53
	–	(59.48)	(42.2)
Medium	141.92	144.43	143.33
	–	(58.89)	(41.8)
Poor	194.84	191.09	192.56
	–	(45.33)	(32.92)

[a] See Table 2 for the level of deterioration associated with each scenario

[b] Standard deviations are show in parenthesis beneath the mean values and are generated over the welfare simulation using the estimated random coefficients logit dispersions

divers, approximately 10% of the population. Our response rate was over 75%. The survey was pre-tested on-site.

Respondents were asked three sp questions pertaining to a hypothetical dive vacation. Each question asked respondents to consider an alternative island to Bonaire for their most recent trip along with an opt-out alternative. The dive tag price at Bonaire was used as our payment vehicle. The three different island alternatives had coral reef ecosystems in poorer quality than Bonaire. The ecosystems varied by three characteristics: visibility, percent coral cover, and diversity of species. These general characteristics are of particular interest to divers. The three characteristics were perfectly collinear across the questions by design. When coral reef systems degrade in quality, these attributes decline commensurately. This made our choice experiment realistic and policy relevant. It also implied that values for individual characteristics where not identified. Instead, we reported values for three overall levels of decline in ecosystem quality. The model was estimated using mixed-logit. The results showed a realistic ordering of island alternatives by quality and that tag price had a strong and negative effect on respondents as expected.

Per diver annual values ranged from $45 for the modest declines in quality to about $192 for extreme declines in quality. These translate to asset values for the coral reef system of $50 to $500 million for recreational SCUBA diving—depending on the level of decline, assumed rate of discount, and expected growth in diving. This ignores all other service flows and non-use values from the ecosystem. Given the decline of coral reef ecosystems globally and the interest in investing resources in reversing the trend, these values are apropos.

At the same time care should be taken in transferring these values to other islands or mainland locations. Bonaire is unique—one of the premier diving sites in the world. Its resources and its diving population will differ from other islands and adjustments should be made accordingly. The values also assume that the quality of the ecosystem at all other 'substitute' sites is stable at current levels. If other sites are in decline, as is widely held, the losses reported here could understate losses significantly. For example, using these losses to estimated climate change damage to coral reef systems would miss the simultaneous widespread decline in the resource.

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References

Adamowicz W, Boxall PC, Louviere JL, Swait J, Williams M (1999) State preference methods for valuing environmental amenities. In: Bateman IJ, Willis KG (eds) Valuing environmental preferences. Oxford Press, Oxford University

Allison GW, Lubchenco J, Carr MH (1998) Marine reserves are necessary but not sufficient for marine conservation. Ecol Appl 8(1S):S79–S92

Arin T, Kramer RA (2002) Divers' willingness to pay to visit marine sanctuaries: an exploratory study. Ocean Coast Manage 45:171–183

Champ P (2003) Collecting survey data for non-market valuation. In: Champ P, Boyle K, Brown T (eds) A primer for nonmarket valuation. Kluwer Academic Publishers, London

Dillman DA (2007) Mail and internet surveys. Wiley, New York

Dixon JA, van't Hof T, Scura LF (1993) Meeting ecological and economic goals: marine parks in the Caribbean. Ambio 22(203):117–125

Dixon JA, Scura LF, van't Hof T (2000) An economic and ecological analysis of the Bonaire Marine Park. Cesar HSJ (ed) Collected essays on the economics of coral reefs. Kalmar Sweden, Cordio, 242 pp

Hanemann WM (1999) Welfare analysis with discrete choice models. In: Herriges JA, Kling CA (eds) Valuing recreation and the environment: revealed preference methods in theory and practice

Holmes TP, Adamowicz WL (2003) Attribute-based methods. In: Champ P, Boyle K, Brown T (eds) A primer for nonmarket valuation. Kluwer Academic Publishers, London

Lindsey G, Holmes A (2002) Tourist support for marine protection in Nha Trang, Viet Nam. J Environ Plann Manage 45(4):461–480

Louviere JJ, Hensher D, Swait J (2000) Stated choice methods: analysis and application. Cambridge University Press, Cambridge

Mathieu LF, Langford IH, Kenyon W (2003) Valuing marine parks in a developing county: a case study of the Seychelles. Environ Devel Econ 8:373–390

Moberg F, Folke C (1999) Ecological goods and services of coral reef ecosystems. Ecol Econ 29:215–233

Pendleton LH (1995) Valuing coral reef protection. Ocean Coast Manage 26(2):119–131

Spash CL (2000) Assessing the benefits of improving coral reef biodiversity: the contingent valuation method. Cesar HSJ (ed) Collected essays on the economics of coral reefs. Kalmar, Cordio, 242 pp
Spurgeon JPG (1992) The economic valuation of coral reefs. Mar Pollut Bull 24(11):529–536
Tongson E, Dygico M (2004) User fee system for marine ecotourism: the Tubbataha Reef experience. Coast Manage 32:17–23
Train K (2003) Discrete choice methods with simulation. Cambridge University Press, Cambridge
Train K, Weeks M (2005) Discrete choice models in preference space and willingness to pay space. In: Alberini A, Scarpa R (eds) Applications of simulation methods in environmental resource economics. Springer & Dordrecht, Netherlands
Train K, Wilson W (2007) Estimation on stated-preference experiments constructed from revealed-preference choices. Transport Res B, forthcoming
Wielgus J, Chadwick-Furman N, Zeitouni N, Shechter M (2003) Effects of coral reef attribute damage on recreational welfare. Mar Res Econ 18:225–237
Wilkinson C (2000) Status of coral reefs of the world: 2000. Australian Institute of Marine Science, Cape Ferguson Queensland