Marine Resource Economics, Volume 18, pp. 225–237
Printed in the U.S.A. All rights reserved
0738-1360/00 $3.00 + .00

Effects of Coral Reef Attribute Damage on Recreational Welfare

JEFFREY WIELGUS
NANETTE E. CHADWICK-FURMAN
Bar-Ilan University

NAOMI ZEITOUNI
MORDECHAI SHECHTER
University of Haifa

Abstract *This paper presents the results of an economic valuation of coral reef degradation at Eilat, Israeli Red Sea. We estimate the marginal prices of coral and fish diversity and water visibility at US$2.60 and US$1.20 per dive, respectively. From the standpoint of recreational diving welfare, the annual social costs of activities contributing to coral reef degradation are approximately US$2.86 million. To our knowledge, this is the first economic valuation of individual coral reef attributes and the first application of a choice experiment to coral reef valuation.*

Key words Attribute, biodiversity, choice, coral reef, damage, diving, economic value, pollution, recreation, welfare.

JEL Classification Code N5.

Introduction

Recreation and Pollution on Coral Reefs at Eilat

Coral reefs worldwide are significant sources of consumptive and non-consumptive economic value (Wielgus *et al.* 2002). The abundance of fish and corals (Dixon, Scura, and van't Hof 1993; Wilkinson 1996; Williams and Polunin 2000), and water clarity (Dixon, Scura, and van't Hof 1993; Wilkinson 1996) are valuable attributes to coral reef recreationists, and both can be reduced through anthropogenic activities (Wielgus *et al.* 2002). For example, nutrient enrichment of coral reef waters can lead

---

Jeffrey Wielgus is a doctoral candidate in the Faculty of Life Sciences at Bar-Ilan University (BIU), Ramat Gan 52900, Israel, and the Interuniversity Institute for Marine Science, P.O. Box 469, Eilat 88103, Israel, email: wielguj@mail.biu.ac.il. Nanette E. Chadwick-Furman is a senior lecturer in the Faculty of Life Sciences at Bar-Ilan University (BIU), Ramat Gan 52900, Israel, and the Interuniversity Institute for Marine Science, P.O. Box 469, Eilat 88103, Israel, email: furman@mail.biu.ac.il. Naomi Zeitouni is a senior Research Fellow in the Natural Resource and Environmental Research Center (NRERC), University of Haifa, Haifa 31905, Israel, email: zeitouni@econ.haifa.ac.il. Mordechai Shechter is Director of the Natural Resource and Environmental Research Center (NRERC) and a professor in the Department of Economics, University of Haifa, Haifa 31905, Israel, email: shechter@econ.haifa.ac.il.

We are indebted to J. Bennett for his generous guidance throughout the study. Thanks are due to M. Hanemann for advice on the questionnaires. We are grateful to J. Herriges and three reviewers for valuable comments on the manuscript and to K. Tarnaruder for assistance with the diver surveys. Financial assistance was provided by the University of Haifa's Natural Resource and Environmental Research Center (NRERC) and by a Bar-Ilan University Presidential Ph.D. Scholarship awarded to Jeffrey Wielgus.

to a decline in coral calcification and to algal blooms that increase turbidity (Fishelson 1995; Dubinsky and Stambler 1996).

The coral reefs at Eilat (Israeli Red Sea) are one of the most northerly located ecosystems of their kind, sustaining a unique biodiversity and a large number of endemic species of corals and fish (Fishelson 1995). Extending along a shoreline of only 3.5 km, the Eilat Coral Beach Nature Reserve (CBNR) is one of the most heavily used reefs worldwide for SCUBA diving, supporting an estimated 250,000 dives annually (Zakai and Chadwick-Furman 2002). Other recreational activities taking place at the reserve are snorkeling and glass-bottom boat cruises.

The CBNR is subject to pollution from the port of Eilat, sewage outflows, and fish culture facilities, which depleted the biodiversity of shallow benthic communities (Fishelson 1973; Loya 1975; Fishelson 1995). At a site within the CBNR, Fishelson (1995) reported reductions in the number of colonies of the common coral, *Stylophora pistillata*, and damselfish aggregations of close to 99%, compared to 1963 levels. These organisms are still abundant at unpolluted sites along the Sinai Peninsula, south of Eilat. Nutrient pollution from the fish farms and the port has also been responsible for a reduction in water clarity (Atkinson, Birk, and Rosenthal 2001).

The intensity of SCUBA diving and snorkeling has also been linked to coral degradation at Eilat (Epstein, Bak, and Rinkevich 1999). At the most popular diving sites, the proportion of branching colonies damaged by divers ranges between 40 and 80% (Zakai and Chadwick-Furman 2002).

Previous economic valuations of coral reefs have been based on the contingent valuation of improvements in reef quality (*e.g.*, Dixon, Scura, and van't Hof 1993; Spash 2000), travel cost (Park, Bowker, and Leeworthy 2002), and on lost revenues to fisheries and tourism (*e.g.*, Hodgson and Dixon 1988, 2000; Cesar *et al*. 1997; White, Vogt, and Arin 2000). We document the economic consequences of a decline in coral reef attributes that are important to the recreational value of the reefs at Eilat, through the use of a choice-based valuation approach. To our knowledge, this is the first economic valuation of individual coral reef attributes and the first application of a choice-based method to coral reef economic valuation.

The Choice Modeling Approach for the Economic Valuation of the Environment

This section briefly describes choice modeling, for the benefit of readers that may not be familiar with the methodology. Choice modeling is a stated-preference technique for analyzing consumer decision-making that has been adopted recently in the economic valuation of the environment (Hanley, Wright, and Adamowicz 1998). It has certain advantages over other valuation methods (Bennett and Blamey 2001), like the generation of a rich data set that permits estimation of the value of a wide array of changes to the environment. The method presents a set of environmental alternatives to respondents, where each alternative is associated with a specific combination of attributes and a price. Choice selection gives an indication of the value of each environmental attribute, and can be translated into economic measurements of changes in environmental quality.

Choice modeling has its foundations in random utility theory (Hensher and Johnson 1981; Louviere, Hensher, and Swait 2000; Bennett and Adamowicz 2001). In this framework, a consumer will choose one type of good over another, whenever consumption of the first results in higher utility than consumption of the second. Utility is represented by an indirect utility function (U) consisting of an observed (conditional) component (v) and a random, unobserved component (E). The conditional component of indirect utility is assumed to be a linear function of a good's attributes. For individual i, the utility of consuming good j that has a vector of attributes, **X**, can be expressed as:

$$U_{ij} = v_{ij}(\mathbf{X}) + E_{ij}. \tag{1}$$

In a utility maximizing framework, the probability that individual i will choose good j over all other choices in a bundle with m choices, is the probability that $U_{ij} > U_{ik}$ for all k different than j. Assuming that the unobserved component (E) of utility is identically and independently distributed with an Extreme Value Type I (Gumbel) distribution, this probability can be expressed as:

$$P_{ij} = e^{vij}\left(\sum_{k=1}^{m} e^{vik}\right)^{-1}. \tag{2}$$

The utility of goods having the same *types* of attributes may differ if the *levels* of the attributes are not equal for each good. The parameters of the conditional indirect utility function can be estimated with maximum likelihood methods (Freeman 1993), and the marginal rate of substitution (MRS) between two attributes, X1 and X2, is given by:

$$MRS = \beta_{X1}/\beta_{X2}, \tag{3}$$

where β_{X1} and β_{X2} are the attribute coefficients. If price is included in the model as a "negative attribute" and its coefficient is represented by β_P, the marginal or implicit price (IP) of any other attribute, A, will be given by:

$$IP_A = -(\beta_A/\beta_P). \tag{4}$$

In the economic valuation of increases in environmental quality, respondents are presented with choice sets consisting of alternatives, where each alternative is a unique combination of attributes of an environmental good such as a coral reef diving site. In order to prevent respondents from feeling forced to make a choice from among the alternatives presented, an "opt-out" option is included. This option is either the opportunity to choose none of the alternatives or select the current state ("*status quo*") of an environmental good that is being valued (Bennett and Adamowicz 2001).

An orthogonal fraction of the full factorial permits the efficient estimation of attribute coefficients (Louviere, Hensher, and Swait 2000). By modeling the choices made by respondents, the implicit prices of the different attributes; *i.e.*, the value of an additional improvement in environmental quality, is calculated as shown above. The influence of the socioeconomic characteristics of respondents on their choices can also be studied. A single alternative specific constant (ASC) is included for all alternatives other than the *status quo* and interacted with socioeconomic variables to avoid "Hessian singularities" (Bennett and Adamowicz 2001). ASC's also allow testing for "*status quo* bias," in which individuals are reluctant to changes in the current situation (Louviere, Hensher, and Swait 2000).

By providing implicit prices for attributes, Choice Modeling can also be used to calculate economic welfare changes. If v_0 represents the conditional indirect utility in the current situation ("*status quo*") and v_1 is the conditional indirect utility with attribute improvements, Compensating Surplus (CS) is given by:

$$CS = (-1/\beta_P)(v_1 - v_0). \tag{5}$$

Individual welfare measurements are then aggregated for a specific population to assess social consequences of changes to the environment.

Due to the model's specifications, it is critical that estimations of indirect utility comply with the Independence of Irrelevant Alternatives (IIA) assumption (Luce 1959); *i.e.*, the attributes of a specific alternative in a choice set do not influence the choice between the other alternatives present. Model compliance with the IIA assumption can be verified with a test developed by Hausman and McFadden (1984). If this assumption is violated in a three-alternative choice set, one way to overcome the problem is to specify a nested model with only two levels of choice (Adamowicz *et al.* 1997). In this model, individuals are assumed to first choose between the *status quo* and either of the two other alternatives, and if choosing the latter, between the non-*status quo* alternatives.

The coefficient ρ^2 ("pseudo R^2") provides a goodness of fit measure for logit models (Hensher and Johnson 1981).

Valuation Methodology

In order to identify the coral reef attributes most valued by SCUBA divers at Eilat, we conducted informal interviews with the staff from SCUBA diving centers. There was a consensus that the most important variable influencing diving decisions was the abundance and diversity of corals and fish. Additionally, water clarity (referred to as "visibility" by divers) was considered an important factor in determining dive quality.

A critical issue in stated preference and stated choice models is the adequate presentation of plausible valuation scenarios and accuracy of descriptions (Mitchell and Carson 1995; Carson, Flores, and Meade 2001). The valuation exercise must present alternatives in a manner that is clearly understood by respondents, and the payment mechanism must be considered realistic and potentially binding. In order to achieve this, we decided to use videos of local coral reefs to present the different alternatives and a hypothetical entrance fee for diving sites as the payment vehicle.

Three coral reef sites, similar in depth and topography and considered by diving guides in Eilat to be of poor, medium, and high quality, were filmed with an underwater video camera. The "high-quality" site is located off the Sinai Peninsula, approximately 70 km. south of Eilat. The "medium-quality site" is inside the CBNR, and the "low-quality" site is off the North Beach of Eilat, outside the limits of the CBNR and adjacent to sources of organic pollution (sewage discharges and aquaculture facilities). Filming was done at a constant speed of approximately 20 m/min., with the camera parallel and at a close distance (approximately 40 cm.) to the coral substrate to avoid images showing water visibility. The width of the transect filmed was approximately 1 m. The number of genera ("genus richness") and the abundance of soft and stony corals and fishes were quantified for each site using a digital video tape player with slow-playing capacity. Species of the same genus, but with obviously distinct morphotypes (*e.g.*, the parrotfish, *Scarus*), were counted as separate taxonomic categories, since average divers easily recognize them as different species.

Since divers at Eilat consider coral and fish diversity and abundance as a single attribute (see above), we combined these variables in a "biological index" (Chanter and Owen 1976). Based on the informal interviews with the staff from Eilat's diving centers, we decided to give equal weight to diversity and abundance, and calculated this index by adding the abundance/m^2 and the number of taxonomic categories of corals and fish for each site (table 1). Based on our own experience as SCUBA divers, we assumed that divers have a good perception of the total number of coral and fish species in a dive site, but that their impression of "abundance" is based on the average number of coral and fish per unit area, not the total number observed during a dive. This conjecture may be supported by the following facts: (*i*) the number of fish observed in shoals is difficult to estimate, even by very experienced divers, and (*ii*) the quality of a diving site in terms of coral is sometimes referred to as "coral cover," which is the proportion of the coral substrate covered by living corals. Consequently, our "biological index" included abundance of fish and corals/m^2, instead of total abundance.

Table 1
Characteristics of Hypothetical Diving Sites

	Low-quality Site	Medium-quality Site	High-quality Site
Corals	*Porites* (18) *Stylophora* (2)	*Porites* (16) *Stylophora* (8) *Sarcophyton* (3) *Favites* (7) *Acropora* (8) *Favia* (3) *Goniopora* (6) *Lobophytum* (3) *Goniastrea* (5) *Litophyton* (3) *Seriatopora* (8) *Fungia* (1) *Montipora* (2)	*Porites* (3) *Acropora* (30) *Nephthea* (6) *Nephthea* (2) *Sarcophyton* (4) *Millepora* (12) *Litophyton* (3) *Lobophytum* (5) *Dendronephthya* (1)
Fish	*Dascyllus* (6) *Scolopsis* (3) *Pomacentrus* (2) *Pseudanthias* (3) *Chromis* (1)	*Dascyllus* (4) *Scolopsis* (30) *Pseudanthias* (1) *Pseudanthias* (2) *Hemigymnus* (1) *Scarus* (3) *Zebrasoma* (1)	*Caesio* (42) *Mulloidichthys* (90) *Scarus* (3) *Scarus* (1) *Scarus* (1) *Scarus* (1) *Scarus* (1) *Chromis* (7) *Chromis* (6) *Acanthurus* (3) *Chlorurus* (1) *Calotomus* (3)
Taxonomic Categories	7	20	21
Abundance/m^2	1.75	5.75	11.25
BI	8.75	25.75	32.25

Taxonomic categories and abundance of corals and fishes (in parentheses) are shown for each video presented in the final surveys. BI ("biological index") is the sum of abundance/m^2 and the number of taxonomic categories.

The length of SCUBA dives is usually determined by limits imposed on air availability, and divers frequently make multiple dives each day, so we assumed in calculating this index that utility is non-decreasing during an average SCUBA dive.

During separate sessions, we filmed the water visibility at the three sites, without showing any corals or fish. A reference SCUBA diver was filmed at the maximum visible distance. Measures of 3, 10, and 30 meters maximum visibility were obtained, the second value being the average visibility in the CBNR. Using editing software, the abundance and visibility videos were combined as factors to create nine, three-minute video clips, each showing two minutes of a particular biological index level, and one minute of a particular visibility level. Prices of 5, 20, and 100 new Israeli shekels (NIS) (US$1.08, $4.32, and $21.60, respectively) were chosen as levels for the diver entrance fee. The middle level is the current entry fee to dive inside the CBNR, where some of the best sites in Eilat are located. The highest level is an estimate of the average cost of diving at a nearby "substitute" coral reef in the Sinai Peninsula. Combining all three attributes (including price) at all three levels for each produced 27 alternatives. Alternatives were combined using a fractional factorial design that produced 48 choice sets of three alternatives each. The *status quo* was always included in the choice sets as one of the alternatives, since the purpose of the exercise was to value willingness to pay for changes to the current situation. The *status quo* was always placed randomly among the alternatives to avoid possible effects of order on choice.

The questionnaire used during the surveys (see Appendix) explained the environmental problems that coral reefs are subjected to at Eilat, and the purpose of the economic valuation study. It stated that one possible way to protect the remaining corals and rehabilitate degraded areas, thereby improving the quality of dive sites, was to convert the entire CBNR into a conservation area where all activities causing damage to the coral reefs would be restricted. In order to dive in the area, an entrance fee would have to be paid which would be used to finance research, rehabilitation, and control activities. To avoid possible biases against governmentally controlled conservation programs, it was stated that the conservation area would be managed by a non-government environmental organization.

After the introductory explanation, respondents were told that they would be shown short videos that were representative of three dive sites with differing levels of fish and coral abundance and average visibility. They would then be asked to select the one at which they would prefer to go diving. Each video included the sound of divers breathing to make the viewing experience more similar to an actual dive. Hypothetical entrance fees for each alternative were provided in the questionnaire. Respondents were reminded to consider their available income and the expenses they incur when diving. It was decided to present a single set of three videos to each respondent because of the relatively long period of time required to read the introductory statement, watch the videos, and complete the survey.

Three focus groups comprised of a total of 42 divers were used in a preliminary test of the relevance of the selected attributes and their levels, and to identify problems with the choice elicitation method. Respondents considered the video clips to be of high quality and representative of the abundance and diversity of corals and fish during an actual diving experience. While there was general agreement on the importance of the attributes and plausibility of their levels, the video clips were generally considered excessively lengthy. Therefore, we decided to reduce them by half: one minute showing abundance and diversity and 30 seconds showing visibility. Each of the videos used in the final survey thus presented a reef area of approximately 20 m^2. Table 1 presents taxonomic composition, abundance, and "biological index" values for the final videos.

During the preliminary focus sessions, participants were encouraged to state if none of the alternatives presented seemed like a suitable diving experience. Since 39 respondents (93%) chose one of the alternatives as likely, we decided to make the *status quo* the "opt-out" alternative in the final survey, instead of an option not to select any of the alternatives presented.

Final surveys were conducted at dive centers and in the CBNR. A total of 189 surveys were administered between August 2001 and May 2002, of which 181 were answered completely. The eight incomplete questionnaires included a choice selection, but lacked answers to one or more socioeconomic questions and were not used for the analyses. LIMDEP 7.0 software (Econometrics Software, Inc.) was used for the econometric analysis.

Results and Discussion

Survey Data

Sample representativeness could not be assessed because of the paucity of diving statistics in Israel. Although the Israel Diving Federation (IDF) and the Israel Diving Authority compile statistics such as the number of active divers and the number of divers holding specific certifications, socioeconomic characteristics of divers are lacking (IDF, pers. comm.). The sample consisted of 118 males (65.2%) and 63 females (34.8%), with a mean age of 26.1± 6.8 (SD) (see table 3). Of the respondents, 77.9% (141) said that the main reason for their current visit to Eilat was SCUBA diving; 2.2% (4) answered snorkeling; 11.6% (21) sun and beach; 3.9% (7) casinos, and 4.4% (8) chose "other." Interviewees attending diving courses during their current visit to Eilat totaled 52.5% (95).

We estimated a Multinomial Logit Model for the attributes only (including price). Application of the Hausman-McFadden test showed that the IIA assumption was rejected at the 1% significance level ($\chi^2 = 48.731$). As a result, a Nested Logit Model was specified. Respondents were assumed to first make a decision between the *status quo* and any other alternative, and if opting for the latter, a selection of one of the two alternatives occurred at a second level of choice. Socioeconomic variables thought to possibly influence decisions by divers (table 2) were included in this model. An alternative specific constant (ASC) was included for the two alternatives other than the *status quo*, and interacted with socioeconomic variables to avoid singularities. Parameter estimations for the model are shown in table 2. Descriptive statistics for the socioeconomic variables are presented in table 3.

The likelihood ratio test showed that the model was significant at the 1% level ($\chi^2 = 199.8388$, 15 d.f.). ρ^2 was 0.4368. All attributes (including price) presented the expected signs and were significant at the 5% level or better, while from the socioeconomic variables, only the experience interaction was significant. Since the coefficient was negative, respondents with more diving experience were more keen in seeing changes in the current situation, as compared to respondents with less diving experience. The negative sign of the alternative specific constant coefficient shows that there was "*status quo bias*" among the respondents.

An identical model excluding socioeconomic variables had a ρ^2 of 0.16283. Similarly, a model specification with log-transformed attributes yielded a lower fit ($\rho^2 = 0.3330$) than the original model, which consequently was used for IP calculations and welfare analysis. IP estimates for the "biological index" and visibility are 11.86 NIS (US$2.60) and 5.46 NIS (US$1.20) per dive, respectively. The conditional indirect utility for the *status quo* is 3.725.

Table 2
Nested Logit Model Results

Variable	Coefficient	Standard Error	P[|Z| ≥ z]
ASC	–0.8160	0.2708	0.0026
BI	0.1227	0.0309	0.0001
VIS	0.0565	0.0190	0.0030
PRICE	–0.0103	0.0042	0.0191
EXP	–0.4344	0.0233	0.0000
INTL	1.4629	2.0810	0.4821
AGE	–0.1334	0.0835	0.1103
SEX	–1.8694	1.7670	0.2901
HINCL	0.2345	3.4344	0.9456
HINCM	–1.0143	2.2207	0.6479
HINCH	–1.0868	2.2230	0.6250
HINCVH	–0.0468	2.4248	0.9846
CON	0.2056	1.5684	0.8957
Model Statistics:			
Log-likelihood:	–228.7386		
X^2:	199.8388		
ρ^2:	0.4368		

Parameter legend: ASC: Alternative specific constant for alternatives other than the *status quo*; BI: biological index; VIS: visibility; PRICE: entrance fee. Socioeconomic variables: EXP: interaction of ASC and diving experience (number of dives, in tens); INTL: interaction of ASC and a "dummy" variable for having dived in other countries during the past two years; AGE: interaction of ASC and age of respondent; SEX: interaction of ASC and "dummy" variable for sex = male; HINCL: interaction of ASC and "dummy" variable for household income level = low; HINCM: interaction of ASC and "dummy" variable for household income level = medium; HINCH: interaction of ASC and "dummy" variable for household income level = high; HINCVH: interaction of ASC and "dummy" variable for household income level = very high; CON: interaction of ASC and "dummy" variable for contributing to an environmental conservation organization.

Table 3
Descriptive Statistics for the Socioeconomic Variables in a Nested Logit Model

Variable	Percentage (Number of Respondents)	Mean ± SD
Number of dives	—	36.7 ± 33.9
Dived in other countries	24.3% (44)	—
Age	—	26.1 ± 6.8
Sex	65.2% male (118)	—
Household income: Considerably lower than average	10.5% (19)	—
Household income: Somewhat lower than average	17.1% (31)	—
Household income: Average	30.9% (56)	—
Household income: Somewhat higher than average	35.9% (65)	—
Household income: Considerably higher than average	5.5% (10)	—
Contribute to environmental conservation	37.6% (68)	—

Welfare Estimations

This study shows that divers value the abundance and diversity of corals and fishes and water visibility on coral reefs at Eilat. In the CBNR, they are willing to pay 11.86 NIS (US$2.60) per dive for an additional unit of a biological index that comprises coral and fish abundance and genus richness, and 5.46 NIS (US$1.20) per dive for an additional meter of visibility, over the current diving fee of 20 NIS. The observed willingness to pay for quality improvements in diving sites by SCUBA divers at Eilat implies that activities causing attribute degradation have a negative impact on the economic welfare of divers.

Economic welfare changes can be calculated for different scenarios. Table 4 presents CS measurements for changes from the *status quo*, taking as a base an annual dive rate of 250,000 dives at Eilat and assuming no changes in the price of SCUBA diving in the CBNR. The first scenario depicts a 25% increase in the abundance and genus richness of corals and fish (measured as a biological index, BI) and in visibility at the CBNR. A second scenario also considers a 25% increase in BI, accompanied by a 50% increase in visibility. The third scenario evaluates attribute increases to the "pre-damage" levels of 1963, assuming that the average visibility at the time was 20 m and that BI resembled that of present-day reefs at nearby sites in Sinai (BI = 32.25). Visibility in Eilat's reefs in 1963 was probably lower than the current average levels at Sinai (30 m), due to the location of the former at the northern tip of the Gulf of Eilat (Aqaba), which makes them subject to higher levels of land-borne particulate matter that increase turbidity.

It was determined that divers at Eilat would be willing to pay relatively small amounts of money for changes that would not represent a substantial improvement over the current situation (Scenario 1 in table 4). However, a 50% increase in average visibility would more than double their willingness to pay (Scenario 2). Finally, environmental improvements that lead to attribute levels similar to those on Sinai reefs would be valued at 13,214,000 NIS (US $2.86 million) per year (Scenario 3). This value also may be viewed as the externalities imposed on SCUBA divers by economic activities that prevent the recovery of coral reef attributes to their previous levels.

Table 4
Compensating Surplus (CS)

Scenario	CS (NIS/year)	CS (US$/year)
1. 25% increase in BI and visibility	2,778,000	600,519
2. 25% increase in BI, 50% increase in visibility	6,160,000	1,331,604
3. Restoration of BI and visibility to "pre-damage" levels	13,214,000	2,856,463

Note: Values are in new Israeli Shekels (NIS) and US$.
Three scenarios of SCUBA attribute improvements are depicted. BI ("biological index") is a measure of coral and fish abundance and genus richness. CS was calculated as $(-1/\beta_P)(v_1 - v_o)$, where β_P is the price coefficient, v_0 is the conditional indirect utility in the current situation ("*status quo*"), and v_1 is the conditional indirect utility with the attribute improvements depicted in each scenario. CS was aggregated for 250,000 annual SCUBA dives in the CBNR. The current price for diving in the CBNR, 20 NIS, was assumed for all scenarios. Conditional indirect utility for improvements to the *status quo* in each scenario was calculated as $v = ASC + \beta_{BI}BI + \beta_{VIS}VIS + \beta\mathbf{S}$, where ASC is an alternative specific constant, β's are attribute coefficients, BI and VIS are attribute levels, and **S** is a vector of the mean values of the socioeconomic variables.

Concluding Comments

To our knowledge, the present study is the first valuation of welfare changes resulting from coral reef attribute damage. Studies to estimate the externalities imposed on other reef users (*e.g.*, snorkelers, glass-bottom boat visitors) would complement this investigation and provide a more complete figure on welfare losses resulting from reductions in the value of the coral reefs at Eilat. Israeli environmental authorities could use the results of these studies to impose charges for damage to the coral reefs. Although some of the assumptions used to develop an index representing a biological attribute are based on the authors' experience as SCUBA divers, research on issues of divers' perception of coral reef biodiversity would permit corroboration of their validity.

References

Adamowicz, W., J. Swait, P. Boxall, J.J., Louviere, and M. Williams. 1997. Perceptions versus Objective Measures of Environmental Quality in Combined Revealed and Stated Preference Models of Environmental Valuation. *Journal of Environmental Economics and Management* 32:65–84.

Atkinson, M.J., Y. Birk, and H. Rosenthal. 2001. *Evaluation of Pollution in the Gulf of Eilat*. Report for the Israeli Ministries of Infrastructure, Environment and Agriculture. Eilat, Israel.

Bennett, J., and W. Adamowicz. 2001. Some Fundamentals of Environmental Choice Modelling. *The Choice Modelling Approach to Environmental Valuation*, J. Bennett and R. Blamey, eds., pp. 37–72. Cheltenham, U.K.: Edward Elgar.

Bennett, J., and R. Blamey. 2001. The Strengths and Weaknesses of Environmental Choice Modelling. *The Choice Modelling Approach to Environmental Valuation*, J. Bennett and R. Blamey, eds., pp. 227–42. Cheltenham, U.K.: Edward Elgar.

Carson, R.T., N.E. Flores, and N.F. Meade. 2001. Contingent Valuation: Controversies and Evidence. *Environmental and Resource Economics* 19:173–210.

Cesar, H., C.G. Lundin, S. Bettencourt, and J. Dixon. 1997. Indonesian Coral Reefs—An Economic Analysis of a Precious but Threatened Resource. *Ambio* 26(6):345–60.

Chanter, D.O., and D.F. Owen. 1976. Nature Reserves: A Customer Satisfaction Index. *Oikos* 27:165–67.

Dixon J.A., L.F. Scura, and T. van't Hof. 1993. Meeting Ecological and Economic Goals: Marine Parks in the Caribbean. *Ambio* 22(2-3):117–25.

Dubinsky, Z., and N. Stambler. 1996. Marine Pollution and Coral Reefs. *Global Change Biology* 2:511–26.

Epstein, N., R.P.M. Back, and B. Rinkevich. 1999. Implementation of a Small-Scale "No-Use Zone" Policy in a Reef Ecosystem: Eilat's Reef-Lagoon Six Years Later. *Coral Reefs* 18:327–32.

Fishelson, L. 1973. Ecology of Coral Reefs in the Gulf of Aqaba (Red Sea) Influenced by Pollution. *Oecologia* 12:55–67.

___. 1995. Eilat (Gulf of Aqaba) Littoral: Life on the Red Line of Biodegradation. *Israeli Journal of Zoology* 41:43–55.

Freeman, A.M. 1993. *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, D.C.: Resources for the Future.

Hanley, N., R.E. Wright, and V. Adamowicz. 1998. Using Choice Experiments to Value the Environment: Design Issues, Current Experience and Future Prospects. *Environmental and Resource Economics* 11(3-4):413–28.

Hausman, M.J., and D. McFadden. 1984. Specification Tests for the Multinomial Logit Model. *Econometrica* 46(5):1219–40.
Hensher, D.A., and L.W. Johnson. 1981. *Applied Discrete Choice Modelling*. New York: John Wiley & Sons.
Hodgson, G., and J.A. Dixon. 1988. Logging Versus Fisheries and Tourism in Palawan. Occasional Paper No. 7, East-West Environment and Policy Institute, Honolulu, HI.
___. 2000. El Nido Revisited: Ecotourism, Logging and Fisheries. *Collected Essays on the Economics of Coral Reefs*, S.J. Cesar, ed., pp. 55–68. Kalmar, Sweden: CORDIO.
IDF (The Israeli Diving Federation). www.isracam.co.il/diving.
Louviere, J.J., D.A. Hensher, and J.D. Swait. 2000. *Stated Choice Methods: Analysis and Application*. Cambridge, U.K.: Cambridge University Press.
Loya, Y. 1975. Possible Effects of Water Pollution on the Community Structure of Red Sea Corals. *Marine Biology* 29:177–85.
Luce, R.D. 1959. *Individual Choice Behavior: A Theoretical Analysis*. New York: John Wiley & Sons.
Mitchell, R.C., and R.T. Carson. 1995. Current Issues in the Design, Administration, and Analysis of Contingent Valuation Surveys. *Current Issues in Environmental Economics,* P. Johansson, B. Kriström, and K. Mäler, eds., pp. 10–34. Manchester: Manchester University Press.
Park, T., J.M. Bowker, and V.R. Leeworthy. 2002. Valuing Snorkeling Visits to the Florida Keys with Stated and Revealed Preference Models. *Journal of Environmental Management* 65:301–12.
Spash, C.L. 2000. Assessing the Benefits of Improving Coral Reef Biodiversity: The Contingent Valuation Method. *Collected Essays on the Economics of Coral Reefs*, S.J. Cesar, ed., pp. 40–54. Kalmar, Sweden: CORDIO.
White, A.T., H.P. Vogt, and T. Arin. 2000. Phillipine Coral Reefs under Threat: The Economic Losses Caused by Reef Destruction. *Marine Pollution Bulletin* 40(7):598–605.
Wielgus, J., N.E. Chadwick-Furman, Z. Dubinsky, M. Shechter, and N. Zeitouni. 2002. Dose-Response Modeling of Recreationally Important Coral Reef Attributes: A Review and Potential Application to the Economic Valuation of Damage. *Coral Reefs* 21(3):253–59.
Wilkinson, C.R. 1996. Global Change and Coral Reefs: Impacts on Reefs, Economies and Human Cultures. *Global Change Biology* 2:547–58.
Williams, D.W., and N.V.C. Polunin. 2000. Differences between Protected and Unprotected Reefs of the Western Caribbean in Attributes Preferred by Dive Tourists. *Environmental Conservation* 27(4):382–91.
Zakai, D., and N.E. Chadwick-Furman. 2002. Impacts of Intensive Recreational Diving on Reef Corals at Eilat, Northern Red Sea. *Biological Conservation* 105:179–87.

Appendix: Choice Modeling Sample Questionnaire

Coral reefs are one of the richest ecosystems in terms of abundance and diversity of living organisms. The coral reefs of Eilat are among the northernmost reefs in the world, and the only such ecosystems in Israel. These reefs are currently affected by various human-caused factors, including pollution and physical damage by boats, divers, and snorkelers. Because of these factors, there has been a reduction in the biodiversity and the underwater visibility at Eilat's dive sites during the past 30 years. According to experts, if this trend continues the last remaining areas of live coral reefs may disappear in the next 10 to 20 years.

One way to protect the remaining coral reefs of Eilat and to increase the levels of biodiversity and visibility is to establish a Marine Protected Area (MPA), managed by a non-government environmental organization. The MPA would extend from the southern limits of the Eilat Port to the border with Egypt, encompassing most of the remaining sites with significant amounts of coral. Human activities that affect the corals would be regulated, so that the MPA would provide an effective means of protecting biodiversity and visibility.

In order to maintain the MPA, a fee would have to be paid by everyone wishing to enter the area, including SCUBA divers. The funds collected by the managing authority would be used for research, rehabilitation of damaged corals in the MPA, and for patrolling the MPA to enforce the regulations to protect it.

You will now be presented with three short video clips, each one showing a combination of fish and coral abundance, average visibility, and an entrance fee. After watching the videos, please select the one that represents a diving site that you would choose.

Please keep in mind your budget limitations during your visit to Eilat and the cost of renting SCUBA/snorkeling equipment.

Which MPA alternative you would prefer?

A. (entrance fee =) __
B. (entrance fee =) __
C. (entrance fee =) __ (This is the current state of the reef and entrance fee for the Coral Beach Nature Reserve)

Please provide the following information about yourself:

a. What is the main purpose of your current visit to Eilat?

SCUBA Diving	Snorkeling	Sun and Beach	Casinos	Other (glass bottom boat, yellow submarine, *etc.*)

b. Are you enrolled, or plan to enroll, in a SCUBA course during your current visit to Eilat?
Yes __ No__

c. Approximately how many SCUBA dives have you done until now? ____

d. Have you SCUBA dived in other countries during the past 2 years?
Yes __ No__

e. What is your age? _____

f. Sex: M__ F__

g. The average income per family in Israel is 7,500 shekels, net, per month. Is your family income:

___ Considerably higher than the average
___ Somewhat higher than the average
___ Average
___ Somewhat lower than the average
___ Considerably lower than the average

h. Do you belong to an environmental organization or contribute to one?
Yes__ No__

Thank you for your participation!