The Australian Journal of
Agricultural and Resource Economics
Journal of the Australian Agricultural and Resource Economics Society

The Australian Journal of Agricultural and Resource Economics, 53, pp. 213–229

Effects of Great Barrier Reef degradation on recreational reef-trip demand: a contingent behaviour approach*

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There is a growing concern that increased nutrient and sediment runoff from river catchments are a potential source of coral reef degradation. Degradation of reefs may affect the number of tourists visiting the reef and, consequently, the economic sectors that rely on healthy reefs for their income generation. This study uses a contingent behaviour approach to estimate the effect of reef degradation on demand for recreational dive and snorkel trips, for a case study of the Great Barrier Reef in Australia. Results from a negative binomial random effects panel model show that the consumer surplus current reef visitors derive from a diving or snorkelling trip is approximately A$185 per trip. Furthermore, results indicate that reef trips by divers and snorkellers could go down by as much as 80 per cent given a hypothetical decrease in coral and fish biodiversity. This corresponds to a decrease in tourism expenditure by divers and snorkellers on full-day reef trips in the Cairns management area of the Great Barrier Reef Marine Park of about A$103 million per year.

Key words: contingent behaviour, coral reef, count data, recreation, random effects panel model.

1. Introduction

The Great Barrier Reef (GBR) is the world's largest coral reef ecosystem, worldwide known for its aesthetic beauty. The GBR stretches for more than 2300 km along the coast of Queensland, Australia (Figure 1) and comprises about 2500 individual reefs which support a great diversity of corals and fish species. The area has been listed under the World Heritage Convention in 1981 and is the largest World Heritage Area ever established. Next to its ecological significance, the GBR is of economic importance for industries operating in the area, of which the tourism industry is the most important.

* The authors gratefully acknowledge the Sustainable Ecosystems division of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for facilitating this research, Dr Katharina Fabricius from the Australian Institute of Marine Sciences (AIMS) for aiding in the survey development, and two anonymous referees for their helpful comments on an earlier draft of this article.

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doi: 10.1111/j.1467-8489.2007.00444.x

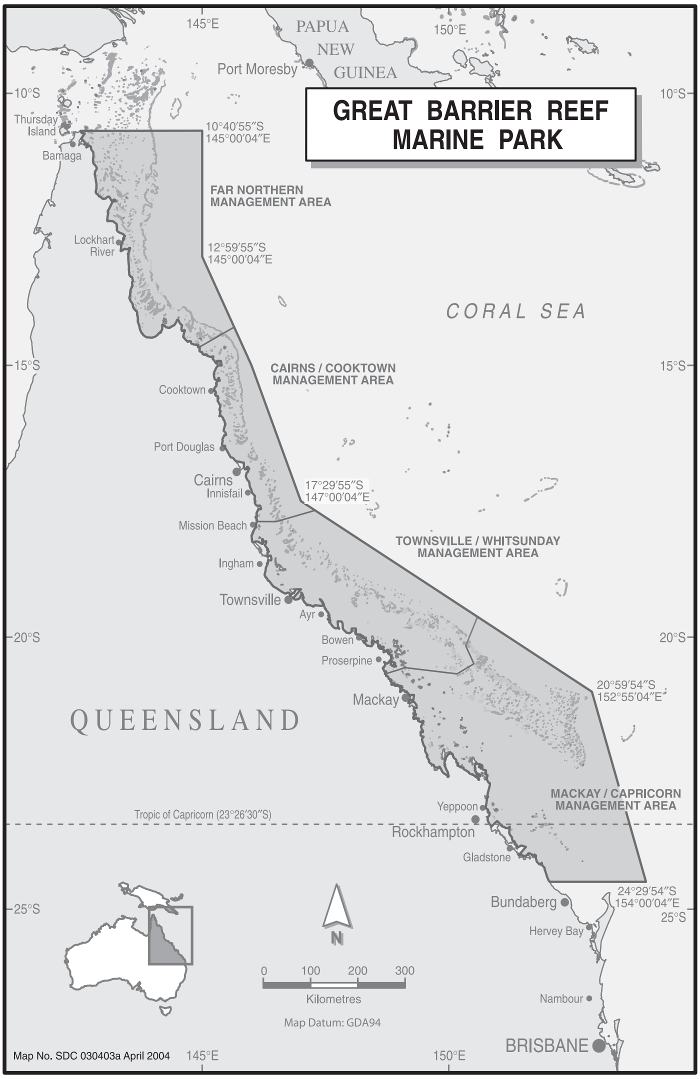

Figure 1 The Great Barrier Reef World Heritage Area (source: Great Barrier Reef Marine Park Authority).

Tourism is the largest commercial activity in the Great Barrier Reef Marine Park (Productivity Commission 2003) attracting a yearly average of 1.54 million full-day reef trips per year. More than 50 per cent of the total number of visitor days is recorded in the section around Cairns (Figure 1), attracting an average of 792 thousand full-day reef trips per year (data derived from GBRMPA Environmental Management Charge data 1994–2003).

Discharges from rivers flowing in the GBR catchment area can influence water quality by carrying sediments and nutrients into the Great Barrier Reef World Heritage Area. Expanding development in the GBR catchment area has caused a substantial increase in the export of sediments and nutrients over the last 150 years (Wachenfeld *et al.* 1998; Haynes 2001; Furnas 2003; GBRMPA 2003). There is significant concern that increased exports of sediments and nutrients are one of the biggest potential sources of reef degradation (Rogers 1990; Fabricius 2005). Increased nutrient and sediment concentrations in river runoff can result in an increase of algal-dominated reef systems, decreased reproductive capacity of coral, and reductions in both coral and fish biodiversity (Brodie *et al.* 2005; Fabricius *et al.* 2005).

Reduced reef quality may have negative effects on the number of tourists visiting the GBR. The relationship between reef trip demand and reef quality still remains unknown (Wielgus *et al.* 2002), thus complicating an estimation of the economic effects of reef quality decline and the design of appropriate policy interventions. Measuring changes in reef trip demand would not only provide insight into the welfare effects for reef visitors, but also allow for an estimation of the income effects for the reef-tourism industry that relies on healthy coral reefs for its income generation. Better information about the economic effects of reef degradation is needed to improve the development of efficient reef management policies (State of Queensland and Commonwealth of Australia 2003).

This study responds to the identified need for further valuation research on coral reefs (Brander *et al.* 2007). We use data from a contingent behaviour (CB) survey conducted in Port Douglas (Figure 1) of divers and snorkellers who take reef trips with commercial operators to the GBR Marine Park. A negative binomial (NB) model is specified to estimate the recreational demand for reef trips at a hypothetical decline in reef quality, as measured by a reduction in fish and coral biodiversity. We argue that a NB random effects panel model is most appropriate to analyse CB data. This is the first CB application to analyse how reef trips are related to degradation of the Great Barrier Reef. An important difference with previous recreation studies is that this research does not model environmental *improvements* but studies the effects of environmental *degradation* on recreational demand.

Our results show that the consumer surplus current reef visitors derive from a diving or snorkelling trip is about A$185 per trip. Furthermore, the results suggest that reef trip demand by divers and snorkellers could go down by as much as 80 per cent given the hypothetical decrease in coral and fish biodiversity. This leads to a substantial decrease in tourism expenditure for reef trips to the Great Barrier Reef Marine Park and could have considerable implications for the reef tourism industry.

The remainder of this article is organised as follows. In the next section, previous studies on recreation and environmental quality are reviewed, followed by a presentation of the theoretical framework in section 3. Section 4 outlines the CB questionnaire and the descriptive statistics of the survey. In section 5 the results of the reef trip demand model and the welfare estimates related to a decline in reef quality are presented. The article concludes with a discussion of the potential welfare effects of reef degradation for reef visitors and the reef-tourism industry.

2. Contingent behaviour and recreational demand

There are several techniques to estimate the effects of changed environmental quality on recreational demand.[1] Early valuations of water based recreation are presented in Smith and Desvousges (1986) and Bockstael *et al.* (1989). These studies pooled travel cost data to recreational sites of different water quality levels. The differences in the number of trips taken to different sites are assumed to relate to the site's environmental quality. A drawback of this method is that it requires variation in quality between sites, which is not documented among recreational dive and snorkel sites of the GBR. There is a growing amount of literature that avoids this problem by using stated preferences (SP) data. An advantage of SP approaches is that they can be applied to site quality changes that are outside the range of observed qualities. Cameron (1992) and Kling (1997) assessed the merits of combining revealed preferences (RP) data from travel cost studies with SP contingent valuation surveys to estimate the welfare effects of environmental quality changes.

One SP approach has been employed by Adamowicz *et al.* (1997), Wielgus *et al.* (2003) and Parsons and Thur (2008). These studies used choice experiments in a random utility framework to analyse recreational site choice. Alternative recreational sites are described in terms of different levels of environmental attributes. This approach allows an estimation of the values associated with a change in each attribute.

Applications more relevant to our study are reported in Englin and Cameron (1996), Eiswerth *et al.* (2000), Bhat (2003) and Hanley *et al.* (2003). These studies combined travel cost data with CB surveys to determine recreational demand. The CB approach employs a survey that describes a hypothetical change in environmental quality and asks people directly for the changes in their behaviour *contingent* to the quality change. This is a valid approach to study quality changes in recreational sites that are outside the range of currently observed conditions (Haener *et al.* 2001; Grijalva *et al.* 2002).

Englin and Cameron (1996) estimated changes in recreational fishing demand in Nevada using a fixed-effects panel data model. Anglers were asked how they would change their number of fishing trips if travel *costs* would increase. Eiswerth *et al.* (2000) used a pooled Poisson model of recreational fishing, but focused on a change in environmental *quality* rather than a change in price. Bhat (2003) combined travel costs and CB in a Poisson random effects model to study changes in the number of visits to the Florida Keys subject to a hypothetical improvement in reef quality. His results indicate a 43–80 per cent increase in visits for a 200 per cent improvement in fish abundance and a 100 per cent improvement in water clarity and coral health. Hanley *et al.* (2003) considered changes in the number of recreational

[1] Excellent reviews on coral reef valuation studies can be found in Cesar, H.S.J., (ed.) 2000. *Collected Essays on the Economics of Coral Reefs*. CORDIO, Kalmar University, Kalmar, Sweden. and Brander *et al.* (2007). The recreational value of coral reefs: A meta-analysis, *Ecological Economics* 63: 209–218.

visits to beaches in Scotland subject to a hypothetical improvement in bathing water quality. The authors combined RP and SP data in a single equation model using a NB random effects panel data model.

The study presented in this article builds on the approach demonstrated by Bhat (2003) and Hanley *et al*. (2003). We argue, however, that combining SP and RP data is likely to skew results in favour of current conditions. Therefore, SP data on recreational diving and snorkelling trips to the GBR are used to estimate future recreational demand given a hypothetical decline in reef quality. To our best knowledge, this approach has not yet been used to estimate recreational values of the Great Barrier Reef. Contrary to previous SP studies, we consider a *decline* in reef quality, which may be more appropriate than hypothetical *improvements*.

3. Theoretical framework

3.1 Statistical model

It is assumed that an individual i ($i = 1, 2, \ldots, N$) aims to maximise utility from consumption, subject to budget and time constraints. In the context of reef recreation, utility u_i is derived from the number of recreational reef trips y_i at reef quality q_t, a vector of other goods and services Z_i, and reef quality q_t itself. We define reef quality such that $q_t = q_0$ for current quality and $q_t = q_1$ for degraded quality. The indirect utility function can be defined as:

$$v_i = \max_{y_i, Z_i}[u_i(y_i, Z_i, q_t, m_i, \eta_i)] \tag{1}$$

subject to: $m_i = y_i p_y + Z_i$
where v_i is the ith individual's indirect utility function, p_y is the price of a reef trip, and m_i is household income. Unobservable individual characteristics are included in η_i, which is a random error distribution with zero mean.

A decline in reef quality can affect utility in two ways. First, assuming that all other variables are held constant, demand for diving and snorkelling reef trips is likely to decrease if reef quality q_t declines. As the number of reef trips y_i contributes to the use-value the visitor attaches to the reef, a decline in reef quality will cause a reduction in net consumer surplus. Second, reef quality enters the utility function u_i directly, implying that reef quality may also contribute to the non-use value an individual attaches to the GBR. Changes in reef quality will therefore affect an individual's utility even at zero trips to the reef (Niklitschek and León 1996). SP survey methods like contingent valuation or choice experiments can be used to estimate such non-use values. The changes in reef trips as measured in this study contribute to the change in use-values and therefore comprise only part of the total value of the reef.

Our variable of interest is a count of reef trip demand, which is limited to non-negative integers. The distribution of data on reef trip recreation is positively skewed towards zero and one, preventing the transformation of a skewed distribution into a normal one and impeding the use of a standard ordinary linear regression model (Cameron and Trivedi 2005). A commonly used model to analyse count data is the Poisson regression model. This model is derived from the Poisson distribution, with density

$$\Pr(y_i^{q_t} = \hat{y}_i^{q_t}) = \frac{e^{-\lambda}\lambda^{\hat{y}_i^{q_t}}}{\hat{y}_i^{q_t}!} \tag{2}$$

with λ being the mean and variance of reef trips y and $\hat{y}_i^{q_t}$ the number of recreational reef trips individual i makes to the reef at quality q_t. An important restrictive property of the Poisson distribution is equality of the mean and variance of the dependent variable ('equidispersion'; Cameron and Trivedi 2001). For recreational demand data, the variance usually exceeds the mean ('overdispersion'), in which case the estimated variances in the Poisson model will be biased. The more appropriate specification of a recreational demand model is provided by a NB regression model (Loomis 2002; Park *et al*. 2002). The NB model allows for a skewed, discrete distribution and is restricted to non-negative values. It also relaxes the Poisson constraint on the equality of the mean and the variance of the dependent variable. In particular, the NB probability function is given by

$$\Pr(y_i^{q_t} = \hat{y}_i^{q_t}) = \frac{\Gamma(\hat{y}_i^{q_t} + 1/\alpha)}{\Gamma(\hat{y}_i^{q_t} + 1)\cdot\Gamma(1/\alpha)}\left(\frac{1/\alpha}{1/\alpha + \bar{y}}\right)^{\frac{1}{\alpha}}\left(\frac{\bar{y}}{1/\alpha + \bar{y}}\right)^{y_{iq_t}} \tag{3}$$

with $\bar{y}$ the mean number of reef trips at quality q_t, Γ a gamma discrete probability density function defined for y_i and α a gamma distributed parameter (Cameron and Trivedi 2001). For this distribution, the variance in the number of reef trips is equal to $\bar{y} + \alpha(\bar{y})^2$. The variance exceeds the mean, as $\bar{y} > 0$ and $\alpha > 0$, accounting for overdispersion in the dataset.

The NB model implicitly determines a log-linear function, given by

$$\ln(y_i) = c + \beta_q q_t + \beta_p p_y + \beta'\mathbf{X}_i + \varepsilon_i \tag{4}$$

where y_i is the number of reef trips by individual i ($i = 1, 2, \ldots, N$) to reefs of quality q_t at trip price p_y. Vector $\mathbf{X}_i$ contains the independent regressors for individual i. This functional form ensures that dependent variable y_i is restricted to non-negative integers. It is assumed that the random error term ε_i follows a gamma distribution with mean 1 and variance σ, giving rise to the NB model.

3.2 Welfare measures

The consumer surplus associated with recreational reef trips is equal to the area below the inverse demand function and above the implicit price of a reef trip p_0. With β_p the coefficient of the reef trip price variable, p_0 the current price of a reef trip and $p_c^{q_t}$ the choke price at which individual i does not take any reef trips at quality q_t, the consumer surplus for individual i (CS_i) at reef quality q_t is estimated by (Bockstael *et al.* 1989)

$$CS_i = \int_{p_0}^{p_c^{q_t}} y_i(p_y, q_t, \mathbf{X}_i)\mathrm{d}p_y = \frac{y_i(p_0, q_t, \mathbf{X}_i)}{\beta_p} \tag{5}$$

Assuming no change in the coefficient of price with reef quality declining from q_0 to q_1, the change in an individual's consumer surplus is (Whitehead *et al.* 2000)

$$\Delta CS_i = \int_{p_0}^{p_c^{q_0}} y_i(p_y, q_0, \mathbf{X}_i)\mathrm{d}p_y - \int_{p_0}^{p_c^{q_1}} y_i(p_y, q_1, \mathbf{X}_i)\mathrm{d}p_y = \frac{y_i(p_y, q_0, \mathbf{X}_i) - y_i(p_y, q_1, \mathbf{X}_i)}{\beta_p} \tag{6}$$

where $p_c^{q_0}$ and $p_c^{q_1}$ are the choke prices of reef trip demand at current and degraded reef quality q_0 and q_1, respectively.

4. Contingent behaviour survey

4.1 Questionnaire design

The aim of this study is to estimate the changes in GBR trip demand resulting from a decline in reef quality. Information on recreational reef trips has been collected by means of a CB survey, directed at GBR visitors in Port Douglas.[2] The survey was carried out over a four-week period in September 2004 on board of tourism vessels of various commercial operators. Interviews were conducted with every second or third diver and snorkeller who boarded, at the end of their full-day trip to the GBR. The survey elicited information on respondents' visits to the GBR region, their perception of reef quality, the price paid for the full-day trip to the reef, the number of recreational reef trips made in the past 12 months and the number of reef trips planned for the next five years (at current reef quality).

Respondents were then presented with a hypothetical scenario of reef degradation and were asked if they would change their planned number of reef trips in the next five years were the specified reef degradation to occur. The reef degradation scenario was based on scientific evidence that coral cover and coral biodiversity declines when a reef has been exposed to pollution. Changes in fish *abundance* are usually not apparent while fish *diversity* generally declines on degraded reefs (Fabricius *et al.* 2005). Following Bhat (2003) and

[2] A copy of the complete survey is available upon request from the authors.

Wielgus *et al.* (2003), the reef degradation scenarios were represented using photographic material. The picture sets represented degradations in coral and fish biodiversity. The choice of pictures was based on scientific material, provided by marine biologist Dr Katharina Fabricius. The first picture set showed a healthy coral reef, representing the current quality of the GBR. The second set included pictures of a degraded coral reef, representing a possible future quality of the GBR. The pictures showed a visible decline in coral cover, coral diversity and fish diversity of approximately 80, 30 and 70 per cent, respectively.

Next to RP and CB reef trip data, the survey collected information on respondents' socio-economic characteristics. Following the guidelines of the National Oceanographic and Atmospheric Administration (NOAA) Panel on Value Elicitation Surveys (Arrow *et al.* 1993), the questionnaire included reminders of budget and time constraints.

4.2 Descriptive statistics

The survey yielded 176 interviews for further analysis. Descriptive statistics of the sample are provided in Table 1. The dataset contains slightly more men than women (100–76) and more snorkellers than divers (118 snorkellers to 58 divers). Of all respondents, 45 per cent came from Australia, mainly from Victoria and New South Wales, and 31 per cent came from Europe. The mean net monthly income was A$7264 and the average respondent had at

Table 1 Descriptive statistics of survey sample ($n = 176$)

Variable	Value
Gender (% of respondents)	
Male	57
Female	43
Origin (% of respondents)	
Queensland	7
Rest of Australia	38
Europe	31
USA/Canada	13
Reef activity (% of respondents)	
Diving	33
Snorkelling	67
Average net income ($/month)	7264
Average education (number of years)	14.3
Reef as a primary reason to come to Port Douglas (% of respondents)	59
Making more than one trip this year (% of respondents)	23
Planning to come back in the next five years (% of respondents)	64
Would make fewer trips at $q = 1$ (% of respondents)	76
Would not come back to the region at $q = 1$ (% of respondents)	35
Mean reef trips in the past 12 months (#)	1.35
Median price paid for recreational reef trip ($)	162.5
Average rating of reef quality (range 1 = very bad to 5 = very good)	4

least finished a college or diploma degree (mean 14.3 years of education). Most respondents (59 per cent) visited the Port Douglas region with the primary purpose of seeing the reef. Although the majority of respondents (77 per cent) visited the GBR only once in 2004, 64 per cent was planning to make more trips in the next five years. If reef quality would decline as presented in the CB scenario, 76 per cent of the respondents would make fewer reef trips and 35 per cent of the respondents would not come back to the region at all.

The average number of recreational reef trips that a respondent made to the GBR in 2004 was 1.35. The median price of a reef trip in the sample was A\$162.5 (mean A\$175.0) for a full-day trip.[3] Reef visitors were asked to rate different aspects of the reef they had seen on a five-point Likert scale ranging from very bad to very good. This rating is assumed to represent the reef visitor's perception of the reef seen that day. The average rating of reef perception was 3.9 with the lowest rating for the 'amount of coral cover' (3.7) and the highest rating for 'water visibility' (4.1). Respondents were also asked what they thought is the most important threat to the GBR. Global warming, too many visitors and pollution were mentioned by, respectively, 19, 16 and 13 per cent of the respondents. Out of 176 respondents, 25 persons stated that they were not familiar with any problems facing the GBR.

5. Results of the reef trip demand model

5.1 Reef trip demand

Table 2 gives the explanatory variables that are used to analyse reef trip demand. The choice of variables is based on their significance in explaining reef trip demand and corresponds to variables used in previous studies on coral reef recreation (for example, Arin and Kramer 2002; Park *et al.* 2002; Bhat 2003). Each respondent i's total demand for reef trips y_i is calculated as the planned number of diving or snorkelling trips for the next five years. Reef trip demand is expected to be negatively correlated to the price of a reef trip p_y and positively with the respondent's perception of the reef. It is expected that reef visitors from Queensland and other Australian states make more trips to the GBR than overseas visitors so two dummy variables, DumQLD and DumAUS, are created. The possibility that divers make more reef trips than snorkellers is captured by adding a dummy variable for reef activity. Diving and snorkelling experience in other parts of the world was originally included in the analysis, but proved to be insignificant, probably due to the variation in experiences with other coral reefs compared to the GBR.

[3] This is the cost of a full-day reef trip and does not take wider trip costs (like transport and accommodation) into account. Results in this paper thus provide a lower bound estimate of travel costs.

Table 2 Description of variables used in demand model

Variable	Definition
Dependent variable	
Demand	Number of planned per person-trips to the GBR
Explanatory variable	
Price	Current price paid for a reef trip
Perception	Rating of reef quality‡
DumQLD	Dummy for respondents from Queensland (0 = not from Queensland)
DumAUS	Dummy for respondents from (rest of) Australia (0 = not from Australia)
Snorkel	Dummy for activity on the reef (0 = diving, 1 = snorkelling)
Female	Gender (0 = male)
Education	Number of years of education
Income	Net monthly income§
DumQ	Dummy for reef quality (0 = current quality, 1 = degraded quality)

‡ On a 5-point Liker scale with 1 = very bad to 5 = very good.
§ From seven net monthly income categories ranging from A$0–1.000 to A$10.000 and over.

Socio-economic characteristics (gender, education and income) are also included in the analysis. Finally, a dummy variable for reef quality is included to test for the difference between the number of reef trips planned at current reef quality and the number of planned reef trips at degraded reef quality.

Following Bhat (2003) and Hanley *et al.* (2003), a RP-SP model was tested combining current and planned reef trips as the dependent variable in a single equation. This specification, however, results in model estimates that are biased towards current conditions as current visits are based on reef quality now while, in fact, the relevant comparison in consumer surplus should be between *predicted* reef trip demand at reef quality now and the predicted number of trips at degraded quality (Bockstael *et al.* 1989). Including current reef visits in the dependent variable are thus likely to result in biased welfare effects. We therefore argue that using the number of planned reef trips at current and degraded reef quality as a dependent variable is more appropriate in the case of GBR quality decline.

The CB data for reef qualities q_0 and q_1 are combined in a single equation to estimate the demand for recreational diving and snorkelling trips to the GBR. Because not all respondents answered the CB questions, this provides 232 observations for planned reef visits at both q_0 and q_1. STATA 9.1 is used to estimate the conditional expectation $E\{y_i^{q_t} \mid \mathbf{X}_i\}$ in a Poisson and NB model. The distribution of the demand variable indicates overdispersion, as the standard deviation in $y_i^{q_t}$ was more than three times larger than the sample mean of 1.85 planned trips. Consequently, the NB model is used for further analysis. The model is estimated in a panel data format, accounting for unobserved individual characteristics (not included in $\mathbf{X}_i$) that impact on recreation behaviour. Our panel consists of two observations per individual respondent. It is reasonable to assume a constant individual-specific effect, which is estimated as a random effects parameter in the model.

Table 3 Negative Binomial Pooled and Random Effect Panel models for recreational reef trip demand†

	Pooled model		Panel model	
	Coefficient	z	Coefficient	z
Price	–0.004	–1.860*	–0.005	–1.980**
DumQ	–1.908	–7.790***	–2.258	–11.270***
DumAUS	1.081	5.130***	1.110	4.960***
DumQLD	2.479	7.730***	2.446	6.620***
Snorkeller	–1.175	–5.130***	–1.169	–4.610***
Perception	0.276	2.040**	0.280	2.010**
Female	0.257	1.270	0.269	1.270
Education	0.077	1.260	0.065	0.970
Income	0.000	–1.890*	0.000	–1.510
Intercept	–0.701	–0.600	2.024	1.250
Observations	232		232	
Log likelihood	–298.38		–299.81	
AIC	618.76		623.63	
LR statistic	92.25 (vs. Poisson model)		22.12 (vs. pooled model)	
Predicted number of planned reef trips at q_0			2.82	
Predicted number of planned reef trips at q_1			0.56	

† Dependent variable is the planned number of recreational reef trips (five years).
**P* < 0.1; ***P* < 0.05; ****P* < 0.01.

Table 3 shows the estimation results for the NB pooled and NB random effects panel model. A likelihood ratio (LR) test, as proposed by Cameron and Trivedi (1990), is used to test whether parameter α (Equation 3) is zero, in which case no overdispersion is present and the Poisson model can be used. The LR-statistic of 92.25 in the pooled NB model indicates that $\alpha \neq 0$ and that the use of a Poisson model is incorrect. STATA also reports the LR test of the appropriateness of the random effects specification vs. the pooled model. The LR-statistic of 22.12 suggests that the random effects panel model is superior to the pooled model.

Most of the estimated coefficients in the random effects panel specification have the expected sign. The price of a reef trip is negatively and significantly correlated to the number of planned reef trips, indicating that fewer trips are made at higher prices. The coefficient of reef quality is negative and significant, indicating that fewer trips are made when reef quality declines. As expected, respondents who live closer to the GBR – from Australia and especially from Queensland – are likely to make more reef trips than overseas reef visitors. Divers are also likely to make more reef trips than snorkellers. The perception of coral quality is positively correlated with reef trip demand, indicating that reef visitors who rate current reef quality higher are likely to visit the reef more often. Although the income variable is hypothesised to be positively correlated with reef trip demand its estimated coefficient is found to be negative but insignificant. Other recreation studies (Park *et al.* 2002; Bhat

2003) have found similar insignificant coefficients for income. The variables for gender and education are not significant at the 90 per cent confidence level. However, as estimating the model without these variables does not lead to a significantly better model, all variables are included in the analysis.

5.2 Welfare estimates

The reef trip demand at current and degraded quality can be estimated using the NB random effects panel specification for planned trips at q_0 and planned trips at q_1. This involves evaluating the model at the sample means (Table 2) and DumQ at zero and one, respectively. The visit rate of divers and snorkellers is estimated to decrease by about 80 per cent if reef quality declines to levels presented in the survey; from a predicted 2.82 number of reef trips at current reef quality to 0.56 reef trips per respondent at degraded quality. Note that these predicted values are similar to the observed number of planned trips in the sample, strengthening trust in the model.

Using Equations (5) and (6) and the estimated change in reef trip demand, it is possible to estimate the change in welfare resulting from reef quality decline, as measured by the consumer surplus (CS). With the estimated coefficient on reef trip price $\beta_p = -0.0054$, the CS per recreational reef trip for an average diver or snorkeller is A$184.84 (Table 4). This estimate is in line with Brander *et al.* (2007), who estimate the average value of coral reef recreation at 184 US$ (approximately A$240) per visit. Estimates by Leeworthy

Table 4 Welfare estimates from recreational demand changes under GBR quality decline

Estimate	Current reef quality	Degraded reef quality
Per person number of planned reef trips (#/5 years)	2.82	0.56
CS per person-trip (A$/trip)	184.84	
CS per person-year (A$/year)	104.14	20.67
Total number of full-day reef trips (thousands/year)†		
Port Douglas‡	258	51
Cairns management area§	792	157
Entire GBR Marine Park	1541	305
Total CS derived from reef trips (million A$/year)¶		
Port Douglas	48	9
Cairns management area	146	29
Entire GBR Marine Park	285	56
Total expenditure on full-day reef trips (million A$/year)††		
Port Douglas	42	8
Cairns management area	129	26
Entire GBR Marine Park	250	50

† Total at q_0 based on GBRMPA Environmental Management Charge data 1994–2003.
‡ Total number of full-day reef visits on commercial vessels departing Port Douglas.
§ Total number of full-day reef visits on commercial vessels in the Cairns management area of the GBR Marine Park (Figure 1).
¶ Estimates based on the Negative Binomial model results.
†† Estimated for full-day reef visits at the sample median price of A$162.50.

and Bowker (1997) and Park *et al.* (2002) are substantially higher than our estimate. Leeworthy and Bowker report an average value of 653 US$ (approximately A$880) per person-trip to the Florida Keys, whereas Park *et al.* find an average per person value for snorkelling trips in the Florida Keys of 481 US$ (approximately A$650). However, these results include the features of the whole Florida Keys region, which is likely to lead to a higher value estimate than when only coral reef sites are considered.

Our results indicate that the number of full-day reef trips on commercial vessels by divers and snorkellers in Port Douglas could decrease from an average annual 258 000 full-day reef trips to 51 000 reef trips per year, were reef quality to decline. Assuming that our results hold for the complete Cairns management area of the GBR Marine Park, the number of annual full-day reef trips on commercial vessels in the Cairns management area could decrease from 792 000 to 157 000 visits. A crude extrapolation of these results to all divers and snorkellers in the GBR Marine Park shows that the average number of full-day reef trips could decrease from 1.54 million to 305 thousand visits per year, if the quality of the entire GBR would decline to the levels presented in the survey. Extrapolation of these results should be interpreted with care, as respondents may have answered the survey with potential substitute sites elsewhere in the GBR region in mind. As a result, the estimates presented here should be interpreted as an upper boundary of the overall effect on GBR visitation.

The CS that current divers and snorkellers in Port Douglas derive from full-day reef visits can be calculated by multiplying the CS per trip with the total number of full-day reef trips. This gives a current annual CS for reef visitors in Port Douglas of approximately A$48 million. If the number of full-day diving and snorkelling trips falls, total annual CS is estimated to decrease to A$9 million – a reduction of nearly AUD 39 million per year (Table 4). The total annual CS in the GBR Cairns management area could reduce by as much as A$117 million if full-day reef visits were to decrease. Applying these results to the total number of annual full-day reef visits to the GBR Marine Park, the CS that divers and snorkellers derive from visiting the GBR Marine Park could decrease from A$285 million to A$56 million per year.

The income effects for the diving and snorkelling industry can be calculated by multiplying the reduction in the number of annual reef visitors with the median price these visitors pay per reef trip. At a median price of A$162.50 the decline in demand will lead to a decrease in expenditure on diving and snorkelling trips in Port Douglas of more than A$33 million per year, which accrues as a potential loss to the local reef-tourism industry. Extrapolation to the Cairns management area indicates a potential decrease in annual expenditure on full-day reef visits of A$103 million. Note that these estimates are based on the changes in behaviour of current reef visitors. If the GBR will continue to attract new reef visitors in the future, the estimated decrease in CS and expenditure will, most likely, be smaller.

6. Discussion and conclusions

This research responds to the need for economic valuation of coral reef damage indicated by Wielgus *et al*. (2002) and the State of Queensland and Commonwealth of Australia (2003). The study is the first to employ the CB approach to estimate a demand function for diving and snorkelling trips to the GBR and the first to assess the effects of reef quality *decline* on recreation by divers and snorkellers. A general concern about CB models is whether intended trips are a robust indicator of actual trips, should the environmental change described to respondents actually occur (Hanley *et al*. 2003). The validity of CB responses has been tested by Loomis (1993), using a test-retest analysis of recreational visits. The study finds no statistical difference between actual and intended behaviour. Two more recent studies (Haener *et al*. 2001; Grijalva *et al*. 2002) also test whether stated preference answers reflect actual behaviour. The results of both studies indicate that CB is an appropriate indicator of actual recreation choices. Assuming that this also holds for reef visits, the intended number of reef trips at a specific reef quality is a valid measure of the actual number of trips were the described circumstances to occur.

A NB regression model is estimated in a random effects panel format. This specification accounts for overdispersion in the data, arising from the large number of zero trips under a reef quality decline scenario. The panel format eliminates unobserved individual heterogeneity that may affect the number of planned reef trips. The dependent variable in our model is the number of recreational diving and snorkelling trips planned for the next five years at current and degraded reef qualities. Using planned reef visits, rather than a combined RP-SP approach, reduces estimation bias towards current conditions.

Model results are used to estimate a consumer surplus (CS) per reef trip of nearly AUD 185. It is shown that a hypothetical reduction in fish abundance, coral cover and coral diversity of 80, 30 and 70 per cent, respectively, may lead to an 80 per cent decrease in the number of reef trips taken by divers and snorkellers. This equates to a decrease in the total CS that current divers and snorkellers in Port Douglas derive from reef trips of approximately A$39 million per year; from A$48 million to A$9 million. Extrapolation to the wider GBR region shows that the reduction in total annual diving and snorkelling CS could amount to as much as A$117 in the Cairns management area or A$228 in the total GBR Marine Park. Reduced demand for reef trips leads to a decrease in diving and snorkelling expenditure in Port Douglas of some A$34 million per year. If reef trip demand would decrease by 80 per cent in the whole Cairns management area or even the entire GBR Marine Park, reef trip expenditure on commercial vessels could fall by up to A$200 million per year. This study does not estimate the possible flow-on effects of a reduction in the number of reef trips on other parts of the tourism sector. But as 35 per cent of the respondents state that they would not visit the region when the quality of the GBR would decline, flow-on effects will be considerable, affecting tourism sectors other than the diving and snorkelling operators as well.

The results are based on a limited number of interviews with divers and snorkellers in Port Douglas. It is likely that coral reef quality and characteristics of divers and snorkellers vary between different sections of the GBR Marine Park. Although the estimated welfare effects have been extrapolated to the Cairns management area and the entire GBR Marine Park, results should be interpreted cautiously. In our extrapolation, it is assumed that respondents do not visit other, substitute regions in the GBR, were reef quality to decline. However, it may be the case that respondents answered the survey with substitute regions in mind, which would lead to an overestimate of the reduction in visitation to the GBR. Moreover, the results reported in this article are based on the change in recreational behaviour of *current* divers and snorkellers in Port Douglas. The likelihood that new reef visitors will continue to visit the GBR is not accounted for in our estimates. Such new visitors will limit the decline in total reef trip demand as estimated in this study.[4] It should also be noted that the estimated CS relates to GBR diving or snorkelling trips only and does not incorporate recreational values derived from other features of the Great Barrier Reef region.

The estimate of expenditure on full-day reef trips at current quality equals about A$250 million for the entire GBR region. This is a low estimate as compared to results presented in KPMG (2000), who estimate total annual expenditure for reef trips at A$454 million, and results of Carr and Mendelsohn (2003), who estimate a use value for the whole GBR region of between US$700 million (A$895 million) and US$1.6 billion (A$2.0 billion). These results are, however, based on all visitors to the GBR region including the full costs associated with travelling to the region. Consequently, their results can not be seen as the value of reef recreation alone. The recreational values of the GBR estimated in this study are based on the costs of a full-day reef trip – the full recreational value associated with GBR trips should include additional travel and accommodation costs. When these additional costs would be included, estimates of CS are likely to be significantly higher.

With increasing evidence that the coral reefs of the GBR are degrading, establishing non-market values of the reef is gaining importance. The results of the research presented in this article are a valuable input in evaluating the effects of policy measures that influence reef quality and can be used to assess the overall cost effectiveness of coral reef management programs. Further research is desirable to estimate how reef trip demand is related to marginal changes in reef quality. Also, to fully consider the total economic value of the GBR it is necessary to extend the valuation to include (i) additional travel costs associated with reef visitation to estimate full consumer surplus, (ii) more sample locations and periods to include a wider variety of GBR visitors and to address possible confounding effects of substitute sites, (iii) economic sectors other than the diving and snorkelling industry alone,

[4] Note that the CS new divers and snorkellers derive from their reef visit may be lower at degraded reef quality than our estimated A$185 per trip.

and (iv) non-use values of the reef using non-market valuation approaches like contingent valuation or choice experiments.

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