Title: **Effects of Great Barrier Reef degradation on recreational demand: a contingent behaviour approach.**

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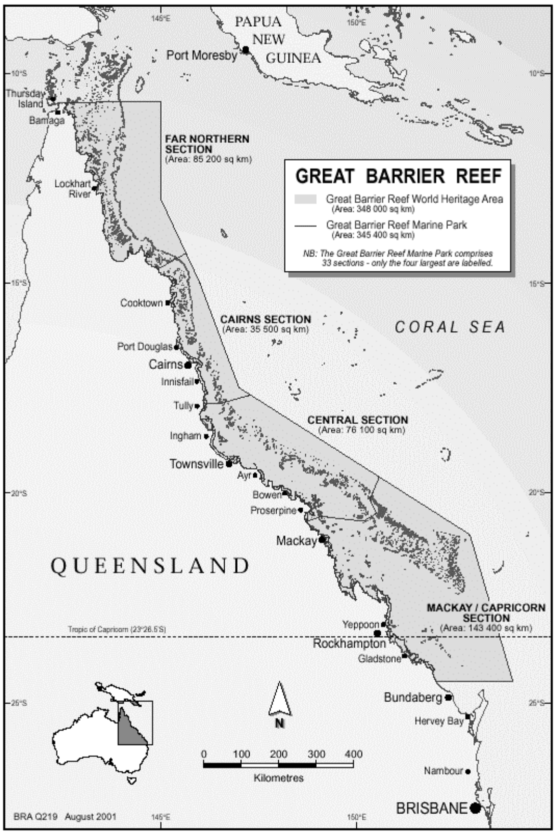
Effects of Great Barrier Reef degradation on recreational demand: a contingent behaviour approach.

1. Introduction.

The Great Barrier Reef (GBR) is the world's largest coral reef ecosystem, worldwide known for its aesthetic beauty. Next to its ecological significance, the GBR is of economic importance for the industries operating in the area, of which the tourism industry is the most important. The GBR attracts about 1.6 million reef visitors each year (GBRMPA, 2004) and the tourism sector provides more employment than any other industry in the GBR Catchment Area (Productivity Commission, 2003).

Figure 1. The Great Barrier Reef World Heritage Area.



Source: Great Barrier Reef Marine Park Authority.

Increased agricultural activity in the GBR Catchment Area has increased sediment and nutrient levels in river discharges into the GBR (ISRS, 2004). There is increasing evidence that this causes a decline in reef quality. As the reef-tourism industry relies on healthy coral reefs for its income generation, reef degradation can have negative effects on the profits made by the reef-tourism sector. Nevertheless, the relationship between reef-tourism demand and reef quality remains unknown (Wielgus et al, 2002).

The objective of this paper is to estimate to what extent a decline in the quality of the GBR influences the demand for recreational reef trips by divers and snorkellers. The relationship between reef-trip demand and reef quality is shown to be more complex than the usually assumed 1:1 relationship (Ruitenbeek and Cartier, 1999). Measuring demand changes not only provides insight into the welfare effects for reef visitors, but also allows for an estimation of the income effects for the reef-tourism industry. Economic valuation of these welfare effects is needed to improve the development of efficient management policies in the Great Barrier Reef Catchment Area (State of Queensland and Commonwealth of Australia, 2003).

This study combines actual (revealed) and stated preference data of reef-trip demand from a Contingent Behaviour survey in a model for reef recreation[1]. A Negative Binomial model is used to analyse demand for recreational reef-trips of current visitors to the GBR, conditional to a hypothetical decline in reef quality. This study is the first to apply a combination of revealed and stated preference techniques to analyse how reef visits are related to reef degradation.

The paper is organised in six sections. The following section explains how agricultural activities may affect water quality in the Great Barrier Reef Marine Park. Section three provides an introduction to the demand model for recreational reef-trips and the econometric count model that is used to analyse reef-trip demand. In section four, we present the contingent behaviour survey. Section five presents and analyses the results of the reef-trip demand model and the welfare estimates related to GBR quality decline. The paper concludes with a discussion of the welfare effects of reef degradation on current visitors and the reef-tourism industry.

2. Agriculture and reef quality.

River discharges from rivers flowing in the GBR catchment area influence water quality by carrying sediments and nutrients into the Great Barrier Reef World Heritage Area. Expanding agriculture in the GBR catchment area has caused a

[1] 'Reef recreation' covers tourists who take a reef-trip with commercial operators to the GBR Marine Park for diving or snorkelling purposes.

substantial increase in the export of sediments and nutrients over the last 150 years. The estimated increase in sediment and nutrient loads in river runoff lies between 3 and 8 times for sediment, between 2 and 4 times for nitrogen and between 3 and 15 times for phosphorus (Furnas, 2003). Grazing areas are estimated to account for 66% of the sediment and nutrients loads in river discharges (GBRMPA, 2003) and sugarcane farming is contributing potentially 25% of additional nitrogen loads to the GBR, primarily through extensive use of inorganic fertilisers and removal of vegetation (Haynes, 2001). It has been observed that nutrient concentrations are up to 3 to 50 times higher in river discharges from catchments with substantial agriculture and urban development when compared to relatively pristine catchments (Wachenfeld *et al.*, 1998).

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). Effects of increased nutrient and sediment concentrations in river runoff on coral reef ecosystems include an increase in algal-dominated reefs; reduced amount of living coral; increased vulnerability to Crown-of-Thorns starfish 'attacks' (Brodie *et al.*, 2005); decreased reproductive capacity of coral, leading to lower recruitment rates; and reductions in both coral and fish biodiversity (Fabricius *et al*, 2005).

3. A demand model for reef trips.

According to microeconomic theory, an individual i (i = 1,2,…,N) maximises utility from consumption, subject to budget and time constraints (Freeman, 1993). In the context of reef recreation, utility u_i is derived from the number of recreational reef trips y_i^q at reef quality q, a vector of other goods and services $\boldsymbol{Z}_i$, and reef quality q itself. We define reef quality in such a way that $q = 0$ for current quality and $q = 1$ for degraded quality. The indirect utility function can be defined as:

$$v_i = \max_{y,z}[u_i(y_i^q, Z_i, q, m_i, \eta_i)] \qquad (1)$$

$$\text{subject to:} \qquad m_i = y_i^q p_y + Z_i$$

where v_i is the i^{th} individual's indirect utility function, p_y is the price of a reef trip, and m_i is household income. Unobservable individual factors are included in η_i, which is a random error distribution with zero mean.

The number of recreational reef trips y_i^q contributes to the use-value the visitor attaches to the reef, measured by the consumer surplus (CS). Assuming that all other variables are held constant, demand for recreational reef trips will go down if reef quality q declines, causing a decline in net consumer surplus. As reef quality also enters the utility function $u_i(.)$ directly, reef quality also contributes 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)[2]. Thus, expenses on reef trips are no weak complement for the total economic value of the reef and the values measured in this study comprise only part of the total value of the reef.

The demand function for recreational reef trips is specified as:

$$\ln(y_i^q) = c + \beta_k X_{ik} + \varepsilon_i \qquad (2)$$

which is a log-linear demand function with X_{ik} (k = 1,2,…,K) representing the independent variables including reef quality q and trip price p_y; β_k are the corresponding regression coefficients; and ε_i is a random error term for individual differences that follows a gamma distribution with mean 1 and variance σ.

The consumer surplus associated with recreational trips to the reef is equal to the area below the inverse demand function and above the implicit price of a reef-trip p_0. Let β_{price} be the coefficient of the reef-trip price variable and λ^q the mean number of reef trips for all individuals at price p_y, then the CS at reef quality q, which follows from demand function (2), is given by

$$CS_i^q = \int_{p_c^q}^{p_0} \lambda^q(p_y)\,dp_y = \frac{\lambda^q(p_0)}{\beta_{price}} \qquad (3)$$

where p_0 is the current price of a reef trip at reef quality *q=0 and where* p_c^q is the choke price at which an individual does not take any reef trips at quality q. Individual CS can be estimated with equation (3) by substituting for $\lambda^q(p_y)$ the number of trips y_i^q that the individual makes (Bhat, 2003).

If reef quality declines, the loss of an individual's use value from the quality decline can be measured as the change in CS (Whitehead et al.,2000):

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2 The fact that reef quality directly enters the utility function $u_i(.)$ implies that an individual i will attach some non-use value to the GBR even when he or she does not visit the reef. There are no complete markets in which transactions express the non-use values of the GBR. Non-use values can be estimated through a Contingent Valuation study, which is beyond the scope of this paper. For a more detailed discussion of use and non-use values of coral reefs see Spurgeon (1992).

$$\Delta CS = \int_{p_c^{q=1}}^{p_0} \lambda^{q=1}(p_y)dp_y - \int_{p_c^{q=0}}^{p_0} \lambda^{q=0}(p_y)dp_y = \frac{\lambda^{q=1}(p_0) - \lambda^{q=0}(p_0)}{\beta_{price}} \tag{4}$$

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, and β_{price} is the coefficient of the reef-trip price variable in the demand model.

Dependent variable y_i^q has a discrete distribution, and is limited to non-negative values. The distribution of data on reef-trip recreation is positively skewed with many observations in the data set having a value of zero. This skewed error distribution rejects the use of a standard ordinary linear regression (OLS) model, which assumes a normal error distribution. A more appropriate specification of recreational demand data is provided by a Negative Binomial data regression model (Loomis, 2002; Park et al., 2002; Shrestha et al., 2002). This type of model follows a skewed instead of a normal, probability distribution (Grace-Martin, 2000) and is restricted to nonnegative values. In particular, the Negative Binomial probability function is given by (Haab and McConnell, 2002)

$$\Pr(y_i^q = \hat{y}_i^q) = \frac{\Gamma(\hat{y}_i^q + 1/\alpha)}{\Gamma(\hat{y}_i^q + 1)\cdot\Gamma(1/\alpha)} \left(\frac{1/\alpha}{1/\alpha + \lambda^q}\right)^{\frac{1}{\alpha}} \left(\frac{\lambda^q}{1/\alpha + \lambda^q}\right)^{y_{iq}} \tag{6}$$

where $\hat{y}_i^q$ is the given number of recreational reef-trips individual i makes to the reef and Γ is a gamma discrete probability density function defined for y_i^q (Shrestha et al., 2002) and where α is the overdispersion parameter. The mean number of trips at quality q is given by λ^q, and the variance is equal to $\lambda^q + \alpha(\lambda^q)^2$. The gamma distributed error term allows for overdispersion in the data set. The Negative Binomial model assumes the log of mean demand λ^q to be a linear function of the independent variables, implicitly determining a log-linear function.

4. Contingent Behaviour survey.

This study estimates the changes in reef-trip demand resulting from a quality decline of the GBR using a stated preference approach. An advantage of this approach is that it can be applied to site quality changes that are currently outside the range of observed qualities. As degradation of GBR sites has not been historically documented, this study uses a Contingent Behaviour (CB) approach to derive the demand function for recreational trips to the GBR. The CB approach has recently been employed by

Richardson and Loomis (2004) to analyse the effects of climate change on recreation. Bhat (2003) and Hanley et al. (2003) have also successfully combined revealed and contingent data on recreational behaviour in a single model, focussing on a change in environmental quality.

Data have been collected through on-site interviews with GBR visitors in Port Douglas[3]. The survey was conducted in September 2004 on board of commercial tourism vessels. Interviews were directed at divers and snorkellers during their day-trip to the GBR in order to obtain information on their current number of recreational reef-trips and the number of reef-trips planned for the coming 5 years[4]. Respondents also identified the maximum price they were willing to pay before they would cease visiting the GBR, allowing an estimation of the choke price for reef-trip demand.

Respondents were presented with a reef degradation scenario[5] and were asked if they would change their number of reef-trips in the coming 5 years would reef degradation occur. The answers to these CB questions were pooled with the data on current reef-trip demand and used to develop a demand model for recreational reef trips. The contingent scenario was based on scientific evidence that coral cover, coral biodiversity and fish biodiversity generally declines when moving from a pristine, undisturbed reef to a reef that has been exposed to pollution. The decline in coral cover, coral diversity and fish diversity in the CB scenario was approximately 80%, 30% and 70% respectively.

The survey yielded 176 suitable interviews. Descriptive statistics of the interviews are provided in Table 1. Most respondents (59%) came to the Port Douglas region with the primary purpose of seeing the reef. The number of recreational reef-trips that the average respondent makes to the GBR this year is 1.4 trips. 64% of the respondents are planning to make more trips in the coming 5 years. Including the number of planned trips at current quality q=0, an average respondent would make 3.8 trips in 6 years or 0.64 trips per year. If reef quality would decline as presented in the CB scenario, 76% of the respondents would make fewer reef-trips and 35% of the visitors

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

[4] A period of 5 years was assumed to be a reasonable time frame for tourists to giver reliable estimates of future visits.

[5] The scenario included two picture sets provided by Dr. K. Fabricius, Australian Institute of Marine Science. The first picture set corresponded to the current quality of the GBR, while the second set represented possible future decline of GBR quality.

would not come back to the Port Douglas region at all. At reef quality q=1, the number of reef trips equals 1.6 trips in 6 years or 0.26 trips per year.

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

Variable	% of sample
Gender	
Male	57
Female	43
Origin	
Queensland	7
Rest of Australia	38
Europe	31
USA/Canada	13
Reef activity	
Diving	33
Snorkelling	67
Reef as a primary reason to come to Port Douglas	59
Making one trip this year	77
Planning to come back in the coming 5 years	64
Would make the same number of trips at q=1	19
Would make fewer trips at q=1	76
Would not come back to the region at q=1	35
Median price for a full-day reef-trip (A$)	150
Maximum willingness to pay for a full-day reef-trip at current quality q=0 (A$)	237

5. Results of the reef-trip demand model.

Data about actual and contingent recreational behaviour are combined in a single equation to estimate the demand function for reef trips. The data are pooled, providing three observations for each respondent (current visits and planned visits at q=0 and planned visits at q=1). This leads to a total of 416 observations. EViews4 is used to estimate demand function (4) in a Negative Binomial model.

Table 2. Negative Binomial model for Great Barrier Reef trip demand.*

Variable	Full model		Reduced model	
	Regression coefficient	z-statistic	Regression coefficient	z-statistic
Intercept	1.152	2.331	1.405	0.456
Price	-0.016	-10.164	-0.016	0.002
DumQ	-0.307	-2.704	-0.309	0.114
DumAUS	0.220	1.831	0.210	0.118
DumQLD	0.870	4.693	0.848	0.185
Perception	0.289	3.061	0.284	0.095
Diver	1.482	10.756	1.451	0.139
Gender	0.177	1.604		
Education	0.068	1.352		
Household	0.131	2.677	0.113	0.047
Income	-0.036	-1.096		
Adjusted R^2	0.42		0.42	
Log likelihood	-646.47		-655.46	
LR statistic	1106.43		1101.06	
Observations	414		416	

*Dependent variable: Number of recreational reef trips (total period of 6 years).

Table 2 shows the estimation results of the Negative Binomial model including and excluding the redundant variables. Price of a reef trip (Price) is negatively and significantly correlated to the number of per person reef trips (Demand), indicating that fewer trips are taken at increased prices. The coefficient of reef quality decline (DumQ = 0 for current quality and 1 for degraded quality) is negative and significant, indicating that fewer trips are made when reef quality declines. The results show that visitors from Australia (DumAUS=1) and especially from Queensland (DumQLD=1) are likely to make more reef trips than overseas visitors. Divers are also likely to make more reef trips than visitors who go on a snorkelling trip. The perception of coral quality[6] is positively correlated with reef-trip demand, indicating that visitors who are satisfied with the reef are likely to visit the reef more often. The coefficient for household size is positive, which is unexpected as it means that larger households will take more reef trips even though total household costs will be larger than for smaller households. The household coefficient is, however, not significant at a 95% confidence level. A redundant variables test for the variables Gender, Education and Income[7] shows that these variables were not significant at a 90% confidence level and can be excluded from the model. Other recreation studies (see, for example Park et al., 2002 and Bhat, 2003) have also found insignificant coefficients for the variable Income.

The Negative Binomial model determines the reef trip demand at current and degraded quality with DumQ set at zero and one respectively. The GBR visit rate is shown to decrease with 59% if reef quality declines: from a yearly average of 0.64 trips to 0.26 reef trips per respondent. Using this decline in reef-trip demand and β_{price} = -0.016 in equation (4) shows an average annual decline in CS of A$ 23.5 per visitor (from A$ 39.8 to A$ 16.3). A 59% reduction in demand will lead to a decline in the number of GBR visitors from an annual 1.54 million[8] to 0.63 million full-day reef visitors. Multiplying the CS per trip with the total number of current reef visitors, gives an annual CS for all current GBR visitors of A$ 96 million. If the number of reef-trips falls, total annual CS of GBR visitors decreases with nearly A$ 57 million, to an annual A$ 40 million (Table 3).

Table 3. Welfare estimates from recreational demand changes under GBR quality decline.

Estimate	Current reef quality	Degraded reef quality
Number of reef trips per person per year (#/yr).	0.64	0.26
Number of GBR visitors (million/yr).	1.54	0.63
Consumer surplus per person-trip (A$/trip)	62.50	

[6] Measured on a 5-point Likert scale with 1 = very bad to 5 = very good.
[7] Measured as net monthly income from seven income categories ranging from A$ 0-1.000 to A$ 10.000 and over.
[8] Average number of reef visitors on full-day reef trips derived from GBRMPA Environmental Management Charge data from 1994-2003 (GBRMPA, 2004).

Consumer surplus per person-year (A$/year)	39.79	16.25
Total consumer surplus for all GBR visitors (million A$/yr)	96.35	39.60
Total tourism expenditure on reef trips (million A$/yr)	231	95

Additionally, the financial consequences for the tourism industry can be calculated by multiplying the reduction in annual reef-visitor numbers with the median price these visitors pay for a reef-trip. When taking the median price of A$ 150 the decline in demand will lead to a decrease in tourism expenditure A$ 136 million per year, which accrues as a potential profit loss to the reef-tourism industry.

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). This paper is the first to combine actual and contingent behaviour data to estimate a demand function for recreational reef-trips to the Great Barrier Reef (GBR) and to assess the effects of environmental degradation on reef-trip demand by divers and snorkellers. This is a viable approach for reef quality changes that are outside the range of currently observed conditions. The use of a Negative Binominal - instead of an OLS - demand model recognises that recreational GBR trips are measured as count data.

Results from the model show that the CS per person is A$ 62.5 per reef-trip, or an annual A$ 96 million for all current GBR visitors. Hypothetical reductions in coral cover, coral diversity and fish diversity of 80%, 30% and 70% respectively, are shown to lead to a 59% decrease in the number of reef-trips taken by divers and snorkellers (i.e. from 0.64 to 0.26 reef trips per visitor per year). This equates to an annual decrease in CS for current reef visitors of A$ 23.5 per person or nearly A$ 57 million for all current GBR visitors.

The estimates of a consumer surplus of A$ 62.5 per person per trip are in line with the estimates of Park et al. (2002) and Bhat (2003), who find a user value of reef trips of respectively US$ 43 (A$ 55) and US$ 122 (A$ 158) per person per trip to the Marine Park of the Florida Keys. Carr and Mendelsohn (2003) employ a travel cost method to estimate the use value of visitors to the whole GBR region. They present an annual recreational value of the GBR that ranges from US$ 700 million to US$ 1.6

billion. However, these estimates disregard the fact that not all visitor to the GBR region are necessarily attracted by the GBR and therefore don't represent the value of the reef.

Furthermore, our results indicate that the 59% reduction in reef-trip demand leads to a reduction in reef-tourism expenditure of some A$ 136 million per year, accruing as a potential profit loss to the reef-tourism industry. It should be noted, however, that our research does not estimate the flow-on effects of a decline in the number of reef trips. As 35% 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 reef-tourism industry as well.

A general concern about contingent behaviour models is whether intended trips are a robust indicator of actual trips, should the reef degradation described to respondents actually occur (Hanley et al., 2003). Several papers have been published that test the validity of contingent behaviour responses. Loomis (1993) uses a test-retest analysis of recreational visits and finds no statistical difference between actual and intended behaviour. Two more recent studies (Grijalva et al., 2002; Haener et al., 2001) also test whether stated preference answers reflect actual behaviour. The results of both reports indicate that contingent behaviour is an appropriate indicator of actual recreation choices. When this also holds for reef visits, the intended number of reef trips at a specific reef quality will be a valid measure of the actual number of trips under the described circumstances.

With increasing evidence that the coral reefs of the GBR are degrading due to increased human activities in the GBR catchment area, establishing non-market values of the reef is gaining importance. The results of this research will be a valuable input in evaluating the effects of policy measures that influence activities in the GBR catchment area and can be used to assess the overall cost effectiveness of policy programmes. However, the quantitative linkages between agricultural practises and reef quality remain unclear. Therefore, further research is required to link changes in agricultural activities in the Catchment Area to changes in downstream water quality and consequently, to changes in reef quality.

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