Bioeconomic Modelling Component

Assessing the community benefits for pollutant reductions

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1. Introduction

The decline in the health of the Great Barrier Reef (GBR) due to poor water quality, from nutrient and sediment pollutants, has resulted in on-ground improved management practices being a priority issue for improved water quality (Carroll *et al.*, 2012). In response to a scientific consensus in 2008 regarding the declining health of the Great Barrier Reef, the GBR Water Quality Protection Plan (Reef Plan), a federal and state initiative, was updated in 2013 (Queensland., 2009). Sugarcane and grazing are the key industries adjacent to the reef, and are large emitters of nutrient (sugarcane) and sediment (grazing) pollutants, which have been identified as bleaching coral and smothering light for coral photosynthesis. The Reef Plan determined targets and listed a series of actions to be achieved, including a 20% reduction in sediment by 2020 and a 50% reduction in nutrient by 2018 (Queensland 2013).

Water Quality Improvement Plans (WQIP) across all catchments adjacent to the reef are in the process of completing individual WQIPs to ensure a clear focus for management and process to achieve targets. For the purposes of the Fitzroy Basin Association (FBA) WQIP the targets align with the Reef Plan targets of the 20% reduction in sediments and a 50% to align targeting of public funds and programs to one overarching target.

A key issue for the WQIP is to determine if the public benefits of reducing agricultural emissions to achieve the targets are sufficiently large to outweigh the costs involved. However, while significant public funds (Reef Rescue contributed $200 million to on-ground best management practices over the past five years, and QLD government contributed $175 million for a series of programs) are being allocated to achieving improved water quality outcomes through changed management practices.

There are currently key deficiencies in knowledge required to ensure targeted and efficient allocation of funds to achieve the targets. Firstly, the link needs to be established between any marginal reductions in pollutants and subsequent improvements in inshore reef health so that the environmental benefits from changing management practices can be identified (Rolfe and Windle, 2011a). Secondly, the costs associated with changing management practices and the subsequent sediment reductions need to be estimated. Thirdly, values are needed for those benefits so that they can be compared with the net costs of making management changes.

The aim of this report is to estimate values for the benefits of improved inshore reef health from sediment and nutrient reductions aligned with the WQIP. Through conducting a choice modelling experiment the report aims to understand three different aspects of community values. Firstly, the differences in values between the Brisbane population and coastal populations. Secondly, the impact on values depending what industry such as from the grazing or sugar industry, and thirdly the impact of values from sediment and nutrient reductions. The results contribute to the policy framework by estimating the public benefits of achieving improved inshore reef health through sediment and nutrient reduction targets from Reef Plan.

2. Choice Modelling

2.1. Theoretical Framework

Choice modelling (CM), also known as choice experiments and choice-based conjoin analysis, involves deriving responses to predefined alternatives (Boxall *et al.* 1996). It involves people choosing between different products (Adamonwicz *et al.* 1998). Using key product characteristics, variables or attributes in experimental design, the methodology formulates alternative product scenarios. Statistical methods are then used to value preferred attributes and simulate preferences, choices or value options (Bennett and Blamey 2001).

Sustainability has been defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs. This would be satisfied by maintaining welfare into the future (Randall 2007). Welfare refers to the level of utility or satisfaction an individual consumer gains from a commodity or basket of commodities, and is described as the concept of satisfaction.

The information obtained from CM includes the attributes that determine the values that people place on non-market goods, the ranking of these attributes within the relevant population, the value of changing a bundle of attributes all together and the changes to the TEV of the good (Adamowicz *et al.* 1998).

There are four ways in which preferences can be measured through different types of stated preference experiments:

1. contingent rating: a series of alternatives are to be rated; however, careful design is required to determine consistent welfare estimates,
2. contingent ranking: the respondent is required to rank scenarios on a scale of one to ten,
3. paired comparisons: the respondent is presented with pairs of scenarios on a similar scale to choose between and
4. choice modelling: where the respondent is required to select between two or more alternatives (where one is the status quo).

These techniques differ in their ability to provide quality welfare estimates and in their degree of complexity.

In CM, the respondent is presented with a series of choices described by attributes, levels and labels. One alternative in each choice set is the ‘status quo’ option or business-as-usual scenario. The respondent is then asked to select their preferred choice. The utility function consists of two components: the function of the attributes of the good and the unobservable influences on personal choice. The characteristics of the good described through use of also influence choice, and this may be quantified in the analysis (Pearce *et al.* 2006).

To create a choice experiment there are several steps (Figure 1):

- Firstly, the attributes of the good being valued must be determined through a literature review and focus groups. This involves understanding the impact of the prospective policy. Usually a monetary trade-off is included to allow the willingness to pay (WTP) to be derived.
- Secondly, the attribute levels are assigned. These should be assigned non-linearly, spaced between the maximum value and the minimum. The levels must also be realistic, and span the range of respondents’ preference maps as determined through attributes allow for the respondent’s utility for the good to be derived. For example, if a respondent prefers option A to alternative options, this can be expressed as the probability that the utility associated with option A exceeds all other options. Socio-economic factors may consultation with focus groups and the literature review. The business-as-usual or status quo scenario is also included.
- Thirdly, the experimental design is then selected. Statistical design theory is used to The construction of the choice set is the next step in the process. The splits that are determined by the experimental design are then grouped together and presented to respondents combine the levels of the attributes into a number of alternate scenarios presented to the respondent. Approaches include factorial design, fractional-factorial design and efficient design.

The construction of the choice set is the next step in the process. The splits that are determined by the experimental design are then grouped together and presented to respondents.

Figure 1: Choice modelling steps.

Once completed, the respondents' preferences or values must be measured. Preferences can be measured through ranking or rating or choices. A statistical estimation procedure is then implemented to determine the part-worth or marginal change in WTP for the good in question.

The theoretical basis for CM is the random utility model (RUM) (Train 2009). The RUM is based on the researcher only being able to observe part of the respondent's utilities. The unobserved component is taken to be randomly distributed. Under the RUM, U_{an}, utility that the respondent *n* enjoys from choice alternative *a* can be described by:

$$U_{an} = V_{an} + E_{an} \qquad \text{(Equation1)}$$

Where V_{an} is the deterministic observable component of the utility that respondent *n* has for option *a*. E_{an} is the stochastic unobserved component of the utility associated with option *a* and consumer *n*.

The observed component (V_{an}) is a function of the attributes Z_{an} and of individual characteristics S_n and a set of unknown parameters (Rolfe et al. 2000).

$$U_{an} = u\,(Z_{an}, S_n) + E_{an} \qquad \text{(Equation 2)}$$

Due to the random component, utilities can never exactly be determined. However, what can be concluded is that if respondent *n* chooses from choice set C_n, then it is probable that the deterministic and stochastic components of that option are greater than the deterministic and stochastic components of the other option *j* in the same choice set. This can be expressed as:

$$P(a/C_n) = P((V_{an} + E_{an}) > (V_{jn} + E_{jn})) \text{ for } j \text{ options in a choice set } C_n,\ a \neq j \qquad \text{(Equation 3)}$$

The greater the difference in observed utility, the greater the probability of choosing alternative *a*. As the distribution of the random component is unknown, in order to estimate the probabilities, assumptions regarding the distribution of the random component must be made. The standard assumption is that the *E* terms are independently and identically distributed Gambel random variables that lead to binary or multinomial logit models (MNL) (Train 2009).

Under this assumption, the probability that an individual *n* chooses alternative *a* over *j* can be represented as:

$P_a / C_n = exp\ (\lambda\ x_{an}) / \sum exp\ (\lambda\ x_{aj})$ for all *j* choice *C*; (Equation 4)

Where *λ* is a scale parameter which is usually normalised to one. The scale parameter is inversely proportional to the standard deviation of the error distribution (Rolfe et al. 2000). The MNL model generates a utility function of the form:

$V_{an} = \beta_a + \sum_k \beta_k X_{kn} + \sum_p \vartheta_p Z_{pn} + \sum_{kp} \gamma_{kp} x_{kn} Z_{pn} + \sum_{pa} \Psi_{pa} \beta_a Z_{pn}$ (Equation 5)

where (Mazur and Bennett 2008) explain:

β_a is a vector of 'intercept' terms (alternative specific constants – ASCs) for *A-1* of the *a=1,…., A* choice options

B_k is a matrix of *k=1,….,K* attributes that relate to choice options, X_{kn}

γ_p is a matrix of *p=1,….,P* characteristics that relate to individual respondents, Z_{pm}

γ_{kp} is a matrix of possible relationships of choice option attributes with the characteristic of the individuals, $X_{kn}Z_{pn}$

Ψ_{pa} is a vector of possible interactions between individual characteristics and choice option intercepts.

The utility function estimated for each alternative contains the effects of attributes, an ASC and the individual characteristics that can be interacted with the attributes of the ASC (Blamey 2001). Any variation in choices that is not able to be explained by the attributes or the socio-economic characteristics is captured by ASCs (Rolfe *et al.* 2000).

Welfare estimates from the MNL model are expressed by:

$CS = -1/\alpha\ (ln \sum exp\ V_{an} - ln \sum exp\ V_{jn})$ (Equation 6)

Where:

CS is the compensating surplus welfare measure and *α* is the marginal utility income as reflected by the *β* coefficient of the other monetary attribute, which is the consumer surplus for changes in a single attribute (Rolfe et al. 2000):

W= -1 (β attribute/β money) (Equation 7)

This formula allows an estimate of the trade-offs between the non-market attributes and the cost attribute. It estimates how much the respondent is willing to pay for gaining or losing units of the attribute (Mazur and Bennett 2008).

CM provides important advantages over other non-market valuation techniques, such as its flexibility and ability to assess non-use values and to decompose values by attributes. It also has appeal in providing information to policy through identification of marginal trade-offs between attributes.

2.2. Application in an Environmental context

There has been significant use of non-market valuation for water quality improvements for environmental goods in Australia, such as the GBR, water supply options and preservation of remnant vegetation.

Adamowicz *et al*. (1998) highlight that the advantage of CM is the ability for the technique to provide a richer description of the attribute trade-offs that individuals are willing to make. Bateman *et al*. (2002) suggest that CM allows four messages to be conveyed in a policy context:

- Attributes are significant determinants of the values people place on non-market goods.
- The implied ranking of attributes in the target population allows values to be derived.
- CM estimates the impacts on specific attributes. For example, to capture how one options alters another attribute's value.
- CM allows the estimate the total economic value of a resource or good.

Blamey (1999) used CM to value multiple water supply options in the Australian Capital Territory. The study investigated different policy options, using the attributes of quality of water available for the household, quality and perceived quality of the water used, annual household costs of water, the aquatic and riparian environment, endangered species losing habitat, and appearance of urban environment.

Similarly, Rolfe et al. (2000) explored the community values for tree clearing in the Desert Uplands. The attributes used were reductions in the population size of non-threatened species and unique ecosystems, the number of endangered species lost to the region, and changes in regional income and employment. The fact that the land being cleared was only marginally improving the production capacity of the land resulted in the community values for biodiversity to be higher. The community valued avoiding the loss of non-threatened species to be $1.69 for each 1 per cent reduction, and WTP to avoid unique ecosystem loss was $3.68 per 1 per cent reduction. Maintaining endangered species were valued at $11.39, job preservation to be $3.04 per job, and maintain each million dollars of regional income to be $5.60.

To evaluate policy measures for reef protection measures Rolfe and Windle (2010) also conducted a CM experiment. The choice experiment identified the pressures coming from land-based activities, urban and industrial activities, ocean-based activities, natural events and climate change. Using the attributes of the amount of the GBR in good condition, level of certainty that reef health would improve and cost of protection measures, the choice experiment was conducted with a split sample or labelled and unlabelled experiments.

The experiment explored the community values across the QLD population. Their results showed that the average Brisbane household was willing to pay approximately $26.37 for each additional one per cent improvement in GBR health. This gave an aggregated range between $132.8 million and $171.5 million per one per cent improvement, depending on the assumptions used regarding the discount rate. Rolfe and Windle (2010) highlight that with the current Reef Rescue program ($200 million) there would need to be a 1.2–1.5 per cent improvement in the health of the GBR to deliver net benefits. The impact of the labelled management options also indicated that 'Increased conservation zones' were valued slightly higher although not significantly higher than 'Improving water quality. However, there was increased variance in the values associated with 'Increasing conservation zones', indicating varying support of this management practice.

To understand the national value for the GBR and the impact of scope and scale in valuing non-market goods, Rolfe and Windle (2010) conducted a national choice experiment. Sampling from Townsville, Brisbane, Sydney, Melbourne, Adelaide and Perth populations, the experiment sought to understand if the WTP values for resource protection would decline with distance from the resource. The results showed there was no impact of scope and scale on the communities values.

Rolfe and Windle (2011) used a CM experiment to calculate the community benefit of linking water quality science with agricultural pollutant emissions to the Great Barrier Reef. The choice experiment used the attributes of water quality improvements, the amount of the GBR in good health, the level of certainty that water quality improvements will happen, and an annual payment for five years. The levels for each of the attributes were determined by the current health of the GBR and the likely trends based on scientific research. For the first time policy makers were able to quantify the value of improved water quality and subsequent reef health. Previously the ability to do this has been limited due to three information gaps: scientific information to link management practices with improved reef health, understanding the values for improved reef health, and information about the costs of management practices. Rolfe and Windle (2011) demonstrated the ability to use this information to further inform policy.

3. Methods

Focus groups were used to identify the key attributes and the frame of reference relating to water quality and sediment reductions. Results of the focus group sessions and a review of the literature indicated that the community were influenced by a limited number of attributes in their preference for water quality improvements. Using the focus groups these were condensed into the following key attributes to allow the policy options to be described adequately and reduce the potential for cognitive burden. (De Shazo and Firmo 2002; Caussade *et al.* 2005).

- Sediment reductions,
- nutrient reductions,
- inshore reef health,
- cost.

These attributes also ensure the links between pollutant reductions and improved GBR health were considered. The key pollutants from the grazing and sugarcane industries were identified as sediment and nutrient respectively. These pollutants, or inputs (sediment and nutrient), influence inshore reef health, which is essentially an output (reef health); however, there is a lack of directly related certainty of achieving changes in reef health. Finally, cost is the input required by the public to achieve the change in inshore reef health

3.1.1. Sediment

Rangelands are complex ecosystems which vary significantly depending on land type, rainfall and land type resilience. There is a strong correlation between stocking rates and grazing strategy to ensure that land degradation does not occur has been established.

Setting the upper levels

The *Reef Water Quality protection Plan – First Report 2009 Baseline* (Queensland Department of the Premier and Cabinet 2011) indicates that 14 million tonnes of sediment exported each year into the GBR is attributed to human activity. With 90% of the land use being for grazing, it is assumed that 80 per cent is attributed to the grazing industry, and the remaining 20 per cent is derived from the sugar industry. *Reef Plan* targets a 20% reduction in sediment by 2020 (Queensland Department of the Premier and Cabinet 2009). In the experiment the upper levels for the sediment reduced attribute were a reduction in sediment by 16% from grazing lands and a reduction of 4% from sugarcane-growing land.

3.1.2. Nutrient

Nutrient delivery to the GBR comes from a range of sources, such as urban storm water, atmospheric inputs from rainfall events, planktonic and microphytobenthic nitrogen fixation and deeper ocean supply. However, the largest single source comes from discharge from rivers and is predominately from application of fertiliser to crops (such as sugarcane). Additional losses of particulate-bound nutrients from soil tillage and decreased pasture cover lead to increased natural nitrogen and phosphorus from soil to waterways (McKergow *et al.* 2005b; Brodie *et al.* 2011).

Setting the upper levels

The Reef Water Quality protection Plan – First Report 2009 Baseline (Queensland Department of the Premier and Cabinet 2011) indicates that 66,000 tonnes of total nitrogen and 14,000 tonnes of total phosphorus exported each year are attributed to human activity. With sugarcane production being the main exporter of nitrogen, it was assumed for the experiments that 60% was attributed to sugarcane, and that the remaining 40 per cent was derived from the grazing industry. Reef Plan targets a 50% reduction in nutrients, both nitrogen and phosphorus (Queensland Department of the Premier and Cabinet 2003), by 2013, and therefore the upper levels for nutrient reduced attribute were a reduction in nitrogen of 40% from grazing lands and a reduction of 60%from the sugarcane industry. Although the Reef Plan targets specify a reduction by 2013, it is expected that changes in reef health will not occur immediately and to restore full health may be an extended time frame. Therefore 2050 was selected as the date by which to observe change in reef health.

3.1.3. Inshore reef health

There are various components to overall reef health, including coral health, diversity of coral species, seagrass health and fish species. These characteristics vary considerably along and across the GBR, depending on the location and proximity to the coast (Fabricius et al. 2011). However, for the purpose of this research, inshore reef health was the amenity to be valued, as the changed land management practices did not specifically target any one of these characteristics. Rolfe and Windle (2010c) explored the value for inshore reef health at three different locations: Cairns, Townsville and the Capricorn coast. They estimated from the research that currently for the Cairns region, 75 per cent or 282 km^2 of the inshore reef was in good health. Townsville had 45% or 117 km^2 and the Capricorn coast had 85% or 23 km^2 of inshore reef in good health. From this research an average of the three proportions were calculated, and the current level of inshore reef in good health was set at 68% or 2,870 km^2. The status quo for inshore reef good health was set at 50%, based on estimates from Windle and Rolfe (2010a) who used the value for inshore reef health in 25 years in their choice experiment. Although the time period for the targets is by 2020, it was assumed that it would take until 2050 before a significant change in inshore reef health would be achieved.

Setting the upper levels

Rolfe and Windle (2010c) also estimate that the most improvement that could be achieved would be to have inshore reef good health at 70%. This is derived from a maximum of 12% improvement of inshore reef health from current levels made through the conservative estimates of De'ath and Fabricius (2010).

3.1.4. Cost

The payment vehicle was worded to capture the different ways that costs could increase as well to avoid protest responses. The cost attribute was described as potential increase in food prices, an annual increase in taxes, or an annual increase in council rates. The cost values were tested in the focus group to understand what the maximum was that respondents would be willing to pay and what costs they considered reasonable. $0 was given as the status quo for no change, and the upper limit was set at $250 per year, with five levels of cost options. Level differences followed a broadly logarithmic scale, rounded to convenient dollar amounts, so as to better capture sensitivity to amount changes.

Setting the upper levels

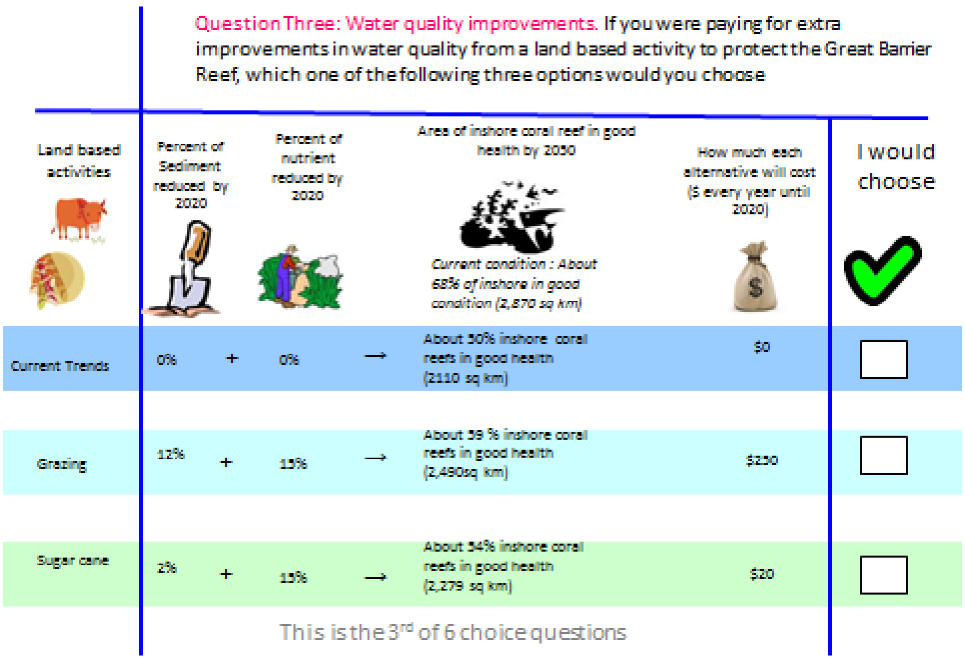
Completing a full-factorial design would have resulted in an unreasonably high number of alternatives, and so a fractional-factorial design was used. The design was created in the Ngene statistical software package. To allow for balance, the design of 12 choice sets was blocked into two groups (Table 1.).

Table 1: Levels in the two experiment blocks

	% of inshore reef in good health by 2050	Cost every year until 2020
Status Quo	50	0
0	53, 54, 56, 59, 62	20, 25, 50, 100, 250
0	53, 54, 56, 59, 62	20, 25, 50, 100, 250

3.2. Splits

The survey was split into three different samples to achieve several comparisons between Brisbane and Coastal communities. The first split was between communities. A comparison was made between the preferences of Brisbane residents and those of the coastal communities, which spanned Gladstone to Cairns, covering the three main cities of Townsville, Mackay and Rockhampton. The second split was between labelled and unlabelled experiments (see Figures 1 and 2). A comparison investigating the impact of the different industries such as sugarcane and grazing led to having labelled and unlabelled survey splits. The third split was to have a water quality path (between the attributes of sediment and nutrient) to understand if there was concern about how the improvement was achieved.



Question Three: Water quality improvements. If you were paying for extra improvements in water quality from a land based activity to protect the Great Barrier Reef, which one of the following three options would you choose

Land based activities	Percent of Sediment reduced by 2020		Percent of nutrient reduced by 2020		Area of inshore coral reef in good health by 2030 (Current condition : About 68% of inshore in good condition (2,870 sq km))	How much each alternative will cost ($ every year until 2020)	I would choose
Current Trends	0%	+	0%	→	About 50% inshore coral reefs in good health (2110 sq km)	$0	☐
Grazing	12%	+	15%	→	About 59 % inshore coral reefs in good health (2,490sq km)	$250	☐
Sugar cane	2%	+	15%	→	About 54% inshore coral reefs in good health (2,279 sq km)	$20	☐

This is the 3rd of 6 choice questions

Figure 2 Split with labels and water quality path (sediment and nutrient reductions)

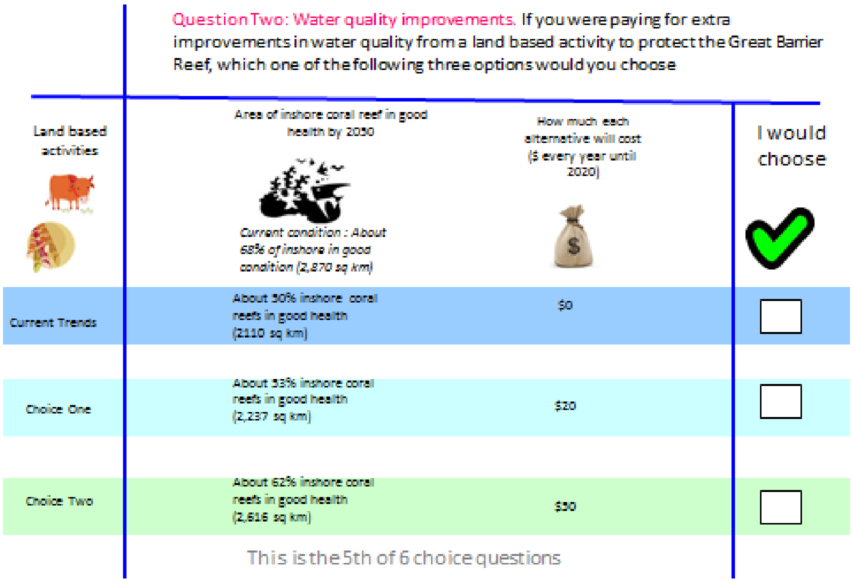


Figure 3: Split with no water quality path

3.3. Experimental design

The experimental design of the choice sets was determined in several stages. The four sample splits were based on efficient designs.

3.3.1. Number of choice sets

Choosing the optimal number of choice sets for the survey depended on two particular aspects: cognitive burden for the respondents and finding a number suitable to create efficient experimental designs. This experiment involves a highly complex public good, and the questionnaire is quite lengthy given the large amounts of information initially required to frame the issue. Therefore, six choice sets in the questionnaire was considered reasonable. This was discussed with participants in the initial two focus groups to confirm the optimal amount to consider without fatigue.

It was apparent that a blocking design would be required to achieve an efficient design. This also resulted in maintaining attribute-level balance, given that they are all multiples of the number of levels of the ecological attributes.

3.3.2. Questionnaire pre-testing

Pre-testing of the questionnaire occurred in two stages. Initially, a focus group was organised in Rockhampton where a different selection of attributes, formats and questions were tested. The focus groups involved eight people living in the Rockhampton region, with a mix of gender, age and income levels. The focus group provided comprehensive feedback on design issues, formatting and general questions. After this focus group, changes were made to the survey and a second focus group was held in Brisbane, with a similar mix of participants. Again, feedback was given and slight modifications made to the survey.

3.4. Questionnaire structure

The questionnaire consisted of three main sections: (1) a set of information and questions relating to the GBR and water quality improvements; (2) the choice sets; and (3) the generic socio-demographic questions. The complete questionnaire is included in Appendix A.

3.4.1. General Great Barrier Reef questions

The first questions asked in each section were aimed at generating an understanding of the respondents' knowledge and experience of the GBR. It was also to get them involved in the questionnaire at an early stage and to gain an understanding about whether the information that followed in the survey was the only influence on their decision-making. Specific questions included:

- how they would describe what has happened to the health of the GBR over the past ten years; response options were 'declined health', 'improved health', 'stayed the same' or 'don't know'.
- the factors they believe cause the greatest adverse pressure on the GBR; they were asked to rank the options of 'climate change', 'over-fishing', 'nutrient run-off' and 'sediment run-off'.
- their motivation to improve the health of the GBR; they could selection one option from 'to maintain recreational fishing', 'to ensure use for future generations', 'to maintain the tourism industry' and to 'visit it myself'.

3.4.2. Information

Attribute information was presented before the choice sets and included information on the two different industries of grazing and sugarcane, how much sediment and nutrient they contribute to the GBR, what the targets of Reef Plan (2009) are, different management practices to reduce these land-based pollutants and the payment vehicle. It was also brought to the respondents' attention that there are other World Heritage Areas in Australia and other environmental issues that may require further funding. Finally, instructions on completing the survey were given to the participants.

Information describing and defining the attributes was presented before the choice sets. The information discussed the land-based activity, addressing the problem, areas of improvement, economic importance of land based industries and tourism, and the spatial scale of the catchments and land based activities. The information then focused on the payment vehicle, budget constraints and an example choice set. Six choice sets then followed.

3.4.3. Choice sets

The choice sets were designed using graphics to allow a visual representation of the trade-offs to be considered. Respondents could also see where in the series of choice sets they were to maintain concentration and avoid fatigue. An example of a choice set is illustrated in Figure 4.

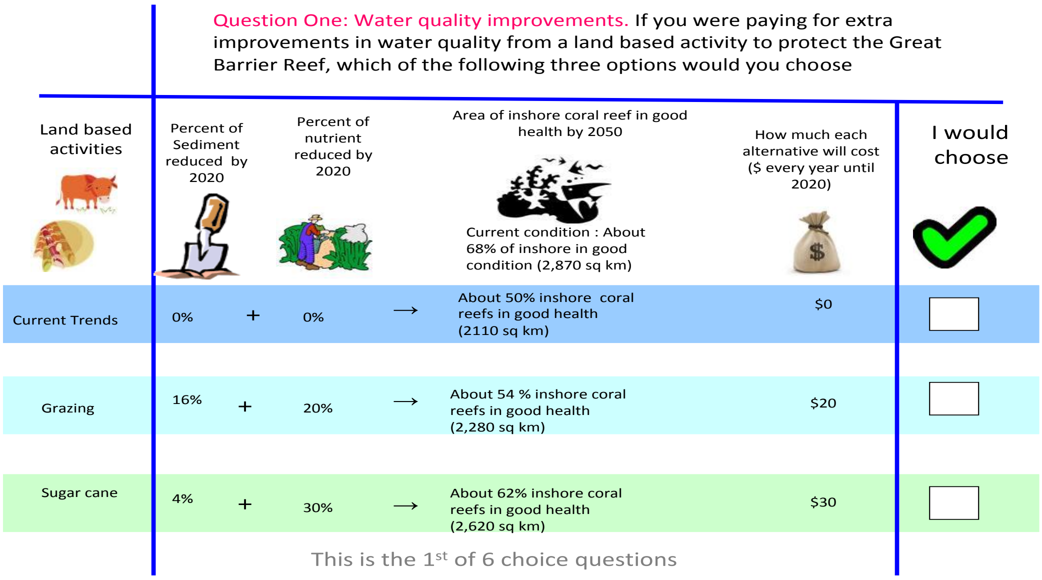


Figure 4. Format for the choice sets, and example of a labelled choice set with the attributes of sediment reduced, nutrient reduced, reef health and cost.

3.4.4. Follow-up questions

Several de-briefing questions followed the choice sets to investigate respondent uncertainty and decision heuristics. To begin with, if the respondent always chose the status quo option, they were asked why. All respondents were then asked to do the following:

- To rank from 1 (strongly agree) to 5 (strongly disagree) the following statements:

- I am confident that I made the correct choices
- I understood the information in the questionnaire
- I needed more information than was provided
- I found the choice options to be credible
- I found the choice options confusing
- Cost was not important in the choices I made

- To rank from 1 (not important) to 5 (very important) the importance of the following management practices in the sugar and grazing industries for improved water quality outcomes:
  - Exclusion of stock from waterways
  - Improved application of nutrients and pesticides
  - Decreased bare ground in grazing lands
  - Reduced application of nutrient and pesticides
  - Excluding stock from an area of the property for the wet season
  - Improved timing of nutrient and pesticides to avoid application before a rainfall event
  - Improved management of gullies which are contributing sediment in grazing lands
- To rank from 1 (not important) to 5 (very important) the various components of the GBR which they thought were important:
  - Coral reefs
  - Fish
  - Seagrass
  - Marine turtles
  - Dugongs and dolphins
  - Sea birds

3.4.5. Socio-demographic questions

Once the questions were completed, respondents were asked about a series of general questions related to their confidence in government departments to impose conservation measures, and whether in previous conservation and development issues they have tended to favour one or the other. Respondents were also asked their prior knowledge of the issues raised in the survey.

Generic questions recording respondents’ age, gender, income bracket, employment or status and industry, or whether they had any children were also asked in this section. Postcode and gender were asked once logged into the survey to ensure that there was the required sample size in coastal populations as well as Brisbane (the full survey is attached in Appendix A).

3.5. Sampling procedure and general statistics

A market research company was engaged to administer the survey using an internet database. The company emailed the survey to their collection panel but did not make mention of the survey topic area. This was done to minimise bias with respondents self-selecting. Respondents were offered a small cash incentive to complete the survey in compensation for their time. The survey was collected from both coastal regional towns and cities in the GBR catchment and from Brisbane. This was done to explore the effects of scope and scale on the responses.

The sample and population characteristics (Table 2) generally reflected the current Queensland population, however there was a higher proportion of females, and a lower proportion of those with a postschool and tertiary education than generally exists in the population.

Table 2: Sample and population characteristics

	Coastal Sample	Coastal Population	Brisbane Sample	Brisbane Population
Gender				
Female	58%*	50%	58%*	50%
Age				
Median (category / years)	36-45	35	46-60	34
Education				
Postschool qualification	31%*	59%	31%*	59%
Tertiary degree	22%*	25%	30%*	25%
Income (gross)				
Less than $25,999 per year	22%	14%	21%	17%
$26,000 – $41,599 per year	23%	18%	22%	18%
$41,600 – $62,399 per year	21%	30%	21%	21%
$62,400 – $103,999 per year	21%	30%	24%	25%
$103,999 or more per year	13%*	14%	12%*	22%

Australian Bureau of Statistics 2011 Census. *Indicates a statistical difference between the sample and the population when applying: b = the normal approximation to the bionomial test.

4. Results

The results presented will be in the order of the three different hypothesis that were tested. To test this hypothesis, models for the labelled and unlabelled split sample experiments with and without a water quality path of sediment and nutrient were compared. To understand the impact of labels and water quality path, the sample data for the two population data sets were pooled to respectively differentiate between the water quality path or the labels (Table 3).

Table 3: Hypotheses testing with the following population and sample splits

	Brisbane population split	Coastal population split	Pooled population
Hypothesis 1	Unlabelled with water quality path	Unlabelled with water quality path	
Hypothesis 2			Labelled with water quality path Labelled with no water quality path
Hypothesis 3			Unlabelled with water quality path Labelled with water quality path

The results of these models will be presented in subsequent sections. Some general observations are noted below with respect to the response patterns across the split-sample choice experiment. The choice frequencies across the sample appear not to favour the status quo, but between samples there are similar frequencies of choices for the various alternatives (Table 4).

Table 4: Choice frequencies across alternatives

Choice frequencies	status quo (%)	Alternative 1 (%)	Alternative 2 (%)
Labelled with water quality path	21.2	41.9	36.8
Labelled no water quality path	23.1	40.3	36.6
Unlabelled with water quality path	19.8	45.7	34.4

The percentage of respondents who always selected the status quo was similar for the three samples: approximately 10 per cent of respondents in each sample, for each of the six choices (Table 5).

Table 5 Percentage of respondents who always selected the status quo

Percentage (%) of respondents who always selected the status quo	
Labelled with water quality path	10.74
Labelled no water quality path	10.96
Unlabelled with water quality path	10.10

The labelled sample had a lower percentage (60% and 56% respectively) of respondents who never selected the status quo. The unlabelled sample had the highest percentage of respondents who never selected the status quo, potentially indicating that the labels influenced choices of respondents (Table 6).

Table 6: Percentage of respondents who never selected the status quo

Percentage (%) of respondents who never selected the status quo	
Labelled with water quality path	60
Labelled no water quality path	56
Unlabelled with water quality path	63

4.1.1. Model form

Mixed logit (random parameter) models were developed for each of the split-sample experiments to take into account the panel nature of the data and the heterogeneity between respondents, as well as to avoid IIA/IID restrictions. Error component models were also developed for this purpose. A normal functional form was utilised for the randomised attributes after testing other forms, and 1,000 halton draws were used for the RPL models analysed. The five main socio-demographic variables were included in all models, even if they were not significant, and were modelled to explain the choice of the base or status quo alternative. In the samples with a water quality path (sediment and nutrient attributes), it was necessary to create a simple attribute to account for the perfect correlation between these two variables. A combined parameter termed Sednut was created by multiplying the levels of the two attributes together Details of the model variables are explained in Table 7. All model results are attached in Appendix B .

Table 7: Variable explaining the status quo choice

Main variables	Description
ASC	Alternative specific constant
Reef health	Improvements in GBR health
Cost	Cost for a 1 per cent improvement in GBR health
Sednut	Sediment and nutrient pollutant reductions
Age	Age in years
Gender	Female = 1; male = 2
Children	Children = 1; no children = 2
Education	Coded from 1= primary to 5 = tertiary degree or higher
Income	Data were collected in a five-category format for gross weekly income. The data were converted to a single variable with the following mid-points applied to the income categories: \$259, \$650, \$1,000, \$2,000

Three tests for each hypothesis were performed, with each testing the difference in models between two samples. Firstly, part-worths for WTP and the confidence intervals for each sample were calculated. Part-worth tests can be used to identify where there is significant difference in WTP for particular attributes. These were then checked for overlapping confidence intervals, with no overlap indicating that there is not a significant difference between the two samples.

The WTP estimates for a 1 per cent improvement in GBR health were calculated as follows:

$$WTP = -1*\beta1(\text{Reef Health})/\beta2(\text{Cost}) \qquad \text{(Equation 8)}$$

Secondly, a Poe *et al.* (2005) test was used to test the difference between the two samples. This involves estimating the 95% confidence intervals using the Krinsky-Robb procedure, a parametric bootstrapping method, to draw a vector of 1,000 sets of parameters for each model, and differences calculated by taking one vector from another. Following Poe *et al.* (2005), this process is repeated 100 times by randomly re-ordering one vector of parameters.

The 95 per cent confidence interval is approximated by identifying the part-worth differences that were less than zero.

Finally, a likelihood ratio test was performed to identify equivalence of parameter vectors. The ratio was calculated as follows:

Log Likelihood ratio= -2 x [$LogL_{ab}$ – ($LogL_a$ + $LogL_b$)] (Equation 9)

Where the $LogL_{ab}$ is the log likelihood value attached to the MNL model of the pooled dataset and the log likelihoods $LogL_a$ and $LogL_b$ relate to individual datasets. The resulting likelihood ratio statistic follows an asymptotic chi-square distribution with (P+1) degrees of freedom, where P is the number of parameters across the models involved (Rolfe *et al.* 2000).

4.1.2. H_1: Coastal populations have a higher willingness to pay for improvements in GBR health than the Brisbane population

The utility function was calculated as below for both the Brisbane and the coastal samples, with *Reef health* the only variable randomised and the five main socio-demographic variables included in the models. Only the unlabelled split-sample experiments were compared to understand the impacts of the water quality path (*sednut*) and the population impacts.

Unlabelled sample utility function:

$U_{(Status\ Quo)}$ = ASC + β1(Reef health) + β2(Sednut) + β3(Cost) + β4(Education) + β5(Income) + β6(Age) + β7Children) + β8(Gender)

$U_{(Alt\ 1)}$ = β1(Reef Health)+ β2(Sednut) + β3(Cost)

$U_{(Alt\ 2)}$ = β1(Reef Health) + β2(Sednut) + β3(Cost)

The socio-demographic variables had some influence on the selection of the status quo option by respondents. *Education* was the only significant variable in both models, with *Age* also significant in the coastal sample. *Income* was not significant in either of the models, suggesting that some respondents did not fully consider their budgetary limitations and indicating that there may be some unexplained or unobserved reasons underlying the respondents' choice selection. Neither model had a significant ASC, indicating that there were no unobserved factors impacting the choices made.

The mean WTP part-worth estimates for a 1 per cent improvement in Reef health was estimated for the Brisbane sample at $73.79 and for the coastal population at $147.40. The coastal population had a larger range ($62.36– $295.38) than the Brisbane population ($32.09–$129.73) (Table 9). Given there is overlap between the two samples, the hypothesis is rejected for this particular test.

Table 9: Part-worths for a 1 per cent improvement in Reef health

	Minimum	Mean	Maximum
Brisbane	$32.09	$73.79	$129.73
Coastal	$62.36	$147.40	$295.38

The Poe *et al.* (2005) test was also conducted on each attribute (Table 10). The results of 0.93116 for *Reef health*, 0.8162 for *Cost* and 0.02363 for *Sednut* indicate that for *Cost* there is no significant difference (at the 5 per cent level) between the values held by the Brisbane and coastal sample, but there is significant difference for the water quality improvement path (*Sednut*).

Table 10: Results of the Poe *et al.* (2005) test

Reef health	ASC	Cost	Sednut
0.93116	0.16375	0.8162	0.02363

The key test for the population hypothesis is a likelihood ratio test. Here, the log-likelihood values for the individual models are compared to the log-likelihood values for the pooled models (Table 11). The log likelihood of the pooled Brisbane coastal model is -1915.42; the test statistic is therefore:

=-2*(-1915.42-(-1333+-568))

=28.84

The appropriate chi-square with ten degrees of freedom is 16.92; therefore, the hypothesis that the models are equivalent must be rejected.

Another follow-up question asked respondents to rank the importance of a number of management practices. Respondents rated the majority of practices as important to very important (rankings 3 to 5), but, interestingly, the management practices of excluding stock from water ways and excluding stock from an area of the property for the wet season had a higher distribution of not important to important (rankings 1 to 3)

Table 11: Percentage of respondents ranking importance of management practices

Respondents: sample set and statements rated	**1 (not important) to 5 (very important) (%)**				
Brisbane sample	1	2	3	4	5
Exclusion of stock from waterways	3	13	15	50	19
Improved application of nutrients and pesticides	1	4	4	45	46
Decreased bare ground in grazing lands	1	4	8	42	45
Reduced application of nutrients and pesticides	1	3	5	42	49
Excluding stock from an area of the property for the wet season	4	16	20	37	23
Improved timing of nutrient and pesticides to avoid application before a rainfall event	1	4	8	41	46
Improved management of gullies which are contributing sediment in grazing lands	1	5	9	44	41
Coastal sample					
Exclusion of stock from waterways	5	14	18	47	16
Improved application of nutrients and pesticides	2	3	0	43	52
Decreased bare ground in grazing lands	3	3	5	49	40
Reduced application of nutrients and pesticides	2	4	5	39	50
Excluding stock from an area of the property for the wet season	6	15	16	45	18
Improved timing of nutrient and pesticides to avoid application before a rainfall event	1	4	5	44	46

Respondents: sample set and statements rated	1 (not important) to 5 (very important) (%)				
Improved management of gullies which are contributing sediment in grazing lands	1	3	6	53	37

A third set of follow-up questions asked respondents to rank the components of the GBR they thought important. Responses were dominated by very high and high rankings (Figure 5 & 6), with coral reefs having the highest percentage of very important ranking and seabirds having the lowest percentage of respondents selecting it as very important.

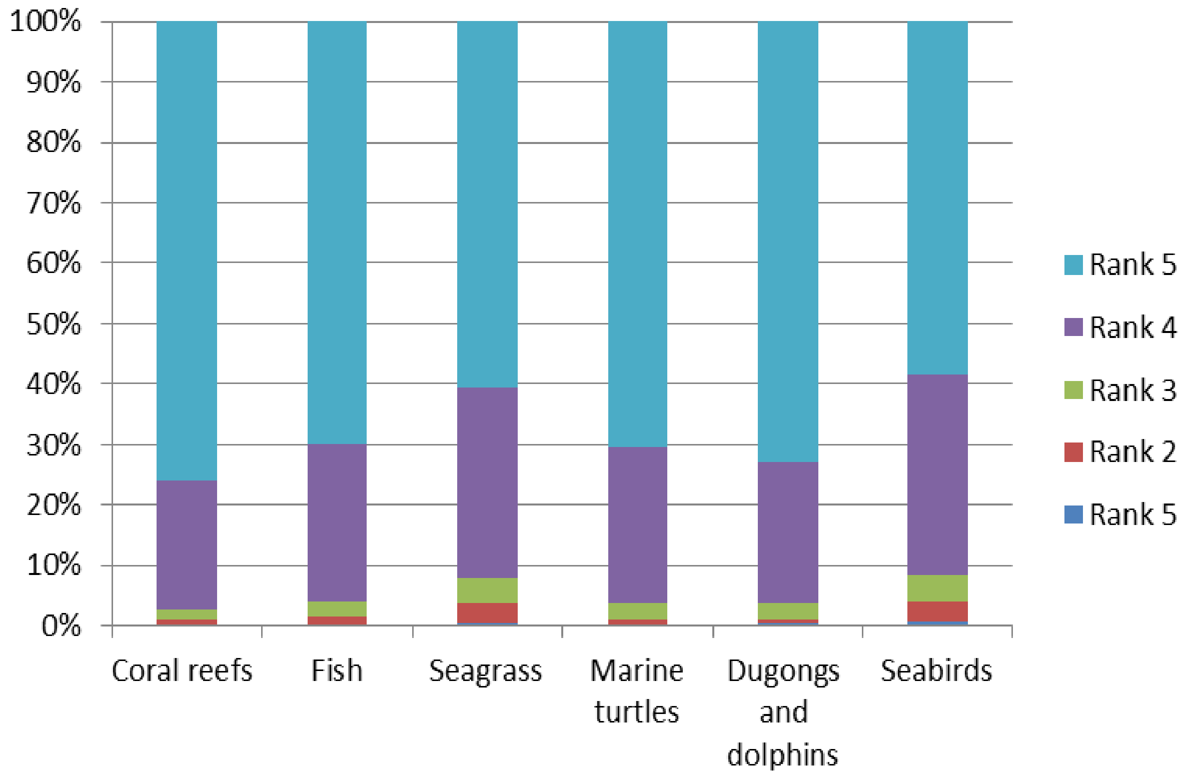


Figure 5. Brisbane ranking of the importance of marine life

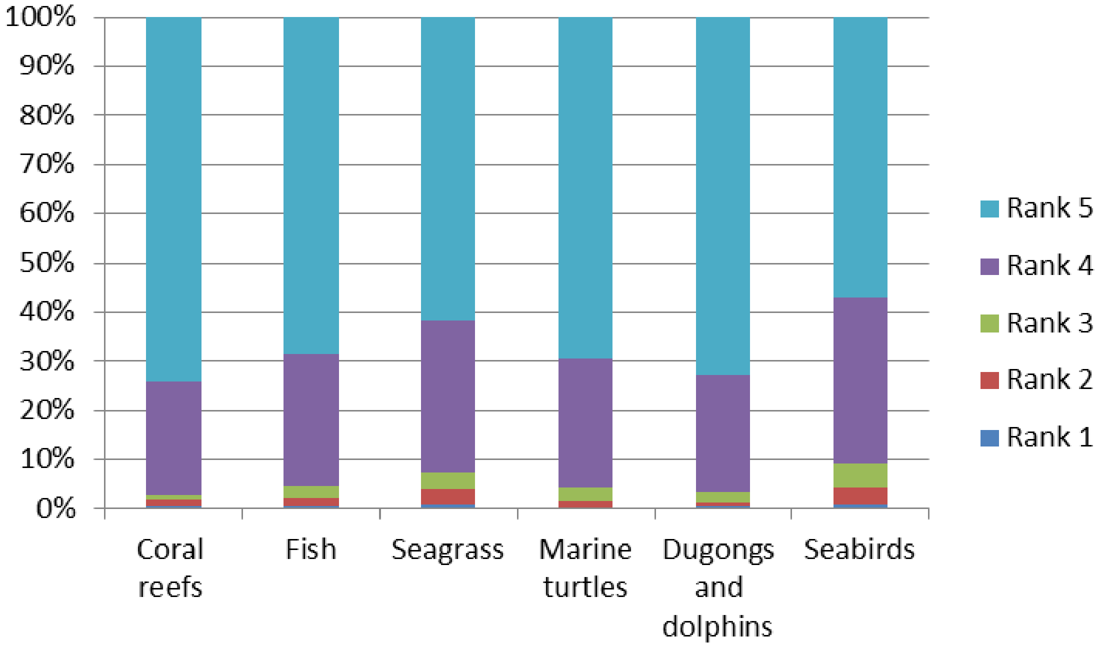


Figure 6. Coastal ranking of the importance of marine life

The Mann–Whitney U test was conducted on the results of these follow-up questions to determine if there was a significant difference in the distribution of rankings for the two samples at a 5 per cent level of significance. The Mann–Whitney U test between samples for management practices did not result in any significant difference in rankings. The high medians (predominately 4, 5) for the two samples indicate the relatively high importance which both populations place on management practices for water quality improvements.

There was also no difference between the two populations for the importance of marine life at a 5 per cent significance level. The median ranking was 5 for both populations, with very limited variation of other rankings as demonstrated by the percentiles for each group being 4 and above, or important and very important on the scale (Appendix C).

4.1.3. H_2: Water quality path (sediment and nutrient reductions) impacts on people's willingness to pay for improvements in GBR health

To test this hypothesis the labelled with water quality path and the labelled with no water quality path splits were analysed with the population splits pooled.

Reef health was the only variable that was randomised to identify the level of support for improved *Reef health*, and the implications the pollutants had on the respondents' willingness to pay. The utility function for the status quo and the alternatives are shown as follows.

Labelled sample with water quality path utility function:

$U_{(Status\ Quo)}$ = β1(Reef health) + β2(Sednut) + β3(Cost) + β4(Education) + β5(Income) + β6(Age) + β7Children) + β8(Gender)

$U_{(Alt\ 1)}$ = $ASC_{grazing}$ + β1(Reef health)+ β2(Sednut) + β3(Cost)

$U_{(Alt\ 2)}$ =$ASC_{sugarcane}$ + β1(Reef health) + β2(Sednut) + β3(Cost)

Labelled sample with no water quality path utility function:

$U_{(Status\ Quo)}$ = β1(Reef health) + β2(Cost) + β3(Education) + β4(Income) + β5(Age) + β6(Children) + β7(Gender)

$U_{(Alt\ 1)}$ = $ASC_{grazing}$ + β1(Reef health)+ β3(Cost)

$U_{(Alt\ 2)}$ =$ASC_{sugarcane}$ + β1(Reef health) + β3(Cost)

The range of WTP estimated for the no water quality path sample was $3.56 -$16.96 and for the water quality path sample was $6.54 - $20.25. Therefore overlap was identified between the two samples and the hypothesis of a difference in WTP was rejected (Table 12).

Table 12: Part-worth's for a 1 per cent improvement in Reef health

	Minimum	Mean	Maximum
Water quality path	$6.54	$17.53	$20.25
No water quality path	$3.56	$9.54	$16.96

The results of the Poe *et al*. (2005) test indicate that there is a significant difference between *Reef health* in the two models indicating that water quality path does impact the WTP (Table 13). There was no significant difference for the *Cost* attribute. The results indicate that the models are equivalent in the areas where the case studies were similar, but vary when the attributes have very different levels in the different samples.

Table 13: Poe et al. (2005) test Reef health and cost

Reef health	Cost
0.03839	0.54195

A log-likelihood ratio test was also undertaken to determine if the samples were independent:

=-2(-3953.43-(-1935.25+-1988.6))

=59.17

The appropriate chi-square with ten degrees of freedom is 18.31, therefore the hypothesis that the models are equivalent must be rejected.

There was a definite preference for a ranking of four across all the management practices for both samples, with the water quality path sample having a higher amount of management practices ranked as very important than the no water quality path sample. This indicated that the management practices were ranked important to very important for the majority of respondents. There was an even stronger preference to rank components of the reef highly, with 93 per cent of respondents across both the samples ranking them as high or very high importance (4 and 5). This is opposed to 80 per cent of respondents for the no water quality path (Appendix D) ranking management practices high to very high and 79 per cent of respondents with water quality path.

All components of the reef were ranked high to very high, with coral reefs having the highest percentage of respondents ranking it very high in both samples. The water quality path sample next ranked dugongs and dolphins, then marine turtles; the no water quality path sample ranked dugongs and dolphins and then fish (Appendix F).

4.1.4. H_3: Participants consider the labels of Grazing and Sugarcane when selecting improvements in Reef health

To test this hypothesis, two samples – one with labels of grazing and sugarcane and the other with option one and option two being the descriptors used – were modelled and the difference between them tested. The utility functions for the two samples were as follows: Labelled sample utility function:

$U_{(\text{Status Quo})}$ = β1(Reef health) + β2(Sednut) + β3(Cost) + β4(Education) + β5(Income) + β6(Age) + β7Children) + β8(Gender)
$U_{(\text{Alt 1})}$ = $ASC_{grazing}$ + β1(Reef health) + β2(Sednut) + β3(Cost)
$U_{(\text{Alt 2})}$ =$ASC_{sugarcane}$ + β1(Reef health) + β2(Sednut) + β3(Cost)

Unlabelled sample utility function:
$U_{(\text{Status Quo})}$ = ASC + β1(Reef health) + β2(Sednut) + β3(Cost) + β4(Education) + β5(Income) + β6(Age) + β7Children) + β8(Gender)

$U_{(Alt\ 1)}$ = ASC1 + β1(Reef health)+ β2(Sednut) + β3(Cost)
$U_{(Alt\ 2)}$ = ASC2 + β1(Reef health) + β2(Sednut) + β3(Cost)

The part-worths resulted in the unlabelled sample having the higher mean of $29.97 and larger range than the labelled sample (Table 14). Given the overlap between the two samples, the hypothesis is rejected for the test.

Table 14: Part-worths for a 1 per cent improvement in Reef health

	Minimum	Mean	Maximum
Unlabelled	13.31	29.97	51.31
Labelled only water quality	6.54	17.53	20.25

The Poe *et al.* (2005) test indicated that there is a significant difference between the labelled and unlabelled samples for *Reef health* but not *Cost* (Table 15). This indicates the hypothesis that the two samples participants consider the labels is accepted.

Table 15: Poe *et al.* (2005) test for Reef health and cost

Reef health	Cost
0.9999	0.2914

The log-likelihood test was also completed, with the pooled model having a log likelihood of -3,871.30. The test resulted in the follow equation:

=-2*(-3,871.30-(-1952.08+-1893))

=86.44

This indicates that the models are different given that the appropriate chi-squared statistic at 5 per cent significance is 19.68. This indicates that the labels do have a significant impact on the choice selected. Therefore the hypothesis that labels affect respondents' willingness to pay is accepted.

The results of the Mann–Whitney U test identified that there were only differences between the two samples for information (p-value 0.008) and for the ranking of seagrass (p-value 0.03)(Table 16). All other follow-up questions did not demonstrate a significant difference between the two sample populations.

Table 16: Results of the Mann–Whitney U test for the unlabelled and labelled results

	Median		Percentiles			Percentiles				
			25	50	75	25	50	75	Mann–Whitney	
	Unlabelled	Labelled	Coastal			Brisbane			U test	P-value
Questions about management practices										
Exclusion of stock from waterways	4	4	3	4	4	3	4	4	74,280	0.685
Improved application of nutrients and pesticides	4	4	4	4	5	4	4	5	77,523	0.463
Decreased bare ground in grazing lands	4	4	4	4	5	4	4	5	79,774	0.134
Reduced application of nutrient and pesticides	4	4	4	4	5	4	4	5	78,365	0.307
Excluding stock from an area of the property for the wet season	4	4	3	4	4	3	4	4	76,496	0.729
Improved timing of nutrient and pesticides to avoid application before a rainfall event	4	4	4	4	5	4	4	5	78,099	0.357
Improved management of gullies which are contributing sediment in	4	4	4	4	5	4	4	5	76,538	0.707

	Median		**Percentiles**			**Percentiles**				
			25	**50**	**75**	**25**	**50**	**75**	**Mann–Whitney**	
	Unlabelled	**Labelled**	**Coastal**			**Brisbane**			**U test**	**P-value**
grazing lands										
Questions about marine life										
Coral reefs	5	5	4	5	5	4	5	5	75,050	0.862
Fish	5	5	4	5	5	4	5	5	76,717	0.625
Seagrass	5	5	4	5	5	4	5	5	81,200	0.036
Marine turtles	5	5	4	5	5	4	5	5	77,793	0.361
Dugongs and dolphins	5	5	4	5	5	4	5	5	77,847	0.334
Sea birds	5	5	4	5	5	4	5	5	79,266	0.173

5. Community values for improvements in reef health

A major challenge for FBA when managing the GBR is to identify when measures to improve water quality through agricultural pollutant reductions generate net benefits to the community. The results contribute to understanding the community benefits of improving GBR water quality to achieve targets both through agricultural reductions and overall improved Reef health. The results contribute to understanding the implications for WTP to achieve the WQIP targets.

This report contributes in several different ways. Firstly, it links the WQIP targets for sediment and nutrient reductions to frame the experiment to value the benefits of subsequent improved Reef health. Secondly, it demonstrates how improvements to Reef health from water quality improvements are viewed consistently across populations therefore not only highlighting the importance of the work of the community within the Fitzroy Basin but also the broader community. Thirdly, the information provided regarding the relevant agricultural industries helps improve management decisions.

The results indicate that there is no significant impact on respondents' WTP based on their location or distance from the GBR. This highlights the iconic nature of the asset and the importance of considering the value to the wider Queensland population. It supports previous research completed by Rolfe and Windle (2010) which indicates for such a large natural asset the values for populations further away do not decrease significantly.

In response to the second hypothesis respondents were more sensitive to the water quality path of pollutant reductions than to the labels of grazing and sugarcane. This may indicate that respondents are more sensitive to what the issues are rather than to the where they came from. The mean WTP results for pollutant reductions from the labelled results were higher than for the water quality path alone, indicating that respondents prefer knowing where the pollutant reduction is coming from, rather than having no direct understanding of how the reductions will be achieved (Table 17).

There was no particular demographic aspect that was significant apart from income, which was not significant in the first hypothesis test, indicating that perhaps respondents did not fully consider their budgetary limitations or were using heuristics in the choice process; income was of little significance across the other samples (Table 17).

Table 17: Results of hypothesis testing

Hypothesis	Part-worth test	Poe *et al*. (2005) test	Log-likelihood test
H_1: Coastal populations have a higher willingness to pay for improvements in Reef health than the Brisbane population.	Reject	Reject	Reject
H_2: Water quality path (sediment and nutrient reductions) impact on people's willingness to pay for improvements in GBR health.	Reject	Accept	Reject
H_3: Participants consider the Land use labels (sugarcane and grazing) impact on people's willingness to pay for when selecting improvements in Reef GBR health.	Reject	Accept	Accept

Respondents' part-worth estimates calculated have been focused on a 1 per cent improvement in Reef health, given that the status quo was identified as 50 per cent of the Reef in good health and a maximum of 70 per cent in Reef health set as the upper limit (Table 18). A 1 per cent improvement is equivalent to 112,000 tonnes of sediment reduced. A 5 per cent improvement was also considered to allow a comparison between the level of sediment reduction that would be achieved. At 5 per cent improvement in water quality 560,000 tonnes of sediment would be reduced.

Present values of benefits for households in the Fitzroy Basin (59,516) were calculated to understand the value of achieving the Reef Plan sediment targets by 2020. The average WTP across all the labelled and unlabelled split samples was used to extrapolate to all households in the catchment. The net present values were estimated with annual WTP values calculated at 5, 8 and 12 per cent to allow for sensitivity to the discount rate. A time frame of five years was calculated to account for the payment vehicle occurring every year until 2019 or the length of the WQIP.

Two potential participation rates of 70 per cent and 90 per cent were used to extrapolate values from the sample to the relevant population based on a response rate of greater than 80 per cent in a similar paper-based version of the survey where accurate response rates were recorded (Rolfe and Windle 2011).

The results of the assessment of benefits indicate that the public benefit of improved Reef health by 1% (112,000 tonnes sediment) ranges between $19 million and $12 million (Table 19). At a 5% level of improved Reef health (560,000 tonnes of sediment) the benefit ranges between $96 million and $62 million depending on the discount rate used.

Table 18: Present values of willingness to pay per person with an five year time frame

		Discount rate (%)		
	Water quality pollutant reductions (tonnes)	5%	8%	12%
1% improvement in water quality ($)	Sediment 112,000	$362	$334	$302
5% improvement in water quality ($)	Sediment 560,000	$1,808	$1,670	$1,510

Table 19: Present values of willingness to pay for households in the Fitzroy Basin with an five year time frame

	Discount rate (%)		
70% Fitzroy households	5%	8%	12%
1% improvement in water quality ($M)	15.0	13.9	12.5
5% improvement in water quality ($M)	75.4	69.4	62.7
90% Fitzroy households			
1% improvement in water quality ($M)	19.3	17.8	16.1
5% improvement in water quality ($M)	96.9	89.4	80.7

6. Conclusions and Recommendations

This report highlights the community in the Fitzroy basin value a reduction of sediment at approximately $133 per tonne for a one per cent improvement. To then achieve the 20% reduction the ceiling is approximately $2,660 however this must also include institutional overheads and landholder in-kind costs. This provides a clear ceiling for the Fitzroy Basin in targeting funds and contribution to projects. The low ranking of management practices in relation to riparian areas is also a key area for increased community communications and the presence.

Some of the key recommendations from this work are:

- Project selection should have a ceiling or cap based on tonnes and therefore project size not just per project.
- Projects are required to be targeted and monitored for effectiveness to ensure the community value is achieved.
- It will be compared to the costs per tonne in subsequent WQIP reports of Component 4 to ensure as a community organisation FBA's on-ground investments are targeted and equivalent to community benefits.
- Ensure the wider community is made aware of the importance of riparian areas and the importance in grazing management this would ideally be done through a communications exercise.

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Appendix A

What priority do you believe that the QLD and federal government should give to the following areas?

Please rank the following from 1 to 4 where 1 is the most important and 4 is the least important.
Click on the boxes in the order that you want them ranked.
You can deselect the boxes by clicking on them again to change your selection

- ☐ Education
- ☐ Law enforcement
- ☐ Environment
- ☐ Public health

- ☐ Yes – Vey confident
- ☐ Yes – Mildly confident
- ☐ No

Aside from the Great Barrier Reef, have you visited any other marine parks or coral reefs in the following areas?

- ☐ Nigaloo and Capes Marine Park in Western Australia
- ☐ In other parts of Australia
- ☐ Overseas
- ☐ None of the above

3. What would your motivation be to improve the health of the GBR? (Please tick one box)

To maintain recreational fishing.. ☐

To ensure use for future generations .... ☐

To maintain the tourism industry... ☐

To visit it myself.. ☐

There are a number of issues that are relevant to the GBR but for this study we are focusing on the following:

1. Reef health and water quality, and

2. The activities to achieve improvements in water quality.

There are many pressures which can lead to poor reef health but a significant contributor is land based activities.

Below is a list of possible actions that could be undertaken to reduce the pressures on the GBR. Keeping in mind the impacts on relevant industries, please score each one from (**1**) NOT important to (**5**) VERY important.

Reduce the impacts of coastal residential development	1	2	3	4	5
Reduce the impacts of coastal infrastructure development	1	2	3	4	5
Reduce the impacts from industrial development	1	2	3	4	5
Improve water quality runoff from cattle grazing	1	2	3	4	5
Improve water quality runoff from cropping and irrigation	1	2	3	4	5
Reduce the impacts of recreational fishing	1	2	3	4	5
Reduce the impacts of commercial fishing	1	2	3	4	5
Reduce the impacts of tourism	1	2	3	4	5
Reduce the impacts of greenhouse gas emissions	1	2	3	4	5
Increase controls over shipping	1	2	3	4	5

The pressure of land based activities on the Great Barrier Reef

The Great Barrier Reef is one of the most diverse ecosystems in the world, and has been classified as a World Heritage area. However, there are many pressures on the system from increased human activity, climate change and natural causes such as cyclones.

This survey looks at a particular aspect of reef health.

We will first ask a couple of questions, followed by some information on the subject and then some more questions.

The pressure of land based activities on the Great Barrier Reef

The majority of the Great Barrier Reef (GBR) is in good condition however areas closer to the coast are not as healthy as they once were. There are a number of issues which impact reef health such as poor water quality from increased sediments and nutrients.

To start with ... some quick questions on your knowledge of the GBR and its catchments:

1. Which of the following do you think best describes what has happened to the health of the GBR over the past ten years? (Please tick one box)

   Declined health........................ ☐

   Improved health........................ ☐

   Stayed much the same........................ ☐

   I don't know........................ ☐

2. From the factors below which do you believe cause the greatest adverse pressure on the GBR? (Please rank from the greatest effect =1 to the least effect =4)

   Climate change........................ ☐

   Over fishing .... ☐

   Nutrient run-off........................ ☐

   Sediment run-off........................ ☐

3. What would your motivation be to improve the health of the GBR? (Please tick one box)

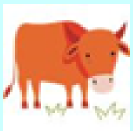
- To maintain recreational fishing........................ ☐
- To ensure use for future generations .... ☐
- To maintain the tourism industry........................ ☐
- To visit it myself... ☐

There are a number of issues that are relevant to the GBR but for this study we are focusing on the following:

1. Reef health and water quality, and
2. The activities to achieve improvements in water quality.

There are many pressures which can lead to poor reef health but a significant contributor is land based activities.

Land- based activity: Activities that occur on agricultural and grazing lands and also in urban and industrial activities impact the water quality that enters into rivers and streams that empty into the GBR.



Water quality is affected by sediment and nutrients. 80 per cent of this sediment and nutrients exported to the GBR is from grazing (Productivity Commission 2003; Wilkinson & Bartley 2010).

Nutrients can best be described as trace elements from fertilisers and soil, and sediment is best described as small soil particles which are carried through the water.

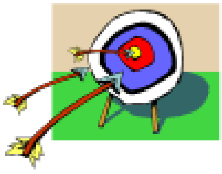
The impacts of water quality on the GBR

1. Reduces the diversity of corals
2. Increases the macro algae which is a reef weed
3. Affects nearly 23% of reefs where water quality guidelines are exceeded

Addressing the problem

- Improvements could be made by reducing sediment and nutrient run off
- It is estimated that for the inner reef area improvements in water quality could;
  - Increase hard and soft corals by about 23%
  - Reduce reef weeds such as macro algae by about 39% (Fabricius & De'ath 2004).

Improved water quality → Better water clarity → Improved reef health



Targets:
The state and federal government have created a plan for water quality improvement. Targets are to reduce from current levels:

- sediment by 20% by 2020 and
- nutrient by 50% by 2020.

Current annual levels of sediment are 14 million tonnes (due to human activity) + 3 million tonnes (from natural processes)= 17million tonnes

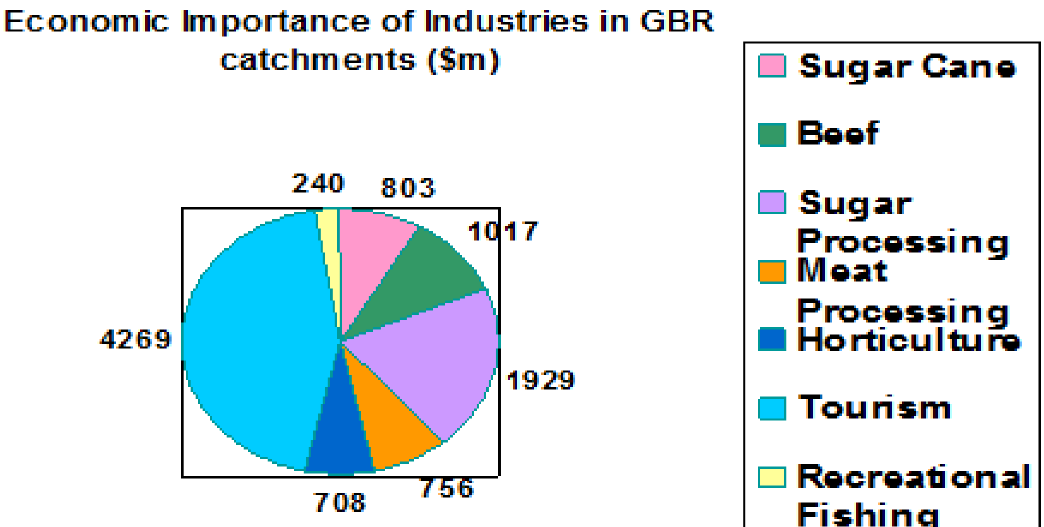
The Fitzroy and Burdekin catchments together contribute 8.8 million tonnes per year, which is approximately 352 Olympic swimming pools full of sediment.

Current levels of total load of dissolved nitrogen are 17,000 tonnes (due to human activity) + 14,000 tonnes (natural process)= 31,000 tonnes per year

The focus of this survey is on improving water quality from land-based activities.

Areas of improvement:
There are three main agricultural industries in the GBR catchments grazing, sugar cane, and horticulture. Grazing (80% of catchment) and sugar cane production (1 %) utilise the highest amount of land area in the GBR catchments (Carroll *et al.* 2011). There may need to be changes to management and production in these industries to achieve improved water quality.

Grazing, sugarcane and horticulture contribute significantly to the economy in the GBR regions, as do the sugar processing, meat processing, tourism and recreational fishing.



Source: Productivity Commission (2003)

Making sediment and nutrient reductions from these industries will involve different costs.

Figure 1. Great Barrier Reef Catchments.
The green area is the approximate area where sugar cane is grown. The majority of the remaining area is used for grazing.

Sugar Cane Production (area marked in Figure 1):

The production of sugar cane uses different applications of fertilizers, chemicals and nutrients.

Trace quantities of nutrient and small amounts of soil are then washed out into the reef and are predominately found in the in-shore and mid-zone reefs (shore to greater than 26km from the coast).

This impacts negatively on coral species and macroalgae

Grazing:
The production of cattle can reduce the amount of grass and pasture species that cover the ground. If the ground is relatively bare this can result in large amounts of soil getting washed out in rainfall events onto the near shore (within 25km from the coast).
This impacts the onshore sea grasses and reduces the light available for coral growth.

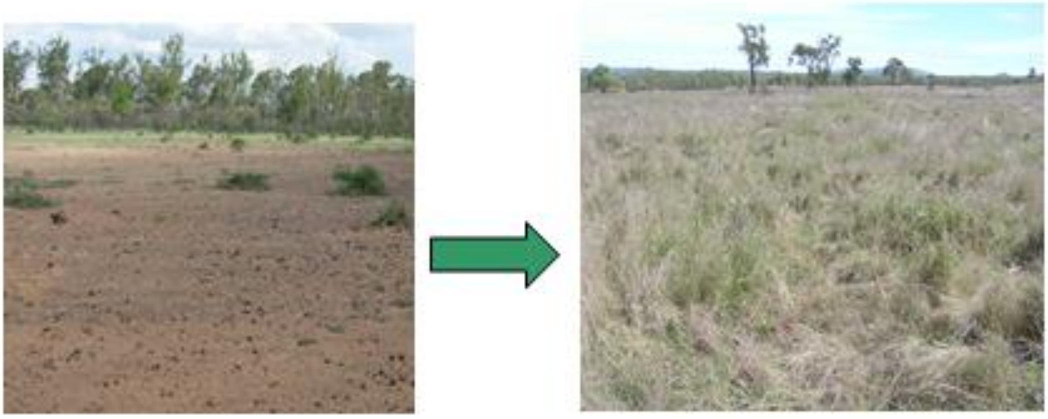
- An overall reduction in nutrients would result in an improvement in overall reef health.
- An overall reduction in sediment (soil) movement would result in improvements in inshore reef health.

To reduce nutrient run-off cane growers can take up practices such as reduced nutrient application, reduced spray chemicals, reduced tillage, controlled traffic and general improvements to improve soil and nutrient run-off. To achieve this new technologies are required with sugar cane growers having large costs to purchase this equipment.

Figure 2. Improving nutrient application to more precise methods like this will reduce nutrient run-off

- To reduce sediment graziers can improve grazing management to increase ground cover and reduce the bare soil that can be washed away.

Figure 3. Improving ground cover in grazing areas like this will reduce sediment run-off



While landholders are already proactive, financial support will be needed to generate changes quickly. The government already has some programs, but larger changes will require more funding.

Guide to survey Questions
In this survey we want to know what you think of different management options for improving water quality into the GBR. To do this we present some scenarios to choose between. Current predictions are for a decline in GBR health over the next 50 years from adverse water quality, climate change and other direct pressures. This decline may be reduced with better water quality. *Information in this survey represents the best available scientific data to date.*
Extra management would cost money which may be paid for by: • Increased taxes levied by state and federal governments. • Increased rate payments to the local council. • Increased prices for goods and services such as food as farmers meet higher environmental standards.

Some other things to consider:

Also you may want to consider that there are ***other World Heritage Areas in Australia*** that may require additional funding for management.

There are ***other important environmental issues*** and Australian or international icons that you may wish to support.

You should consider ***your income and other expenses***. The cost is an annual amount, per household until 2020.

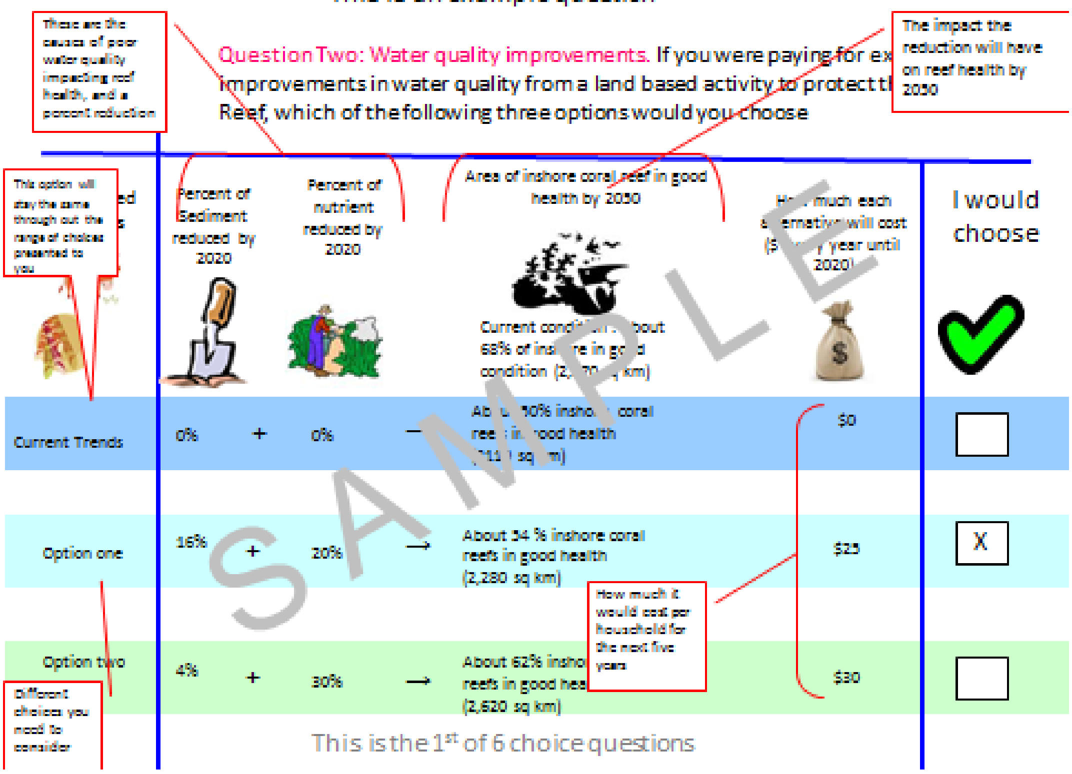
The next page is an example question, there will be six like this on the following pages.

These scenarios are hypothetical but are based on ***current scientific knowledge*** about what might happen.

Please make your choices as if they were ***real***.

The choices on each page ***may look very similar, but they do differ***. Please treat each page separately.

This is an example question



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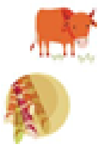
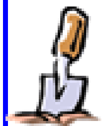
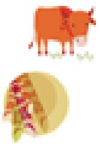
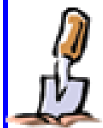
Question One: Water quality improvements. If you were paying for extra improvements in water quality from a land based activity to protect the Great Barrier Reef, which one of the following three options would you choose

Land based activities 	Percent of Sediment reduced by 2020 		Percent of nutrient reduced by 2020 		Area of inshore coral reef in good health by 2050  *Current condition : About 68% of inshore in good condition (2,870 sq km)*	How much each alternative will cost ($ every year until 2020) 	I would choose 
Current Trends	0%	+	0%	→	About 50% inshore coral reefs in good health (2110 sq km)	$0	☐
Grazing	16%	+	20%	→	About 54 % inshore coral reefs in good health (2,280 sq km)	$20	☐
Sugar cane	4%	+	30%	→	About 62% inshore coral reefs in good health (2,620 sq km)	$30	☐

This is the 1st of 6 choice questions

Question Two: Water quality improvements. If you were paying for extra improvements in water quality from a land based activity to protect the Great Barrier Reef, which of the following three options would you choose

Land based activities 	Percent of Sediment reduced by 2020 		Percent of nutrient reduced by 2020 		Area of inshore coral reef in good health by 2030  *Current condition : About 68% of inshore in good condition (2,870 sq km)*	How much each alternative will cost ($ every year until 2020) 	I would choose 
Current Trends	0%	+	0%	→	About 50% inshore coral reefs in good health (2110 sq km)	$0	☐
Grazing	12%	+	18%	→	About 50 % inshore coral reefs in good health (2,280 sq km)	$20	☐
Sugar cane	6%	+	32%	→	About 60% inshore coral reefs in good health (2,620 sq km)	$30	☐

This is the 2nd of 6 choice questions

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Question Three: Water quality improvements. If you were paying for extra improvements in water quality from a land based activity to protect the Great Barrier Reef, which of the following three options would you choose

Land based activities	Percent of Sediment reduced by 2020		Percent of nutrient reduced by 2020		Area of inshore coral reef in good health by 2050 Current condition : About 68% of inshore in good condition (2,870 sq km)	How much each alternative will cost ($ every year until 2020)	I would choose
Current Trends	0%	+	0%	→	About 50% inshore coral reefs in good health (2110 sq km)	$0	☐
Grazing	8%	+	10%	→	About 27 % inshore coral reefs in good health (2,280 sq km)	$13	☐
Sugar cane	2%	+	15%	→	About 31% inshore coral reefs in good health (2,620 sq km)	$15	☐

This is the 3rd of 6 choice questions

Question Four: Water quality improvements. If you were paying for extra improvements in water quality from a land based activity to protect the Great Barrier Reef, which of the following three options would you choose

Land based activities	Percent of Sediment reduced by 2020		Percent of nutrient reduced by 2020		Area of inshore coral reef in good health by 2050 Current condition : About 68% of inshore in good condition (2,870 sq km)	How much each alternative will cost ($ every year until 2020)	I would choose
Current Trends	0%	+	0%	→	About 50% inshore coral reefs in good health (2110 sq km)	$0	☐
Grazing	12%	+	15%	→	About 15 % inshore coral reefs in good health (2,280 sq km)	$15	☐
Sugar cane	3%	+	23%	→	About 38 % inshore coral reefs in good health (2,620 sq km)	$23	☐

This is the 4th of 6 choice questions

Question Five: Water quality improvements. If you were paying for extra improvements in water quality from a land based activity to protect the Great Barrier Reef, which of the following three options would you choose

Land based activities	Percent of Sediment reduced by 2020		Percent of nutrient reduced by 2020		Area of inshore coral reef in good health by 2050 (Current condition : About 68% of inshore in good condition (2,870 sq km))	How much each alternative will cost ($ every year until 2020)	I would choose
Current Trends	0%	+	0%	→	About 50% inshore coral reefs in good health (2110 sq km)	$0	☐
Grazing	32%	+	3%	→	About 43 % inshore coral reefs in good health (2,280 sq km)	$20	☐
Sugar cane	8%	+	13	→	About 50% inshore coral reefs in good health (2,620 sq km)	$24	☐

This is the 5th of 6 choice questions

Question Six: Water quality improvements. If you were paying for extra improvements in water quality from a land based activity to protect the Great Barrier Reef, which of the following three options would you choose

Land based activities	Percent of Sediment reduced by 2020		Percent of nutrient reduced by 2020		Area of inshore coral reef in good health by 2050 (Current condition : About 68% of inshore in good condition (2,870 sq km))	How much each alternative will cost ($ every year until 2020)	I would choose
Current Trends	0%	+	0%	→	About 50% inshore coral reefs in good health (2110 sq km)	$0	☐
Grazing	16%	+	20%	→	About 54 % inshore coral reefs in good health (2,280 sq km)	$25	☐
Sugar cane	4%	+	30%	→	About 62% inshore coral reefs in good health (2,620 sq km)	$30	☐

This is the 6th of 6 choice questions

Q.12 Do you work or volunteer in any of the following fields?

Please tick all the relevant boxes

- ☐ Environmental planning and policy
- ☐ Environmental conservation
- ☐ Sugarcane or ethanol industry
- ☐ Grazing or beef industry
- ☐ Marine industries
- ☐ Commercial fishing
- ☐ Tourism

Considering the choices you have just made, please score the following statements from (1) STRONGLY AGREE to (5) STRONGLY DISAGREE

I am confident that I made the correct choices	1	2	3	4	5
I understood the information in the questionnaire	1	2	3	4	5
I needed more information than was provided	1	2	3	4	5
I found the choice options to be credible	1	2	3	4	5
I found the choice options confusing	1	2	3	4	5
Cost was not important in the choices I made	1	2	3	4	5

In this final section we would like to ask you a few questions to make sure the people we are surveying come from a wide range of backgrounds.

Do you have any children?

Yes ☐ No ☐

What is the highest level of education you have obtained or are obtaining?

☐ Primary only

☐ Junior/Year 10

☐ Secondary/Year 12

☐ Diploma or trade certificate

☐ Tertiary degree

☐ Other (please specify)

Over the years, when you have heard about proposed projects where there is a conflict between development and the environment, have you tended to:

☐ Favour preservation of the environment more frequently

☐ Favour development more frequently

☐ Favour development and environmental preservation equally

Do you have confidence in Government agencies to enforce conservation measures

☐ Yes – Vey confident

☐ Yes – Mildly confident

☐ No

How would you rate your knowledge of the issues addressed in this survey on a scale of **1** to **10** from **(1)** having NO knowledge to **(10)** having EXTENSIVE knowledge.

Rating: ______________

To the best of your knowledge please indicate the total **weekly** income (**before taxes**) that you and your spouse (if applicable) currently earn.

- ☐ less than $499 per week ($25,999 per year)
- ☐ $500 – $799 per week ($26,000 – $41,599 per year)
- ☐ $800 – $1199 per week ($41,600 – $62,399 per year)
- ☐ $1200 – $1999 per week ($62,400 – $103,999 per year)
- ☐ $2000 or more per week ($104,000 per year)

Appendix B

Table B-1: Mixed logit model for the Brisbane and coastal unlabelled with water quality path samples

	Brisbane		Coastal	
	coefficients	**SE**	**coefficients**	**SE**
Random parameters in utility functions				
Reef health	0.581***	0.149	1.011***	0.239
Non-random parameters in utility functions				
ASC	-0.384	0.660	-1.706	1.163
Cost	-0.008***	0.000	-0.007***	0.000
Sednut	-0.166***	0.050	-0.359***	0.080
Education	-0.183*	0.097	-0.466***	0.169
Income	0.26100d-04	0.000	0.000	0.000
Age	-0.017	0.083	0.424**	0.188
Gender	-0.177	0.251	0.095	0.437
Children	-0.271	0.224	-0.477	0.429
Model statistics				
Observations	1620		696	
Log L	-1333		-568	
AIC	1.658		1.661	
McFadden R^2	0.251		0.257	
Chi-squared (D.o.F = 9)	8925		392	

Note. ***=p<0.01, **p<0.05, *p<0.10

Table B-1: Percentage of respondents rating confidence, credibility and understanding of their choices

Respondents: sample set and statements ranked	1 (strongly agree) to 5 (strongly disagree) (%)				
Brisbane sample	1	2	3	4	5
I am confident that I made the correct choices	23	37	18	16	6
I understood the information in the questionnaire	31	29	16	16	8
I needed more information than was provided	10	28	18	34	10
I found the choices to be credible	15	32	26	22	5
I found the choice options confusing	9	20	16	37	18
Cost was not important in the choices I made	15	24	10	33	18
Coastal sample					
I am confident that I made the correct choices	28	33	18	12	9
I understood the information in the questionnaire	33	31	14	17	5
I needed more information than was provided	16	26	18	23	17
I found the choices to be credible	16	34	19	24	7
I found the choice options confusing	10	25	13	30	22
Cost was not important in the choices I made	13	16	12	41	18

Table B-3: Mixed logit models for labelled with water quality path and labelled with no water quality path

	Labelled with water quality path		Labelled with no water quality path	
	Coefficient	**S.E**	**Coefficient**	**S.E**
Random parameters in utility functions				
Reef health	0.099***	0.022	0.060***	0.179
Non-random parameters in utility functions				
$ASC_{grazing}$	1.347**	0.525	0.370	0.490
$ASC_{sugarcane}$	1.197*	0.515	0.412	0.488
Cost	-0.008***	0.000	-0.006***	0.000
Sednut	-0.018***	0.006		
Education	-0.189**	0.074	0.056	0.061
Income	0.141**	0.070	-0.000***	0.000
Age	-0.207***	0.067	0.103*	0.061
Gender	0.400**	0.176	-0.117	0.186
Children	0.174	0.183	-0.450***	0.157
Model statistics				
Observations	2346		2244	
Log L	-1935.25		-1988.60	
AIC	1.659		1.781	
McFadden R^2	0.2491		0.1916	
Chi-squared (D. of F. = 100)	1284.18		953	

Note. ***=p<0.01, **p<0.05, *p<0.10

Table B-4: Mixed logit models for the labelled and unlabelled sample

	Labelled		Unlabelled	
	Coefficient	**S.E**	**Coefficient**	**S.E**
Random parameters in utility functions				
Reef health	0.099***	0.022	0.241***	0.062
Non-random parameters in utility functions				
$ASC_{grazing/1}$	1.349**	0.525	0.639	0.589
$ASC_{sugarcane/2}$	1.197**	0.515	0.184	0.587
Cost	-0.008***	0.000	-0.008***	0.005
Sednut	-0.018**	0.006	-0.006***	0.002
Education	-0.189**	0.074	-0.198**	0.081
Income	0.141**	0.070	0.78134D-04	0.000
Age	-0.207***	0.067	0.066	0.071
Gender	0.397**	0.174	-0.011	0.190
Children	0.174	0.183	-0.319	0.214
Model statistics				
Observations	2346		2316	
Log L	-1935		-1893	
AIC	1.659		1.645	
McFadden R^2	0.2474		0.2556	
Chi-squared (D. of F.= 11)	1284		1300	

Note. ***=p<0.01, **p<0.05, *p<0.10

Appendix C

Table C-1: Results of Mann–Whitney U test for Brisbane and Coastal populations for the importance of marine life

	Median		Percentiles							
			25	50	75	25	50	75		
	Coastal	Brisbane	Coastal			Brisbane			Mann–Whitney U test	P-value
Coral reefs	5	5	4	5	5	5	5	5	16,633	0.204
Fish	5	5	4	5	5	4	5	5	16,567	0.267
Seagrass	5	5	4	5	5	4	5	5	15,152	0.556
Marine turtles	5	5	4	5	5	4	5	5	16,246	0.469
Dugongs and dolphins	5	5	4	5	5	4	5	5	15,701	0.958
Sea birds	5	5	4	5	5	4	5	5	16,563	0.308

Appendix D

Table D-1: Results of Mann–Whitney U test for management practices and marine life.

	Median		Percentiles			Percentiles				
			25	50	75	25	50	75		
	Water quality path	No water quality path	Water quality path			No water quality path			Mann-Whitney U test	P-value
Questions about management practices										
Exclusion of stock from waterways	4	4	3	4	4	3	4	4	73,202	0.976
Improved application of nutrients and pesticides	5	4	4	5	5	4	4	5	70,097	0.272
Decreased bare ground in grazing lands	4	4	4	4	5	4	4	5	71,723	0.622
Reduced application of nutrient and pesticides	4	4	4	4	5	4	4	5	74,207	0.696
Excluding stock from an area of the property for the wet season	4	4	3	4	4	3	4	4	77,639	0.121
Improved timing of nutrient and pesticides to avoid application before a rainfall event	4	4	4	4	5	4	4	5	71,825	0.643
Improved management of gullies which are contributing sediment in grazing lands	4	4	4	4	5	4	4	5	71,601	0.589
Questions about marine life										
Coral reefs	5	5	5	5	5	4	5	5	72,011	0.629
Fish	5	5	4	5	5	4	5	5	72,652	0.854
Seagrass	5	5	4	5	5	4	5	5	70,291	0.296
Marine turtles	5	5	4	5	5	4	5	5	70,798	0.353
Dugongs and dolphins	5	5	4	5	5	4	5	5	72,483	0.795
Sea birds	5	5	4	5	5	4	5	5	71,116	0.465

Our country, Our future.

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