

Table 7: Additional variables used in subsequent analyses for tourists – descriptors and abbreviations

Variable of interest	Description	Abbreviations used in this report
Origin of visitors		
QLD	=1 if visitor from QLD, 0 otherwise	Visitor QLD
Elsewhere in Australia	=1 if visitor from the rest of Australia, 0 otherwise	Visitors AUS (not QLD)
China	=1 if visitor from China, 0 otherwise	China
Japan	=1 if visitor from Japan, 0 otherwise	Japan
International	=1 if international visitor, 0 otherwise	International visitor
Type of travel party		
Couple	=1 if travelling as a couple, 0 otherwise	Couple
Family with children	=1 if travelling as a family with children, 0 otherwise	Family with children
Friends	=1 if travelling with friends, 0 otherwise	Friends
Tour group	=1 if travelling with a tour group, 0 otherwise	Tour group
Visitor to Mackay/Rockhampton area	=1 if visitor to Mackay/Rockhampton area	Visitor Mackay/Rockhampton
Visitor to Townsville/Whitsunday area	=1 if visitor to Townsville/Whitsunday area	Visitor Townsville/Whitsunday
Will return to the GBRWHA	Scale variable =2 if visitor will definitely return to visit the region in the future, = -2 if definitely will not return	Return
Importance	Importance of water clarity- scale variable (=1 if water clarity is very unimportant; =5 if very important)	Importance
Satisfaction	Satisfaction with water clarity- scale variable (=5 if very dissatisfied; =1 if very satisfied)	Satisfaction
Importance and Satisfaction	Importance multiplied by Satisfaction	IS

Males place more importance on coming to do business, but consider nature, culture, seafood and recreation, socialising and value for money as less important reasons to come to the region.

Table 8: Characteristics of respondents determining importance scores for groups of values tested using OLS

Nature, culture, seafood & recreation	Business	Socialising & value for money
Male (-)	Male (+)	Male (-)
Education (-)		Age (+)
	Income (+)	Education (-)
	Visitor QLD (+)	
	Visitor AUS (not QLD) (+)	
	Couple (-)	Couple (+)
	Family with children (-)	Family with children (+)
	Friends (-)	Friends(+)
	Tour group (-)	
		Visitor Mackay/Rockhampton (-)
	Visitor Townsville/Whitsunday (+)	Visitor Townsville/Whitsunday (-)

Note: Only significant variables reported. A plus sign (+) indicates that the variable was found to have a positive and statistically significant relationship with the score assigned to the corresponding value; a negative sign (-) indicates negative and statistically significant negative relationship

(Table adapted from Esparon *et al.*, forthcoming)

We also looked at visitor responses to a range of different hypothetical scenarios. Specifically, we asked visitors to tell us how 8 different 'changes' would have affected their decision to come to the region and/or their decision about how long to stay. Visitors reacted more negatively to the prospect of oil spills, a reduction in water clarity, twice as much rubbish and half as much live corals, than to the prospect of a 20% increase in local prices.

We then used OLS regression and SUR to look for statistically significant relationships between the socio-demographic and economic characteristics of visitors and their stated reaction to these various hypothetical changes. Our findings clearly indicated that different types of tourists would be likely to respond in a different way to environmental changes. We found that environmental deterioration would have a greater negative impact on Indigenous visitors' decision to come to the region than on non-Indigenous visitors. Our results also indicated that Chinese and Japanese tourists were more averse to the prospect of environmental degradation than other tourists. Moreover, and in accordance with findings from the residential sample, we found a clear north-south spatial pattern to responses. Those visiting the Cairns/Port Douglas region reacted more negatively to the prospect of environmental degradation than those in the south, although southern visitors were more sensitive to the prospect of a decline in the chance of catching fish than those in the two northern regions (Figure 11).

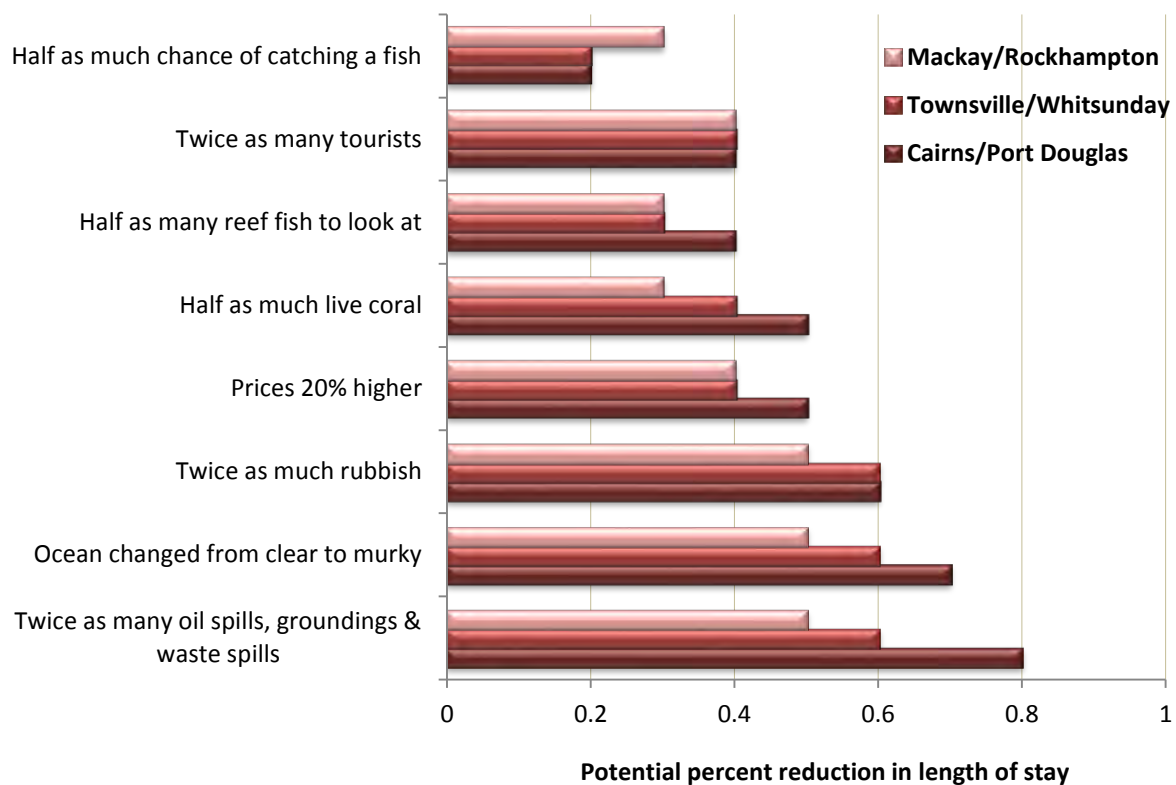


Figure 11: Mean length of stay and potential % reduction in days for each respective change across regions

(Figure adapted from Esparon *et al.*, forthcoming)

Conclusions

Environmental amenity values are more important drawcards to the region than good quality accommodation, and low prices. Most tourists are reasonably satisfied with a range of different ecosystem services provided by the GBRWHA, but similar to residents, the 'gap' between importance and satisfaction scores is largest for environmental non-use values, and respondents seem more averse to the prospect of environmental degradation than to the prospect of prices increasing by 20%. Also similar to our analysis of residents, we find that different types of tourists (e.g. the old, those from QLD or other parts of the world), are motivated by different factors and are likely to react differently to environmental degradation. Moreover, there is a north/south effect with those visiting the north being more environmentally sensitive than those in the south.

4.2 The potential impact of reef degradation on the tourism industry

The material presented in this section summarises material from:

Mustika, P. L. K., Stoeckl, N., & Farr, M. (forthcoming). The potential implications of environmental deterioration on business and non-business visitor expenditures in a natural setting: a case study of Australia's Great Barrier Reef, *Tourism Economics*.

Abstract

Nature based tourism can be an important source of income for regional economies, but relies on a healthy environment. Using data collected from business and non-business visitors to Australia's coast adjacent to the Great Barrier Reef, we generate estimates of the potential financial impact of environmental degradation, demonstrating a novel way of testing and controlling for hypothetical response bias. More than 90% of non-business visitors and 67% of business visitors came to the region for at least one nature related reason. Average daily expenditure was similar for both visitor segments (\$190), but because non business visitors spent longer in the region, they spend more overall. All visitors reacted much more negatively to the prospect of environmental degradation than to a 20% increase in (local) prices, although business visitors were much less responsive than non-business visitors. Adjusting for hypothetical response bias, we estimate that substantial environmental degradation could reduce visitor expenditures (and thus local tourism incomes) by at least 17%.

Keywords: business and non-business visitors, visitor expenditure, Great Barrier Reef, hypothetical response bias, environmental degradation

Methods and main findings

In this paper we used data about visitor expenditure, and responses to questions about the various hypothetical scenarios, to generate estimates of the potential financial impact of environmental degradation – considering both business and non-business visitors.

Total expenditure per visitor per trip was higher for non-business visitors than for business visitors (approximately to \$1,760 compared to \$1,290) – largely because non-business visitors spent a similar amount to business visitors each day, but they stay longer in the region. As show in Figure 12, for each expenditure item, non-business visitors' expenditure was greater than business-visitors expenditure. Nearly 30% of all money was spent on accommodation; with an additional 30% spent on food and beverages at restaurants, cafes and bars or from grocery stores.

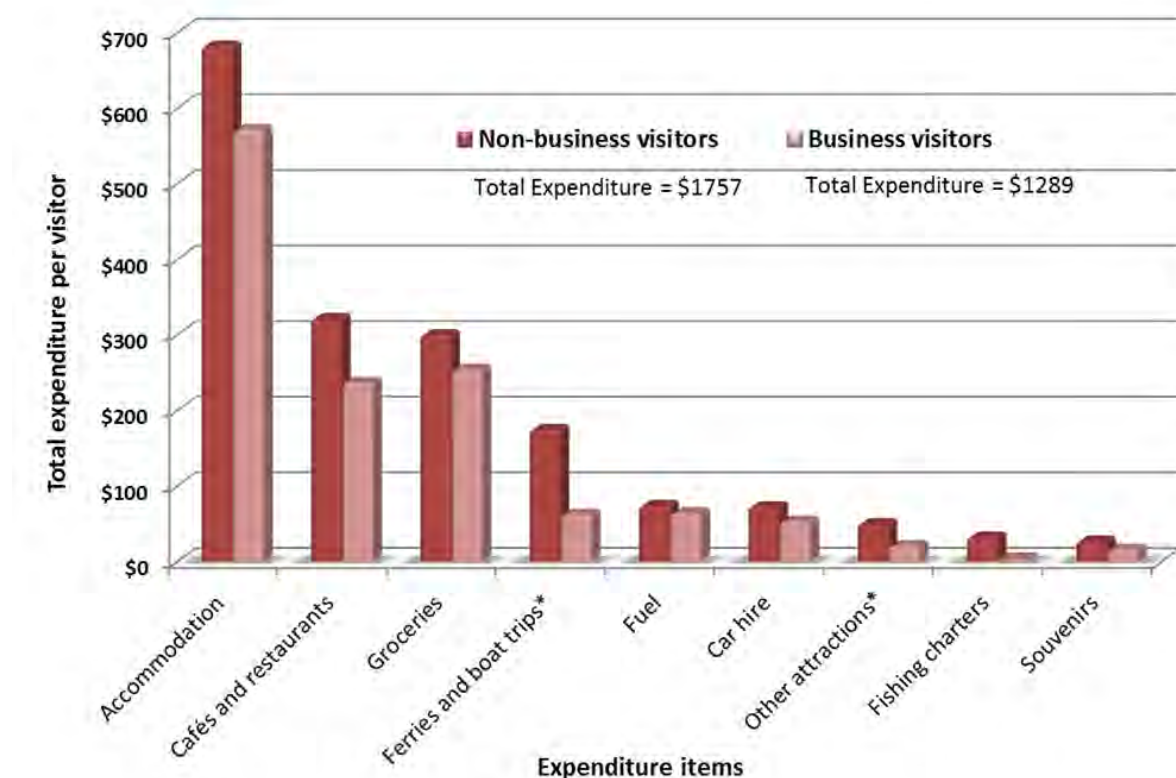


Figure 12: Visitor expenditure by category of expenditure and visitor segment (mean AUD, per visitor).

A '*' indicates statistically significant differences between spending of business and non-business visitors

(Figure adapted from Mustika *et al.*, forthcoming)

We used various types of regression (probit, negative binomial, tobit) to identify statistically significant relationships between socio-economic descriptors of the visitors (Table 7) and total business expenditure². Results are summarized in Table 9. Those business visitors, who spent most, were relatively young and non-nature motivated. This contrasts markedly with non-business visitors: those 'big spenders' were relatively old and highly motivated by nature.

We then looked at responses to our questions about the way in which various hypothetical scenarios would have impacted decisions to come to the region. Both groups of visitors responded negatively to environmental degradation (water clarity, oil spills and reduction in live coral cover) – much more so than to a 20% increase in price. Business visitors were, as expected, much less responsive to all hypothetical changes than non-business visitors.

We adjusted responses for hypothetical bias, and estimated the potential loss of visitor expenditure under each hypothetical change (Figure 13). The results indicate that deterioration of the environment in the GBRWHA could cause much greater financial losses than a 20% increase in regional prices. Economic sectors most affected include those currently receiving the

² We also investigated determinants of expenditure for each expenditure item and the results were consistent with those explaining total expenditure.

most money (Figure 12), namely: the accommodation sector, the café, restaurants and retail sectors, and the operators of boats and ferries.

GBR 'value' to residents and tourists

Table 9: Characteristics of business and non-business visitors who were likely to spend most

Business visitors	Non-business visitors
Australian visitors (excluding those from QLD)	Australian visitors (excluding those from QLD)
Those who stay for long periods of time	Those who stay for long periods of time
Those who spent much time on the beach, and/or who went to an island or the reef spent	Those who spent much time on the beach, and/or who went to an island or the reef spent
Relatively young	Relatively old
Those who were non-nature motivated	Those who highly motivated by nature
	Those on high incomes
	International visitors

Note: Only significant variables reported (Table adapted from Mustika *et al.*, forthcoming)

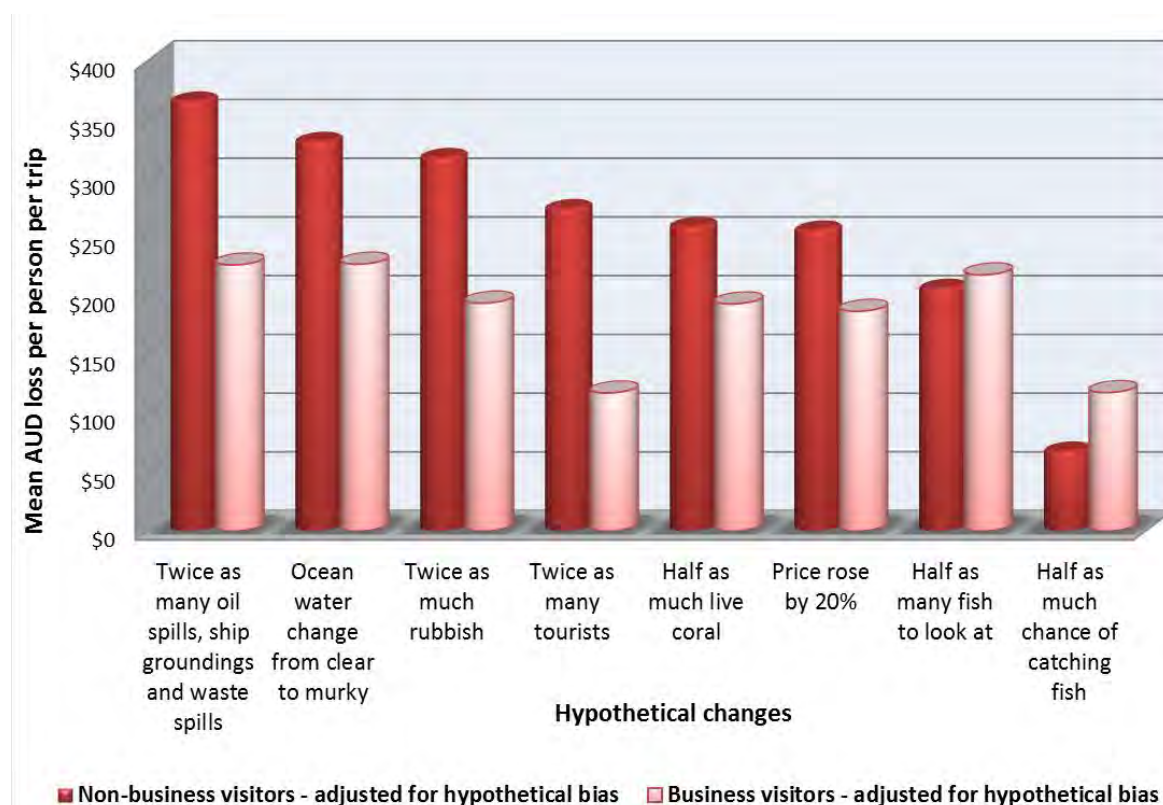


Figure 13: The potential loss in visitor expenditure from shorter stay (AUD per visitor per trip)

(Figure adapted from Mustika *et al.*, forthcoming)

Conclusions

Non business visitors spend more within the GBR catchment than business visitors, primarily because they stay for longer.

Visitors (both business and non-business) who spent a large proportion of their time on a beach, island or at the offshore reefs, spent more than other visitors. Non-business visitors who were strongly motivated by nature also spent more than visitors with other motivations. But nature-motivated business visitors spent less than other business visitors (the nature motivated business visitors stayed for longer – presumably to enjoy nature – but spent significantly less, per night, on accommodation).

Both visitor segments would likely be affected by environmental deterioration. These effects could be more significant than a 20% increase in local prices, suggesting that the tourism industry could lose hundreds of dollar per visitor, if the environment were to deteriorate substantially.

4.3 The potential impact of climate change on the tourism industry

The material presented in this section summarises material from:

Jarvis, D. (accepted paper). Could climate change redistribute global tourism activity by impacting trip satisfaction? Paper to be presented at the 25th Annual CAUTHE Conference, Gold Coast, Queensland, 2-5th Feb 2015.

Abstract

Understanding the elements influencing tourist trip satisfaction is critical if we are to understand the risk tourism faces from climate change. If it affects satisfaction, and thus repeat visitation and/or recommendations to others, it could affect the sustainability of the tourism industry. This case study of tourists visiting the Great Barrier Reef (GBR) catchment investigates the impact of daily maximum temperatures on trip satisfaction. The relationship is found to have an inverted U shape; increased temperatures improve trip satisfaction until a turning point at around 29 degrees centigrade, beyond this point increased temperatures reduce satisfaction. As current temperatures in the region are very close to this turning point, a temperature increase would decrease trip satisfaction, adversely impacting the region's tourism industry. However, currently cooler regions would benefit as increasing temperatures improve the satisfaction of tourists visiting those areas; the net effect being a global redistribution of the tourism activity.

Keywords: trip satisfaction; sustainable tourism; climate change; global warming; maximum daily temperatures; repeat visits

Methods and main findings

We combined data collected from the visitor survey described in section 2 with data from the Bureau of Meteorology (BOM) about the maximum daily temperature experienced by each visitor (i.e. we matched location, and time of visit, to daily temperature data from the BOM). We used both OLS and ordinal regression, to estimate a model describing overall trip satisfaction, as a function of socio-demographic, economic and temperature data. We found that the highest levels of trip satisfaction were associated with tourists who

- Had a high income
- Stayed in the region for a relatively long period
- Believed that a lost wallet and its contents would be returned
- Were satisfied with water quality in the GBR lagoon
- Did not experience maximum daily temperatures that were 'too high', or 'too low'.

More specifically, we found that low average daily temperatures were associated with relatively low levels of trip satisfaction, but that once temperatures rose to about 29.1 or 29.3 degrees centigrade (dependent on whether using ordinal regression or OLS regression models respectively), the relationship reverses; further increases in average daily maximum temperatures reduce the overall level of trip satisfaction. Thus, we have an inverted U shaped relationship between these variables (Figure 14).

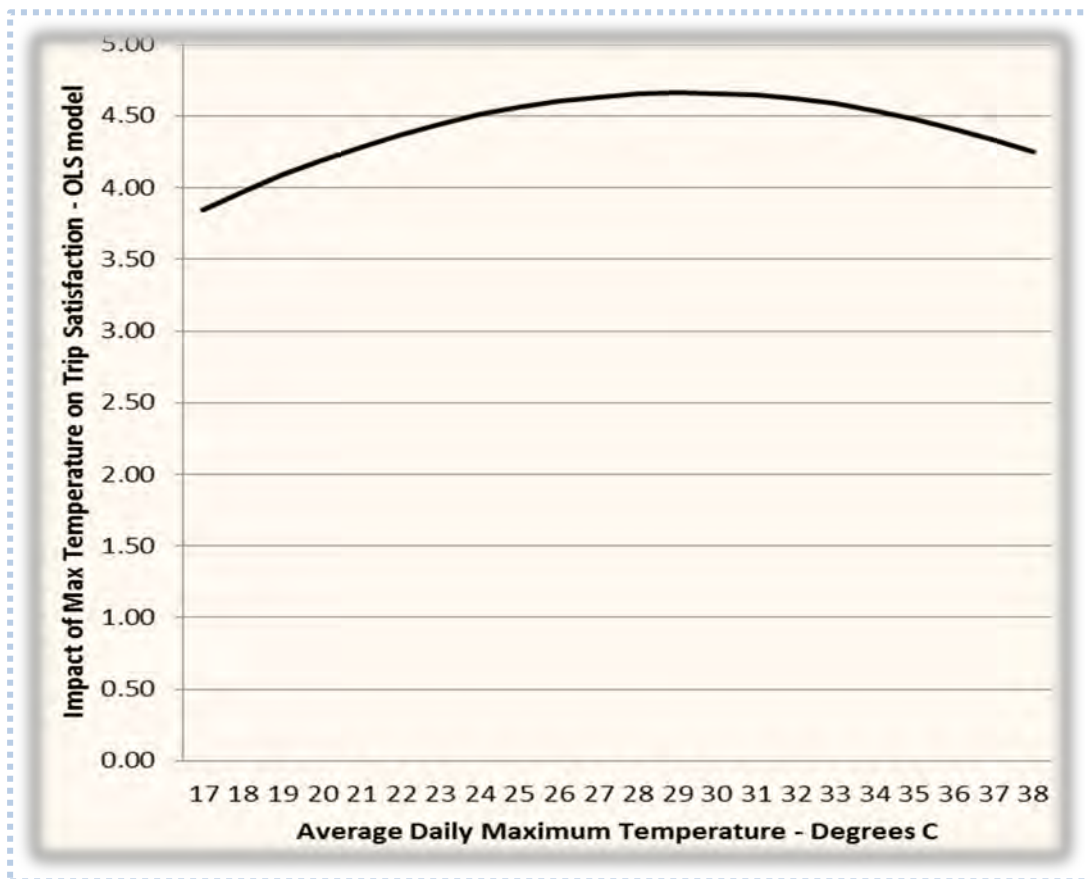


Figure 14: The relationship between overall trip satisfaction and average maximum daily temperatures

(Figure adapted from Jarvis, accepted)

Controlling for other factors, we find there is a non-linear relationship between trip satisfaction and maximum daily temperatures; trip satisfaction improves as temperatures increase to around 29 degrees centigrade, but falls beyond that point. This may have important implications for tourism within the GBR region. With current average maximum temperatures across the region approximately 28 degrees centigrade, and exceeding 29 degrees centigrade in the northern part of the region, any increase in temperature from current levels is likely to result in a decrease in overall trip satisfaction experienced by visitors to the region. Thus a direct consequence of global warming could be a reduction in trip satisfaction, which could seriously impact the sustainability of the tourism industry in the GBR region. However, for locations that are currently cooler than the GBR region, this finding could have positive implications as increasing temperatures would increase the satisfaction of tourists which could significantly boost their tourism industry.

The global implications on tourism from increased temperatures experienced as part of climate change could therefore be a redistribution of tourists between regions, with hotter regions suffering due to the negative relationship between temperatures and trip satisfaction above 29 degrees, whilst currently cooler regions benefit from the positive relationship between maximum temperatures and tourist satisfaction at lower temperatures. Whilst the overall impact on global tourism is unclear, it appears likely that some regions could experience great benefits whilst in other regions tourism may become unsustainable.

4.4 Water clarity, visitor satisfaction and repeat visitation

The material presented in this section summarises the material from

Jarvis, D., Stoeckl, N., & Liu, H. (in review). The impact of economic, social and environmental factors on sustainable tourism.

Abstract

Tourism is vital to the economy of many regions; however visitor numbers are stagnating in some areas. We use tourist survey data supplemented by objective data from secondary sources to develop a model of overall trip satisfaction in the GBRWHA. We also quantify the link between the likelihood of a tourist returning and their overall trip satisfaction.

We find that increased construction work, decreased water clarity and decreased perceptions of tourist safety are all likely to reduce satisfaction, and thus the likelihood of repeat visits. Linking that information to expenditure data, we are able to estimate the potential losses in expenditure / tourism revenue that could occur as a result of reduced repeat visitation, should there be more construction, decreased water clarity, or increased perceptions of crime. We conclude that future development within the region should be evaluated holistically, noting that expansion of one industry, will likely affect others.

Key words: Sustainable tourism, Repeat visitors, Tourist trip satisfaction, Life satisfaction, Triple bottom line impacts on tourism

Methods and main findings

Using data collected from 641 visitors, we first used ordinal regression to explore the link between responses to a question about the likelihood of returning to the GBRWHA, trip satisfaction, and various other socio-demographic factors. Those most likely to return were

- Already repeat visitors (i.e. they had been before)
- Not from North America, Europe or Asia
- Satisfied with their trip

We then supplemented our survey data with data from a variety of other sources (including the Australian Bureau of Statistics, Australian Institute of Marine Science [AIMS]), that described the region in which tourists were visiting when surveyed (e.g. crime rates, construction activity) at the time they were there (e.g. rainfall, water turbidity).

We used ordinal regression to model the relationship between trip satisfaction and these other variables. We found that those most satisfied with their trip were

- On relatively high incomes
- Staying for more than one night
- Of the opinion that a lost wallet would be returned, intact³
- Not in a region with high levels of construction activity
- Visiting a region that had low levels of water turbidity at the time of their visit (we used instrumental variables to control for endogeneity between rainfall, sunshine, turbidity and satisfaction).

We then used coefficients from the models to make quantitative predictions about the way in which (a) higher water turbidity, (b) higher construction activity; (c) higher perceptions of crime would impact firstly overall trip satisfaction and subsequently, the probability that a person would return. We were then able to use predicted reductions in the probability of return, to generate estimates of the likely financial impact of those changes (in terms of lost tourist revenue, with lower numbers of repeat visitors). For example, we were able to estimate that a:

- 10% increase in water turbidity within the GBR lagoon would reduce tourist revenues by approximately \$430,000 per annum
- 10% increase in the level of construction activity within the region would reduce tourist revenues by approximately \$392,000 per annum
- 10% reduction in the number of tourists perceiving that a lost wallet would be returned with contents intact would reduce tourist revenues by approximately \$305,000 per annum

Conclusions

High numbers of repeat visitors help sustain an industry. Visitors most likely to return to the GBRWHA are those who were most satisfied with their most recent visit (controlling for other factors). Satisfaction is influenced by a range of factors – social, economic, and environmental. In this part of the world, there is a statistically significant relationship between tourist satisfaction, perceptions of crime, construction activity, and water turbidity. Increases in any of those three factors could thus impact the tourism industry.

³ Actual crime rates were not correlated with responses to the lost wallet question; neither were they correlated with trip satisfaction.

4.5 Tourist willingness to pay for improvements in water quality

The material presented in this section summarises material from:

Farr, M., Stoeckl, N., Esparon, M., Larson, S., & Jarvis, D. (2014a). The importance of water clarity to tourists in the Great Barrier Reef and their willingness to pay to improve it. *Tourism Economics*. Available at <http://www.ingentaconnect.com/content/ip/tec/pre-prints/content-teft157>

Abstract

Using the Great Barrier Reef as a case study area, we investigate visitors' willingness to pay (WTP) to improve water clarity (WC). We also explore the extent to which people's objective and subjective measures of WC influenced WTP. Our results suggest that people's stated perceptions (importance and satisfaction) and the interaction between them have a significant influence on WTP. Those for whom WC was very important and who were very satisfied with WC were willing to pay more to preserve it. The importance variable interacts with subjective perceptions that drive behaviour. Thus one needs to consider not only satisfaction, but also the importance of the environment rather than using only subjective (or objective) measures when trying to explain behaviour. Further deterioration in WC could adversely affect the tourism industry and the average visitor would be willing to pay up to Aus\$14.5 per visit to help improve it (although this amount is different for different visitors).

Key words: Contingent Valuation; Great Barrier Reef World Heritage Area; hurdle model; Payment card; visitors' willingness to pay; water clarity; objective and subjective measures

Methods and main findings

We asked one-half of our tourist sample to answer questions about willingness to pay for various improvements to the environment (the other half were asked expenditure questions). In this paper we focused on responses to questions about how much visitors were willing to pay (each visit) to contribute to a fund that would seek to improve water clarity in the GBR lagoon; 80 % were willing to pay something, some even more than \$50 (see Figure 15).

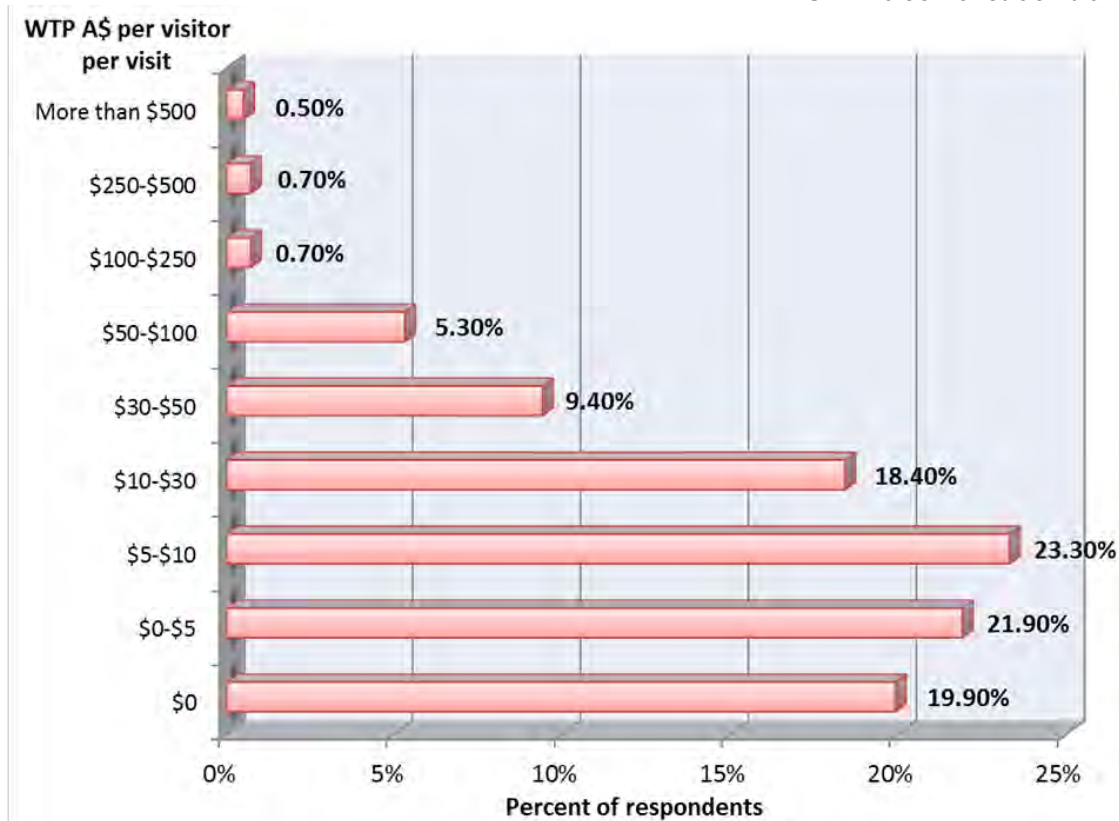


Figure 15: Distribution of responses to question about WTP to improve ocean water clarity

(Figure adapted from Farr *et al.*, 2014a)

We used various types of regression (probit, tobit and Heckman selection) to look for statistically significant relationships between socio-economic and demographic descriptors of visitors (Table 7) and the amount they were willing to pay to improve ocean water clarity. We also included in those regressions, visitor responses to questions about (a) how important water quality was to them when deciding whether to come to the region (b) how satisfied they were with water quality and (c) actual measures of water turbidity – provided to us by the AIMS.

We found that actual water quality (turbidity) was irrelevant. Instead, we found that tourists who are most likely to be willing to pay something to improve WC were:

- Females
- Relatively young
- Highly educated
- Relatively low income earners
- Not employed in tourism-related industries
- Planning to return to the GBRWHA in the future
- Not from China but from Japan
- Happy to pay to help protect the GBRWHA, providing that other users pay too
- Do not believe that only those who live near the GBR should care for it
- Completed a questionnaire with low dollar values on the 'bid card' (see comments about this in section 3.5)
- Of the opinion that WC was important when deciding to visit this part of Australia

Of the 80% of visitors who were willing to pay something, those offering to pay most were visitors who were

- Not from China
- Not from Queensland
- Presented with a questionnaire where high dollar values were part of the 'bid card'
- Very satisfied with water clarity and thought it was very important

The average respondent was willing to pay about \$14.5 per visit for water clarity improvement – although, as shown in Figure 16, that varies significantly according to attitudes about how important water is, and perceptions of water quality.

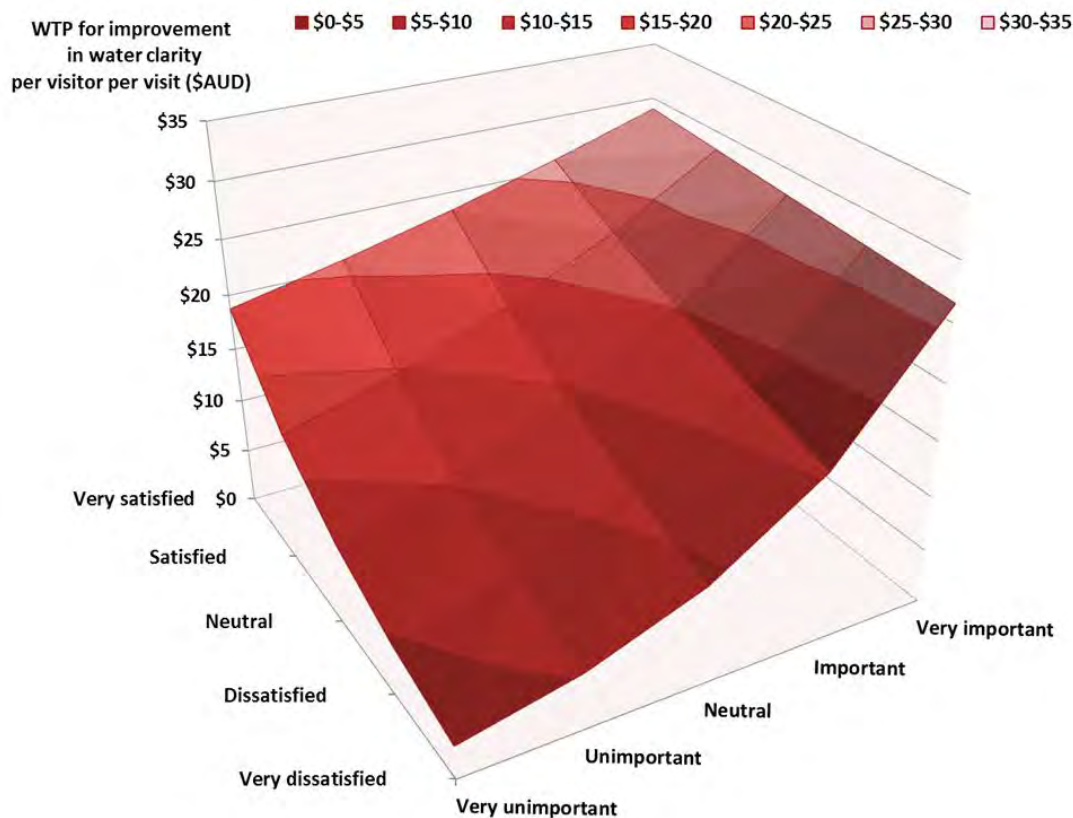


Figure 16: Importance, perceptions and WTP for water clarity improvement

(Figure adapted from Farr et al., 2014a)

Conclusions

Water quality is important to visitors and they state that they are willing to pay, on average, about \$14 each time they visit to help improve water quality – although these amounts differ significantly according to the origin of visitors, their income, and the attitudes and perceptions of water quality. These results indicate that one could, in theory, collect between \$30 million and \$90 million per annum from visitors (depending upon whether the money were collected only from those visiting the reef or from all those visiting the region). We do, however, need to be aware that hypothetical responses do not always translate directly into actual behaviours – as evidenced in the paper described in section 4.2.

4.6 Additional insights

The material presented in this section is based and builds on data reported in

Stoeckl, N., Farr, M., & Sakata, H. (2013). What do residents and tourists 'value' most in the GBRWHA? Project 10-2 Interim report on residential and tourist data collection activities including descriptive data summaries. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns, pp. 112. Available at: <http://www.nerptropical.edu.au/publication/project-102-technical-report-what-do-residents-and-tourists-'value'-most-gbrwha>

4.6.1 Visitor willingness to pay to reduce the risk of shipping accidents or to protect top predators

Tourists were not only asked about their WTP to improve water clarity; they were also asked about their WTP to reduce the risk of shipping accidents and to protect top predators. A relatively large proportion of respondents were not willing to pay anything at all (Figure 17), although these proportions were significantly smaller than for residents (Figure 8).

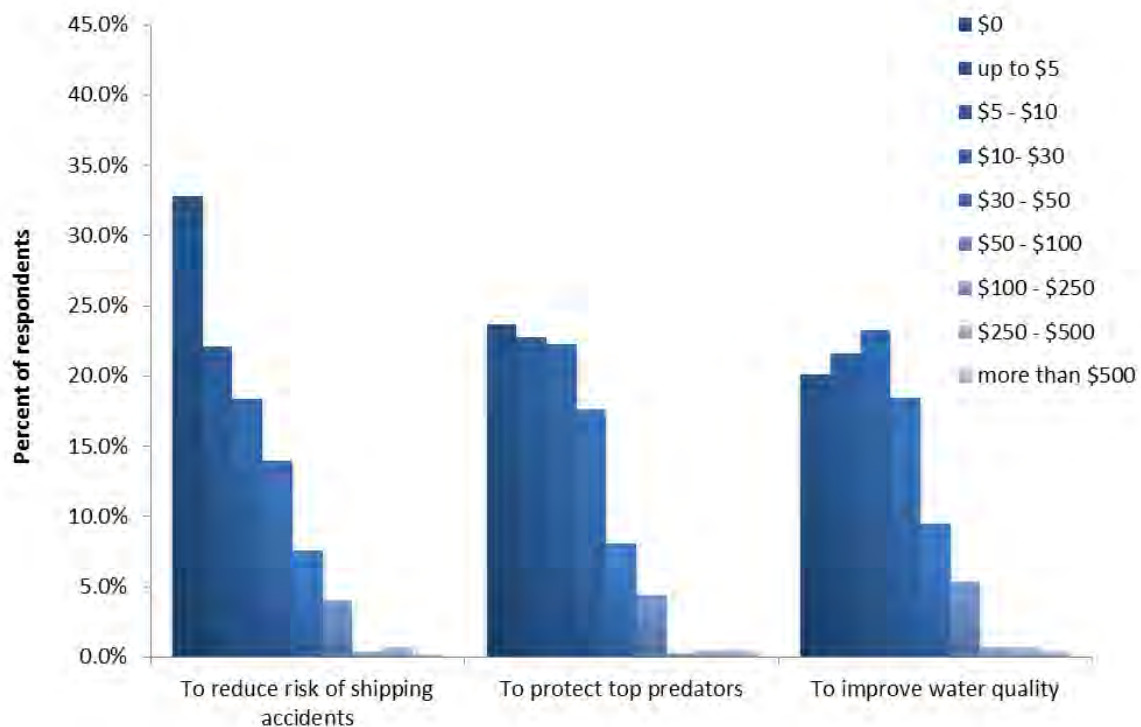


Figure 17: Distribution of visitor responses to questions about willingness to pay (per person per trip) for environmental improvements

(Figure adapted from Stoeckl et al., 2013)

As was done for the residential data, and for the tourist, water quality data, we used the hurdle model to look for statistically significant relationships between various socio-economic and

demographic descriptors of respondents (Table 7) and their WTP. Here again, we found that the determinants were very similar for all three WTP improvements (Table 10).

Table 10: Determinants of WTP to improve water clarity, to reduce the risk of shipping accidents and to protect top predators

Tourists					
Water Clarity		Shipping*		Predators*	
To pay or not to pay amount >\$0	How much to pay (if agreed to pay >\$0)	To pay or not to pay amount >\$0	How much to pay (if agreed to pay >\$0)	To pay or not to pay amount >\$0	How much to pay (if agreed to pay >\$0)
Age (-)		Age (-)	Age (+)	Age (-)	
Only people who live or visit should care (-)		Only people who live or visit should care (-)		Only people who live or visit should care (-)	Only people who live or visit should care (-)
Not prepare to pay unless all users pay too (+)		Not prepare to pay unless all users pay too (+)		Not prepare to pay unless all users pay too (+)	
	Visitor QLD (-)		Visitor QLD (-)	Visitor QLD (-)	Visitor QLD (-)
China (-)	China (-)				
Japan (+)		Japan (+)			
Return (+)		Return (+)	Return (+)	Return (+)	Return (+)
Education (+)				Education (+)	
WTP Bid range (-)	WTP Bid range (+)	WTP Bid range (-)	WTP Bid range (+)		
Income (-)					
Importance (+)					
Male (-)					
Tourism (-)					
	Satisfaction (-)				
	Importance*				
	Satisfaction (+)				
Estimated WTP = \$14.51		Estimated WTP = \$15.53		Estimated WTP = \$8.93	

Note: Only significant variables reported. A plus sign (+) indicates that the variable was found to have a positive and statistically significant relationship with the score assigned to the corresponding value; a negative sign (-) indicates negative and statistically significant negative relationship. * These WTP models did not include 'Importance', 'Satisfaction', and 'IS' explanatory variables.

Several variables are strongly associated with all responses. For example, older people are generally much less likely to be willing to pay anything (or to 'play' the WTP game in our surveys). Similarly, residents of QLD who are visiting the GBRWHA are willing to pay less than other visitors – likely reflecting the fact that the question asked how much people were willing to pay for each visit, and these people visit more often. That said, those who say they are likely to return to the region (irrespective of origin), were generally willing to pay more. As expected, questionnaire design has an impact: high bid ranges deterred people from answering the question, but if they did choose to answer the question, higher bid ranges typically generated higher WTP responses.

Equity issues feature prominently. People feel that caring for the GBRWHA is the responsibility of many and are willing to pay to help protect it, but not unless others are also making a contribution.

It seems that visitors from Japan were more likely to agree to 'play' our Contingent valuation game (and were thus more likely to have a non-zero WTP), but the amount these visitors were willing to pay were not different from the amount visitors that domestic (non QLD) or other overseas visitors were willing to pay. Visitors from China were willing to pay less to protect WC than those from elsewhere; so too were males, those dependent upon the tourism industry for their household income, and those dissatisfied with water quality.

5 Do changes in world prices impact the GBRWHA?

A significant body of research has established that ocean turbidity impacts reef health. There are many plans to reduce sediment loads by encouraging best management practices; there is also interest in the use of market based instruments. But it is exceedingly difficult to assess the potential efficacy of market policies, since that requires one to determine how changes in the socioeconomic system (e.g. price changes) impact the biophysical (e.g. sediment loads). In this exploratory segment of the project, we set out to develop a prototype model that would allow us to use statistical/econometric techniques developed within the (macro)economics literature to explore such issues. Simplistically, the econometric techniques which we tested (time series analysis and vector auto regression models) allow one to model interactive sub-systems simultaneously, to control for seasonality, and to consider the fact that changes in one part of a system may only impact another with lags. As such, they are well suited to complex real-world systems, yet (to the best of our knowledge) untested in this context.

We undertook this investigation in two parts: firstly testing to see if we could use these econometric techniques to adequately model hydrological systems, and then (having established that it was possible to do so), expanding the model to also incorporate economic variables. The sub-sections below summarise key aspects of that investigation.

5.1 Relationship between rainfall and river discharge in the Burdekin River Catchment

The material presented in this section summarises material described in:

Jarvis, D., Stoeckl, N., & Chaiechi, T. (2013). Applying econometric techniques to hydrological problems in a large basin: Quantifying the rainfall–discharge relationship in the Burdekin, Queensland, Australia. *Journal of Hydrology*, 496(0), 107-121. doi: <http://dx.doi.org/10.1016/j.jhydrol.2013.04.043>

Abstract (shortened)

This study seeks to explore the relationship between rainfall and river discharge within a large river basin (the Burdekin) flowing into the waters surrounding the Great Barrier Reef (GBR), and to investigate the best method of measuring the relationship. Modern econometric time series techniques are utilised, and compared with results using an alternate technique developed by researchers from the bio-physical sciences; the widely used Thiessen Polygon method. We find that modern econometric time series techniques provide a viable alternative to other methods, and may thus be useful in data-poor environments.

Keywords: Rainfall–discharge relationship, Thiessen Polygons, Temporal scale, Time series estimation techniques, Stationarity, Unit root testing

Methods and main findings

First we collated rainfall and temperature data from Australia's Bureau of Meteorology (BOM) and river discharge data from the Department of Environment and Resource Management (DERM) from 1939 to the present day in the Burdekin River catchment. We checked for 'stationarity' using the Augmented Dickey-Fuller (ADF) test, the Phillips-Peron (PP) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS), finding it to be so (the implication being that climate

GBR 'value' to residents and tourists
change has not had a statistically discernable impact on either river discharge or rainfall in the Burdekin catchment during the research period).

We then tested several different time-series models, specifically trying to determine

- What is the best measure of rainfall that can be used to quantify this relationship including the optimal number of rain stations?
- What is the optimal temporal scale for measuring the relationship (e.g. monthly, quarterly or annual data)?

We found that models which used a small number of rain stations had higher explanatory power and were more robust than models with a larger number of stations for both pre-dam and post-dam periods. We also found that models which used annual time-series data performed better than those using monthly or quarterly data and that the time-series analysis can be easily extended to include other explanatory variables (e.g. as the seasonality index and the temperature measure).

Conclusion

It is possible to model hydrological relationships using econometric techniques; and that when doing so, models with coarser temporal and geographic scale tend to perform best.

5.2 Is there evidence to suggest that prices affect the GBRWHA?

The material presented in this section summarises material reported on, in detail, in

Chaiechi, T., Stoeckl, N., Jarvis, D., Lewis, S., & Brodie, J. (in review). Assessing the impact of price changes and extreme climatic events on sediment loads in a large river catchment near the Great Barrier Reef.

Abstract

Ocean turbidity (associated with sediment from rivers) can significantly impact reef health. In Australia, there are many plans to reduce sediment loads by encouraging best management practices; there is also interest in the use of market based instruments. But it is exceedingly difficult to assess the potential efficacy of market policies, since that requires one to determine how changes in the socioeconomic system (e.g. price changes) impact the biophysical (e.g. sediment loads). We use historical data (from 1938 - 2011) in a Vector Auto Regression to simultaneously model interactions between the economic and biophysical systems in the Burdekin River Catchment adjacent to the Great Barrier Reef lagoon. This allows us to statistically test for the impact of changes in prices and costs on sediment load, while controlling for biophysical influences. We find that changes in rainfall and extreme events have the most impact on sediment loads, but that prices also impact sediment loads, once controlling for these other factors. Evidently market based policies may have the potential to reduce sediment loads. Our empirical results provide useful information for those interested in the Burdekin River Catchment and the Great Barrier Reef; the modelling approach may have wide applicability in a variety of contexts.

Methods and main findings

Our underlying hypothesis was that sediment loads are a function of climate (and extreme events), rainfall & catchment wetness, vegetation & land cover, and cattle numbers, which are a function of input and output prices (e.g. Wages and beef prices) and climate. The modelling challenge, therefore, was to determine if it was possible to detect a 'price signal' after controlling for external factors such as climate and extreme events.

We collated data from a variety of different sources to 'populate' and then build a vector auto regression (VAR) model – developing a separate one for the period from 1938 – 1983 (before the Burdekin dam was built), and one for the entire period (using dummy variables to control for the fact that the dam would have fundamentally altered streamflow-sediment relations).

We found that it was possible to successfully integrate economic and biophysical data within a VAR, and that one could detect a price signal, after controlling for extreme events (and for the construction of the dam, which seems to act as something of a sediment catch). Evidently, higher beef prices will, with one year's lag, increase cattle numbers, which will, with another year's lag, increase sediment loads. There was also evidence to suggest that the system is becoming more price sensitive with time.

Conclusion

Rainfall and extreme events are the two most significant drivers of sediment loads in the Burdekin Catchment, but after controlling for that, it is possible to pick up a price signal. Some argue that 'efforts to encourage land managers to adopt recommended management actions may, alone, be insufficient to achieve more significant improvements in water quality' (Thorburn *et al.*, in The Scientific Consensus (2013)). If so, then our results suggest that market based incentives may offer themselves as a supplementary strategy – how successful they could be in comparison to other policies or strategies, or in other contexts, remains to be investigated.

6 Synthesis

This project set out to collect economic data relevant to the GBRWHA and to explore the interaction between economic variables and biophysical variables known to be related to reef resilience (e.g. indicators of water turbidity). Its overarching aim was to improve our understanding of the way in which the economy and the GBRWHA interact, making it easier to judge (a) which economic variables are most important to monitor, and (b) how to interpret trends in those variables (i.e. whether changes are likely to be 'good' or 'bad' for the reef). Simplistically, we focused on the 'value' of various ES provided by the GBRWHA to residents and tourists, and on the way in which the economy affects those ES (thus explicitly acknowledging the existence of dynamic feedbacks).

To begin we conducted a substantive literature review. The review revealed that most valuation studies have concentrated on a narrow range of ecosystem services (Stoeckl *et al.*, 2011) such as recreation (Carr and Mendelsohn, 2003; Knapman and Stoeckl, 1995; Kragt *et al.*, 2009) or fishing and boating (Farr *et al.*, 2014b; Prayaga *et al.*, 2010). More recent studies have sought to improve our understanding about some of the region's *non-use values* (Rolfe and Windle, 2012a; Rolfe and Windle, 2012b; Windle and Rolfe, 2005), but significant knowledge gaps remain (see also Stoeckl *et al.*, 2014). The literature review also revealed the lack of comparative information. No assessments existed that simultaneously valued numerous different ecosystem services using the same methodological approach. Different valuation techniques produce different types of estimates (e.g. marginal prices or expenditures) and may not be comparable or additive. If policy makers and managers need to make decisions about potentially competing values (e.g. fishing versus tourism versus aesthetic/cultural values), then the lack of comparable information about these different values may stand as a significant knowledge gap.

We also conducted workshops with a variety of regional stakeholders/managers/decision makers in Cairns, Brisbane and Townsville. Not only did we use these workshops to identify a set of regionally relevant 'values' for assessment (as discussed in previous sections), but to learn more about the issues confronting these people and about how they hoped to be able to use the information generated from this project. The workshops highlighted the fact that participants were interested in a broad range of different community benefits (some of which related directly to various ecosystem services provided by the GBRWHA, and some of which related to the economy in general). It also revealed that people wanted to be able to use our research results in a variety of different ways. Some wanted to simply raise public awareness of the importance of the GBRWHA; others wanted to be able use the results to help them assess the way in which people and/or the economy might be impacted by particular management changes which could impact the reefs ecosystem services (e.g. further reductions in water quality). In other words, some stakeholders were looking for information about (in economic jargon) the 'total' value of the GBRWHA; others wanted information about 'marginal' values (or trade-offs).

We thus set out to assess the 'value' of a broad range of ES, using methods that allowed us to generate such information.

We found that:

- The non-market goods and services provided by the GBR (e.g. having healthy coral reefs, healthy reef fish, clear ocean water, and preserving the reef for future generations) are considered, by residents of the catchment, to be more important to their overall quality of life than recreational values (e.g. being able to go fishing, boating, or spending time at the beach). These recreational values are, themselves, considered to be more important than the jobs and incomes associated with different industries (Larson *et al.*, 2014a, 2014b).

- Environmental and recreational values of the GBR are also considered, by tourists, to have been more important in their decision to visit the coastal area adjacent to the GBRWHA than other market-related 'values' such as good quality accommodation, being able to meet budget, visiting friend and relatives and/or attending to business (Esparon *et al.*, forthcoming).
- Residents and tourists react more negatively to the prospect of degradation of the environment than to the prospect of a 20% increase in prices (Stoeckl *et al.*, 2013; Esparon *et al.*, forthcoming; Mustika *et al.*, forthcoming).

Our finding that GBR-based environmental values – particularly non-use values – are more important than market values appears consistent across sample groups (residents and tourists) and across methodological approaches.

As regards estimates of 'total' value

- We used novel approaches to control for the problem of inseparable values, estimating that collective value of all of the ecosystem services provided by the GBRWHA is likely to be worth at least \$15b per annum – possibly as much as \$20b (Stoeckl *et al.*, 2014). This figure is not implausible. The tourism industry is 'worth' in excess of \$4b per annum to residents of the catchment (Deloitte Access Economics, 2013), and our estimate of 'total' value includes tourism, recreational and other non-use values (both deemed to be 'more important' to the overall quality of life of residents than the jobs and incomes associated with reef-based tourism).
- Using other novel approaches, we also generated estimates of the financial value of only non-use values: approximately \$7.5b (Jarvis *et al.*, in review). This is consistent with Stoeckl *et al.*'s (2014) finding that non-use values are worth a minimum of \$4b.
- We found that total expenditure per visitor per trip was higher for non-business visitors than for business visitors (approximately to \$1,760 compared to \$1,290) – largely because non-business visitors spent a similar amount to business visitors each day, but they stayed longer in the region. More than 60% of expenditure is on accommodation and food (at cafes, restaurants, and other retail outlets). (Mustika *et al.*, forthcoming).

We also generated estimates of several different 'marginal' values.

- We combined responses to our contingent behavior questions with information about tourist expenditure to generate estimates of the potential loss in visitor expenditure that could happen, should various types of environmental degradation occur. Using novel methods to control for hypothetical response bias, we estimate that these amounts could be up to \$300 per visitor, or about 17% of current expenditure (Mustika *et al.*, forthcoming).
- After controlling for factors such as income, gender and length of stay, we found that tourists who experienced clearer water and/or maximum daily temperatures that were close to 29 degrees centigrade while in the region had higher levels of overall trip satisfaction than other tourists (Jarvis, forthcoming; Jarvis *et al.*, in review). We were able to use coefficients from our model with water turbidity, to generate estimates of the potential loss of tourism revenues that could occur if sediment increased by 10% (about \$400,000 across the entire GBR catchment area) – Jarvis *et al.* (in review).
- We found that residents were willing to pay about \$32 per annum per household for to help improve water clarity, \$27 to reduce the risk of shipping accidents and \$29 to protect top predators per household per annum (not yet published). For tourists these figures were \$14.5, \$15.5 and \$9 per person per visit, respectively. The amount people

GBR 'value' to residents and tourists were willing to pay, however, was contingent upon 'others paying too' (respondents did not want to be the only person paying). In the case of water quality and tourists, the amount people were willing to pay also depended upon the importance of water quality to the respondent and upon their perceptions (not actual measures) of its quality while in the region (Farr *et al.*, 2014a).

Averages aside, different people 'value' things differently. Our results confirmed this to be true, with patterns that were consistent across samples (tourists and residents) and across methodological approaches – see pages 53 and 54 for a synthesised summary of findings. Most notably,

- Gender matters
 - Both males and females agree that non-use values are more important to their overall quality of life than other values. But males seem to attach less 'value' to non-use environmental values, Indigenous cultural values and 'bragging rights' than females. This is true for 'importance' scores and for Larson's IDS. It is also true for both residents and tourists. Moreover, male residents are not willing to pay as much for improvements in water clarity and to protect top predators as females.
 - Males residents are likely to rate fishing and boating as being (relatively) more important than females – this is true for 'importance' scores and for Larson's IDS. Male residents are also willing to pay more, on average, than females to reduce the risk of shipping accidents.
 - Similarly, male tourists also value fishing and boating more than female tourists and are WTP less for improvements in water quality.
 - Females are generally more satisfied with their life, overall, than males (controlling for other factors).
- Education matters
 - The higher a resident's education, the more 'importance' they are likely to attach to Indigenous cultural values, and the less importance they were likely to attach to boating, fishing, or mining. WTP to improve water quality, to reduce the risk of shipping accidents and to protect top predators was also positively related to education for residents. Those with more education were also likely to be much less satisfied with various environmental factors than their less educated counterparts.
 - The higher a tourist's education, the more important were various environmental values (such as having little rubbish, healthy coral reefs, etc.) as a reason for coming to the region; these tourists were also more likely to be willing to pay at least some small amount to improve water quality or to protect top predators than their less educated counterparts.
- Income matters – and, in contrast to expectations, it does not always have the same effect as education
 - Residents with a relatively high income were more frequent recreational users of the GBRWHA than others, and were likely to place a higher value on mining, seafood, beaches industry and a lower value on 'bragging rights', than residents on lower incomes. Residents on a high income were willing to pay more, on average, to improve water quality than those on lower incomes – most likely because of the strong link between willingness to pay and ability to pay.

- Visitors on a relatively high income were, on average, willing to pay more to improve water clarity than those on lower incomes. They also spent more when in the region, and had higher levels of overall trip satisfaction than their poorer counterparts.
- That said, Indigenous cultural and environmental values were a less important draw-card to visitors on high incomes than they were to those on lower incomes.
- Age matters
 - Elderly residents are generally more satisfied with life as a whole than younger residents. They are also likely to consider Indigenous culture, preservation of the GBR (for its own sake), boating, iconic marine animals, clear oceans and 'bragging rights' to be less important to their overall quality of life than their younger counterparts. Seafood was more important to this group and they were generally willing to pay less to protect the environment than their younger counterparts.
 - Elderly tourists place a higher value on friends/socializing, seafood, and land-based environmental values (seeing the wet tropics rainforest and mangroves/wetlands) than their younger counterparts; boating and spending time at the beach are relatively less important for older tourists than for younger ones.
 - Younger business visitors are likely to spend more money in the region than older business visitors; but for non-business visitors, it is, on average, the older ones who spend more money locally.
- Place of origin / birth matters
 - Residents of the GBRCA who were born in QLD were not willing to pay as much to improve water quality, to reduce the risk of shipping accidents or to protect top predators as those born outside QLD. They were likely to feel that Indigenous culture was less 'valuable' (using just raw importance scores, or Larson's IDS) than those born elsewhere, and were more frequent recreational fishers than others.
 - Visitors from within QLD were not willing to pay as much to improve water clarity, to reduce the risk of shipping accidents or to protect top predators as others. They were more likely to have come to the region for friends/family/socializing, and were less likely to be drawn by environmental values.
 - Domestic visitors (excluding those from within QLD) spent, on average, more within the region than visitors from elsewhere.
 - Tourists from China were generally not willing to pay as much to improve water clarity as visitors from elsewhere.
- Location matters
 - Income is a relatively more important contributor to overall quality of life to residents in the southern parts of the GBR than to residents in the north. Being satisfied that the GBR is being preserved for future generations is less important (to overall quality of life) to those in the southern parts of the GBR than to those in the north.
 - Tourists visiting southern parts of the GBR were less concerned by the prospect of environmental degradation than tourists visiting the north. They were however, relatively more concerned by the prospect of having fewer fish to catch.

- Tourists visiting places with relatively little construction activity, clear water and maximum daily temperatures of approximately 29 degrees centigrade were generally more satisfied with their overall trip (controlling for other factors) than other tourists.
- Marital status matters
 - Single people are generally less satisfied with their life, overall, than those in a long-term relationship (controlling for other factors)
 - Single residents are likely to view industry values as being less important than other values; Indigenous culture and bragging rights are relatively more important to this group.
 - Single residents are more frequent recreational fishers and also more frequent swimmers & snorkelers than their married counterparts.
 - Single travelers are more likely to be in the region for business than others
- Industry of association matters
 - Residents whose household incomes were dependent upon the mining industry felt that recreational (e.g. boating and fishing) and industry values were more important than those dependent on other industries (with the exception of fishing). They also spent less time at the beaches, on islands, or at the reef than others.
 - Residents whose household incomes were dependent upon the commercial fishing industry felt that recreational values were more important than those dependent on other industries (with the exception of mining). They also felt that Indigenous cultural values, clear oceans and undeveloped beaches were more important than those dependent on other industries, and they spent more time engaging in marine-based recreational activities (except spending time at the beach) than those dependent on other industries.
 - Residents whose household incomes were dependent upon the tourism industry felt that 'bragging' rights were more important than those dependent on other industries and they spent more time at the beach, fishing, boating, snorkeling and sailing than those dependent on other industries.

The fastest growing demographic group in the GBRC is of young lesser educated males working in the mining and associated industries receiving relatively high incomes (Deloitte Access Economics, 2013). We used coefficients from our models describing the link between industry of association, other demographics and the 'importance' of different ES to overall quality of life, to compare the current distribution of 'values' with one that could prevail if there was significant growth in either the tourism or the mining/manufacturing sector (Figure 18). Growth in the mining/manufacturing sector would likely mean that recreational values would become more important when compared to other values.

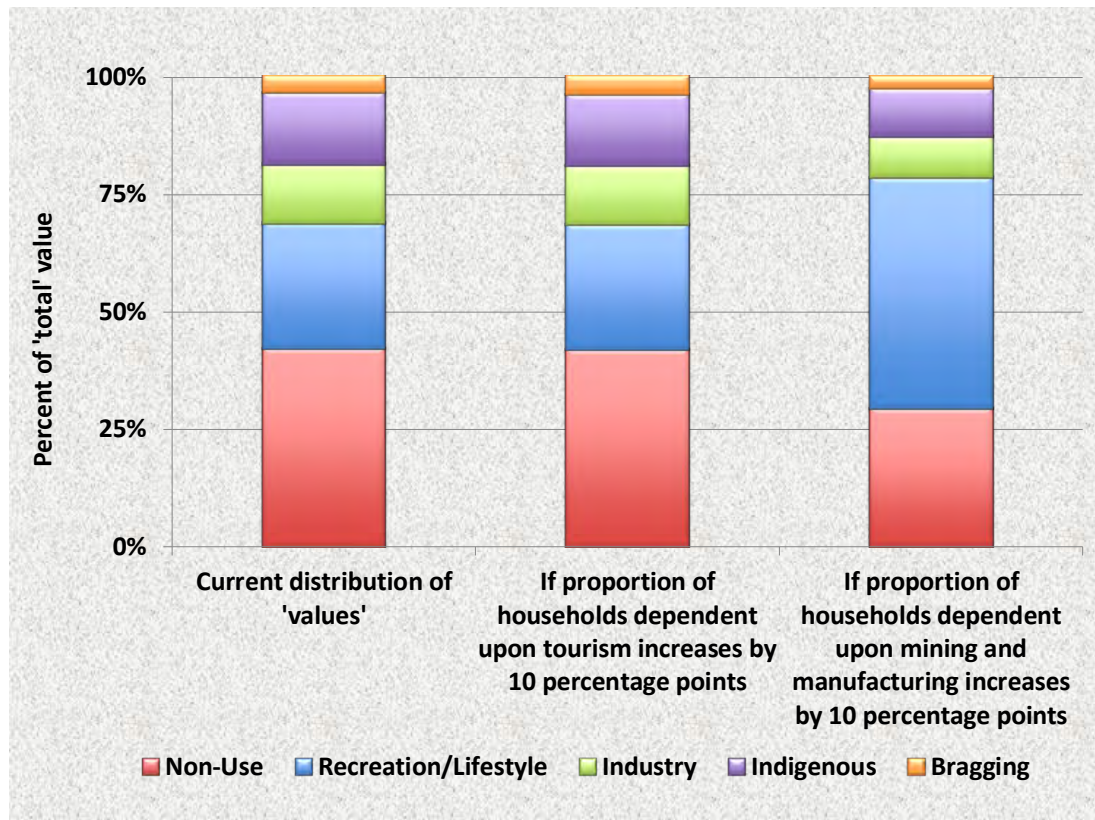


Figure 18: Impact of change in economic structure on values provided by GBRWHA - 'Simulated' finding

Table 11: Characteristics of residents that had statistically significant relations with importance, satisfaction, reaction to hypothetical change (SUR model); and WTP (To pay or not to pay amount >\$0; and How much to pay (if agreed to pay >\$0) decisions)

Variables	Importance (I) and Satisfaction (S)												Importance (I), Satisfaction (S) & Change in environmental quality (C)								WTP		
	Commercial fishing (I,S)	Mining/Agriculture (I,S)	Cheap shipping (I,S)	Future generations (I,S)	Seafood (I,S)	Beach/Swimming (I,S)	Boating (I,S)	Indigenous (I,S)	Bragging (I,S)	Undeveloped (I,S)	Iconic marine species (I,S)	Mangroves (I,S)	No rubbish (I,S,C)	Coral reefs (I,S,C)	Reef fish (I,S,C)	Fishing (I,S,C)	Clean ocean (I,S,C)	Tourists (I,S,C)	Oil spills, groundings & waste spills (C)	Increase in prices (C)	Water Clarity amount >\$0, How much to pay (if agreed to pay >\$0)	Shipping amount >\$0, How much to pay if agreed to pay >\$0)	Top predators amount >\$0, How much to pay (if agreed to pay >\$0)
Male				-	-	-	+	-	-	-	-	-	++	++	-	+	-	++	++	++	-	++	-
Single	-	-		-		+	+	++	+							+							
Age				++	+		-		-		-		--	-	--	--	--	--	--	--	-	-	-
Indigenous		-						+		-	-	+		++	++	--	+	--	--	--			
Education		-	-	-			-	+			-	-		-	+	-			--		+	+	+
Income		++			+	+			-				--		--	--	--	--	--		++	++	++
HH size							+			+	+				+								
Born QLD		+						-					-	--		++	-				-	-	-
Fishing						+	++	+	+	++	+	+	+	++	+	+	++	++					
Mining		++			+	+	++					+			--	++	+						
Tourism		+	++			+			+						--	--					+	+	+
Agriculture															--	--	--	--	--				
Not prepared to pay unless all Australians pay too																					+	+	+

Table 12: Characteristics of visitors that had statistically significant relations with importance, satisfaction, reaction to hypothetical scenarios (SUR model); and WTP (To pay or not to pay amount >\$0; and How much to pay (if agreed to pay >\$0) decisions)

Variables	Importance (I) and Satisfaction (S)																Importance (I), Satisfaction (S) and Change environmental quality (C)								WTP		
	Friends (I,S)	Business (I,S)*	Close (I)	Budget (I,S)	Accommodations (I,S)	Seafood (I,S)	Beach/Swimming (I,S)	Boating (I,S)	Indigenous (I,S)	Sunshine (I,S)	Bragging (I,S)	Undeveloped (I,S)	Iconic marine species	Wet tropics (I,S)	Iconic land species (I,S)	Mangroves (I,S)	No rubbish (I,S,C)	Coral reefs (I,S,C)	Reef fish (I,S,C)	Fishing (I,S,C)	Clean ocean (I,S,C)	Tourists (C)	Oil spills, groundings & waste spills (C)	Increase in prices (C)	Water Clarity amount >\$0, How much to pay (if agreed to pay >\$0)	Shipping amount >\$0, How much to pay (if agreed to pay >\$0)	Top predators amount >\$0, How much to pay (if agreed to pay >\$0)
Male	-	+				-	-		-	-	-	-	-		-		-			+	-				-		
Single		-	+			-						+									+						
Age	+	+	+	-	+	+	-	-			-		-			+		+	+					+	-	-	-
Indigenous	-								+					+	+	+		+	+		+						
Education	-	-	-	-	-		+		+	-		+	+		-		+	+	+		+	-	-	-	+		+
Income				-					-	-	-		-	-	-			-	-						-		
HH size														-													
Visitor QLD	+	+	+	+	+		-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-			-	-	-
Visitor AUS (not QLD)		+	+	+	+	+		-	-		-	-	-	-	-	-		-	-	+	-						
China		+	+	+	-	+			+	-	-		+				+			+	+				-		
Japan		+	+	+	-	+	-		-	-	+	-	-	-	-	+	-	-	-	+					+	+	
Couple	-	-		+	+		+		-	+		+	+	+	+	+	+	+	+	+	+						
Family with children		-	+	+	+		+			+		+	+	+	+	+	+	+	+	+	+						
Friends		-		+		+	+	+	-	+	+		+		+	-	+	+	+	+	+						
Tour group	-	-		-											+				+	+	+						
Business Visitor																	+	+	+		+	+	+	+			
Visitor Mackay/ Rockhampton	+	+			-		-	+		-	+			-	-	-				+	+		+				
Visitor Townsville/ Whitsunday	+	+			-			+		-				-	-	-						+	+				
Only people who live or visit should care																									-	-	-
Not prepare to pay unless users pay too																									+	+	+
Return																									+	+	+
Tourism																									-		
Importance																									+		
Satisfaction																									-		
IS																									+		

* For Satisfaction Friends + Business combined; no Close variable for satisfaction.

(+) indicates the relationship was positive and statistically significant; (-) = negative and statistically significant; a blank field indicates no statistically significant relationship.

7 Concluding remarks and recommendations

Multiple lines of evidence suggest that residents of, and visitors to the GBRCA feel that environmental non-use values are more important, to their overall quality of life or as a 'draw-card' to the region, than recreational or market-based values. As such, developments or changes which degrade those values are likely to be met with some resistance.

Degradation of environmental values is likely to have real financial impacts in the tourism industry, with reductions in tourist satisfaction and hence less repeat visitation, reduced numbers of tourists visiting the region and/or tourists staying for shorter periods of time.

It is possible that reductions in aesthetic and/or recreational values could also have a financial impact on non-tourism related businesses. A significant body of literature suggests that workers will trade-off wages for lifestyle (Chen and Rosenthal, 2008), so businesses located within the GBRCA may be enjoying a wage 'discount', largely attributable to the regional environmental amenity and attractive 'lifestyle' offered to workers. Degradation of lifestyle values may mean that businesses need to pay workers higher salaries in compensation. Whether or not this is occurring in the GBR region is an issue worthy of further investigation.

In short, changes in the environment (light green lines, Figure 19) have a real impact on people and on the decisions of people, which affects the broader economy (dark green lines, Figure 19).



Figure 19: Linkages demonstrated within this report

Multiple lines of evidence also suggest that different groups of people have different values. There are many differences between individuals, but our work suggests that 'on average', those born in QLD, males, those with relatively less education, and those whose primary source of income is the mining and manufacturing industry, are likely to feel that recreational values are relatively more important to their overall quality of life, and that environmental non-use values are relatively less important to their overall quality of life than others. As such changes to the economic and demographic composition of the population will likely change prevailing values (pink lines, Figure 19), and this will affect the broader economy as well as priorities and decisions about future developments (red lines, Figure 19).

More direct links between the economy and the environment also exist: changes in the broader economy such as increases in the price of beef and/or in wages, affect sediment loads (albeit with a lag) – (black line, Figure 19). Clearly, the economic system is inextricably linked to the environment, with multiple, dynamic feedbacks.

Monitoring systems should thus keep track of:

- The demographic composition of the population, and its economic structure.
- The 'values' of different demographic groups and of those associated with different industries (particularly in regions undergoing rapid economic and or demographic change).
- Changes in the broader economy (particularly the prices of commodities produced in and around the region).
- Variables that describe key linkages between the economy and the environment (e.g. water use, pesticide and fertilizer use, land clearing)

Moreover, our research indicates that it may not be necessary to require people to 'value' long detailed lists of different ecosystem services. Many of these ecosystem services are viewed, by respondents, as being all but inseparable, suggesting that the 'valuations' could be done at a fairly coarse level (asking people, for example, to assess industry, recreational, cultural and non-use values, and giving broad examples/descriptors of each). That would leave more 'room' within questionnaires (since long ones tend to induce survey fatigue) to elicit other potentially very useful information (about, for example, expenditure, water or chemical use, or other behaviours likely to impact the GBR).

Finally, it is worth noting that different types of valuation approaches generate quite different types of information (e.g. the dollar value associated with an entire ecosystem, the relative importance of different groups of ecosystems, peoples stated reaction to hypothetical scenarios, or WTP to improve the environment). But in this study, we have found that the methods generate similar information at a 'big picture' level (e.g. that the environment is more important to most people than industry, but that there are recognizable/predictable differences between people). There is often considerable resistance, by respondents, to questions about WTP. Recent decades has seen a substantive growth in the literature about ways to deal with 'protest votes', and (in the related choice modelling literature) 'non attendance to attributes', so those wishing to obtain specific information about WTP can do so. But our research suggests that it might be possible to use more respondent-friendly importance/satisfaction and contingent behavior type questions to monitor values across time and people instead (perhaps comparing findings to those of more traditional valuation approaches at irregular intervals for calibrative / quality-control purposes).

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Appendix A: Project outputs

Journal articles

Stoeckl, N., Farr, M., Larson, S., Adams, V., Kubiszewski, I., Esparon, E., & Costanza, R. (2014). A new approach to the problem of overlapping values: a case study in Australia's Great Barrier Reef. *Ecosystem Services*, 61-78, DOI: 10.1016/j.ecoser.2014.09.005.

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Larson, S., Farr, M., Stoeckl, N., Chacon, A., & Esparon, M. (2014b). Does Participation in Outdoor Activities Determine Residents' Appreciation of Nature: A Case Study From the Great Barrier Reef, Australia. *Environment and Natural Resources Research*, 4(3), 211-226.

Jarvis, D., Stoeckl, N., & Chaiechi, T. (2013). Applying econometric techniques to hydrological problems in a large basin: Quantifying the rainfall–discharge relationship in the Burdekin, Queensland, Australia. *Journal of Hydrology*, 496(0), 107-121. doi: <http://dx.doi.org/10.1016/j.jhydrol.2013.04.043>

Bos, M., Pressey, B., & Stoeckl, N. (2014). Effective marine offsets for the Great Barrier Reef World Heritage Area, *Environmental science & policy*, 42, 1 – 15.

Farr, M., Stoeckl, N., & Sutton, S. (2014b). Recreational Fishing and Boating: are the determinants the same? *Marine Policy*, 47, 126-137

Mustika, P. L. K., Stoeckl, N., & Farr, M. (forthcoming). The potential implications of environmental deterioration on business and non-business visitor expenditures in a natural setting: a case study of Australia's Great Barrier Reef, *Tourism Economics*.

Esparon, M., Stoeckl, N., Farr, M., & Larson, S. (forthcoming). The significance of environmental values for destination competitiveness and sustainable tourism strategy making: Insights from the Great Barrier Reef World Heritage Area. *Journal of Sustainable Tourism*.

Papers in review

Jarvis, D., Stoeckl, N., Liu, H-B. (in review). Can the life satisfaction technique be used to estimate non-use values? A case study of the Great Barrier Reef.

Jarvis, D., Stoeckl, N., & Liu, H-B. (in review). The impact of economic, social and environmental factors on sustainable tourism.

Chaiechi, T., Stoeckl, N., Jarvis, D., Lewis, S., & Brodie, J. (in review). Assessing the impact of price changes and extreme climatic events on sediment loads in a large river catchment near the Great Barrier Reef

Reports

Stoeckl, N., Farr, M., & Sakata, H. (2013). *What do residents and tourists 'value' most in the GBRWHA? Project 10-2 Interim report on residential and tourist data collection activities*

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including descriptive data summaries. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns, pp. 112, available at: <http://www.nerptropical.edu.au/publication/project-102-technical-report-what-do-residents-and-tourists-value-most-gbrwha>

Prideaux, B., Sakata, H., & Thompson, M. (2013). *Tourist Exit Survey Report: February – September 2012*. Annual Patterns of Reef and Rainforest Tourism in North Queensland from Exit Surveys Conducted at Cairns Domestic Airport. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns.

Book chapter

Jamal, T., Prideaux, B., Thompson, M., & Sakata, H. (forthcoming). A micro-macro assessment of climate change and visitors to the Great Barrier Reef, Australia. In V.J. Reddy & K. Wilkes (Eds.), *Tourism in the Green Economy*. Routledge.

Conference Papers

Jamal, T., Prideaux, B., Thompson, M., & Sakata, H. (2014). A preliminary exploration of tourists as a key stakeholder in climate change impact management. Referred paper presented at the meeting of the CAUTHE national conference Tourism and hospitality in the contemporary world: trends, change and complexity, Brisbane, 10-13TH February, 2014.

Prideaux, B., Lee, L., & Thompson, M. (2014). Tourists' perspectives on protecting Australia's Great Barrier Reef: Concerns, challenges and possible policy responses. Paper presented at the meeting of the Global Tourism and Hospitality Conference and Asia Tourism Forum Charting the new path: innovations in tourism and hospitality, Hong Kong, 18-20th May, 2014.

Jarvis, D. (accepted paper). Could climate change redistribute global tourism activity by impacting trip satisfaction? Paper to be presented at the 25th Annual CAUTHE Conference, Gold Coast, Queensland, 2-5th Feb 2015.

Factsheets and presentations

(available at <http://e-atlas.org.au/nerp-te/gbr-jcu-socio-economic-reef-resilience-10-2>)

An overview with interim results (largely for DOE) – April 2014

Tourism factsheets, developed for the industry

One of each region (Cairns/Port Douglas; Townsville/Whitsundays; Mackay/Rockhampton); One for Chinese visitors, one for Japanese visitors

Series focusing on Domestic visitors (at request of TTNQ);

Series on specialist issues – drive tourists, food tourists etc.

Data sets and maps submitted to e-atlas

Residential and Tourist data summaries; LT visitor exit survey data submitted to e-atlas; Maps summarising responses to most questions in residential survey, by postcode – available in e-atlas.

Appendix B: Extra insights from research that was associated with this project

(but which did not use the data collected in activities (a), (b) and (c))

Recreational fishing and boating in the Townsville Region

The material presented in this section summarises material reported on, in detail, in

Farr, M., Stoeckl, N., & Sutton, S. (2014b). Recreational Fishing and Boating: are the determinants the same? *Marine Policy*, 47, 126-137. Available at <http://www.sciencedirect.com/science/article/pii/S0308597X14000529>

Abstract

The research uses household survey data collected from 656 people in Townsville** (adjacent to the Great Barrier Reef, Australia) within a hurdle model to investigate key factors influencing both the probability of participating and the frequency of (a) boating trips which involve fishing; (b) boating trips which do not involve fishing; and (c) land-based fishing trips. The findings suggest that there are differences in determinants, highlighting the importance of disaggregating the fishing/boating and boat/land-based experience (an uncommon practice in the literature) if wishing to obtain information for use in the design of monitoring programs, policy and/or for developing monitoring and enforcement strategies relating to fishing and boating.

Keywords: Determinants of the demand, Great Barrier Reef, Hurdle model, Negative binomial, Recreational boating and fishing

** The data used here is separate to that collected in the main survey described in section 0.

Methods and main findings

Most previous studies have assumed that fishing and boating are an inseparable activity. In this study, we did not – deliberately setting out to see if there was a difference between the characteristics of those who go boating frequently, and those who fish frequently.

First we looked at the characteristics of those who did, and did not have a boat. We found that males and those who live a long distance from the boat ramps were more likely to have a boat than others.

Second, we divided people into those who had or had not gone on a fishing and/or boating trip in the last two years. Then we used a probit regression to look at the characteristics of people who had gone fishing or boating at least once (left side of Table 13). Not surprisingly, boat owners were more likely to have gone boating at least once. Those who had moved to the Townsville region in the last 10 years were more likely to have tried boating or boat-fishing at least once, as were single people, or those who live close to the boat ramp. Next we used zero truncated negative binomial regression, to look at the characteristics of those who went fishing or boating most frequently (right side, Table 13). Long term residents take more boating (fishing and no fishing) and boat-based fishing trips. Single people take fewer boating trips, as do people earning less than \$100,000 per annum. Those who live on the outskirts of town (away from the boat ramps) are the most frequent boat-fishers. Older people are more frequent land-fishers than the young.

Table 13: Characteristics of boaters, boat-fishers and land-fishers

Characteristics of people who went fishing or boating at least once in the last two years			Characteristics of people who went fishing or boating most frequently in the last two years (ignoring those who didn't go at all)		
a boating trip (fishing and no fishing)	a boat-based fishing trip	a land-based fishing trip	a boating trip (fishing and no fishing)	a boat-based fishing trip	a land-based fishing trip
Own a boat	Own a boat				
Young	Young	Young		Not employed as a clerical or administrative worker	Older
Moved to Townsville region in the last 10 years	Moved to Townsville region in the last 10 years		Long term resident of Townsville (> 10 years)	Long term resident of Townsville (> 10 years)	
Single	Single		Not single	Not single	
Live close to boat ramp	Live close to boat ramp			Live far away from boat ramp	
	Household income is less than \$100,000 per annum		Household income is less than \$100,000 per annum		

Note: only significant determinants reported

(Table adapted from *Farr et al.*, 2014b)

Conclusion

Boat ownership is clearly a pre-requisite for boating, but not all people who own a boat use it frequently. Income, age and length of residence are key determinants of fishing and boating activity, suggesting that changes in the demographic composition of the population will be associated with changes in demand for fishing and boating facilities, and with changed pressures to fishing stocks. New arrivals to the region are apt to try boating and fishing at least once in their first few years of residence, but the most frequent boaters and boat-fishers are those who have lived here longest. Married people with household incomes less than \$100,000 are more likely to go boating (without fishing) than others. Age is strongly associated with land-based fishing activity suggesting that an aging population could increase land-based fishing but decrease boating and boat-based fishing activities.

Marine offsets for the GBRWHA

Bos, M., Pressey, B., & Stoeckl, N. (2014). Effective marine offsets for the Great Barrier Reef World Heritage Area, *Environmental science & policy*, 42, 1 – 15.

Abstract

Biodiversity offsets are a prevalent mechanism to compensate for development impacts to natural resources, but the appropriateness and efficacy of offsets remain the subjects of research and debate. Effective offsets for impacts to marine resources present even more challenges than those for terrestrial impacts. The Great Barrier Reef World Heritage Area is globally valuable for both biodiversity and heritage, but coastal development is undermining these values, and more effective offsets are needed to compensate for the damage. To improve the effectiveness of marine offsets for the Great Barrier Reef, we recommend that: (1) proponents be required to follow and document their adherence to the mitigation hierarchy, which considers offsets only as a last resort after avoidance and mitigation, (2) proponents and regulators consider the risk of offsetability prior to offset design, (3) the Australian government require offsets to achieve additional, measurable net benefits, relative to the counterfactual baseline, for all affected values, (4) specialist third parties (not government or proponents) design and implement marine offsets, (5) offsets are direct and specific to the affected values, with very minimal investment into research, (6) offsets are consolidated into strategic implementation sites, with long-term legal protection, that are consistent with the zoning of the Great Barrier Reef Marine Park and adjacent coastal land uses, (7) the time between impact and net benefit should be minimized, and net benefits should be maintained in perpetuity, (8) proponents pay the full cost of offset implementation, monitoring and evaluation, and cost is agreed upon before the development is approved, and (9) monitoring of the efficacy of offsets is separate to but coordinated with regional monitoring programs for ecosystem health, and monitoring data are made publically available. Within this context, and with careful and rigorous methods as described herein, offsets can contribute to maintaining the Outstanding Universal Value of the multiple-use World Heritage Area.

Keywords: Great Barrier Reef World Heritage Area Biodiversity Offsets Mitigation Compensation