National Research FLAGSHIPS
Wealth from Oceans
CSIRO

# Ningaloo Collaboration Cluster: **Estimation and integration of socioeconomic values of human use of Ningaloo**

Atakelty Hailu, Lei Gao, Jeffrey Durkin and Michael Burton
Ningaloo Collaboration Cluster Final Report No. 4
6 June 2011


www.csiro.au

THE UNIVERSITY OF WESTERN AUSTRALIA

ISBN: 978-0-86905-983-8

This report is an outcome from the Ningaloo Collaboration Cluster – a partnership between Murdoch University, The University of Western Australia, The Australian National University, The University of Queensland, Edith Cowan University, Curtin University of Technology, The Sustainable Tourism Cooperative Research Centre and CSIRO's Wealth from Oceans Flagship. The Cluster is funded through CSIRO's Flagship Collaboration Fund and the partners' in-kind support.
www.csiro.au/partnerships/NingalooCluster

Enquiries should be addressed to:

**Atakelty Hailu**
School of Agricultural and Resource Economics, M089
University of Western Australia
35 Stirling Highway
Crawley (Perth), WA 6009
Australia
*atakelty.hailu@uwa.edu.au*

## Copyright and Disclaimer



## Important Disclaimer

# Contents

## List of Figures



## List of Tables

# 1. SUMMARY OF MAJOR FINDINGS AND THEIR IMPLICATIONS

Both conservation and socioeconomic objectives need to be addressed in the management of natural assets like Ningaloo. If these concerns are perceived to be in conflict or partly in conflict with each other, policy-makers and managers face the difficult task of balancing the two. This balancing exercise becomes more difficult in the case of resources where some of the socioeconomic benefits are largely non-market and, therefore, cannot be directly observed or valued in market transactions.

Visitors are attracted to Ningaloo for fishing and other non-fishing recreation. These recreational activities generate non-market benefits. That is, we are not able to observe directly the value people attach to the opportunities or the sites that are made available for recreation. The market transactions associated with recreation, such as the money that visitors spend for accommodation, food, transport and other activities, represent only a portion of the socioeconomic benefits of these recreational activities in the region. The approach adopted in our study therefore adds a new dimension to the information typically reported on tourism and economic benefits of recreation. Visitor expenses are cost to the visitors and, although they generate benefits to the regional economy, do not capture or reflect the full value derived from recreation. The true value of recreation is the economic surplus that visitors gain over and above what they spend as they engage in recreational activities. This economic surplus is defined as the monetary amount visitors would be willing to pay (WTP) for the opportunity to recreate over and above the cost associated with the recreation. This surplus value has to be inferred using non-market valuation techniques which utilize information derived from surveys of visitors (see below) or from observations of recreational behaviour. The term “economic welfare” is alternatively used to describe the economic surplus value.

Economists have developed techniques that help generate value estimates for the natural environment and these have been applied to a diverse set of valuation problems over the last three decades. In studies of recreation, economists usually employ site choice models, which hypothesize that people make choices to maximize the satisfaction (utility) they derive from recreational choices. Further, the techniques link choice to site characteristics, making it possible for the researcher to infer the relative values of different site attributes or characteristics. In summary, site choice models provide two useful results: a model of recreational behaviour and value estimates for both sites and site attributes.

This project developed site choice models for Ningaloo and used these models to evaluate economic surplus value (or economic welfare) changes arising from management changes. Further, the project developed the site choice models into agent-based models that can be used for simulating recreational choices and associated welfare changes under different management scenarios. In the sections below, we present the specific objectives of the project, its findings and their management implications.

The models developed (and the data collected) provide a means by which managers can tackle key questions:

1) Are there particular sites/hotspots where people prefer to fish and recreate?

2) What factors can be used to predict where people will choose to fish and/or recreate? and

3) If current 'hot spots' or high pressure areas were closed for fishing and/or other recreation, where would visitors be expected to go?

## 1.1 Objectives

The project had two major objectives.

1. Use data collected on observed fishing and non-fishing recreational choices to develop econometric models that can be used to predict the sites people choose for recreation (site choice modelling) and estimate the values that people attach to different sites and site attributes.

2. Develop simulation models (known as agent-based models) that can be used to assess the impact on choice and economic welfare of changes in management strategies, which can be integrated into CSIRO’s management strategy evaluation (MSE) model.

## 1.2 Outcomes

Over the period from 2007 to 2009, the project surveyed visitors to Ningaloo using a questionnaire that asked for information on recreational choices, visitor demographics and visitor satisfaction rates. A total of 426 visitors were surveyed and data were obtained for 1,102 fishing and non-fishing trips from these respondents. A third of these trips involved recreational fishing.

Econometric models of site choice were then estimated using the data. The model for non-fishing recreation included 40 sites throughout Ningaloo, several of which were on the Exmouth Gulf. Our models indicate that recreational site choice is influenced significantly by a diverse set of site attributes including: the cost of access to a site and the suitability of the site for a range of activities such as beach walking, snorkelling, swimming, swimming with marine fauna such as whale sharks and manta rays, and water sports. Further, we found that some demographic characteristics (age and presence of children) also affect the value of some of these attributes. In summary, our site choice model for non-fishing recreation provides an empirically based behaviour model that can be used to link choice to observable site characteristics and thus provide a basis for accomplishing the following:

1. Estimating value for site access (individual or groups of sites)

2. Estimating the value of changes in site attributes

3. Providing a behavioural model for structuring agents in the agent-based model of site choice that is used in management strategy evaluation (MSE)

We found that site access values range from almost nothing for some sites (e.g. T-Bone Bay – for non-fishing recreation) to as much as $125 per trip for Gnaraloo Surfing. Other sites that are highly valued for non-fishing recreation include Turquoise Bay, Coral Bay, Oyster Stacks, Yardie Creek, and Warroora. Sites that have very attractive attributes and/or very few competing sites are highly valued. The results from the modelling are reported in detail below (Section 2). Earlier results (using smaller samples) have been reported in Raguragavan, Hailu and Burton (2010a). Previous results have also been presented in Ningaloo Cluster symposia and other seminars as listed in Section 2.

In the econometric modelling for recreational fishing, sites in Ningaloo were grouped into eleven destination choices. The primary influences on angler site choice were the cost of accessing the site and expectations regarding the angler's ability to catch high value fish, namely, prize and reef fish. Sites on the southern half of the region had high site access values. The value per fishing trip can be as much as $74 (Coral Bay). Other highly valued recreational fishing sites include Warroora, Yardie Creek, and Pilgramunna. Further details are provided in Section 3 below.

In addition to the recreational fishing study focussing on Ningaloo referred to above, a study of state-wide recreational fishing choices using the 2000/2001 National Survey of Recreational Fishing (NSRF) data was also completed. These results are reported in Raguragavan, Hailu and Burton (2010b) and have been presented in Ningaloo Cluster symposia and other seminars as listed in Section 2. Further details on the study and its results are provided in Appendix D.

Finally, in addressing its major objective, the project has developed agent-based models of recreational choice behaviour using the estimated econometric models. These models have been coupled with coral-reef ecosystem models to provide integrated models for simulating both economic and biophysical outcomes. The integrated models have been used to undertake demonstrative simulations and results have been reported in several conference presentations and articles submitted to journals (Gao, Durkin and Hailu, 2010); Gao and Hailu, 2010b). There is a complex and two-way interaction between fishing site choices (human behaviour) and ecosystem dynamics. The implications of this complexity are that it is difficult to determine the socioeconomic and biological outcomes of a management change or the relative performance of alternative management strategies without the benefit of integrated modelling. Gao and Hailu

(2010b) illustrate this by simulating the effects of three alternative site management strategies: a baseline strategy where no fishing sites are closed; a 2 month closure of a site; and a 6 month closure of a site. The alternative strategies are compared in terms of fish biomass and angler economic welfare outcome streams obtained over time. Further, these comparisons are done for two different fishing pressure environments: a low level (or baseline) fishing pressure level and a high fishing pressure level. They find that, because of the spill-over effects of site closure, overall target fish biomass might not improve as a result of site closure if the fishing pressure level is low. Fishing effort just gets shifted to open sites. Further, angler welfare is reduced as a result of the closure with the reduction being higher under the 6 month site closure than the 2 month site closure. In summary, for a low fishing pressure environment, angler welfare is reduced less with the shorter (2 month) closure than with longer (6 month) site closure. This observation is intuitive and thus ‘expected’. However, in cases where the underlying fishing pressure is higher, both fish biomass and angler economic welfare gains increase with the length of the closure period. That is, a longer site closure strategy (6 month) is preferred to a shorter (2 month) closure strategy or to a strategy where there is no site closure. These observations highlight the need for the use of simulation platforms to track complex outcomes and help managers and other stakeholder explore conservation and economic tradeoffs implied by alternative resource management choices. Further details are provided in Gao and Hailu (2010b).

## 1.3 Implications for Management

Our models look at the set of all available sites in Ningaloo. They link choice to site attributes and the characteristics of the visitor. These features allow resource managers to find consistent answers to different questions. Some of the key management implications can be summarized as follows:

1) Since sites differ greatly in access values, management changes that restrict access or limit recreation in highly valued sites cause higher economic welfare losses among visitors. These welfare losses occur because visitors have to recreate less or recreate at sites that are less desirable. The corollary to this is that there are many sites where the access values are low. This provides managers with some flexibility when it comes to balancing conservation and recreational benefits.

2) The closure of sites that have low value is unlikely to have spill-over effects (redistributed pressure) on other sites.

3) The values of some sites vary by household type. For example, sites offering water sporting opportunities such as diving and surfing, are valued more by younger people and people without children. Improvements in these sites are likely to cause more welfare gains for some segments of society than others. Similarly, welfare losses from site deterioration or site use restrictions are distributed unevenly.

4) The recreational fishing data from the surveys in Ningaloo indicates that site choice among anglers is driven by their expectation of catching high value fish. The expectations of catching low value fish had statistically insignificant effects on angler site choice.

5) We have generated access site values averaged across all respondents as well as across respondents who recreate at a site. These values provide a per trip value that can be aggregated to generate total estimates of the value of recreation at a site. This is a key, and previously unavailable, piece of information that managers and other stakeholders can use as they consider different management alternatives.

6) The models developed in this project can be used to optimize access regimes, both spatially and temporally.

7) Models can be used to guard against unintended consequences of management change, particularly any potential spill-over effects of restrictions on recreational access to sites. Below we present the modelled effects of site closure for non-fishing recreation (Table 1) and recreational fishing (Table 2). In the case of non-fishing recreation, sites that are expected to receive the highest frequency of trips are Turquoise Bay, Coral Bay, Oyster Stacks, Yardie Creek and Gnaraloo Surfing (column 1, Table 1). The remaining columns in Table 1 show how the trips to each of these sites would be distributed into other sites if the site was closed. For example, if Turquoise Bay was closed, 16.5% of the trips allocated to this site would spill over to Oyster Stacks and 15.2% would spill over to Yardie Creek (column 2, Table 1). In the case of regions with too few substitutes, these spill-over effects can be severe, as in the case of Gnaraloo – closure of this site would mean that most of the pressure (81.68%) would be redistributed to Red Bluff.

8) From our sample, the recreational fishing sites that would receive the most trips are the North West Reef, Tantabidi, Exmouth, Coral Bay and Lighthouse Bay. It is recognized that boats can be launched from most of these sites. There is very little spill-over effects between the northern and southern section of Ningaloo. The most severe case of spill-over occurs from a closure of Coral Bay, which would mean that Warroora fishing sites would receive almost 85% of the baseline fishing trips from Coral Bay. Spill-over effects for the full set of sites are shown in Appendix C.

Table 1: Matrix of spill-over effects from the closure of recreational (non-fishing) sites at Ningaloo.

| Site affected by trip spill | Predicted share of trips | Spill-over effects from closed site (% increase in trips) | | | | |
|---|---|---|---|---|---|---|
| | | Turquoise Bay | Oyster Stacks | Yardie Creek | Coral Bay (CB) | Gnaraloo |
| The Dunes Surfing Beach | 3.52 | 5.67 | 4.91 | 4.36 | 0.29 | |
| Tantabiddi | 3.45 | 5.78 | 5.00 | 4.62 | 0.21 | |
| Lakeside | 2.32 | 4.03 | 3.48 | 3.40 | 0.12 | |
| Turquoise Bay | 17.97 | | 27.23 | 27.53 | 0.94 | |
| Oyster Stacks | 9.44 | 16.49 | | 14.71 | 0.49 | |
| Pilgramunna | 3.20 | 5.60 | 4.89 | 5.21 | 0.16 | |
| Sandy Bay | 4.34 | 7.59 | 6.65 | 7.24 | 0.22 | |
| Yardie Creek | 8.71 | 15.22 | 13.42 | | 0.45 | |
| Coral Bay | 10.84 | 0.72 | 0.63 | 0.62 | | |
| Eco Tour (CB) | 1.18 | 0.08 | 0.07 | 0.07 | 17.91 | |
| Whale Shark Tour (CB) | 4.13 | 0.27 | 0.24 | 0.24 | 62.60 | |
| Warroora | 0.68 | | | | 8.28 | |
| Quobba Station | 0.31 | | | | | 18.32 |
| Red Bluff | 0.97 | | | | | 81.68 |
| Gnaraloo | 5.24 | | | | | |

Table 2: Matrix of spill-over effects of the closure of selected recreational fishing sites at Ningaloo.

| Site affected by trip spill | Predicted share of trips | Spill over from site closure (% increase in trips) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Exmouth | North West Reef | Lighthouse Bay | Tantabiddi | Yardie Creek | Coral Bay |
| Learmonth | 3.58 | 7.81 | 6.21 | 5.86 | 4.20 | 1.44 | 9.07 |
| Exmouth | 11.23 | | 20.22 | 18.82 | 14.28 | 4.83 | 5.49 |
| Bundegi | 8.53 | 16.27 | 15.11 | 14.63 | 11.51 | 5.17 | 0.08 |
| North West Reef | 14.70 | 25.89 | | 24.17 | 22.48 | 10.92 | 0.16 |
| Lighthouse Bay | 10.57 | 18.61 | 18.52 | | 15.19 | 7.28 | 0.08 |
| Tantabiddi | 13.92 | 17.93 | 21.12 | 18.89 | | 19.38 | 0.14 |
| Ned's Camp | 5.75 | 5.39 | 7.04 | 6.87 | 10.58 | 11.92 | 0.08 |
| Pilgramunna | 8.71 | 5.27 | 7.77 | 7.10 | 14.32 | 38.30 | 0.18 |
| Yardie Creek | 5.55 | 2.42 | 3.88 | 3.56 | 7.31 | | 0.25 |
| Coral Bay | 10.71 | 0.40 | 0.14 | 0.10 | 0.12 | 0.76 | |
| Warroora | 6.74 | 0.01 | | | | | 84.46 |

## 1.4 Other Benefits

This study is the first to integrate empirically based models of recreational fishing site choice and a biophysical model of coral-reef ecosystem dynamics. As indicated above, these models provide a very useful way of assessing economic and conservation outcomes. In some cases, perceived conflicts might not be real whereas in others real conflicts are the more usual case. These models allow managers and stakeholders to identify trade-off more clearly and quantitatively and make more informed choices. Currently, we are working in collaboration with Project 5 on Integration and Modelling and with others to refine the coral-reef ecosystem model.

## 1.5 Problems Encountered

The project faced one major challenge. The rate of survey responses obtained for questionnaires handed out in Ningaloo was initially low. This is because the nature of data required was detailed and the survey was long. Consequently, respondents were discouraged and forms were not returned in sufficient numbers to provide data to develop the models. As a result, the empirical analysis was delayed. The project changed its approach to data collection and began employing face-to-face interviews to maximize completion rates of the questionnaires. This change in approach enabled us to generate a usable sample that was bigger than was initially planned.

## 1.6 Acknowledgements

We are grateful to the Department of Fisheries WA and Neil Sumner for providing the data from the National Survey of Recreational Fishing (NSRF) (2000/1). Ningaloo Cluster Project 3 leaders, Dr Tod Jones and Professor David Wood, also provided data and help distributing surveys. We are also grateful to Professor Lynnath Beckley (Project 2 – Reef Use) for information on fishing data sources.

The project benefitted greatly from survey work undertaken by Dominique Leib, John Curry, Sayed Iftekhar, Julie Sharper, Heidi Khojasteh, Doc Lap Tran, and Jeffrey Durkin. Dominique and John contributed to the development of the survey. Jeffrey Durkin was a key player in the second stage of the survey where it became necessary to undertake face-to-face interviews. Jeff also processed the survey data and wrote a report on the survey results. We are also thankful to Professor Jessica Meeuwig and Heather Taylor at the Centre for Marine Futures (UWA) for help with surveys. Sam McMillan and Derek Walker from the Centre undertook surveying activities in Ningaloo for the project.

Jananee Raguragavan worked on the project from 2006 to 2009 and played a key role in the development of the survey questionnaire. She organized the field surveys until April 2009. Jananee worked on the Random Utility Models (RUM) using earlier Ningaloo data on recreation (Raguragavan, Hailu and Burton 2010a) and the state-wide fishing study using the NSRF data (Raguragavan, Hailu and Burton 2010b).

We thank the CSIRO Cluster leader, Professor Neil Loneragan, for useful comments on the draft versions of this report.

# 2. COMMUNICATION OF PROJECT RESULTS AND DATA

## 2.1 Publications and planned Publications

There are several papers that have been submitted to journals:

1. Raguragavan, J., Hailu, A., and Burton, M. P. (submitted). "Valuation of marine based non-fishing recreation" Coastal Management. (**In revision**)

2. Raguragavan, J., Hailu, A., and Burton, M. P. (submitted). "Economic valuation of recreational fishing in Western Australia: State-wide random utility modelling of fishing site choice behaviour". Australian Journal of Agricultural and Resource Economics. (**In revision**)

3. Gao, L., and Hailu, A., (Submitted). "Evaluating the effects of area closure for recreational fishing in a coral reef ecosystem: The benefits of an integrated economic and biophysical modelling". Ecological Economics (**In press**).

4. Gao, L., and Hailu, A., (2011). "Recreational Trip Timing and Duration Prediction". Tourism Economics (**In press**)

The following papers have been presented in conferences and subsequently published in refereed conference proceedings:

1. Gao, L. and Hailu, A. (2010) "Integrating recreational fishing behaviour within a reef ecosystem as a platform for evaluating management strategies", The 24th IEEE International Conference on Advanced Information Networking and Applications, April 20-23, 2010 Perth, Western Australia.

2. Gao, L., Durkin, J., and Hailu, A. (2010) "An agent-based model for recreational fishing management evaluation in a coral reef environment" Proceedings of the International Conference on Agents and Artificial Intelligence, January 22 - 24, 2010 Valencia, Spain.

Planned publications

1) Multi-criteria decision methods (MCDM) for evaluation management outcomes: Balancing economic and conservation outcomes in the management of marine based recreation (authors: Lei Gao and Atakelty Hailu)

2) Nested logit modelling of recreational choices in Ningaloo (potential authors: Atakelty Hailu and Lei Gao)

3) Site management and spill-over effects: Ningaloo recreational modelling using RUM (potential authors: Lei Gao and Atakelty Hailu)

## 2.2 Communications

The findings of this project are being disseminated through publications and presentations in seminars and conferences. Information on findings and the model will be made available on the web for wider dissemination. Several papers have been published in the scientific literature. Planned communications include presentations in the Oceans Institute of the University of Western Australia.

### 2.2.1 Presentations

Project results have been presented both to local, national and international audience. The presentations are listed below:

- Raguragavan, J., Hailu, A., and Burton, M. P. (2008) "Modelling Recreational Site Choice for Ningaloo", Second Annual Ningaloo Research Symposium, May 28-29, Murdoch University, WA.
- Hailu, A., Burton, M. P., and Raguragavan, J. (2009) "The value of recreation and management strategy evaluation", Third Ningaloo Research Symposium, Exmouth, Australia.
- Raguragavan, J. and Hailu, A. (2009) "The value of recreation in Ningaloo", School of Agricultural and Resource Economics (UWA) Seminar Series. October 23.
- Gao, L. and Hailu, A. (2010) "Integrating recreational fishing behaviour within a reef ecosystem as a platform for evaluating management strategies", The 24th IEEE International Conference on Advanced Information Networking and Applications, April 20-23, Perth, Western Australia.
- Gao, L., Durkin, J., and Hailu, A. (2010) "An agent-based model for recreational fishing management evaluation in a coral reef environment", The International Conference on Agents and Artificial Intelligence, January 22 - 24, Valencia, Spain.
- Gao, L. and Hailu, A. (2010) "Evaluating the effects of recreational fishing access fees: a coupled model of site choice and a coral reef ecosystem", Australian Agricultural and Resource Economics Society Annual Conference, February 9-12.
- Gao, L. and Hailu, A. (2010) "Using agent-based modelling to integrate econometric models (RUMs) of recreational fishing behaviour and coral reef ecosystem as a platform for policy simulation", June 23-25, ESHIA, Alessandria, Italy.

### 2.2.2 Student Projects

There is a linked PhD project by Abbie McCartney (ARE, UWA) that looks at public and expert values on passive-use values related to marine resources. This research investigated whether, and under what circumstances, valuations of marine resources differed between the general public and expert groups. The results highlight the importance of knowledge in valuation. In the case of Ningaloo, values held by experts and the general public were similar. However, this finding is not expected to hold for marine resources that are less well known to the general public, highlighting the need to create resource awareness among the public.

The study also investigated how values were affected by envisaged management processes. In the case of Ningaloo, it found that people driving four wheel drive vehicles on the coast were less likely to support turtle protection program that somehow restricted their driving. In general, the study finds that it is useful to clarify management processes in the valuation of proposed changes to marine resource management.

### 2.2.3 Data Summary and Accessibility

The project conducted a survey of people who were fishing and recreating in the Ningaloo region of Western Australia. The questionnaire was revised on at least two occasions. These revisions resulted from feedback from staff members who visited the region and interacted with respondents who were willing to participate in the survey.

The survey questionnaire consisted of three sections. The first set of questions relate to the demographic details of the respondent and included information on country of origin, length of stay in the region, by what means the respondent travelled in the region as well as the size of the cohort with which the respondent was travelling. This section of the survey also collected information pertaining to the previous twelve month recreational and fishing experience in the region. For those who were fishing, information on the skill and experience of the angler as well as cost of the angler’s fishing equipment was collected.

The second section of the survey asked participants to keep a log book of the fishing trips that they undertook to fishing sites in the Ningaloo region. The data requested in this section included: the site; the time at which fishing occurred; and the location at which the respondent lodged the night prior to the day of the trip. The participants, when choosing a site, were asked to allocate a rank to a set of reasons or recreational site attributes, i.e. scenery, time available, etc. Other information solicited included: the age of the anglers; the species and number of fish caught and released; and cost incurred as part of the trip (including the cost of bait, tackle, boat hire, boat fuel and food). Anglers were also asked to identify any fish species that they were targeting. A map of the Ningaloo sites that was included in the questionnaire is shown in Figure B1 in Appendix B.

The third section of the survey collected information on non-fishing recreational trips undertaken by the respondent. As with the fishing information, these data were collected in the form of a log book for each trip and for up to a maximum of seven trips. Again the recreational site chosen, the time of recreation and the location of the previous night’s accommodation are recorded in the survey. In this section of the survey, the participant ranked the site on a set of choice parameters or reasons, which included scenery, time available, etc. The respondent then allocated a rank to the site on satisfaction parameters that included beach walking, swimming with animals, sightseeing, etc. The allocated ranks range from 1 (high) to 5 (low). Data on the cost of car fuel, recreational equipment, refreshment and accommodation were also collected.

Participants responded to the questions that they wished to answer and consequently there are a considerable number of surveys with incomplete data. In some instances, there are survey forms with only demographic data and, in other surveys, there are fishing or recreational trip records lacking the associated demographic data. Not all participants undertook both fishing and recreational trips (Table 3).

Initially, the surveys were handed out to visitors. Respondents were asked to fill in their demographic and recreational trip data and post the completed questionnaire to the School of Agriculture and Resource Economics at the University of Western Australia. This approach yielded a response rate of only 18% and a decision was made in May 2009 to change the project's approach to data collection. Face-to-face interviews were used using the same questionnaire. These face-to-face surveys were undertaken in July and August 2009. The first of these two field trips concentrated on non-fishing recreational data gathering and the second field trip concentrated on fishing recreation.

Table 3: Response numbers from the surveys conducted in Ningaloo

| Description | Total | Fishing Only | Recreation Only | Rec & Fishing | Demographic Only |
|---|---|---|---|---|---|
| Respondents | 426 | 98 | 209 | 95 | 24 |
| Respondents with trip data | 402 | 98 | 209 | 95 | |
| Trip Records | | | | | |
| Fishing Trips | 332 | 171 | | 161 | |
| Recreational Trips | 774 | | 584 | 190 | |

A total of 426 visitors were surveyed, and 402 of these provided trip information. About half (48%) of the surveyed respondents visited the region in order only to recreate while a further 22.5% were there for the fishing only, and the rest of the respondents combined fishing with other recreational activities. Data collected covered a total of 774 trips. Of the 774 recreational trips reported, 75% were purely for recreational purposes; the other 25% combined fishing and non-fishing recreation in a trip.

On average, respondents who were in the region for non-fishing recreation only recorded 2.8 trips and those in the region for fishing only recorded 1.7 trips. The other respondents recorded an average of 3.7 trips for either fishing or recreation.

The data collected in the survey are stored in an Excel spreadsheet with a worksheet for each of the survey sections, i.e. demographic, fishing trips and recreational trips. The data from face-to-face surveys were standardised so that names of fishing and recreational sites as well as sites of accommodation were checked for consistency in spelling. Where possible the location of the site is entered before the site name itself for easy identification, e.g. Exmouth Ningaloo Lodge.

Each section of the survey has been analysed using SPSS and the results are reported in a summary report produced by Durkin (2009). It should be noted that this analysis in Durkin (2009) was carried out so that there is a better understanding of the strengths and weaknesses of the collected data. These data underpin the development of revised econometric models for recreational site choice and econometric models for fishing in Ningaloo.

During the initial data analysis, it became apparent that the survey information would be better stored in a database. The database not only records the information collected in the survey but also tables pertaining to the species of fish caught, the distance between sites and a reference point, as well as information on respondents who were visiting in groups. This later information would enable a more accurate analysis of cost data. Descriptions of database table contents are provided in Tables A1 to A10 in Appendix A.

# 3. DATA CHAPTERS

## 3.1 Summary

This study uses non-market valuation methods to determine influences on recreational site choice behaviour in Ningaloo. More than 400 visitors to Ningaloo were surveyed generating about 1100 recreational trip information. About a third of these trips involved recreational fishing. Random utility models were used to link site choice to visitor demographic characteristics, a range of site quality measures, and the cost of accessing a recreational site. The results show that non-fishing site choice is influenced by the cost of access and a range of site desirability indicators. In the case of fishing site choice, the key determinants are cost of access and the chance to catch high value fish (reef fish and prize fish). The study estimated site access values; these values measure the welfare losses that visitors would incur if a site is closed down. The values range from very low amounts in the case of sites that are dominated (attribute wise) by other sites to very high values in the case of attractive and/or isolated sites that have few substitutes. Among recreational destinations, sites such as Turquoise Bay, Coral Bay, Oyster Stacks, Gnaraloo Surfing and Yardie Creek were found to be highly valuable. Highly valued fishing sites include Coral Bay, Warroora, and Yardie Creek.

## 3.2 Introduction

The management of iconic marine environments like Ningaloo tends to be controversial. The attractiveness of these resources means that they generate economic activities that support local and regional economies. However, the resources can be under pressure for a multitude of reasons, including pressures from intensive human use. Proper management requires balancing economic, environmental and social outcomes. The economic benefits that are generated through visitor expenditures in the region are relatively well understood. However, these economic benefits reflect only a portion of the economic benefits that visitors (and society) derive from these resources.

There is very little information on the non-market benefits or values generated by recreational activities that depend on these marine resources. This lack of information can hinder informed policy making on resource use (Loomis and Walsh, 1997) as it becomes very difficult to balance the socioeconomic against conservation benefits. Without good estimates of the full benefits of recreation, it is difficult for managers and public policy makers to determine effective levels of resource allocation (e.g. level of fishing allowed, degree of access to sites) or to determine effective levels of investment in protecting these natural resources.

The non-market benefits are real benefits. In fact, when anglers or other recreationists are arguing against restrictions or lobbying for greater access to resources, they are somehow making statements about these non-market values. These benefits or values are not reflected in market transactions such as expenditure on travel, accommodation, etc. The expenses incurred by a recreationist in the process of accessing the natural resources are a cost to the recreationist, although these costs or expenditures are a benefit to the local and regional economies because these expenditures generate incomes and employment. The true value of marine or coastal resources to the recreationist is not directly observable. In other words, the non-market values from recreation are the pure economic surplus or economic welfare that the recreationist derives from the opportunity to recreate.

Non-market valuation methods (NVM) can be used to estimate these values. NVM generally employs techniques that indirectly quantify people's willingness to pay for a natural asset or the opportunity to recreate; and these techniques have been applied to the valuation of diverse environmental and natural resources over the last three decades (Bennett and Adamowicz, 2001).

In the case of marine based resources there has been very little valuation research undertaken in Australia. In Western Australia, for example, there have been no previous studies attempting to quantify the economic value of marine based recreation in spite of the fact that beach-based recreation is very popular in the state. Most research on marine based non-fishing recreation has mainly focused on the US (Lew and Larson, 2005; Bin *et al*. 2004; Shivlani, David and Theis, 2003; Parsons, Massey and Tomasi, 1999; Adamson-Badilla and Castillo, 1998; and Bockstael, Hanneman and Kling, 1987).

Valuation studies on recreational fishing in Western Australia are similarly limited in number (Swait, Admowicz and van Bueren, 2004; Zhang, 2003; van Bueren, 1999). As in the case of non-fishing recreation, the bulk of published research on recreational fishing has focused on the US or Europe (Lew and Larson, 2005; Navrud, 1999; Adamowicz, 1994; Morey, Shaw and Rowe, 1991; Walsh, Johnson and McKean, 1992). These studies clearly show that site values vary greatly, depending on location as well as site and angler characteristics. These studies are reviewed in Raguragavan, Hailu and Burton (2010b).

This project has addressed the knowledge gap on recreational values by undertaking the following studies:

1. A study on recreational site choices and site valuation in WA using data collected through surveys of people recreating in the Ningaloo region. The most recent results based on the complete data set are presented in this report. Earlier valuation results using a smaller set of the Ningaloo data used here are presented in Raguragavan, Hailu and Burton (2010a).

2. A state-wide study on recreational fishing choices was undertaken. This study covered eight fishing regions and fourty eight fishing destinations in the state, extending the set of fishing destinations than those used in Zhang (2003). Three out of the fourty eight destinations are in the Ningaloo region, namely, Quobba, Coral Bay and Exmouth. The results from this study have been presented in Raguragavan, Hailu and Burton(2010b). The behavioural models from this study have also been used to develop integrated models for management strategy evaluation as reported in Gao and Hailu (2010b) and Gao, Durkin and Hailu (2010).

3. Ningaloo fishing data collected by this project were used to develop site choices models for eleven sites. The results from this study are presented in this report.

Below, we first present in Section 3.3 a description of the econometric models used. These site choice models (also known as random utility models (RUM)) formulate site choice as a utility maximizing decision that depends on the attributes of the recreational sites as well as personal characteristics. The RUMs provide the basis for generating value estimates for accesses to sites as well as for site attribute variables. In this section, we also present the various models that have been used in our research either to develop input variables into RUM models (e.g. catch rate models) or to predict trip timing and length choices for the integrated RUM-coral reef system model used in management strategy evaluation. We then present the main results in Section 3.4, first for non-recreational fishing choices and then for fishing recreation. In both cases, econometric estimation results as well as site value estimates are presented. The report concludes by discussing the results in section 3.5.

## 3.3 Materials and methods

We start by presenting an overview of the methods used, econometric and other. We then describe the structure of the site choice models used to develop empirically based behavioural models for fishing and non-fishing site choice. This is followed by a description of the catch rate models used to generate fish catch expectation for use in the model for fishing site choice. We then present a description of the coral-reef ecosystem model. The section concludes with a description of the method used to calculate economic welfare changes for the evaluation of management changes affecting opportunities for recreation.

### 3.3.1 Overview of methods used

The key steps involved in the econometric modelling of recreational choice and associated benefit calculation are outlined in Table 4 below. For both fishing and non-fishing recreation, the first step is to obtain data on visitors and the choices they make. In our case, these data have come primarily from the survey conducted in Ningaloo. Data from the National Survey on Recreational Fishing was also used for a state-wide fishing study that included three sites in the Ningaloo region (Raguragavan, Hailu and Burton 2010b). In the second step, a theoretical model is used to provide a framework for describing observed behaviour or choices made. This theoretical framework is the random utility modelling (RUM) framework. In the third step, econometric estimation is undertaken to estimate the parameters of these behavioural (RUM) models. Finally, the estimated models are used as predictive tools and also to calculate welfare change estimates relating to site condition or site management changes.

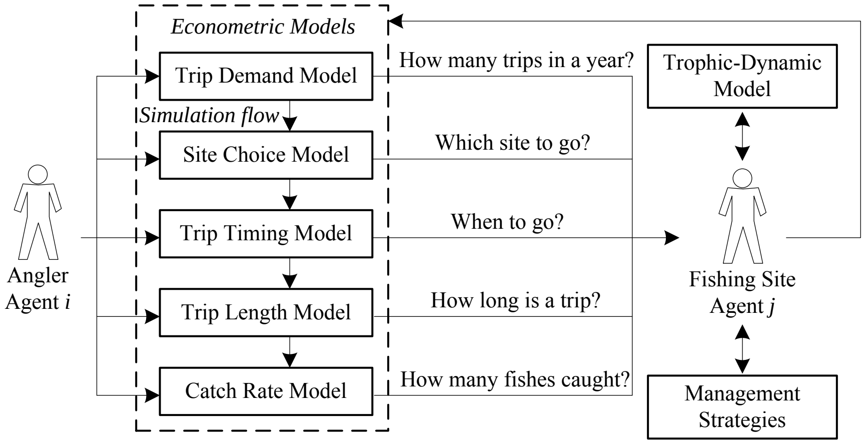
Table 4: Research steps in econometric modelling and welfare change analysis

| Research Steps | Recreational fishing studies | Non-fishing recreation studies |
|---|---|---|
| Observe choices and profiles | National Survey of Recreational Fishing data (2000/1) and Ningaloo fishing survey data collected by the project since 2007 | Ningaloo Cluster data collected since 2007 |
| Use a theoretical framework/model (RUM) | Three models: expected catch rate model, Site choice model (RUM), and trip demand model (Negative binomial model) | Discrete site choice models (logit) |
| Estimate model parameters (Econometrics/MLE) | Data fitted to models using maximum likelihood estimation (MLE) | Maximum likelihood estimation (MLE) |
| Use model to predict behaviour & derive values | Value of fish (part worth), value of change in fish stocks, site attributes, total fishing site values | Value of site quality attributes (part worth), value of changes qualities, total site values |

The project also developed and used a simulation platform for management strategy evaluation. Unlike CSIRO's (project 5) simulation platform, ours focuses only on recreational fishing activities. The platform (SimReefs) has been developed as an agent-based model and combines a host of econometric models with a trophic-dynamic model of a coral reef ecosystem. A schematic diagram of SimReef's components is presented in Figure 1.

Five econometric models (*trip demand model*, *site choice model*, *trip timing model*, *trip length model*, and *catch rate model*) underpin the decision-making process on which the recreational agent's behaviour is structured. These models predict, respectively, the number of recreational trips taken in a year, the choice of recreational site in any one trip, the timing of a trip in a year, the length or duration of a trip, and the agent's expected fish catch for any given site. The *trophic-dynamic model* in SimReefs is a discretized version of the model in Kramer (2008); this discrete version is described in section 3.3.5. The trophic-dynamic model describes interactions among four components in a coral reef environment, namely, algal growth, coral cover, herbivore fish and piscivore fish. Detailed descriptions of this model are available in Gao, Durkin and Hailu (2010) and Gao and Hailu (2010b).

Figure 1 Schematic diagram of model components




### 3.3.2 Site choice models

In the literature on non-market valuation, random utility models (RUMS) have become the dominant technique used to investigate influences on choice where the choice involves discrete alternatives (e.g. recreational sites). A detail specification of the RUM modelling framework is presented in several key papers, including McFadden (1974), Bockstael, McConnell and Strand (1989 & 1991), Kaoru, Smith and Liu (1995), Hanemann (1999), Train (1998) and Herrings and Kling (1999). For a study on recreation, choice is modelled as a utility maximization exercise where utility is hypothesized to depend on cost recreation (travel and any other access cost to site) as well as other site attributes that impact on the recreational experience. The modelled or systematic part of utility, $V_{ij}$, of a visit by the $i^{th}$ individual to the $j^{th}$ recreational site is defined as:

$$V_{ij} = \alpha + \theta . c_{ij} + \gamma . q_{ij} \quad (1)$$

Where $c_{ij}$ is the cost $i$ of a visit to site $j$, $q_{ij}$ is a vector of site attributes, and θ and γ are model parameters to be estimated econometrically using empirical data. However, not all influences on choice are observable. Therefore, the RUM modelling framework allows for a stochastic or error term in equation (1) to capture unobservable influences provides the following full specification for the stochastic utility ($U_{ij}$) that visitor $i$ derives from a visit to site $j$:

$$U_{ij} = V_{ij} + \xi_{ij} = \alpha + \theta . c_{ij} + \gamma . q_{ij} + \xi_{ij} \quad (2)$$

This form provides a basis for a probabilistic model of choice. Choice is defined by modelling the probability of individual $i$ going to site $j$. This probability is given by the probability that the utility of a visit to site $j$ is greater than the utility of a visit to any alternative site $k$, i.e.:

$$prob_{ij} = prob(V_{ij} + \xi_{ij} > V_{ik} + \xi_{ik}),\ j \neq k \quad (3)$$

If one assumes that the random or unobserved variable $\xi$ is independently and identically distributed as type I extreme value, one can derive the most commonly used mathematical representation for the probability values, namely, the multinomial logit (MNL) (McFadden, 1974). The probability, $prob_{ij}$, that individual $i$ chooses site $j$ out of the available $M$ sites is given by:

$$prob_{ij} = \frac{\exp(V_{ij})}{\sum_{m=1}^{M} \exp(V_{im})} \tag{4}$$

Given empirical data on choices, maximum likelihood procedures can be applied to estimate the parameters of the systematic components of utility (θ and γ) in equation (4), by maximizing the joint probability of the observed site choices.

One can then use the estimated RUM model to predict site choice behaviour and to provide welfare change estimates for changes in site attribute values or the availability of sites. For the valuation of changes in recreational opportunities, one uses the concept of Inclusive Value (IV). The IV measures the expected maximum utility from the set of $M$ alternatives (Bockstael, McConnell and Strand 1991) and can be calculated as:

$$IV_i = \ln(\sum_{m=1}^{M} \exp(V_{in}) + 0.5772 \tag{5}$$

Generally, the expected maximum utility would vary by individual. By comparing IV values before and after changes in access rules or changes in site attributes, one is able to derive welfare measures that reflect the monetary value (gains or losses) for these changes. These welfare measures would be useful inputs into cost benefit analysis and management strategy evaluation. Further details on the use of the IV in benefit calculation are provided below.

### 3.3.3 Fish catch rate models

We described above the general structure of site choice models. In the case of recreational fishing, one of the attributes of a site would be the fish that an angler would expect to catch at the site. That is, the utility that an individual $i$ derives from a visit to fishing site $j$ is assumed to depend on the cost of visiting the site ($c_{ij}$), the number of fish of type $f$ that the angler expects to catch at that site ($CR_{ijf}$) as well as other relevant fishing site characteristics ($q_{ikj}$):

$$V_{ij} = \alpha + \theta \cdot c_{ij} + \sum_f \gamma_f \cdot CR_{ijf} + \sum_k \gamma_k \cdot q_{ikj} \tag{6}$$

The expected catch rates, however, are not directly observable. These rates depend on fish stocks and the angler's experience and skills. In our model, these rates are generated by another econometric model, the *catch rate model*, estimated by regressing observed fish catch rates on a set of variables that include:

1. fish stock or fish availability proxy variable
2. whether the angler is fishing from a boat or not (a dummy variable)
3. the skill level of the angler, represented by dummy variables indicating whether the skill level is “intermediate”, “advanced”, or “highly advanced” as opposed to being “basic”

4. the amount of bait used as measured by bait cost

Catch rates for each type of fish is estimated using a negative binomial model with the following specifications.

$$\ln \lambda_{ijk} = \beta_0 + \beta_1 \cdot stock_{jk} + \beta \cdot S \quad (7)$$

where: $\lambda_{ijk}$ is the expected catch per trip for angler $i$ at site $j$ of fish type $k$; $stock_{jk}$ is the annual total stock at site $j$ of fish type $k$; $S$ is the vector of demographic characteristics listed above including the bait cost.

Given the predicted catch rates, which can be generated for all sites, and the other observed variables that go into (2), one can estimate the discrete choice model of site choice for recreational fishing.

### 3.3.4 Coral reef ecosystem model

To describe interactions among algae, corals, and fish at a site, we use a trophic-dynamic model based on a modified Lotka-Volterra model of predator-prey interactions and inter species competition developed by Kramer (2008). Our trophic-dynamic model converts the continuous model (Kramer, 2008) into difference equations using a numerical scheme proposed by Liu and Elaydi (2001). Another modification to Kramer's model is that our fish harvests levels are based on the agent-based model for fishing site choice described above. The equations describing the dynamics in algal growth, coral cover, herbivorous fishes, and piscivorous fishes, are shown in equations (8)-(11):

$$A(n+1) = \frac{[1+\phi_A(h)\cdot r_A]\cdot A(n)}{1+\phi_A(h)\cdot[\frac{r_A}{K_A}\cdot A(n) + \frac{r_A \cdot a_{AC}}{K_A}\cdot C(n) + a_{AH}\cdot H(n)]} \quad (8)$$

where $A(n)$ is algal cover as proportion of sea floor at time step $n$, $r_A$ is algal intrinsic rate of growth, $K_A$ is algal carrying capacity as cover, $a_{AC}$ is a competition coefficient of coral on algae, and $a_{AH}$ is an interaction coefficient of herbivores on algae.

$$C(n+1) = \frac{[1+\phi_C(h)\cdot r_C]\cdot C(n)}{1+\phi_C(h)\cdot[\frac{r_C}{K_C}\cdot C(n) + \frac{r_C \cdot a_{CA}}{K_C}\cdot \frac{A(n)^{Slope}}{A(n)^{Slope}+HA^{Slope}}]} \quad (9)$$

where $C(n)$ is coral cover as proportion of sea floor at time $n$, $r_C$ is coral intrinsic rate of growth, $K_C$ is coral carrying capacity, $a_{CA}$ is a competition coefficient of algae on coral, $Slope$ and $HA$ are the slope and a half saturation constant of Hill function.

$$H(n+1) = \frac{[1-\phi_H(h)\cdot a_{HH}]\cdot H(n)}{1+\phi_H(h)\cdot[-a_{HA}\cdot A(n) + a_{HP}\cdot P(n)]} - \sum_{i=1}^{N} Catch_H^i(n) \quad (10)$$

where $H(n)$ is herbivorous fish density at time step $n$, $a_{HH}$ is a density-dependent coefficient of herbivorous fish, $a_{HA}$ is an interaction coefficient of algae on herbivorous fish, $a_{HP}$ is an interaction coefficient of piscivores on herbivores, $N$ is the number of recreational anglers, and $Catch_H^i(n)$ is the biomass of herbivorous fish caught by angler $i$.

$$P(n+1) = \frac{[1-\phi_P(h)\cdot a_{PP}]\cdot P(n)}{1-\phi_P(h)\cdot a_{PH}\cdot H(n)} - \sum_{i=1}^{N} Catch_P^i(n) \quad (11)$$

where $P(n)$ is the piscivorous fish density at time step $n$, $a_{PP}$ is the density-dependent coefficient of piscivorous fish, $a_{PH}$ is an interaction coefficient of herbivores on piscivores, and $Catch_P^i(n)$ is the biomass of piscivorous fishes caught by angler $i$.

The function $\phi_X(h)$ (*X* is *A, C, H,* or *P*) in equations (8)-(11) is a conversion function, and

$$\phi(h) = e^{r_X \cdot 0.5} - 1 \big/ r_X \quad (12)$$

where $r_X$ is an intrinsic rate of growth of *X* (algae, coral, herbivorous fish, or piscivorous fish).

### 3.3.5 Welfare change calculation for management strategy evaluation

There are a range of strategies at the disposal of resource managers when it comes to regulating recreational fishing. Commonly used measures include: site closure, limits to fish harvest (or bag limits), and exclusion of fish species from the allowable list of target species. Resource managers can also employ incentive-based strategies such as license fees, which are used in many jurisdictions. For non-fishing recreation, management changes can involve limits to site access, limits to recreational activities allowed at a site as well as investments that would lead to changes in site quality.

The welfare impact of a management change can be calculated as the difference between the inclusive sums after and before the change in management, as follows:

$$W = \sum_{i}^{N}\left(\frac{1}{\theta}\cdot \ln(\sum_{j=1}^{M} e^{U^1_{ij}})\right) - \sum_{i}^{N}\left(\frac{1}{\theta}\cdot \ln(\sum_{j=1}^{M} e^{U^0_{ij}})\right) \quad (13)$$

where $\theta$ is the marginal utility of income from the site choice model; $V^1{}_{ij}$ and $V^0{}_{ij}$ are the utility angler $i$'s derives from site $j$ after and before the change, respectively; $M$ is the number of recreational sites for fishing; and $N$ is the number of visitors for whom the welfare change calculations are done (e.g. all visitors or visitors who chose a particular site).

## 3.4 Results

We first present econometric estimates for the RUM model of site choice for non-fishing recreation. This is followed by a presentation of the econometric results for recreational fishing. In both cases, we present welfare change measures for management change evaluation, where the change relates to the closure of a site. These welfare change estimates reflect the value of access to the site. The welfare changes are presented both as average values across all respondents and as average values only across respondents who visited the particular site.

### 3.4.1 Non-fishing recreation modelling results

Forty recreational sites were identified for the site choice model. These choices include actual sites on the Ningaloo coast as well as recreational tours out of Coral Bay (CB) and Exmouth

(Ex). The full set of choices is shown in Table 5. The set of explanatory variables in the model is listed in Table 6.

Table 5: Ningaloo sites and recreational choices included in site choice model

| Site ID | Site name | Site ID | Site name |
|---|---|---|---|
| 1 | Bundegi Beach | 21 | Oyster Stacks |
| 2 | Charles Knife Canyon | 22 | Pebble Beach |
| 3 | Coral Bay | 23 | Pilgramunna |
| 4 | Eco Tour CB | 24 | Point Murat |
| 5 | Eco Tour Ex | 25 | Quobba Station |
| 6 | Exmouth Town Beach | 26 | Red Bluff |
| 7 | Five Mile Beach | 27 | Sandy Bay |
| 8 | Gnaraloo | 28 | Shothole Canyon |
| 9 | Janzs Bay | 29 | T-Bone Bay |
| 10 | Jurabi Point | 30 | Tantabiddi |
| 11 | Lakeside | 31 | The Dunes Surfing Beach |
| 12 | Lighthouse Bay | 32 | Tulki Beach |
| 13 | Mandu | 33 | Turquoise Bay |
| 14 | Mangrove Bay | 34 | Varanus Beach |
| 15 | Manta Ray Tour CB | 35 | Warroora |
| 16 | Mesa Camp Site | 36 | Whale Shark Tour CB |
| 17 | Mildura Wreck | 37 | Whale Shark Tour Ex |
| 18 | Navy Pier | 38 | Winderabandi |
| 19 | Ned's Camp | 39 | Wobiri |
| 20 | Osprey Bay | 40 | Yardie Creek |

Table 6: Definition of variables in recreational site choice model

| Variables | Description |
|---|---|
| *cost_total* | Total cost of travelling (from the place where visitor/household *i* stayed to site *j*), park entry, and tour ticket |
| *md_beach* | Median respondent “beach walking” satisfaction score for site *j* |
| *md_snorkel* | Median respondent “snorkelling” satisfaction score for site *j* |
| *md_swim* | Median respondent “swimming” satisfaction score for site *j* |
| *md_animals* | Median respondent “swimming with animals” satisfaction score for site *j* |
| *md_water* | Median respondent “water sports” satisfaction score for site *j* |
| *is_whale_shk* | Equals 1 if choice *j* is a whale shark viewing place, and equals 0 otherwise |
| *is_gorges* | Equals 1 if there are gorges in site *j*, and equals 0 otherwise |
| *is_coral_viewing* | Equals 1 if site *j* is a coral viewing place, and equals 0 otherwise |
| *is_diving* | Equals 1 if site *j* is a good diving place, and equals 0 otherwise |
| *is_turtle_watching* | Equals 1 if site *j* is a turtle watching place, and equals 0 otherwise |
| *is_fishing* | Equals 1 if site *j* is a fishing place, and equals 0 otherwise |
| *kid_snorkel* | Dummy for kid times median “snorkelling” score |
| *kid_water* | Dummy for kid times median “water sports” score |
| *age_water* | Dummy for age times median “water sports” score |

Note: *kid* is a dummy which takes a value of 1 if respondent has children, and *age* is the mean age of all adults in recreating party.

Maximum likelihood methods were used to estimate the logit model using the data collected in Ningaloo. The estimation results are shown in Table 7 below. We find that most of the coefficients are statistically significant at the 95 percent level and have the expected signs.

Site choice is determined by the cost of access to the site (which has a negative coefficient) as well as a diverse set of desirable site quality attribute. In particular, site attributes relating to the attractiveness of the site for activities such as beach walking, snorkelling, swimming, swimming with animals, coral viewing, water sports and suitability for diving all have positive signs. Further, the influences of some of these attributes depend on household characteristics, with the attractiveness of water sporting opportunities declining with age or with the presence of children in the recreating party. Sites where fishing activities are undertaken tend to be less attractive to visitors who are not engaged in recreational fishing, all else being the same. The insignificance of the turtle variable might be because of the poor quality of the variable used in the model and because of the timing of data capture as turtle watching is a seasonal event.

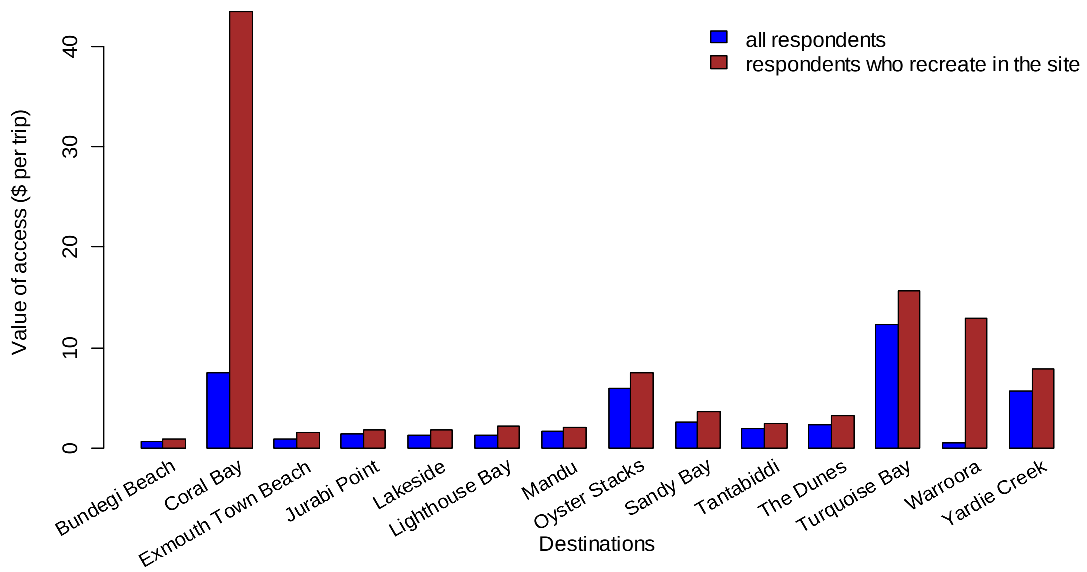
Table 7: Coefficient estimates of improved recreation site choice model

| **Variables**[a] | **Estimated coefficient** | **Std. Err.** | **z** | **P>\|z\|** |
|---|---|---|---|---|
| $cost\_total_{ij}$ | -0.017410*** | 0.001845 | -9.44 | 0.000 |
| $md\_beach_j$ | 0.441327*** | 0.061247 | 7.21 | 0.000 |
| $md\_snorkel_j$ | 0.299148*** | 0.063318 | 4.72 | 0.000 |
| $md\_swim_j$ | 0.443727*** | 0.086138 | 5.15 | 0.000 |
| $md\_animals_j$ | 0.244685*** | 0.048949 | 5.00 | 0.000 |
| $md\_water_j$ | 0.327873*** | 0.080085 | 4.09 | 0.000 |
| $is\_whale\_shk_j$ | 3.588419*** | 0.699682 | 5.13 | 0.000 |
| $is\_gorges_j$ | 2.166939*** | 0.182983 | 11.84 | 0.000 |
| $is\_coral\_viewing_j$ | 0.455966* | 0.199089 | 2.29 | 0.022 |
| $is\_diving_j$ | 0.916515** | 0.33275 | 2.75 | 0.006 |
| $is\_turtle\_watching_j$ | 0.213652 | 0.201327 | 1.06 | 0.289 |
| $is\_fishing_j$ | -0.968130*** | 0.118077 | -8.20 | 0.000 |
| $kid\_snorkel_{ij}$ | 0.182265 | 0.108319 | 1.68 | 0.092 |
| $kid\_water_{ij}$ | -0.115970* | 0.057366 | -2.02 | 0.043 |
| $age\_water_{ij}$ | -0.003820* | 0.001675 | -2.28 | 0.022 |

Note: Log likelihood: -1363.74; Chi-square: 992.93. Three asterisks (***) indicate significance at the 0.1% level, while ** and * indicate significance at the 1% and 5% levels, respectively. [a] Variable definitions are provided in Table 6.

The model presented above was used to compute site access values. These site values indicate the benefit derived from the availability of a site in the set of recreational sites that a visitor can choose from. As a result, these values depend on whether the visitor chose the site or not. Averaging over all respondents, site values vary from very little or nil for the case of sites like T-Bone Bay to as much as $12.28 per trip in the case of Turquoise Bay. Other highly valued sites include Gnaraloo Surfing, Coral Bay, Oyster Stacks and Yardie Creek. The site values for the top 14 sites are plotted in Figure 2. Values are higher if one averages across only respondents who visited the particular site. This ranges from very little in the case of T-Bone Bay to as much as $124.57 per trip for Gnaraloo Surfing. Again, Oyster Stacks, Yardie Creek, Turquoise Bay and Coral Bay are among the most valued sites.

Figure 2 The value of access to recreational sites




### 3.4.2 Recreational fishing modelling results

A smaller number of sites (11) are included in the recreational fishing model. These include: Learmonth, Exmouth, Bundegi, North West Reef, Lighthouse Bay, Tantabiddi, Ned's Camp, Pilgramunna, Yardie Creek, Coral Bay, and Warroora. The order in which the sites are listed in the table reflects their locations going clockwise from Learmonth in the south of the Exmouth Gulf, over the West Cape, down to Warroora on the western most coast of the region. Our aggregation of sites into these 11 groups was based on the number of surveys collected at individual fishing sites.

A site choice model is fitted to estimate the influence of cost of visit to site, expected catch rates, the isolation score of the site, as well as recreational attributes of the site. The recreational attributes are based on the satisfaction scores obtained from the survey on non-fishing recreation and reflect the suitability of a site for a host of activities including beach walking, snorkelling and swimming. These scores are averaged to generate a single aggregate measure of suitability for recreation (*recscr*) for inclusion in the model for recreational fishing. Since households with children might be more attracted to fishing sites that offer recreational opportunities, an interaction term between this variable and a dummy variable indicating the presence of kids (*recscr_kids*) is included in the model. We also include an interaction term between this aggregate recreational satisfaction score and a dummy variable indicating whether the group was also engaged in non-fishing recreational activities at the site (*recscr_rec*). The full set of variables used in the fishing site choice model is described in Table 8 below.

Table 8: Definition of variables in fishing site choice models

| Variables | Description |
|---|---|
| *cost_total* | Cost (travel to site, park entry fees, and tour ticket prices) |
| *expected_prf* | Expected prize and reef fish catch |
| *expected_t* | Expected table fish catch |
| *average_isolation* | Site isolation score (averaged across respondents) |
| *recscr* | Recreational value score of site |
| *recscr_kids* | Recreational value score times kid dummy |
| *recscr_rec* | Recreational value score times rec dummy |

Note: *kid* has a value of 1 if fishing party included children; *rec* has a value of 1 if the fishing trip is also a recreational trip.

The RUM model estimates indicate that the most important influences on site choice are the cost of access to the site and expected fish catch rates. Expected catch rate for highly valued fish types (namely, prize and reef) is statistically significant and has a positive influence on the utility or attractiveness of a site. However, the estimated coefficient sign for expected catch rates of table fish has the expected positive sign but it is not significant. The isolation of the site has a positive influence on its utility, but this coefficient is not significant. Finally, the quality of the site for recreational (non-fishing), as indicated by the coefficient signs for the satisfaction score variable or interactions including it, has a positive influence on utility but is not statistically significant. In short, the model results indicate site choice as being primarily driven by the cost of the visit to the site and the high valued fish that an angler expects to catch at the site. Coefficient estimates are shown in Table 9.

It should be noted, however, that there are other influences on site choice that are recognized by the estimated model but only indirectly. For example, the personal characteristics of the angler will affect site choice because the amount of fish an angler expects to catch at a site depend on the angler's skills and how they are fishing (with or without a boat). Similarly, fish stocks affect site choice through their effects on expected fish catch rates. That is, the number of variables indicated in the table below does not fully reflect the number of factors driving site choice among anglers.

Table 9: Coefficient estimates of fishing site choice model

| Variables | Estimated coefficient | Std. Err. | z | P>\|z\| |
|---|---|---|---|---|
| *cost_total* | -.0340683*** | 0.0031957 | -10.66 | 0.000 |
| *expected_prf* | 0.0832593*** | 0.0233831 | 3.56 | 0.000 |
| *expected_t* | 0.0131676 | 0.0133626 | 0.99 | 0.324 |
| *average_isolation*$_i$ | 0.2027971 | 0.1424689 | 1.42 | 0.155 |
| *recscr_kids* | 0.5178030 | 0.3427785 | 1.51 | 0.131 |
| *recscr_rec* | 1.4651180 | 1.055489 | 1.39 | 0.165 |

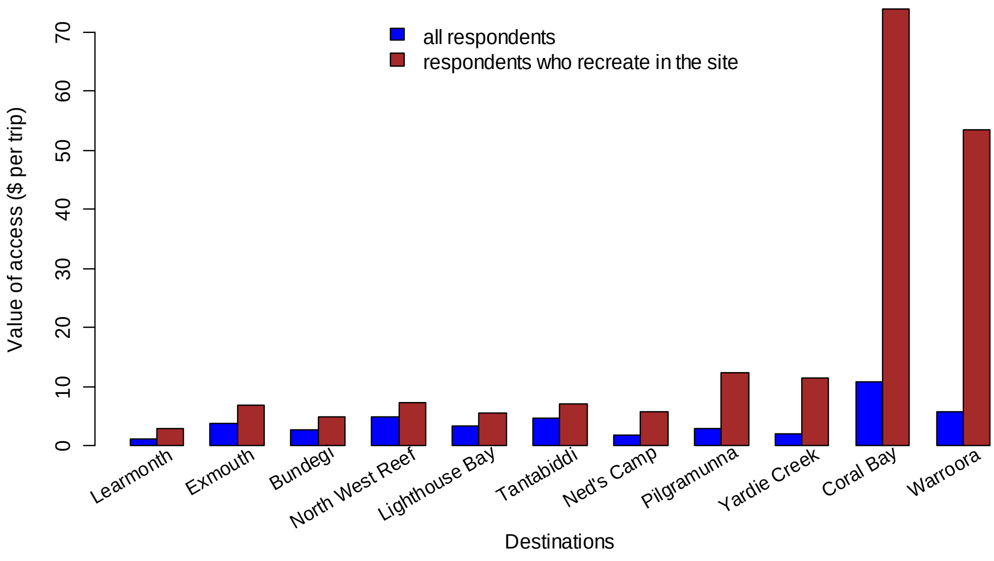
Note: Log likelihood: -419.28; Chi-square: 234.36. Three asterisks (***) indicate significance at the 0.1% level, while ** and * indicate significance at the 1% and 5% levels, respectively.

Site access values are shown in Table 10. There are two sets of values in the table: site values averaged across all respondents and site values averaged only across respondents who fished at the site. There are two main points to note about the results. First, the value of a site for those who visited the site is higher than the value obtained by averaging across all respondents in the sample. This is simply because anglers who fish at a site tend to have characteristics (including distance from site) that make them more inclined fish at the chosen site. Second, site access values vary widely across the different Ningaloo sites. Learmonth, for example, has a site access value of only $1.09 per trip while Coral Bay has a site access value of $10.76. These values become $2.81 and $73.85 if one looks at values averaged across anglers who fished at those sites. The values are plotted in Figure 3.

Table 10: Economic surplus values of fishing sites averaged across respondents

| Site ID | Site name | All respondents | Respondents who chose the site |
|---|---|---|---|
| 1 | Learmonth | 1.09 | 2.81 |
| 2 | Exmouth | 3.67 | 6.91 |
| 3 | Bundegi | 2.68 | 4.90 |
| 4 | North West Reef | 4.83 | 7.32 |
| 5 | Lighthouse Bay | 3.37 | 5.48 |
| 6 | Tantabiddi | 4.59 | 7.00 |
| 7 | Ned's Camp | 1.80 | 5.81 |
| 8 | Pilgramunna | 2.97 | 12.31 |
| 9 | Yardie Creek | 1.95 | 11.53 |
| 10 | Coral Bay | 10.76 | 73.85 |
| 11 | Warroora | 5.79 | 53.55 |

Figure 3 Site access or economic surplus values for fishing sites.



### 3.4.3 Management strategy evaluation (MSE)

The models developed by this project can be used to undertake evaluation of management strategies including:

1) **Site closure**
The welfare losses per person per trip for the closure of a site are given by the site access values. For the Ningaloo non-fishing and fishing recreation studies presented above, these values are shown in Figures 2 and 3 above. For the state-wide recreational fishing model, these results are reported in Raguragavan, Hailu and Burton (2010b).

2) **Changes in site attributes**
One can look at increases or decreases in desirable site attributes. These calculations have been undertaken for fishing recreation in Raguragavan, Hailu and Burton(2010b) using the state-wide fishing site choice model and for Ningaloo recreational sites in Raguragavan, Hailu and Burton (2010a). The models presented above can be used to simulate welfare changes for different combinations of changes in site attribute values.

3) **Integrated modelling of economic and biophysical effects**
Simulations of management changes using the econometric models do not allow for the feedback effects from the coral-reef ecosystem. To evaluate changes in ways that take into account such feedback effects, the integrated RUM-coral reef ecosystem model described in the methods section (SimReefs) can be used. The project has undertaken several demonstrative simulations of some changes in management strategies: site access and fishing bag limit changes (Gao, Durkin and Hailu, 2010); and alternative seasonal site closure regimes (Gao and Hailu, 2010b). These exercises clearly demonstrate the usefulness of integrated modelling. The results are not reproduced here to save space but they do highlight the fact that management outcomes might be different than what people would expect to occur without the benefit of integrated modelling. In particular, the results reported in Gao and Hailu (2010b) indicate that it is possible for some restrictive access policies to be welfare improving even for anglers, because the stock gains and improved catch effects can outweigh the losses from reduction in access times. For further details, see Gao and Hailu (2010b) or Gao, Durkin and Hailu (2010).

## 3.5 Discussion

In both fishing and non-fishing recreational studies we observe that the proximity of the site and, therefore, the cost of accessing a site is one of the most important influences. Thus, choice of recreational sites and the effects of recreation on environmental quality are influenced by accommodation locations. Specifically, sites close to areas where people stay or are allowed to stay (e.g. camping grounds) are likely to face heavier demands or pressures from recreation and fish harvest.

However, the site cost attribute is weighted against other desirable attributes by anglers and others recreating in Ningaloo. In the case of fishing, expected fish catches are very important, as is the type of fish expected. Choice of fishing sites is driven largely by the chance to catch highly valued fish (prize and reef fish).

A diverse set of site quality measures or perceptions affect choice in Ningaloo as discussed in the first set of RUM results above. These include variables that reflect the health or condition of the ecosystem at the site (e.g. corals and other sea wildlife), aesthetic attributes (e.g. water clarity, scenery) as well as the type of recreational activities available.

The site access value calculations indicate that the value to society of sites vary greatly. While this is an obvious fact, the research has put quantitative estimates on these values. A few sites are highly valued by both anglers and non-anglers, e.g. Coral Bay, Yardie Creek and Warroora. Turquoise Bay and Oyster stacks are highly valued among non-fishing visitors. Management changes that restrict fishing or recreational opportunities in these sites are likely to have significant effects on economic welfare.

Finally, management needs to balance conservation and socioeconomic benefits from recreation. The models and outputs from this project shed light on the values that visitors attach to different sites and their attributes. More important, the project has provided models that can be used to simulate resource use changes arising from management or exogenous changes affecting the attractiveness of fishing sites. The models provide quantitative estimates of value changes and also changes in conservation outcomes (in the case of the integrated modelling). Resource managers and other stakeholders are able to use these models to examine tradeoffs and make informed decisions.

## 3.6 Acknowledgements

We are grateful to the Department of Fisheries WA and Neil Sumner for providing the data from the National Survey of Recreational Fishing (NSRF) (2000/1). Ningaloo Cluster Project 3 leaders, Todd Jones and David Wood, also provided data and help distributing surveys. We are also grateful to Lynnath Beckley (Project 2) for information on fishing data sources.

The project benefitted greatly from survey work undertaken by Dominique Leib, John Curry, Sayed Iftekhar, Julie Sharper, Heidi Khojasteh, Doc Lap Tran, and Jeffrey Durkin. Dominique and John contributed to the development of the survey. Jeffrey Durkin was a key player in the second stage of the survey where it became necessary to undertake face-to-face interviews. Jeff also processed the survey data and wrote a report on the survey results. Jeff's contributions to the project have also extended in the analysis of the data. We are also thankful to Jessica Meeuwig and Heather Taylor at the Centre for Marine Futures (UWA) for help with surveys. Sam McMillan and Derek Walker from the Centre undertook surveying activities in Ningaloo for the project.

Jananee Raguragavan worked on the project from 2006 to 2009 and played a key role in the development of the survey questionnaire. She organized the field surveys until April 2009. Jananee worked on the RUM models using earlier Ningaloo data on recreation (Raguragavan, Hailu and Burton 2010a) and the state-wide fishing study using the NSRF data (Raguragavan, Hailu and Burton 2010b).

Finally, we would like to thank Professor Neil Loneragan for providing constructive comments on the draft version of this report.

# REFERENCES

Adamowicz, W. L. (1994). Habitat formation and variety seeking in a discrete choice model of recreation demand, *Journal of Agricultural and Resource Economics,* 19, 19-31.

Adamson-Badilla, M., and Castillo, F. (1998). *Using Contingent Valuation to Estimate Prices for Non-Market Amenities Provided by Protected Areas*, University of Costa Rica, Costa Rica.

Bennett, J., and Adamowicz, W. L. (2001). Some fundamentals of environmental choice modelling, in: J. Bennett and R. Blamey (eds.), *The Choice Modelling Approach to Environmental Valuation*, Edward Elgar, Northampton, pp. 37-69.

Bin, O., Landry, C. E., Ellis, C. L., and Vogelsong, H. (2004). *Some Consumer Surplus Estimates for North Carolina Beaches*, Department of Economics, East Carolina University.

Bockstael, N. E., Hanneman, W. M., and Kling, C. L. (1987). Estimating the value of water quality improvements in a recreational demand framework, *Water Resources Research*, 23(5), 951-60.

Bockstael, N. E., McConnell, K. E., and Strand, I. (1989). A random utility models for sport fishing: some preliminary results for florida, *Marine Resources Economics*, 61, 245-260.

Bockstael, N. E., McConnell, K. E., and Strand, I. (1991). Recreation, in Braden, J. B. and Kolstad, C. (ed), *Measuring the demand for Environmental Quality*, Elsevier Science Publishing Co, Netherlands.

Burton, M. P., Raguragavan, J. and Hailu, A. (2008). State-wide recreational fishing site choice study, unpublished technical report, School of Agricultural and Resource Economics, University of Western Australia.

Durkin, J. (2009). Survey of fishing and recreation in the Ningaloo region, unpublished technical report, School of Agricultural and Resource Economics, University of Western Australia.

Gao, L., Durkin, J., and Hailu, A. (2010). An agent-based model for recreational fishing management evaluation in a coral reef environment, Proceedings of the International Conference on Agents and Artificial Intelligence, January 22 - 24, Valencia, Spain.

Gao, L., and Hailu, A. (2010a). *Recreational trip timing and duration prediction: A research note*, Working Paper 1002, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia.

Gao, L., and Hailu, A. (2010b). Evaluating the effects of area closure for recreational fishing in a coral reef ecosystem: The benefits of an integrated economic and biophysical modelling, unpublished paper (currently under revision with a journal), School of Agricultural and Resource Economics, University of Western Australia.

Henry, G. (2001). Unpublished report on the National Survey of Recreational Fishing (2000/2001), *NSW Fisheries*, Sydney.

Herrings, J. A., and Kling, C. L. (1999). *Valuing Recreation and Environment* (eds.), Edward Elgar Publishing Limited, UK

Hanemann, W. M. (1999). Welfare analysis in discrete choice models. In: Herriges, J.A., Kling, C.L. (Eds.), Valuing Recreation and the Environment: *Revealed Preference Methods in Theory and Practice*. Edward Elgar Publishers, p. 33–64.

Kaoru, Y., Smith, V. K., and Liu, J. L. (1995). Using random utility models to estimate the recreational value of estuarine resources, *American Journal of Agricultural Economics*, 77:141-151.

Kramer, D. B. (2008). Adaptive Harvesting in a Multiple-Species Coral-Reef Food Web, *Ecology and Society,* 13, 17.

Lew, D. K and Larson, D. W. (2005). Valuing recreation and amenities at San Diego County beaches, *Coastal Management*, 33, 71-86.

Loomis, J., and Walsh, R. G. (1997). *Recreation Economic Decisions: Comparing Benefits and Costs* (2nd ed.), State College, PA: Venture Publishing.

Liu, P., and Elaydi, S.N. (2001). Discrete competitive and cooperative models of Lotka-Volterra type, *Journal of Computational Analysis and Applications,* 3, 53-73.

McFadden, D. (1974). The measurement of urban travel demand, *Journal of Public Economics,* 3, 303-328.

Morey, E. R., Shaw, W. D., and Rowe, R. D. (1991). A Discrete-choice model of recreational participation, site choice, and activity valuation when complete trip data are not available, *Journal of Environmental Economics and Management*, 20, 181-201.

Navrud, S. (1999). Assessment of environmental valuation reference inventory (EVRI) and the expansion of its coverage to the European union, Report of the European Commission, DG XI.

Parsons, G. R., Massey, D. M., and Tomasi, T. (1999). Familiar and favourite sites in a random utility model of beach recreation, *Marine Resource Economics*, 14(4), 299-315.

Raguragavan, J., Hailu, A. and Burton, M. (2010a) Valuation of marine based non-fishing recreation, Working Paper 1003, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia.

Raguragavan, J., Hailu, A. and Burton, M. (2010b) Economic valuation of recreational fishing in Western Australia, Working Paper 1001, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia.

Shivlani, M. P., David, L., and Theis, M. (2003). Visitor preferences for public beach amenities and beach restoration in South Florida. *Coastal Management,* 31, 367-385.

Swait, J., Adamowicz, W. L. and van Bueren, M. (2004). Choice and the temporal welfare impacts: incorporating history into discrete choice models, *Journal of Environmental Economics and Management*, 47, 91-116.

Train, K. (1998). Recreation demand models with taste differences over people, *Land Economics*, 74, 230-239.

Van Bueren, M. (1999). Economic models of recreational fishing for guiding allocation policy and managing stocks: An application to the recreational fishery of South Western Australia, PhD Thesis, University of Western Australia, Perth.

Zhang, J. (2003). Valuing recreational fishing in Western Australia using Random Utility Model, unpublished Masters Thesis, University of Western Australia, Perth.

# APPENDIX A – DATABASE TABLES

Table A1: Demographic metadata description

| Field Name | Type | Meaning |
|---|---|---|
| survey_id | Integer | Survey number |
| date_filled | Date | Date fill out |
| day_filled | Integer | Day fill out |
| month_filled | Integer | Month fill out |
| year_filled | Integer | Year fill out |
| num_days_fish_lastweek | Integer | Number of days spent fishing last week |
| num_days_fish_last12m | Integer | Number of days spent fishing last 12 months |
| num_days_fish_next12m | Integer | Number of days spent fishing next 12 months |
| num_days_rec_lastweek | Integer | Number of days spent recreating last week |
| num_days_rec_last12m | Integer | Number of days spent recreating last 12 months |
| num_days_rec_next12m | Integer | Number of days spent recreating next 12 months |
| fishing_skill_level | Enum: Highly Advanced/ Advanced/Intermediate/Basic/Nil | Level of fishing skill |
| value_rod | Float | Cost for rod reel |
| value_clothes | Float | Cost for clothes |
| value_other | Float | Cost for other |
| value_boat | Float | Cost for boat |
| member_fishing_club | Enum: Y/N | Is a member of fishing club |
| general_fishing_style | Enum: Shore/Boat/Both | General fishing style |
| active_fishing_years | Integer | How many years actively fished |
| active_fishing_years_wa | Integer | Active fishing years in Western Australia |
| active_fishing_years_australia | Integer | Active fishing years in Rest of Australia |
| active_fishing_years_overseas | Integer | Active fishing years overseas (years) |
| country | String | Country |
| postcode | Integer | Post code |
| days_in_region | Integer | Total days in this region |
| camp | String | Locality/place camp |
| camp_nights | Integer | Number of nights |
| caravan | String | Locality/place caravan |
| caravan_nights | Integer | Number of nights |
| back_pack_place | String | Locality/place back |
| back_pack_nights | Integer | Number of nights |
| hotel | String | Locality/place hotel |
| hotel_nights | Integer | Number of nights |
| other_accomdation | String | Locality/place other |
| other_accom_nights | Integer | Number of nights |
| travel_to_region | Own Vehicle/Hire Vehicle/Scheduled Bus/Package Tour/Plane/Others | The way travelling to the region |
| travel_in_region | Own Vehicle/Hire Vehicle/Scheduled Bus/Package Tour/Plane/Others | The way travelling in the region |
| salary_range | Below 20,000/20,000-40,000/ 40,001-60,000/60,001-80,000/80,00-120,000/Above 120,000 | Salary range |
| num_people_alone | Integer | Visiting the region with/alone/number of people |
| gender_people_alone | String | Visiting the region with/alone/gender |
| age_people_alone | Integer | Visiting the region with/alone/age |
| num_people_partner | Integer | Visiting the region with/partner/number of people |
| gender_people_partner | String | Visiting the region with/partner/gender |
| age_people_partner | String | Visiting the region with/partner/age |
| num_people_friends | Integer | Visiting the region with/family/friends/number of people |
| gender_people_friends | String | Visiting the region with/family/friends/gender |

| | | |
|---|---|---|
| age_people_friends | String | Visiting the region with/family/friends/age |
| num_people_tour | Integer | Visiting the region with/tour/number of people |
| gender_people_tour | String | Visiting the region with/tour/gender |
| age_people_tour | String | Visiting the region with/tour/age |
| num_people_other | Integer | Visiting the region with/others/number of people |
| gender_people_other | String | Visiting the region with/others/gender |
| age_people_other | String | Visiting the region with/others/age |
| visit_region_again | Enum: Y/N | Whether visit the region again |
| respondent_age | Integer | Age of respondent |
| num_males | Integer | Number of males |
| num_females | Integer | Number of females |
| mean_Age | Integer | Mean age |
| min_age | Integer | Min age |
| max_age | Integer | Max age |
| num_children | Integer | Number of children |
| mean_age_adult | Integer | Mean age of adults |
| num_adults | Integer | Number adults |
| mean_age_children | Integer | Mean age of children |
| num_children | Integer | Number of children |
| comment | String | Comment |

Table A2: Fish caught-released-target metadata description

| Field Name | Type | Meaning |
|---|---|---|
| survey_id | Integer | Survey number |
| trip_id | Integer | Trip number |
| fish_species | String | Type of fish caught |
| num_fish_caught | Integer | Number of fish caught (kept and released) |
| num_fish_released | Integer | Number of fish released |
| fish_species_target | String | Type of any target fish |

Table A3: Fish species metadata description

| Field Name | Type | Meaning |
|---|---|---|
| fish_id | Integer | Unique IDs |
| is_herbivore | Boolean | 1/0 with 0 being piscivores |
| fish_common_name | String | Common name |
| fish_species | String | Fish category |
| fish_family_name | String | Fish family name |
| other_common_names | String | Other common names |
| fish_name | String | Fish scientific name |
| fish_dof_group | Enum: Reef/Butter/Table/Prize/Key Sport | Fish DOF group |
| fish_hab | Enum: Bottom Dweller/Pelagic/Inshore | Fish species catalogue from Department of WA |
| fish_risk | Enum: L-Low/M-Medium/H-High | Fish risk level |
| fish_bagl | Integer | Bag limit |
| fish_minl | Float | Minimum length |
| fish_minw | Float | Minimum weight |
| fish_mina | Integer | Minimum age |
| fish_matl | Float | Mature length |
| fish_matw | Float | Mature weight |
| fish_mata | Integer | Mature age |
| fish_maxl | Float | Maximum length reported |
| fish_maxa | Integer | Maximum age reported |
| fish_maxw | Float | Maximum weight reported |
| fish_food | String | Food source noted |

Table A4: Fishing trip metadata description

| Field Name | Type | Meaning |
|---|---|---|
| survey_id | Integer | Survey number |
| date_filled | Date | Date fill out |
| day_filled | Integer | Day fill Out |
| month_filled | Integer | Month fill out |
| year_filled | Integer | Year fill out |
| trip_id | Integer | Trip number |
| day_trip | Integer | Trip day |
| month_trip | Integer | Trip month |
| year_trip | Integer | Trip year |
| date_trip | Date | Trip date |
| start_time_trip | Time | Trip start time |
| finish_time_trip | Time | Trip end time |
| chosen_site | String | fishing site chosen |
| stay_last_night | String | Stay last night |
| reason_scenery | Enum: 1/2/3/4/5 | Respondent score for the reason “scenery” |
| reason_time_available | Enum: 1/2/3/4/5 | Respondent score for the reason “time available” |
| reason_never_been_here | Enum: 1/2/3/4/5 | Respondent score for the reason “never been before” |
| reason_isolation | Enum: 1/2/3/4/5 | Respondent score for the reason “isolation & solitude” |
| reason_accoomodation | Enum: 1/2/3/4/5 | Respondent score for the reason “accommodation” |
| reason_cost_travel | Enum: 1/2/3/4/5 | Respondent score for the reason “cost of travelling” |
| reason_target_fish | Enum: 1/2/3/4/5 | Respondent score for the reason “chance of getting target fish” |
| other_reason_description | String | Other description |
| age_fishers | String | Ages of fishers |
| mean_age_adult | Integer | Mean age of adults |
| num_adults | Integer | Number of adults |
| mean_age_children | Integer | Mean age of children |
| num_children | Integer | Number of children |
| cost_car_fuel | Float | Cost for car fuel |
| cost_bait_ice | Float | Cost for bait & ice |
| cost_tackle | Float | Cost for tackle |
| cost_boat_hire | Float | Cost for boat hire |
| cost_boat_fuel | Float | Cost for boat fuel |
| cost_food | Float | Cost for food |

Table A5: Group metadata description

| Field Name | Type | Meaning |
|---|---|---|
| group_seq | Integer | Sequential group number |
| survey_number | Integer | Survey number |
| group_id | Integer | Group id |
| group_loc | String | Location where group surveyed |
| group_total | Integer | Number adults in goup |
| group_comment | String | Description of ages in group |

Table A6: Previous fishing experience metadata description

| Field Name | Type | Meaning |
|---|---|---|
| survey_id | Integer | Survey number |
| fish_zone | Integer | Fishing zone Id |
| fish_num_visits | Integer | Number of times visited each site/zone in the last 12 months for fishing |
| fish_num_expected | Integer | Number of fish expected to catch at each site |
| fish_size_rate | Integer | Score from 1 (high) to 5 (low) of satisfaction of fish size |
| fish_range_rate | Enum: 1/2/3/4/5 | Range of desirable fish |

Table A7: Previous recreation experience metadata description

| Field Name | Type | Meaning |
|---|---|---|
| survey_id | Integer | Survey number |
| rec_zone_site | String | Site/zone name |
| rec_num_visits | Integer | Number of times visited each site/zone in the last 12 months for recreation |
| rate_snorkel | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of snorkelling |
| rate_swim_anim | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of swimming with animals |
| rate_relax_walk_beach | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of walking on the beach |
| rate_diving | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of diving |
| rate_sight_seeing | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of sight seeing |
| rate_bush_walk | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of bush walking |
| rate_coral_view | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of coral viewing |
| rate_turtle_watch | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of turtle watching |
| rate_water_sport | Enum: 1/2/3/4/5 | Score from 1 (high) to 5 (low) of satisfaction of water sports |

Table A8: Recreational trip metadata description

| Field Name | Type | Meaning |
|---|---|---|
| survey_id | Integer | Survey number |
| date_filled | Date | Date fill out |
| day_filled | Integer | Day fill Out |
| month_filled | Integer | Month fill out |
| year_filled | Integer | Year fill out |
| trip_id | Integer | Trip number |
| day_trip | Integer | Trip day |
| month_trip | Integer | Trip month |
| year_trip | Integer | Trip year |
| date_trip | Date | Trip date |
| start_time_trip | Time | Trip start time |
| finish_time_trip | Time | Trip end time |
| chosen_site | String | Recreation site chosen |
| stay_last_night | String | Stay last night |
| reason_scenery | Enum: 1/2/3/4/5 | Respondent score for the reason “scenery” |
| reason_time_available | Enum: 1/2/3/4/5 | Respondent score for the reason “time available” |
| reason_never_been_here | Enum: 1/2/3/4/5 | Respondent score for the reason “never been before” |
| reason_isolation | Enum: 1/2/3/4/5 | Respondent score for the reason “isolation & solitude” |
| reason_accoomodation | Enum: 1/2/3/4/5 | Respondent score for the reason “accommodation” |
| reason_cost_travel | Enum: 1/2/3/4/5 | Respondent score for the reason “cost of travelling” |
| reason_target_fish | Enum: 1/2/3/4/5 | Respondent score for the reason “chance of getting target fish” |
| other_reason_description | String | Other description |
| age_rec | String | Ages of Recreational visitors |
| mean_age_adult | Integer | Mean age of adults |
| num_adults | Integer | Number of adults |
| mean_age_children | Integer | Mean age of children |
| num_children | Integer | Number of children |
| score_beach_walking | Enum: 1/2/3/4/5 | Respondent score for “beach walking” |
| score_snorkelling | Enum: 1/2/3/4/5 | Respondent score for “snorkelling (shore/boat)” |
| score_turtle_watching | Enum: 1/2/3/4/5 | Respondent score for “turtle watching” |
| score_pad_swim | Enum: 1/2/3/4/5 | Respondent score for “paddling/swimming” |
| score_swim_animals | Enum: 1/2/3/4/5 | Respondent score for “swimming with animals” |
| score_diving | Enum: 1/2/3/4/5 | Respondent score for “diving (boat/shore)” |
| score_sight_see | Enum: 1/2/3/4/5 | Respondent score for “sight seeing” |
| score_water_sport | Enum: 1/2/3/4/5 | Respondent score for “water sports” |
| other_satisfaction | String | Others satisfaction |
| cost_transportation | Float | Cost for car fuel, hire or other transportation |
| cost_equipment | Float | Cost for recreational equipment hire |
| cost_food | Float | Cost for refreshments and food |
| cost_accommodation | Float | Cost for accommodation |
| cost_other | Float | Cost for others |
| cost_reason | String | Reason description |
| cost_total | Float | Total cost |
| comment | String | Comment |

Table A9: Ningaloo stay metadata description

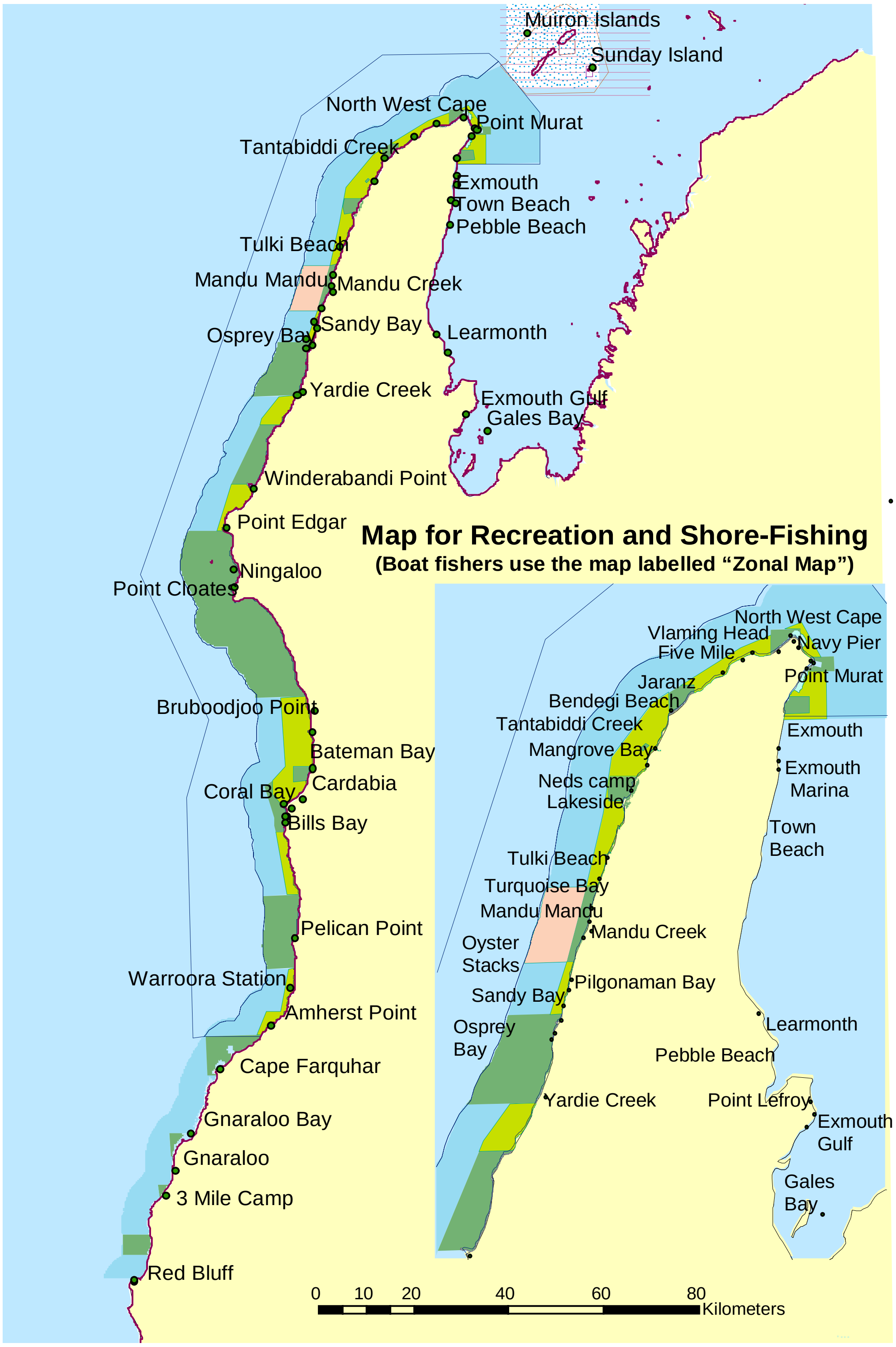
| Field Name | Type | Meaning |
|---|---|---|
| site_id | Integer | Site id |
| site_name | String | Site name |
| site_number | Integer | Site number |
| zone_id | Integer | Zone id |
| zone_model | Integer | Previous model zone |
| description | String | Description |
| accom_type | Enum: BP-Backpackers/ CVP-Caravan Park/H-Hotel/C-Camp | Accommodation type |
| distance_from_BayofRest | Float | Distance from bay of rest |
| dist_ind | Enum: G-Gnaraloo/W-Warroora/ C-Carnarvon/S-4 Wheel Track/GS-Giralia Station | Distance indicator |
| rel_cb | Enum: NCB-North of Coral Bay/SCB-South of Coral Bay | Relative CB |
| area | Float | Area |
| latitude | Float | Latitude |
| longitude | Float | Longitude |

Table A10: Trip site metadata description

| Field Name | Type | Meaning |
|---|---|---|
| site_id | Integer | Site id |
| site_name | String | Site name |
| zone_id | Integer | Zone id |
| number_sites | String | Number of sites in a trip |
| zone_model | Integer | Zone in previous models |
| description | String | Description |
| is_fishing_site | Boolean | Is it a fishing site |
| is_recreation_site | Boolean | Is it a recreational site |
| distance_from_bayofrest | Float | Distance from bay of rest |
| distance_indicator | Enum: G-Gnaraloo/W-Warroora/ C-Carnarvon/S-4 Wheel Track/GS-Giralia Station | Distance indicator |
| rel_cb | Enum: NCB-North of Coral Bay/SCB-South of Coral Bay | Relative CB |
| boat_tour | Boolean | Whether boat tour |
| land_tour | Boolean | Whether land tour |
| on_land | Boolean | Whether trip via land |
| on_boat | Boolean | Whether trip via boat |
| area | Float | Area |
| latitude | Float | Latitude |
| longitude | Float | Longitude |

# APPENDIX B – MAP OF NINGALOO SITES

Figure B1 Map of Ningaloo sites



# APPENDIX C – SHARE OF TRIPS AND THE SPILL OVER FROM CLOSED SITES

Table C1: Share of trips and spill-over effects from closed recreational sites

| Site ID | Site name | Predicted share of trips | Spill over from site closure(% increase in trips) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Turquoise Bay | Oyster Stacks | Yardie Creek | Coral Bay | Gnaraloo |
| 1 | Shothole Canyon | 0.62 | 0.85 | 0.73 | 0.64 | 1.45 | 0.00 |
| 2 | Charles Knife Canyon | 0.20 | 0.27 | 0.24 | 0.21 | 0.39 | 0.00 |
| 3 | Pebble Beach | 0.45 | 0.65 | 0.56 | 0.49 | 0.68 | 0.00 |
| 4 | Exmouth Town Beach | 1.87 | 2.78 | 2.41 | 2.11 | 2.10 | 0.00 |
| 5 | Bundegi Beach | 1.37 | 2.19 | 1.90 | 1.68 | 0.12 | 0.00 |
| 6 | Eco Tour Ex | 1.94 | 3.11 | 2.69 | 2.38 | 0.17 | 0.00 |
| 7 | Mildura Wreck | 1.38 | 2.23 | 1.93 | 1.71 | 0.11 | 0.00 |
| 8 | Lighthouse Bay | 2.44 | 3.94 | 3.41 | 3.03 | 0.20 | 0.00 |
| 9 | The Dunes | 3.52 | **5.67** | **4.91** | **4.36** | 0.29 | 0.00 |
| 10 | Point Murat | 1.11 | 1.80 | 1.56 | 1.39 | 0.09 | 0.00 |
| 11 | Navy Pier | 0.07 | 0.12 | 0.10 | 0.09 | 0.01 | 0.00 |
| 12 | Janzs Bay | 0.10 | 0.16 | 0.14 | 0.12 | 0.01 | 0.00 |
| 13 | Wobiri | 1.30 | 2.14 | 1.85 | 1.68 | 0.10 | 0.00 |
| 14 | Five Mile Beach | 0.16 | 0.27 | 0.23 | 0.21 | 0.01 | 0.00 |
| 15 | Jurabi Point | 2.38 | 3.93 | 3.40 | 3.11 | 0.18 | 0.00 |
| 16 | Tantabiddi | 3.45 | **5.78** | **5.00** | **4.62** | 0.21 | 0.00 |
| 17 | Whale Shark Tour Ex | 0.68 | 1.14 | 0.99 | 0.91 | 0.04 | 0.00 |
| 18 | Mangrove Bay | 0.56 | 0.96 | 0.83 | 0.79 | 0.03 | 0.00 |
| 19 | Ned's Camp | 0.04 | 0.06 | 0.05 | 0.05 | 0.00 | 0.00 |
| 20 | Mesa Camp Site | 0.04 | 0.07 | 0.06 | 0.06 | 0.00 | 0.00 |
| 21 | Lakeside | 2.32 | **4.03** | 3.48 | 3.40 | 0.12 | 0.00 |
| 22 | T-Bone Bay | 0.03 | 0.06 | 0.05 | 0.05 | 0.00 | 0.00 |
| 23 | Varanus Beach | 0.78 | 1.36 | 1.18 | 1.16 | 0.04 | 0.00 |
| 24 | Tulki Beach | 0.63 | 1.09 | 0.95 | 0.94 | 0.03 | 0.00 |
| 25 | Turquoise Bay | **17.97** | | **27.23** | **27.53** | 0.94 | 0.00 |
| 26 | Oyster Stacks | **9.44** | **16.49** | | **14.71** | 0.49 | 0.00 |
| 27 | Mandu | 2.58 | **4.51** | 3.94 | **4.12** | 0.13 | 0.00 |
| 28 | Pilgramunna | 3.20 | **5.60** | **4.89** | **5.21** | 0.16 | 0.00 |
| 29 | Sandy Bay | **4.34** | **7.59** | **6.65** | **7.24** | 0.22 | 0.00 |
| 30 | Osprey Bay | 2.20 | 3.85 | 3.38 | 3.79 | 0.11 | 0.00 |
| 31 | Yardie Creek | **8.71** | **15.22** | **13.42** | | 0.45 | 0.00 |
| 32 | Winderabandi | 0.60 | 1.01 | 0.91 | 1.26 | 0.05 | 0.00 |
| 33 | Coral Bay | **10.84** | 0.72 | 0.63 | 0.62 | | 0.00 |
| 34 | Eco Tour CB | 1.18 | 0.08 | 0.07 | 0.07 | **17.91** | 0.00 |
| 35 | Manta Ray Tour CB | 0.15 | 0.01 | 0.01 | 0.01 | 2.24 | 0.00 |
| 36 | Whale Shark Tour CB | **4.13** | 0.27 | 0.24 | 0.24 | **62.60** | 0.00 |
| 37 | Warroora | 0.68 | 0.00 | 0.00 | 0.00 | **8.28** | 0.00 |
| 38 | Quobba Station | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | **18.32** |
| 39 | Red Bluff | 0.97 | 0.00 | 0.00 | 0.00 | 0.00 | **81.68** |
| 40 | Gnaraloo | **5.24** | 0.00 | 0.00 | 0.00 | 0.00 | |

Table C2: Share of trips and spill-over effects from closed fishing sites

| Site ID | Site name | Predicted share of trips | Spill over from site closure(% increase in trips) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Exmouth** | **North West Reef** | **Lighthouse Bay** | **Tantabiddi** | **Yardie Creek** | **Coral Bay** |
| 1 | Learmonth | 3.58 | 7.81 | 6.21 | 5.86 | 4.20 | 1.44 | 9.07 |
| 2 | Exmouth | **11.23** | | **20.22** | **18.82** | **14.28** | 4.83 | 5.49 |
| 3 | Bundegi | 8.53 | **16.27** | **15.11** | **14.63** | **11.51** | 5.17 | 0.08 |
| 4 | North West Reef | **14.70** | **25.89** | | **24.17** | **22.48** | **10.92** | 0.16 |
| 5 | Lighthouse Bay | **10.57** | **18.61** | **18.52** | | **15.19** | 7.28 | 0.08 |
| 6 | Tantabiddi | **13.92** | **17.93** | **21.12** | **18.89** | | **19.38** | 0.14 |
| 7 | Ned's Camp | 5.75 | 5.39 | 7.04 | 6.87 | **10.58** | **11.92** | 0.08 |
| 8 | Pilgramunna | 8.71 | 5.27 | 7.77 | 7.10 | **14.32** | **38.30** | 0.18 |
| 9 | Yardie Creek | 5.55 | 2.42 | 3.88 | 3.56 | 7.31 | | 0.25 |
| 10 | Coral Bay | **10.71** | 0.40 | 0.14 | 0.10 | 0.12 | 0.76 | |
| 11 | Warroora | 6.74 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | **84.46** |

# APPENDIX D – SUMMARY OF RESULTS FROM STATE-WIDE RECREATIONAL FISHING SITE CHOICE STUDY

Raguragavan, Hailu and Burton (2010b) used the National Survey of Recreational Fishing (Henry 2001) obtained from the Department of Fisheries to develop a state-wide random utility model (RUM) of site choice for angler fishing in WA. The model includes 48 fishing destinations across all the major coastal fishing regions in Western Australia that are shown in Table D1. Four of these fishing destinations (Exmouth, Coral Bay, Quobba, and Carnarvon) are in Ningaloo or close to Ningaloo. The data used in the study include: profile of households; choice of fishing sites; fish catch data; data on fish released by anglers; method of fishing; and fish targeted by anglers. Fish have been grouped into the following five broad categories: prize (e.g. barramundi, mackerel), reef (e.g. red emperor, pink snapper), key sport (e.g. cobbler, bonito), table fish (e.g. red snapper, whiting), and butter fish (e.g. garfish, Australian herring blue mackerel).

The study estimates econometric models that predict expected fish catch rates as a function of site and angler characteristics. These are estimated for each fish type category. The econometric results show that fish stock levels, fishing methods (target and bait), and the time spent fishing significantly and positively influence the expected catch rate for all the fish types. Among angler characteristics, age was found to have the expected sign and is a statistically significant influence on catch rates for prize fish and butter fish.

The study uses the catch rate models and other survey data to develop random utility models (RUM) of fishing site choice. Statistically significant influences on site choice include cost of travel to site and expected fish catch. Costal length at the destination also affects site choice. When the fishing site has a longer coast, the site becomes more attractive to anglers. The estimated RUM model is used to calculate part-worths for fish. These part-worth values indicate that prize, reef and sports fish are valued between 2 and 4 times more than table and butter fish. Please see Raguragavan, Hailu and Burton (2010b) for further details on the study and its results

Table D1. Fishing sites and regions identified in state-wide recreational fishing study

| Fish Site Code | Fishing Sites | Fishing Region |
|---|---|---|
| 11 | Cape arid | South Cost |
| 12 | Esperance | |
| 13 | Hopetoun | |
| 14 | Bremer Bay | |
| 15 | Albany | |
| 16 | Denmark | |
| 17 | Walpole | |
| 18 | Windy Harbour | |
| 21 | Augusta | Lower West |
| 22 | Busselton | |
| 23 | Bunbury | |
| 24 | Mandurah | |
| 31 | Warnbro Sound | Perth South |
| 32 | Cockburn Sound | |
| 33 | West of Garden Island | |
| 34 | Fremantle | |
| 35 | Swan/canning River | |
| 36 | Rottnest Island | |
| 41 | Cottesloe | Perth North |
| 42 | Floreat | |
| 43 | Hillarys | |
| 44 | Burns Beach | |
| 45 | Quinns Rock | |
| 46 | Yanchep | |

| Fish Site Code | Fishing Sites | Fishing Region |
|---|---|---|
| 51 | Lancelin | Mid West |
| 52 | Jurien Bay | |
| 53 | Dongara | |
| 54 | Geraldton | |
| 55 | Abrolhos Island | |
| 56 | Port Gregory | |
| 57 | Kalbarri | |
| 61 | Shark Bay Oceanic | Gascoyne (including Ningaloo) |
| 62 | Shark Bay – Western Gulf | |
| 63 | Shark Bay – Eastern Gulf | |
| 64 | Carnarvon | |
| 65 | Quobba | |
| 66 | Coral Bay | |
| 67 | Exmouth | |
| 71 | Onslow | Pilbara |
| 72 | Dampier | |
| 73 | Point Samson | |
| 74 | Port Hedland | |
| 75 | 80 Mile Beach | |
| 81 | Broom | Kimberly |
| 82 | West Kimberly | |
| 83 | North Kimberly | |
| 84 | East Kimberly | |
| 90 | Inland | |

Source: Raguragavan, Hailu and Burton (2010b)

## Contact Us

Phone: 1300 363 400
+61 3 9545 2176

Email: enquiries@csiro.au

Web: www.csiro.au

## Your CSIRO