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Valuing Western Australia's Recreational Fisheries

Jing Zhang, Greg Hertzler and Michael Burton[1]

Abstract

This paper uses a random utility model to valuate shore-based recreational fishing in Western Australia by using the data from the newly finished National Survey of Recreational Fishing (2000/2001)(NSRF). There are a number of findings. 1. Socio-economic characteristics of anglers didn't affect their catch of high quality fish (prize fish, reef fish or key-sport fish) as much as their catch of low quality fish (table fish and butter fish). 2. For a given trip, anglers were willing to pay \$1.63, \$26.03, \$1.03 and \$0.53 for the first prize fish, reef fish, key-sport fish or butter fish caught, respectively. 3. The top four valuable fishing sites in the survey period were Geraldton, Esperance, Albany and Broome, with annual access values of \$6.45 million, \$4.52 million, \$3.47 million and \$2.47 million, respectively. 4. The per trip estimates are of similar magnitude with those of USA studies.

Keywords: Recreational fishing, Random utility model, Non-market valuation

[1]School of Agricultural and Resource Economics, Faculty of Natural and Agricultural Science, The University of Western Australia, Crawley, 35 Stirling Highway, Perth, 6009. Email: jzhang@agric.uwa.edu.au. We wish to thank Neil Sumner, Ben Malseed and Peta Williamson in the Fisheries Department of Western Australia (FWA) for providing access to the NSRF and for insightful suggestions.

1. Introduction

A decade ago, Linder and McLeod (1991) reported that recreational fishing in Western Australia (WA) had an annual economic impact of $389 million and an employment impact of 5,700 full time jobs. However, it was not until 1997 that the Fisheries Department of WA started to collect more reliable information on the catch and effort by the recreational fishers (FWA 2002). The surveys have shown the rapid increase in demand for recreational fishing as well as the impacts on fish stocks. In some fisheries, recreational fishing has been the major reason for the degradation of the fish stocks, at least locally (FWA 2000b). Simultaneously, conflicts between recreational fishing and commercial fishing have also increased and have become a challenge for fisheries management. Recreational fisheries management that has been based largely on a precautionary approach (FWA 2000a) can no longer cope. Unless the benefits of recreational fishing are considered, any allocation policies, no matter how scientifically sound are likely to be rejected by the public and fail. Therefore, more in-depth studies of the recreational fisheries, especially on valuing the recreational fisheries, are needed.

Since early 1980s, recreational fishing has been valued in the USA using the random utility model (RUM), which has become a norm for such valuation studies (Whitehead and Haab 2000). Few similar studies have been conducted in Australia, especially in Western Australia. One important reason is the lack of data. Fisheries managers have focused on the control of the commercial sector and there were very few surveys conducted on recreational fishing. Until now, the only valuation study using RUM is by van Bueren (1999a). It is the first study that successfully estimates marginal values for fish and access values for particular sites in Western Australia. He found that the welfare estimates calculated from the model were of a similar magnitude to those obtained by studies conducted in the USA. He concluded that the RUM was capable of producing reliable estimates and was preferred to the contingent valuation method (CVM) and the travel cost methods (TCM) in valuing recreational fishing.

This study has four objectives. First, since fisheries are managed at the State level, this study uses the State level data drawn from the National Survey of Recreational Fishing (2000/2001) to value

Western Australia's recreational fisheries. Second, it is well known that the welfare estimates from the RUM model are sensitive to the model's specification. This study provides estimates that can be compared with those of similar studies to help validate the RUM model. Third, even though RUM applications in recreational fishing have been extensively reported for the USA, many studies aim to advance the methodology of RUM. The interaction between fish species, recreational fishers and policies is often simplified to facilitate estimations. This paper uses Poisson production functions to predict individuals' expected catch rates of different fish species. In doing so, the catch rates are allowed to vary across individuals, sites, species and time. Finally, despite important econometric advances, researchers have not used all the information contained in the estimated coefficients of the RUM. Gillig *et al.* (2000) pointed out that none of the studies calculated the marginal effects for any of the estimated models. These marginal effects can reveal how the changes in the quality of a site influence the probability of that site being chosen and the probability of its substitutes being chosen. This paper estimates these effects to better predict the behaviour of recreational fishers and help policy-makers create more realistic policies.

This study estimates a complete recreational demand model for the Western Australia's recreational fisheries. In the next section, the modelling framework including RUM is introduced together with some theoretical considerations. Subsequent sections explain the data, and reports the estimations. Finally, welfare estimates are calculated to value recreational fisheries in Western Australia.

2. Modelling framework and some theoretical considerations

The RUM has established its superiority over TCM and CVM in valuing recreational fishing where fishing sites are often substitutes for each other. This is especially true for coastal fisheries. The RUM specification is discussed in McFadden (1974), Bockstael *et al*. (1989), Bockstael *et al*. (1991), Kaoru *et al*. (1995), Herriges and Kling (1999), Morey *et al*. (1993). To build a complete recreational demand model, the multi-stage modelling framework used by van Bueren (1999b) is adopted. As shown in Figure 1, the modelling framework is centred around the RUM to explain the choice among sites, extending forward with a trip demand model to account for trip

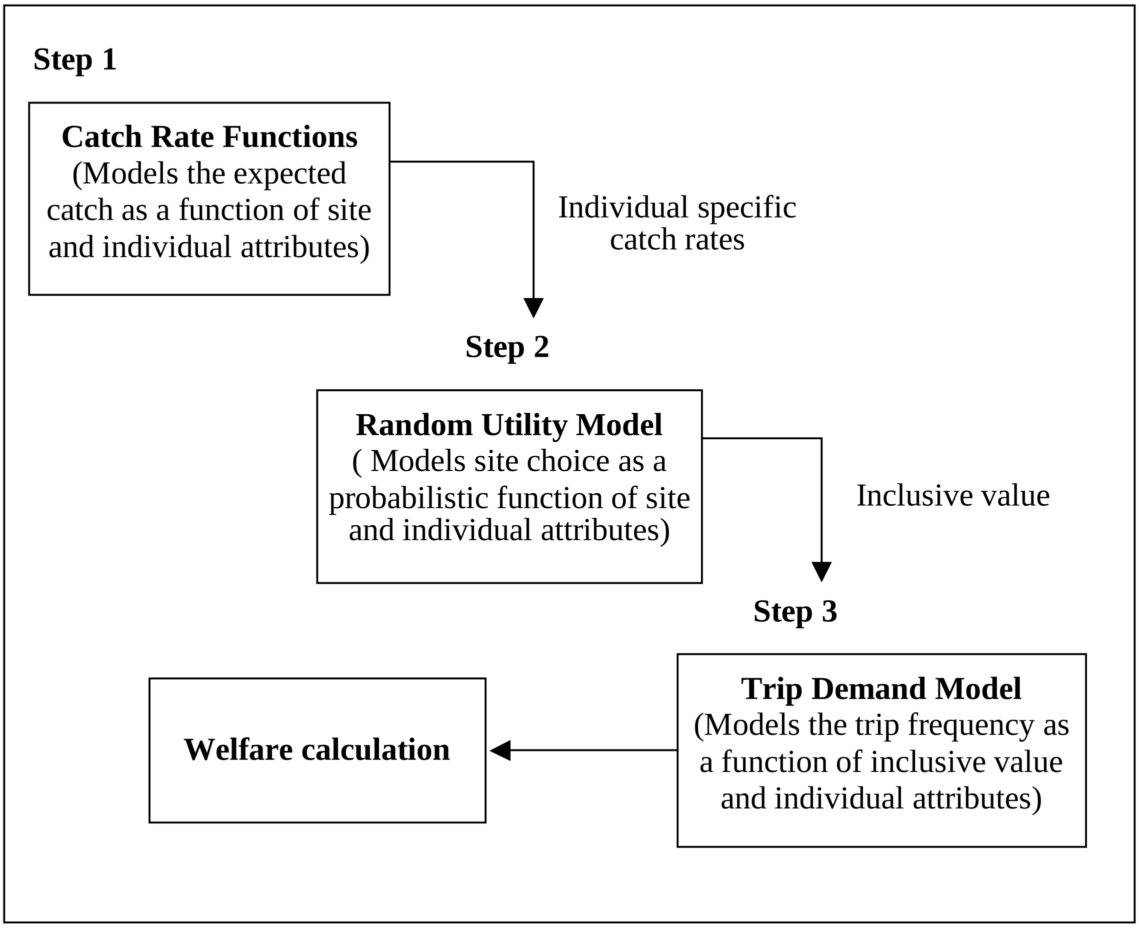

Figure 1 Modelling Framework of Recreational Fisheries in WA
Note: Adapted from van Bueren (1999b). The steps are the order of estimation.

frequency for recreational fishing and backward with catch rate models predicting individual expected catch rates. This framework is basically an extension of the two-stage budget model proposed by Hausman *et al.* (1995). In the first stage, an individual decides the number of trips he or she is going to take in a period, and then, in the second stage, decides how to allocate these trips across alternative sites with different attributes. The two-stage budget model is extended to allow the expected catch rates to vary across individuals to account for preference heterogeneity. This is achieved by modelling the actual number caught as a Poisson production process, or its generalization, a negative binomial production process, of site attributes and individual inputs (McConnell *et al.* 1995).

Using the RUM, the inclusive values that measure an individual's expected maximum utility per trip can be derived. The trip demand model is linked with RUM by regressing the inclusive values against the number of trips in a certain period. The catch rates specific to each fisher are predicted by catch rate models and used as explanatory variables in the RUM. For both catch rate functions and the trip demand model, count data modelling techniques are adopted for the number of fish caught per trip or number of trips demanded in a certain period (McConnell *et al*. 1995, Schuhmann 1998, Haab and McConnell 1996, Feather *et al*. 1995, Creel and Loomis 1990). However, because the number of trips is greater than zero, the Poisson distribution for trip demand is truncated at 1 (van Bueren 1999b).

To implement RUM, the choice set must be first defined. Many researchers found that parameter and welfare estimates are sensitive to the definition of the choice set (for example, Hicks and Strand 2000, Peters *et al.* 1995). There are mainly three approaches to define the choice set: Full Choice Set approach, Distance-Based approach and Familiarity-based approach (Hicks and Strand 2000). Familiarity-based approach proposed by Perter *et al.* (1995) is appealing because it is likely to represent the true choice set. However, collecting the information from anglers will increase the survey cost substantially. It is unrealistic to assume that all sites are relevant to an individual (Hicks and Strand 2000) and the Full Choice Set approach can introduce bias because the choice set is defined constant across individuals.

The Distance-Based model approach is growing in popularity. Parsons and Hauber (1998) found that adding remote fishing sites have little impact on welfare estimates. However, Hicks and Strand (2000) indicated that the Distance-Based approach may give different estimates from the Familiarity-Based approach unless the geographical range of the choice set is defined broadly enough. In Western Australia, every fisher is likely to be aware of fishing sites that extend continuously along the coastline and their familiarity with fishing sites is likely to be distance dependant. Therefore, estimates from the Distance-Based approach are more likely to converge with the true estimates. For this reason, the Distance-Based approach is chosen for this study.

The effectiveness of the RUM in modelling the impact of policy variables depended on variables used to measure the quality of fishing sites (McConnell *et al.*1995). The variables need to be measurable, differ among sites, and be of policy concern. Catch rate is the most important variable that can be found almost in every RUM study. In this study, two types of RUM are specified with different catch rate specifications. One is specified with catch rates of five individual fish types, namely prize fish, reef fish, key-sport fish, table fish and butter fish[2]. Another RUM is specified with catch rates of two aggregated fish groups, high-value fish and low-value fish. High-value is composed of prize fish, reef fish and key-sport fish whilst low-value fish is composed of table and butter fish. It is expected that marginal values of the first three fish types are higher than the remaining two.

Apart from marginal value of fish, access value and the welfare impact of quality changes of sites are also important. Measurements of welfare in the context of RUM are straightforward. Using the indirect utility function V_{ij}, the compensating variation of a change in any explanatory variable can be calculated (Bockstael *et al*. 1991). RUM can be also used to value the addition or elimination of a site (Hanemann 1984, Small and Rosen 1981).

Notwithstanding the same modelling framework, this study differs from van Bueren's in several ways. First of all, this study uses the NSRF database to estimate marginal values of prize fish, reef fish and key-sport fish where share conflicts are prominent. Analysing the differences in estimated parameters of catch rate functions for each fish species is likely to reveal angler preferences and behaviour. Secondly, the seasonal change of fish stock is incorporated into the catch rate functions by allowing the stock to vary across months. Finally, marginal analysis of site attributes helps to better understand the behaviour of recreational anglers.

3. Data and estimations

The data were drawn from the 2000/2001 National Survey of Recreational Fishing (NSRF), which is by far the most comprehensive recreational fishing survey (Henry 2002). The NSRF was conducted mainly in two steps. The first step is to identify fishing households. In Western Australia, 5400 households were phoned and 1848 households were found to be fishing

[2] The five individual fish groups are classified by the Fisheries Department WA in conducting bag and minimum size limits. The prize fish, reef fish and key-sport fish have similar bag limits of 8 and are believed more valuable compared with the others. Table fish has a bag limit of 20 per fisher per day while butter fish has a bag limit of 40.

households. Then, the fishing households who agreed to participate were sent logbooks to record every fishing day between April 2000 and April 2001. The fishing records include the following items:

- Fishing site (indicated in the site maps included in the survey kit);
- Primary target species and secondary target species;
- Fishing method (bait, lure, pot, spear and etc.);
- Party size (number of people in the trip);
- Fishing mode (shore-fishing or boat-fishing);
- Fishing subregion (offshore, inshore, estuary, river or lake);
- Shore type (beach, man-made structure or natural rock);
- Fishing hours;
- Catch details (number kept and released of each species of fish);
- Incurred expenditure by items, (e.g. tackle, bait, ice, food, accommodation, or travel expense if not by car);
- Driving distance.

In the NSRF, a total of 48 fishing sites were identified based on the location of towns, marine parks and geographical features such as bays or sounds in WA. These 48 fishing sites are elemental fishing sites for the choice set of the RUM model. Sixteen fishing sites are more frequently visited (Esperance, Albany, Denmark, Augusta, Busselton, Bunbury, Mandurah, Fremantle, Swan river, Hillary, Lancelin, Geraldton, Point Samson, Port Hedland, Broome and West Kimberly) and are shown in Figure 2. The reason for not aggregating infrequently visited sites is that aggregating results in distortion in the descriptions of site attributes by combining diverse components (Kaoru *et al*. 1995). Some fishing sites, especially in the north of the WA, have long coastlines. For example, fishing sites of the northern region have an average coastal line of 1115 kilometres. This makes aggregation a problem because sites are more likely to be heterogeneous in terms of fish species, climate and geographic aspects. Sites in the south are smaller but more popular. Therefore, aggregation may miss detailed information for each site. For these reasons, sites were not aggregated and infrequently visited sites were not included in the estimations.

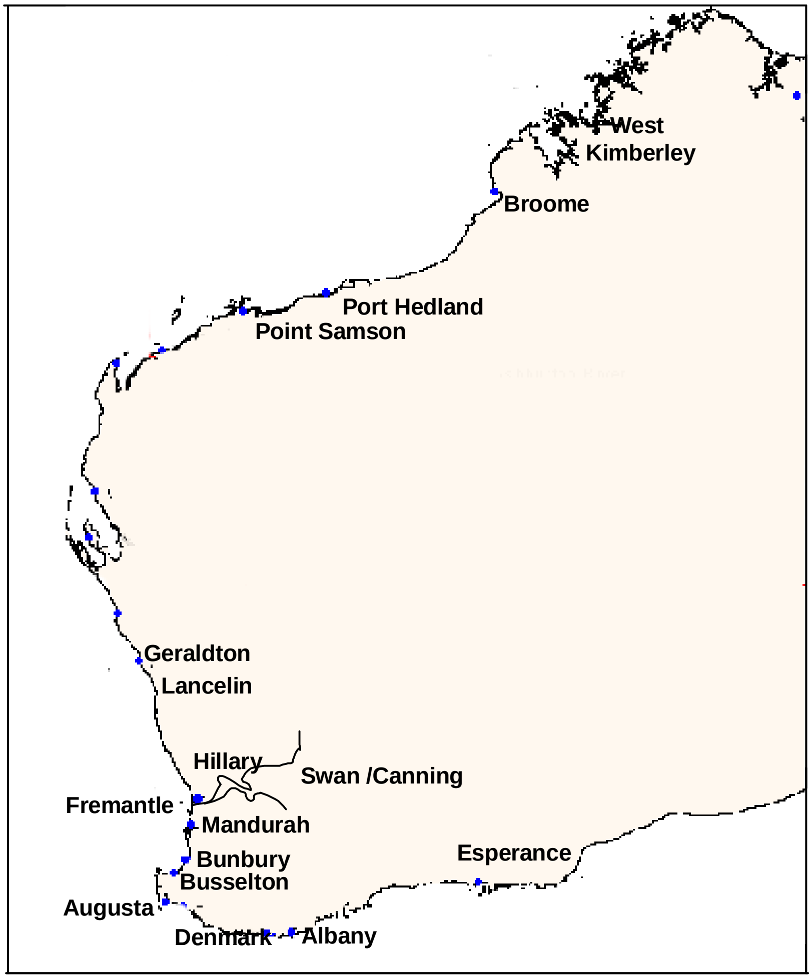

Figure 2 The 16 fishing Sites in the RUM of Western Australia's Recreational Fisheries

As catch rate is a key attribute of a fishing site, it is very important to keep it homogenously defined, and therefore, comparable between sites. Because catch rates between boat-fishing and shore-fishing are quite different, only shore-fishing data are used. Catch rates between line-fishing and non-line-fishing are also quite different, as are the catch rates for finfish and non-finfish. For simplicity, only shore-based line-fishing day-trip data are used. This includes 2944 fishing trips that were made by 674 individuals.

Estimation of Catch rate functions

The number caught and kept per trip, Q_{ijk} of angler *i* fishing at site *j* catching fish type *k*, is drawn from a Poisson distribution. It was assumed that the catch rate is a function of site and angler attributes. However, the interactions between sites, angler attributes and fish types are not known. Therefore, catch rate models were first specified to include all variables listed in Table 1. The mean of the expected catch rate of fish type *k* is specified as:

$\lambda_k = \exp(\beta_0+\beta_1 Stock_{jkt} +\beta_2 Lnhour_i+\beta_3 Party_i +\beta_4 Target_{ik} +\beta_5 Bait_{ik}+\beta_6 Member_i +\beta_7 Age_i +\beta_8 Retire_i +\beta_9 Employ_i +\beta_{10} Experience_i +\beta_{11} Familarity_{ij} +\beta_{12} Estuary_i +\beta_{13} Inshore_i+\beta_{14} Beach_i +\beta_{15} Manmade_i)$

The models were then refined by removing variables that were not statistically significant at 5% level [3].

The preferred catch rate models for prize fish, reef fish, key-sport fish, table fish and butter fish, and the aggregated fish groups, high-value fish and low-value fish, are reported in Table 2. Explanatory variables are different for each catch rate function. Only three variables *Stock*, *Lnhour* and *Target* are found in all catch rate functions. These all have positive signs and are statistically significant. Other site and individual attributes such as anglers' fishing experience, familiarity of sites, fishing method (with bait or not), type of site (beach or man-made structure), fishing subregion (estuary or shore), party size, age and employment status influence the catch rate of some fish types or fish groups but not all.

[3] Nested tests (Log-likelihood ratio test) between unrestricted models (before removing a variable) and restricted models (after removal of a variable) were conducted for every removal.

Table 1 Definition of Variables in Catch Rate Functions

Variables	Definition
Q_{ijk}	actual number caught and kept per trip of angler *i* at site *j* of fish type *k*;
$Stock_{jkt}$	mean catch rate of fish type *k* at site *j* in month *t* of the survey period;
$Lnhour_i$	logarithm of the number of hours angler *i* spent fishing;
$Party_i$	total number of persons included in the fishing trip with angler *i* ;
$Target_{ik}$	= 1 if angler *i* targets fish type *k*, and = 0 otherwise;
$Bait_{ik}$	= 1 if angler *i* uses bait to catch fish type *k*, and = 0 otherwise;
$Member_i$	= 1 if angler *i* is a member of a fishing club, and = 0 otherwise;
Age_i	age of angler *i* ;
$Retire_i$	= 1 if angler *i* is retired, and = 0 otherwise;
$Employ_i$	= 1 if angler *i* is employed, and = 0 otherwise;
$Experience_i$	category level of the frequency of fishing trips taken by angler *i* over the previous 12 months, ranging from 0 to 5;
$Familarity_{ij}$	= 1 if angler *i* has been to the fishing site *j* in the survey period, and = 0 otherwise;
$Inshore_i$	= 1 if angler *i* goes fishing inshore, and = 0 otherwise;
$Estuary_i$	= 1 if angler *i* goes fishing at an estuary, and = 0 otherwise;
$Beach_i$	= 1 if angler *i* fishes from the beach, and = 0 otherwise;
$Manmade_i$	= 1 if angler *i* fishes from a man-made structure, and = 0 otherwise.

Note: *k* =1 to 7; 1=prize fish, 2=reef fish, 3=sport fish, 4=table fish, 5=butter fish, 6=high-value fish, 7=low-value fish.

Looking first at aggregated fish groups, an angler's actual catch per trip of high-value fish depends on the site attributes (*Stock, Manmade, Estuary, Inshore*), fishing efforts (*Lnhour, Party*) and fishing method (*Targe, Bait*). Only one socio-economic variable is significant (*Age*). An angler's catch of low-value fish also depends on an additional site attribute (*Beach*) and more social-economic variables (*Retire, Experience, Familiarity*). The chance of catching a high value fish is much smaller than for a low-value fish and, therefore, the catch is more random and depends more on site attributes rather than angler attributes.

Table 2 Coefficient Estimations of Catch Rate Functions for Different Fish Types

Variables	Individual fish types					Aggregated fish groups	
	Prize fish	Reef fish	Key-sport fish	Table fish	Butter fish	High-value fish	Low-value fish
Constant	-1.60	-6.21	-3.13	-5.04	-5.48	-0.74	-4.63
	(-4.62)	(-16.53)	(-12.9)	(-8.87)	(-11.24)	(-2.95)	(-12.6)
$Stock_{jkt}$	1.95	10.95	0.94	1.23	0.26	0.76	0.24
	(13.21)	(11.09)	(13.17)	(12.11)	(17.48)	(15.72)	(18.71)
$Lnhour_i$	0.63	1.07	0.67	0.79	0.81	0.53	0.79
	(6.0)	(4.26)	(6.34)	(6.64)	(11.16)	(7.21)	(12.1)
$Party_i$	0.30	-	-	0.13	0.09	0.13	0.11
	(4.85)			(2.37)	(2.34)	(3.35)	(3.17)
$Target_{ik}$	1.01	1.33	1.93	0.94	0.9	0.73	0.73
	(6.03)	(2.05)	(15.25)	(5.80)	(11.48)	(9.19)	(10.4)
$Bait_{ik}$	-1.09	-	-	1.31	0.46	-0.63	0.48
	(-5.21)			(3.97)	(2.95)	(-4.02)	(3.38)
$Member_i$	1.23	-	-1.01	-	-	-	-
	(2.97)		(-2.84)				
Age_i	-	-	0.007	-	0.02	0.21	0.02
			(5.31)		(4.68)	(2.3)	(5.29)
$Retire_i$	-	-	-	-	-0.58	-	-0.6
					(-3.06)		(-3.47)
$Employ_i$	-	-	-	-	-0.28	-	-0.26
					(-2.31)		(-2.4)
$Experience_i$	-	-	-	-0.09	0.09	-	0.08
				(-2.52)	(3.66)		(3.62)
$Familiarity_i$	-	-	-	-	0.21	-	0.15
					(2.53)		(2.0)
$Inshore_i$	-0.92	-	-0.25	1.44	2.78	-0.91	2.17
	(-3.5)		(-4.43)	(3.34)	(6.36)	(-4.67)	(7.05)
$Estuary_i$	-1.66	-	-	1.08	2.16	-0.62	1.72
	(-5.19)			(2.39)	(4.85)	(-2.87)	(5.44)
$Beach_i$	-	-	-	-	0.36	-	0.3
					(4.19)		(3.8)
$Manmade_i$	-	-	-	-	0.52	3.06	0.41
					(5.32)	(15.45)	(4.69)
Alpha	5.05	19.16	3.75	5.91	3.01	3.06	2.56
	(9.22)	(1.74)	(9.69)	(13.03)	(24.13)	(15.45)	(25.44)
L likelihood	-1693	-143	-2052	-2183	-5689	-3338	-6278
Pseudo R^2	0.51	0.30	0.57	0.53	0.66	0.47	0.65
Observations	2944	2944	2944	2944	2944	2944	2944

Notes: Values in brackets are asymptotic t ratios.

Over-dispersion with significant Alpha is found in all catch rate functions except for the reef fish model. For over-dispersion, a negative binomial model is used rather than a Poisson regression model.

Pseudo R^2 is calculated as: $1-[\log(L_u)/\log(L_r)]$, where L_u is the maximum value of the likelihood functions of the unrestricted model, L_r is the likelihood of the restricted model.

Both high-value and low-value fish models include *Stock*, *Lnhour*, *Party* and *Target*, all with the positive signs. The marginal effects of fishing efforts are shown in Table 3. *Lnhour* has a marginal effect[4] of 4.35 for low-value fish but a much lower effect of 0.65 for high-value fish. Although *Party* has insignificant marginal effects in both models, the magnitude for low-value fish is 3.6 times that of high-value fish. Overall, the catch of low-value fish is more closely related to the total fishing efforts. Therefore, defining a catch rate variable as a total catch per trip is more meaningful than catch per person per hour per trip because it can reveal the relationship between catch and fishing efforts for different fish types or fish groups.

Table 3 Marginal Effects of *Lnhour*, *Party* on the Expected Catch of High-value and Low-value fish

Variables	High-value fish	Low-value fish
Lnhour	0.65 (2.15)*	4.35 (3.09)**
Party	0.16 (1.41)	0.58 (1.60)

Note: values in brackets are asymptotic t ratios. * denotes 5% significance level, ** denotes 1 % significance level.

As expected, *Estuary, Inshore* and *Bait* are found to have opposite signs in the two models. More low-value fish and less high-value fish can be caught in estuaries and inshore areas. Anglers who fish using bait catch more low-value fish. Those who fish using lures catch more high-value fish. Contrary to expectations, *Experience* doesn't enter into the catch rate function of the high-value fish. This may be due to the specification of *Experience* as the trip frequency in the previous period, which may not reflect the angler's experience or skill. The number of years an angler has been fishing may be a more suitable measure of experience. However, this information was not available.

Similar results are found for the five individual fish types. Fewer explanatory variables are included in prize fish, reef fish and key-sport fish catch rate functions than in the table fish and

[4] The marginal effects are computed at the means of the variables.

butter fish functions. The catch rate function of reef fish includes only *Stock*, *Lnhour* and *Target* and, therefore, has the lowest pseudo R^2 of 30%. This model is also believed to have econometric problems, because the sample mean of the monthly stock of reef fish is not independent from an angler's individual catch. Very few trips caught reef fish in a month so that successful trips had a large impact on the sample mean of the stock. Historical mean catch rate would be a better regressor. However, that data is not available.

As can be seen, the estimated catch rate equations provide not only predicted catch rates as instrumental variables for the next step modelling, but also reveal the different interactions between anglers and different fish types and groups. With these results, fisheries managers may be able to design different policies for different anglers or fish species.

Estimation of RUM

Two RUMs are estimated. One included catch rates of five fish types: prize fish, reef fish, key-sport fish, table fish and butter fish (called the five-fish RUM hereafter), and the other included catch rates of two fish groups, high-value fish and low-value fish (called the two-fish RUM hereafter). Although the five-fish RUM would provide more information, the suspected specification problems in the prediction of catch rates of reef fish may influence the validity of the RUM estimation. Therefore, a model with two aggregated fish groups is also estimated to help check the validity of the estimation results.

In the five- fish RUM, the conditional indirect utility function is specified as

$$\begin{aligned} \mathrm{V}_{\mathrm{ij}} &= \beta_0 \mathrm{Cost}_{\mathrm{ij}} + \beta_1 CR\_prize_{ij} + \beta_2 CR\_reef_{ij} + \beta_3 CR\_keysport_{ij} \\ &\quad + \beta_4 CR\_table_{ij} + \beta_5 CR\_butter_{ij} + \beta_6 Diversity_j + \beta_7 Wind_{jk} \end{aligned}$$

Similarly in the two-fish RUM, the indirect utility function is specified as

$$V_{ij} = \gamma_0 Cost_{ij} + \gamma_1 CR\_highvalue_{ij} + \gamma_2 CR\_lowvalue_{ij} + \gamma_3 Diversity_j + \gamma_4 Wind_{jk}$$

The trip costs of fishing trips were the sum of incurred driving cost and on site costs. Driving costs were calculated as 14.4 cents per kilometre (Nature Conservation Council 2002)[5] for a

[5] 14.4 cents is the average operational cost of a car per kilometre, including fuel costs, maintenance costs and depreciation costs but not parking fees, fines and tolls.

return trip. Driving distances were obtained directly from the web page Whereis™ Online (2002) by entering the departure town or city where an angler lived and the destination town or city at or close to each site. For those sites that were chosen by anglers, actual driving distances were used. The opportunity cost of time is not taken into account for two reasons. First, there is a wide disparity in the literature for how wage rates are used in the calculation. Second, the opportunity cost for recreation may be unrelated to wages and may even be zero. If the opportunity costs are positive, the welfare estimates would be a lower bound. In addition to costs, a variable *Wind* is used to indicate climate (Commonwealth Bureau of Metrology 2002). Surveys often reveal that the diversity and size of fish caught are also important for a successful fishing trip. Therefore, the variable *Diversity* is included. Although there is no data on the size of fish, the catch rates of different fish types might be able to capture part of this effect, as more sizable fish are included in the high-value fish category.

Table 4 Definition of Variables in the RUMs

Variables	Definition
$Cost_{ij}$	fuel cost of a returned trip from home to site *j* by angler *i* plus on-site cost that are constant across sites;
CR_prize_{ij}	angler *i's* predicted expected total catch per trip of prize fish at site *j* ;
CR_reef_{ij}	angler *i's* predicted expected total catch per trip of reef fish at site *j* ;
$CR\_keysport_{ij}$	angler *i's* predicted expected total catch per trip of key-sport fish at site *j* ;
CR_table_{ij}	angler *i's* predicted expected total catch per trip of table fish at site *j* ;
CR_butter_{ij}	angler *i's* predicted expected total catch per trip of butter and other fish at site *j* ;
$CR\_highvalue_{ij}$	angler *i's* predicted expected total catch per trip of prize fish, reef fish and key-sport fish at site *j* ;
$CR\_lowvalue_{ij}$	angler *i's* predicted expected total catch per trip of table fish, butter fish and other fish at site *j* ;
$Diversity_j$	sample mean number of species of fish caught at site *j* across the survey year;
$Wind_{jk}$	historical monthly mean 9 am wind speed (km/h) at site *j* in the month *k*.

An angler's choice set is defined using the Distance-Based approach. Sites that are out of reach for a daily trip are eliminated. A maximum return road distance of 1,200 kilometres was chosen in order to include the most avid anglers and also to ensure that at least two fishing sites will be included in each choice set. So, the minimum number of sites considered by an angler are 2 and the maximum number are 11.

Results in Table 5 show that both the five-fish RUM and the two-fish RUM have excellent goodness of fit. The pseudo R^2 of the two models are 0.85 and 0.86, respectively. In fact, these are surprisingly high when a pseudo R^2 of 0.2 is said to be approximately equivalent to an R^2 of 0.5 in a linear regression model (Veall and Zimmermann 1996). This can be explained by the discrete geographic distribution of fishing sites and population centres in the Western Australia. Most Western Australians live in the population centres, mainly towns or cities, within 50 km of the coastline (ABS 1996). Fishing sites were defined mainly at the town level, as indicated from the names of the fishing sites, although some sites were at the regional level such as West Kimberley. Therefore, anglers tended to choose fishing sites in their home districts because recreational fishing is found to be mainly a proximity activity (Jantzen 1998). This is especially true for day trip makers. Greene *et al*. (1997) also obtained a pseudo R^2 of 0.77 for the fishing sites at a county level, which is similar to the town level in this study.

The success rate of prediction of choice is another important measure to reflect the goodness of fit. Using the McFadden prediction success index σ (McFadden *et al.* 1977), the five-fish RUM and two-fish RUM predict 71% and 72% of choices respectively. In a similar study conducted by van Bueren (1999a), only 15% choices were predicted correctly.

Table 5 Coefficient Estimations of the RUMs

Variables	Five-fish model	Two-fish model
Cost	-0.13 (-30.91)**	-0.13 (-30.62)**
CR_prize	0.11 (3.49)**	-
CR_reef	2.77 (2.39) *	-
CR_keysport	0.11 (2.29) *	-
CR_table	0.002 (0.30)	-
CR_butter	0.05 (7.88) **	-
CR_highvalue	-	0.21 (4.88) **
CR_lowvalue	-	0.12 (9.91) **
Diversity	1.83 (11.07) **	1.77 (10.72) **
Wind	-0.15 (-8.42) **	-0.16 (-8.94) **
L likelihood	-1195	-1166
Pseudo R^2	0.85	0.86
σ	0.71	0.72
Observations	2944	2944

Note: Values on brackets are asymptotic t ratios.

* denotes significant level at 5%. ** denotes significant level at 1%.

σ is the McFadden prediction success index, calculated as: $\sigma = \sum \left[\frac{N_{ii}}{N_{..}} - \left(\frac{N_{.i}}{N_{..}} \right)^2 \right]$, where N_{ii} refers to the number of correct predictions for alternative *i;* $N_{..}$ refers to the total number of observation; $N_{.i}$ refers to the total predicted number of choice *i*.

All estimated coefficients of variables in the two models are statistically significant at the 1% or 5% level, except *CR_table*, and all have the expected signs. The estimated parameters in the two models are quite similar. This shows the five-fish RUM to be reliable. It is a crucial finding that the estimated coefficients of *Cost* are the same because they will be used as scale factors for later welfare analysis.

In the five-fish RUM, the coefficients of the prize fish, reef fish and key-sport fish are greater than those of less sought-after table and butter fish as expected. Similarly, in the two-fish RUM, the coefficient of high-value fish is greater than that of low-value fish. This shows that the models are able to reflect the angler's preference toward the fish species and again validates the five-fish RUM.

While there is no expected preference order among prize fish, reef fish and key-sport fish, they are expected to be preferred to table fish, and table fish is expected to be preferred to butter fish. Prize fish, reef fish and key-sport fish have higher coefficients than table and butter fish. However, the coefficient for table fish is not statistically significantly different from zero. The coefficient of low-value fish is significantly different from zero and lower than that of high-value fish also indicating that high-value fish are preferred. In addition to the catch rates of different fish groups, diversity of fish is found to be important in selecting a fishing site. Both the number and the variety of fish caught are important to a successful fishing experience.

Although both RUMs are found to have excellent goodness of fit, the two-fish RUM fits better because all estimated coefficients are statistically significant from zero at 1%. However, the five-fish RUM has significant coefficients for prize fish, reef fish and key-sport fish, which are important in making policies for the recreational fisheries. Consequently, results from two-fish RUM fish are used in calculating aggregated welfare estimates, and the results from five-fish RUM are used when more detailed information about high valued fish is needed.

Marginal effects of site attributes

One of the strengths of the RUM is its capacity to explain how marginal changes of a site attribute influence an individual's choice. The marginal effect of site attribute *m* on site *i* is the partial derivatives of the probability P_i. Unlike a linear regression model, in which marginal effects are the estimated coefficients and therefore constant, the marginal effect in RUM is a function of P_i. According to Stynes and Peterson (1984),

$$\frac{\partial P_i}{\partial m_i} = b_{m_i} P_i (1 - P_i)$$

where b_{m_i} is the coefficient of an explanatory variable. A marginal change of a site attribute is equivalent to a one-dollar change in the total cost or a one unit change in other fishing quality attributes (catch rates, wind and diversity). Similarly, the marginal effect for site attribute *m* of site *i* on the probability of site *j* being chosen is defined as:

$$\frac{\partial P_j}{\partial m_i} = b_{m_i} P_j (1 - P_j)$$

The marginal effects of m_i on P_i and P_j are the average changes in the probability of site *i* or *j* being chosen over all observations.

Marginal effects of all explanatory variables for 16 fishing sites were calculated but due to the space limitations only those for Fremantle are reported. Table 6 and 7 report the average changes in probability of Fremantle being chosen due to a one unit change of a fishing quality attribute for the five-fish RUM and two-fish RUM, separately. Average changes over 0.1% in the probability of other sites being chosen are also reported.

Table 8 shows the fishing quality attributes at Fremantle: mean catch of different fish types, average cost of fishing, average diversity of species caught and average wind speed. Because the mean catch of reef fish is zero, it is expected that an additional reef fish would greatly increase the probability of Fremantle being visited. Similarly, because the butter fish are abundant, it is also expected that an additional butter fish won't change anglers behaviour very much. As Table 6 and 7 indicate, the changes in the probability of Fremantle being chosen are inversely related to the abundance of a fish type. In the five-fish RUM, changes due to reef fish rank the first, followed by prize fish, key-sport fish and butter fish. In the two-fish RUM, changes due to high-value fish rank ahead of low-value fish. Changes in the catch rate of less abundant fish induce greater behavioural responses from recreational anglers.

Table 6 The Average Changes in Probability of Fishing Sites Being Chosen Due to Marginal Changes of Fishing Quality at Fremantle Using the 'Five-Fish RUM'

Fishing quality attributes at Fremantle	Change in probability of Fremantle being chosen	Other sites	Changes in probability of other sites being chosen
An additional reef fish	11.21%	Swan River Mandurah Hillary	-5.39% -2.81% -2.76%
An additional species of fish	7.42%	Swan River Mandurah Hillary	-3.57% -1.86% -1.83%
One meter wind speed increase	-0.60%	Swan River Mandurah Hillary	0.29% 0.15% 0.15%
One dollar increase of total cost	-0.54%	Swan River Mandurah Hillary	0.26% 0.14% 0.13%
An additional prize fish	0.46%	Swan River Mandurah Hillary	-0.22% -0.12% -0.11%
An additional key-sport fish	0.43%	Swan River Mandurah Hillary	-0.21% -0.11% -0.11%
An additional butter fish	0.18%	Swan River Mandurah Hillary	-0.05% -0.09% -0.05%
An additional table fish	not significant		

Table 7 The Average Changes in Probability of Fishing Sites Being Chosen Due to Marginal Changes of Fishing Quality at Fremantle Using the 'Two-Fish RUM'

Fishing quality attributes at Fremantle	Change in probability of Fremantle being chosen	Other sites	Changes in probability of other sites being chosen
An additional species of fish	6.97%	Swan River Mandurah Hillary	-3.26% -1.89% -1.66%
An additional highvalue fish	0.82%	Swan River Mandurah Hillary	-0.38% -0.22% -0.19%
One meter wind speed increase	-0.64%	Swan River Mandurah Hillary	0.30% 0.17% 0.15%
One dollar increase of total cost	-0.53%	Swan River Mandurah Hillary	0.25% 0.14% 0.13%
An additional low-value fish	0.46%	Swan River Mandurah Hillary	-0.22% -0.12% -0.11%

As shown in Table 6, if the total catch of reef fish increased by 1 at Fremantle, the probability of visiting Fremantle would increase by 11% while the probability of visiting Swan River, Mandurah and Hillary would decrease by 5.4%, 2.8% and 2.8% respectively. As a result, 17% of trips would be allocated to Fremantle after this change compared to 6% before the change. Fewer trips would be allocated to Swan River, Mandurah and Hillary. Also in Table 6, an additional species of fish would increase the probability of visiting Fremantle by 7%. Table 7 shows the similar probability changes induced by an additional species of fish, wind speed, and cost. Changes in the catch rate of high-value fish introduce greater behavioural responses compared to those of low-value fish.

Table 8 Fishing Quality at Fremantle

Site attributes	Mean Values
Catch rate variables (catch/trip)	
Prize fish	0.06
Reef fish	0.00
Key-sport fish	0.65
Table fish	0.58
Butter fish	6.59
High-value fish	0.71
Low-value fish	7.16
Cost ($/trip)	10.84
Diversity (species caught/trip)	1.81
Wind (metres/hour)	18.03

Although not reported in a table, similar results are found for other fishing sites. The marginal effects ranked in the order of reef fish, an additional species of fish, wind speed, cost and an additional prize fish. The two exceptions are Busselton and Lancelin where the largest effect is an additional species of fish. However, the changes in probability of some fishing sites are less than 1% for all proposed changes in fishing qualities. These sites are Esperance, Lancelin, Geraldton, Point Samson, Port Hedland, Broome and West Kimberley. These are geographically isolated sites with no close substitutes.

Trip demand models

As mentioned, the actual number of trips T_i in the survey period is drawn from a truncated Poisson distribution with parameter λ_i, which is the expected number of trips in the period,

$$\lambda_i = Exp(\beta_0 + \beta_1 IV_i + \beta_2 Experience_i + \beta_3 Retire_i + \beta_4 Education0_i + \beta_5 Educationh_i + \beta_6 Employ_i + \beta_7 Member_i + \beta_8 Age).$$

Table 9 Definition of Variables in the Trip Demand Models

Variables	Definition
T_i	number of fishing trips taken by angler *i* over the survey period;
IV_i	angler *i*'s mean inclusive value reported by RUM, representing the expected average utility per trip;
$Experience_i$	category level of trip frequency of angler *i* over the previous 12 months of the survey, ranging from 1 to 5;
$Retire_i$	= 1 if angler *i* is retired, and = 0 otherwise;
$Education0_i$	= 1 if the level of education of angler *i* is missing, and = 0 otherwise;
$Educationh_i$	= 1 the level of education of angler *i* is above Year 12, = 0 otherwise;
$Employ_i$	= 1 if angler *i* is employed, and = 0 otherwise;
$Member_i$	= 1 if angler *i* is a member of a fishing club, and = 0 otherwise;
Age_i	age of angler *i*.

Table 10 shows the estimated result of two trip demand models using the inclusive values (IV) from the fish-fish RUM and the two-fish RUM.

There is little difference in parameter estimates between the two demand models, which indicates the estimated IVs are consistent and reliable. Most estimated coefficients are found to be statistically significant from zero at the 1% or 5% level. In particular, both IVs are found to have positive effect on the number of fishing trips and are significant at the 1% level. The higher is angler's utility derived from a fishing trip, the more trips are taken.

Experience, Retire and *Employ* have positive signs while *Educationh* and *Member* have negative signs. People who went fishing frequently in the previous period are more likely to go fishing this period. This accords with the habit formation process in the demand for recreational fishing. Retired people went fishing on average more frequently as did employed people. However, an angler with an educational level higher than Year 12 took fewer trips. This is similar to a result of van Bueren (1999a)'s study in which he found employed people fished more frequently but most of them were low-income earners. If education level is positively linked with income, the negative effect of education on trip frequency is similar to an income effect on fishing.

Table 10 Coefficient Estimates of Five-Fish and Two-Fish Trip Demand Models

Variables	Five-fish trip demand		Two-fish trip demand	
Constant	-1.19	(-3.19)**	-1.13	(-3.14)**
IV	0.17	(4.59)**	0.17	(4.93)**
Experience	0.34	(8.35)**	0.34	(8.51)**
Retire	1.36	(4.72)**	1.26	(4.47)**
Education0	-0.10	(-0.41)	-0.12	(-0.48)
Educationh	-0.41	(-2.64)**	-0.40	(-2.63)**
Employ	0.53	(2.38)**	0.48	(2.20)*
Member	-1.04	(-1.95)*	-0.96	(-1.73)
Alpha	4.78	(2.72)**	4.58	(2.82)**
L likelihood	-1374		-1372	
Pseudo R^2	0.58		0.58	
Observations	674		674	

Note: Values in brackets are asymptotic t-ratios.

** denotes 1% significance level, and * denotes 5% significance level.

The negative binomial model is used because of the presence of over-dispersion of the dependent variable T_i.

It is expected that *Education0* would be not significant, but it is kept in the models to avoid leaving out data that are linked with the RUMs.

Member is expected to have a positive effect on trip demand, but, in fact, is negative. The dependant variable in the trip demand models is the number of shore-fishing trips. It is conjectured that a fishing club member is more likely to choose boat-fishing rather than shore-fishing. Looking at the data, the average shore-fishing days for non-members was more than twice those of fishing members.

4. Welfare analysis

Access value

Table 11 reports the per trip access values for each fishing site as derived from the five-fish RUM and the two-fish RUM. There is little difference between results from the two models. The more isolated is a fishing site, the higher is its access value. Closing a fishing site with fewer substitutes would incur greater welfare loss. The access values for Geraldton and Esperance were the highest, about $12 and $10 per trip respectively. This is partly because these sites are far from other sites and partly because these are the main fishing sites for inland anglers. Fishing sites that are geographically close to each other have low access values. Weighting the per trip access values by the number of trips to each site gives a weighted average access value per trip of $3.79 using the two-fish RUM. According to the NSRF, each recreational fisher averaged 9 fishing days during the survey period. Therefore, the annual access value for each fisher is about $24[6]. This value is in the middle range for multi-species fisheries found by Freeman (1993) and support van Bueren's (1999a) conclusion of welfare estimates similar to those in the USA.

Marginal value of fish

The marginal values of fish types and groups are derived from the five-fish RUM and the two-fish RUM. Table 12 shows that anglers were willing to pay $26.03 to for an additional reef fish in a trip. The marginal value of reef fish is much higher than that of prize fish or key-sport fish. Perhaps this is because reef fish are rarely caught. The disparity between the marginal value for prize fish and key-sport fish is much less, with marginal values of $1.63 and $1.03 respectively, about three-fold and two-fold of the marginal value of butter fish. The catch rate of table fish is not significant in the five-fish RUM, and, the estimated marginal value of table fish is not reliable.

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[6] According to Sumner and Williamson (1999), the average fishing days per fisher is 18 days, which would double the access value.

Table 11 Per Trip Access Values of Fishing Sites

Sites	Access value ($/trip)	
	Five-fish RUM	Two-fish RUM
Geraldton	11.52	11.60
Esperance	10.01	10.11
Broome	5.52	5.56
Albany	3.63	3.54
Port Hedland	2.48	2.60
Point Samson	2.15	1.91
Busselton	1.57	1.59
West Kimberley	1.49	1.47
Mandurah	1.42	1.57
Swan/Canning River	0.67	0.63
Fremantle	0.66	0.70
Bunbury	0.47	0.48
Lancelin	0.43	0.51
Hillary	0.40	0.38
Denmark	0.38	0.43
Augusta	0.15	0.16

Table 12 Per Trip WTP for a 100% Increase in Catch Rate of Each Fish Type

Fish types	Sample mean catch	Five-fish RUM		Two-fish RUM	
	No. of fish /trip	$/trip	$/fish	$/trip	$/fish
Prize fish	0.4	0.65	1.63	-	-
Reef fish	0.01	0.26	26.03	-	-
Key-sport fish	0.65	0.67	1.03	-	-
Table fish	0.61	0.03†	0.06†	-	-
Butter fish	3.99	2.1	0.53	-	-
High-value fish	1.06	-	-	1.85	1.75
Low-value fish	4.60	-	-	5.47	1.19

†denotes that the result is not statistically significant.

While the results are not strictly comparable with other studies due to different definitions of fish types and groups, low-value fish[7] have a similar definition in van Bueren's (1999a) study. He estimated an average WTP for a 100% increase in catch rates for low-value fish of $1.38 per fish, which is close to $1.19 per fish in this study. The value per fish per trip estimated in this study and in van Bueren's study are in the lower range of estimates in USA. Freeman (1993) summarised three RUM studies that found an increase of US$8.2 to $19.6 per fish per trip, and another study that found a US$60 increase per trip from a 100% increase in catch rates. The two lowest estimates in the studies reviewed were US$0.25 to $1.87 increase per trip from 20%-25% increase in catch rates.

WTP per trip is aggregated to obtain total benefits for a 100% increase in catch rate. Remember that an improvement of fishing quality will not only increase the per trip benefit but also the number of trips demanded, Table 13 shows the aggregated WTP for the sample and population,

[7] In Van Beuren's study, only catch rates of table and butter fish are specified in the RUM. Therefore, his "all fish types" is similar to the " low-value fish" in this study. The mean catch per day for all fish types was 5.9 in his study which was close to 4.6 low-value fish in this study.

taking into account the increased trip demand. The aggregation for the population is based on a total of 10 million fishing days annually in WA (Baharthah and Sumner 1999) with 53.5% of those days spent shore-fishing (calculated from the NSRF data).

Table 13 Aggregated WTP for a 100% Increase in Catch Rates of Each Fish Type

Fish types	Mean % change in trip frequency	Per trip WTP ($)	Aggregated WTP for the sample ($)	Aggregated WTP for population ($ million)
Prize fish	3.37%	0.65	1,978	3.59
Reef fish	1.04%	0.26	773	1.41
Key-sport fish	1.31%	0.67	1,998	3.63
Table fish	0.04%	0.03	100	0.18
Butter fish	5.71%	2.10	6,535	11.88
High value fish	4.13%	1.85	5,671	10.31
Low value fish	15.00%	5.47	18,526	33.65

For the sample, the aggregated benefit derived from the 100% increase in catch rates of low-value fish is about $18,500, which is more than three times that of high-value fish. For the population, the aggregated benefit is about $34 million.

5. Conclusions

This paper estimated recreational demand model of Western Australia’s recreational fisheries using a three-stage modelling framework. Models in all three stages fit the data well, particularly the RUMs, which have low predictive power in most other studies. Therefore, the parameter estimates are believed to be reliable. Anglers were found to be willing to pay $1.63, $26.03, $1.03 and $0.53 for an additional prize fish, reef fish, key-sport fish or butter fish per trip, respectively. The top four valuable fishing sites in the survey period were Geraldton, Esperance, Albany and Broome, with annual aggregated access values of $6.45 million, $4.52 million, $3.47 million and $2.47 million respectively. As the models didn’t take into account the opportunity cost of time, all the welfare estimates are a lower bound. The results are of similar magnitude with those in van Bueren's study and with studies in the USA.

Smith (1996) said, 'what is really at issue is not whether economic analysis solely determines decisions, but whether it informs the process so that the parties involved recognise the opportunity costs of alternative decisions in seeking a resolution.' This paper estimated the marginal values of prize fish, reef fish, key-sport fish, and therefore, informed allocation decisions in these fisheries can be made. This is important to the sustainability of fish stocks in Western Australia because there are increasing share conflicts between recreational and commercial sector in these fisheries. The estimated welfare impacts on recreational anglers can help fisheries managers choose between alternative policies. The heterogeneous preferences and behaviour revealed in this study also show policy impacts are likely to be different for different anglers.

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