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Economic valuation of recreational fishing in Western Australia: statewide random utility modelling of fishing site choice behaviour*

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Allocation of fish resources is a controversial subject. This is partly because of our limited understanding of the values of fishing opportunities. This study investigates fishing site choices in Western Australia using national survey data covering eight major fishing regions and forty-eight fishing sites. We estimate a random utility model (RUM) of site choice with a supporting negative binomial model of angler-specific expected catch rates. Value estimates for fish types, fishing site attribute changes and access values are presented and discussed.

Key words: fisheries management, marine environment management, nonmarket valuation, random utility models, recreational fishing.

1. Introduction

Management of marine resources involves difficult decisions. One of the most difficult areas is the management of recreational fishing. In the case of Western Australia (WA), for example, the state government has recently introduced changes to recreational fishing licence fees, penalty levels and seasonal limits for some regions.[1] The controversy that accompanied these changes highlights the degree to which decision-making can be rendered difficult by conflicting claims. Different groups provide estimates of values,[2] but these values tend to be based on some direct but inappropriate monetary transactions figures (e.g. angler expenditures). What is lacking is information on the economic surplus generated by recreational fishing opportunities. Of course, there is no guarantee that such information would be utilised by

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[1] See the summary on FishWrecked.com; at http://fishwrecked.com/forum/government-announces-new-recreational-fishing-licences.

[2] One estimate of the annual contribution of recreational fishing to the state's economy is $500 m (Recfishwest 2008). However, Recfishwest does not indicate how this figure is estimated.

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decision makers, but it improves the set of data that managers have at their disposal.

Unlike for commercial fishing, the benefits from recreational fishing cannot be observed in market transactions except in cases where charter fishing services are used. The benefits are generally nonmarket values and reflect the utility anglers derive from fishing opportunities. These values represent the economic surplus anglers derive from fishing over and above the costs they incur and can be estimated only indirectly using econometric recreational demand models.

These models serve two main purposes. First, they predict demand for recreational activities and site choices as a function of site characteristics, the angler's characteristics and other possible influences. Second, the models provide a basis for estimating the utility of fish and site attributes and, therefore, for estimating the willingness to pay (WTP) for these resources. WTP estimates can be generated for individual or combinations of attributes as well as for site access opportunities. In sum, these empirical models provide a wealth of information that resource managers rarely have, but are vital to improving decision-making.

In WA, recreational fishing is a major social activity involving about 34 per cent of the population and contributes more than $500 million annually to the economy (Recfishwest 2008;[3] Fisheries Western Australia (WA) 2011). The importance of recreational fishing started to become clearer only after 1997, when the Department of Fisheries WA began surveying fishing effort and catches. Participation rates in recreational fishing increased from 26.6 per cent in 1987 to 30 per cent in 1996 (Fisheries WA 1999; p. 21). More recent figures indicate the rate is now about 34 per cent, with higher rates in regional areas (Fisheries WA 2011). Fishing effort as measured by the number of fishing days taken had also increased from about three million in 1987 to 11.2 million fishing days in 1997 (Fisheries WA 1999). Increased access to once isolated areas, improved fishing technology and population growth contribute to the pressure on stocks (Fisheries WA 1999). The increase in demand together with the noticeable depletion of some species highlights the need for managing the impact of recreational fishing (Recfishwest 2008). Management strategies have the potential to reallocate stocks between recreational and commercial sectors. Values for the latter are well established, but the same is not true for the recreational sector. Therefore, there is a need to understand recreational values to evaluate the welfare impacts of policies that reallocate stocks and also to evaluate the welfare impacts of particular management strategies that target specific fish types and/or sites. And, in circumstances where the precau-

[3] As noted in footnote above, Recfishwest (2008) does not indicate how this figure has been estimated.

tionary approach[4] (Fisheries WA 2000) is used to manage recreational fishing, economic models can be used to estimate the welfare losses caused by these 'precautions'.

To date, very few studies have focussed on WA (Van Bueren 1999; Zhang 2003; Swait *et al*. 2004) or on Australia or New Zealand in general (Rolfe and Prayaga 2007). Van Bueren (1999) uses random utility modelling to value recreational fishing on 13 sites along the south-west coast of WA, stretching from the North Perth Metropolitan region to the Augusta region. Swait *et al*. (2004) use data from Van Bueren (1999) but incorporate dynamics into their modelling of choice decisions. Most published recreational fishing studies have focussed on the United States or Europe (Wegge *et al*. 1986; Morey *et al*. 1991; Walsh *et al*. 1992; Adamowicz 1994; Navrud 1999; Lew and Larson 2005). Results show that site values vary greatly, depending on angler characteristics and location, with value estimates varying greatly from US $0.20 to US$146 per fishing trip. These variations partly reflect differences in the design of the valuation studies, including estimation techniques.

This study is the first investigation covering all the major fishing regions of WA. Eight major regions and 48 subregions, stretching along the coast from Esperance in the south to the Kimberley in the north, are included. Data from the 2000/2001 National Survey of Recreation Fishing (NSRF) (Henry 2001; Fisheries WA 2002) are used to econometrically estimate a random utility model (RUM).

The paper is organised as follows. Section 2 presents a discussion of the modelling framework used, including the negative binomial fish catch rate model and the random utility model of site choice, which includes the predicted catch rates as an explanatory variable. This is followed by a brief review of the literature. Section 4 describes the data and their sources. The estimation results and welfare change estimates are presented in Section 5. In Section 6, we summarise and conclude the paper.

2. Random utility model of fishing site choice

The model describes a choice occasion in which person i has a set of J alternative fishing sites to choose from. It is hypothesised that the utility V_{ij} derived by angler i from a trip to a site j depends on a vector q_{ij} of distance and other site attributes (as perceived by i) as well as a vector of angler characteristics z_i, that is:

$$V_{ij} = V_{ij}(q_{ij}, z_{ij})$$

Angler i will visit site j if the utility of site j is greater than that of any other site k, where $k = (1, 2\ldots, j-1, j+1 \ldots, n)$. However, the model recognises

[4] The precautionary approach recognises maximum levels of fishing and the minimum safe size of stocks required to ensure sustainability, and requires fisheries managers to take account of uncertainty in managing stocks.

that utility cannot be fully described. Utility is to have a systematic component (V_{ij}) and an unobservable component (ε_{ij}):

$$U_{ij} = V(q_{ij}, z_{ij}) + \varepsilon_{ij} \tag{1}$$

Given a distribution for the unobservable component, we can obtain an estimable model that describes site selection as a probabilistic choice. The most common mathematical representation of the RUM is the multinomial logit (MNL), which assumes that the ε_{ij} terms are independent and identically distributed as type I extreme values. The MNL probability, $prob_{ij}$, that individual i chooses site j can be expressed as:

$$prob_{ij} = \frac{\exp(U_{ij})}{\sum_{j=1}^{J} \exp(U_{ij})} \tag{2}$$

To implement this model, one needs to identify relevant site attributes. Cost of travel is typically found to be important, as is expected fish catch rate. One approach to estimating expected catch rates (henceforth CR's) is to use the average number of fish caught. However, this approach does not accommodate differences among anglers (Bockstael *et al.* 1991).

To overcome this problem, many studies (e.g. Schuhmann and Schwabe 2004; McConnell *et al.* 1995; Van Bueren 1999) have modelled individual angler expected catch rates using Poisson models, in which the intensity variable in the model is specified as:

$$\mathrm{CR}^{e}_{ijf} = \exp(\beta x_{ijf}) \tag{3}$$

where CR^{e}_{ijf} denotes the expected catch rate for fish type f; x is a covariate vector; and β is a vector of regression coefficients. However, the Poisson model has a drawback in that it assumes uniform dispersion in the random variable Y since, for a Poisson model, the expected value and variance of the variable are both equal to the intensity variable, that is, E[Y] = Var[Y] = CR_{ijf}. This property is restrictive because over dispersion is often observed in reality (Cameron and Trivedi 1986). One solution is to use a model that allows for unobserved heterogeneities such as the negative binomial distribution model, which was first introduced into economics by Hausman *et al.* (1984) and expresses the intensity variable as follows:

$$\widetilde{\mathrm{CR}}^{e}_{ijf} = \mathrm{CR}^{e}_{ijf}.u_i \tag{4}$$

where u is unobserved and distributed as a one parameter gamma variable $\Gamma(\theta, \theta)$ with mean and variance:

$$E[u] = 1 \text{ and } \mathrm{var}[u] = \theta^{-1} \tag{5}$$

This leads to the negative binomial distribution (Greene 2008):

$$f(\mathrm{CR}_{ijf}|\theta,\beta) = \frac{\Gamma(\theta + \mathrm{CR}_{ijf})\left(\frac{\theta}{\theta+\mathrm{CR}^{e}_{ijf}}\right)^{\theta}\left(\frac{\mathrm{CR}^{e}_{ijf}}{\theta+\mathrm{CR}^{e}_{ijf}}\right)^{\mathrm{CR}_{ijf}}}{\Gamma(1+\mathrm{CR}_{ijf})\Gamma(\theta)} \tag{6}$$

The negative binomial model generalises the Poisson model as taking the limit of $\theta \rightarrow \infty$ in (6) leads to the latter.

In this study, we use the negative binomial model to predict expected catch rates using the log-linear form:

$$\ln \mathrm{CR}^{e}_{ijf} = \beta_0 + \beta_1 stock_{jf} + \beta_2 S_i + \beta_3 X_i \tag{7}$$

where CR^{e}_{ijf} is expected catch per trip of angler i at site j for fish type f; $stock_{jf}$ is the stock of fish type f at site j; S_i is the vector of other site characteristics that impact on the catch rate; and X_i represents a vector of angler attributes that influence expected catch rates.[5] The stock ($stock_{jf}$) variable is a proxy measure of fish abundance approximated by the average catch of all anglers at that site. Other site attributes in the model include indicators of shore type (man-made, inshore, estuary or beach). Angler characteristics incorporated include the following: age, whether the angler fished with a group (party), target, hours spent fishing, membership in the fishing club, retirement status and employment status. The variables are outlined in Table A2 (Appendix). The model in (7) was estimated separately for the five fish types using maximum likelihood.

The catch rates are included in the utility specification for the model of site choice:

$$V_{ij} = \beta TC_{ij} + \sum_{f} \beta_f \mathrm{CR}^{e}_{ijf} + \beta CL_{ij} \tag{8}$$

where V_{ij} is angler i's observable utility from a visit to site j; TC_{ij} is the cost of travel to the site; CR^{e}_{ijf} represents the fish type (f) catch predicted for angler i at site j; and CL_j represents the length of coast line (km) for the site.

3. Review of the recreational fishing literature

Application of RUM techniques to estimate values of recreational resources has become a standard approach. Numerous studies have been conducted in the United States, Canada as well as European countries (Walsh *et al.* 1992;

[5] As discussed below, the species are grouped into the five fish categories shown in Table A1.

Adamowicz 1994; Navrud 1999; Lew and Larson 2005). These are reviewed in several papers. Loomis *et al*. (1999) review 109 consumer surplus studies in the United States. Detailed reviews can be found in Raybould and Lazarow (2009), Markowski *et al*. (1997) and Freeman (1979). To save space, we will limit the discussion below to studies using RUM.

Among the early studies in the United States, Morey *et al*. (1991) focus on access to coastal salmon fishing sites in Clatsop County (Oregon) and use data from the National Marine Fisheries Service intercept surveys conducted along the Pacific coast. They find that access values for salmon fishing are low in California, Oregon and Washington, and that these values are inversely related to distance from residence. For example, they find the value local residents attach to sites in Clatsop County are five times more than the values held by residents from the nearby County of Deschutes. The study also estimated value changes from increases in salmon catches and concluded that an extra fish caught in a trip is worth US$1.58 for a resident of Clatsop County but only US$0.20 for residents from the neighbouring county.[6]

McConnell and Strand (1994) use 1987/1988 Marine Recreational Fishery Statistical Survey (MRFSS/United States) data to evaluate values for Atlantic sports fishing. They derive benefit estimates for increases in fish catch, for extra game fish catches and for a fishing trip. They obtain a US $26.59 per trip value for a 50 per cent increase in catch rates across all species in Maryland. This figure is higher for Georgia and ranges from US$66.06 to US$70.12. They also find that an extra half of a big game fish per day is valued at US$17.56 per person in Florida but only US$0.21 in Delaware. They attribute the disparity to differences in the predominant big game species between the states.

McConnell *et al*. (1995) use a Poisson model to predict catch rates for sport fishing trips and use the predicted values as variables in a random utility model of site choice. Their empirical application combines data from a household survey and MRFSS intercept surveys. They find that welfare losses from policy changes such as bag limits range from US$0.00 to US $287.49, with higher estimates for anglers who would expect to catch most of the fish.

Whitehead and Haab (2000) use the MRFSS data to evaluate the impact of participation on values in the south-east region of the United States. A random effects Poisson model that allows for angler heterogeneity was used to estimate catch rates. They find that alternative choice set definitions, based on distance or fish catch, do not lead to significant changes in welfare estimates for a fishing trip. Their estimate for Florida amounts to US$30.19 per trip, but is only US$0.82 for Alabama.

A Poisson catch rate model was also used by Lipton and Hicks (2003) to study fishing values among anglers who target striped bass (*Morone saxatilis*)

[6] Please note that the value estimates are nominal values and not adjusted for inflation or for comparability with more recent estimates.

in Chesapeake Bay, Maryland. Their model incorporates the effects on catch of bottom temperature and dissolved oxygen (DO) and indicates that catch rates are negatively affected by low levels of DO. Predicted angler catch rates were then used in a random utility model along with monetary and time cost variables. Site value estimates were small, and the authors attribute this to the presence of many substitute fishing sites along the Patuxent River, a tributary to Chesapeake Bay. Further, they conclude that limited increases in DO have a small effect on angler welfare. However, if levels are allowed to deteriorate to a very low level, the welfare effects become much larger, with the net present value of welfare losses exceeding $100,000 if fishing sites become anoxic.[7]

Previous studies from New Zealand and parts of Australia outside WA have employed either contingent valuation (Blamey and Driml 1998; Wheeler and Damania 2001) or travel cost methods (Dragun 1991; Blamey and Hundloe 1993) or both (Rolfe and Prayaga 2007), rather than RUM. Wheeler and Damania (2001) use WTP surveys to estimate values for different types of fish and find that the value of a species depends on whether it is targeted primarily for recreation or consumption. Rolfe and Prayaga (2007) estimate demand for fishing at three dams in Queensland; they find that values differ across sites and between regular and occasional fishers.

In WA, Van Bueren (1999) uses methods and fish categories similar to ours to estimate values for fish and for 13 recreational fishing sites on the south-west coast. His results show that angler benefits range from A$13.00 to A $39.00 per day of fishing. Zhang (2003) uses a similar approach to evaluate shore-based recreational fishing in WA using data similar to ours. However, she limits her focus to only 16 of the 48 major fishing sites in the state. Like Van Bueren (1999), Zhang grouped the fish species into five types (namely, prize fish, reef fish, key sports fish, butter fish and table fish) shown in Table A1. Her estimates of willingness to pay for an additional fish catch ranges from A$0.53 to A$26.03 depending on fish type. The annual aggregated welfare benefit of recreational fishing is estimated assuming that a total of 10 million fishing days per year are undertaken by anglers in WA. She obtains an aggregate value of A$10 million for the high-value fish (i.e. prize fish, reef fish and key sports fish) and A$33.6 million for low-value fish (i.e. butter and table fish).

In summary, RUM modelling is a well-established technique for nonmarket valuation of recreational fishing. It treats the demand for recreational fishing as a series of discrete choices, with decision made for every trip in the form of a one-off discrete choice between multiple sites (Blamey 2002). Angler site choice is modelled as functions of the expected utilities of different choices (Sandefur *et al.* 1996). RUM techniques involve estimating the probability of an individual's choice as a function of the characteristics of the site and its

[7] These present values are for an infinite horizon, calculated using a discount rate of 5 per cent.

substitutes as well as the characteristics of the angler (Sandefur *et al.* 1996). The ability to relate values to individual characteristics is very useful for exploring the distribution of the benefits/costs of management changes.

4. Data

We use data from the 2000/2001 National Survey of Recreational Fishing. The NSRF was a joint initiative of state and commonwealth governments (Henry 2001; Fisheries WA 2002). The survey consisted of two parts, a telephone survey and a detailed log book. We use data from the latter, consisting of responses from 778 anglers who made a total of 4008 trips. The fishing trips cover all eight fishing regions in the state (Figure 1). Within these regions, 48 sites (listed in Table A3) are identified as the set of available fishing destinations in our model.

The survey gathered fishing trip and demographic data. Trip specific data include the following: date of fishing trip; fishing site for the trip; whether fishers targeted particular species; method of fishing used; size of party involved in a fishing trip; fishing mode (shore or boat fishing); fishing location type (offshore, inshore, estuary, river or lake); time spent fishing in the trip; number of fish kept and released; and expenditure on the fishing trip. Collected demographic data include age, gender and education. The average

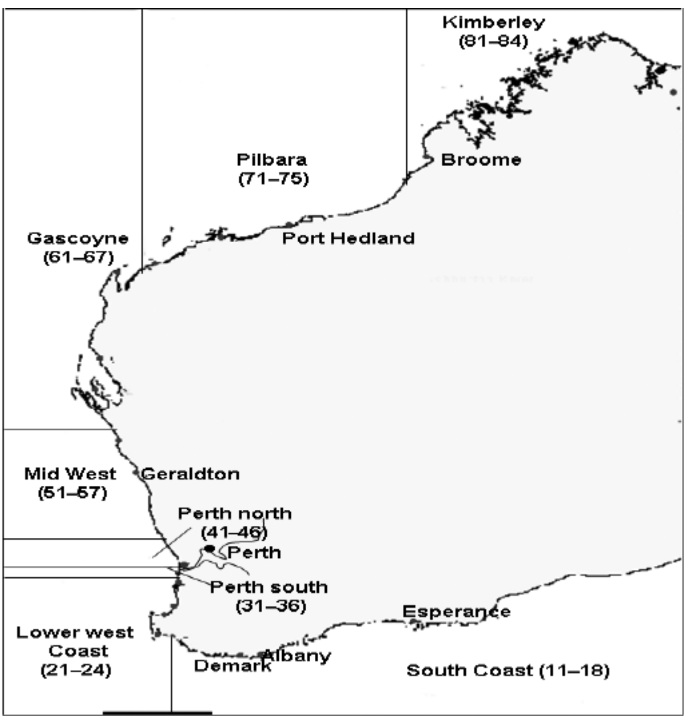

Figure 1 Major fishing regions of Western Australia.

age of the sample participants is 46 years, and less than half belonged to a fishing club, while more than half were employed (See Table A4). On average, the size of a fishing party was about two. As indicated above, demographic profile data on age, membership in fishing club, employment status, education and retirement status are used in the models to predict expected catch rates.

Travel cost figures are based on a cost for the distance to the site. Distance is converted into cost using a value of \$0.50/km, which is the estimated cost of fuel and associated vehicle wear and tear costs. For sites that are actually visited by an angler, the distance is the actual distance recorded on the survey. Travel distances to alternative sites are calculated. For overnight or multiple day trips, distance per trip is obtained by dividing the distance from home by the number of fishing trips resulting from that particular travel. This requires getting an estimate of the number of fishing days (trips) for sites that are in the angler's choice set but were not actually visited. This expected number of days was predicted using an empirical Poisson model estimated using data on actual number of trips reported in the survey and the corresponding reported distances. Although this approach provides a means of generating useful counterfactual data, it should be noted that the predicted number could underestimate or overestimate the number of trips for a given angler.

5. Results

We first present estimation results for the catch rate and site choice models. This is followed by a discussion of welfare measures relating to fish values and site access values.

We estimate expected catch rate for different fish types, and the negative binomial model results are presented in Table A5. Fish stock levels, bait use, time spent fishing and wether the angler is targeting the particular fish type are found to have significant and positive influence on catch rates for all types. Among angler characteristics, age was found to have the expected sign and is a statistically significant influence on prize and butter fish. Variables that influence catch rates for some but not all fish types include fishing site type (inshore or beach), whether the angler is retired and the size of the fishing party.

The site choice model coefficient estimates are presented in Table 1. Initially, the model in Equation (8) was specified as a function of a large number of variables, including interaction terms between stock and expected catch rate variables. It was refined by removing variables that were insignificant at the 95 per cent level. The coefficient of the catch rate variable is significant and positive for all fish types. Travel cost is also significant and has the expected negative effect on the attractiveness of a site. Coastal length plays a significant role in site choice, the positive sign suggesting that anglers prefer sites that offer more choice (availability of fish) and possibly isolation.

Table 1 Random utility model (RUM) coefficient estimates

Variables	Five fish models
Travel cost	−0.001 (0.001)***
CR_Prize fish	0.090 (0.005)***
CR_Reef fish	0.010 (0.005)***
CR_Key sports fish	0.050 (0.001)***
CR_Table fish	0.030 (0.004)***
CR_Butter fish	0.010 (0.001)***
Coastal length	0.003 (0.000)***
CR_Reef fish * (stock of reef fish)	0.001 (0.000)***
Pseudo-R^2	0.42

Note: Values in the parentheses are standard errors. *** indicates that the coefficient is significant at the 99 per cent level.

These estimates link site choice to site characteristics and (through catch rate estimates) to angler characteristics. They can be used to calculate part-worth for a site attribute, a value that reflects the trade-off between the attribute and the cost variable. For example, the part-worth for a fish type is the ratio of utility coefficients on the expected catch rate for that type and the travel cost variable. Such calculated values are reported in Table 2.[8] The results indicate that the values for prize fish, reef fish and key sports fish are greater than those for table and butter fish. Values from previous studies are also included in Table 2 for comparison. Van Bueren (1999) values for table and butter fish are $5.56 and $4.14. Zhang's (2003) estimates for these two fish are much lower and provide an opposite ranking of the two fish types in Van Bueren (1999). The prize fish value from Zhang (2003) is also very low ($0.83), while her reef fish value estimate ($21.31) is much higher than any of our estimates.

Table 2 Part-worth estimates ($/fish)

Fish type	Our estimates	Results from previous studies	
		Van Bueren (1999)*	Zhang (2003)†
Prize fish	15.94	—	0.83
Reef fish	9.47	—	21.31
Key sports fish	9.40	—	0.85
Table fish	4.65	5.56	0.02
Butter fish	2.28	4.14	0.38

Note: *See Van Bueren (1999). †Calculated from RUM estimates in Table 6.4 of Zhang (2003).

[8] The values are linear. It is possible to check whether these values diminish as the expected catch for an individual increases. However, given the number of fish types in the model and the large number of different combinations one could test for, we have decided to keep the model simple by including only linear terms.

5.1. Calculating welfare change measures

The model can also be used to calculate welfare values for changes in single or multiple site attributes or for site closure. The calculation of the welfare measures follows the approach used in Small and Rosen (1981) where the compensating variation (CV) for a change in site quality vector (q) is computed as:

$$CV = -\frac{1}{\beta}\left[\ln\left(\sum_{j=1}^{J} \exp V_j(q^1)\right) - \ln\left(\sum_{j=1}^{J} \exp V_j(q^0)\right)\right] \quad (9)$$

where J denotes the number of alternative fishing sites; V_j is the utility function for site j; q^0 and q^1 represent, respectively, site attributes before and after the change; and β is the absolute value of the price coefficient in the utility function.[9] In the case of an improvement, the compensating variation value indicates the maximum an individual is willing to pay for the change in quality. For example, we are able to simulate the welfare effects of a percentage increase or decrease in the expected catches. Mean CV for a 100 per cent increase in catch rate of a fish type across all fishing sites is shown in Table 3. On average, anglers would be willing to pay \$31.40 for a doubling in the expected catch rates for prize fish and \$23 for reef fish. It may seem counterintuitive that a 100 per cent increase in catch rates, which has an observed sample mean value close to unity in the case of prize fish, should generate such a distinctly different value when compared to the part-worth of \$15.94 presented above. A proportional change in catch rates does generate a change in the probability of site choice and, hence, induces two sources of change in value: the value that arises due to the increase in expected catch plus the effect of a shift in fishing effort across sites. This is because the variation in catch rates across sites and anglers can be large. This highlights the importance of making welfare change judgements based on the mean

Table 3 Economic welfare estimates for a 100 per cent catch rate increase (\$/trip)

Fish type	Sample mean catch (per trip)	Our estimates	Results from previous studies	
			Van Bueren (1999)	Zhang (2003)
Prize fish	1.28	31.41	—	0.65
Reef fish	1.47	23.13	—	0.26
Key sports fish	1.39	21.79	—	0.67
Table fish	1.97	14.88	5.68	0.03
Butter fish	8.86	20.20	3.30	2.10

[9] Note that utility and CV value estimates are angler specific, but angler subscripts have been suppressed in the equation to reduce crowding.

values of the individual welfare effects, as opposed to the welfare effect on an average or representative angler.

The catch rate increase values obtained by Van Bueren (1999) are much lower than ours as shown in Table 3. Note that Van Bueren's study area covers a much smaller region, covering only the Perth Metropolitan and Mandurah areas. Zhang's study covers 16 of the 48 sites included in ours; but her catch rate increase value estimates are very small and almost nil in the case of table fish.

The access value of a fishing site is the welfare loss suffered by an angler if a site becomes unavailable. Values for all sites are presented in Table 4. Averaged across all sites, welfare losses from site closure amount to \$3.81 per trip per angler. Losses are almost always higher for anglers who fish at the

Table 4 Access value of fishing sites

Sites	Welfare losses (\$/trip)		Sites	Welfare losses (\$/trip)	
	Value for anglers who fished at site	Value for all anglers		Value for anglers who fished at site	Value for all anglers
Cape Arid	−4.77	−5.07	Lancelin	−4.42	−3.55
Esperance	−4.53	−6.01	Jurien Bay	−4.59	−3.64
Hopetoun	−8.84	−2.07	Dongara	−11.85	−9.10
Bremer Bay	−11.11	−8.17	Geraldton	−7.77	−5.45
Albany	−7.51	−5.48	Abhrolhos Islands	−4.84	−5.45
Denmark	−7.16	−5.63	Port Gregory	−8.12	−6.36
Walpole	−7.27	−4.99	Kalbarri	−5.60	−4.61
Windy Harbour	−11.64	−8.01	Shark Bay Oceanic	−1.91	−2.89
Augusta	−4.07	−3.29	Shark Bay–Western Gulf	−4.98	−2.95
Busselton	−5.30	−3.76	Shark Bay–Eastern Gulf	−3.51	−2.18
Bunbury	−7.21	−3.89	Carnarvon	−4.97	−2.09
Mandurah	−5.40	−3.84	Quobba	−3.58	−3.21
Warnbro Sound	−4.71	−3.70	Coral Bay	−14.46	−4.24
Cockburn Sound	−3.97	−3.32	Exmouth	−13.31	−6.16
West of Garden Island	−3.49	−2.83	Onslow	−2.74	−2.95
Fremantle	−3.76	−2.82	Dampier	−6.63	−2.06
Swan River	−3.59	−2.64	Point Samson	−5.70	−1.74
Rottnest Island	−3.37	−3.54	Port Hedland	−7.45	−1.88
Cottesloe	−3.23	−2.15	80 Mile Beach	−4.25	−1.36
Floreat	−3.94	−2.71	Broome	−5.62	−1.77
Hillarys	−3.46	−2.56	West Kimberley	−9.87	−5.20
Burns Beach	−2.91	−2.00	North Kimberley	−6.47	−2.70
Quinns Rocks	−2.52	−2.32	East Kimberley	−7.33	−4.04
Yanchep	−3.41	−2.67	Mean across all sites	−5.61	−3.81

Table 5 Comparison of access value estimates

Site	Values ($/trip)		
	Our estimates*	Van Bueren (1999)	Zhang (2003)
Esperance	4.53	—	10.01
Albany	7.51	—	3.63
Denmark	7.16	—	0.38
Augusta	4.07	—	0.15
Busselton	5.30	—	1.57
Bunbury	7.21	—	0.47
Mandurah	5.40	0.32 – 1.47	1.42
Cockburn Sound	3.97	0.17	—
Fremantle	3.76	0.22	0.66
Swan River	3.59	—	0.67
Floreat	3.94	0.16	—
Hillarys	3.46	—	0.40
Lancelin	4.42	—	0.43
Geraldton	7.77	—	11.52
Point Samson	5.70	—	2.15
Port Hedland	7.45	—	2.48
Broome	5.62	—	5.52
West Kimberley	9.87	—	1.49

Note: *Absolute values of figures from Table 4.

closed site. Among the 48 sites, access values are highest for Coral Bay ($14.46) and Exmouth ($13.31). The magnitude of losses from site closure depends on the availability of substitute sites. For example, Dongara and Windy Harbour site access values are also high as these sites have few substitute sites.

Compared with ours, Zhang's (2003) estimates for Esperance and Geraldton are higher, at $10.01 and $11.52, respectively. Her estimate for Broome is similar, but higher, than ours, and for the remaining 13 sites in her study Zhang's estimates are lower than ours (See Table 5). Site access values for the four sites that are common between ours and van Bueren's study also differ, with our results being much higher.

Finally, these site access values could be used to generate some approximate estimates of the value of recreational fishing in a region or State. One could, for example, generate an aggregate annual access value for WA, if one calculated the mean (across the sample) welfare loss that would occur if all sites were simultaneously closed and multiplied that loss by the number of fishing days in the state (see Van Bueren 1999). Of course, such a calculation would be valid only if the sample used to generate our results was representative of the entire population. Further, our estimates are based on 2000/2001 data, and values and fishing conditions at sites have changed since then. However, it does highlight how the results could be used to provide an indicative value for recreational fishing.

6. Summary and conclusion

This study is the first statewide investigation of the value of recreational fishing in WA, where fishing is a highly popular activity. The management of recreational fishing is a controversial subject; and public dialogue and decision-making could be improved if claims about the value of recreational fishing are based on sound economic studies rather than on *ad hoc* estimates.

This study estimates a random utility model (RUM) linking fishing site choice to site attributes and angler characteristics. We find that fish catch rates, travel cost and coastal length are statistically significant influences on fishing site choice. Catch rates in turn depend on fish stocks, fishing effort (hours spent), use of bait and whether the particular fish is being targeted by the angler.

Part-worths reflecting trade-offs between fish and cost of travel are calculated. Welfare changes resulting from variations in site attributes and site access are also presented. These and similar estimates can be used to inform the development of fishery management policies through, for example, setting out the welfare costs of imposing bag limits or closing fishing sites.

Finally, the value to decision-making of econometric modelling of choice can be enhanced if these models are integrated with biophysical models that simulate the dynamics of fish stocks and marine ecosystems. The RUM model would utilise information on fish stocks (and catch rates) from the biophysical model. And the biophysical model would utilise fish extraction information simulated by the RUM model. The integrated model would thus account for feedback effects and make it possible to evaluate the effects of management changes on economic and ecological outcomes. Until recently (Gao and Hailu 2011, 2012, 2013), there was little work done using integrated models to evaluate management changes.

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Appendix

Table A1 Classification of recreational species in Western Australia

Prize fish	Billfish Cobia, Cods, Coral trout, Dhufish WA, Mackerel, Wahoo, Spanish broad-barred, Spanish narrow-barred, Mackerel shark, Spotted and old school, Mahi Mahi, Mulloway, Northern mulloway, Queen fish, Salmon Australian, Samson fish, Sharks, Trout, brown and rainbow, Tuna Southern blue fin, Yellowtail kingfish, Barramundi*, Groper Western blue* (4 of each species, total mixed bag limit 8)
Reef fish	Emperor red, Groper and tusk fish, Snapper pink, Snapper North-west, Snapper queen, Spangled emperor (Mixed bag limit 8)
Key sports fish	Bream black (in Swan/Canning river), Bonito, Cobbler, Tailer, Mangrove jack, Fingermark bream, Giant threadfin salmon (Mixed bag limit 8)
Table fish	Bream black, Northern black and yellow fin, Flathead, Flounder, Leatherjackets, Pike, Snook, Skipjack trevally, Snapper red, Tarwhine, Threadfin, Northern Gunther's and black finned salmon, Whiting king George (20 per fisher per day)
Butter fish	Garfish, Australian herring Blue mackerel, Sea and yellow eye mullet, Western sand school and yellow fin whiting, Other finfish not listed in other categories (40 per fisher per day)

Notes: *Denoted special bag limits: Barramundi – possession limit 5, in lower Ord river 1; Groper, Western blue – daily bag limit 1. These bag limits are adopted from Fisheries Western Australia (FWA, 2001).

Table A2 Variables in catch rate models

Variables	Description
Stock	Proxy for stock (annual mean catch of fish type)
Inshore	1 if inshore, 0 otherwise
Estuary	1 if an estuary, 0 otherwise
Beach	1 if beach, 0 otherwise
Man-made	1 if a mad made structure, 0 otherwise
Lnhour	Logarithm of the number of hours spent fishing
Party	Total number of persons included in the fishing trip
Target	1 if angler targets fish type *k*, 0 otherwise
Bait	1 if angler uses bait to catch fish type *k*
Member	1 if angler is a member of a fishing club, 0 otherwise
Age	Age of angler
Retire	1 if angler is retired, 0 otherwise
Employ	1 if angler employed, 0 otherwise

Table A3 Fishing sites, regions and trip distribution

Fish site code	Fishing sites	Fishing region	Trip count
11	Cape Arid		22
12	Esperance		327
13	Hopetoun		42
14	Bremer Bay	South Coast	158
15	Albany		455
16	Denmark		75
17	Walpole		34
18	Windy Harbour		32
21	Augusta		124
22	Busselton		278
23	Bunbury		85
24	Mandurah	Lower West	377
31	Warnbro Sound		24
32	Cockburn Sound		34
33	West of Garden Island		2
34	Fremantle		165
35	Swan/canning River	Perth South	109
36	Rottnest Island		57
41	Cottesloe		05
42	Floreat		28
43	Hillarys	Perth North	70
44	Burns Beach		02
45	Quinns Rock		15
46	Yanchep		20
51	Lancelin		86
52	Jurien Bay		73
53	Dongara	Mid-west	64
54	Geraldton		233
55	Abrolhos Island		02
56	Port Gregory		58
57	Kalbarri		74
61	Shark Bay Oceanic		12
62	Shark Bay – Western Gulf		11
63	Shark Bay – Eastern Gulf	Gascoyne Ningaloo	09
64	Carnarvon		41
65	Quobba		37
66	Coral Bay		57
67	Exmouth		105
71	Onslow		69
72	Dampier		24
73	Point Samson	Pilbara	83
74	Port Hedland		97
75	80 Mile Beach		30
81	Broom		125
82	West Kimberly		82
83	North Kimberly	Kimberly	10
84	East Kimberly		86
90	Inland		0

Table A4 Summary statistics of variables used in estimation

	Variables	Mean	SD	Min	Max
Caught	Prize fish	1.13	3.91	0	80
	Reef fish	0.24	1.44	0	34
	Key sports fish	1.39	4.15	0	60
	Table fish	1.98	5.47	0	88
	Butter fish	8.86	15.74	0	240
Shore type	Inshore	0.83	0.37	—	—
	Estuary	0.17	0.37	—	—
	Beach	0.49	0.50	—	—
	Man-made	0.20	0.40	—	—
Bait	Prize fish	0.22	0.42	—	—
	Reef fish	0.03	0.18	—	—
	Key sports fish	0.20	0.40	—	—
	Table fish	0.19	0.39	—	—
	Butter fish	0.27	0.45	—	—
Target	Prize fish	0.14	0.35	—	—
	Reef fish	0.02	0.15	—	—
	Key sports fish	0.20	0.40	—	—
	Table fish	0.07	0.26	—	—
	Butter fish	0.60	0.49	—	—
Demographic features	Age	45.70	15.21	16	85
	Member	0.024	0.15	—	—
	Employ	0.54	0.50	—	—
	Retire	0.27	0.44	—	—
	Party	1.75	1.14	1	12
	Hours	0.90	0.51	−1.39	2.64
	Education	0.20	0.40	—	—
Other variables	Coastal length	1104.33	1113.91	10	4461
	Travel cost	141.81	118.39	0	1221.45

Table A5 Coefficient estimates for the catch rate fuctions

Variable	Prize fish	Reef fish	Key sports fish	Table fish	Butter fish
Constant	−3.36	−4.25	−2.02	−2.32	−0.54
	(−16.31)	(−17.8)	(−16.7)	(−18.51)	(−3.92)
Stock	0.40	2.21	0.23	0.24	0.09
	(11.23)	(13.47)	(10.79)	(10.02)	(17.58)
Lnhours	0.28	1.01	0.364	0.94	0.47
	(4.03)	(5.75)	(4.75)	(11.84)	(9.84)
Target	0.92	1.68	1.26	1.18	1.19
	(10.77)	(5.02)	(15.61)	(9.29)	(8.73)
Bait	3.02	4.078	2.36	2.10	0.54
	(40.94)	(14.5)	(31.37)	(23.18)	(10.11)
Party	0.26	—	0.21	0.36	0.28
	(8.49)		(7.49)	(9.72)	(12.4)
Member	−1.44	—	—	—	—
	(−3.92)				
Age	−0.01	—	—	—	0.012
	(−3.32)				(4.26)
Retire	—	—	—	−0.20	—
				(−2.37)	

Table A5 (*Continued*)

Variable	Prize fish	Reef fish	Key sports fish	Table fish	Butter fish
Employ	—	—	—	—	−0.18 (−3.22)
Inshore	0.93 (8.72)	—	−0.82 (−9.74)	—	—
Estuary	—	−0.83 (−3.83)	—	—	−0.48 (−7.32)
Beach	−0.66 (−8.73)	−1.09 (−4.53)	—	−0.43 (−5.73)	—
Man-made	—	—	—	—	0.33 (5.46)
Alpha	1.63 (18.54)	7.56 (9.66)	2.27 (18.66)	3.95 (23.63	1.98 (37.00)
L likelihood	−3539.78	−1101	−4015.72	−5337.61	−8549.28

Notes: The *t*-ratios are given in the parenthesis.