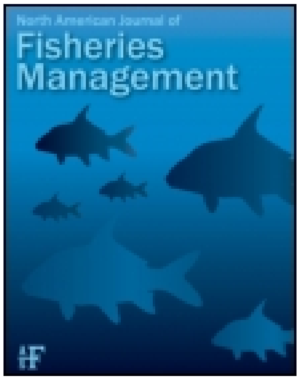

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Valuing Recreational Fishing in the Great Lakes

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ARTICLE

Valuing Recreational Fishing in the Great Lakes

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Abstract
We estimated a pair of models to characterize the demand for Great Lakes recreational fishing in Michigan. With a nested logit framework, the models tested whether anglers have an unobserved tendency to substitute between fishing sites based on target species or lake-specific preferences. Results indicated that anglers tend to substitute more readily between sites within a lake, although we found that the choice of model did not qualitatively influence measures of nonmarket value. Both models predicted that the fishing destinations of anglers would be strongly influenced by catch rates. Using these results, we estimated the sportfishing value for several fish species and found that anglers have the highest willingness to pay for Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *O. kisutch*, steelhead *O. mykiss*, and Walleyes *Sander vitreus*. We also derived the access values of Michigan's coastal fishing sites and determined that day trips to a typical Great Lake site are worth about $30 per trip.

Efficient fisheries management requires the consideration of different values. In the Great Lakes region, both commercial fishing and recreational fishing are important sources of economic benefits. Although the value of commercial fisheries can be determined from observed market prices, alternative techniques are required to calculate the value of recreational fisheries. One valuation approach, the random utility maximization (RUM) model and travel cost method, uses observed behavior to estimate the value of goods or activities that are not traded in traditional markets, such as sportfishing. The RUM models are capable of valuing changes in the quality of activities and are especially useful for valuing recreational activities that take place at many similar—that is, substitutable—sites. These models are therefore well suited for use in the valuation of recreational fishing in the Great Lakes.

The literature on Great Lakes recreational fisheries valuation dates to Daniel Talhelm (Talhelm et al. 1979; Talhelm and Bishop 1980), who used both market and nonmarket valuation methods to derive the access values for Great Lakes sportfishing sites. This work was followed with nonmarket applications by Samples and Bishop (1985), who used a 1979 survey of Wisconsin trout and salmon anglers to value several Lake Michigan fishing sites, and Hushak et al. (1988), who used a 1982 survey of Ohio-resident Lake Erie anglers to value Yellow Perch *Perca flavescens* fishing on western Lake Erie. Later, a large number of studies were published that valued recreational fishing in Wisconsin, both for trips to Lake Michigan (Provencher et al. 2002; Provencher and Bishop 2004; Murdock 2006) and trips to Lake Superior (Phaneuf et al. 2000). Nonmarket valuation has also been applied to sportfishing on New York waters of Lake Ontario (Montgomery and Needelman 1997) and Ontario waters of Lake Superior (Hunt et al. 2007). Several studies have estimated the value of Great Lakes recreational fishing in Michigan: Jones and Sung (1993) and Jones and Lupi (2000) used 1984 data to model the demand for recreational fishing in Michigan; and Hoehn et al. (1996), Lupi et al. (2003), and Kotchen et al. (2006) used 1995 data to model sportfishing demand in Michigan. Approximately one-third of all Great Lakes anglers fish in

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Michigan waters—double Wisconsin's share (USFWS and USCB 2008)—so studies of Great Lakes recreational fishing in Michigan are particularly important. Furthermore, as the population of anglers continues to turn over, age, and generally decline in number (Dann et al. 2008), studies that utilize older data may diminish in relevance. Periodic surveys of the population are therefore useful to maintain an accurate understanding of angler preferences and recreational fishing values.

We developed and analyzed two RUM models of anglers' fishing site choice in Michigan waters of the Great Lakes. The models were parameterized by using several years of data on historic catch rates and responses from a survey of Michigan fishing license holders. Many previous studies of recreational fishing demand have lacked a similar time element, which can improve the interpretation of the results (Loomis and Cooper 1990). To learn about anglers' willingness to substitute between different fishing sites, we used each model to test a unique partitioning of sites. We found that anglers may be more willing to substitute between some fishing sites than others, even after we controlled for observed site characteristics, such as catch rates. We also calculated per-trip values for the species included in our model and the access values of Michigan's coastal fishing sites.

We first describe the data, sample, and recreational fishing models used in this study. We then present the results of the models, which include the estimation of per-trip economic values. We also discuss some of the implications and limitations of the models.

METHODS

Survey data.—The population of interest in this study consisted of Great Lakes recreational anglers from Michigan. We used data from a general survey on Michigan sportfishing trips. Questionnaires were mailed to a sample of Michigan fishing license holders drawn from the Retail Sales System database of the Michigan Department of Natural Resources (MDNR). Anglers were selected into the sample by randomly drawing from the pool of anglers who purchased licenses between 1 April 2008 and 31 March 2009 for the 2008–2009 fishing season (anglers could purchase licenses in March for the upcoming season). The sampling process was repeated monthly between July 2008 and June 2009, with the initial round of mailing dates occurring in the first week of each month. License holders were discarded from a round of sampling if their entries in the MDNR database were missing key information (e.g., name or address). Licensees with addresses outside of the USA or Canada were also removed from the sample. Anglers that were selected in a given round were removed from the population for future drawings. Questionnaires were mailed in packets that included a business reply envelope. License holders who did not respond within a few weeks were mailed a reminder postcard and, if needed, a second questionnaire. After 1 year of surveying with follow-ups, the survey had a response rate of 47%.

The questionnaire totaled three pages of text and made a number of inquiries about recent fishing behavior. Anglers were asked to report general information about their manner of fishing (e.g., species sought and methods used). Anglers were questioned in detail about their two most recent fishing trips; the exception was for the first round of sampling, in which half the surveys inquired only about the most recent fishing trip. The questionnaire also asked about economic status and demographics. Anglers could indicate their household income within one of six ranges: \$0–25,000, \$25,000–50,000, \$50,000–75,000, \$75,000–100,000, \$100,000–150,000, and \$150,000+. For a detailed treatment of the survey, see Simoes (2009).

Of the returned questionnaires, 67% included answers to the detailed trip questions with identifiable destinations, the majority of which were actually to inland sites. We checked the reported type, name, and nearest city or county of the water body the anglers had fished. For anglers who indicated that they fished the Great Lakes, it was often sufficient to know the nearest city, since most cities in Michigan lie in proximity to only one Great Lake. After discarding all trips to inland waters, we were left with a sample of 4,705 trips to Great Lakes sites.

As is typical for developing models such as ours, the sample of Great Lakes trips was trimmed in the following manner. The sample was restricted to Michigan residents, who contributed 85% of the Great Lakes trips in the data (a 2006 survey of anglers found that 80% of Great Lakes anglers who fished in Michigan were Michigan residents; see USFWS and USCB 2008). Furthermore, we only considered day trips and trips that were taken primarily for the purpose of fishing, which constituted 71% and 88% of the sample of trips, respectively. Undated trips and trips to sites that required more than 200 mi of travel one way, which we considered the maximum feasible distance for day trips, also were dropped from the sample.

Anglers who reported an identifiable destination were matched to one of 70 site locations defined by the MDNR creel catch rate data (see below). Of the 70 sites, four rarely visited sites lacked usable catch data and were not included in the model, thus reducing the choice set to 66 sites. The few trips that did go to these sites were removed from the final sample. After these refinements, 2,233 trips were available for our analysis; this number of trips is about half of all identifiable Great Lakes trips that were reported in the angler survey.

Target species.—We placed trips into two target species categories: coldwater species and warmwater species. This distinction in economic models originated with Kikuchi (1986); see also Jones and Sung (1993). On the questionnaire, anglers were asked to report the species they targeted and/or caught during each trip. Table 1 presents the percentage of trips that were targeted toward the most popular fish species. Based on what an angler fished for during a trip, we assigned each trip in the sample to the coldwater or warmwater category. Specifically, coldwater trips were defined as trips taken to fish for Chinook Salmon, Coho Salmon, Lake Trout, steelhead/Rainbow Trout, Brook Trout *Salvelinus fontinalis*, Brown Trout, and Lake Whitefish *Coregonus clupeaformis*. Warmwater trips were defined as those that were taken to fish for Largemouth Bass, Rock

TABLE 1. Average target rates of popular fish species in the sample of Great Lakes sportfishing trips (N = 2,233 trips) and their ranks among coldwater trips, warmwater trips, and all trips taken by Michigan-resident anglers.

Species	Average target rate[a]	Coldwater trips rank	Warmwater trips rank	All trips rank
Walleye *Sander vitreus*	0.425		1	1
Yellow Perch *Perca flavescens*	0.294		2	2
Smallmouth Bass *Micropterus dolomieu*	0.129		3	4
Largemouth Bass *M. salmoides*	0.087		4	8
Northern Pike *Esox lucius*	0.059		5	9
Bluegill *Lepomis macrochirus*	0.058		6	10
Crappies *Pomoxis* spp.	0.023		7	12
Chinook Salmon *Oncorhynchus tshawytscha*	0.177	1		3
Coho Salmon *O. kisutch*	0.113	2		5
Steelhead/Rainbow Trout *O. mykiss*	0.093	3		6
Lake Trout *Salvelinus namaycush*	0.088	4		7
Brown Trout *Salmo trutta*	0.046	5		11

[a]The averages do not sum to 1.0 because more than one species may be targeted on a trip. A small number of anglers did not report a target species.

Bass *Ambloplites rupestris*, Smallmouth Bass, Bluegills, crappies, Common Carp *Cyprinus carpio*, Northern Pike, Muskellunge *Esox masquinongy*, Yellow Perch, and Walleyes. Trips that reported targeting coldwater or warmwater species were assigned to the appropriate category (coldwater or warmwater). If a returned questionnaire did not report a target species, the assignment was based on which species were reportedly caught. For the rare cases in which an angler reported targeting or catching both coldwater and warmwater species during a trip, we assigned the trip to the coldwater category if the angler possessed an all-species fishing license, which permits anglers to catch trout and salmon; we assigned the trip to the warmwater category if the angler did not possess an all-species fishing license. Finally, a trip without any target or catch data was assigned to the warmwater category if the angler did not possess an all-species fishing license. In this manner, nearly all of the trips were assigned to a target species category. Table 2 summarizes the trip information for the coldwater and warmwater categories.

Catch rate data.—To describe the quality of a fishing site, we obtained data on per-hour fish catch rates from the MDNR creel survey program. Per-hour catch rate estimates from Great Lakes sites were available for the six most popular fish species, although the type of catch rate was somewhat different between species. For coldwater species, catch rates (CR) were defined as

$$\mathrm{CR}_i = \frac{\text{number of species } i \text{ landed}}{\sum_{\forall j} \text{hours spent fishing for species } j},$$

where j, i = Chinook Salmon, Coho Salmon, steelhead, or Lake Trout. Thus, the catch rate of a coldwater species depended on

TABLE 2. Characteristics of the sample of Great Lakes sportfishing trips taken by Michigan-resident anglers.

Variable	Coldwater trips		Warmwater trips	
	Average	SD	Average	SD
Distance (mi)	42.766	48.212	31.627	32.051
Travel cost ($)	60.855	74.998	45.151	50.396
Metro Detroit resident[a]	0.044	0.204	0.331	0.471
Fishing mode				
Private boat	0.757	0.429	0.688	0.463
Shoreline	0.115	0.179	0.179	0.500
Charter	0.092	0.018	0.018	0.384
Wading	0.004	0.008	0.008	0.135
Ice	0.033	0.117	0.117	0.091
Trips (N)	528 (522)[b]		1,705 (1,680)[b]	

[a]Defined as living within 25 mi of downtown Detroit.
[b]Values in parentheses are N for fishing mode. Six coldwater fishing trips and 25 warmwater fishing trips did not report fishing mode.

the amount of effort spent fishing for all coldwater fish. For the warmwater species, the catch rate utilized species-specific effort:

$$\mathrm{CR}_i = \frac{\text{number of species } i \text{ landed}}{\text{hours spent fishing for species } i},$$

where i = Walleyes or Yellow Perch.

The catch rate data for Lakes Erie, Michigan, Huron, and Superior were reported by site and month from 2007 to 2009. Catch rates for the Lake St. Clair system, which includes Lake St. Clair, the Detroit River, and the St. Clair River, were also reported by month but only from 2002 to 2004. Due to missing catch rates for several months at most sites, we used predicted hourly catch rates by site and month that were calculated from a series of Tobit regressions. Each regression was particular to a fish species and a region of the Great Lakes. Specifically, the catch rate models took the form

$$\mathrm{CR}_{srkt} = \begin{cases} \mathrm{CR}^*_{srkt} & \text{if } \mathrm{CR}^*_{srkt} > 0 \\ 0 & \text{if } \mathrm{CR}^*_{srkt} \leq 0 \end{cases}, \tag{1}$$

where $\mathrm{CR}^*_{srkt} = \boldsymbol{\beta_t}\mathbf{t} + \boldsymbol{\beta_k}\mathbf{k} + \varepsilon_{srkt}$. The left-hand side of equation (1) describes the observed catch rate for species s in region r at site k during month t. In the Tobit regressions, catch rates were explained by a vector of month dummy variables (**t**) and site dummy variables (**k**), while the error term (ε_{srkt}) is assumed to have a standard normal distribution. For each Great Lake, regions were defined by the physical geography of the lake portion occurring within Michigan. The number of regions was one for Lake Erie, six for Lake Huron, five for Lake Michigan, and two for Lake Superior. Therefore, across 14 regions and 6 species, we estimated a total of 84 catch rate models. Due to more limited data, the catch rates used for the Lake St. Clair system were simply the MDNR reported catch rates for each water body and month, averaged across available years.

Random utility maximization model.—The recreational fishing model we used assumes that an angler decides where to fish from among a set of K possible fishing sites, which are referred to as alternatives. The generic alternative, $k \in \{1, \ldots, K\}$, has a set of qualities that affect the value an angler derives from a trip. This includes a price (p_{ik}), which is the cost of travel to the alternative, and a vector of observable attributes ($\mathbf{q}_{ik}$), which include catch rates and site amenities. There is also a random element (ε_{ik}), which contains the components that are known to the angler but are unobserved by the researcher. Angler i's welfare (i.e., utility; V_{ik}), which includes the benefits received from the trip to fishing alternative k, can be written generally as

$$V_{ik} = V\left(x_{ik}, \mathbf{q}_{ik}, \varepsilon_{ik}\right), \tag{2}$$

where x_{ik} is a composite measure of goods (other than the fishing trip itself) that the angler consumes. Letting y denote income, our representative angler faces the problem

$$\max_k(V_{ik}), \text{ subject to: } x_{ik} = y_i - p_{ik},$$

which is to say that angler welfare is maximized subject to the constraint that less money is available for other goods when the price of a fishing trip increases. Substituting the expression for x_{ik} into V_{ik} yields the typical RUM model (Haab and McConnell 2003).

Since ε_{ik} is unobserved, we can estimate the utility by forming the probability that the site visited by the angler is "best." We assume that ε_{ik} is distributed as generalized extreme value, which yields the estimable nested logit model (McFadden 1981). Use of the nested logit model is convenient because it allows us to group or "nest" fishing sites so that the sites within a nest are linked by common but unobserved characteristics that may be important to anglers (Herriges and Kling 1996; Bingham et al. 2011). This implies that sites within the same nest can more readily substitute for each other than for sites in other nests. We adopted a two-level nesting structure in which the top level consisted of several nests and the bottom level consisted of the sites within each nest. Alternative models (e.g., the mixed logit) were considered, but we found that they offered little improvement over the nested logit.

The particular specification of the utility function we used is

$$V_{inkt} = \beta_{\mathrm{TC}}\mathrm{TC}_{ink} + \boldsymbol{\beta}_{\mathrm{CR}}\mathbf{CR}_{nkt} + \boldsymbol{\beta}_Q\boldsymbol{Q}_{nk} + \varepsilon_{inkt}, \tag{3}$$

where TC_{ink} is angler i's travel cost to alternative k in nest n, $\mathbf{CR}_{nkt}$ is a vector of catch rates specific to alternative k in nest n during month t, $\mathbf{Q}_{nk}$ is a vector of variables describing other features of alternative k in nest n, and ε_{inkt} is the random error. Catch rates that vary by month and location are included in the model because anglers experience different catch rates depending on the date of the trip and which alternative they choose to visit. Our model is unusual in that catch rates vary across time *and* sites, as most sportfishing demand models use only site cross-sectional data on catch rates (for exceptions, see Lupi et al. 2003 and Provencher and Bishop 2004). This may increase the reliability of the sportfishing value estimates derived from the model (Loomis and Cooper 1990). The form of equation (3) is the one used in estimation of the site choice model and is essential to interpretation of the results. Presumably, the parameters on the catch rate terms are positive and significant, implying that higher catch rates generate higher welfare levels for visitors, *ceteris paribus*. Since the parameters themselves do not vary across visitors, a change in site values for a visitor is attributable entirely to differences in the characteristics of the alternatives.

The set of possible fishing alternatives that anglers could visit was defined as follows. First, 66 distinct fishing sites were identified from MDNR creel survey records. We then divided each site into two alternatives: a coldwater alternative and a warmwater alternative. In essence, this structure identifies two fishing "goods" at a single site. Thus, between 66 sites and the 2 species categories, there were 132 total alternatives.

We examined two different nesting structures of the alternatives, each of which could plausibly reflect possible substitution patterns between trips. First, we adopted a model wherein alternatives are grouped according to the coldwater or warmwater species categories, and nested within each target species category are the respective alternative fishing sites. We refer to this model as the "target-species-nested model." In the alternative nesting structure we considered, sites are grouped according to each Great Lake, and nested within each Great Lake are the respective alternative fishing sites for that lake. We refer to this model as the "lake-nested model." There are four nests in the lake-nested model: Lake Huron, Lake Michigan, Lake Superior, and a joint Lake Erie–Lake St. Clair system.

To estimate the model, we constructed the probability that a particular alternative is selected for a trip. For the target-species-nested model, the probability of selecting alternative j in nest m is

$$\pi_{jm} = \frac{\left(\sum_{k=1}^{66} e^{V_{km}/\theta}\right)^{\theta}}{\sum_{n=1}^{2}\left(\sum_{k=1}^{66} e^{V_{kn}/\theta}\right)^{\theta}} \times \frac{e^{V_{jm}/\theta}}{\sum_{k=1}^{66} e^{V_{km}/\theta}}, \tag{4}$$

where V_{kn} is the nonrandom portion of utility as expressed in equation (3). The probability for the lake-nested model is not presented here, but it is a close analog of equation (4). The dissimilarity parameter θ is a measure of the unobserved correlation between alternatives within a nest. Although it is not necessary, a sufficient condition for θ to be consistent with economic theory is that it should lie between 0 and 1 (Herriges and Kling 1996).

With the site choice probability, we can form the likelihood function that characterizes anglers' observed site choice (Haab and McConnell 2003). Employing the nlogit routine in Stata (StataCorp 2009), we use maximum likelihood estimation on the sample of 2,233 fishing trips to estimate the model.

Welfare measurement.—An angler's utility or welfare is affected by changes in the quality of the alternative visited by the angler. For example, a decline in the catch rates at a fishing alternative will reduce angler welfare. We can monetize a welfare loss (or gain) by computing anglers' willingness to pay (WTP; or accept) to avoid this quality change per choice occasion (Champ et al. 2003). We denote the amount that would be given up from an angler's income as WTP. Let V_{nk}^0 and V_{nk}^1 refer to an angler's welfare before and after a quality change, respectively. Then,

$$\mathrm{WTP} = \frac{1}{\beta_{\mathrm{TC}}}\left\{\log_e\left[\sum_{n=1}^{N}\left(\sum_{k=1}^{K_n} e^{V_{nk}^1/\theta}\right)^{\theta}\right] - \log_e\left[\sum_{n=1}^{N}\left(\sum_{k=1}^{K_n} e^{V_{nk}^0/\theta}\right)^{\theta}\right]\right\}. \tag{5}$$

In practice, V_{nk}^0 and V_{nk}^1 are the expressions in equation (3) across the set of various alternatives, computed at the fitted parameter values derived from maximum likelihood estimation. Equation (5) is an angler's per-trip WTP to avoid a negative change or an angler's per-trip willingness to accept to forgo an improvement. Willingness to pay (or to accept) is a measure of the economic damages or benefits that accrue due to a change in environmental quality. The use of "per trip" means that these are values per trip that fall within the scope of the model, so in our case they are values per day trip taken in Michigan waters of the Great Lakes by Michigan-resident anglers.

The formula for WTP is also used to estimate the impact of total site loss, wherein the affected alternative is removed from the summation of V_{nk}^1 in the right-hand side of equation (5). To facilitate comparison of our site values with values from single-site studies, we will sometimes change the units into WTP "per trip to a particular site" by dividing equation (5) by the share of trips that are taken to the site in question (Haab and McConnell 2003).

Model variables.—To describe the fishing quality of these alternatives, the predicted catch rates were used as variables. The coldwater alternatives included Chinook Salmon, Coho Salmon, steelhead, and Lake Trout catch rate variables but not the Walleye or Yellow Perch variable. The warmwater alternatives included Walleye and Yellow Perch catch rate variables but not the Chinook Salmon, Coho Salmon, steelhead, or Lake Trout variable.

Travel cost is a critical factor in the fishing trip decision. By following the standard approach in recreation demand models, we constructed the travel cost variable from distance, fuel cost, and angler income data. The distance from an angler's home to a fishing site was calculated using PC⋆MILER software (ALK Technologies 2010). From this, the driving cost was estimated by using a cost of $0.386 per mile, which is based on American Automobile Association (AAA) estimates for a medium-sized sedan (AAA 2009). For trips that included trailering a boat, we used a driving cost of $0.526 per mile, which is the AAA estimate for a large sedan plus $0.05 per mile to account for reduced gas mileage due to the trailer. For the time cost of the trip, we calculated a wage rate. Assuming that an angler's income was the midpoint of the income range indicated in the questionnaire (because there was no midpoint in the highest income category, we assumed an income of $200,000 for that category), we devised an hourly wage rate as the income divided by 2,000, which is approximately the number of hours worked in 1 year. For anglers who did not report their income, the household median income from the Census 2000 ZIP code tabulation area was used. For anglers who reported being unemployed, we assumed a wage rate of $7.40, which is the minimum wage in Michigan. The time cost of a trip was computed as one-third the wage rate multiplied by the time spent driving (Sorg and Loomis 1986). We assumed an average driving speed of 45 mi/h. The travel cost of a trip was thus the round-trip driving cost plus the time cost. Descriptive statistics for this variable are presented in Table 2.

The model also included a set of variables that measured the presence of general physical features or amenities at an alternative. These variables equaled 1 if the feature was present and zero otherwise. The *highway* variable was meant as a measure of the remoteness of a site. The *bay_or_seaway* variable was intended to capture preferences for fishing in warmer, safer areas of a lake. The *urban* variable indicated whether the alternative lies in a ZIP code that the Census 2000 defined as at least partially urban, and it was used as a proxy for the availability of food, fuel, etc., at a site. The variable *warmwater* was included as a nest-specific constant in the target-species-nested model. The *warmwater* × *bay_or_seaway* interaction was used to test whether bay or seaway sites are valued differently between trips targeting coldwater and warmwater species. Finally, the lake-nested model also included nest-specific constants (i.e., dummy variables) for the different Great Lakes.

RESULTS

In the models, a fishing trip included several dozen observations, each representing a potential site that an angler could visit during a trip; the total number of observations was 102,004. Note that because the set of sites was restricted to those within 200 mi of a trip's origin, no trip included the complete choice set of 66 sites (132 alternatives). On average, there were 23 sites (46 alternatives) that an angler could visit during a day trip.

Target-Species-Nested and Lake-Nested Models

The parameter estimates showed that travel cost had the expected negative effect on the fishing site choice decision (Table 3). Both the target-species-nested and lake-nested models indicated that the probability of a trip to a specific alternative was a decreasing function of travel costs—that is, anglers tended to visit sites nearest to home. This effect was also highly statistically significant at greater than the 95% confidence level in both models.

The effect of catch rate on the site choice decision was positive for all six species in both models (Table 3), implying that an angler's probability of visiting an alternative increases with the catch rate. The estimated effects were also generally significant at a high confidence level, so we can be confident that Great Lakes anglers in Michigan do respond to changes in the distribution of fish between sites. The only exception was the effect of Lake Trout in the lake-nested model, which was not found to be significantly different from zero at any reasonable confidence level.

Several other site characteristics were found to be important in the site choice decision. Both sets of results indicated that an angler's probability of visiting an alternative increases when the site features city amenities and is accessible from a highway (Table 3). The results also indicated that a bay or seaway location has a mixed effect on site choice. The positive and significant coefficient of the *bay_or_seaway* × *warmwater* interaction revealed that warmwater trips tend to end up at sites on bays and seaways, even when controlling for observed catch rates. In contrast, coldwater trips tend to be located away from bays and seaways.

A key difference between the target-species-nested model and lake-nested model estimates lies with the parameter θ. In the target-species-nested model, the θ estimate was significantly larger than 1.0, whereas in the lake-nested model the θ estimate was significantly less than 1.0. These results imply that the nesting structure of the lake-nested model is more consistent with the observed choices of anglers—in other words, anglers tend to substitute more readily between different target species and sites within a lake than between different sites across lakes while targeting the same species.

Welfare Estimates

To demonstrate the site valuation capabilities of the model, we calculated the welfare impacts for several scenarios: a 50% decline in the catch rates at all sites for each species, a one-unit increase in the per-trip catch at all sites for each species, loss of fishing access to individual sites, and the loss of access to each Great Lake.

The welfare measures for a 50% decline in catch rates reflect the monetary loss in the value of a fishing trip if catch rates for a species were to decline at all sites by 50%. Both models identified the proportional decrease in Walleye catch rates as the most detrimental to angler welfare (Table 4). The target-species-nested model estimated a per-Great Lakes trip WTP of about $4 for Walleyes, whereas the lake-nested model estimated a WTP of about $6. The discrepancy in welfare estimates between the two models, which was particularly large for Lake Trout and Yellow Perch, is attributable to the different substitution patterns assumed between the models.

The welfare measures for a one-unit increase in trip catch reflect the added value to a fishing trip if the catch for a species increased at all sites by one fish. Following the work of Johnston et al. (2006), we assumed a fishing day length of 4 h to convert per-hour WTP into a per-trip measure. These estimates highlight the value of the coldwater species to Great Lakes anglers. Estimated angler WTP for Chinook Salmon, Coho Salmon, and steelhead ranged from $40 to $80 depending on the model and were all significantly higher than the Walleye and Yellow Perch measures, which ranged from $1–2 for Yellow Perch to $17–23 for Walleyes (Table 4). The relative WTP values were quite different from those for the proportional decrease in catch rates; this is partly due to differences in the observed catch rates. Some species tended to have very low catch rates (e.g., Coho Salmon), while others had moderate (e.g., Lake Trout) to high (e.g., Yellow Perch) catch rates.

In terms of site loss, the two models yielded WTP values that were quite similar. For the average per-trip WTP to forego the loss of access to each Great Lake (where the units were per trip to the respective lake; Table 5), both models identified access to Lake Michigan as the most valuable, with a WTP of $136–144 per trip, while the WTP for access to Lake Erie was the lowest at $37–44 per trip, depending on the model. These

TABLE 3. Results of the site choice models describing Great Lakes recreational fishing by Michigan-resident anglers (CR = catch rate; see Methods for a description of variables).

Parameter or variable	Target-species-nested model		Lake-nested model	
	Estimate	SE	Estimate	SE
Quality variables[a]				
Travel cost	−0.065	0.006	−0.028	0.001
CR, Chinook Salmon	17.909	1.430	8.907	0.744
CR, Coho Salmon	11.554	2.871	5.786	1.575
CR, Lake Trout	3.130	0.672	0.234	0.378
CR, steelhead	17.915	4.685	5.490	2.119
CR, Walleye	5.267	0.579	2.550	0.258
CR, Yellow Perch	0.366	0.086	0.254	0.036
Urban	1.348	0.186	0.524	0.062
Highway	3.217	0.565	1.323	0.196
Bay_or_seaway	−0.466	0.238	−0.850	0.091
Bay_or_seaway × *warmwater*	1.173	0.236	1.253	0.100
Nest-specific constants				
Warmwater	−0.844	0.215		
Lake Erie–Lake St. Clair			0.611	0.167
Lake Huron			0.595	0.161
Lake Superior			−0.692	0.275
Dissimilarity parameter θ	1.94	0.18	0.74	0.04
Trips (*N*)	2,233		2,233	
Observations	102,004		102,004	
Log-likelihood	−4,117.380		−4,134.302	

[a]All quality variables are significant at the 0.01 level except *bay_or_seaway* in the target-species-nested model, which is significant at the 0.05 level, and the CR of Lake Trout in the lake-nested model.

values can be used to estimate the seasonal sportfishing value of a lake for Michigan anglers as the WTP value multiplied by the total number of fishing day trips taken to the lake by Michigan residents during a season.

We also calculated the average per-trip WTP to avoid lost access to a site within each lake (Table 6). These measures reflect the access value for trips to a typical site within the lake of interest. Again, both models were generally consistent in their estimated WTP values. On average, sites in the Lake St. Clair system and Lake Erie were the most valuable, with a WTP of about $29–31, depending on the model. These values can be used to estimate the seasonal sportfishing value of a single site for Michigan anglers as the WTP value multiplied by the total number of fishing day trips taken to the site by Michigan residents over a season. Not surprisingly, the site WTP values were smaller than the lake WTP values because the geographic scope of the closure considered for an individual site is much smaller than that for an entire lake. However, while we found that lakes with many sites (e.g., Lake Huron) were more valuable on a lakewide basis, the smaller lakes (e.g., Lake St. Clair system)

TABLE 4. Michigan-resident anglers' average per-trip willingness to pay ($) from catch rate (fish/trip) changes for trips taken in Michigan waters of the Great Lakes.

Species	50% decline in catch rates		Increase in catch by 1 fish/trip		
	Target-species-nested model	Lake-nested model	Target-species-nested model	Lake-nested model	Average catch rate
Chinook Salmon	−3.70	−3.16	64.70	80.17	0.056
Coho Salmon	−0.68	−0.55	40.30	52.08	0.013
Lake Trout	−0.40	−0.04	8.35	2.11	0.056
Steelhead	−0.99	−0.50	64.73	49.42	0.017
Walleye	−3.90	−5.77	16.58	22.95	0.083
Yellow Perch	−1.49	−3.26	0.83	2.29	0.766

TABLE 5. Michigan-resident anglers' average per-trip willingness to pay ($) to forego the loss of access to a Great Lake.

Lake	Target-species-nested model	Lake-nested model
Erie	36.87	43.84
Huron	89.31	98.18
Michigan	144.33	135.52
St. Clair system	63.90	54.56
Superior	98.64	85.28

tended to contain the more valuable individual sites, although overall the values were similar across the lakes.

DISCUSSION

Overall, we found that Chinook Salmon, Coho Salmon, and steelhead are the most valuable fish to Great Lakes anglers in Michigan. Trout and salmon fisheries are known to be popular among recreational anglers (Loomis and Ng 2012), and prior studies have identified Coho Salmon, followed by steelhead and Chinook Salmon, as the most valuable fish in the Great Lakes (Johnston et al. 2006). Our results also indicate that these are the most valuable species, although we consistently estimated Chinook Salmon as being more valuable than Coho Salmon, which may reflect changing preferences among Great Lakes anglers. Our results also highlight the value of Walleyes, which had previously been identified as an important Great Lakes sport fish (Kotchen et al. 2006).

Furthermore, we found that the sportfishing values we estimated lie toward the high end of comparable estimates in prior studies. In a meta-analysis, Johnston et al. (2006) reported a mean WTP of $20 per fish, with Great Lakes salmon ranging in value from $5 to $27 per fish and Walleyes ranging from $2 to $25 per fish for trips in Michigan (these values are in 2009 dollars, which we converted from the original values [2003 dollars]). For studies that examined Great Lakes fishing trips in other states, the value of salmon ranged as high as $61 per fish, while the value of Walleyes reached $27 per fish. We found that for trips in Michigan, the values of popular Great Lakes salmon species (Chinook Salmon, Coho Salmon, and steelhead) were about $40–65 per fish (up to as much as $80 per fish for Chinook Salmon) and that Great Lakes Walleyes were valued at $17–23 per fish depending on the model. These results could imply that sportfishing values for Great Lakes species have increased in recent years.

TABLE 6. Michigan-resident anglers' average per-trip willingness to pay ($) to forego the loss of access to a site in one of the Great Lakes.

Site	Target-species-nested model	Lake-nested model
Lake Erie site[a]	31.14	28.68
Lake Huron sites	29.69	26.64
Lake Michigan sites	29.93	26.76
Lake St. Clair system sites	31.15	28.81
Lake Superior sites	29.72	26.83

[a]Lake Erie contains only one site, so the per-trip willingness to pay values reported in Tables 5 and 6 are both valid measures of the access value for Lake Erie. The difference in estimates is attributable to using the individual covariates to calculate the probability of visiting a site (Table 5) versus the observed sample probabilities of visiting a site (Table 6). See Haab and McConnell (2003).

Although the two models made qualitatively similar predictions, there were discrepancies between the precise WTP estimates, so the choice of model could have important implications for valuation. One method of model selection is to choose the model with the lowest likelihood value (Table 3), thereby effectively selecting the model that best fits the observed data. Based on this method, the target-species-nested model would be the preferred model. However, the target-species-nested model does not satisfy the condition that θ should lie between 0 and 1. This indicates that the nesting of fishing alternatives by the target species categories may be invalid and that anglers may just as readily substitute between alternatives in the coldwater and warmwater categories as between alternatives within a single category. On the other hand, it is possible that the estimate of θ in the target-species-nested model is poor. For comparison, Jones and Lupi (2000) estimated a θ value slightly above 1.0 in a similar Great Lakes target-species-nested model.

In contrast, the lake-nested model yielded evidence that anglers are, *ceteris paribus*, more willing to substitute between alternatives within a single lake than between alternatives in different lakes. This is because the θ estimate in the lake-nested model was less than 1.0, and the structure of the model then implies that alternatives within the same lake substitute for each other better than alternatives in different lakes.

We therefore do not rule out either of the two models. To be cautious, when applying the WTP estimates, the more conservative value between the two models can be used. Nonetheless, the substitution pattern embedded in the lake-nested model may offer a valid insight into angler preferences: our findings from the lake-nested model indicated that anglers have a tendency to substitute between species at a Great Lake if it means that they can continue fishing in their preferred lake.

It is important to note that the fish values we report here are subject to the quality of the catch data employed in the model. We chose to use catch rates derived from MDNR creel data, which were collected separately from our survey of anglers. The advantage of creel data over the catch reported in angler surveys is twofold. First, the creel data are collected on-site, minimizing recall bias. Second, the sample sizes of the MDNR creel data are several times greater than our own, thus minimizing problems with measurement error in the catch rate variable (Morey and Waldman 1998). Indeed, the creel survey was designed to include data on trip catch for which our angler survey would have low coverage—that is, for sites and months of the year that receive relatively few fishing trips. A shortcoming of the catch data, which is in fact a permanent concern in recreational fishing site choice modeling, is that the estimated catch rates could differ from the catch rates expected by the anglers in our sample. Nevertheless, given the strong identification of the catch effects in both of the site choice models, our results appear to be robust.

These results apply to a subpopulation of Great Lakes anglers. Specifically, the models were estimated from a sample of day trips to Great Lakes destinations within Michigan that were taken by in-state residents for the purpose of fishing, which is representative of about half of all fishing trips to Great Lakes destinations in the state. Naturally, we recommend caution in applying our reported WTP estimates to other types of fishing trips, including trips taken by out-of-state residents, multiple-day trips, and trips to sites other than those in the Great Lakes.

Conclusions

We presented two RUM models of Great Lakes anglers' site choice in Michigan, and we found that fishing trip decisions are strongly influenced by the catch rates of the most popular Great Lakes fish species. In terms of measuring economic benefits, the models were generally in agreement but did occasionally yield divergent estimates. It is unclear *ex post* which RUM model is preferable. By comparing the models, though, we did find evidence that anglers' observed target species and fishing site are partly driven by their preference for fishing a particular Great Lake.

It is critical that our understanding of Great Lakes recreational activities be kept up to date—a factor that motivated the present work, which focused on recreational anglers. Our results indicated that values for fish, particularly for salmon, may have increased over the past decade for Michigan anglers fishing in the Great Lakes. However, our sample was composed of Michigan anglers who went on day trips to Great Lake sites in Michigan, so our results reflect only a subgroup of all Great Lakes recreational fishing trips. Work remains to be done on the multitude of other Great Lakes fishing sites, multiday trips, and other Great Lakes recreational activities. Nevertheless, with these estimates we can at least set an important lower bound on the recreational value of fisheries in Michigan waters of the Great Lakes.

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