The Welfare Effects of Toxic Contamination in Freshwater Fish

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ABSTRACT. *Very little study has been made of the welfare cost of toxic contamination in freshwater fish, primarily because appropriate data sets have not been available. This paper estimates the benefits of removing toxic contamination from New York State water bodies by linking the Environmental Protection Agency's Aquatic Based Recreation Survey with water-quality data from the New York Department of Environmental Conservation. Using a repeated discrete choice model of fishing behavior, we find that the elimination of toxic contamination from New York lakes and ponds would generate an annual benefit of about $63 per capita, per season.* (JEL Q22)

I. INTRODUCTION

It has long been known that fish are storehouses of various kinds of toxic contaminants that run off into oceans, lakes, rivers, and streams. These toxic contaminants can pose a significant health hazard to anyone eating affected fish, sometimes even when consumed in small quantities. This issue is of sufficient concern that the Environmental Protection Agency (EPA) is currently developing a Great Lakes Water Quality Initiative specifically targeted toward toxic pollutants in the Great Lakes basin. Though there have been a number of studies attempting to value the benefits from various forms of water quality improvements, little effort has been made to value the elimination of toxic contamination, primarily because an appropriate data set is difficult to develop.

This paper attempts to estimate the benefits resulting from the removal of toxic contamination from lakes and ponds in New York State, using a 1989 survey of freshwater anglers conducted in support of the National Acid Precipitation Assessment Program (NAPAP). We make the valuation of eliminating toxics by linking the NAPAP angler data with lake-specific water-quality information provided by New York's Department of Environmental Conservation (NYDEC) (1987, 1990, 1991). Our methodology is the repeated discrete choice model used by Morey, Rowe, and Watson (1993) for valuing recreational amenities. We find that toxic contamination significantly affects an angler's choice of fishing site, and that the estimated value of eliminating toxic contamination in all sites for one season amounts to about $63 per New York resident. This estimate may be upward biased as we discuss below.

A number of previous studies have analyzed the economic value of sports fisheries and their change in value when water quality improves. (Bockstael, McConnell, and Strand [1989] and Cameron [1988] are recent examples.) For sportfishing, however, toxic contamination represents an interesting special case of a pollution problem, one that until now has not been addressed in the published literature. There are two primary differences between toxic contamination of fish and other problems examined in the literature on demand for recreational fishing. First, models of the effect of changing water body attributes (e.g., pollution levels) on sportfishing behavior tend to assume that these attributes affect anglers mainly by reducing the rate at which they are able to catch fish. (For example, in his review of the literature for marine fishing, Freeman [1993] cites 27 studies that incorporate some measure of catch rate or abundance.) In most

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cases it is reasonable to assume that water pollution affects anglers via the catch rate; more pollution means fewer fish caught or more time spent catching them. Toxics are no exception; at high doses they can impair propagation and survival. But toxic contaminants in fish become dangerous to humans eating fish before they become dangerous to the fish themselves.[1] Officials at the NYDEC report that toxicity levels in New York appear to have had little effect on the size of fish populations in state water bodies.[2] The toxic contamination problem (in New York, at least) is generally less about *how many* fish can be landed than about whether they can be eaten once caught. It is hard to predict *a priori* how much this will matter to anglers—they may never have intended to eat the fish anyway.

Another reason why toxic contamination is especially interesting from a policy perspective is that the fishing public—again, at least in New York—is better informed about this issue than about other kinds of water pollution. The reason is simple: each recipient of a fishing license is given a pamphlet called the *Fishing Regulations Guide* which displays a health advisory about toxic contamination at various fishing sites. The toxicity warnings are right inside the front cover. Also the NYDEC warns about contaminated fishing sites in brochures and news releases. This puts the issue of contaminated fish in interesting contrast to most other forms of water pollution like eutrophication, acidic deposition, or chemical spills. In the latter case, the angler is less aware of the exact nature of the pollution in the water, but is influenced by it through the rate of fish catch. In the former case the angler is aware that a pollution problem exists, but catch rate may well be unaffected. This makes the issue an interesting and important one to analyze empirically.

The next section of this paper reviews previous attempts to account for water quality in models of demand for recreational fishing and contrasts them to the method used here. Section III provides a brief sketch of the econometric method. The following two sections, IV and V, describe our data sources and our empirical results, respectively. In a final section, VI, we summarize our findings and suggest further work to be done on this topic.

II. INCORPORATING MEASURES OF WATER QUALITY INTO THE MODEL

The economic literature on how anglers value fishing opportunities is an extensive one. In a literature review Walsh, Johnson, and McKean (1988) identify more than 50 studies of freshwater fishing alone. Freeman (1993) reviews 30 studies of saltwater fishing. However, all but a handful of the previous studies have a serious limitation in terms of their usefulness in analyzing water-pollution policy: they have no direct measures of water quality. In the case of New York, for example, Mullen and Menz (1985) did an interesting study of the effect of acidification on the economic value of New York's Adirondack fisheries. But they were unable to include any actual measures of lake acidification.

Five recent studies of sportfishing did employ some measures, at least indirect ones, of water quality. Kaoru and Smith (1990), Kaoru (1991), Smith (1993), and Kaoru (1995) all use data from a 1981–82 survey of users of the Abermarle and Pamlico Sound in North Carolina. These studies included three measures of water pollution, all indirect, that is, not measured from the water bodies themselves. The first two were phosphorous and nitrogen contamination, estimated from loadings of these chemicals in local counties. The second two were biological oxygen demand and total suspended solids, based on data from local municipal water treatment plants. Using these proxies for water pollution levels, Kaoru (1995) estimated the effect of a 25 percent improve-

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[1] In the scientific literature, Leatherland (1993), for example, reports that, "The evidence in support of contaminant-related dysfunction states in Great Lakes fish is not as convincing as in fish-eating mammals and birds."

[2] The authors are grateful to Jay Bloomfield, Chief of Lake Management, NYDEC, and Ron Sloan, Research Scientist, Division of Fish & Wildlife, NYDEC, for consultation on this issue.

ment in all four pollution variables to be \$2.58 (in 1982 dollars) if the catch rate were unadjusted, and \$2.77 if the catch rate were adjusted. Only Parsons and Kealy (1992) include direct water quality data actually drawn from the water bodies. Their model of fishing in Wisconsin lakes and ponds included a measure of whether dissolved oxygen was high or low, and a dummy for whether water clarity was high. They estimate that improving all lakes to a "high standard" of dissolved oxygen and water clarity yields average benefits per angler of \$1.64 per choice occasion (i.e., per day of potential fishing).[3]

Without direct measures of water quality, most studies rely on variations in either the catch rate, or fish abundance, to capture all water quality variation that affects the fishing experience. For example, Freeman (1993) cites 26 studies of marine fisheries that measure the value of additional fish catch. But a serious limitation of using catch rates to measure water quality is the difficulty of linking catch rates back to water quality variables which are relevant for policy. To predict the effect of, say, reducing pollution on angler welfare, we first need to know the effect of pollution on the catch rate—information the analyst rarely has. Also, as noted above, for the current study, a limitation of using catch rate as a measure of water quality is that for the toxicity problem it may be irrelevant. The toxicity levels observed in New York State are generally not high enough to much affect fish propagation or survival. For our study it is necessary to have direct measures of the water quality problems in the whole range of fishing sites. A very extensive effort was made, therefore, to link independent water quality data from all potential lakes to the survey that provided the angler data for this study.

The primary policy variable used in this study is whether the lake in question is considered by the New York Department of Environmental Conservation (NYDEC) to have a toxic contamination problem. Since all such lakes are reported by the NYDEC, we have this information for both sites that were, and sites that were not, visited by anglers in our survey. The binary nature of this variable gives us an easily interpretable policy result: we estimate the value of eliminating toxic contamination to the point where fish are safe enough that no toxicity warning is issued. This variable alone, however, will not sufficiently control for water quality to allow us to estimate an acceptable model: toxic contamination may be correlated with lake characteristics that affect the fishing experience. Fortunately, NYDEC provided data on a wide array of lake and pond attributes, including other measures of pollution problems. These are described in the data section.

III. THE MODEL

In this section we briefly describe the repeated discrete choice model used to estimate the changes in welfare associated with eliminating toxic contamination in New York fish. The model applies a technique developed by Morey, Rowe, and Watson (1993). The estimation proceeds in three steps. First we estimate a site-choice model which determines the impact of water quality and other lake characteristics on choice of a fishing site among the J potential sites. From the results of the site-choice model we calculate the value to each individual of having available these J sites. That value, the so-called inclusive value, is then included in a second model: one predicting whether a particular New York resident will decide to fish on a given day. Finally, from the coefficient estimates of the fishing-decision and the site-choice model we calculate the welfare impact of altering the inclusive value by changing water quality.

The first stage of estimation, the site-choice model, employs the Random Utility Model (RUM) which was formalized by Manski in 1977. The RUM approach assumes that the utility, U^F, associated with a

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[3] The Parson and Kealy (1992) high standard was that dissolved oxygen in the hypolimnion was maintained at 5ppm at all times and water clarity was maintained at 3 meters or greater for all lakes. For perspective, note that approximately 5 percent of lakes met the dissolved oxygen criterion and 30 percent met the water clarity criterion.

fishing trip to site j by angler i is given by

$$U_{ij}^F = V_{ij}^F + \varepsilon_{ij}^F \qquad [1]$$

where V^F is an observable portion of utility and ε^F an unobservable portion. (The F stands for "fishing".) It is standard in RUM models to assume that V_{ij}^F is a linear function of (i) site characteristics X_j, (ii) the income available for recreation on a given day, M_i, and (iii) the cost, or "price," of visiting site j, which we call P_j.[4] That is,

$$V_{ij}^F = \beta_M(M_i - P_{ij}) + \beta_X X_j. \qquad [2]$$

We assume, following Morey, Rowe, and Watson (1993), that the errors in equation [1] follow a Type 1 Extreme Value distribution across individual anglers. From [2] we estimate the conditional probability that angler i, having decided to go fishing on a given day, will choose site j. Unfortunately, when the number of potential sites, J, is large, the problem of estimating the two-stage maximization likelihood model becomes extremely cumbersome. In our sample, the average angler had more than a thousand alternative fishing sites within a three-hour drive of home. Fortunately, Parsons and Kealy (1992) show that the process of estimation can be greatly simplified without introducing any bias, if we replace the individual's *actual* opportunity set of lakes with a *representative* set drawn from the full group of potential sites. Following Parsons and Kealy, we estimated our site-choice model using 12 lakes for each angler. That is, for each angler, we include the chosen lake plus 11 lakes selected at random and without replacement from the group of lakes within three-hours drive of the individual's home.

Using the coefficients of the site-choice model, we calculate the inclusive value, I_i, which represents the maximum expected utility an individual receives given that he/she decides to take a trip:

$$I_i = \ln \sum_{j=1}^{J} e^{\mu\beta_X X_{ij} - \mu\beta_M P_{ij}}. \qquad [3]$$

In [3] μ is a scale parameter indicating that (at this stage) β_M and β_X can only be estimated up to a proportion of their true value. Note that we calculate an inclusive value for all sample members (not just the anglers), using all sites in their individual choice sets (not just those randomly sampled to estimate the site-choice model).

The second estimation step is to model an individual's decision whether to go fishing at all on a given day. We assume that the utility of not fishing is defined by

$$U_i^N = V_i^N + \varepsilon_i^N \qquad [4]$$

where, as above, V and ε stand for the observable and unobservable components of utility, respectively. (The N stands for "not fishing".) Consistent with the assumptions made above, we allow V_i^N to be a linear function of income available for recreation, M_i, and of other individual characteristics, Z_i, which might influence the decision whether to fish on a given day. That is,

$$V_i^N = \beta_M M_i + \beta_Z Z_i. \qquad [6]$$

Morey (1994) shows that, given individual attributes Z_i, the probability that an individual will go fishing on a given day—call it Pr_i (*fish* = 1)—is equal to

$$Pr_i(fish = 1) = \frac{e^{\frac{1}{\mu}I_i}}{e^{\frac{1}{\mu}I_i} + e^{\beta_Z Z_i}}. \qquad [7]$$

The coefficients $1/\mu$ and β_Z are estimated from a binomial logit model of the fishing decision using the full sample of anglers and nonanglers.

Once the model described above has been estimated, we take the third estimation step: calculating the welfare effects of improving water quality by allowing changes in site characteristics X_j to influence the inclusive

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[4] It is the nature of the RUM the utility V_{ij} is uninfluenced by any attribute that does not vary across sites. This also implies that income M_i drops out of the model. It is included in equation [2], however, to emphasize the important point that parameter β_M is actually the marginal utility of income.

value, I_i. Hanemann (1982) shows that assuming zero income effects, the compensating variation for individual I on a given day caused by an improvement in water quality, call it CV_{it}, is given by

$$CV_{it} = \frac{\ln(e^{\frac{1}{\mu}\hat{I}_i^2} + e^{\hat{\beta}_Z Z_i}) - \ln(e^{\frac{1}{\mu}\hat{I}_i^1} + e^{\hat{\beta}_Z Z_i})}{\hat{\beta}_M} \quad [8]$$

where I_i^1 and I_i^2 are inclusive values calculated with and without the water quality changes, respectively, and the hats indicate that all coefficients are estimated values. Recall that β_M is the coefficient of price in the site-choice model (after being scaled by $1/\mu$) and represents the marginal utility of income.

Because CV_{it} applies to one individual on one day, to get the seasonal welfare effect from the change in water quality we aggregate CV_{it} across all days in the season to get an individual's seasonal welfare change. Then we take the average of these seasonal changes across all individuals in the sample to get a sample average of seasonal per-capita welfare change. Next we discuss the data needed to implement this model.

IV. THE DATA

In this section we describe the data used to estimate our model using a sample of New York residents who may or may not have fished in New York State lakes and ponds. Estimating the model described in the previous section requires three distinct types of data:

- Personal information about individuals who were potential anglers,
- Information about characteristics of the lakes and ponds that were possible fishing sites,
- Travel distances (and travel times) between each angling candidate's hometown and each possible fishing site (used in the measure of the price of a visit).

We will consider each of these in turn.

Data on Individuals

The data on fishing behavior among New York residents were taken from a survey conducted in 1989 by Pacific Northwest Laboratories at the behest of the U.S. Environmental Protection Agency. The survey—referred to here as the Aquatic-Based Recreation Survey (ABRS)—was part of the National Acid Precipitation Assessment Program (NAPAP) which studied acidic deposition in four northeastern states: New York, New Hampshire, Maine, and Vermont. Using a stratified random sample of 5,724 households in the four states mentioned, the survey collected data on demographic characteristics and water-based recreation behavior. Among the 3,432 New York residents in our estimation sample, some 266 made one or more trips to an identifiable lake or pond between mid-April and October of 1989. For people who had gone fishing, information was collected on each visit to each site during the target season. In this paper we confine our analysis to fishing trips of no more than a single day in length. We exclude overnight fishing trips which are generally regarded in the literature as fundamentally different, in terms of behavior and value to the angler, from day trips.

Table 1 reports descriptive demographic statistics for sample members who did, and who did not, go fishing during our study period, respectively.

Data on Potential Fishing Sites[5]

Measuring the impact of water quality on the behavior of anglers requires information about both sites our survey respondents visited, and sites they *could have* visited but did not. We therefore required data on all sites within a three-hour drive of home.[6] The basic source of data on New York wa-

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[5] In our study a site differs from a lake in that large lakes in the state, including Great Lakes Erie and Ontario, were divided up into segments, each associated with a particular town, as explained below.

[6] We chose three hours as the cutoff because few anglers taking day trips traveled more than three hours from home.

TABLE 1
MEANS OF DEMOGRAPHIC VARIABLES

	Anglers $N = 266$			Non Anglers $N = 3{,}013$		
Variable	Mean	Min	Max	Mean	Min	Max
Age	38	18	75	42	18	99
Income (ln)	35,908	5,000	175,000	37,374	5,000	300,000
College Graduate (dummy)	0.29	0	1	0.34	0	1
High School Grad (dummy)	0.35	0	1	0.30	0	1
Male (dummy)	0.62	0	1	0.34	0	1
Kids (5–16) at home	0.72	0	6	0.50	0	6
Works Part-time (dummy)	0.08	0	1	0.13	0	1
Works Full-time (dummy)	0.68	0	1	0.53	0	1
Not Employed (dummy)	0.21	0	1	0.32	0	1
Student (dummy)	0.02	0	1	0.03	0	1

ter bodies is the New York Department of Environmental Conservation (NYDEC). We obtained information from a number of databases which NYDEC collects and maintains. In New York much more (and more consistent) data are available for lakes and ponds than for rivers and streams. This fact, and the difficulty of matching angler-reported fishing sites with locations along a given river or stream, forced us to confine this analysis to lakes and ponds in the state.[7]

The State of New York has more than 7,500 lakes and ponds. Of these, some 3,100 —all those of more than .01 square miles in area—are listed in the NYDEC's *Characteristics of New York State Lakes*: *Gazetteer of Lakes and Ponds and Reservoirs* (hereinafter called the *Gazetteer*). The water bodies in that document form the basic set of potential fishing sites for anglers in our ABRS sample. The *Gazetteer* gives such physical descriptions as latitude and longitude, surface area, elevation, and shoreline. It also classifies each lake or pond by the water quality class which NYDEC considers the best use of the water body (called the designated use). The best use designations reflect a number of factors that NYDEC considers relevant in determining appropriate use of the water body, including location and accessability as well as water-quality factors. We aggregated the designated uses into four categories of declining usefulness for human consumption: (i) the water is suitable for all uses; (ii) suitable for all uses but drinking; (iii) suitable for all uses but drinking or swimming; (iv) suitable for all uses but drinking, swimming, or fishing. In addition to assigning a best use category, the *Gazetteer* indicates whether a given water body is suitable for the propagation of trout. We included an additional dummy for this designation.

Next we consider our direct pollution variables. Pursuant to Section 305(b) of the 1977 Amendments to the Federal Clean Water Act, states are required to monitor and report water-quality problems in their respective jurisdictions. The 1990 version of New York's published water-quality assessment, which we call the 305b Report, is a second key source of data about the sites in our study. The report contains water-quality information gathered in 1988, the year before our angler survey was taken. From the 305b report we identified sites that were reported to have one of two key water-quality problems: reduced pH (elevated acidity) or toxic contamination. NYDEC puts acidified lakes—lakes in which fish have more difficulty propagating—into two categories: pH threatened (pH from 6.0 to 7.0) or pH impaired (pH less than 6.0). About 6 per-

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[7] The implication of not including rivers and streams in the analysis is that to the extent that river and stream fishing acts as a substitute for lake and pond fishing, we will be overstating the benefits of improving the water quality in New York's lakes and ponds.

cent of our potential fishing sites were threatened and another 5 percent were impaired.

As stated in the introduction, toxic contamination of fish is reported to the angling public by the NYDEC. The inside cover of the New York State *Fishing Regulations Guide* contains a list of health advisories regarding toxic contamination of fish in state water bodies. For any problem site, the advisories identify the species of fish implicated and one of two levels of warning: eat none of the fish caught, or eat no more than one per month. Our data on toxicity come mainly from the fishing regulations for 1991–92. We then supplemented this list with 1988 data from the list of bodies reported in the 305b Report as having toxic-impaired usage. Though relatively few members of our set of potential fishing sites had toxic advisories—about 23 out of more than 2,500—some of these were on large and prominent lakes such as Lake Ontario and Lake Champlain.

A final source of site characteristics was a list of which lakes were stocked with fish, and with which species, by the NYDEC.

Table 2 gives descriptive statistics for the water-quality variables used in this study.

Measuring the Price of Visits to Sites

A key variable in the site-choice model is the "price" an angler must pay to visit any potential fishing site. The literature on valuation of environmental commodities recognizes travel cost (including the opportunity cost of time involved) as the best measure of this important variable. The RUM requires that for each person in the sample we measure the travel cost to *all* potential fishing sites, that is, to all lakes and ponds which would make feasible day trips. To estimate these travel costs we used a software package called Hyways/Byways which computes travel times between members of a large set of cities and towns in New York State. The

TABLE 2
DESCRIPTIONS OF THE LAKE SITES (TOTAL SITES = 2,586)

Acidity:	Non-Acidic	Acidic		
	2,299	287		
		Threatened	Impaired	
		153	134	
Toxics:	No Toxic Species	Some Toxic Species[a]		
	2,561	23		
		One per Month	Eat None	
		14	9	
Designated Best Use by NYDEC:	All Uses	All Uses but Drinking	All Uses but Swimming or Drinking	All Uses but Swimming, Drinking, or Fishing
	470	534	858	724
Suitable for Trout:	Yes	No		
	550	2,036		
Stocking:	Stocked	Not Stocked		
	371	2,215		

[a] The NYDEC Fishing Guide has two kinds of warnings: "Eat no more than one fish per month" and "Eat none" for each contaminated species. We classify a site as having an "Eat none" designation if it does so for any species.

towns recognized by this program are called "mapped towns," and we identified the closest mapped town to the residence of each member of our sample, and the closest to each lake or pond in the *Gazetteer*.[8] This was used to create a matrix of travel times associated with each person-site combination. Multiplying travel time by a proxy for the individual's hourly wage gives the opportunity cost of travel. We add to that the direct cost of travel (measured at $.25 per mile) to get the price of a visit.[9]

V. ESTIMATION RESULTS

In Table 3, we present the results from the RUM site-choice models. There are three versions of the model. In Model 1 we include the basic dummy for toxic contamination and separate dummies for pH Impaired and pH Threatened. With Model 2, we add the pH Threatened and pH Impaired variables together to get a single dummy indicating pH less than 7.0. In Model 3 we add in a dummy for the more extreme toxicity warning "Eat None," (of the fish caught) as opposed to the normal "Eat No More Than One Per Month."

Nearly all of the estimated parameters in the RUM models have the expected signs, and most key variables are significant. The price coefficient (cost of travel to the site) is negative and extremely significant in all models. In all three models the water-quality coefficients: pH Threatened, pH Impaired, Acidity, and Toxic Contamination, have the expected negative signs. Toxic Contamination is highly significant in all three models. Acidic damage is also significant when we combine pH Threatened and pH Impaired into a single variable. The Eat None dummy in Model 3 has an unexpected positive coefficient which is significant. Because there are fewer than 10 lakes with this designation, we expect that this dummy is picking up unobserved lake-specific characteristics.

Note that in Models 2 and 3 the coefficient on the acidity dummy (pH Threatened or Impaired) is larger than that on toxic contamination. This suggests that acidic pollution, which reduces fish catch, provides a stronger deterrent to visiting a site than does the fact that fish at the site, once caught, may be somewhat dangerous to eat. This result is not surprising.

The sign and significance levels of the Designated Use coefficients indicate that when water quality declines from the potable level the attractiveness of the lake as a fishing site also declines. Not surprisingly, being designated as suitable for trout makes a lake more attractive as a fishing site. (Recall that the suitable-for-trout dummy is turned on in addition to the designated use.) The variables representing other lake characteristics—surface area, the fish-stocking dummies, presence of a boat ramp, presence of a state park—are almost all significant and have the expected signs.

Table 4 presents the results for the models of whether to go fishing during the season. There are two models, one with income and one without income. In both models the coefficient on the Inclusive Value is positive and highly significant. All other variables in the model are significant except Works Part-Time.

The final step in estimating the benefits from the elimination of toxic contamination is to take the results from Table 4 and calculate compensating variation measures (via equation [8]). We estimate compensating variation (CV) for eliminating toxic contamination in all New York lake sites. For purposes of comparison we also calculated CV values for eliminating acidic impairment. In all, three policy scenarios are generated:

1. Eliminate toxic contamination in all lakes,
2. Raise pH in acidic lakes so that none is threatened or impaired,
3. Carry out scenarios 1 and 2 together.

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[8] For a number of the smaller lakes in the *Gazetteer* we were unable to find mapped towns because we failed to locate the lakes on maps. This reduced our set of potential sites to 2,586.

[9] See Bockstael, Strand, and Hanemann (1987), McConnell and Strand (1981), and Milon (1988) for discussions on different approaches to valuing travel time and distance.

TABLE 3
RANDOM UTILITY MODELS OF SITE CHOICE

Variable	Model 1		Model 2		Model 3	
	Coef.	*T*-Stat.	Coef.	*T*-Stat.	Coef.	*T*-Stat.
Price	−0.08	−37.37	−0.08	−37.38	−0.08	−37.49
Water Quality						
Some Toxic Species	−1.35	−7.73	−1.35	−7.25	−1.93	−8.26
Extra Warning: Eat None[a]					1.35	4.04
Threatened by Acidity	−12.23	−0.09				
Impaired by Acidity	−1.60	−1.57				
Threatened or Impaired			−2.68	−2.62	−2.71	−2.64
Designated Best Use						
All Uses but Drinking	−1.08	−10.95	−1.08	−10.96	−1.10	−11.08
All Uses but Drinking or Swimming	−1.72	−10.10	−1.72	−10.10	−1.69	−9.79
All Uses but Drinking, Swimming, or Fishing	−1.14	−7.94	−1.15	−7.99	−1.12	−7.76
Also Suitable for Trout[b]	0.57	4.16	0.58	4.20	0.49	3.48
Physical Characteristics						
Shoreline in New York (ln)	0.43	16.11	0.43	16.10	0.04	16.31
State Park on Lake	1.20	11.19	1.20	11.19	1.12	10.03
Boat Ramp on Lake	1.30	11.75	1.30	11.75	1.38	12.23
Stocked	1.26	15.23	1.26	15.21	1.30	15.15
Chi-square (d.f.)	10,322.4	(12)	10,320.2	(11)	10,366.5	(12)
N	5,028		5,028		5,028	

[a] The "Eat None" dummy is turned on in addition to the "Some Toxic Species" variable.
[b] The "Also Suitable for Trout" dummy is turned on in addition to the "Designated Best Use" dummy.

TABLE 4
LOGIT MODELS OF WHETHER TO GO FISHING

Variable	Coeff.	*T*-Stat.	Coeff.	*T*-Stat.
Inclusive Value	0.291	14.24	0.313	15.42
Age	0.080	14.49	0.073	13.38
Age Squared	−0.001	−14.06	−0.001	−12.91
Income (ln)	−0.199	−8.93		
College Graduate	−0.591	−16.12	−0.660	−18.42
High School Graduate	0.062	2.01	0.061	1.99
Male	1.331	44.22	1.331	44.11
Kids (5–16) at home	0.146	9.97	0.143	9.73
Works Part-time	0.027	0.55	0.064	1.29
Not Employed	0.162	4.22	0.221	5.85
Student	0.488	5.95	0.509	6.21
Constant	−6.352	−22.87	−8.371	−51.40
N	4,124[a]		4,124	
Chi-squared (d.f.)	3,195.4	(11)	3,117.4	−10

[a] There are more observations than sample members because for computational reasons, for anglers each observation is site-specific. In the likelihood function, however, all observations are weighted by number of visits.

To better place these numbers in context we also calculate two additional alternative scenarios: that all toxic lakes are closed to fishing, that all acidic lakes are closed to fishing. Finally, for comparison with earlier studies, we calculate the welfare cost per trip. The coefficients used in the calculation of the CVs are those from Model 2 in Table 3 and from Model 1 in Table 4.

Table 5 reports the welfare effects we calculate from the successful implementation of the policies listed above. For elimination of toxicity problems we predict a per-capita compensating variation of $.45 per day.[10] This means that if toxic contamination were eliminated from New York lakes and ponds, people, on average, would value an additional day's fishing about 45 cents more on average. If we were to expand this effect to an entire season, we get a benefit of $63.25 per person.[11] This is a substantial effect. Indeed, the discouraging effect of the toxicity is about three-fourths of the effect of closing the sites to fishing.

Note the interesting contrast with eliminating acidity. That would generate only $.10 per capita for one day or $13.82 for one season. It is instructive that the estimated benefit of eliminating the acidic impairment in New York is smaller than that for toxic contamination even though many more lakes suffer from the former problem than the latter. This may seem odd in light of our observation from Table 3 that acidity had a larger effect on site choice than toxic contamination. Indeed, Table 5 suggests that the welfare loss from acidity is nearly as large as the loss from closing the sites altogether, which suggests that the acidity effect on fishing desirability is quite large.[12] Why, then, is the total, welfare effect smaller? Recall that in Table 3, the site choice model, other lake characteristics were held constant. The figures in Table 5 take into account the location of the polluted lakes; acidity occurs mainly in high-altitude lakes in the Adirondack region, while toxicity is common to urban and industrial areas. Thus toxicity is likely to be a more serious problem in that it arises in lakes close to where many people live—people who might enjoy fishing more if the water were less polluted.[13]

One further comment should be made about the results for acidity. Almost all of our acidified lakes are in the Adirondack Region. In an earlier study, Mullen and Menz (1985) estimated the benefits of eliminating acidic damage in the Adirondacks at about one million dollars per annum. Our results imply a much higher figure: more than ten times that amount. We attribute the difference to the fact that Mullen and Menz had no direct measures of acidity in the lakes. This illustrates the importance of having good measures of water quality if our recreation demand models are to be useful for policy.

Some Caveats About These Results

There are several reasons to expect that our estimates of the welfare effects of toxicity are biased. The first reason has to do with how we measure a lake site. Each lake site in our study is associated with a mapped town that can be identified by the Hyways/Byways distance-measuring program. Large lakes are broken up into multiple sections, each section, or site, associated with a town. Because of this sectioning of large lakes,

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[10] The compensating variation estimator is a nonlinear combination of random variables, and is therefore itself a random variable with a standard error. This standard error can be estimated using a technique developed by Krinsky and Robb (1986). However, this technique requires the retention of the variance-covariance matrix. Unfortunately, the only way to obtain this matrix in our model is to estimate using the FIML approach which, as we explained earlier, is infeasible given the number of alternative sites.

[11] The per-capita benefits estimate is taken across all individuals in our sample, both participants and nonparticipants. The benefits to nonparticipants come about only as a result of an increase in their probability of taking a fishing trip. The model does not capture non-use benefits.

[12] It should be noted that the fact that the acidity effect is nearly as large as the effect of closing the sites may suggest that the model is picking up some other unobserved characteristic of these lakes.

[13] It should be noted that to the extent that our toxic variable is picking up other disamenities associated with being near urban centers, we will be overestimating the benefits of removing toxic contamination from the water. Rural lakes may be more pleasant to visit.

TABLE 5
ESTIMATES OF THE WELFARE COST OF WATER QUALITY PROBLEMS

Problem	Compensating Variation per Trip	Compensating Variation per Capita per Day	Compensating Variation per Capita per Season
Toxic Contamination	$1.51	.45	$63.25
Toxic Sites Closed to Fishing	2.08	.62	87.09
Acidity (threatened or impaired)	.32	.10	13.82
Acidic Sites Closed to Fishing	.34	.10	14.85
Toxic Contamination plus Acidity	1.89	.56	79.44

some of our "sites" on lakes Ontario and Champlain that we designate as toxic are actually larger than the portion of the lake that is really contaminated. For example, the *Fishing Regulations Guide* warns of toxic contamination in fish in "Lake Ontario, and the Niagara River below the falls," meaning a section of Lake Ontario near Buffalo. Our methodology requires that we call the entire section of Lake Ontario within a few miles of Buffalo to be contaminated. In this, and a few other cases, the limitations of our measurement of a "site" exaggerate the extent of contamination along these large lakes. This would tend to bias downward the toxicity coefficient in the RUM models: anglers who appear to be visiting a toxic "site" are actually visiting a nearby location that isn't toxic, so toxicity seems to act as less of a deterrent.

Another potential source of bias (but in the opposite direction) is in the way we measure seasonal welfare. As Bockstael, McConnell, and Strand (1989) have pointed out, a limitation of the nested logit model is that it treats every day of the fishing season as a potential day of fishing. For most people this exaggerates the number of actual choice occasions; they may only be able to fish on vacation or on weekends. Because of this, our measures of compensating variation per season may be biased upward. Similarly, our model assumes that each daily fishing decision is independent of the others. This may be untrue: if the marginal utility of fishing declines with the level of activity, fishing on one day will reduce the probability of fishing the next. Again, this could bias our seasonal welfare calculations upward, by exaggerating the number of potential fishing days.

A final source of potential bias with these calculations is our failure to include alternative types of water bodies. Even though this study offers a much more comprehensive set of alternative fishing sites than most recreational fishing studies (our inclusive values include more than a thousand lakes for the average angler), we were unable to account for rivers and streams, or for lakes and ponds in nearby states. To the extent that these alternative sites—particularly, rivers and streams in New York—are substitutes for New York lakes, our welfare measures may overstate the benefits of cleaning up toxics in lakes and ponds. In view of these several caveats, we suggest that the reader view our welfare measures as approximate upper bounds. Even as such, however, our results show that the benefits from cleaning up toxic contamination in freshwater fish would be of great benefit to freshwater fishers in New York.

VI. CONCLUSIONS

In this paper, we attempted to estimate the benefits resulting from the elimination of toxic contamination found in freshwater fish in New York State. It is one of a very few studies of recreational fishing to use direct measures of water quality in a site-choice model. Our repeated discrete choice model of fishing behavior suggested that these benefits are significant. Holding travel costs and other aspects of water quality constant, New York anglers are less willing to visit sites where the fish are known to contain toxic substances. The estimated benefits per-person from eliminating this contamination was about $.45 per day. If we scale this up to the level of a fishing season to get a (rough) measure of benefits per year, the figure comes to about $63 per person. Even this rough measure shows that in a state the size of New York, the seasonal benefits from the elimination of toxic contamination is in the scores of millions of dollars. We also compared the toxic contamination problem with that of acidic impairment and found the latter to be of less consequence than toxics, in spite of affecting a larger number of water bodies. This comparison in particular suggests that toxic contamination and other forms of pollution can influence angler welfare by other means than affecting the number of fish they catch. Given EPA's current interest in confronting the toxic contamination problem in the Great Lakes basin, these estimates should prove valuable to policymakers.

A useful avenue for additional work would be integrating data on rivers and streams into models of this sort. While this would require a sizeable data collection effort, our results suggest that the issue is important enough that the effort may be justified.

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