Natural Resource Damages from Fishing Site Impairments: Evidence from a Repeated Cross Section of New York Anglers

Charles Gibbons
The Brattle Group

David Sunding
Berkeley Research Group

Charlie Gibbons
Principal, The Brattle Group
555 Mission Street
Suite 1500
San Francisco, CA 94105
charlie.gibbons@brattle.com
(415) 217-1055
Corresponding author

David Sunding
Vice Chairman, Berkeley Research Group
99 High Street
27th Floor
Boston, MA 02110
dsunding@thinkbrg.com

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Abstract

Repeated surveys of New York State anglers eliciting fishing trips taken are used to estimate the willingness-to-pay to avoid fish consumption advisories. We consider over 1,300 in-state origins and 1,700 destinations and use site-specific constants to address time-invariant unobserved characteristics. Conditional logit models produce WTP values between $2.91 and $5.96 per day, while mixed logit models give average values of $1.16 to $1.72. We also estimate the values of recreational amenities (such as boat launches), which can be used to offset resource losses.

JEL Codes: Q26, H41, C25

doi:10.3368/le.102.4.011224-0004R2

More than one-in-seven adults in the United States goes fishing. In 2016, 39 million US adults spent 459 million days and $46 billion on the pastime (U.S. Department of the Interior et al., 2016). Many of these anglers fish in order to consume their catch, but recreationally-caught fish and shellfish can expose consumers to toxic substances, such as mercury, dioxins, and polychlorinated biphenyls ("PCBs"). To avoid excessive exposure, states can issue fish consumption advisories warning anglers to limit their consumption of specific species from specific locations.

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Anglers could respond to these advisories by releasing their catch, fishing less often, or fishing elsewhere. Each of these behavioral changes reduces the surplus that they receive from fishing. To mitigate these losses, a government agency may require remediation of the contaminated waterbody. The value of such a project depends upon the willingness-to-pay ("WTP") of anglers to avoid contamination. The WTP can also serve as an input when calculating the natural resource damages caused by a responsible party that may be pursued in litigation.

Estimates of the WTP often arise from discrete choice models of angler site choice. In these models, anglers trade off travel distances and associated costs with site amenities; observing the resulting choices enables the researcher to place a dollar value on each amenity. While angler behavior has been widely studied, a relatively small number of papers have focused on the importance of consumption advisories to site choice. We add to this literature by using modern modeling and identification techniques applied to a detailed dataset collected over time.

We rely on two surveys of anglers from New York State in 2007 and 2017 to estimate a model that incorporates precise angling destinations. Our model has nearly 1,700 site options (all of which are visited by at least one angler in our data) and 1,300 angler origins (defined by

respondent ZIP codes). We use reports from the New York State ("NYS") Department of Environmental Conservation and Department of Health that identify sites experiencing water contamination that impact fish consumption. Crucially, the contamination status of a site can change between the two survey years that we consider. This enables the use of site-specific constants to control for time-invariant unobservable site characteristics, which identifies the impact of fish consumption impairments using within-site changes over time. We estimate and compare conditional logit and mixed logit travel cost models, with the latter permitting angler-specific cost and contamination status preferences. We reparameterize both variants to estimate the WTP directly; such a model is said to be in "WTP space" rather than "preference space."

Our conditional logit models find that anglers are willing to pay roughly $2.91 to $5.96 per day to avoid contamination that leads to fish consumption advisories. Our mixed logit models find that the average angler is willing to pay approximately one-quarter of these values ($1.16 to $1.72). We also find evidence that anglers are less averse to sites undergoing remediation than sites yet to begin a remediation plan. Lastly, we provide estimates of the value to anglers of boat launches, parking lots, campgrounds, and parks that can be used to estimate the value of compensatory projects to anglers.

In Section 1, we situate our approach within the literature that estimates angler WTPs to avoid a variety of water contamination issues. Section 2 presents the data that we use. Our modeling approaches are discussed in Section 3. Section 4 gives our estimates of anglers' WTP to avoid fish consumption advisories and Section 5 concludes.

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1. Literature Review

Our paper considers a specific question related to fishing site choice: how do anglers respond to fish consumption advisories?[1] In Table 1, we list papers that use revealed preference data to consider similar questions related to water quality issues.[2] These WTP values range from $2.73 to $49.56, with a median of $25.95.

Owing to the detailed responses in the available data, our study considers nearly 1,700 possible sites within a single state and avoids issues that can arise from site aggregation.[3] Furthermore, because the survey that serves as the source of our data is conducted periodically, we use variation in contamination status over time as a source of identification. This repeated cross-section feature of our data also enables inclusion of site- (or "alternative-") specific constants to account for time-invariant unobserved site characteristics, a factor whose importance was demonstrated by Murdock (2006). Lastly, we estimate both conditional and mixed logit models; when these approaches are compared within the studies listed in Table 1, mixed logit estimates are 12% to 45% of those estimated using the analogous common coefficient model.[4]

<<Table 1 about here>>

Two additional studies also serve as useful points of comparison. The trustees of the St. Lawrence River in upstate New York conducted a natural resource damages assessment ("NRDA") using data from a survey conducted in the St. Lawrence Seaway from June 1991 to May 1992 that includes over 4,000 trips (Natural Resource Trustees of the St. Lawrence River Environment, 2013). The report estimates a travel cost model that includes an indicator for the presence of a fish consumption advisory and finds a WTP to avoid an advisory of $2.94, which is on the lower end of the values shown in Table 1.

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A particularly relevant point of comparison from the broader fishing site choice literature is He and Poe (2021). They use the same surveys of New York State anglers that we use in this paper. However, they use responses from the 1988, 1996, and 2007 surveys, while (for reasons discussed in Section 2) we use data from the 2007 and 2017 surveys. As fishing destinations, they consider the centroid of the county where the respondent fished for inland trips and, for trips to the Great Lakes, the center of the border of the county of the trip with the lake. This provides 72 destinations (62 inland and 10 Great Lakes sites). This aggregation is necessary in part due to the limited data collected by the survey in 1988 and 1996 (see Section 2).[5] While we combine the surveys to enable the use of site-specific constants, He and Poe (2021) are interested in parameter stability over time and, for that reason, estimate their model separately for each survey year. Lastly, the authors' objective is to estimate total welfare from angling, whereas our focus is valuing specific site features (*i.e.*, the presence of a fish consumption advisory).

In summary, we build on a literature that considers a key question in environmental recreation and restoration by leveraging a detailed dataset using modern empirical techniques.

2. Data and Variable Creation

Our approach is based on repeated cross sectional surveys of New York State anglers ("NYS Angler Surveys"), which provide the locations of fishing trips taken by the respondents. We incorporate data indicating water contamination status as disclosed by New York State under Section 303(d) of the Clean Water Act and fish consumption advisories from the New York State Department of Health. Angler origins and destinations were mapped to specific latitude-longitude locations, which were used to calculate travel costs based on time, maintenance, and gasoline costs. This section details the data collection and assembly process.

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NYS Angler Surveys

For over 40 years, the New York Department of Environmental Conservation has commissioned surveys to understand anglers' preferences, attitudes, and contributions to the state economy. These surveys collected information on the 1973, 1976-1977, 1988, 1996, 2007, and 2017 fishing seasons and cover statewide freshwater fishing activity. Prior to 2017, these surveys were conducted primarily by mail, with telephone interviews conducted in some cases to study non-response bias. In 2017, online responses were permitted.

For the purposes of this paper (studying angler site choice), it is essential that the surveys provide the precise locations where anglers fished. While the 1996 (and earlier) data do provide some information on site choice, recorded responses are limited to either prominent bodies of water or generic locations within a county (*e.g.*, "River" in Seneca County). Data from 2007 and 2017, on the other hand, include specific waterbody name and county locations. As a result, we include only these most recent surveys in our analysis.[6] A dedicated team of research assistants cleaned destination names and counties in order to link angling activity with latitudes and longitudes. Respondents provide their home ZIP code, which we map to a precise latitude and longitude by choosing the centroid of the associated ZIP Code Tabulation Area.

For the 2017 survey, anglers were asked to record all fishing trips taken in the calendar year. The 2007 survey had an annual phase that asked respondents about all trips taken during the year, plus three partial year waves; we include only the annual wave to avoid selection bias (see discussion in Section 3). The survey design was used to study recall bias by comparing reported angler activity combined across the shorter waves to the annual wave; Connelly and Brown (2009) report finding limited bias in most survey phases.[7] Respondents were selected from residents and non-residents who held fishing licenses active during the period covered by the

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survey. The selection was proportionally stratified based on license type, as well as age in 2017.[8] For additional detail on the sampling methodology, see Connelly and Brown (2009) and Connelly and Brown (2019). We provide additional detail on our data cleaning process in Appendix A. Table 2 provides summary statistics for respondents, sites, and trips after these (and other basic) preparation steps concluded. The sites per angler, days per angler, and average distance traveled are similar between the two survey years, suggesting little change in general fishing patterns.

<<Table 2 about here>>

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Fish Consumption Advisory Indicator

We next determine whether a site is contaminated for purposes of fish consumption. We assess this using two sources: 303(d) listings from the NYS Department of Environmental Conservation ("DEC") and NYS Department of Health ("DOH") fish consumption advisories. In this section, we describe and compare these two sources and discuss the importance of combining both sources to provide an additional indicator of advisory status.

Contamination Sources

DEC 303(d) listings. Section 303(d) of the Clean Water Act directs the US Environmental Protection Agency ("EPA") to assist states in developing lists of "impaired waters" for use in devising remediation plans. The underlying impairments are tied to specific uses that are not permitted in those waterbodies due to contamination by particular pollutants. States were required to submit these lists to the EPA biannually beginning in 1992.

Each state may have its own monitoring, listing, and reporting standards. In the case of New York, these lists are developed by the DEC. In response to changes in EPA regulations expanding the scope of 303(d) listing requirements (New York State Department of Environmental Conservation, 2000), the DEC implemented a new classification system in 2002 that, notably, categorized certain waterbodies as impaired due to "fish consumption advisories" (Part 2b).[9]

As discussed further below, the contaminants that generate a fish consumption impairment are predominantly PCBs and mercury. Because these contaminants so often lead to fish consumption advisories, we will consider waterbodies recorded in other parts of the 303(d) list to also have fish consumption impairments if they are contaminated by either PCBs or mercury.[10] We use the 303(d) reports from 2006 (New York State Department of Environmental Conservation, 2006) and 2016 (New York State Department of Environmental Conservation, 2016) to determine the waterbody contamination status of sites in the 2007 and 2017 NYS Angler Surveys respectively. Contamination status is determined for waterbody-county combinations that match our definition of destinations.

DOH Fish Consumption Advisories. The DOH provides fish consumption advisories to warn anglers about potential contamination in their catch. They provide lists of species to avoid and how to reduce exposure to contaminants in catch that is consumed. These advisories are both general to sportsfish found across the state and tailored to specific waterbodies of concern.[11] In its specific advisories, the DOH provides the waterbody-county pair for the advisory. We use the 2006-2007 (New York State Department of Health, 2006) and 2016-2017 (New York State Department of Health, 2016) advisories to determine the status of the sites visited in the 2007 and 2017 NYS Angler Surveys respectively.[12] The DOH states that "these advisories are

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primarily based on information that the [DEC] gathers on contaminant levels in fish and game" (New York State Department of Health, 2006), suggesting that the two sources of advisories should provide similar categorizations.

Combining the Contamination Indicators. In reviewing the DEC and DOH lists, we find a few patterns. First, the DOH advisories tend to focus on larger, more popular waterbodies, whereas the 303(d) list covers a range of smaller waterbodies as well.[13] Second, the consumption advisories tend to cover larger areas of an included waterbody than the 303(d) list does for the same waterbody. As an example demonstrating both patterns, the DOH advisory for the St. Lawrence River covers three counties. The 303(d) list only includes the St. Lawrence River in one county, but also includes tributaries of the river that are not listed in the DOH advisory; those tributaries are found in the two other counties mentioned in the DOH advisory.

We believe these patterns are consistent with the purpose of each source, namely:

- The DOH list is based on the concentration of contaminants in the tissues of fish and game from the waterbody, while the DEC list is based on concentrations in the environment;
- The DOH list focuses on the most popular fishing sites, whereas the 303(d) list is meant to fulfill regulatory requirements to remediate waterbodies across the state; and
- The DOH advisory covers a larger geographic range to reflect the mobile nature of the resource, whereas the 303(d) list narrowly covers physical locations that require remediation.

As a result, these two lists could be viewed as *complementary*. Therefore, in addition to the separate DEC and DOH advisory status indicators, we also provide a third ("overall") advisory

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metric for sites that have a fish consumption impairment under either the DEC's 303(d) list or a DOH advisory.

Comparison of Indicators and Changes Over Time

Figure 1 shows the number of sites (defined as waterbody-county pairs) under each contamination status. Over 150 sites appear on one or both lists, while about 1,500 sites are on neither. Nearly twice as many sites are listed in the DOH list alone than the DEC list alone, but that the majority of sites are found in both. This figure also shows that the total number of contaminated sites increased from 2007 to 2017.[14] Using our combined advisory indicator, Figure 1 shows how many entities were contaminated by PCBs or mercury only, both of those contaminants, or by something else. Most sites with a consumption advisory had one or both of these contaminants present.

<<Figure 1 about here>>

Figure 2 explores the patterns of advisory changes between the two survey waves. The 2007 status is shown on the *x*-axis and the bars are divided into the proportion of those sites falling into each status category in 2017. A site with a given status in 2007 most likely retains that status in 2017; this is particularly true for sites where both sources are in agreement, either including or excluding the waterbody. Our model relies on site-specific constants to account for unobservable site attributes. Because of this, the impact of fish consumption advisories is identified by those sites that change overall advisory status between 2007 and 2017—that is, being listed by one or both sources to listed by neither or the reverse. In counts rather than proportions, 28 sites were added to one or both lists, while 2 were removed entirely. These sites that change status are spread across 19 counties and include rivers, lakes, harbors, and reservoirs.[15] Considering

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specific contaminants, 7 sites became newly contaminated by PCBs and 24 sites became contaminated by mercury; no site lost its contamination of either.

<<Figure 2 about here>>

Constructing the Choice Set and Calculating Travel Costs

The sources above were harmonized to rely on common naming conventions for waterbodies and counties; the waterbody-county pair defines a *site* (for example, the St. Lawrence River in Jefferson County). Across the 2007 and 2017 surveys, anglers in our data visit 1,683 sites. Angler origins are defined by ZIP code.

To develop our choice model, we generate all angler-site pairs as potential options. For these pairs, we construct travel costs from an angler's home ZIP code to each site in their choice set based on both travel time and distance. We find the travel time and distance between the centroid of each ZIP code and the location of each site in the choice set using Google Maps API.[16] In the angler surveys, respondents were asked to give the distance traveled to a fishing site; we find a correlation of 0.69 between our metric and the self-reported distance.

Using travel distance, we calculate the per mile cost of driving, which includes: (a) gasoline costs (New York State Energy Research and Development Authority, 2020);[17] (b) fleet-average fuel economy (U.S. Environmental Protection Agency, 2020); and (c) per mile maintenance, tire, and repair costs.[18] In this calculation, we follow Hang et al. (2016) and include measures that pertain to the marginal cost of driving an automobile, excluding fixed costs such as licensing fees and depreciation.[19] For the time cost of driving, we multiply the travel time by one-third the county average non-farm employee wage rate (New York State Department of Labor, 2020).[20]

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We sum the distance and time costs and place the total in 2019 dollars (U.S. Bureau of Labor Statistics, 2020).

Lastly, we add data on the number of boat launches, parks, and parking lots within half a mile and campgrounds within three miles of the site location (New York State Department of Information Services, 2010, 2012, 2018, 2020; U.S. National Park Service, 2020). This is in addition to the waterbody type information we obtain from U.S. Board on Geographic Names (2021).

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3. Model and Estimation

In this section, we present two models of fishing behavior based on a logit model with alternative- or (site-) specific constants. We begin by laying out the standard utility maximization framework for both models and show how the utility function can be parameterized in "WTP space" (Train and Weeks, 2005). In our first approach ("site choice"), we condition on the number of sites that an angler actually visited, then model which specific sites would comprise that group. For example, if an angler visited 5 unique sites, they would face 5 distinct choice scenarios. In our second approach ("trip choice"), we weight each choice scenario based on the number of days spent at that location. Continuing with the example where an angler visited 5 unique sites, they would still have 5 unique choice scenarios, each weighted by the number of days spent at that site. We present the formal models for each approach, then discuss estimation via maximum (simulated) likelihood and a contraction mapping for the alternative-specific constants.

Parameterization in Preference and WTP Spaces

An angler $i \in 1, \ldots, N$ chooses K_i sites to visit during the survey period. A choice situation becomes each angler-site selection, denoted k. The utility obtained when site j is selected by angler i is:

$$v_{ij} = \dot{\alpha}_i c_{ij} + x'_{ij}\dot{\beta}_i + \delta_j$$
$$u_{ij} = v_{ij} + \epsilon_{ij}.$$

The utility of angler i from site j is a function of the angler's cost of reaching the site c_{ij}, site characteristics that may vary across anglers (or, of particular relevance, over time) x_{ij}, and a site-specific factor δ_j. A Type 1 extreme value error term results in a logit model. Assuming that $\dot{\alpha}_i = \dot{\alpha}$ and $\dot{\beta}_i = \dot{\beta}$ for all anglers results in a conditional logit, whereas allowing the coefficients to vary across anglers yields a mixed logit model. Note that the site-specific factors are constant across anglers even in our mixed logit formulation.

This formulation is said to be based in "preference space," as the coefficients measure the impact of attributes on utility. To convert these impacts from utils to dollars, they are divided by the coefficient on the cost term, yielding the willingness-to-pay ("WTP") for the site attribute (Train, 2003):

$$\beta_{ki} \equiv WTP_{ki} = -\frac{\dot{\beta}_{ki}}{\dot{\alpha}_i}.$$

Because our interest lies primarily in these WTP values, utility can be reparameterized as:

$$u_{ij} = -\alpha_i c_{ij} + x'_{ij}\beta_i\alpha_i + \delta_j + \epsilon_{ij}, \quad (1)$$

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with $\alpha_i \equiv -\dot{\alpha}_i$. This is a model in "WTP space" (Train and Weeks, 2005).[21] We assume that the individual-specific travel cost coefficient has a lognormal distribution and the remaining individual-specific coefficients each have a normal distribution.[22] These can be parameterized as:

$$\begin{aligned} \alpha_i &= \exp(\alpha + \exp(\gamma_\alpha)\nu_{0i}) \\ \beta_{ik} &= \beta_k + \exp(\gamma_{\beta_k})\nu_{ki}; \end{aligned} \tag{2}$$

that is, a common mean plus a standard deviation of the distribution (represented as a parameter with support over the real line that has been exponentiated) multiplied by a draw from a standard normal. These parameters are collected into the vector $\theta = [\alpha, \beta', \gamma_\alpha, \gamma'_\beta, \delta']'$.

For a conditional logit, the point estimates of the WTP will be identical under the preference space and WTP space parameterizations.[23] For this model, the advantage of estimating in WTP space is that maximum likelihood estimation delivers asymptotic variances for the WTP (*i.e.*, β) directly, whereas such variances would need to be approximated (by the Delta method, for example) when the WTP is calculated using parameters from the model in preference space.

The two approaches generate different estimates of the WTP when a mixed logit model is employed, however. The difference arises because mixed logit places distributions on the parameters within the selected parameterization. In the preference space model, those distributions would be over the coefficients in utils; in the WTP space model, the distributions would be over the WTP directly. Because the distributions exist in different spaces, the estimates will be different.[24]

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Site Choice Probabilities

The extreme value error structure implies that the probability that angler i chooses waterbody j in choice situation k is:

$$\Pr_{ijk} \equiv \Pr\left(Y_{ijk} = 1 | \boldsymbol{x}_i; \theta\right) = \frac{\exp(v_{ij})}{\sum_m \exp\left(v_{im}\right)},$$

where Y_{ijk} indicates whether the choice is made. Angler i chooses a set of K_i waterbodies to visit. The probability that angler i chooses this portfolio of sites is:[25]

$$\Pr_i \equiv \prod_k \prod_j \Pr_{ijk}^{Y_{ijk}}. \tag{3}$$

These portfolio probabilities are the ones for which we derive a likelihood.

The log likelihood is straightforward for a conditional logit model:

$$\ell(\theta|\boldsymbol{x}) = \sum_i \sum_j \sum_k Y_{ijk} \log(\Pr_{ijk});$$

see that the log is able to travel through the products, leaving a simple expression. The log likelihood is not so straightforward for the mixed logit model, however. Intuitively, this is because the v terms in Equation 2 are unobservable; only unconditional probabilities (*i.e.*, those that integrate over the individual-specific coefficients) are observable. In particular:

$$\Pr_i = \int \prod_k \Pr\left(Y_{ij_k k} = 1 | \boldsymbol{x}_i; \theta\right) f\left(\gamma_\alpha, \gamma_\beta\right) d\gamma_\alpha d\gamma_\beta, \tag{4}$$

where j_k is the selected site in choice k. In considering the log likelihood, the log operator is not able to travel through the integral, leaving a more complex expression.

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The portfolio probability is key to account for the same angler choosing multiple locations, which in turn is the variation that best identifies the γ parameters within the random coefficients.

Trip Choice Probabilities

The model in Equation 3 is for the portfolio of sites chosen by an angler. An alternative model would represent the set of trips taken by an angler, which are defined as unique visits by an angler to a specific site. Let d_{ik} be the number of visits angler i takes in choice scenario k, then the analogue to Equation 3 is:

$$\Pr\left(\{Y_{ijk}, d_{ik}\}|\boldsymbol{x}_i\right) = \prod_k \prod_j \Pr_{ijk}^{d_{ik}Y_{ijk}}. \quad (5)$$

See that the only modification relative to the site choice model in Equation 3 is the incorporation of the number of days spent at location k by angler i. Hence, the trip choice approach incorporates intensity of choice, whereas the site choice model counts all sites equally.[26] For example, suppose that an angler spends 10 days fishing near their home and 1 day fishing several hours away. The portfolio probability would weight each probability equally, while the trip choice model would weight the closer, more intensely visited site more heavily. At a minimum, this additional information is expected to enhance the precision of the estimates.

Note that both the site choice model and the trip choice model are derived from the utility given by Equation 1. As a result, the interpretations of the coefficients in both models are the same—that is, denominated in dollars per angling-day (as the cost term c_{ij} is measured as the round-trip cost per day of fishing). Hence, the results across all our specifications will be comparable on the same scale.

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The log likelihood for a conditional logit is:

$$\ell(\theta|\boldsymbol{x}) = \sum_i \sum_j \sum_k d_{ik} Y_{ijk} \log(\Pr_{ijk}).$$

In comparing the log likelihoods of the site- and trip choice conditional logit models, it is clear that the primary difference is that each site is weighted by the number of days visited in the trip choice model, providing a stronger signal of preferences.

This additional information can be misleading in a mixed logit model, however. Keeping with our simple example above, the angler chose to visit one site in particular 10 times, implying a strong correlation in their choices. Our mixed logit model only permits this correlation to manifest in a subset of the predictors—namely the ones with angler-specific coefficients—such as travel cost and advisory status. Instead, these correlations likely reflect angler-specific *site* factors (having fished there since they were a child, perhaps). Without individual-specific alternative-specific δ terms, this correlation would be mis-attributed to other predictors in the model (the ones that do have individual-specific coefficients); put differently, there would be omitted variables bias. Including thousands of individual-specific terms in our model is not tractable, however. For this reason, we estimate a trip choice model using a conditional logit approach only.

Lastly, though the trip choice model accounts for the degree of participation in fishing by conditioning on the number of days visited, neither it nor the site choice model considers the option to not fish at all. The question we address is, conditional on making a trip, how much would an angler be willing to pay for various site attributes? The extent to which those site

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attributes also impact the willingness of an angler to make a trip is outside the scope of our study—that is, we focus on the intensive, rather than the extensive, margin.[27]

Estimation

For estimation, our model is approximated in two ways. First, we use maximum simulated likelihood to estimate the parameters in the mixed logit specifications. We generate a certain number of draws for each respondent to "fill in" the unobservable components of their individual-specific coefficients. Second, to handle the large number of potential angling destinations that we consider, we offer each respondent a limited number of options for each choice scenario: the site actually chosen plus a random sample of the rest. It is well established that a conditional logit model can be estimated consistently using this approach (Train, 2003) and has been used to estimate models of recreational demand (Parsons and Kealy, 1992). The cost of this sampling is inefficiency in estimation.

Mixed logit, on the other hand, is not consistent when only a sample of alternatives is provided. This is essentially for the same reason that mixed logit fails to satisfy independence of irrelevant alternatives. The bias is not readily calculable, though a few papers have assessed it. McConnell and Tseng (1999) use data from ten potential fishing sites in Wisconsin, offering each angler three alternatives plus their chosen site and find that mixed logit performs as well on this sample as using the full set of alternatives. Nerella and Bhat (2004) and von Haefen and Domanski (2018) perform numerical simulations using a larger number of alternatives and vary the share of alternatives offered. Both papers find that 25% or more of sites should be included for the approach to be reasonably accurate.[28] In the Online Appendix, we examine the sensitivity of our results to choice set sampling.

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The estimating equations for the site-specific constants δ ensure that the chosen number of visits to each site equals the predicted number (see Online Appendix 9).[29] Because we allow anglers to choose specific sites across the entire state, we have thousands of parameters to estimate and the log likelihood would be relatively flat in estimating these parameters. To avoid the resulting difficulty of numerical optimization, we instead determine the δ terms that match actual and predicted shares for candidate values of the other coefficients using a contraction mapping. Computational implementations of contraction mappings have become quite time efficient and numerically precise, rendering this a more successful calculation approach.[30]

The contraction mapping approach to estimation was popularized in econometrics by Berry et al. (1995) and brought to the recreation demand modeling space by Murdock (2006). The classic BLP model is based on more general moment conditions because of their reliance on aggregate shares, rather than observations of individual-level choices. Their moment- rather than likelihood-based econometric approach prevents deriving estimates of variances that account for estimation error in their alternative-specific constants (*i.e.*, arising from parameters estimated using a contraction mapping, rather than through moment conditions directly). In our case, the maximum likelihood approach gives closed-form equations for the asymptotic variance that account for all parameters. In Online Appendix D, we derive variances that furthermore account for clustering by angler and that are robust to misspecification.

Lastly, we return to a note from the data section above: in 2007, additional surveys were conducted asking respondents about only a portion of the year. Because only a portion of the year appears in the data, we are not able to estimate a model based upon the full portfolio of sites visited, as presented in Equation 3. To the extent that the sites visited change over the year, this introduces a bias to the portfolios.[31] Because the trip model has a measure of intensity (days), it

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would seem less susceptible to such bias. A bias remains, however, because we do not observe anglers in the partial year waves who did not fish, but did fish during other times of the year. This introduces selection bias. For these reasons, we only include the annual wave data from 2007.

4. Results

In this section, we present results using our site- and trip-choice models using each measure of advisory status (DEC only, DOH only, and overall). We begin by offering our primary specifications, then consider the impact of partial remediation. We also consider the value of amenities modeled directly and indirectly through those constants.

WTP of fish consumption advisories

Table 3 summarizes estimated WTP across our three model formulations (conditional and mixed logit models of site choice and a conditional logit model of trip choice) for each of the three indicators of fish consumption advisories. The conditional logit models yield WTP values of approximately $2.91 to $5.96; the mixed logit values are lower, from $1.16 to $1.72, and are quite variable across the population, with standard deviations of $4.07 to $5.15.[32] Looking across models, the trip choice model yields WTP values that sit between those of the conditional logit and mixed logit results from the site choice models. The mixed logit results are approximately one-quarter of those found by the conditional logit model.[33] This pattern is consistent with findings from the literature (see Section 1).

<<Table 2 about here>>

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Impact of partial remediation

Our use of site-specific constants eliminates bias arising from time-invariant factors influencing the desirability of a site. We may be concerned, however, that sites with advisories may be undergoing remediation, thereby improving their quality over time. These improvements are unmeasured, but may be correlated with changes in advisory status and, therefore, may bias our estimates. We can investigate this possibility using the DEC's 303(d) list categorizations.

Recall that the purpose of the DEC's 303(d) list is to develop remediation plans. The difference between a fish consumption impairment listing in the main body of the 303(d) list (Part 2b) and one on the supplementary Category 4 listing is that the latter have a remediation plan in place, whereas the former require developing a plan. Based upon this classification, a site on the impaired list should not be improving (since it does not yet have a plan in place), while a site on the Category 4 list may be improving. Table 4 compares the impact of these two classifications. The WTP to avoid an impaired site is higher than that of a Category 4 site, consistent with improving site characteristics during the process of remediation.[34] In fact, the impact of a fish consumption impairment is larger than that of a DOH advisory, as shown in Table 3 and a Category 4 fish consumption-related impairment is not statistically distinguishable from other Category 4 impairments.[35]

<<Table 4 about here>>

Values of amenities

These models can also be used to estimate the value of boat launches, parks, and parking lots near a fishing destination. We first control for amenities directly in models without site-specific constants and give the results in Table 8. We cannot control for these factors in models with site-

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specific factors due to multicolinearity, as these amenity values are recorded at only a single point in time. Instead, for models with site-specific constants, we perform an analysis akin to Berry et al. (1995): we regress the estimated site-specific constants on the amenity values. To obtain standard errors, we first bootstrap the site-specific constants by drawing from their distribution and dividing by the travel cost coefficient (the δ terms in Equation 1 are not modified by the travel cost coefficient during estimation). For each of those draws, we perform a second bootstrap where we sample from the selected sites.

<<Table 5 about here>>

The results are shown in Table 5. For each amenity, we show the value of the first of its kind at a waterbody and the marginal value of each additional unit of that amenity. For example, according to the site choice conditional logit model with site-specific constants, the value of the first boat launch is $27.26 and the value of an additional boat launch is $7.26 (see column 2).

The most valuable addition to a site is a boat launch, followed by campgrounds and parking lots. Parks appear to be detrimental to start, but a site can gain from having several parks nearby. As with consumption advisories, the WTP values for amenities tend to be lower in the mixed logit model. These results can be useful for assessing the value of site enhancements provided as compensation for natural resource damages.

5. Conclusion

In this paper, we estimate a model of angler site choice that incorporates site-specific constants for a large number of alternatives (about 1,700). Using our conditional logit models, we find that anglers are willing to pay between roughly $3 and $6 per angler-day to avoid fish consumption

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impairments. These estimates are similar to those found in the literature when compared to papers that model site choice using precisely-defined destinations. Our mixed logit results are about one-quarter of the conditional logit results, which is also consistent with findings in the literature. These models find WTP values of roughly $1 to $2 per angler-day. We also use our model to estimate the value to anglers of boat ramps, parking lots, campgrounds, and parks. These values can be used when considering projects to compensate anglers for lost use due to waterbody contamination.

Our results generally find that publicized warnings from the state Department of Health generate the highest willingness-to-pay values, reflecting the importance of educating anglers about consumption advisories (see Lauber et al., 2017). We also find that anglers are less inclined to avoid sites in the process of remediation, demonstrating the value that comes from site improvements. Overall, our estimates provide a useful guide to the value that anglers lose when visiting a contaminated site. Conversely, they provide the benefit that can be attained through site remediation or enhancement. When combined with statistics on the levels of visitation (or potential visitation) to a site, they can be used to perform a cost-benefit calculation of remediation from a human use standpoint or calculate human use losses in a natural resource damages assessment.

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Acknowledgments

The authors would like to thank Avishi Agarwal, James Banovetz, Ryan Chapman, Jingchen Jiang, Michael Span, and Ivy Yang for excellent research assistance. We would also like to thank James Banovetz and Kenneth Train for helpful comments. We would like to thank Nancy

Connelly for providing survey response data. Lastly, we thank the editor and referees for their helpful comments.

Declaration of interest: The authors disclose that they have been retained through their firms by outside counsel for Monsanto Company in litigation related to PCB contamination of waterways. Dr. Sunding was retained to provide expert testimony and Dr. Gibbons directed his support staff and provided consulting services. This research was conducted and funded in part through that engagement. However, these parties did not participate in or provide comments on the design of the study, collection or analysis of the data, drafting of this report, or submission for publication.

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Tables

TABLE 1: LITERATURE CONSIDERING THE WTP OF ANGLERS TO AVOID WATER QUALITY ISSUES

Paper	Location	Contamination of interest	WTP ($)
Alvarez et al. (2014)	Gulf of Mexico	Oil spill	29.65
Bingham et al. (2011)	New Jersey	Fish consumption advisories	8.84
Chen and Cosslett (1998)	Michigan	Elevated toxicity	22.51
Hausman et al. (1995)	Alaska	Oil Spill	6.75
Jakus et al. (1997)	Eastern Tennessee	Fish consumption advisories	10.00
	Middle Tennessee	Fish consumption advisories	41.74
Jakus et al. (1998)	Tennessee	Fish consumption advisories	7.73
MacNair and Desvousges (2007)	Wisconsin	PCB advisories	2.73
Montgomery and Needelman (1997)	New York	Acidity, toxicity, designated use	29.39
Parsons and Hauber (1998)	Maine	Elevated toxins	49.83
Parsons et al. (1999)	Tennessee	Fish consumption advisories	39.62
Phaneuf et al. (1998)	Wisconsin	Toxins in trout	34.38

Notes: Estimates were selected according to the primary model the authors use to calculate per trip WTP values or were otherwise the primary focus of their discussion. WTP values are converted to 2019 dollars. For additional details on the sources of the estimates, see Table E1 in Online Appendix E.

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TABLE 2: NYS ANGLER SURVEY SUMMARY STATISTICS

	2007	2017
Total days	33,821	167,403
Angler-sites visited	3,593	16,623
Number of anglers	1,286	5,840
Unique sites visited	931	1,396
Unique ZIP codes of residence	669	1,236
Days per angler	26.3	28.7
Average sites per angler	2.7	2.9
Average distance traveled	43.8	49.6

Notes: Average distance traveled is weighted by days and is one directional (though the choice model considers roundtrip travel distance).

TABLE 3: SUMMARY OF ESTIMATES OF WTP BY ADVISORY STATUS ($ PER ANGLER-DAY)

	Overall	DEC	DOH
Site choice, conditional logit	-5.35***	-4.65**	-5.96***
	(2.05)	(1.91)	(2.25)
Trip choice, conditional logit	-2.91***	-4.51***	-3.82***
	(0.49)	(0.46)	(0.52)
Site choice, mixed logit	-1.64***	-1.16***	-1.72***
	(0.41)	(0.41)	(0.42)
	[4.92]	[4.07]	[5.15]

Notes: Standard errors clustered by respondent in parentheses; standard deviation of random coefficient in brackets. Each estimate is from a separate model with site-specific constants and a per day round-trip cost. Values are in 2019 dollars per angler-day.

For all tables: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

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TABLE 4: WTP BASED ON 303(D) LISTING TYPE ($ PER ANGLER-DAY)

	Site (conditional)	Trips	Site (mixed)
Fish consumption impairment (Part 2b)	-7.18***	-7.23***	-1.82***
	(2.18)	(0.53)	(0.47)
Category 4 fish consumption impairment	-4.27*	-3.49***	0.38
	(2.24)	(0.57)	(0.70)
Shellfishing impairment (Part 2c)	-10.86	-12.96***	-2.76
	(8.31)	(2.18)	(2.76)
Other 303(d) listing impairment	-4.20***	-2.70***	-1.58***
	(1.23)	(0.29)	(0.41)
Other Category 4 impairment	-4.05**	-2.74***	-0.84
	(1.99)	(0.51)	(0.67)

Notes: Standard errors clustered by respondent in parentheses. Impairment indicators within a model are mutually exclusive. A common random effect was estimated for the two fish consumption impairment terms (standard deviation: $3.49, standard error of $0.61 using the Delta method) and for the three other impairments (standard deviation: $2.82, standard error of $0.43 using the Delta method) due to data limitations (these parameter restrictions could not be statistically rejected). Each model also includes travel cost and site-specific constants. Values are in 2019 dollars per angler-day.

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TABLE 5: WTP FOR SITE AMENITIES ($ PER ANGLER-DAY)

	Site (conditional)		Trip		Site (mixed)	
	(1)	(2)	(3)	(4)	(5)	(6)
First boat launch	16.39***	27.26***	13.28***	25.92***	9.05***	19.11***
	(0.44)	(2.74)	(0.11)	(2.56)	(0.27)	(1.93)
Each additional launch	5.23***	7.26***	4.88***	7.47***	3.07***	5.03***
	(0.19)	(2.02)	(0.05)	(1.88)	(0.12)	(1.39)
First parking lot	12.69***	12.78***	7.52***	11.21***	6.73***	9.71***
	(0.56)	(3.53)	(0.15)	(3.07)	(0.36)	(2.68)
Each additional lot	3.04***	3.75***	2.16***	3.30***	1.51***	3.00***
	(0.10)	(0.89)	(0.03)	(0.79)	(0.07)	(0.63)
First campground	13.86***	24.50***	11.72***	22.37***	7.29***	17.21***
	(0.71)	(3.46)	(0.19)	(3.20)	(0.54)	(2.49)
Each additional campground	18.67***	11.30**	14.84***	10.76***	11.91***	9.18***
	(0.50)	(4.75)	(0.13)	(4.00)	(0.36)	(3.35)
First park	17.86***	-1.69	14.85***	-3.60	9.10***	1.71
	(0.46)	(3.16)	(0.12)	(2.95)	(0.28)	(2.25)
Each additional park	3.96***	4.23	2.88***	3.26	2.48***	3.64
	(0.29)	(3.45)	(0.07)	(2.99)	(0.20)	(2.48)
Site factors	Variables	SSCs	Variables	SSCs	Variables	SSCs

Notes: Standard errors clustered by respondent in parentheses. Coefficients on the overall advisory status and travel cost are given in the Online Appendix C, Table C1. Amenity values for models with site-specific constants are estimated by bootstrapping from the distribution of site-specific constants, both by drawing from the distribution of the parameters and by sampling sites. For the mixed logit models, amenity values are common across respondents to ensure comparability with the model that uses site-specific constants (which do not vary across respondents). Values are in 2019 dollars per angler-day.

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Figure Captions

FIGURE 1: CONTAMINANTS ASSOCIATED WITH AN ADVISORY BY SOURCE AND YEAR

FIGURE 2: ADVISORY SOURCE CHANGES FROM 2007 TO 2017

Endnotes

[1] Our analysis considers the intensive margin of choosing a site, rather than whether to go fishing; Wolf et al. (2017) considers the extensive margin of angling in response to algal blooms by considering the impact of this hazard on fishing license sales. We note that contamination is not the only factor that influences the quality of a fishing site (see, for example, Melstrom et al., 2015) and that water contamination can impact more than angling opportunities (see, for example, Alvarez et al., 2019; Wolf et al., 2019). For a recent review of the broader fishing site choice literature, see Hunt et al. (2019) and Johnston et al. (2006).

[2] The MacNair and Desvousges (2007) paper also incorporates some stated preference analysis along with revealed site choices.

[3] Parsons and Needelman (1992) show that, unless utility functions satisfy strong restrictions, aggregating across sites leads to biased estimates. This bias has been demonstrated empirically by Lupi and Feather (1998). Additionally, Parsons and Hauber (1998) provide evidence of attenuation in the travel cost coefficient when the choice set is limited. They consider different choice sets not based on the specificity of sites, but instead on the maximum driving distance to sites included as potential choices. As the driving distance boundary increases, so does the magnitude of the travel cost coefficient. In separate guides for practitioners, Feather (1994) and Parsons (2017) discuss the importance of considering how to define sites to avoid bias from aggregation and other factors.

[4] See Chen and Cosslett (1998); Phaneuf et al. (1998); and Alvarez et al. (2014).

[5] The additional detail in the 2007 and 2017 surveys allow us to identify nearly 1,700 distinct waterbody-county pairs visited by respondents, which we consider as separate sites.

[6] As discussed in Section 1, He and Poe (2021) also estimate a fishing site choice model using NYS Angler Survey data, but they use data from 1988, 1996, and 2007.

[7] The three partial year phases include: trips in the first five months of 2007 (January through May); the next four months (June through September); and the final three months (October through December). Respondents differed across the waves.

[8] Sampling weights were only provided for the 2017 data. Due to this inconsistency, we did not incorporate them.

[9] The 303(d) list also includes "shellfishing restrictions" (Part 2c), but these are largely due to pathogens outside the type of fish consumption advisory we consider in this paper. Other parts of the 303(d) list are: Part 1 lists waters that require additional evaluation; Part 2a are waters impaired by acid rain; and Part 3 are waters that require re-assessment. Beginning in 2006, an additional Category 4 lists waters that do not require 303(d) listing, but may nonetheless be impaired. A waterbody is listed in Part 4 if it is impaired, but does not require development of a total maximum daily load ("TMDL") for its contaminants (New York State Department of Environmental Conservation, 2006). The new standards promulgated by the EPA and subsequent reclassification by the DEC prevent direct comparison of waterbody impairments before and after 2002, another reason we focus our attention on the 2007 and 2017 NYS Angler Surveys. In particular, the 1996 303(d) report does not identify sites as specifically contaminated by PCBs or mercury (New York State Department of Environmental Conservation, 1996).

[10] Note that this includes waterbodies in the 303(d) list proper as well as those in Category 4. Only one (2006) or two (2016) waterbodies had one of these contaminants in the 303(d) list proper but were not categorized as having a fish consumption impairment. Waterbodies in Category 4 are not specifically designated as having a fish consumption impairment; hence having PCB or mercury contamination is considered definitional for this list.

[11] In outlining the scope of the advisories, the Department states that: "Sampling focuses on water bodies with known or suspected contamination, water bodies susceptible to mercury contamination, popular fishing waters and waters where trends in fish contamination are being monitored. Also, testing focuses on those species that are most likely to be caught and eaten by sport anglers." (New York State Department of Health, 2006). In providing a general advisory on all "fish taken from the state's freshwaters and some marine waters at the mouth of the Hudson River," the DOH cites the presence of "some chemicals [that] are commonly found in New York State fish (mercury

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and PCBs for example)" and notes that "fish from all waters have not been tested" (New York State Department of Health, 2006).

[12] As a final justification for limiting our analysis to these two years of the NYS Angler Surveys, we have not been able to find earlier DOH fish consumption advisories that would be needed to categorize sites in other survey years.

[13] If the Department of Health focuses on developing advisories for popular fishing sites, as their documentation contends, then the advisory indicator may be positively related to positive site amenities. To the extent that these amenities are time-invariant, they are accounted for by our site-specific constants. What would bias this parameter is if a site's quality is *improving* (*i.e.*, getting better) when an advisory is added, not simply a consistent preference for contaminated sites relative to sites without a DOH advisory. A plausible mechanism would be that the enactment of a DOH advisory comes with action to remediate or otherwise improve the site. We evaluate this possibility in Section 4.

[14] No sites were on the Category 4 fish consumption impairment list in 2007; 67 were on this list in 2017. Category 4 sites represent about half of sites listed by the DEC that year.

[15] The distribution of site-specific constants for these sites is similar to that for sites that have advisories in both years.

[16] More precisely, though we have each respondent's ZIP code, we use the centroid of the ZIP Code Tabulation Area as the origin point. The API was queried using the Google Maps Services library for Python. Travel times and distances were for Saturday, September 25, 2021 at 1pm local time. Origin and destination inputs are the latitude and longitude of the locations. We remove any destinations that are islands or are otherwise inaccessible by car.

[17] Gasoline prices are separated by "downstate," which includes New York City (Manhattan, Kings, Bronx, Richmond, and Queens Counties), Long Island (Nassau and Suffolk Counties), Rockland County, Westchester County, and Putnam County, and "upstate," which includes the remainder of the state. Annual estimates are calculated via an unweighted average of monthly values.

[18] Values are found in American Automobile Association (2007) and American Automobile Association (2017). The 2017 data include fleet averages for operating costs. To impute 2007 fleet averages, EPA production weights are used to weight the AAA costs for each vehicle class as follows: AAA's sedan measures were weighted using the EPA's sedan/wagon weight; AAA's SUV category was weighted using the sum of the EPA's weights for pickups, truck SUVs, and car SUVs; AAA's minivan category was weighted using the EPA's minivan/van weight. Further, AAA reports separate tires and maintenance categories in 2007; these values are summed to be consistent with 2017.

[19] See also Lupi et al. (2020).

[20] The implied wage rate is created by dividing annual income by 2,000. Using 1/3 of the hourly wage rate is consistent with the literature; see, for example, Alvarez et al. (2014).

[21] Note that we do *not* simply divide all the terms by $\dot{\alpha}_i$. Recall that logit models implicitly fix the variance of the unobserved components to be $\pi^2/3$. Dividing through by $\dot{\alpha}_i$ would generate a logit model where the unbserved term $\epsilon_{ij}/\dot{\alpha}_i$ would have variance $\pi^2/3$. Because utility is scale-invariant, such a rescaling of the unobserved component would be innocuous, *if we weren't simultaneously fixing the coefficient on travel cost to be 1*. In this case, the observable component of utility is no longer able to rescale itself to match the scale of the unobservable component. Hence, this approach to reparameterization would impose an arbitrary constraint on the model. Instead, Train and Weeks (2005) propose a model in WTP space that factors out the absolute value of the cost coefficient, leading to a common coefficient appearing in front of the (negative) cost and in front of the β term.

[22] See that parameterization in WTP space allows us to specify that the WTP itself is normally distributed. If we estimated our model in preference space, the WTP would be the ratio of two normal variables, which is not itself normally distributed.

[23] This is due to the standard invariance property of the maximum likelihood estimator.

[24] This lack of invariance to parameterization is the same result found in Bayesian estimation, of which mixed logit is a flavor: a mixed logit model is essentially a Bayesian model with uniform priors on each random coefficient. Placing uniform priors on the preference coefficients yields different estimates than placing uniform priors on the WTP coefficients.

[25] This equation uses probabilities implying choice with replacement, though each waterbody can be selected only once in the portfolio. Given the large number of "dense" choices (*i.e.*, there are several waterbodies that provide similar utility as the chosen one), this simplification is acceptable. It also becomes straightforward to add trip counts, discussed later on.

[26] Put differently, the site choice model is conditioned on the number of sites chosen K_i by each angler. The trip choice model conditions on the number of sites chosen as well as the set of days spent at the selected site in each choice scenario. This is stricter than conditioning on the total days spent fishing.

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[27] Of the papers in Table 1, 7 of 11 (including Hausman et al., 1995) consider the decision to take a fishing trip in addition to site choice.
[28] Both papers also find that a 12.5% sample is enough to achieve good results for conditional logit models.
[29] Note that, in the case of mixed logit, the predicted shares are weighted based on their likelihood; see Equation D1 in Online Appendix D. For a more detailed treatment of the properties of maximum simulated likelihood, see Train, (2003).
[30] We use the SQUAREM package in R (Du and Varadhan, 2020).
[31] Our annual data do not indicate the timing of the visits, so we cannot model visitation patterns.
[32] Using a conditional logit model, the NRDA for the St. Lawrence River found a WTP of $2.94 to avoid a DOH advisory (Natural Resource Trustees of the St. Lawrence River Environment, 2013). This value falls between our conditional logit and mixed logit estimates. This analysis, which uses data source that covers a subset of the geographic region that we study, corroborates our results.
[33] Log likelihood values are significantly lower in the mixed logit models, rejecting common WTP values across anglers.
[34] This difference is statistically significant for the trip choice and mixed logit models.
[35] The negative coefficients on the other impairment classifications suggest that remediation efforts (which occur for all impairments) improve the quality of a site beyond permitting fish consumption. It could be argued that the impact of a fish consumption advisory *on its own* is the difference between the fish consumption impairment coefficient and the other 303(d) listing impairment coefficient; this difference is statistically significant only for the trip choice model.

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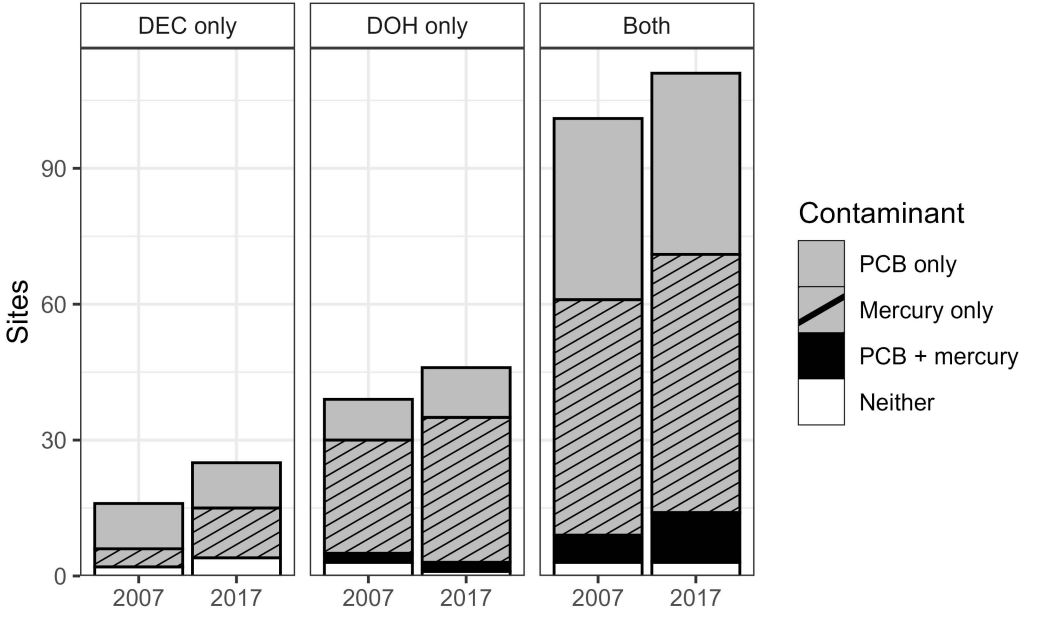
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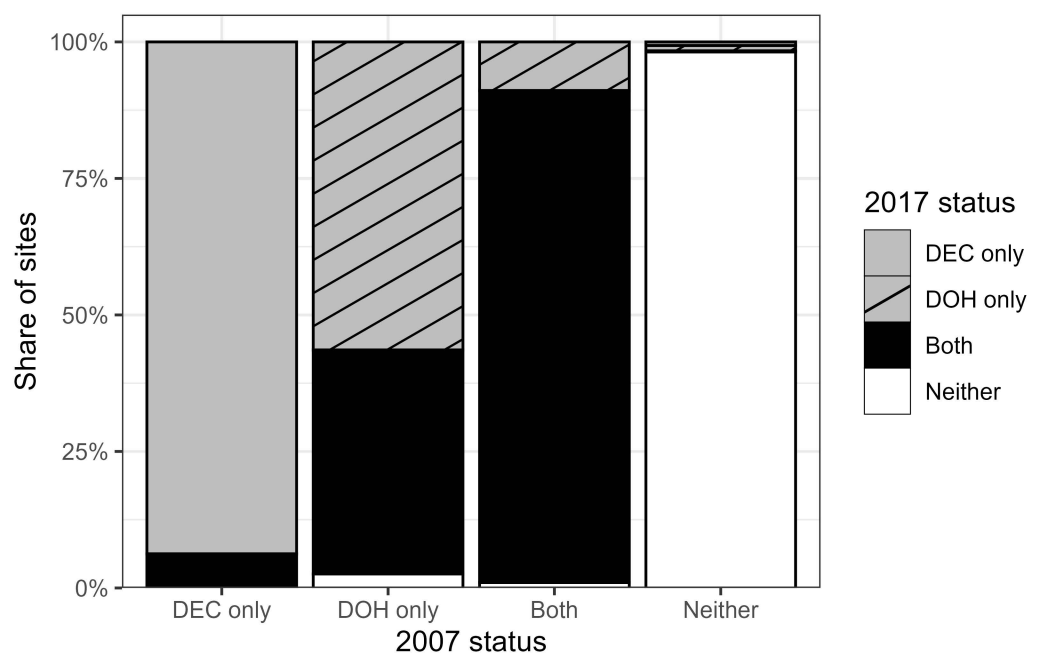
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