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Water quality warnings and recreational fishing: effects over time and across space

Cameron Speir
University of Illinois at Urbana-Champaign
Department of Agricultural and Consumer Economics
326 Mumford Hall, MC-710
1301 West Gregory Drive
Urbana, IL 61801
speir@uiuc.edu

Amy W. Ando
University of Illinois at Urbana-Champaign
Department of Agricultural and Consumer Economics
326 Mumford Hall, MC-710
1301 West Gregory Drive
Urbana, IL 61801
amyando@uiuc.edu

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This paper examines how recreational fishing behavior is affected by information on fish consumption advisories. We develop a model of recreational fishing effort at different sites and explore how effort changes with the issuance of fish consumption advisories and other government-provided water quality information. This research tests whether changes in fishing behavior due to official water quality warnings persist over time (i.e., do warnings lose their effectiveness as time passes since the initial warning?). Our empirical model examines changes in angler behavior that are induced by advisories for PCBs in the Wisconsin portion of Lake Michigan. In 1997, the Wisconsin Department of Natural Resources revised the fish consumption advisories for Lake Michigan. The advice became more detailed and more stringent. This study tests whether anglers changed their fishing behavior in response to such changes in fish consumption advisories.

Fish Consumption Advisories and Contaminants in Sport Fish

Fish consumption advisories (FCAs) are issued by authorities to warn sport fishers about possible adverse health effects from eating the fish they catch. They are typically issued at the state level by agencies such as departments of natural resources, health, and/or environmental protection. FCAs generally apply to specific locations and species, and may issue advisories that apply only to sensitive subpopulations (e.g., pregnant women or small children). Authorities hope that by issuing FCAs, they can influence people to alter their behavior, either by avoiding fishing at a contaminated location or by avoiding consumption of potentially contaminated fish.

As of 2004, the federal Environmental Protection Agency reports that 3,221 FCAs have been issued by 48 states, Washington, DC, one territory and three Native American tribes. These advisories affect 35 percent of the total lake acreage and 24 percent of the total river miles in the United States. All of the Great Lakes are covered by some form of advisory. Most FCAs issued in the United States are based on five contaminants: mercury, PCBs, chlordane, dioxins, and DDT (EPA 2005). All five contaminants are classified as persistent bioaccumulative toxic substances (PBTs). Once emitted into the ambient environment, PBTs take a long time to break down. They bioaccumulate up the aquatic food chain – thus, concentrations in gamefish can be high enough to be harmful to human health.

In the Wisconsin portion of Lake Michigan, the study area for this research, PCBs are the main contaminants of concern. PCBs (poly chlorinated biphenyls) are a class of man-made chemicals that were once used in a variety of industrial applications, including electrical insulators and in recycling carbonless paper. The U.S. Environmental Protection Agency banned the manufacture of PCBs in 1977 (McCarty et al 2004). PCBs degrade only very slowly and thus remain present for many years following release into the aquatic environment. PCBs are a probable human carcinogen, and human health effects of PCB exposure include stomach, kidney, and liver damage, liver and gallbladder cancer, and effects on developing fetuses (Johnson et al 1998).

FCAs and Angler Behavior

Whether fish consumption advisories change anglers' behavior has been of considerable interest to social scientists. If anglers are aware of FCAs and pay attention to them, they can alter their behavior in at least four ways. First, they may choose to go fishing less frequently (or stop fishing altogether). Second, they may change their location and fish in places with less heavily contaminated fish. Third, they may alter the species that they target. Different species of fish have different bio-accumulative properties. FCAs reflect this and anglers may use this information to fish for less contaminated species. Fourth, anglers may choose to eat less of the fish that they catch. FCAs provided to anglers include a recommended maximum amount of fish to consume.

Fishing Frequency

Morey and Breffle (2006) examine stated preferences for FCA removal in Green Bay, Wisconsin. Their study values changes in FCA stringency and determines whether the total number of fishing trips would increase if FCAs were not present. They perform a survey and ask respondents to choose between a pair of alternatives. Each alternative consists of 6 characteristics (a launch fee, catch rates for four fish species, and FCA stringency). For each choice, respondents indicate how many days they would fish under their preferred circumstances. Morey and Breffle then use the survey data to estimate the number of trips taken as a function of several factors, with FCA stringency being the variable of interest. They find that the parameters on the FCA variables become larger and more negative as FCAs become more stringent. They find that if FCAs for Green Bay were rescinded, then fishing trips would increase by 9.7%.

MacDonald and Boyle (1997) surveyed anglers in Maine following the issuance of a statewide FCA for mercury. Of the anglers that were aware of the FCA, about 10 percent said that they would have fished more days if the advisory had not been issued. However, results from an econometric model of the net economic value of fishing show that the advisory did not significantly affect angler willingness-to-pay.

Location Choice

A number of revealed preference studies address the issue of whether FCAs (and water quality generally) influence angler behavior. A series of articles by Jakus and others (Jakus, Downing, Bevelheimer and Fly 1997; Jakus, Dadakas and Fly 1998; Jakus and Shaw 2003) examines patterns of fishing location choice among reservoir anglers in east Tennessee. These studies surveyed households by phone an asked them the number of times they went fishing and their average catch rate at each site over a single fishing season. In each study they found that the presence of an FCA makes anglers less likely to fish at a given reservoir. Jakus et al 1998 incorporate anglers' knowledge about FCAs and reason for fishing into the analysis. This paper finds that when all responses are pooled, FCAs make a fishing site less likely to be chosen. Further, it shows that anglers who knew about specific FCAs *and* were fishing with the express purpose of eating their catch were more likely to choose clean sites.

Montgomery and Needleman (1997) examined the effect of water quality on fishing location choice. They estimate a model of site choice for lakes and streams in New York State that includes the presence of an FCA, along with other pollution indicators such as acidity and presence of a site on the 305(b) list of impaired waters.

They surveyed households and obtained the number of trips made to each site. They find that the presence of species for which New York had issued a state-wide FCA made a site less desirable. However, they also found that a site-specific “Do Not Eat” warning actually increased the chance that anglers would choose a site. The authors believe that the dummy variable for this warning was picking up some unobservable attributes of the “Do Not Eat” sites - less than 10 out of 2,500 sites had this warning.

Chen and Cosslett (2000) examined the effect of a site being designated an Area of Concern (AOC). This study used a survey of Michigan’s Great Lakes salmon anglers to estimate a travel cost model. They find that designation as an AOC makes a site less likely to be chosen.

Tilden et al (1997) surveyed households in Great Lakes states to examine advisory awareness and compliance. Of those respondents who ate sport caught fish and were aware of FCAs, 43.6 percent of men and 28.2 percent of women responded to the FCAs by changing fishing location to avoid heavily contaminated fish. The authors of the study believe that the difference between men and women is due to the fact that a large majority of sport fishers are men. These results are self reported and no effort was made to verify the reported compliance. Imm et al (2005) conducted a follow up survey. This study found that 71 percent of those who ate sport caught fish and were aware of FCAs responded to FCAs by changing fishing location. This appears to be a greater proportion than reported by Tilden et al, although no formal statistical tests were performed. Both studies reported that about half of those surveyed were aware of FCAs and that awareness varied by age, gender, education, and ethnicity.

Target Species

Tilden et al (1997) surveyed households in Great Lakes states to examine advisory awareness and compliance. Of those respondents who ate sport caught fish and were aware of FCAs, 50.3 percent of men and 29.4 percent of men responded to the FCAs by changing target species or fish size to avoid heavily contaminated fish.

Consumption Quantity

Connelly, Knuth and Brown (1996) examined consumption patterns of people who fished in Lake Ontario in New York. This study estimated how much fish people ate, how consumption changed as a result of PCB advisories and whether anglers used safe cooking practices to limit their exposure to contaminants. Anglers kept a diary of their fishing and fish eating activities over one year. The study finds that almost all survey respondents were aware of Lake Ontario FCAs. Further, it finds that over one-third of the sample (including more than half of a sensitive subpopulation – women) consumed more than FCA guidelines. Over 90 percent of those who ate more than the recommended amounts thought they were within the guidelines. The study also found that most people in the survey (73 percent) would increase their consumption if the FCAs did not exist.

Studies by Burger et al (1999a and 1999b) find that differences in fishing behavior and FCA awareness can be explained by differences in ethnicity. Minorities fishing in New York harbor were found to be less aware of FCAs and the potential adverse health consequences of eating PCB-contaminated fish. A meta-analysis by Burger (2000) indicates that awareness of FCAs can vary widely between fisheries. But, even when anglers were aware of FCAs, a majority (over 60 percent in every study reviewed) said the fish they consumed were safe to eat.

MacDonald and Boyle (1997) surveyed anglers in Maine following the issuance of a statewide FCA for mercury. They found that fewer about 15 percent of anglers who knew of the FCA would have eaten more fish if the advisory had not been in effect. The authors speculate, however, that most of the survey respondents may have been within the safe eating guidelines anyway.

Steenport et al (2000) surveyed sport fishers on the lower Fox River, a heavily PCB-contaminated area in Wisconsin. This study found that 83 percent of interviewees did not eat any of the fish they caught and that of these 75 percent said contamination was the reason they did not eat the fish. However, most interviewees, including non-fish eaters, were not aware of FCAs for the area.

Tilden et al (1997) surveyed households in Great Lakes states to examine advisory awareness and compliance. Of those respondents who ate sport caught fish and were aware of FCAs, 50.1 percent of men and 42.8 percent of men responded to the FCAs by eating less than the recommended maximum number of meals. These results are self reported and no effort was made to verify the reported compliance. Imm et al (2005) conducted a follow up survey. This study found that 52 percent of those who ate sport caught fish and were aware of FCAs complied with the recommended maximum number of meals. This result is similar to that of Tilden et al. Both studies reported that about half of those surveyed were aware of FCAs and that awareness varied by age, gender, education, and ethnicity.

Anglers' response to FCAs – A Dynamic Component

All of the existing studies on the effects of FCAs on angler behavior examine data for a snapshot in time – typically one fishing season. But, there is good reason to think that peoples' perception of risk and resultant behavior may change as time passes. The food safety literature consistently finds a temporary drop in demand due to a perceived health risk. Anglers' who do not immediately perceive any adverse health effects may begin to ignore warnings over time. Alternative, people may become more responsive to FCAs over time as information dissemination improves and they learn more about contamination in fish.

Many studies have examined the effects of health warnings on food consumption. Dahlgren and Fairchild (2002) estimated the demand impacts following well-publicized bacterial outbreaks in the poultry industry. They found that consumers responded to outbreak events (and the resultant publicity) but that demand rebounded in a brief period of time. Reduced demand due to the outbreaks was detected up to 24 weeks following the outbreak. However, demand generally began to rebound within two to four weeks of the outbreak. This study used weekly observations of poultry demand.

Schlenker and Villas-Boras (2006) examined market responses to outbreaks of mad-cow disease and warnings about red meat consumption on the Oprah Winfrey show. They found that demand reductions were large and occurred quickly after the event. However, the effects vanished gradually over the three months following events and were not permanent.

Thomsen, Shiptsova, and Hamm (2005) examine the dynamics of the demand effects from bacterial outbreaks involving packaged meat products. They found a very large drop in demand immediately following recall events. Consistent with other studies, they also found that these effects were temporary and demand recovered four to five months later. They also found that recall events affected only the specific brands involved. Consumers therefore used the detailed information they were given when making their purchasing decisions. This study used monthly observations and estimated separate demand equations for each geographic market.

Data

Data are provided by the Wisconsin Department of Natural Resources (WDNR). Effort, catch rates, and fish sizes are all calculated from WDNR's annual creel survey. The primary purpose of the survey is to keep track of total effort and harvest from the sport fishery in Lake Michigan. The survey is conducted by clerks who visit sites, count the number of anglers, and interview anglers (see Peterson and Eggold 2007 for more detailed information on the Wisconsin creel survey).

The creel survey is conducted using a modified access-point design to select which sites will be sampled on a given day. All potential sites are stratified by four dimensions: statistical management unit (an area unit comparable to a county), fishery type (ramp, pier, shore, and stream), survey period (month), and day type (weekday or weekend/holiday). Survey sites with each statistical management unit (SMU) were placed into site groups. Before conducting the survey on a given day, site groups were selected randomly for visitation. At each site, clerks make instantaneous counts of effort. Clerks counted boat trailers at ramp sites and the number of anglers at pier, shore and stream sites. Clerks interviewed angler parties at the end of their trips and collected information on how long the trip lasted and what was caught. Clerks also weighed and measured any fish that were kept.

Each site surveyed has information on the following variables: date, time of day, weekend/weekday, fishery type (ramp, pier, shore or stream) and count of anglers. In addition, clerks interviewed randomly selected anglers to interview at randomly selected sites and days. These interviews contained information on the following variables: date, time of day, fishery type, species targeted, fish caught (by species), fish kept (by species), time spent fishing, number of resident and non-resident anglers in each party and the size of each fish kept. We calculate catch rate and average size from the interview data.

In addition to data on observed fishing behavior from the Wisconsin creel survey, we include data on fish consumption advisories, fishing regulations, fishing license sales, and weather. WDNR furnished copies of the FCAs issued with fishing licenses from 1985 through 2006. Each advisory lists the recommended maximum number of meals of that may be safely consumed by species, fish size, and waterbody. Current advisories have five categories of maximum safe consumption, which we list in order of increasing severity: unlimited consumption, no more than 52 meals per year, no more than 12 meals per year, no more than 6 meals per year, and do not eat (zero meals per year). However, prior to 1997, FCAs for Wisconsin were worded differently. Pre-1997 advisories grouped species of fish at a given location into three groups, based on consumption advice. Group 1 species were labeled “These fish post the lowest health risk.” Group 2 species were labeled “Women and children should not eat these fish.” Group 3 species were labeled “No one should eat these fish.” Tables 1, 2, and 3 show the current advisories for species of interest in the lower Fox River, Green Bay, and Lake Michigan.

WDNR also furnished copies of recreational fishing regulations from 1986 to 2005. These regulations vary by species and location and consist of open season dates, bag limits (number of fish per person per day that may be harvested) and minimum size restrictions. WDNR also provided the number of fishing licenses sold by county from 1986-2005. Data on monthly average weather conditions for one station within each SME was obtained from the National Weather Service.

Empirical Model

For this preliminary draft, three empirical models are estimated using ordinary least squares regression: effort, target species, and fish kept. The data are aggregated up from daily observations at individual fishing locations to monthly observations statistical management units (SMUs). In all three models the unit of observation is the average fishing activity (effort, targeting behavior, or fish kept) in an SMU in a given month. Each model is estimated as a function of control variables and the policy variables of interest - FCA stringency. In this section we describe in detail the variables used in the model. The effort model is a single regression equation. The target species and fish kept models have an equation for each species of interest.

Dependent Variables

In the effort model, the dependent variable is the average number of anglers at a site. The data are a random sample where not every site is sampled on every day. Therefore, in this model observations are aggregated so that each observation is the average number of anglers per day at sites within an SMU for each month. In the target species model, the dependent variable is the percentage of fishing time and effort the average angler at each site spends targeting a species of fish. For example, on a given trip if an angler is fishing mostly for yellow perch but also for walleye, the angler might express his target percentage for yellow perch as 75 percent and his target percentage for walleye as 25 percent. Observations are aggregated from angler interviews so that each observation used in the model is the average target percentage at sites within an SMU for each month. This is the *TARGET PERCENT* variable. In the fish kept model the dependent variable is the percentage of fish kept. This is calculated by dividing the number of fish kept by the number of fish caught for each angler interview. Percentage of fish kept is recorded by species. Observations are then aggregated from angler interviews so that each observation used in the model is the average percentage kept at sites within an SMU for each month. This is the *PCT KEPT* variable.

Explanatory Variables – Control Variables

The control variables consist of catch rate, average and maximum sizes of the fish caught at a site, time of year, weather, total fishing population, fishing regulations, and site indicator variables.

Catch rate is the number of fish caught per hour at a site. It is calculated for each angler interview and the individual catch rates are averaged over each site for each month. Average and maximum sizes of fish caught are calculated for each angler interview and then averaged over each site for each month. The *CATCH RATE*, *AVG SIZE*, and *MAX SIZE* variables represent the quality of fishing at each site.

Time of year is represented by dummy variables for months of the year. Time of week variables account for differences that may be due fishing that occurs on weekends or holidays. More people fish on weekends. It is possible that more catch-and-release fishing occurs or that fishing trips are longer on weekends. This may affect the target species or amount of fish kept. The *PCT WEEKEND* variable is the number of survey counts performed on weekend days expressed as a percentage of the total number of days that an effort count occurs at a site. A higher percentage of weekend days should result in a higher average effort count (our results do, in fact, confirm this).

Weather variables account for variation that may be due to uncomfortable conditions for anglers. The *RAINY DAYS* variable is the number of days in the month with precipitation greater than 0.10 inches. The *CLDD* variable is cooling degree days in the month.

In the effort model, the number of anglers counted at a given site will depend on the number of potential sport fishers that live nearby. The *LICENSES* variable is annual sales of Great Lakes fishing stamps by county. This stamp is required for anglers (both Wisconsin residents and non-residents) to fish in Lake Michigan.

Fishing regulations should influence the dependent variables. We include in all three models variables to capture season closures, bag limits, and minimum size requirements. We create variables for bag limits and minimum size. Bag limits are restrictions on the number of fish that can be kept and vary by site and time of year. The

BAG LIMITS variable is the number of fish anglers can keep. If there is a season closure during a particular month, this is captured by setting the bag limit variable to 0. The *MIN SIZE* variable is the smallest fish that may be kept in an SMU during a particular month.

We also add SMU-specific dummy variables to account for additional unexplained variation in the data. There are 14 SMUs and we include dummy variables for 11 of them in the model.

Explanatory Variables - FCA Stringency Variables

This study is interested in the effect of FCAs on sport fisher behavior and whether any such effects vary over time. We include two variables that measure the stringency of FCAs at a location. The first FCA stringency variable is *FCAMEAL* - the recommended maximum number of meals per year for a species. Wisconsin FCAs are issued in terms of recommended maximum meals per year. There are five categories of advice that give a recommended maximum level of consumption. The five categories are listed here in order of increasing stringency: unlimited, no more 52 meals per year, no more than 12 meals per year, no more than 6 meals per year, and do not eat. We define *FCAMEAL* in terms of meals per year that correspond with the five advice categories: 365 meals per year, 52 meals per year, 12 meals per year, 6 meals per year, and 0 meals per year. Advisories may contain up to three recommended number of meals per species according to the size of the fish (refer to Tables 1, 2, and 3 for examples). Therefore, to express *FCAMEAL* as a single number we average the recommended number of meals over the 5 categories. For example, the FCA for lake trout in Lake Michigan is 12 meals for fish less than 23 inches, 6 meals for fish between 23 and 28 inches, and 0 meals for fish greater than 28 inches. The *FCAMEAL* variable thus takes on a value of 6 in this case ([12 meal + 6 meals + 0 meals]/3 categories of advice). *FCAMEAL* increases as advisories become more stringent. If anglers pay attention to FCAs, the coefficient on the *FCAMEAL* variable should be positive for all three models.

Because contaminant levels can be higher in bigger fish, advisories for given species may also vary by size (refer to Tables 1, 2, and 3 for examples). To account explicitly for the size component of FCAs we create the *FCASIZE* variable. *FCASIZE* is the maximum size of the smallest fish affected by an advisory. As an example, consider again the FCA for lake trout in Lake Michigan: 12 meals for fish less than 23 inches, 6 meals for fish between 23 and 28 inches, and 0 meals for fish greater than 28 inches. The *FCASIZE* variable takes a value of 23. We also add a dummy variable if a "Do Not Eat" warning is part of the advice for any fish.

As discussed above, many previous studies have analyzed whether sport fishers pay attention to FCAs. What is novel about the current study is that it analyzes sport fishers' response to FCAs over time. To do this, we construct lag variables of *FCAMEAL* and *FCASIZE* variable. Total effort, target percentage and fish kept are therefore estimated as functions not only of FCAs in the current time period, but also of FCAs in past time periods. Time periods are one year. The present paper does not attempt to trace out anglers' full dynamic response to FCAs. Rather, the FCA variables are lagged one year in an attempt to determine whether information on past years' FCAs affects fishing behavior in the current period.

Model Specification and Hypotheses to be Tested

The equation below gives the specification of the models to be estimated. Q is the dependent variable – angler count, target percentage, or fish kept. $\boldsymbol{X}$ is a vector of the control variables described above. The equation contains a random error term, ε, and β and the γs are parameters to be estimated. The subscript *t* denotes the time period.

$$Q_t = X_t \beta + \gamma_{m,t} FCAMEAL_t + \gamma_{s,t} FCASIZE + \gamma_{m,t-1} FCAMEAL_{t-1} + \gamma_{s,t-1} FCASIZE_{t-1} + \varepsilon$$

We can use this model to test the hypotheses that angler behavior depends on FCAs and that angler behavior depends on FCAs in past periods. If none of the parameters for the FCA policy variables are significant, then anglers do not pay attention to FCAs when making decisions. If the parameters for the FCA policy variables are not significant in time t, but are positive and significant in time t-1, then we could conclude that anglers do not use current FCAs to make decisions. Instead, they use their knowledge of prior FCAs to make decisions. Negative and significant results for the FCA parameters are problematic. These would indicate that anglers prefer more contaminated fish.

With the three models (effort, target species, and fish kept) we can analyze angler response to FCAs in terms of the four possible responses listed earlier: fish less frequently, change location, change target species, and keep fewer fish. If we detect a change in angler behavior total effort model, then anglers choose to fish less frequently in response to FCAs. Similarly, significant results in the target species and fish kept models would indicate that anglers respond to FCAs by changing what they fish for and how many fish they keep for consumption.

Results

Results for the three models are reported in Tables 4, 5, and 6. Overall, conclusions that can be drawn from the regression coefficients are ambiguous. However, there is some evidence that past FCAs influence angler behavior.

Effort

A selection of estimated coefficients for the variables of interest in the effort model are reported in Table 4. The dependent variable in this model is the average number of anglers per day fishing in a given statistical management unit. Many of the control variables, including fishery type, dummy variables for location, and time of year, are significant in determining the number of anglers fishing at each site. Site quality variables (catch rates and average size of fish caught) and fishing regulations are also significant for some species and have signs that make intuitive sense; these finding afford some confidence in the general quality of the data we use. Note that some variables, such as *BAG LIMITS* and *MIN SIZE*, were dropped for some species because the do not vary over time. For example, *MIN SIZE* for the three trout species is 10 inches in all years. Similarly, *FCASIZE* is dropped for yellow perch because it does not vary during the sample.

The policy variables of interest are the *FCAMEAL* (the average number of recommended meals per year) and the *FCASIZE* (the size of the smallest fish affected by a given advisory). The two policy variables are created for the most popular target species in an area. If anglers pay attention to FCAs then the number of anglers fishing in an area should be positively associated with both of these variables. More people should fish in an area where the recommended number of meals is higher and more people should fish in an area where the advisory only applies to larger fish.

Our results show that the current FCA variables for are not significant. This implies that the level of fishing effort at a site is not affected by the current year FCA. *FCASIZE* advice is not significant while *FCAMEAL* is significant. This suggests that there may be a dynamic component to how anglers react to FCAs, but if so, the dynamic component is small.

Target species

The results of the targeting behavior model are presented in Table 5. The dependent variable is the percentage of fishing time and effort the average angler at each site spends targeting a species of fish. We estimate one equation for each of seven species of interest. The results show that location and time of year drive anglers' decisions on what to fish for. Site quality variables (catch rate and average fish length) are also important, especially for rainbow trout. Again, some variables, such as *BAG LIMITS* and *MIN SIZE,* were dropped for some species because the do not vary over time. As in the previous analysis, the policy variables of interest are the FCA meal advice and the FCA size advice for each fish species, where we expect that the dependent variable should vary positively with both policy variables.

Our results indicate that FCASIZE in time *t* affects targeting behavior. As the size of fish affected increases, the percentage of time and effort spent on targeting a given species increases. The results for FCA meal advice in time *t* are more ambiguous.

Fishing for rainbow trout and yellow perch appear increase as the number of recommended meals increase (meaning the FCA becomes less stringent). In addition, the presence of a “Do Not Eat” warning for rainbow trout, brown trout, and walleye greatly reduces the degree to which those species are targeted. However, the *FCAMEAL* result is counterintuitive for coho salmon, chinook salmon, brown trout, and walleye – these fish are targeted less as meal advice increases (that is, as the fish become cleaner).

FCASIZE and *FCAMEAL* in time *t-1* both appear to influence target species behavior, indicating that there may be a dynamic component to how anglers respond to FCAs. *FCASIZE* in time *t-1* is positive and significant for coho salmon and lake trout. This indicates that past advisories, even if they are different from current advisories, influence anglers’ decision about whether to fish for coho salmon and lake trout. *FCASIZE* in time *t-1* is for chinook salmon, rainbow trout, and walleye is negative and significant – a result that is more difficult to interpret. *FCAMEAL* in time *t-1* is positive and significant for coho salmon, rainbow trout, lake trout, and walleye. This indicates that knowledge of past advisories persists even after new warnings are issued. *FCAMEAL* in time *t-1* is negative and significant for chinook salmon and yellow perch. In summary, the target model indicates that there is some evidence for a dynamic component to anglers’ response to FCAs in some species. However, negative and significant coefficients are counterintuitive and present some difficulties with interpretation.

Percent of fish kept

The results of the percent of fish caught model are presented in Table 6 below. The dependent variable is the percentage of fish kept per trip by the average angler at each site. We estimate one equation for each of eight species of interest. The results show that location and time of year drive anglers' decisions on what to fish for. The average size of the fish is also important – larger fish mean that a higher percentage of fish are likely to be kept for consumption. The policy variables of interest are again the average number of recommended meals per year and the maximum size of the smallest fish affected by a given advisory for each fish species, where we expect that the dependent variable should vary positively with both policy variables.

Yellow perch anglers appear to exhibit a dynamic response to FCAs, as measured by changes in the percent of fish caught. FCAMEAL in the current year does not affect how many yellow perch are kept. FCAMEAL in t-1, however, does not affect how many yellow perch are kept. Other species, however, exhibit coefficients that are negative and significant, a result that is counterintuitive and difficult to interpret.

Discussion

This paper attempts to determine whether anglers respond to fish consumption advisories. Unlike previous studies, we attempt further to determine whether knowledge of past advisories has any effect on anglers' current fishing behavior. Some results in our three models (effort, target species, and percent of fish kept) indicate, via positive and significant lagged policy variables, that response to FCAs may have a dynamic component. However, these results are not consistent across species or models and negative coefficient values on the FCA variables (indicating that anglers prefer more contaminated fish) suggest that the model should be improved.

Further work in three areas may improve our ability to model anglers' response to FCAs. First, we should incorporate conditions at other sites and/or with other species. Effort at one site depends not only on the FCAs at the site, but also FCAs at other sites. For example, if FCAs change to become more stringent at both of two neighboring sites, the absolute stringency of the warnings may not affect effort as much as the relative stringencies. Similarly, anglers may choose to target or keep a certain species not because of the absolute level of the FCA for the fish, but the level of the advisory relative to other species.

Second, we should experiment with a single FCA variable rather than two. The current version of the model has variables to represent both the meal advice and size component of Wisconsin FCAs. These variables are closely related our model may be conflating the effects of the two separate components. We will develop a single FCA stringency variable to remove this possible source of multicollinearity.

Third, the model is currently estimated using OLS regression. Specification testing will determine if other, more sophisticated methods are appropriate. In particular, a grouped multinomial logit model might better reflect the discrete choice nature of fishing behavior.

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Table 1. FCA for Fox River from the DePere Dam downstream to the mouth

Species	Unlimited	1 meal/week (52/year)	1 meal/mo. (12/year)	1 meal/2 mo. (6/year)	Do Not Eat
Smallmouth bass			All sizes		
Walleye			< 16”	16 – 22”	> 22”
Yellow Perch			All sizes		

Table 2. FCA for Green Bay south of Marinette and its tributaries (except the Lower Fox River) from their mouths up to the first dam

Species	Unlimited	1 meal/week (52/year)	1 meal/mo. (12/year)	1 meal/2 mo. (6/year)	Do Not Eat
Brown trout			< 17”	17 – 28”	> 28”
Chinook salmon			< 30”	> 30”	
Rainbow trout			All sizes		
Smallmouth bass			All sizes		
Walleye			< 16”	16 – 22”	> 22”
Yellow Perch		All sizes			

Table 3. FCA for Lake Michigan and its tributaries up to the first dam

Species	Unlimited	1 meal/week (52/year)	1 meal/mo. (12/year)	1 meal/2 mo. (6/year)	Do Not Eat
Brown trout			< 22”	> 22”	
Chinook salmon			< 32”	> 32”	
Coho salmon			All sizes		
Lake trout			< 23”	23 – 27”	> 27”
Rainbow trout			All sizes		
Yellow Perch		All sizes			

Table 4. Effort - average number of anglers (not all variables shown)

Variable	Estimated Coefficient (p-value)
CATCH RATE Brown Trout	-1.641 (0.152)
CATCH RATE Rainbow Trout	0.588 (0.666)
CATCH RATE Lake Trout	3.934 (0.671)
CATCH RATE Coho Salmon	-5.942* (0.054)
CATCH RATE Chinook Salmon	2.161 (0.203)
CATCH RATE Yellow Perch	0.039 (0.802)
CATCH RATE Walleye	5.169*** (0.000)
CATCH RATE Smallmouth Bass	-1.973* (0.053)
CATCH RATE Other Species	-0.350 (0.456)
AVG SIZE Brown Trout	0.034 (0.439)
AVG SIZE Rainbow Trout	0.142*** (0.001)
AVG SIZE Lake Trout	0.104 (0.155)
AVG SIZE Coho Salmon	0.267*** (0.000)
AVG SIZE Chinook Salmon	0.094*** (0.006)
AVG SIZE Yellow Perch	0.157* (0.062)
AVG SIZE Walleye	0.079 (0.221)
AVG SIZE Smallmouth Bass	0.015 (0.856)
AVG SIZE Other Species	0.027 (0.583)
BAG LIMIT Lake Trout	0.766*** (0.001)
BAG LIMIT Yellow Perch	0.055*** (0.003)
BAG LIMIT Walleye	0.000 (0.623)
BAG LIMIT Smallmouth Bass	-0.964*** (0.000)
MIN SIZE Walleye	0.073** (0.047)
MIN SIZE Smallmouth Bass	0.025 (0.669)
FCAMEAL	-0.002 (0.460)
FCASIZE	0.026 (0.528)
$FCAMEAL_{t-1}$	0.006** (0.014)
$FCASIZE_{t-1}$	0.056 (0.150)

***Estimated coefficient significant at the 1% level.
**Estimated coefficient significant at the 5% level.
*Estimated coefficient significant at the 10% level.

Table 5. Targeting behavior (not all variables shown)

	Estimated Coefficients (p-values)						
	Coho Salmon	Chinook Salmon	Rainbow Trout	Lake Trout	Brown Trout	Yellow Perch	Walleye
CATCH RATE	35.728*** (0.000)	34.55347 (0.000)	6.721991 (0.002)	99.16243 (0.000)	21.01284 (0.000)	6.937*** (0.000)	41.787*** (0.000)
AVG SIZE	1.913*** (0.000)	1.518875 (0.000)	1.513567 (0.000)	1.063003 (0.000)	1.847989 (0.000)	3.745*** (0.000)	2.337*** (0.000)
BAG LIMIT				4.0734 (0.000)		0.100*** (0.001)	0.003*** (0.000)
MIN SIZE							0.031 (0.278)
FCASIZE	1.044*** (0.000)	1.108*** (0.001)	2.704*** (0.000)	1.702*** (0.000)	0.571*** (0.000)		2.359*** (0.001)
FCAMEAL	-0.204*** (0.000)	-0.058*** (0.000)	0.081*** (0.000)	0.006 (0.752)	-0.049*** (0.000)	0.028*** (0.000)	-0.030*** (0.000)
DoNotEat		3.166662 (0.149)	-85.5361 (0.000)		-18.5419 (0.000)		-53.191*** (0.001)
$\mathit{FCASIZE}_{t-1}$	0.113** (0.054)	-2.144*** (0.000)	-0.487*** (0.002)	1.336*** (0.000)	0.019 (0.840)		-2.578*** (0.000)
$\mathit{FCAMEAL}_{t-1}$	0.059*** (0.000)	-0.025** (0.013)	0.044*** (0.000)	0.140*** (0.000)	-0.012 (0.308)	-0.018*** (0.000)	0.0161*** (0.000)
$\mathit{DoNotEat}_{t-1}$		0.707 (0.745)	7.057 (0.118)		11.031*** (0.000)		58.050*** (0.000)
_cons	29.769*** (0.000)	32.936*** (0.000)	31.082*** (0.000)	-72.891*** (0.000)	37.247*** (0.000)	-10.826*** (0.000)	6.611** (0.010)

***Estimated coefficient significant at the 1% level.

**Estimated coefficient significant at the 5% level.

*Estimated coefficient significant at the 10% level.

Table 6. Percent of fish kept by species (not all variables shown)

	Estimated Coefficients (p-values)							
	Chinook Salmon	Coho Salmon	Brown Trout	Rainbow Trout	Lake Trout	Yellow Perch	Walleye	S.mouth Bass
CATCH RATE	-1.628	-4.865	-8.651***	-7.436***	-5.716	-0.211	-9.359**	-9.818***
	(0.649)	(0.469)	(0.002)	(0.001)	(0.776)	(0.593)	(0.013)	(0.000)
AVG SIZE	0.150***	0.899***	0.981***	0.736***	0.569***	1.259***	0.874***	1.186***
	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
BAG LIMIT					1.771976	0.155517	0.001259	-1.23241
					(0.080)	(0.010)	(0.780)	(0.139)
MIN SIZE							-0.43311	-1.34659
							(0.107)	(0.000)
FCASIZE	0.212	-0.037	-0.022	0.201	-0.964		0.778**	
	(0.436)	(0.754)	(0.853)	(0.260)	(0.122)		(0.028)	
FCAMEAL	0.012	-0.000	-0.004	-0.006	-0.0753**	0.003	0.038**	0.007
	(0.239)	(0.993)	(0.819)	(0.506)	(0.014)	(0.752)	(0.014)	(0.449)
FCASIZE$_{t-1}$	0.004	0.0749	-0.201**	-0.413**	0.110		-0.418	
	(0.986)	(0.330)	(0.047)	(0.013)	(0.793)		(0.105)	
FCAMEAL$_{t-1}$	0.007	-0.002	-0.024	-0.004	0.013	0.026**	-0.032**	0.008
	(0.458)	(0.823)	(0.183)	(0.585)	(0.601)	(0.013)	(0.026)	(0.506)
_cons	36.396***	42.763***	46.787***	45.045***	47.770***	39.321***	10.995	17.283**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.006)	(0.000)	(0.317)	(0.056)

***Estimated coefficient significant at the 1% level.

**Estimated coefficient significant at the 5% level.

*Estimated coefficient significant at the 10% level.