FINAL REPORT

NMFS-Sea Grant Fellowship in Marine Resource Economics - Cameron Speir, Incorporating Contaminant Levels into Models of Fishing Location Choice: An Application to Fisheries in the Great Lakes

July 31, 2008

FELLOW
Cameron Speir
Agricultural and Consumer Economics
University of Illinois
326 Mumford Hall, MC 710
Urbana, IL 61801-3605
Phone: (217) 493-5087
speir@uiuc.edu

FACULTY ADVISOR
John Braden
Agricultural and Consumer Economics
University of Illinois
326 Mumford Hall, MC 710
Urbana, IL 61801-3605
Phone: (217) 333-5501
jbb@uiuc.edu

ABSTRACT

This report presents an economic model of human behavior as it applies to toxic contamination in the Great Lakes basin. Toxic contamination and fish consumption by recreational anglers is regarded as among the most important issues facing the Great Lakes ecosystem (Environment Canada and U.S. EPA 2007). While much time and resources are devoted to ecological assessment and monitoring and developing regulations, much less research has been directed toward how people respond to management policies (Dobsen et al 2003). The study described here estimates people's response to government-issued information on the risks of eating PCB-contaminated sportfish. We use 19 years of creel survey data to estimate the effect of more lenient fish consumption advisories (FCAs) on the size of Chinook salmon kept and the effect of more stringent FCAs on the number of yellow perch kept. We find that in both cases the FCAs appear to have had the intended effects – people kept relatively larger Chinook salmon and fewer yellow perch.

Fish consumption advisories are a way to reduce human exposure to toxic contamination while avoiding expensive cleanup costs. These FCAs are voluntary, so there is no guarantee that exposure to toxins will be reduced simply by issuing an advisory. If advisories are ineffective, then policy makers must re-assess whether the benefits of cleanup outweigh the costs of the public's continued exposure. The findings presented here, that these FCAs appear to have an effect on fish consumption, should be heartening to policy makers.

Economic models of human behavior are often not included in the analysis of policies designed to improve environmental quality. However, economic behavioral

models can show that policies do not achieve the state goal or, worse yet, have unintended negative consequences (Smith and Wilen 2003). The purpose of this dissertation is to incorporate economic behavior into analysis of fisheries management policies in the Great Lakes region.

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NARRATIVE REPORT

Introduction

This paper estimates recreational fishers' response to government-issued warnings regarding consumption of PCB-contaminated sportfish. Consuming fish can expose people to contaminants that may be harmful to human health. Fish consumption advisories (FCAs) are used to warn the public about contaminants in fish and the potential adverse health effects from consuming harvested fish. Authorities hope that by issuing FCAs, they can influence people to alter their behavior, either by avoiding fishing at a contaminated location or by eating less fish. This paper addresses two research questions regarding whether and how recreational fishing behavior is affected by information on fish quality. First, are FCAs effective at altering the behavior of recreational anglers? Second, is angler response to FCAs instantaneous or distributed over time?

Empirical Strategy and Data

Yearly FCAs in Wisconsin are stable for a period of time in our data and then change. Warnings vary by location, depending on the levels of PCB in fish tissue at given locations. From 1976 to 1994, FCAs placed fish species into three categories of health risk. The 1994 advisories covering Green Bay and Lake Michigan are reproduced in Table 1. In 1995 and 1996, Wisconsin, in conjunction with other Great Lakes states, undertook a comprehensive revision of FCAs and changed the format for FCAs beginning in 1997. FCAs at each location listed a recommended maximum number of meals: unlimited consumption, no more than 52 meals per year, no more than 12 meals per year, no more than 6 meals per year, or do not eat. The 1997 advisories covering Green Bay and Lake Michigan are reproduced in Table 2.   FCAs in general change infrequently. Table 3 shows the size advice for Chinook salmon in Lake Michigan and Green Bay from 1997 through 2005. Table 4 shows that the recommended maximum number of meals for yellow perch from 1987 through 2005.

Data are from an annual creel survey conducted by the Wisconsin Department of Natural Resources. We use data on the size of fish kept from 2000 through 2005 to analyze changes in Chinook salmon FCAs. We use data on the number of fish kept from 1987 through 2005 to analyze the effects of changes in yellow perch FCAs.

Empirical Model of the Size of Fish Kept (Chinook Salmon)

The Chinook salmon model uses a differences-in-differences (DD) approach to estimate changes in the size of fish kept as a function of a change in the FCA. We examine the FCAs in two adjacent areas, Lake Michigan (the treatment group) and Green Bay (the control group. From 1997 through 2002, WDNR advised anglers to eat no more than 6 meals per year of fish greater than 30 inches long and no more than 12 meals per year of fish less than 30 inches long. In 2003 the FCA changed so that anglers were advised to eat no more than 6 meals per year of fish greater than 32 inches long and no more than 12 meals per year of fish less than 32 inches long. This change implies that larger fish in Lake Michigan were deemed safer in 2003. During this time period, the size of Chinook salmon specified in the advisory for Green Bay remained at 30 inches. If anglers pay attention to FCAs and use them in determining what fish to keep, there should be an increase in the average length of fish kept in the affected area, relative to the control area. Ideally, we would estimate the length of fish kept as a function of the size distribution of the population of fish. These data, however, are not available. One advantage of the DD model is that if the difference in size distribution of fish between the control and treatment locations is constant, then this effect is controlled for. We restrict the areas we analyze in Lake Michigan to sites in Door and Kewaunee counties in order to further minimize the differences between the treatment and control groups. These sites are very close to sites in Green Bay and thus should encounter similar temperature and rainfall conditions from year-to-year. Figure 1 shows trends in the average length of fish kept for the Green Bay FCA area and sites in Door and Kewaunee counties in the Lake Michigan FCA area. The two trend lines in Figure 1 appear to track closely over the entire time series, and Green Bay does not exhibit an independent downward trend immediately prior to the policy change in 2003.

Empirical Model of the Number of Fish Kept (Yellow Perch)

The second empirical model estimates the number of yellow perch kept per fishing trip as a function an FCA change in 1997. Our empirical model estimates the effect of a more stringent FCA for yellow perch in all areas beginning in 1997 (changes are summarized in Table 4). We estimate fish kept as a function of the FCA level. Each observation is a survey response and the dependent variable is the number of fish kept per trip.

There are three possible patterns of time-varying response. First, anglers could adjust their behavior immediately and the effect would remain consistent as time passes. Second, anglers may adjust their behavior by a small amount initially and gradually reduce the number of fish kept over time. Third, anglers may respond initially to the change in FCAs (by reducing the amount of fish kept) and then gradually revert to their previous behavior (by increasing the amount of fish kept). To test for such time-varying effects, we adopt an empirical approach similar Liu et al's model of milk consumption following an episode of bacterial contamination. In this approach, the number of fish kept is a function of the amount of time that has passed since the change in FCA.

Results

Size of Fish Kept (Chinook Salmon)

The results of the static difference-in-differences model are presented in Table 5. Changes in the FCA for Lake Michigan that made larger fish appear safer in those waters may be responsible for the difference in sizes of fish kept after the policy change. To test for time-varying impacts, we re-estimate the DD model for Chinook salmon length and allow the time impacts to differ in the three years following the change in FCAs. Wald tests fail to reject the null hypotheses that the parameters on the time-varying impacts are equal, therefore, the differences in fish size following the more permissive FCA do not appear to be distributed over time.

Number of Fish Kept (Yellow Perch)

We estimate a model of the amount of fish kept following changes in the FCA for yellow perch. The data used to estimate the yellow perch kept model are summarized in Table 6. Although the mean number and percentage of yellow perch kept is much lower in the period with more stringent FCAs, the population of yellow perch declined dramatically through the 1990s, as measured by the catch per fishing trip in out data and by fishery-independent stock assessment (WDNR 2007). Figure 2 shows the average number of yellow perch caught and kept per angler by year over the length of the data set.

The number of fish kept tracks the number of fish caught so we require an econometric model to control for reduced catch rates.

Table 7 shows the results of the estimated count regression in models that does not incorporate time varying effects. There is evidence that anglers respond to more stringent FCAs by keeping fewer fish per fishing trip. All estimated coefficients for the FCA variables are negative, indicating that on average people kept fewer fish when an advisory was in place. The estimated coefficients for the 52 meals and 12 meals FCA variables are significant. The 12 meals variable is more negative than the 52 meals variable. This is consistent with people keeping fewer fish when warnings are more stringent.

Marginal effects, presented in Table 8, show the magnitude of the effect of FCAs. Anglers keep about 2 fewer fish when an "Eat no more than 52 meals" FCA is present and keep almost 4 fewer fish when an "Eat no more than 12 meals" FCA is present. The marginal effect of the "Do not eat" FCA is not significant. The difference in marginal effects between the three dummy variables indicates that the effect of the meal advice may be non-linear. Also, the result that the "Do not eat" FCA has no effect on consumption is contrary to what we would expect if people pay attention to FCAs. This result is difficult to interpret, however, because there is only one location in the data set (Sheboygan Harbor) with only 15 observations with a do not eat advisory in effect.

We add a series of trend variables to test for evidence that angler's response to FCAs varies over time, as described above with results presented in Table 9. Model I models any time-vary response by interacting the FCA variable with $\gamma(t) = \gamma_0 + \gamma_1 *t + \gamma_2*t^2 + \gamma_3*t^3$. Model II interacts FCA with $\gamma(t) = \gamma_0 + \gamma_1 *t + \gamma_2*t^2$. Model III interacts

FCA with $\gamma(t) = \gamma_0 + \gamma_1 * t$. In each case, t is time in years where $t = 1$ in 1997, the first year the more stringent FCAs were in place.

Figure 3 shows that the predicted number of fish kept generated by each of the three models (Models I, II, and III from Table 9) rises from the beginning of the data set to the point where FCAs became more stringent (1997). This is because the estimated overall trend over the entire 18 years of data is positive after controlling for the effect of lower catch rates. The predicted number of fish drops by almost 1.5 fish. In the nonlinear trend models (Models I and II) the predicted number of fish kept rises again and then declines.

Conclusion

We address two questions regarding recreational fishing behavior and warnings on toxic contamination in fish tissue. First, do recreational anglers respond to changes in expert assessments of the risk of eating contaminated fish? Second, does this response vary over time? Our results regarding the first question indicate that recreational fishers change their fishing behavior when FCAs change. A difference-in-differences analysis shows that anglers tend to keep relatively larger fish after FCAs were revised to indicate larger Chinook salmon were less contaminated. Additional regression analyses show that anglers kept fewer yellow perch after FCAs became more stringent and advised people to eat fewer yellow perch meals.

Previous studies on the effects of FCAs on angler behavior reach differing conclusions. Both of the results above are evidence that FCAs do influence anglers' decision on whether to keep and consume a fish that they have caught. This study adds to the existing literature on FCAs by providing a broad-based policy analysis using many thousands of observations rather than a small sample of anglers. Our results must also be interpreted with caution, because the strongly significant coefficients on the policy variables of interest that we obtain may be due to year-to-year fluctuations unrelated to the policy changes. We also find that anglers gradually adjust their behavior over time in response to an increase in the expert assessed risk of fish consumption. Our models of yellow perch anglers are able to detect a gradual reduction in the amount of fish kept rather than an immediate adjustment. This pattern of time-distributed response is consistent with what we would observe if people change their subjective risk assessments only slowly in response to objective information on risk.

We find that FCAs affect anglers' fishing behavior. Further, we are able to detect a time trend where people respond more strongly to the advisory as time passes. This time-varying impact may be due to some form of habit persistence or distrust of the expert assessed risk. The time-varying impact could also be due to a slow process of information dissemination from the government agency issuing the FCA to the public.

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Tables

Table 1. FCA 1994, selected species and water bodies

Species	Category 1	Category 2	Category 3
Green Bay, South of Marinette			
Chinook salmon	<25 inches		>25 inches
Rainbow trout	<22 inches		>22 inches
Brown trout	<12 inches		>12 inches
Yellow perch	All sizes		
Lake Michigan			
Chinook salmon	<21 inches	21-32 inches	>32 inches
Rainbow trout	All sizes		
Brown trout		<23 inches	>23 inches
Yellow perch	All sizes		

Category 1 = "These fish pose the lowest health risk"
Category 2 = "Women and children should not eat these fish"
Category 3 = "No one should eat these fish."

Table 2. FCA 2005, selected species and water bodies

Species	Unlimited	Eat no more than 1 meal a week or 52/year	Eat no more than 1 meal a month or 12/year	Eat no more than 1 meal every 2 mo or 6/year	Do Not Eat
Green Bay, South of Marinette					
Chinook salmon			<30 inches	>30 inches	
Rainbow trout			All sizes		
Brown trout			<17 inches	17-28 inches	>28 inches
Yellow perch		All sizes			
Lake Michigan and its tributaries up to the first dam					
Chinook salmon			<32 inches	>32 inches	
Rainbow trout		<22 inches	>22 inches		
Brown trout			<22 inches	>22 inches	
Yellow perch		All sizes			

Table 3. Policy change: Length advice increases for Chinook salmon

Year	Lake Michigan: Eat no more than 12 meals	Lake Michigan: Eat no more than 6 meals	Green Bay: Eat no more than 12 meals	Green Bay: Eat no more than 6 meals
1997	< 30 inches	> 30 inches	< 30 inches	> 30 inches
1998	< 30 inches	> 30 inches	< 30 inches	> 30 inches
1999	< 30 inches	> 30 inches	< 30 inches	> 30 inches
2000	< 30 inches	> 30 inches	< 30 inches	> 30 inches
2001	< 30 inches	> 30 inches	< 30 inches	> 30 inches
2002	< 30 inches	> 30 inches	< 30 inches	> 30 inches
2003	***< 32 inches***	***> 32 inches***	< 30 inches	> 30 inches
2004	***< 32 inches***	***> 32 inches***	< 30 inches	> 30 inches
2005	***< 32 inches***	***> 32 inches***	< 30 inches	> 30 inches

Table 4. Changes in FCA meal advice for yellow perch by area

Recommended maximum number of yellow perch meals per year

Years	Lake Michigan	Green Bay	Lower Fox River	Sheboygan Harbor
1987 – 1996	Unlimited (365)	Unlimited (365)	Unlimited (365)	Unlimited (365)
1997 – 2005	52	52	12	0

Table 5. Difference-in-differences, static model of Chinook salmon

Variable	Treatment = Door & Kewaunee Counties
Treatment Effect	2.60 (0.76)***
Time Effect (After the policy change)	-2.30 (0.69) ***
Group Effect (Lake Michigan)	0.68 (1.06)
Pier fishery	3.36 (0.95) ***
Shore fishery	5.13 (0.70) ***
Stream fishery	4.40 (0.65) ***
Summer	-1.71 (0.43) ***
Autumn	0.32 (0.67)
Marinette County	-0.30 (1.08)
Door County (Lake Michigan)	--
Kewaunee County (Lake Michigan)	-0.53 (0.34)
Manitowoc County	--
Milwaukee County	--
Ozaukee County	--
Sheboygan County	--
Oconto County	1.00 (1.11)
Racine County	--
Intercept	28.86 (1.09) ***
Number of obs	1,953
F-statistic	60.08
Prob > F	0.00
R-squared	0.19

Table 6. Summary statistics – yellow perch kept model

Variable	Mean (Std. Error) pre-change 1987-1996	post-change 1997-2005	All years 1987-2005
Yellow perch kept (fish per party)	12.3 (17.2)	5.8 (9.1)	10.9 (16.0)
Yellow perch kept (fish per angler)	6.9 (8.7)	3.2 (4.6)	6.1 (8.2)
Percent kept (per party)	0.7 (0.4)	0.5 (0.4)	0.7 (0.4)
Percent kept (per angler)	0.5 (0.3)	0.4 (0.4)	0.5 (0.3)
Yellow perch caught (per party)	16.2 (21.8)	10.6 (15.5)	14.9 (20.8)
Yellow perch caught (per angler)	9.4 (12.0)	6.0 (8.3)	8.6 (11.4)
Anglers per party	1.8 (0.9)	1.9 (1.0)	1.9 (0.9)
Hours fished per trip	3.2 (2.1)	3.1 (2.0)	3.2 (2.1)
Percent of parties targeting yellow perch	98.8 %	94.9 %	97.9 %
Observations	30,505	8,520	39,025

Table 7. Count model – number of fish kept

	Estimated Coefficient (Standard Error)
FCA dummy – Do Not Eat	-0.1739 (0.1955)
FCA dummy – 12 meals	-0.8835 (0.1395)***
FCA dummy – 52 meals	-0.3247 (0.0454)***
Trend	0.0107 (0.0060)*
Number of fish caught	0.0991 (0.0046)***
(Number of fish caught)^2	-0.0007 (0.0001)***
Bag Limit	0.0033 (0.0011)***
Targeting yellow perch	1.7131 (0.3000)***
Number of anglers in party	-0.0892 (0.0147)***
Hours fished	0.0431 (0.0071)***
Boat fishery	0.4518 (0.0663)***
Pier fishery	0.2272 (0.0570)***
Shore fishery	0.1692 (0.0545)***
Weekend	-0.0506 (0.0137)***
April	0.1122 (0.0628)*
May	-0.0318 (0.0223)
June	-0.0121 (0.0148)
August	0.0170 (0.0140)
September	0.0525 (0.0171)***
October	0.0847 (0.0268)***

Table 8. Marginal Effects, count model – number of fish kept

	Estimated Coefficient (Standard Error)
FCA dummy – Do Not Eat	-1.0474 (1.0682)
FCA dummy – 12 meals	-3.8523 (0.4643)***
FCA dummy – 52 meals	-1.9076 (0.2621)***
Trend	0.0702 (0.0393)*
Number of fish caught	0.6506 (0.0604)***
(Number of fish caught)^2	-0.0049 (0.0004)***
Bag Limit	0.0215 (0.0081)***
Targeting yellow perch	5.4533 (0.4332)***
Number of anglers in party	-0.5854 (0.1257)***
Hours fished	0.2971 (0.0559)***
Boat fishery	3.2549 (0.5493)***
Pier fishery	1.0727 (0.2622)***
Shore fishery	0.7716 (0.2248)***
Weekend	-0.0759 (0.0200)***
April	0.4405 (0.2606)*
May	-0.0580 (0.0399)
June	-0.0184 (0.0224)
August	0.0277 (0.0231)
September	0.1398 (0.0467)***
October	0.3661 (0.1208)***

Table 9. Count model with dynamic response variables – FCA dummies

	Model I	Model II	Model III
FCA dummy	-0.1850 (0.1624)	-0.3779 (0.0571)***	-0.1781 (0.0324)***
FCA dummy*(years after change)	-0.1211 (0.1507)	0.0667 (0.0321)**	-0.0464 (0.0103)***
FCA dummy*(years after change)^2	0.0331 (0.0343)	-0.0112 (0.0031)***	--
FCA dummy*(years after change)^3	-0.0029 (0.0023)	--	--
Trend	0.0253 (0.0061)***	0.0254 (0.0060)***	0.0222 (0.0064)***
Number of fish caught	0.0995 (0.0047)***	0.0993 (0.0047)***	0.0992 (0.0047)***
(Number of fish caught)^2	-0.0007 (0.0001)***	-0.0007 (0.0001)***	-0.0007 (0.0001)***
Bag Limit	0.0050 (0.0012)***	0.0051 (0.0013)***	0.0039 (0.0011)***
Targeting yellow perch	1.7073 (0.2992)***	1.70231 (0.3005)***	1.7087 (0.3027)***
Number of anglers in party	-0.0860 (0.0145)***	-0.0861 (0.0147)***	-0.0857 (0.0146)***
Hours fished	0.0414 (0.0067)***	0.0415 (0.0068)***	0.0416 (0.0068)***
Boat fishery	0.4539 (0.0655)***	0.4570 (0.0669)***	0.4568 (0.0664)***
Pier fishery	0.2327 (0.0565)***	0.2343 (0.0567)***	0.2307 (0.0561)***
Shore fishery	0.1811 (0.0546)***	0.1822 (0.0545)***	0.1777 (0.0540)***
Weekend	-0.0492 (0.0139)***	-0.0492 (0.0139)***	-0.0486 (0.0138)***
April	0.1038 (0.0610)*	0.1084 (0.0641)*	0.1034 (0.0644)
May	-0.0258) (0.0216)	-0.0265 (0.0215)	-0.0278 (0.0214)
June	-0.0007 (0.0155)	-0.0004 (0.0156)	-0.0016 (0.0159)
August	0.0139 (0.0138)	0.0132) (0.0139)	0.0126 (0.0138)
September	0.0472 (0.0182)***	0.0459 (0.0177)***	0.0450 (0.0174)***
October	0.0841 (0.0265)***	0.0829 (0.0247)***	0.0790 (0.0240)***

Figures

Figure 1. Average size of Chinook salmon kept – Door, Kewaunee Counties only

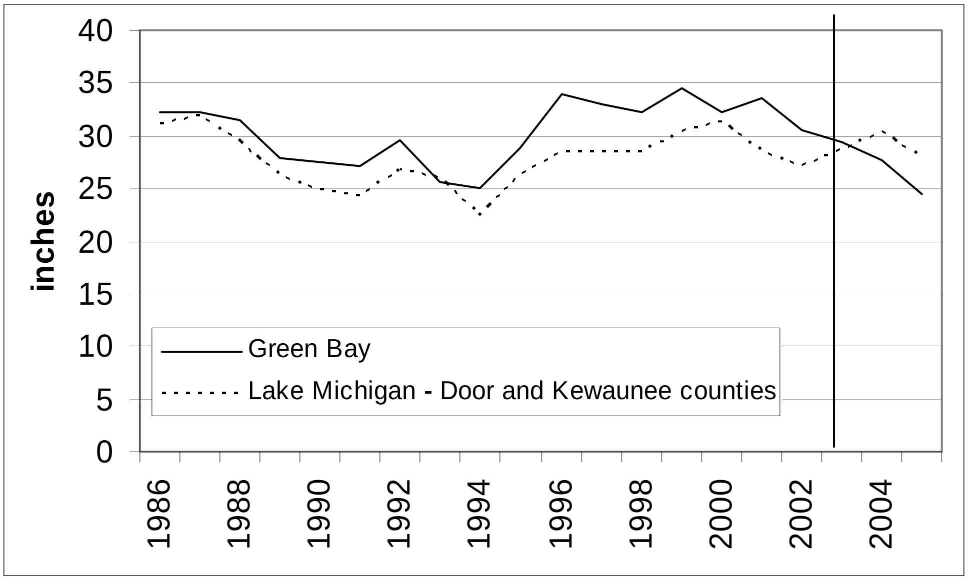


Figure 2. Average number of yellow perch caught and kept per angler by year

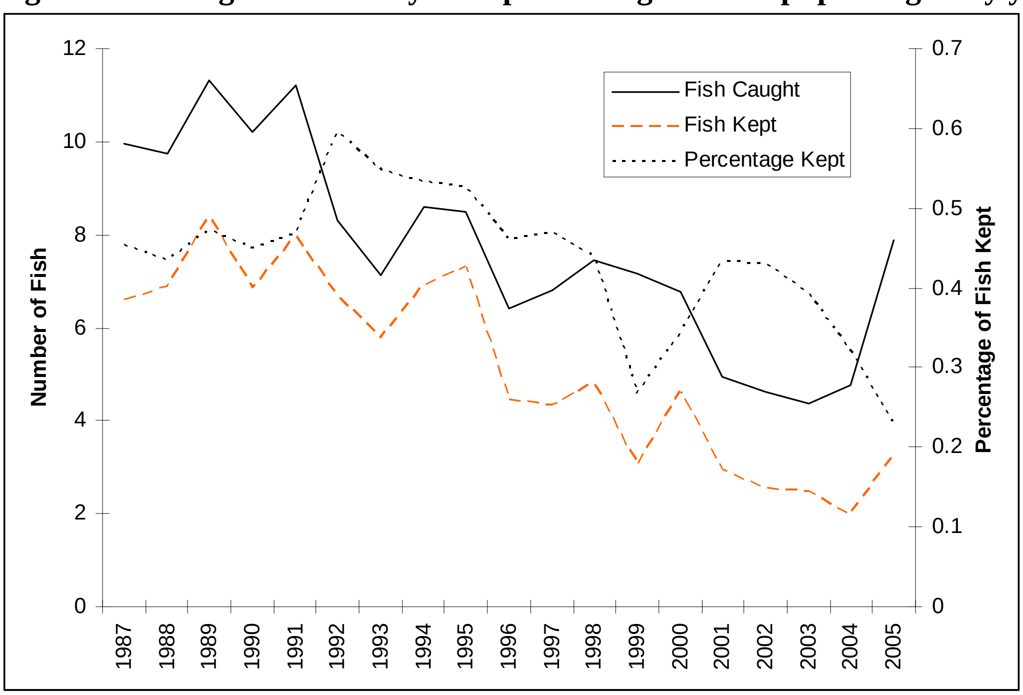


Figure 3. Predicted number of fish kept per fishing trip over time

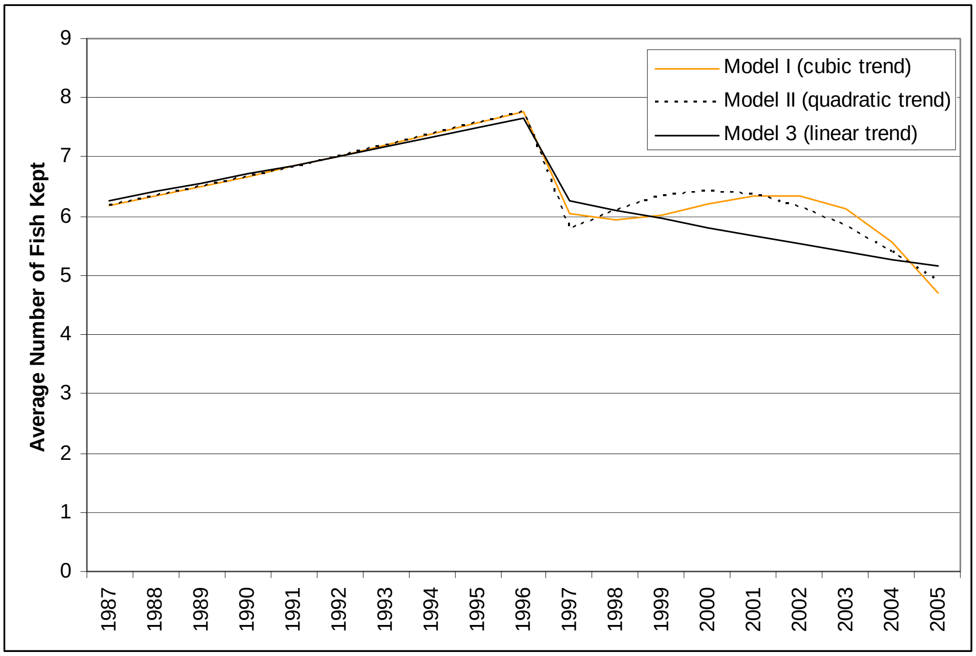
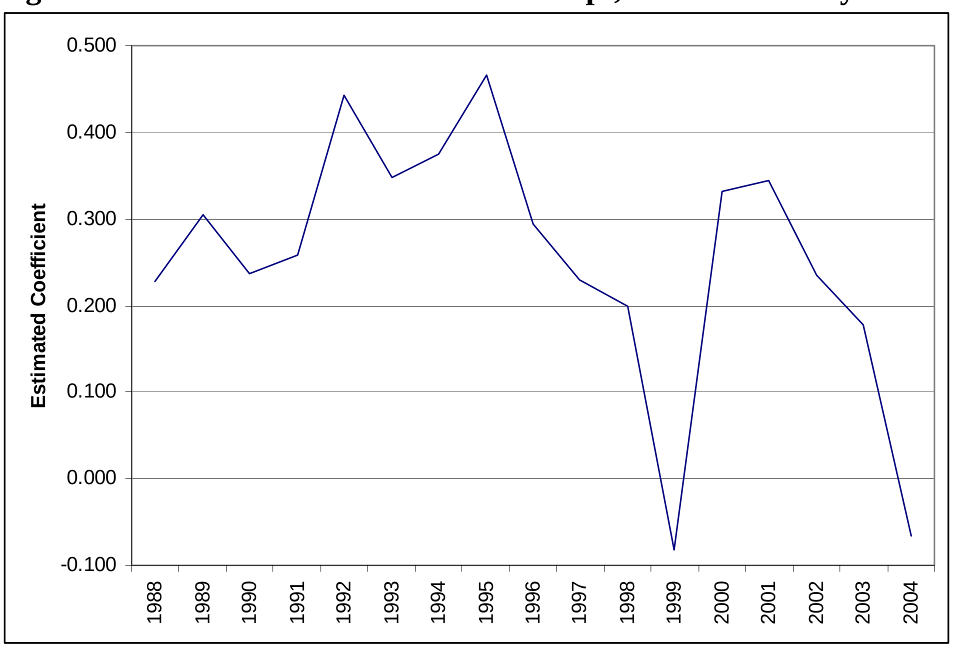


Figure 4. Count model – number of fish kept, coefficients for year fixed effects



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KEYWORDS
Fish consumption advisories, recreational fishing, count data regression

PUBLICATIONS

C. Speir and A. W. Ando. "Estimating Recreational Angler Response to Fish Consumption Advisories Over Time." ASSA Annual Meeting, New Orleans, LA. January 4 – 7 2008.

C. Speir and A. W. Ando. "Water quality warnings and recreational fishing: effects over time and across space." American Agricultural Economics Association Annual Meeting. Portland, OR. July 29 – August 1, 2007.

C. Speir, N. Brozovic and J. Wright. "Harvester response to changes due to invasive species: A spatial analysis of Asian carp in the MI and IL Rivers." American Fisheries Society Annual Meeting, Lake Placid, NY. September 10-14, 2006

N. Brozovic, C. Speir, and J. Wright. "Using harvest data to monitor the Asian carp invasion in the Illinois and Mississippi Rivers: applications and policy implications". The Invasive Asian Carps in North America: A Forum to Understand the Biology and Manage the Problem, Peoria, IL. August 22-23 2006.

C. Speir and N. Brozovic. "Supply response of commercial fishermen and implications for management of invasive Asian carp." American Agricultural Economics Association Annual Meeting, Long Beach. CA July, 2006.

GRADUATE STUDENTS SUPPORTED BY THIS GRANT

Cameron Speir, Dissertation Title: "Economic Models of Recreational and Commercial Fishing and Their Impact on the Great Lakes Ecosystem", PhD Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, 2008