Recreational Valuation and Management Implications for the Southern Lake Michigan Fishery

Illinois-Indiana Sea Grant Integrated Assessment Research Project
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Section A: Summary

Title of Project
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Abstract

Southern Lake Michigan supports a diverse recreational fishery that is ecologically and economically important. Over the past 30 years, fishing effort and catch has changed dramatically, likely due to ecosystem and management changes. Fishery changes may have also impacted the value of recreational fishing in southern Lake Michigan. This project first collated more than 50,000 data records from creel surveys conducted in Illinois and Indiana waters of Lake Michigan. Linear models were used to explore relationships between fisheries data and ancillary data such as fish abundance, fish stocking, prey densities and environmental parameters. Fishing effort, predominantly by shore-based anglers, declined four-fold between 1985 and 2013 in Illinois waters, largely driven by similar declines in harvest rates of yellow perch. Fishing effort was variable but relatively stable through time in Indiana waters, and was most strongly correlated with Alewife densities. Harvest rates of Chinook salmon were negatively correlated with prey densities and positively correlated with conductivity values in both Illinois and Indiana waters of Lake Michigan. Special questions were included in the 2015 creel survey in both states that enabled an economic valuation of the shoreline and boat fishing activity to anglers themselves. The overall estimated average value of a day spent fishing is $30. Illinois anglers ($32.09) have a higher average willingness-to-pay (WTP) for a day trip than Indiana anglers ($29.61), and all boaters in southern Lake Michigan ($40) have a higher average WTP that shoreline ($26) anglers. The estimated economic value of non-charter recreational fishing to anglers in 2015 was $3.6-4.0 million. This estimate represents additional economic value over and above any angler expenditures contributed to the region's economy. A key extension deliverable for this project was the development of an interactive data website, www.AnglerArchive.org, which allows stakeholders and anglers access to historical creel survey data. Overall, this project has provided insight into the drivers of change, and estimated the value of the recreational fishery in southern Lake Michigan. This information will be valuable to managers and other stakeholders interested in enhancing Lake Michigan fisheries.

Key Words
Creel Survey; Historical data; Travel Cost Method; Website; Willingness-to-pay

Lay Summary

Recreational fishing is important to communities and businesses of southern Lake Michigan. State agencies interview anglers each year to estimate total fishing effort and catch of popular fish species. Over the past 30 years, the recreational fishery has changed quite dramatically, likely due to changes to the ecosystem, as well as changes to fisheries management and fish stocking. This project pulled together all available data for recreational fishing in Illinois and Indiana waters of Lake Michigan with the aim of identifying specific factors that might be driving changes in fishing effort and catch. Prey fish availability and environmental factors influenced effort and catch rate of some species. Interestingly, fish stocking rates were not related to catch rates. Working closely with state agencies in 2015, we collected new data from anglers to determine their willingness-to-pay for a fishing trip, which allows us to estimate the value of recreational fishing in southern Lake Michigan. Based on these estimates, we find that (non-charter) recreational fishing originating from Illinois and Indiana shores of Lake Michigan in 2015 was worth \$3.6-\$4.0 million to anglers themselves, which represents additional value over and above expenditures on food, fishing supplies and other items associated with recreational fishing. An important outcome for this project was to develop an easy-to-use website where scientists, managers, anglers and any other interested people can view and explore fishery data. This project has increased our understanding of the dynamics of recreational fishing and may help fishery managers and community planners develop strategies to enhance the fishery in southern Lake Michigan.

Acknowledgements

First and foremost, we would like to thank the Illinois-Indiana Sea Grant and the National Sea Grant Program for funding this research and extension project. We would like to thank the partners who provided us with historical data and collected new data for 2015: the Illinois Natural History Survey and Indiana Department of Natural Resources. We also thank these two agencies, in addition to the Illinois Department of Natural Resources for constructive feedback throughout project including review of our final report. We thank the undergraduate and graduate students who did much of the data transcribing, collation and analysis for this project. Last, but certainly not least, we thank all anglers in the Illinois and Indiana waters of southern Lake Michigan who participated in angler surveys.

Section B: Accomplishments

Introduction

Recreational fishing is a socially, environmentally and economically important pastime worldwide (Arlinghaus et al. 2015). In the United States, more than 14% of the population went fishing during 2011, spending an estimated $41.8 billion in fishing related expenditure: two times higher than what U.S. residents spent on attending spectator sporting events (U.S. Department of the Interior et al. 2011; U.S. Census Bureau 2012). Freshwater environments are most important to recreational fishing in the U.S., with 81% of all fishing trips in 2011 occurring in freshwater streams, ponds and lakes (U.S. Department of the Interior et al. 2011).

The Great Lakes are expansive and unique freshwater systems important to recreational fisheries in the U.S. and Canada. In the U.S. waters of these lakes, 1.7 million people fished in 2011, spending $1.9 billion (U.S. Department of the Interior et al. 2011). The Great Lakes have undergone a number of historical perturbations that have impacted their ecology and fisheries. Water quality decreased throughout the early 20th century due to increases in industrial and agricultural runoff, but has subsequently increased since the Clean Water Act 1972 (Binding et al. 2007). The Great Lakes have also experienced the introduction and establishment of many invasive species such as alewife, *Alosa pseudoharengus*, and freshwater mussels, *Dreissena* spp. (Cuhel and Aguilar, 2013). These changes have drastically affected the distribution and abundance of fish species that are targeted by recreational fisheries; such as salmonids (e.g. Chinook salmon, rainbow trout) and percids (e.g. yellow perch, walleye).

Lake Michigan is the second largest of the Great Lakes by volume and is the only lake located entirely within the U.S., bordered by Michigan, Wisconsin, Illinois and Indiana. Each state is responsible for the monitoring, assessment and management of recreational fisheries in their jurisdictional area. Illinois and Indiana have the smallest jurisdictional area of Lake Michigan, with 63 and 43 miles of shoreline, and 1,576 and 224 square miles of lake surface area, respectively. Despite their close proximity to each other, recreational fisheries in Illinois and Indiana are quite different. In Illinois, shore-based fishing is popular and historically constitutes the majority of fishing effort, driven by the large population in Chicago and the large proportion of lake shoreline that is accessible to fishers (Roswell and Czesny, 2016). In Indiana, industrial operations along the shoreline limit access for shore-based fishing and boat-based fishing constitutes the majority of fishing effort in Lake Michigan (Dickinson, 2014). There are also number of tributaries in Indiana that flow into Lake Michigan and are popular with shore fishers. The Illinois Natural History Survey (INHS) and Indiana Department of Natural Resources (IN DNR) have conducted creel surveys since the 1980s. These surveys provide annual estimates of fishing effort and species-specific harvest, as well as other data on expenditure, preferences and satisfaction. Each agency disseminates results via technical reports and participates in a lake-wide technical committee (Hanson, 2012).

Despite this long-term data collection in southern Lake Michigan, few studies have explored the potential drivers of changes in the recreational fishery through time. There is also little known about the socioeconomic characteristics of the fishery. Without these analyses, it is difficult to identify current impediments and potential areas for future fishery enhancement. This project had two main goals: 1) utilize, explore and publish long-term fishery data; and 2) estimate the value of the recreational fishery in southern Lake Michigan. Within goal 1 there were 3 specific aims: a) Collate historical creel survey data from the INHS and IDNR; b) use statistical modelling approaches to explore trends and correlate fishery data with ancillary data such as fish stocking, prey density and environmental variables to identify potential drivers of fishery change; and c) develop a website where scientists, managers and other stakeholders can explore long-term recreational fishery data from southern Lake Michigan. Within goal 2 there were 2 specific aims: d) develop a list of new questions to include in creel surveys for 2015 to facilitate an economic analysis; and e) develop a travel cost function to estimate the non-marginal value of recreational fishing in southern Lake Michigan.

Project Narrative

Goal 1: Utilize, explore and publish long-term recreational fishery data in southern Lake Michigan

Methods

To address aim (a), we worked closely with the INHS and IDNR to obtain historical creel survey data. Most data were only available from scanned or pdf reports. We obtained a total of 55 annual reports from state agencies: 29 from the INHS (1985-2013) and 26 from the IDNR (1988-2013). Significant effort was made to transcribe data from these reports into a database and perform the necessary data quality control checks. We compiled three separate databases based on state and fishery type: one for the Lake Michigan fishery in Illinois (ILM), one for the Lake Michigan fishery in Indiana (INM), and one for fishing in Indiana streams that flow into Lake Michigan (INS). Overall, we compiled more than 50,000 data records for recreational fishing in southern Lake Michigan. Fishing variables included effort (in angler hours), species-specific harvest (in numbers of fish) and species-specific harvest rate (in numbers of fish per angler hour) for both Illinois and Indiana. The main species harvested were brown trout (BNT; *Salmo trutta*), Chinook salmon (CHS; *Oncorhynchus tshawytscha*), coho salmon (COS; *O. kisutch*), lake trout (LAT; *Salvelinus namaycush*), rainbow trout (RBT; *O. mykiss*) and yellow perch (YEP; *Perca flavescens*). The total harvest and mean harvest rate of all trout and salmon (TAS) were also calculated. Travel distance (in miles per angler hour) and fishing-related expenditure (in inflation-adjusted USD) were available for Illinois only, while species preferences and angler satisfaction were available for Indiana only. Depending on the year and data type, data were stratified by month (April to October), site (seven for ILM, four for INM and three for INS; Figure 1), angler type (shore- or boat-based) and species.

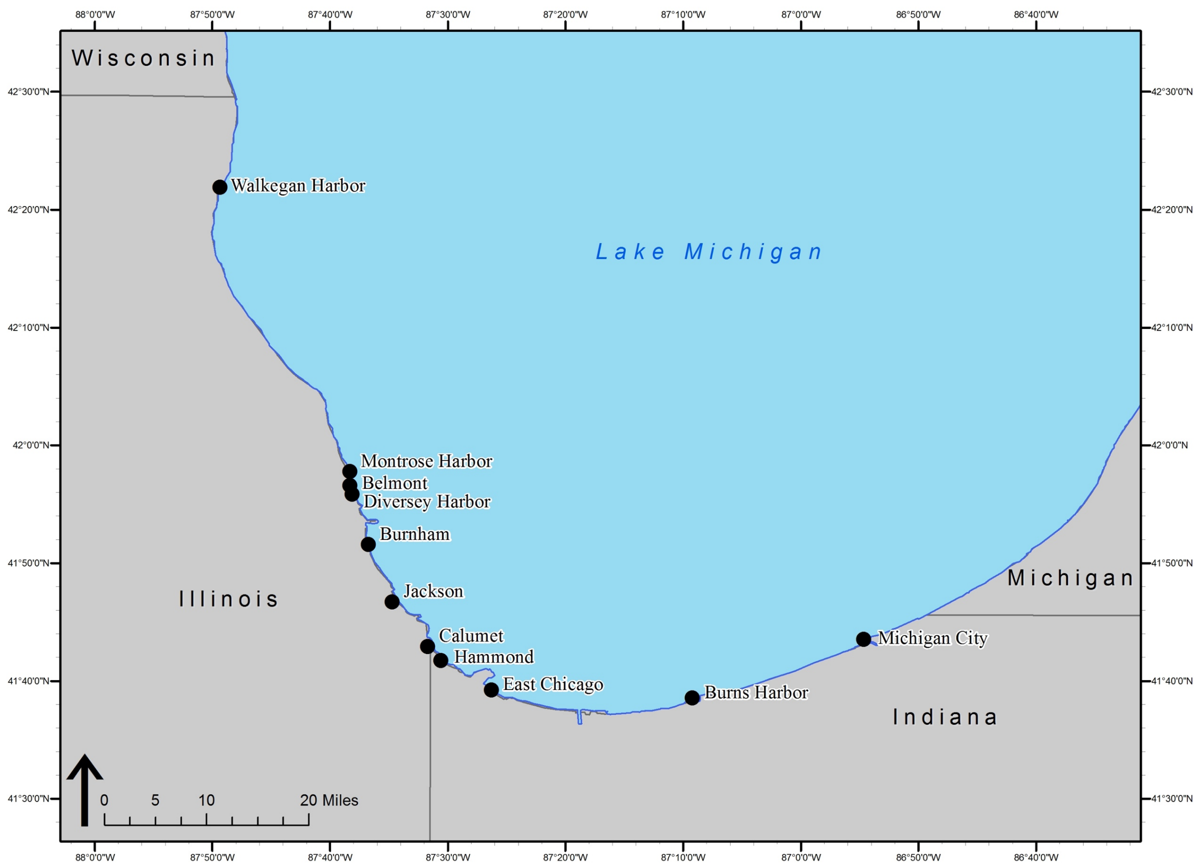

Figure 1: Map of the study area highlighting creel survey sites in Illinois and Indiana.

For aim (b), we first explored temporal and spatial trends in each fishing variable and compared trends between states and fisheries. Next, we explored the drivers of these trends by (i) comparing effort to harvest rate (e.g. does harvest rate drive effort?), and (ii) comparing fishing variables (effort and harvest rate) to a range of ancillary data. We expected that fishing effort and harvest may be influenced by stocking and abundance of target species. Therefore, we obtained annual stocking numbers (lake-wide and state-specific) for five salmonid species from state agencies around the lake. We also obtained an annual index of abundance for yellow perch from fishery-independent sampling conducted in Indiana (Ball State University) and Illinois (Illinois Department of Natural Resources), and model-derived estimates of all five trout and salmon species from the Lake Michigan Salmonid Working Group. We expected that prey availability might influence species-specific catch rates (and fishing effort); therefore, we obtained species-specific prey density estimates for all of Lake Michigan from the United States Geological Survey (USGS). Density estimates were available for eight fish species: alewife

(ALE), bloater (BLO; *Coregonus hoyi*), deepwater sculpin (DES; *Myoxocephalus thompsonii*), nine-spined stickleback (NIS; *Pungitius pungitius*), rainbow smelt (RAS; *Osmerus mordax*), round goby (ROG; *Neogobius melanostomus*), slimy sculpin (SLS; *Cottus cognatus*) and yellow perch (YEP). We also grouped prey species into broader groups: all prey (AP), pelagic prey (PP) and benthic prey (BP). Fishing variables may be influenced by environmental conditions. Therefore, we obtained measurements of four water quality parameters: Chlorophyll a concentration (Chla; μg/L), conductivity (Cond; μmho/cm), total phosphorus concentration (Phos; μg/L) and turbidity (Turb; NTU). These measurements were obtained from the EPA monitoring site in the central southern basin of Lake Michigan. For our analyses, we used mean measurements taken in spring (e.g. April) above the thermocline (typically <15m). Finally, we obtained measurements for three weather parameters: Temperature (Temp; °C), precipitation (Prec; mm) and cooling degree days (CDD; number). These were obtained from NOAA weather monitoring site in Michigan City, IN, and we used mean measurements taken in April. The resulting datasets had 8-10 fishing variables, seven abundance variables, 12 stocking variables, 11 prey variables, four water quality variables and three weather variables (Table 1).

For comparison among fishing variables, we summarized data by month and year, resulting in n=198 for Illinois and n=112 for Indiana. Significance for analyses with these data were assessed using the traditional alpha value of 0.05. For comparison between fishing variables and ancillary data, we condensed fishing data to an annual time series in each data set as many of the ancillary data represented annual estimates or indices. This resulted in a relatively small sample size for each variable (n<30) based on the number of years were data were available. As such, we set an alpha value of 0.01 (instead of the more common 0.05) to take a conservative approach for assessing significance. Further, we did not include more than two variables at a time in our model to avoid overfitting data.

Table 1: A summary of the fishing variables and ancillary data included in our analyses.

Variable type	No. of variables	Variables
Fishing variables	7	Effort, Harvest rate (BNT, CHS, COS, LAT, RBT, YEP)
Abundance indices	6	BNT, CHS, COS, LAT, RBT, YEP
Lake-wide stocking	5	BNT, CHS, COS, LAT, RBT
State-specific stocking	5	BNT, CHS, COS, LAT, RBT
Prey variables	11	ALE, BLO, DES, NIS, RAS, ROG, SLS, YEP, AP, PP, BP
Water quality variables	4	Chla, Cond, Phos, Turb,
Weather variables	3	Temp, Prec, CDD

Prior to analyses, we tested each variable for normality using a Shapiro-Wilk test and conducted cube-root transformations if required. We used linear modelling whereby each fishing variable was included as a response variable. Where possible, fishing variables were also split into shore-based and boat-based data to explore differences between these two fishing sectors. In the models, ancillary data were included as explanatory variables in a stepwise manner to avoid overfitting (see above). Significant temporal autocorrelation existed in many variables; specifically, those that saw large changes through time (e.g. fishing effort). To account for this, we first tested for autocorrelation, and if detected, used an autoregressive integrated moving average (ARIMA) model, rather than a standard linear model. We identified significant explanatory variables by examining the Bonferroni-corrected p-value.

For aim (c), we worked with web developers at Purdue University to publish historical creel survey data via an interactive website. Throughout the web development process, we liaised with creel survey biologists at INHS and IDNR to ensure that data were displaying accurately, and that the website was intuitive to use. The website (www.AnglerArchive.org) was made available to the public on May 1, 2017.

Results

Illinois Lake Michigan Data

Historical Data Trends

In 1985, total recreational fishing effort in the Illinois waters of Lake Michigan was estimated as more than 2 million angler hours. Effort decreased dramatically from 1985 to approximately 500,000 angler hours in the late 1990s, and has been relatively stable throughout the 2000s (Figure 2a). Historically, shore-based anglers constituted a higher proportion of fishing effort than boat-based anglers but recently, contributions are relatively similar between both groups suggesting that shore angling effort has declined the most through time (Figure 2a). Targeted fishing effort has only been recorded in Illinois since 2009, and while effort targeted at TAS has remained relatively stable, effort targeted at YEP has drastically declined from almost 300,000 angler hours in 2009 to about 70,000 angler hours in 2013 (Figure 2a). Total fishing effort at each site has varied slightly through time but Montrose and Waukegan Harbors have consistently experienced the highest effort (Figure 2b).

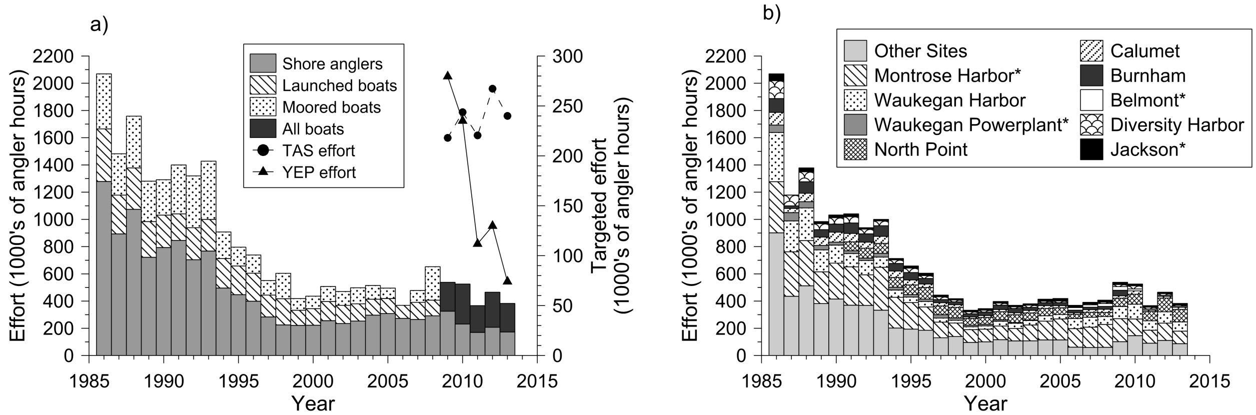

Figure 2: Annual recreational fishing effort as estimated from creel surveys in Illinois waters of Lake Michigan. a) displays total effort (y-axis 1) for different angler types and combined targeted effort (y-axis 2) towards trout and salmon (TAS) and yellow perch (YEP). b) displays total combined effort at each fishing site in Illinois. Note that sites marked with an * are sites that only facilitate shore fishing.

Similar to effort, recreational harvest of YEP in Illinois waters of Lake Michigan has decreased dramatically in the last 30 years, and despite a small increase in the 2000s, harvest is almost at all-time lows (Figure 3a). Harvest rate of YEP showed similar trends to harvest, but had a more substantial increase in the 2000s, likely due to lower levels of effort during this period compared to the 1980s (Figure 3a). Total harvest of TAS has been variable but is currently similar to historical levels, while harvest rates of TAS is relatively high compared to the past 30 years (Figure 3a). The TAS species with the highest harvest are COS and CHS (Figure 3b).

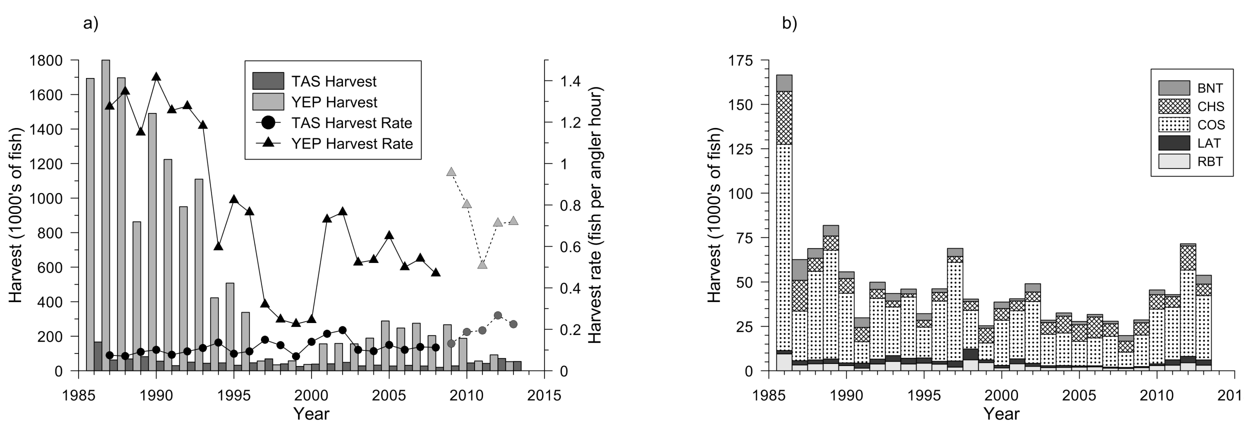

Figure 3: Annual recreational harvest and harvest rates as estimated from creel surveys in Illinois waters of Lake Michigan. a) displays annual harvest (y-axis 1) and harvest rates (x-axis) for trout and salmon (TAS) and yellow perch (YEP). b) displays annual harvest for brown trout (BNT), Chinook salmon (CHS), coho salmon (COS), lake trout (LAT) and rainbow trout (RBT). Note that in a), targeted harvested rate was not recorded after 2008; therefore, non-targeted harvest rate is shown.

Mean travel distance has increased from 3.5 to 5.3 miles per angler hour over the past 30 years (Figure 4a). Travel distances for boat-based fishing his increased more than for shore-based fishing, suggesting differential changes in the socioeconomics of these angler types. Inflation-adjusted expenditure per angler hour increased through the early 2000s, but has decreased since 2007 and is currently at some of the historically low values (Figure 4b). As would be expected, shore-based anglers have typically had lower expenditure than boat-based anglers.

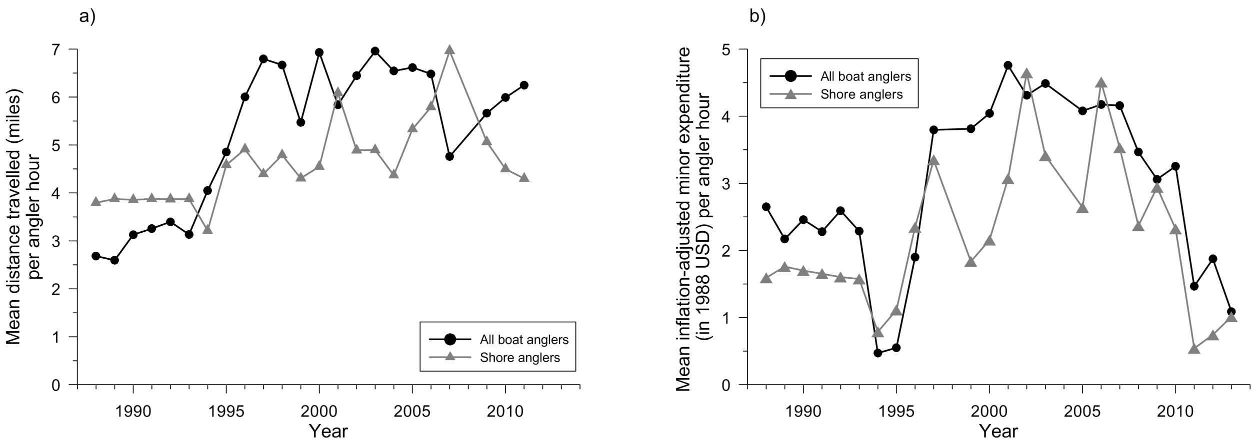

Figure 4: a) Mean distance travelled per angler hour, and b) mean minor expenditure per angler hour, for boat and shore anglers from creel surveys in Illinois waters of Lake Michigan.

Analysis among fishing variables

When fishing variables were represented by month and year, all variables were extremely skewed. Cube-root transformed variables were also skewed, so we used untransformed variables for this analysis. There was strong seasonality in effort; therefore, we used a seasonal and autoregressive ARIMA to model effort with other fishing variables. Total effort was significantly correlated with the harvest rates of YEP and RBT. Boat-based effort was significantly correlated with harvest rates of YEP, COS and RBT, while shore-based effort was only significantly correlated with harvest rates of YEP.

Analysis of Fishing and Ancillary Data

Each explanatory variable was compared to 40 response variables, but few significant correlations were found (Table 2). Effort was significantly correlated with LAT abundance (for total and boat), lake-wide stocking of LAT (all sectors) and COS (boat only), and prey abundance of YEP (for total and shore) and AP (shore only). Harvest rates of YEP were significantly correlated with effort, driven by shore-based fishing. Harvest rates of CHS were significantly correlated with pelagic prey (PP) and turbidity for boat-based fishing, but not for shore-based fishing. Harvest rates of BNT, CHS, COS and RBT showed no significant comparisons.

Table 2: A summary of linear (LM) and autoregressive integrated moving average (ARIMA) models between response and explanatory variables (see Table 1) for Illinois Lake Michigan Data. Explanatory variables were deemed significant based on an alpha value of 0.01.

Response variable	Data transformation	Model	Significant Explanatory Variables		
			Total	Boat	Shore
Effort	Cube-root	ARIMA	Abundance (LAT) Lake-wide stocking (LAT) Prey (YEP)	Abundance (LAT) Lake-wide stocking (COS, LAT)	Lake-wide stocking (LAT) Prey (AP, YEP)
HR (YEP)	None	ARIMA	Effort	-	Shore Effort
HR (BNT)	Cube-root	LM	-	-	-
HR (CHS)	None	ARIMA	Prey (PP)	Prey (PP) Water quality (Turb)	-
HR (COS)	None	LM	-	-	-
HR (LAT)	None	LM	-	-	-
HR (RBT)	Cube-root	LM	-	-	-

Indiana Lake Michigan Data

Historical Data Trends

In contrast to data from Illinois, recreational fishing effort in the Indiana waters of Lake Michigan has remained relatively stable between 1988-2013, and is dominated by boat-based anglers (Figure 6a). Targeted fishing effort was recorded between 1988-92, and again in 2013. More effort is targeted at TAS than YEP and as the effort targeted at one species increases, the effort targeted at the other tends to decrease (Figure 6a). Effort has been split relatively evenly among the Michigan City, Burns Harbor and East Chicago, and since the inception of Hammond Marina as a surveyed fishing location in 1991, it has contributed less than 10% of the total annual fishing effort (Figure 6b).

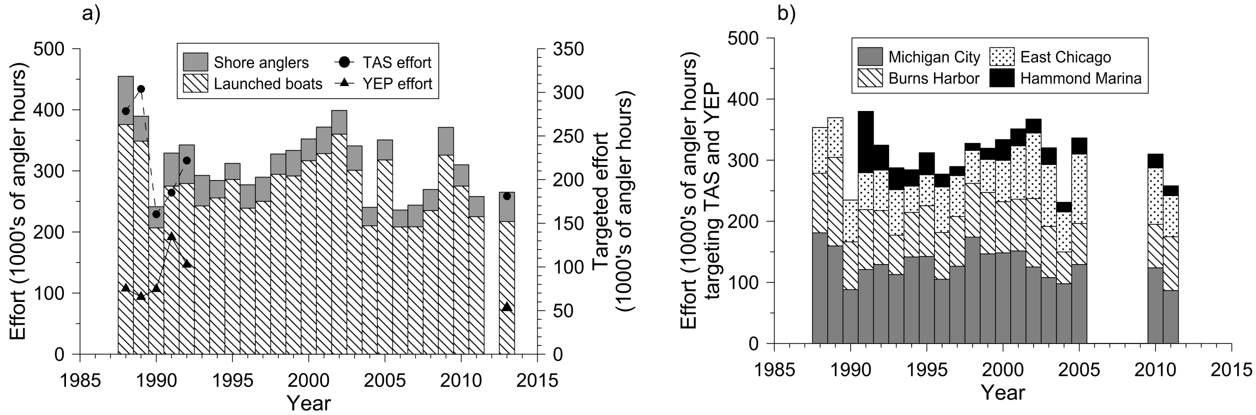

Figure 6: Annual recreational fishing effort as estimated from creel surveys in Indiana waters of Lake Michigan. a) displays total effort (y-axis 1) for different angler types and combined targeted effort (y-axis 2) towards trout and salmon (TAS) and yellow perch (YEP). b) displays total combined effort at each fishing site in Indiana.

Similar to effort, recreational harvest of YEP in Indiana waters of Lake Michigan has varied year-to-year but remained relatively stable over the past 30 years (Figure 6a). Overall harvest of TAS peaked at more than 150,000 fish per year in the mid 1990s, but since the early 2000s has been less than half of that amount (Figure 7a). Targeted harvest rates of YEP have declined substantially from the late-1980s to 2010, while targeted harvest rates of TAS have remained relatively stable during the same period (Figures 7a). Similar to Illinois data, the species with the highest harvest in Indiana waters of Lake Michigan are COS and CHS, but substantial harvest of LAT and RBT also occurs in some years (Figure 7b).

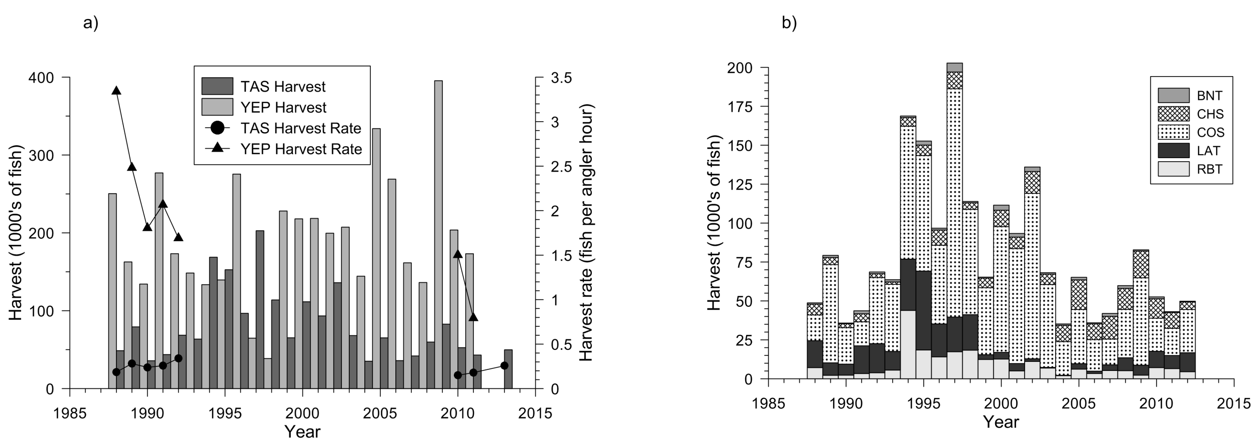

Figure 7: Annual recreational harvest and harvest rates as estimated from creel surveys in Indiana waters of Lake Michigan. a) displays annual harvest (y-axis 1) and harvest rates (x-axis) for trout and salmon (TAS) and yellow perch (YEP). b) displays annual harvest for brown trout (BNT), Chinook salmon (CHS), coho salmon (COS), lake trout (LAT) and rainbow trout (RBT).

Creel surveys in Indiana collected information on species preferences and angler satisfaction for some years. Approximately 50% of people surveyed prefer to target TAS, with this percentage increasing from 2008-2013 (Figure 8a). In 2013, the most preferred TAS species was RBT, followed by CHS and COS (Figure 8b). The percentage of anglers who prefer to target YEP decreased from 33% in 2009 to 11% in 2013, while the percentage of anglers satisfied with YEP fishing also decreased, from 70% in 2005 to 29% in 2013 (Figure 8a). In 2013, 50% of anglers surveyed were satisfied with TAS fishing, which was the highest since 2007 (Figure 8a). (Figure 7b). Angler satisfaction has increased through time for LAT, decreased through time for CHS, and remained relatively stable for BNT, COS and RBT (Figure 8b).

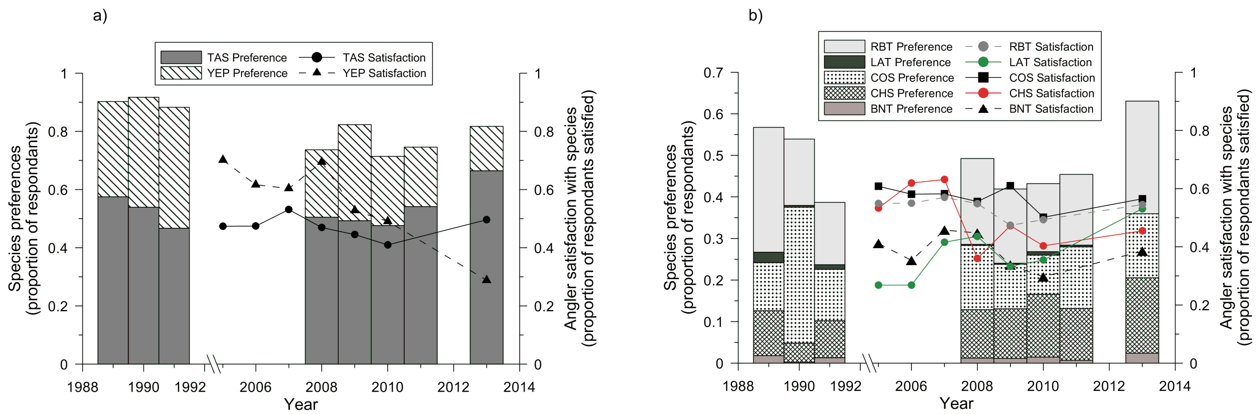

Figure 8: Species preferences and angler satisfaction reported from creel surveys in Indiana waters of Lake Michigan. a) displays preferences (y-axis 1) and satisfaction (y-axis 2) for yellow perch (YEP) and trout and salmon (TAS). b) displays preferences (y-axis 1) and satisfaction (y-axis 2) for brown trout (BNT), Chinook salmon (CHS), coho salmon (COS), lake trout (LAT) and rainbow trout (RBT).

Analysis among fishing variables

Similar to ILM data, fishing variables were extremely skewed despite transformation; therefore, untransformed variables were used for analysis among fishing variables. There was strong seasonality in effort; therefore, we used a seasonal and autoregressive ARIMA to model effort with other fishing variables. Total effort was significantly correlated with the harvest rates of COS, driven by a significant correlation among shore-based data. Boat-based effort was not significantly correlated with harvest rates of any species.

Analysis of Fishing and Ancillary Data

Similar to ILM data, few significant correlations were found between fishing variables and ancillary data for INM data (Table 3). Effort was the only variable for INM data that was able to be split between boat-based and shore-based fishing: All effort variables were not significantly correlated with any ancillary data. Total harvest rates of YEP were significantly correlated with prey abundance of STS. Total harvest rates of CHS were significantly correlated with lake-wide stocking of COS. Total harvest rates of LAT were significantly correlated with abundance of COS. Harvest rates of BNT, COS and RBT showed no significant comparisons.

Table 3: A summary of linear (LM) and autoregressive integrated moving average (ARIMA) models between response and explanatory variables (see Table 1) for Indiana Lake Michigan Data. Explanatory variables were deemed significant based on an alpha value of 0.01.

Response variable	Data transformation	Model	Significant variables (Total data)
Effort	None	LM	-
HR (YEP)	None	LM	Prey (SLS)
HR (BNT)	Cube-root	LM	-
HR (CHS)	None	ARIMA	Lake-wide stocking (COS)
HR (COS)	Cube-root	ARIMA	-
HR (LAT)	Cube-root	ARIMA	Abundance (COS)
HR (RBT)	Cube-root	LM	-

Indiana Streams Data

Historical Data Trends

Between 1988 and 2013, recreational fishing effort in Indiana streams that flow into Lake Michigan has decreased by half (Figure 10a). Historically, more fishing effort was conducted at Trail Creek than the other two sites, but more recently, total annual fishing effort has been split relatively evenly among the three sites (Figure 10a). Annual harvest of TAS in Indiana streams has varied year-to-year and harvest of RBT typically constitutes approximately 50% of all fish harvest (Figure 10b). This corresponds with RBT being the preferred species for 50-75% of anglers each year (Figure 11). Angler satisfaction for TAS in Indiana streams has followed similar trends to INM data, with satisfaction at the highest levels since 2005. For each year in Indiana streams, the highest satisfaction was reported for RBT fishing and the lowest satisfaction was reported for BNT fishing (Figure 11).

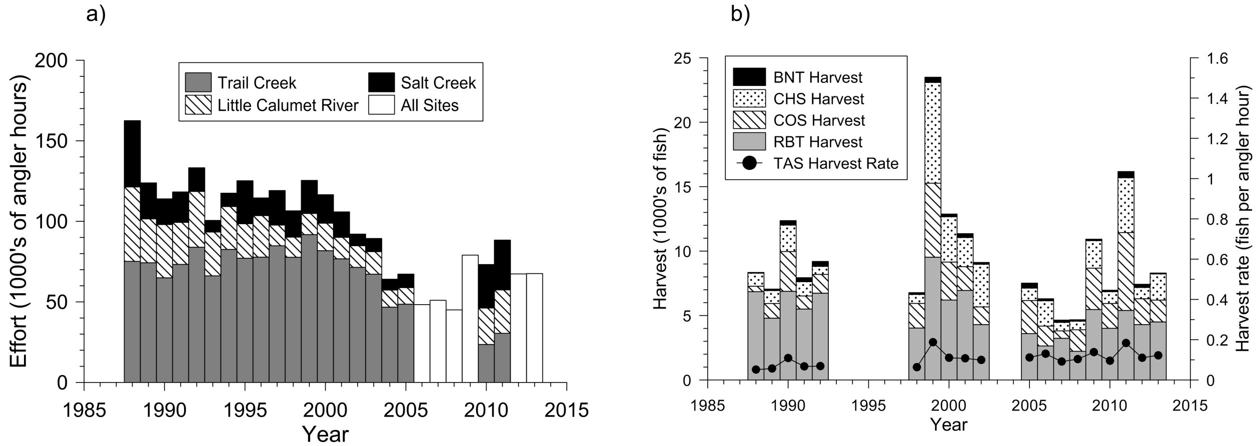

Figure 10: Annual recreational fishing effort as estimated from creel surveys in Indiana streams. a) displays total effort by site, and b) displays annual harvest for brown trout (BNT), Chinook salmon (CHS), coho salmon (COS), and rainbow trout (RBT) on y-axis 1, and harvest rate for all trout and salmon (TAS) on y-axis 2.

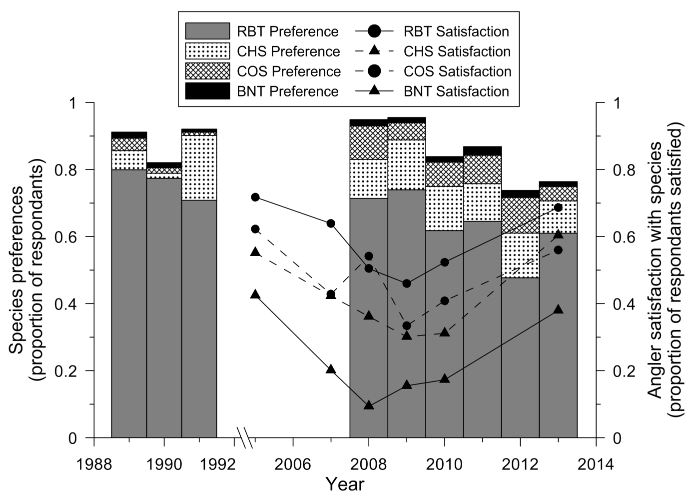

Figure 11: Species preferences (y-axis 1) and angler satisfaction (y-axis 2) for brown trout (BNT), Chinook salmon (CHS), coho salmon (COS) and rainbow trout (RBT) reported from creel surveys in Indiana streams.

Conclusions

Long-term creel survey programs in Illinois and Indiana have collected invaluable data for recreational fisheries in southern Lake Michigan. Through collaboration with the INHS and IN DNR, we have collated these data, made them easily accessible to others, and performed a series of analyses to explore trends and drivers of change in these fisheries.

We were unable to compare absolute estimates between states as each agency used slightly different survey and estimation methods. Nevertheless, we were able to compare historical trends and analysis results between states to explore possible similarities and differences in drivers of change in these fisheries.

There was a drastic decline in effort in ILM from in the 1980s and 1990s, primarily driven by declining harvest rates of YEP (Figures 2, 3 & 5). Harvest rates and satisfaction of YEP have also declined in INM, but there has not been a similar decline in total effort (Figures 6-8), suggesting that fishers are less dependent on YEP and utilize other resources such as TAS. This hypothesis is further supported by the fact that densities of Alewife, the most important forage species for many TAS, was the only significant covariate of effort (Table 3; Figure 9).

Our analyses among fishing variables yielded interesting insights into what fishing characteristics might drive recreational fishing effort in southern Lake Michigan. In Illinois, harvest rate of YEP may drive both boat- and shore-based effort. Boat-based effort may also be driven by harvest rates of COS and RBT. In Indiana waters of southern Lake Michigan, harvest rates of COS may also drive shore-based fishing effort. Boat-based effort does not appear to be driven by the harvest rates of any species. This suggests that despite occurring in neighboring areas of southern Lake Michigan, recreational fisheries in Illinois and Indiana may have state-specific drivers of change.

Our analyses also yielded interesting insights as to what ancillary variables may drive recreational fishery characteristics in southern Lake Michigan. In Illinois, fishing effort may be driven by a number of factors including fish abundance (LAT), stocking (COS, LAT) and prey species (AP, YEP). In contrast, fishing effort in Indiana was not significantly correlated with any variables. Harvest rates of CHS in Illinois may be driven by pelagic prey abundance. Declining ALE abundance in Lake Michigan has been suggested as a major factor causing decreases in CHS abundance, condition and catch rates (Tsehaye et al., 2014). In Indiana, harvest rates of CHS may be linked to stocking of COS, but it is unclear how this mechanism might work. In both Illinois and Indiana, harvest rates of BNT and RBT were not significantly correlated with any ancillary data explored in this study. This may be due to most ancillary variables being Lake Michigan variables (e.g. water quality), while BNT and RBT are more stream-orientated than other salmonid species.

Our analysis highlights the difficultly in modelling fisheries and ancillary data to explore drivers of change. Using annual data resulted in a small sample size and necessarily conservatively analyses (i.e. p<0.01). While we tried to incorporate autocorrelation and seasonality in our time series data, there may be other factors (e.g. time-lag between cause and effect) that might obscure linkages between fisheries data and potential drivers of change. Nevertheless, our preliminary analyses yielded interesting results that should be explored further.

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Goal 2: Estimate the value of the recreational fishery in southern Lake Michigan

Economic value is measured in willingness to pay (WTP) for a good or service. In the current context, we estimate anglers' WTP for a day trip fishing in southern Lake Michigan. The total economic value of a natural resource is the sum of *use value* derived from either consumptive (fish harvested) or non-consumptive (scenic beauty) direct use, the *non-use (or existence) value* associated with a resource, and the *option value* derived from the possibility to use or experience a resource in the future. The focus of this valuation study is limited to the direct use value that anglers receive themselves from recreational fishing. Recreational fishing generates economic benefits to local economies through the purchase of goods—food, gasoline, tackle, bait, etc.—that are most likely in excess of the non-market benefits quantified in this study that are limited to the benefits that accrue to anglers themselves. Further, it should be noted that the value estimates reported here are based solely on the number of recreational angling trips estimated to have been taken at the creel survey intercept sites during the peak 2015 fishing season. In this sense, our estimated value is conservative and likely represents a lower bound to the total economic value of the fishery to anglers and the broader economy.

Methods

Data Collection

We worked closely with INHS and IDNR to develop and operationalize the smallest set of additional questions as part the 2015 creel survey in each state that would allow us to conduct a Travel Cost study to estimate the economic value of a day-trip fishing in southern Lake Michigan. Input on the selection of question content was received from non-market valuation experts at the 2015 annual meeting of the USDA-HATCH Multi-State project W-3133: Costs and Benefits of Natural Resources Policies Affecting Ecosystem Services on Public and Private Lands. The creel survey was conducted between March and October by creel clerks at locations on days and times selected by each state agency to obtain a statistically valid estimate of fishing catch and effort. Survey clerks in each state intercepted shoreline (e.g. beach, pier, etc.) and returning non-charter boat anglers (e.g. marinas, boat ramps, etc.) to collect data and enter it into spreadsheet files before sending it to our research team.

There were six new questions included in the 2015 survey to facilitate the economic valuation study. The zip code where an angler traveled from to reach the intercept site was collected for two primary reasons. First, the centroid of their zip code was used to map the road miles traveled to reach the fishing site where the angler was intercepted. Second, because household income is a sensitive question subject to non-response or difficult to ask in a creel survey/interview elicitation format, the zip code-level US Census data on mean household income at the angler trip origin was used as the basis for calculating angler's opportunity cost of time spent fishing as described below. Third, anglers were asked, on the day they were intercepted, "How many times (before today) have you fished at this location over the last 2 months?" This was asked to determine total number of trips taken to the site recently. Two months was used as the recall period because of prior research indicating that recall accuracy diminishes for trips taken farther in the past. Fourth, because we were interested in the value of a day-trip, anglers were asked if they were on a single day trip. If not, they were asked what the primary purpose of their multi-day trip was. Fifth, to gather information about substitute fishing locations anglers were also asked, "Would you have still gone fishing today if you could not have fished here?" If the response was yes, then anglers were asked a sixth question, to name (open-ended response) a site where they would have gone fishing instead.

The total number of anglers intercepted was 2796, but the total number of respondents that answered all the valuation questions was smaller: 787 in Illinois (295 boaters, 492 pedestrians) and 640 in Indiana (190 boaters, 450 pedestrians). If an angler was intercepted more than once in the data, only the trip data for the trip with the most reported trips in the last two months was included in the data used to estimate the travel cost models below based on fishing trip and angler data described below.

Data description

Fishing trip data

There were 187 unique fishing sites, including all of the intercept sites and substitute sites on inland lakes and Lake Michigan identified by intercepted anglers in Indiana and Illinois. Each fishing site was identified using the substitute site names provided by the anglers when they were asked where else they would go fishing if the intercept site were not available on the day they were intercepted. Since the probability is low that an angler spends more than 6 hours driving (roundtrip) in a single day trip, each angler's choice set was reduced to include only those substitute sites within a three-hour one-way drive from the center of their residence zip code. All survey intercept sites (colored diamonds along Lake Michigan shores) and substitute sites named (black diamonds) by intercepted anglers are mapped in Figure 12.

The total travel cost includes three elements: distance cost, opportunity cost of angler's time, and the cost of any tolls. Distance cost is calculated by multiplying round-trip distance by average vehicle operating cost plus depreciation cost. Vehicle operation costs include gasoline, maintenance, and tire wear are based on the AAA (American Automobile Association 2015) estimated cost. Different average cost per mile is assumed for boat and shoreline anglers because boat anglers need vehicles with higher towing capacity that tend to have different costs of operation. Average costs per mile of 52.19 cents for boaters and 42.18 cents for shoreline anglers by assuming pedestrians drive medium size sedans and boaters drive 4WD sport utility vehicles capable of towing a boat. The vehicle cost breakdown and comparison is shown in Table 4.

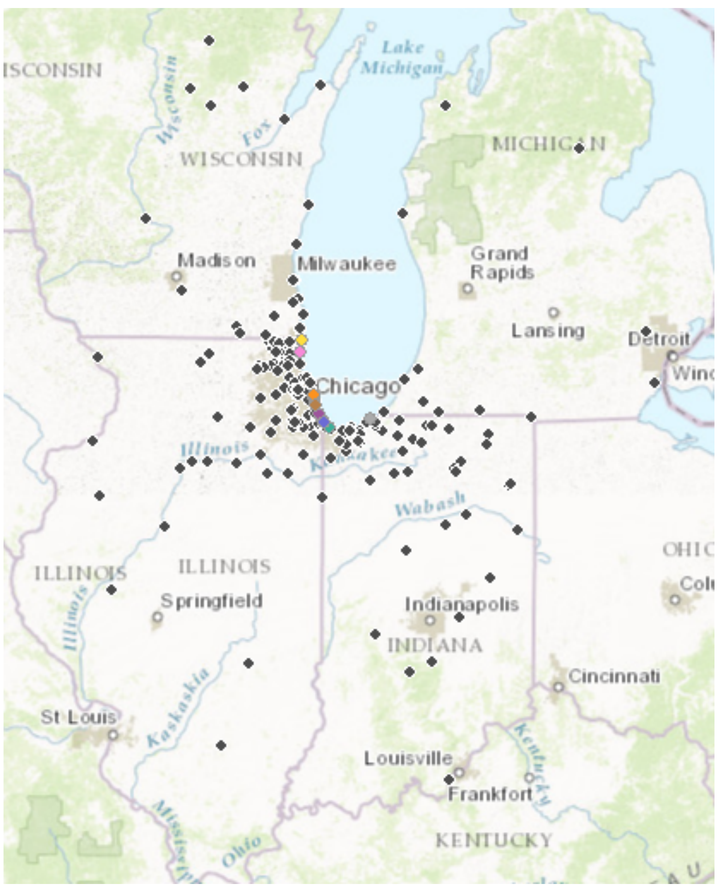

Figure 12: Intercept and Named Substitute Fishing Sites in southern Lake Michigan and surrounding areas.

Table 4: Cost Per Mile by Vehicle Size (American Automobile Association 2015)

Vehicle Size	Medium Sedan	4WD SUV
Operating cost (per mile in $)	0.17	0.20
Depreciation cost (per mile in $)	0.25	0.32
Total cost (per mile in $)	**0.42**	**0.52**

Opportunity cost is calculated by multiplying one-third by round-trip travel time by hourly-equivalent wage (Sorg and Loomis 1986). Hourly wage is calculated from zip code average annual income (United States Census Bureau 2015) divided by the average working hours per year (50 weeks*40 hrs/week = 2000 hours worked per year). Round-trip travel time, travel distance, and toll cost are calculated from the center of each angler's residence zip code to each fishing destination within their choice set using PC*Miler (ALK Technologies 2011) vehicle routing and mileage calculation software.

Summary statistics for the calculated travel cost and its major components are listed in Table 5. Total travel costs from center of angler's residence zip code to the intercept fishing site, to their named substitute(s), and to all other substitutes named by other anglers are listed separately in Table 5.

Table 5: Travel Cost Variable Summary Statistics

	Intercept Site Data		Named Substitute Sites		Substitute Sites Not Named by Respondents	
Variables	Mean	SD	Mean	SD	Mean	SD
Travel Cost ($)	**42.20**	**38.84**	**49.08**	**46.73**	**97.01**	**60.40**
Time (min)	32.96	27.66	37.93	34.07	73.87	42.45
Distance (mile)	28.60	27.66	33.67	33.70	69.07	42.84
Tolls ($)	0.31	0.61	0.34	0.71	1.15	1.40

Site attributes data, such as water body (Lake Michigan or not), parking availability, boat ramp accessibility, and whether the site has a harbor, were collected online by investigating each site's satellite image and street view using Google Earth. Zip code average population and income data are obtained from 2010-2014 American Community Survey 5-Year Estimates (United States Census Bureau 2015). In Table 6, summary statistics of these site attribute variables are displayed separately, grouped by intercept sites, respondents' named substitute site(s), and other respondents' named substitute sites.

Table 6: Site Attribute Summary Statistics

	Intercept Site Data		Named Substitute Sites		Substitute Sites Not Named by Respondents	
Variables	Mean	SD	Mean	SD	Mean	SD
Population (1,000)	43.15	23.15	33.65	21.30	27.22	19.91
Parking (yes=1)	1.00	0.00	0.96	0.20	0.85	0.36
Boat ramp (yes=1)	1.00	0.00	0.79	0.41	0.55	0.50
Harbor (yes=1)	1.00	0.00	0.51	0.50	0.21	0.41
GL (yes=1)	1.00	0.00	0.49	0.50	0.25	0.43

Illinois and Indiana Anglers

Seven fishing sites (North Point, Waukegan Harbor, Montrose, Belmont, Jackson, Diversey and Calumet) in Illinois and four fishing sites (Burns Harbor, East Chicago, Hammond, and Michigan City) in Indiana were previously chosen by the INHS and IDNR to intercept anglers fishing from (returning) boats and along the shoreline (Figure 1). There is a different mean total travel cost between intercepted anglers fishing in the two states; anglers that went fishing in Indiana spent more time and traveled longer distances, on average, than anglers fishing in Illinois. When comparing substitute sites named by anglers in the two states, the percentage of sites with parking, a harbor and boat ramp in Illinois was higher than Indiana. Anglers at Illinois sites named more sites on Lake Michigan as substitutes than did those at Indiana intercept sites. Detailed summary statistics of these variables by state are listed in Table 7.

Table 7: Day Trip Summary Statistics for Anglers Intercepted at Illinois and Indiana Sites

		Intercept Site Data		Named Substitute Sites		Sites Not Named by Respondent	
	Variables	Mean	SD	Mean	SD	Mean	SD
ILLINOIS	Travel Cost ($)	39.78	38.67	49.78	45.10	95.13	63.97
	Time (min)	30.17	26.42	37.61	31.41	70.02	42.84
	Distance (mile)	25.05	24.43	32.62	31.41	64.89	43.30
	Tolls ($)	0.27	0.51	0.38	0.65	1.19	1.43
	Population (1,000)	50.93	27.67	37.29	24.16	27.35	19.81
	Parking	1.00	0.00	0.96	0.19	0.85	0.36
	Boat ramp	1.00	0.00	0.85	0.36	0.56	0.50
	Harbor	1.00	0.00	0.68	0.47	0.22	0.41
	GL	1.00	0.00	0.64	0.48	0.26	0.44
INDIANA	Travel Cost ($)	45.19	38.88	48.21	48.69	99.28	55.69
	Time (min)	36.41	28.77	38.32	36.78	78.55	41.49
	Distance (mile)	32.97	28.67	34.96	36.29	74.13	41.72
	Tolls ($)	0.36	0.72	0.29	0.78	1.11	1.36
	Population (1,000)	33.58	9.32	29.13	16.01	27.06	20.03
	Parking	1.00	0.00	0.95	0.22	0.85	0.36
	Boat ramp	1.00	0.00	0.72	0.45	0.55	0.50
	Harbor	1.00	0.00	0.30	0.46	0.21	0.41
	GL	1.00	0.00	0.30	0.46	0.25	0.43

Boat and Shoreline Anglers

In addition to the difference in vehicle towing capacity/operation cost, boat anglers and shoreline anglers also differ in terms of average travel time, distance, and toll cost. Boat anglers tend to drive longer distances that take more time than shoreline anglers. Furthermore, shoreline anglers visit angling sites located in zip codes with higher populations, the most notable being downtown Chicago. Table 8 presents these summary statistics by angler mode.

Table 8: Summary Statistics for boat and shoreline anglers using intercept data

	Boat Anglers		Shoreline Anglers	
Variables	Mean	SD	Mean	SD
Travel Cost ($)	59.81	38.93	33.18	35.59
Time (min)	42.60	25.98	28.02	27.21
Distance (mile)	36.49	24.63	24.55	26.83
Tolls ($)	0.40	0.58	0.26	0.62
Population (1,000)	30.20	25.48	49.79	18.65

Choice Modeling

Three statistical models of site choice are used in the analysis. First, we employ the Conditional Logit (Clogit) discrete choice model, which is the workhorse model in the travel cost method literature. In the Clogit model, all possible substitute angling sites identified by all anglers are treated as part of each angler's total choice set when they choose the one site where they actually went fishing (were intercepted).

Second, the Rank-Order Logit (ROlogit) model utilizes the substitute site information in a more structured way. Anglers revealed their first choice by visiting intercept sites and were asked to indicate the substitute(s) if they were unable to visit the intercept site. The substitute site(s) they named are assumed to be their second choice among all fishing site options in the choice set if their first choice were unavailable. Because ROlogit model allows unbalanced and parallel choice occasions, named substitute sites are ranked identically whenever more than one substitute was indicated. A way to further structure the data would be to have respondents *rank* their preference over the name substitutes if more than one site is given, but this was not done to minimize the time required to administer the entire creel survey.

A third model is derived and estimated, to relax some of the restrictions on site substitution behavior in the rank-ordered logit model by allowing random taste variation (or heterogeneous preferences) and unrestricted substitution patterns; we estimate a highly flexible random parameter rank-ordered (RPRO) logit model (Train 2009). This allows site attribute variables to exhibit individual angler preference heterogeneity with random parameters following a normal distribution with mean *b* and standard deviation *w*.

Conditional Logit Model

Anglers who were intercepted more than once in the same or different sites are identified by their first initial, last initial, and last four digits of telephone number used to construct a unique angler identifier. Each fishing destination traveled to is treated as a choice occasion *t*, where *t=1, 2… T* for each individual. We denote the utility that angler *n* receives from site *j* on choice occasion *t* by: $V_{njt} = \boldsymbol{X'\beta} + \varepsilon_{njt}$.

Vector $\boldsymbol{X'} = [TC_{nj}, Pop_j, GL_j, Parking_j, Harbor_j, Boat\ ramp_j]$ and the corresponding vector $\boldsymbol{\beta}$ contains the associated parameters:

- TC_{nj} is the travel cost from the centroid of angler residence zip code to a destination site;
- Pop_j is the zip code level population at destination (as a proxy for site congestion);
- GL_j is a dummy variable indicating if destination site *j* is on a Great Lake (=1 if is GL); and
- $Parking_j, Harbor_j, Boat\ ramp_j$ are dummy variables which equal to 1 if destination site has these facility attributes.

The probability angler *n* prefers an alternative *i* to all other *J-1* alternatives (*j*=1, 2, …,*i*,…, *J*) in trip *t* is $P_{nit} = \frac{\exp(\boldsymbol{X_{ni}\beta})}{\sum_{j=1}^{J}\exp(\boldsymbol{X_{nj}\beta})}$.

Weight is denoted as w_{ni}, to take account of individual *n*'s total fishing frequency to site *i* during the two month before s/he was intercepted, which was asked in the survey. Thus, angler *n*'s choice probability with *t* choice occasions is $P_n = \prod_{t=1}^{T}(P_{nit})^{w_{nt}}$. The likelihood function is $L = \prod_{n=1}^{N} P_n$ with associated log-likelihood function $LL = \sum_{n=1}^{N} lnP_n$.

Rank-Ordered Logit Model

Our data permit delineation of three ranks. The observed fishing site where anglers were intercepted is ranked first in their choice set. Any substitute site(s) an angler named are ranked second. All I_n sites not named by angler *n*, from all the intercept and substitute sites named by all intercepted anglers, located within a 3-hour travel time of angler *n*'s origin zip code are jointly ranked third in their choice set.

Denote the set of alternative sites with rank index *m*=1,2,3 by O_m. The probability that alternative *i* is ranked 1st and the other J-I_n alternatives are ranked either 2nd or 3rd is

$$P_{nit}^{i\in O_1} = \frac{\exp(\boldsymbol{X_{ni}\beta})}{\sum_{j=1}^{J}\exp(\boldsymbol{X_{nj}\beta})}.$$

Similarly, if there are *S* total sites ranked 2nd in angler *n*'s choice set on choice occasion *t* the probability that alternative *i* ranked 2nd is preferred to all alternatives ranked 3rd is

$$P_{nit}^{i\in O_2} = \prod_{s=1}^{S} \frac{\exp\,(\boldsymbol{X_{ni}\beta})}{\sum_{j\in O_2,O_3} \exp\,(\boldsymbol{X_{nj}\beta})}.$$

So, angler *n*'s choice probability is $P_n = \prod_{t=1}^{T} (P_{nit}^{i\in O_1} P_{nit}^{i\in O_2})^{w_{nt}}$. The likelihood function is $L = \prod_{n=1}^{N} P_n$ with associated log-likelihood function $LL = \sum_{n=1}^{N} lnP_n$.

Random Parameter Rank-Ordered Logit Model

Let θ^*denote a normal distribution of individuals' tastes, with mean *b* and covariance *w*, where $\beta^r = b + w * a^r$. a^r is the *r*th random draw from a standard normal distribution and *r=1,2…,R*. Similarly, we model *k* variables in $\boldsymbol{X^r}$ with random parameters and $\boldsymbol{X^f}$ contains fixed coefficient variables such that the probability that alternative *i* is ranked 1st and therefore is preferred to all other alternatives *j*=1,2,3,…, J-l_n for angler *n* on choice occasion *t* is:

$$RP_{nit}^{i\in O_1} = \frac{\exp\,(\boldsymbol{X_{ni}^r\beta^{r|\theta}} + \boldsymbol{X_{ni}^f\beta^f})}{\sum_{j=1}^{J} \exp\,(\boldsymbol{X_{nj}^r\beta^{r|\theta}} + \boldsymbol{X_{nj}^f\beta^f})}.$$

Correspondingly, there are *S* total sites ranked 2nd in angler *n*'s choice set on choice occasion *t* and the probability that alternative *i* ranked 2nd is preferred to all other alternatives ranked 2nd and 3rd is

$$RP_{nit}^{i\in O_2} = \prod_{s=1}^{S} \frac{\exp\,(\boldsymbol{X_{ni}^r\beta^{r|\theta}} + \boldsymbol{X_{ni}^f\beta^f})}{\sum_{j\in O_2,O_3} \exp\,(\boldsymbol{X_{nj}^r\beta^{r|\theta}} + \boldsymbol{X_{nj}^f\beta^f})}.$$

So, the simulated probability of angler *n*'s rank-ordered choice is:

$$RPRO_n = \frac{1}{R} \sum_{r=1}^{R} \left[\prod_{t=1}^{T} (RP_{nit}^{i\in O_1} RP_{nit}^{i\in O_2})^{w_{nt}} \right].$$

The likelihood function is $L = \prod_{n=1}^{N} RPRO_n$ and the associated log-likelihood function can be written as $LL = \sum_{n=1}^{N} lnRPRO_n$.

Welfare Estimates

The calculation of average angler willingness to pay (WTP) per day is a monetary estimate of the impact of site loss, on average, across all sites and all anglers. Following Haab, Whitehead, and McConnell (2001), the compensating variation of loss of site access to site *k* is

$$C_{ik} = \frac{\ln\left[\sum_j e^{V_{ijt}}\right] - \ln\,[\sum_{j\neq k} e^{V_{ijt}}\ ]}{\beta_c} = \frac{-\ln\,[1 - P_{nit}]}{\beta_c}$$

where β_c is estimated coefficient for travel cost. So the lower bound is $\frac{P_{nit}}{\beta_c}$ and for the population, the average CV of lost access to site *k* is $\frac{\overline{P_k}}{\beta_c}$, where $\overline{P_k}$ is the population mean probability of visiting site *k*. Thus, on average, for each angler, the approximated willingness to pay (WTP) for each trip for all sites is

$$\widehat{WTP} = -\frac{1}{\beta_c}.$$

In addition to welfare approximation for loss of site access, the expected welfare change from an increase in the quality of a site attribute at all sites is calculated as

$$C_{ik} = \frac{\ln\left[\sum_j e^{(\boldsymbol{TC_{ijt}}*\beta_c+\boldsymbol{AT_{ijt}}*\beta_{at})}\right] - \ln\left[\sum_j e^{\boldsymbol{TC_{ijt}}*\beta_c+(\boldsymbol{AT_{ijt}}+\mathbf{1})*\beta_{at}}\right]}{\beta_c},$$

where $\boldsymbol{TC_{ijt}}$ denotes travel cost and $\boldsymbol{AT_{ijt}}$ are site attribute variables. β_{at} is estimated coefficient of site attributes. This can be simplified to

$$-\frac{\beta_{at}}{\beta_c},$$

the upper bound of the estimate of the welfare gain from a one unit increase in a site attribute.

Standard Error and Confidence Interval

The calculation of the standard error of average angler's willingness to pay (WTP) is based on Taylor expansion. Given $\widehat{WTP} = g(\beta_c) = -\frac{1}{\beta_c}$ and $u = E(\beta_c)$, by the Taylor expansion theorem,

$$g(\beta_c) = g(u) + (\beta_c - u)g'(u) + \frac{(\beta_c-u)^2}{2}g''(u) + \cdots$$

$$var[g(\beta)] = var\left(g(u) + (\beta_c - u)g'(u) + \frac{(\beta_c-u)^2}{2}g''(u) + \cdots\right)$$

and $g(u)$ is constant. The $RHS = g'(u)^2 var(\beta_c - u) + 2g'(u)cov\left[(\beta_c - u), \frac{(\beta_c-u)^2}{2}g''(u), \ldots\right] + var[\frac{(\beta_c-u)^2}{2}g''(u) + \cdots]$. Keeping only the first term, $var[g(\beta_c)] = g'(u)^2 var(\beta_c - u) = g'(u)^2 var(\beta_c)$ and utilizing the estimated mean and variance of β_c, yields $var[g(\beta)] = \frac{1}{E(\beta)^4}var(\beta)$. Based on Hole (2007), a symmetric confidence interval can be created in standard way as $\widehat{WTP} \mp z_{\frac{\alpha}{2}}\sqrt{var(\widehat{WTP})}$

The standard error and confidence interval of Marginal Willingness to Pay (MWTP) for each site attribute quality increase is based on Delta Method. An alternative method to compute asymmetric confidence intervals for MWTP is to apply the Krinsky-Robb process (Krinsky and

Robb, 1986) using the simulation method. Both methods have previously been demonstrated to yield consistent results when sample size is large enough (Hole 2007) and this is not a concern for our study.

Results

All regression results for each of the three site choice models are presented in Table 9. Anglers' average WTP to avoid the loss of a day-trip spent fishing are calculated in the first row of the table, and estimated parameters and corresponding standard errors are reported below. The results from the Clogit (1) model have abnormally large standard errors for all site attributes, indicating this model is mis-specified. This model was estimated mainly because it is the workhorse model in the recreational site demand literature. The mis-specification or poor model fit of the Clogit model to our site choice data is also evident from the more than $11 difference compared to WTP estimates from the ROlogit (2) and RPROlogit (3) models. The Clogit model does not take into account the preference ordering over sites information contained in the named substitute site responses. By accounting more explicitly for the ranked nature of site preferences in the rank-ordered models (2) and (3), standard errors are reasonable, the presence of a harbor or boat ramp is positively associated with the probability of taking a fishing trip, and the model log-likelihood is considerably lower (reduced by over 28% compared to the Clogit model) indicating a much better fit to the data. Comparing the two RO models, there is no evidence that anglers exhibit individual preference heterogeneity over site attributes (insignificant estimated *w* parameters) and otherwise the RPRO and RO logit models yield very similar results in terms of parameter estimates, model fit and estimated mean MWTP. The ROlogit and RPROlogit results suggest that the RO model is the most appropriate specification for our data. Therefore, we only discuss the MWTP result for the ROlogit model in what follows. Using the ROlogit model, separate estimates of WTP were calculated for each state and for each angler type in each state (Table 10). The WTP estimates and confidence intervals in Table 10 are the result of six separate regressions not reported, and are included to provide estimates of MWTP for each state overall, pooling shoreline and boat anglers together, and by angler mode within each individual state. Most confidence intervals are fairly narrow except for Indiana overall that has a standard error 7.8 times larger than for the comparable estimate from Illinois.

Table 9. Estimation results from three choice models

	(1) Clogit	(2) ROlogit	(3) RPROlogit	
Estimated WTP per angler day	$18.28 (0.248)	$30.18 (6.544)	$29.82 (6.575)	
			b	*w*
Travel cost	-0.05	-0.03	-0.03	--
	(0.001)***	(0.007)***	(0.007)***	--
Population(1/10,000)	0.24	0.17	0.17	--
	(0.005)***	(0.008)***	(0.008)***	--
GL(=1 if Great lake)	29.12	-0.10	-0.09	-0.49
	(9.0E+04)	(0.081)	(0.084)	(0.109)***
Parking	-1.67	0.04	0.24	0.66
	(9.4E+05)	(0.104)	(0.257)	(0.433)
Harbor	33.72	1.76	1.80	0.002
	(9.9E+05)	(0.087)***	(0.090)***	(0.117)
Ramp	0.19	0.76	0.77	0.01
	(1.2E+06)	(0.071)***	(0.072)***	(0.198)
Num. of Angler	1,427	1,427	1,427	
Num. of Choice Occasion	1,437	3,047	3,047	
Max L. Likelihood	16700.62	11993.56	11989.8323	

Note: standard error in the bracket; * denote significant at 10% level, ** denote significant at 5% level, *** denote significant at 1% level.

Table 10: WTP estimates broken down by state and angler type with 95% confidence intervals.

	Illinois	Indiana
Overall WTP	$32.09 [29.98, 34.20]	$29.61 [13.16, 46.06]
Shoreline WTP	$23.95 [23.16, 24.74]	$26.98 [26.22, 27.84]
Boat WTB	$39.99 [37.57,42.41]	$32.24 [30.47,34.02]

Marginal WTP estimates for each statistically significant site attribute in Table 9 are presented in Table 11 based on parameters estimated using the ROlogit model. Anglers are willing to pay, on average, $40 to $65 dollars more for a trip to a site with a harbor than to a site without a harbor. This finding may be a result of individual angler heterogeneity that we are not able to control for in our model, such as specific household income or larger investment in boating and fishing equipment. Anglers have a more modest additional WTP of between $8 and $37 for a trip to a site with a boat ramp than to one without. The boat ramp site attribute mean MWTP estimate of $23 has a higher standard error and a much lower MWTP than the $53 harbor attribute, resulting in a wider confidence interval. This provide insights on the importance of different fishing site attributes that could inform investment in physical facilities.

Table 11: Marginal WTP estimates of site attributes

Site Attribute	$\widehat{\textbf{WTP}}$	Std. error	95% Confidence Interval
Harbor	$53.21	(6.347)***	[40.77, 65.65]
Boat ramp	$22.84	(7.173)***	[8.78, 36.90]

Total angler days per year and average angler WTP per angler year for Illinois and Indiana are calculated using the estimated results above (by state and angler mode) together with creel survey estimates of total fishing effort by angler mode. In Indiana, based on estimated angler hours by fishery mode from the 2015 IDNR Lake Michigan Creel Survey, the estimated total effort hours by both boat and shoreline anglers is 211,924 hours a year. The total hours spent fishing by angler mode per month in Indiana were divided by the mean hours spent fishing per trip by angler mode to calculate the equivalent number of fishing day trips. Monthly mean hours spent fishing per trip were not available in Illinois, so the annual mean trip length for shoreline (3.92 hours) and boat anglers (5.73 hours) were used to allocate total effort hours to each angling mode and calculate the total number of day trips taken. The total effort hours by state and mode are reported in Table 12.

Average total angler WTP per angler year for Illinois (April-September) and Indiana (March-October) is obtained by multiplying estimated total angling days per year (for each angler mode) by estimated average willingness to pay per angler day (Table 12). A more precise estimate of total angler economic surplus would be possible if sampling weights for each angler type in each state were available to map intercept data from a limited number of intercept sites to total recreational fishery effort. It seems clear from the current intercept data, when compared to INHS and IDNR estimates of total angler effort by mode at each site, that shoreline anglers are over-sampled relative to boat anglers. How the total effort estimates for the intercept sites in each state map to total fishing effort on Lake Michigan along the IL and IN shores does not appear to be addressed by the current creel sampling strategies employed, thus resulting in a lower-bound estimated value of going fishing.

Table 12: Estimated 2015 Total Angler Days and Total Willingness-to-Pay (WTP) by State

	Illinois	Indiana	Total
Total Angler Days per Year	66,803	55,710	122,513
Shoreline angler days	34,154	18,384	52,538
Boat angler days	32,649	37,326	69,975
Angler Total WTP [95% confidence interval]	$2,123,632 [2,017,632, 2,229,624]	$1,699,464 [1,619,346, 1,781,635]	$3,823,096 [$3,636,985, $4,011,259]

Conclusions

Anglers intercepted during the annual creel surveys along the shore of southern Lake Michigan in Indiana and Illinois in 2015 were willing to pay an average of $30 to take a day trip fishing. Among anglers, Indiana pedestrians travelled over twice as far (34 miles) to reach fishing sites as their Illinois counterparts (16 miles). Conversely, boating anglers in Illinois (40 miles) were found to travel farther to reach fishing sites than in Indiana (30 miles). These findings with respect to distance travelled by boater and pedestrian anglers alike, seem to accord with intuition; the Illinois shoreline is much more densely and heavily populated than in Indiana, and there is likely more limited ability to store boats in more urbanized areas closer to Illinois fishing sites but also likely many more pedestrian anglers located closer to shoreline fishing sites in Illinois than Indiana. The mean distance travelled (time spent) by anglers to reach the fishing sites where they were intercepted is 28 miles (33 minutes). This distance increased to 33 miles (37 minutes) for substitute sites anglers themselves named and further to 69 miles (74 minutes) for the set of substitutes identified by other anglers. This is consistent with economic choice behaviour and the assumptions employed to statistically estimate angler willingness-to-pay for a day trip spent fishing on Lake Michigan in our study. The total estimated economic value of recreational fishing in this fishery during the 2015 peak season is estimated to be $3.6-$4.0 million.

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Potential Applications, Benefits and Impacts

This project has had many positive impacts on the stakeholders of the recreational fishery in Lake Michigan. First and foremost, this project has formed strong collaborations among Purdue University, Illinois-Indiana Sea Grant, the Illinois Natural History Survey and the Indiana Department of Natural Resources. In addition to supporting data collation and collection for the project, this collaboration has resulted in combined extension and outreach that will continue long after the project is finished. Increased collaboration among these groups will facilitate greater participation in the monitoring, assessment and management of the fishery, and will provide diverse opportunities for anglers to interact with scientists and managers.

The first goal of this project collated historical recreational fishing data in southern Lake Michigan. This will allow future projects to utilize these data without having to go to the significant trouble of collating and transcribing data from historical reports. Furthermore, scientists, managers and other stakeholders can explore and export these data from the interactive website developed as part of this project: www.anglerarchive.org. Presentation of historical data trends and analysis of relationships between fishing data and ancillary data provides a unique insight into the dynamics of this recreational fishery. Exploring data trends alongside fisheries management changes may help inform future management decisions.

The second goal of this project provided a first estimate of the non-market economic value of recreational fishing in southern Lake Michigan. Furthermore, we found that non-charter recreational anglers value having a boat ramp and/or marina (highest value) at fishing sites compared to a limited number of other physical site characteristics at Great Lakes and other substitute fishing destinations. This information could be used to guide capital investments in recreational fishing sites in the region to complement biological fishery management. The estimated values in this study are in addition to many angler expenditures and the associated direct and indirect economic multipliers that benefit businesses and communities along the southernmost shores of Lake Michigan.

Section C: Accomplishments

Media Coverage

1. Interactive data website
   This website was one of the key objectives of our project.
   www.AnglerArchive.org

2. Purdue Agriculture Video
   A video describing our project and how to use the interactive data website
   https://www.youtube.com/watch?v=IL45jBimtr0&t=12s

3. Illinois-Indiana Newsroom Article
   "Lake Michigan fisheries workshops bring anglers and researchers together"
   http://www.iiseagrant.org/newsroom/lake-michigan-fisheries-workshop-brings-anglers-and-researchers-together/

Publications

Peer-reviewed journal publications

1. Zischke, M.T., Gramig, B.M., Dickinson, B., & Roswell, C.R. In prep. A quantitative analysis of long-term recreational fishery and environmental data to explore drivers of fishery change southern Lake Michigan. To be submitted to Fisheries Research.

2. He, X, Zischke, M.T., Dickinson, B, Roswell, C.R. & Gramig, B.M. In prep. Least-cost Travel Cost Estimation Using a Multi-site User Intercept Survey of Southern Lake Michigan Anglers. To be submitted to Marine Resource Economics.

Conference presentations

1. He, X., Gramig, B.M., Zischke, M.T., Dickinson, B. & Roswell, C. 2017 (August). Least-cost Travel Cost Estimation Using a Multi-site User Intercept Survey of Southern Lake Michigan Anglers. Selected poster, Agricultural and Applied Economics Association Annual Meeting, Chicago, IL.

2. Gramig, B.M., He, X., Zischke, M., Dickinson, B. & Roswell, C. 2017 (February). Least-cost Travel Cost Estimation Using a Multi-site User Intercept Survey of Southern Lake Michigan Anglers. Presentation at the USDA W-3133 multi-state project annual meeting, Carlsbad, CA.

3. Gramig, B., He, X., Zischke, M., Dickinson, B. & Roswell, C. 2016 (November). Least-cost Travel Cost Estimation Using a Multi-site User Intercept Survey of Southern Lake Michigan Anglers. Poster presentation at the Heartland Environmental and Resource Economics workshop, University of Illinois, Urbana-Champaign, IL, USA.

4. Turney, D., Zischke, M., Zollner, P., Gramig, B., Roswell, C. & Dickinson, B. 2016 (April). Using capture-recapture models to estimate angler abundance in southern Lake Michigan. Poster presentation at the Purdue Forestry and Natural Resources student poster symposium, West Lafayette, IN, USA.

5. Zischke, M., Dickinson, B, Roswell, C., Turney, D.*, Dennis, B*., Zollner, P. & Gramig, B. 2016 (April). New research on anglers in the Indiana waters of Lake Michigan. Poster presentation at the 2016 Purdue Life Sciences Postdoctoral Symposium, West Lafayette, IN, USA.

6. Zischke, M., Dickinson, B, Roswell, C., Turney, D.*, Dennis, B.*, Zollner, P. & Gramig, B. 2016 (March). New research on anglers in the Indiana waters of Lake Michigan. Poster presentation at the Purdue International Scholar Research Symposium, West Lafayette, IN, USA.

7. Turney, D., Zischke, M., Zollner, P., Gramig, B., Roswell, C. & Dickinson, B. 2016 (March). Using capture-recapture models to estimate angler abundance in southern Lake Michigan. Oral presentation at the Indiana Academy of Science Conference, Indianapolis, IN, USA.

8. Zischke, M., Dickinson, B, Roswell, C., Turney, D., Dennis, B., Zollner, P. & Gramig, B. 2016 (March). New research on anglers in the Indiana waters of Lake Michigan. Poster presentation at the Joint Conference of the Indiana Chapters of the American Fisheries Society, Society of American Foresters, and The Wildlife Society, Bloomington, IN, USA.

9. Zischke, M., Roswell, C., Dickinson, B. & Gramig, B. 2016 (January). Using historical creel survey data for southern Lake Michigan to identify drivers of fishery change. Oral presentation at the 76th Midwest Fish and Wildlife Conference, Grand Rapids MI, USA.

10. Zischke, M., & Roswell, C. 2016 (January). Recreational fisheries in the Midwest: Challenges and opportunities. Symposium at the 76th Midwest Fish and Wildlife Conference, Grand Rapids MI, USA.

Undergraduate/Graduate Names and Degrees

1. Xiaoyang He, Purdue University, Department of Agricultural Economics, Doctoral student, expected to graduate in 2020.

2. Hannah Smith, Purdue University, Department of Biological Sciences, Undergraduate student, expected to graduate in May 2019.

3. Dominique Turney, Purdue University, Department of Forestry and Natural Resources, Undergraduate student, graduated in May 2016.

4. Brooke Dennis, Purdue University, Department of Agronomy, Undergraduate, graduated in December 2015.

Project Partnerships

1. Ben Dickinson & Brian Breidert, Indiana Department of Natural Resources
2. Charles Roswell & Sergiusz Czesney, Illinois Natural History Survey

   The Indiana Department of Natural Resources and Illinois Natural History Survey provided ~30 years of historical creel survey data for use in our analyses and website development. They also worked with us to collect new data from anglers for the valuation component of our project. These partnerships have been integral to the success of this project, both through data collection and interpretation of results. These partnerships are ongoing and have led to other research and outreach projects in southern Lake Michigan.

3. Dr. Craig Miller, University of Illinois

   Dr. Miller is a PI on a similar IISG-funded project to examine the economic impacts of recreational fishing in southern Lake Michigan. At the start of both our projects, we worked closely with Dr. Miller to develop a collaboration plan. This plan identified areas where we could work together (e.g. data collection) and areas of distinction (e.g. economic modelling approaches) to ensure high efficiency of both projects. This partnership is ongoing: A graduate student of Dr. Miller will be presenting the results of her work at a series of workshops organized by Dr. Zischke.

4. Vic Santucci, Illinois Natural History Survey

   Mr. Santucci partnered with us throughout our project. He provided valuable feedback on project design and methods, as well as interpreting results. He also provided important critical feedback on earlier versions of this final report.

Related Projects

Title:	Public workshops on recreational fishing in southern Lake Michigan
PI:	Mitchell Zischke, Purdue Univeristy
Co-PI's:	Kara Salazar, Leslie Dorworth, Jay Beugly; Purdue University & IISG
Funding:	Indiana Lake Michigan Coastal Program.

Awards and Honors
Nil

Patents/Licenses
Nil

Section D: Metadata for Data Management Plan
Nil