LINKED PARTICIPATION-SITE CHOICE MODELS OF RECREATIONAL FISHING

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ABSTRACT

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This thesis consists of two chapters that explore the impacts of ecosystem threats to recreational fisheries in Michigan using linked participation-site choice demand models. The first chapter analyzes changes in angler behavior in response to state natural resource agency regulations designed to limit the spread of an invasive disease, Viral Hemorrhagic Septicemia virus (VHSv), in the Great Lakes and connecting waterways. We employ the model to identify the combined effect of the disease and associated regulations on angler site choice and trip frequency. Results indicate that anglers significantly alter their behavior at the site choice and participation levels in response to a new disease and its regulations. We expect that natural resource policy makers will utilize these results in developing and maintaining the regulations necessary for the sustainable use of recreational fisheries.

The second chapter develops a linked model for inland lakes site choices and participation. In the complex demand model, angler decisions are connected to site and species-specific abundances of game fish at over one thousand inland lake fishing alternatives available in Michigan. Policy scenarios illustrate how ecosystem changes such as altering species abundance affect angler participation and site choices. We find that anglers value walleye more than other species, and monthly trips are significantly affected by walleye abundance, which has important implications since walleye distributions and abundance are expected to be adversely affected by climate change. More generally, the demand system should be a useful tool for agency decision-making to sustain healthy fisheries and retain the angler population.

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INTRODUCTION

Natural resource agencies are the primary managerial institutions that maintain and monitor environmental systems in the United States. Their mission is to be committed to the sustainable conservation, protection, management, use and enjoyment of the state's natural and cultural resources (Michigan DNR). Traditionally, natural resource management emphasized the use of biological information in decision making (Decker et al., 2001; Manfredo, 2002). While this may provide a benefit to the agency on the technical requirements of a balanced ecosystem, this source of information does not incorporate the human element to natural resource management, leading to potentially inefficient policy making (Salz and Loomis, 2005). In order to design and implement effective policies, agencies must have an understanding of stakeholders' economic values, attitudes towards resource use, and behaviors regarding their recreation choices (Fiske, 1992; Cocklin et al., 1998; Salz and Loomis, 2005; Decker et al., 2001; Manfredo, 2002). Non-market valuation techniques are useful for understanding these behaviors and determining the value of recreational use of the environment (Parsons, 2003). By utilizing this sophisticated human dimensions technique in their construction of policies, agencies can make more informed decisions that may better meet recreationists' demands while maintaining the quality of the resource (Arlinghaus, Mehner, and Cowx, 2002).

Recreational demand models provide a method to model behavior and measure the value of recreational use of the environment through non-market valuation techniques (Parsons, 2003). The models capture behavioral aspects of the consumer that can inform agencies of their preferences for recreational fishing sites, species, seasonality, and how often they are willing to fish. The most frequently used technique in recreation demand is the travel cost method (Haab and McConnell, 2002). Costs are used as the prices to visit the site(s). The models use revealed preferences from surveys that collect information on where recreationists have visited to develop demand models that can address a multitude of questions the researcher or agency might be interested in, such as an environmental quality change, the impacts of a policy, or shifts in behavior that might affect the resource (e.g. fishery). Although most random utility models in the literature focus solely on site choices, the travel cost method can also be used to identify factors that affect participation rates in a given recreational activity by linking site choice models to models of total trips, referred to as linked participation-site choice models.

This thesis develops linked participation-site choice recreational angling demand models of Michigan's anglers to capture preferences for fishing in inland lakes and the Great Lakes that might indicate what attributes of a fishing site they consider to be valuable and what might deter them from participating. In particular, this concept is approached using two chapters. The first chapter develops a model of Great Lakes fishing to assess the impacts of agency-implemented disease regulations designed to slow the spread of an invasive fish virus that has altered fish populations in the Great Lakes system. The second chapter develops a model for Michigan's inland lakes that incorporates the large number of available fishing alternatives and connects angler behaviors to site and species-specific biomass of gamefish.

Chapter one analyzes changes in angler behavior in response to state natural resource agency regulations designed to limit the spread of an invasive disease, Viral Hemorrhagic Septicemia virus (VHSv), in the Great Lakes and connecting waterways. It is likely that anglers that fish these waters have changed their behaviors, both in the frequency of trips taken and the location of trips. We measure the change in demand using a multi-dimensional database to demonstrate how the disease and regulations have altered the demand for and value of Great

Lakes fishing. The study is unique in that it exploits a natural experiment and long-term angler behavior data for an environmental shock that actually occurred, rather than one that was simulated or hypothesized through survey design. The demand model used in the chapter illustrates the kinds of shifts in behavior that can be expected from the combined effect of an invasive disease and regulation, supporting the idea that anglers do not respond uniformly to a multifaceted policy.

The model developed in chapter two addresses another important fishery in Michigan, inland lakes. Inland lakes are subject to their own environmental stressors, such as climate change which is expected to shift species compositions and abundances at Michigan's inland lakes. While it is not uncommon for recreational demand models for saltwater fishing locations or Great Lakes sites to relate fishing quality to angler behaviors, the necessary biological data is usually lacking for inland fishing. Chapter two makes use of unique biological and behavioral datasets to develop a model that connects angler decisions about fishing locations and participation to site and species-specific abundances of game fish at over one thousand inland lake fishing alternatives available in Michigan. The linked recreational demand model represents a first of its kind combination in the literature in terms having such a large number of individual lakes as sites, which are also described by their biomasses of key game fish. With a broad scope and connection to fish biomass, the model can estimate value and trip changes for shifts in abundance of various game fish in inland lakes due to fisheries management, as well as climate change, nutrient loadings, and a wide variety of environmental stressors.

CHAPTER 1

A Natural Experiment Identifying Invasive Disease and Regulation Effects on Recreational Fishing

1.1 Introduction

Freshwater biodiversity is declining faster than any other group of organisms (Dudgeon et al, 2006). Since 1970, the abundance of freshwater species has declined by 50%, while the abundance of terrestrial and marine species has each fallen by about 30% (MEA). In North America, over 100 freshwater animal species have gone extinct since 1900 and one-third of freshwater fishes are currently considered vulnerable or imperiled (Ricciargi and Rasmussen, 1999; Strayer and Dugeon, 2010).

One of the largest drivers of global freshwater biodiversity decline is biotic exchange, which includes invasive alien species and disease organisms. The economic impact of biotic exchange on freshwater ecosystems is substantial. In the U.S., the impacts of exotic species such as the zebra mussel (*Dreissena polymorpha*), sea lamprey (*Petromyzon marinus*), ruffe (*Gymnocephalus cernuus*), Eurasian milfoil (Myriophyllum spicatum) and hydrilla (*Hydrilla spp*.) compel state and local governments to adopt costly control programs; it is estimated that upwards of one billion dollars is spent each year to manage zebra mussels alone (Lovell et al, 2006; Pimentel et al, 2005). Given the state of current regulations on the pathways for introductions to freshwater systems, biotic exchange is expected to become an even greater biodiversity threat to freshwater systems as trade and travel activities increase across the globe (MEA).

The growing economic literature on freshwater invasions includes bioeconomic and econometric analyses. Prior bioeconomic research has focused on determining efficient prevention and control strategies. This work has shown that the preferred management strategy is sensitive to a wide range of factors, including the probability of invasion, species interactions and management costs. The empirical studies on freshwater invasions largely focus on estimating the nonmarket value of control efforts, including the benefits of control (Lupi et al, 2003; Leigh) and of prevention (Davis and Moeltner, 2006; Nune and van den Bergh, 2004; Provencher et al, 2012; Zhang and Boyle, 2010). However, little empirical research has assessed the nonmarket costs of management (Timar and Phaneuf (2009) is an exception), even though this information is critical in formulating an efficient invasion management strategy.

This paper presents a demand model that takes advantage of a natural experiment to measure the nonmarket impacts of regulations designed to limit the spread of a freshwater invader. These regulations apply to fishing methods, and our focus is on measuring the joint impacts of the regulations and the disease presence on angler welfare. Our identification strategy uses variations in the managers' response to the invasion over time and space – that is, our data on fishing trips includes the times before and after the onset of the new regulations, including trips taken to sites left free of the restrictions. We characterize angler behavior as a participation and site choice problem using a linked model, in order to analyze the different ways that managing this invader affects anglers.

We apply the model to the case of Viral Hemorrhagic Septicemia virus (VHSv), a non-toxic, infectious disease devastating fish populations across the Great Lakes region. The Michigan Department of Natural Resources has responded to the invasion by placing restrictions on bait and boat use, which can alter the rate of VHSv spread, in the areas most closely associated with the disease. We utilize data spanning a five year period on fishing trips taken to Great Lakes sites in Michigan. Our hypothesis is that anglers have been driven away from sites affected by VHSv regulations and the disease. This is a critical issue for fisheries managers because effective management requires agencies anticipate angler reactions to new regulations (Beardmore et al, 2011). Furthermore, to our knowledge, no prior work has empirically examined the economic impacts of disease and disease regulations on fishing behavior. Consumption advisories in freshwater systems have been studied before (Jakus et al, 1997; Montgomery and Needelman, 1997), but these advisories were due to chemicals and not infectious wildlife disease. Overall, our results provide strong evidence that the VHSv regulations, in addition to disease presence, have affected angler behavior.

1.2 VHSv and Michigan DNR Regulations

Viral Hemorrhagic Septicemia virus is a deadly fish disease that originated in Europe in the 1930s (Bowser, 2009, Faisal et al, 2012). This virus causes hemorrhaging in the eyes, skin, gills, fins, skeletal muscles and internal organs as well as odd sporadic behavior, although consuming VHSv-infected fish is not a threat to human health (Cornell University, 2012). In 2005, VHSv was confirmed as a cause of fish mortality in the Great Lakes system. The ballast water of Great Lakes ships has been implicated as one of the likely pathways for VHSv introduction (Elsayad, et al, 2006; Whelan, 2007). Since its discovery the disease has spread rapidly and become a major concern of Great Lakes fisheries managers (Bowser, 2009). The Great Lakes outbreak is believed to be a new strain that is responsible for the die-offs in several fish species including muskellunge, smallmouth and largemouth bass, northern pike, freshwater drum, gizzard shad, yellow perch, black crappie, bluegill, rock bass, white bass, redhorse sucker, bluntnose sucker, round goby, and walleye (Aphis Veternary Services, 2006). Recently, VHSv infections have been identified in Great Lakes trout and salmon.

A primary factor in the spread of VHSv is the unintentional movement of contaminated water by boaters and recreational anglers (DNR, 2009). The Michigan Department of Natural Resources (DNR) initially responded to this risk in December of 2008 by implementing regulations intended to slow the rate of VHSv spread. Broadly, the goals of the VHSv regulations are to protect populations of wild fish in inland waters and in VHSv-free areas of the Great Lakes, protect wild populations of fish used for broodstock in fisheries management, and prevent the infection of fish being reared in state-owned fish hatcheries (DNR, 2009).

Fisheries Disease Control Order FO-245.09 is the DNR regulation implemented statewide against this virus. FO-245.09 consists of statewide regulations as well as regulations by management area. There are three management areas classified by disease status, as illustrated in Figure 1-1. VHSv positive (red) is the management area where the presence of the virus has been confirmed. This area includes Lake Huron and all of its tributaries up to the first barrier (i.e. dam) as well as Lake Erie. VHSv surveillance (yellow) is the management area where the virus is likely to spread in the future. This includes all of Lake Michigan and the St. Mary's River system, including most of their tributaries up to the first barrier, as well as all of the waterbodies in the Lake Huron watershed that do not have confirmed disease presence. VHSv free (green) is the management area where the virus is not likely to be confirmed in the near future. This includes the entire Lake Superior watershed and all of the waterbodies in the Lake Michigan watershed that are not currently under surveillance.

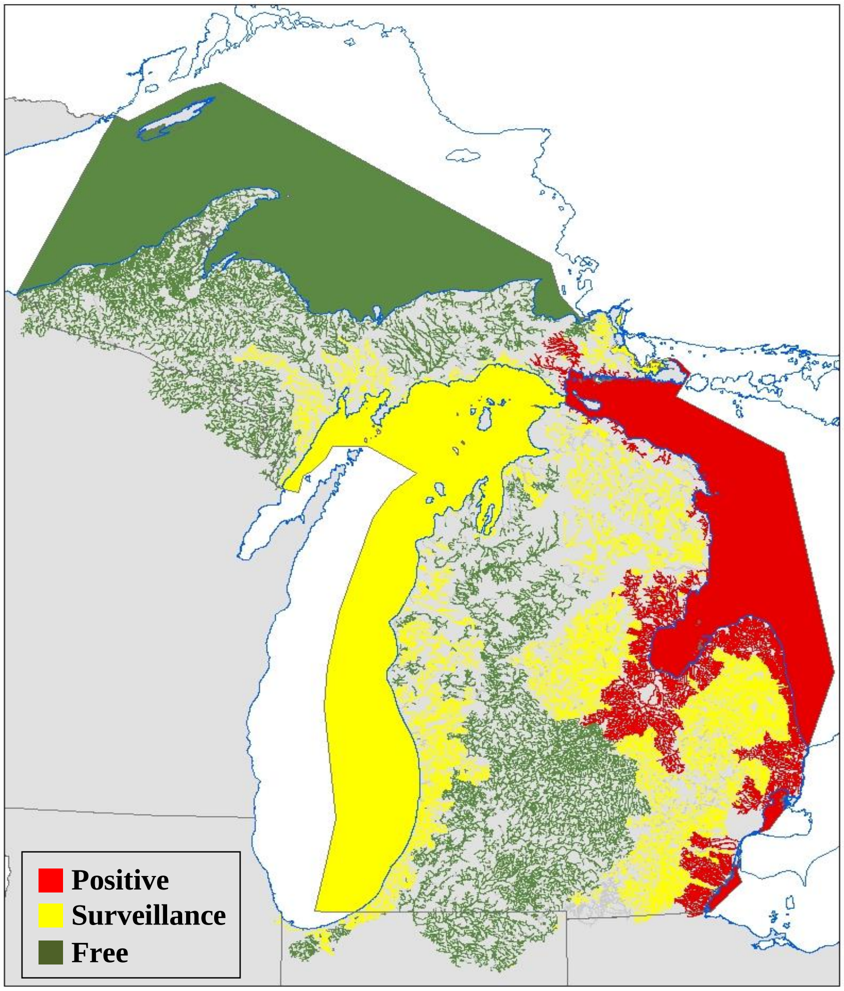

Figure 1-1: Map of VHSv management areas (Source: Gary Whelan, Michigan Department of Natural Resources).

Each disease management area has a unique set of regulations that target bait use and vary in severity with disease status, which are summarized in Table 1.1 (DNR, 2009). In addition to these restrictions, every boater in the state is required to drain their live wells and bilges prior to leaving any site, and anglers are prohibited from transporting live fish between waters of the state, as well as from releasing bait fish to the water unless attached to a hook.

Table 1-1: Regulation by management area

VHSv management area	Restrictions	Number of affected alternatives
Positive (D_{jnt}^{P})	All live bait collected or purchased from this region can only be used within the management area.	62
Surveillance (D_{jnt}^{S})	Live bait collected or purchased from this region can only be used in the positive and surveillance areas.	58
Free	Live bait collected or purchased from this region can be used anywhere in the state.	24
Statewide	All boaters must drain their live wells and/or bilge tanks prior to leaving the waterbody site. Transportation of live fish is not allowed.	144

This paper analyzes the effects of the Michigan DNR VHSv regulations on two aspects of angler behavior. We have developed the following hypothesis based upon the restrictions described above: the presence of VHSv coupled with the VHSv regulations by management area will have a significant effect on where and how frequently anglers choose to fish. Specifically, Great Lakes anglers will be least likely to select sites in the positive management area, followed by the surveillance management area. Furthermore, the total number of trips anglers take to the Great Lakes will be negatively affected. Testing for these effects will provide insights into the costs of the disease and its management as well as the effectiveness of fisheries policies.

To identify the effects of VHSv regulations on angler behavior, we exploit variation in VHSv regulations over space and time, and we make use of data on angler behaviors from the time before and after the implementation of VHSv regulations. Our hypothesis on fishing trip behavior is addressed by developing a demand model of Great Lakes fishing location choice and frequency. We include controls in our model for the timing and multiple severity levels of the disease regulations across the state, which allows us to identify changes in angler site selection and trip frequency due to the regulations.

1.3 Model

A linked participation site choice model is used to assess the effects of VHSv and the disease regulations on Michigan anglers' fishing participation and location decision. Specifically, the model measures participation and site choice in two stages that are linked by an inclusive value index. The first stage consists of a random utility maximization (RUM) model, which is used to estimate the probability that an angler visits a specific fishing site or region based on the known characteristics of sites. The RUM model is also used to calculate an "inclusive value" measuring the relative value of the fishing sites available to each angler in the sample. This index is then used as an explanatory variable in the trip frequency model (Hausman et al, 1995; Parsons et al, 1999).

1.3.1 Site choice model

The location choice determines the utility, or benefit, that an angler experiences when they go fishing. Generally, angler i's utility function for visiting site j in time t can be described as:

$$U_{ijt} = U(z_i, q_{jt}, \varepsilon_{ijt}) \tag{1}$$

where z_i represents other goods or activities that the angler could consume besides fishing at site j, q_{jt} represents a vector of time variant and time invariant observable attributes (e.g., catch rates that change monthly and regional features that do not change), and ε_{ijt} is a random element for all unobservable characteristics of the angler and site during time t. It is assumed that on a given fishing trip, each angler chooses to fish the site that results in the highest utility over all the other alternatives. While each angler strives to maximize their utility when they choose where to fish, they are limited by their budget, represented as follows:

$$\max_{j} U_{ijt}$$

$$s.t. \quad tc_{ijt}y_{ijt} + z_{it} \leq M_{it} \tag{2}$$

where M_{it} represents the angler's income. Anglers choose to spend their income on travelling to the fishing site at a price (tc_{ijt}), and on other goods or activities (z_i). y_{ijt} captures the angler's decision to travel to site j or not, where $y_{ijt} = 1$ for the chosen site and $y_{ijt} = 0$ otherwise. Conditional on this choice, the constraint in (2) can be rearranged and substituted into the utility function (1) as $z_{it} = M_{it} - tc_{ijt}$. Assuming that ε_{ijt} is additively separable from observed utility, this results in the following conditional indirect utility function:

$$v_{ijt} = v\left(M_{it} - tc_{ijt}, q_{jt}\right) + \varepsilon_{ijt} \tag{3}$$

We assume that ε_{ijt} is independently and identically distributed Generalized Extreme Value (GEV) (McFadden, 1981) to produce a jointly estimated two-level site choice model (Haab & McConnell, 2002) in which the top level is a grouping of sites, or nests, and the bottom level consists of the sites themselves. This structure allows the model to control for unobservable similarities between grouped sites. In this analysis sites are grouped by Michigan's three shorelines: east (Lake Huron, Lake Erie and Lake St. Clair), west (Lake Michigan) and north (Lake Superior).

The specific form of the indirect utility function that we adopt for the RUM model is:

$$v_{ijnt} = \beta_{tc}tc_{ijnt} + \boldsymbol{\beta}'_{\boldsymbol{CR}}\boldsymbol{CR_{jnt}} + \beta_P D^P_{jnt} + \beta_S D^S_{jnt} + \beta_E E_j + \beta_W W_j + \boldsymbol{\beta}'_{\boldsymbol{q}}\boldsymbol{q_{jn}} + \varepsilon_{ijnt} \tag{4}$$

where the variable tc_{ijnt} is the travel cost of each angler i to site j along shoreline n (i.e., it is the price term from above). The term $\boldsymbol{CR_{jnt}}$ is a vector of targeted hourly catch rates for six species, which vary by time (month) and site. The variable $\boldsymbol{q_{jn}}$ is a vector of several physical features known to play a role in site choice.

The effects of the VHSv regulations for each site j are separated into two dummy variables. The variables, D_{jnt}^{P} and D_{jnt}^{S}, capture the effects of a site being located in the VHSv positive management area and VHSv surveillance management area, respectively, after the regulation was applied. The baseline (i.e., zero values) for these VHSv dummy variables includes any trips to sites in the time period before the regulations were in effect and any trips at any time to sites within the VHSv free management area. To correctly identify the effects of the VHSv regulations it also critical that the model controls for any time-invariant regional effects that could be correlated with the disease regulations. We therefore include the variables E_j and W_j, which are regional fixed effects for sites located along the eastern and western shores of Michigan, respectively. A regional effect for all sites located along Lake Superior was excluded to avoid perfect collinearity in the model. The regulation dummy variables (D_{jnt}^{P},D_{jnt}^{S}) then capture the changes in site preferences after the regulation is introduced.

The GEV error distribution allows the model to be estimated using the following probability structure:

$$P_{ijnt}(y_{ijn} = 1) = \Pr\left(v_{ijnt} > \forall v_{iknt}\right) = \frac{\exp\left(\frac{v_{ijnt}}{\theta_n}\right)\left[\sum_{k=1}^{Jn} \exp\left(\frac{v_{iknt}}{\theta_n}\right)\right]^{\theta_n - 1}}{\sum_{m=1}^{N}\left[\sum_{k=1}^{Jm} \exp\left(\frac{v_{ikmt}}{\theta_m}\right)\right]^{\theta_n}} \qquad (5)$$

where v_{ijnt} is the deterministic portion of the angler's indirect utility function from (4). The parameter θ_n is a measure of the unobserved dissimilarities between sites in the three groups of sites. The coefficients on the variables are then estimated using maximum likelihood estimation using the likelihood function:

$$L = \prod_{i=1}^{N} \prod_{j=1}^{A_i} P_{ijn}{}^{y_{ijn}} \tag{6}$$

where N is the total number of anglers in the sample population and A_i is the set of alternatives in each angler's choice set. Conditional on an angler taking a trip, the estimates from (6) can then be used to determine the site visitation probabilities before and after the VHSv regulations went into effect.

The estimated coefficients from (6) can also be used to calculate the inclusive value, the expected value of taking a Great Lakes trip for each angler in the sample. The inclusive value is defined as:

$$IV_{it} = \ln\left[\sum_{n=1}^{N} \left(\sum_{j=1}^{Jn} \exp\left(\frac{v_{ijnt}}{\theta_n}\right)\right)^{\theta_n}\right] \tag{7}$$

where IV_{it} is the expected maximum indirect utility (Haab and McConnell, 2002) for all available alternatives in each angler's choice set. There is one measure per individual for the month surveyed, regardless of whether they fished or not. Therefore, IV_{it} can be interpreted as an index of the overall quality of fishing opportunities during a fishing choice occasion (Carson, Hanemann, and Wegge, 2009), which can be computed before and after the VHSv regulations went into effect. Once each value is calculated it is used as an independent variable in the participation stage and becomes the linking mechanism between the two models.

1.3.2 Participation model

Trips taken by anglers are unlikely to remain constant as fishing conditions change throughout the year; therefore, it is necessary to estimate each angler's trip frequency over each month. The inclusive value index was used as the linkage to site choices in a model predicting the mean number of trips occurring over each month in our sample. We use a Tobit model to estimate trip frequency because it allows for a large occurrence of zeroes in the dependent variable as anglers choose to participate in a given month. The generalized Tobit model is:

$$T_{it} = \max(0, T_{it}^*) \tag{8}$$

$$T_{it}^* = \boldsymbol{\beta}'\boldsymbol{X_{it}} + \mu_{it} \tag{9}$$

where T_{it}^* is a latent variable and T_{it} is the observed number of trips taken by angler i in month t. Anglers with $T_{it} = 0$ are considered to be non-participants and to accommodate the non-interger nature of our trip data (described below). It is assumed that anglers will optimize the number of trips taken per month over a vector of characteristics ($\boldsymbol{\beta}'\boldsymbol{X_{it}}$), which includes angler demographics, the site utility index, and the time of year. Specifically:

$$T_{it}^* = \alpha + \alpha_t \boldsymbol{S_t} + \boldsymbol{\beta}_{\boldsymbol{Z}}'\boldsymbol{Z}_i + \beta_{IV} IV_{it} + \mu_{it} \tag{10}$$

where $\boldsymbol{S_t}$ is a vector of seasonal dummy variables that capture preferences for specific seasons, $\boldsymbol{Z}_i$ represents a vector of angler characteristics, and IV_{it} is the estimated inclusive value measure from the site choice model. μ_{it} is a random error term that is assumed to be independently distributed with a mean of zero and constant variance, σ^2. The Tobit likelihood function is:

$$L = \prod_{i=1}^{N} \left[1 - F\left(\frac{\boldsymbol{\beta}'\boldsymbol{X_{it}}}{\sigma}\right)\right]^{1-I(T_{it})} \left[\frac{1}{\sigma} f\left(\frac{T_{it} - \boldsymbol{\beta}'\boldsymbol{X_{it}}}{\sigma}\right)\right]^{I(T_{it})} \tag{11}$$

where f and F are standard normal probability and cumulative density functions, respectively, and $I(T_{it})$ is an indicator function equaling one if angler i fishes in month t and zero otherwise.

1.3.3 Welfare Estimation

The results of the linked model can be used to estimate the change in angler welfare from the presence of VHSv and its regulations. The introduction of the regulations on alternatives in the angler's choice set will change their expected maximum utility from visiting the affected sites. A willingness to pay (WTP) measure, conditional on taking a trip, is estimated by using the site choice model to take the difference from the expected utility before and after the quality change and normalizing by the marginal utility of income (Haab and McConnell, 2002):

$$WTP_{trip,i} = \frac{1}{-\beta_{tc}}[IV_{it}^1 - IV_{it}^0] \tag{12}$$

where IV_{it}^1 and IV_{it}^0 are the inclusive value parameters from (7) with the VHSv regulations and disease presence, and without the regulations and VHSv presence, respectively. WTP_{trip} as defined in (12) provides a per-trip estimate conditional upon taking a Great Lakes fishing trip. If the total number of Great Lakes trips taken by angler i is constant with and without the VHSv regulations, then this measure can be multiplied by trips to derive a total WTP. However, if the angler changes the number of monthly trips taken in response to the introduction of the VHSv regulations, then the change in trip participation should also be accounted for when computing the total WTP measure for angler i (Haab and McConnell, 2002).

The above Tobit model can be used to predict the number of trips taken by each angler in the sample with and without the VHSv regulations, which are used to form upper and lower bounds for changes in welfare. Let $E(T_{it}^1)$ be the expected number of trips taken by angler i in month t with, and $E(T_{it}^0)$ be the expected trips without, the VHSv regulations. The total WTP_i measure for i will exist in the range (Haab and McConnell, 2002):

$$E(T_{it}^0) * WTP_{trip,i} \leq total\ WTP_i \leq E(T_{it}^1) * WTP_{trip,i} \tag{13}$$

The average of these bounds on the welfare measure accounting for changes in trips becomes:

$$\frac{E(T_{it}^1)+E(T_{it}^0)}{2} * WTP_{trip,i} = \overline{WTP_{\iota t}} \tag{14}$$

The welfare measure from (14) can be aggregated up by the population to estimate the total loss in consumer surplus from the presence of VHSv and regulations.

1.4 The Michigan Recreational Angler Survey Data

Data for the model was collected using the Michigan Recreational Angler Survey (MRAS), which began in 2008 and was designed to gather information on the status and distribution of angling effort for all of Michigan's recreational fisheries (Simoes, 2009). The mail survey queries anglers monthly, and the sample population consists of anglers who purchased a Michigan recreational fishing license for the given year during or before the sampled month. The monthly mail questionnaire was delivered following a protocol adapted from Dillman (2007) that involved up to four contacts over a two month period. Over five years of surveying, the average monthly response rate has been 48%. The questionnaire asks respondents about their fishing activity over the previous month, as well as the details of their most recent and second most recent fishing trips. Respondents are questioned about the number of fishing trips taken, where they fished, what species they targeted and caught, the method of fishing, and household demographics.

1.4.1 Fishing Trips and Travel Costs

The MRAS data collected from July 2008 through December 2012 was used to estimate the effect of the VHSv regulations on angler fishing choices. The data were weighted to adjust for differences over time in the total number of surveys sent in each month as well as angler characteristics including age, gender, and license type (Appendix C).

The site choice model was estimated using the reported details of anglers' most recent fishing trips. The model was applied only to day trips taken to Great Lake sites with the primary purpose of fishing (these two factors represented 70% and 88% of the collected sample, respectively), which yielded a sample of 2,802 fishing trips for the site choice model.

The choice set includes 72 fishing sites spread along Michigan's Great Lakes shoreline, including ports on Lake Huron, Lake Michigan, Lake Superior, and in the Lake Erie-St. Clair system. Each location consists of a cold and warm water fishable alternative to account for differences in anglers' fishing options and their potential response to the regulations, resulting in a total of 144 possible fishable alternatives in the overall choice set. Since the model was for single day fishing trips, we limited the number of sites that could fall within an angler's choice set to the fishable alternatives within 200 miles of an angler's residence. As a result, angler choice sets contained an average of 49 alternatives.

Each of these alternatives has varying travel costs depending on the angler's distance, income and year of trip (summarized in Table 1.2). The average cost per mile was calculated using annual AAA estimates for a medium-sized sedan published in *Your Driving Costs* (AAA, 2008-2012). These values were used in accordance with each angler's round trip distance to estimate driving cost to each alternative. Distance traveled from the angler's home to the fishing site was calculated using the PC*Miler software (ALK Technologies, 2010). Income range was a demographic question included in the survey and was used to calculate a wage rate for each individual by taking the midpoint from each range and dividing by 2000 (approximate number of hours worked in one year). Any angler's income that was not reported was proxied by the Census 2012 ZCTA household median income. Unemployed anglers were assigned the Michigan minimum wage of $7.40. The time cost was calculated as one-third of the estimated wage rate multiplied by time spent driving. We use one third of the hourly wage rate because it has been generally accepted by the recreation demand literature as the lower bound on the value of travel time (Parsons, 2003). The average driving speed is assumed to be 45 mph.

Table 1-2: Summary of weighted travel cost components for trips taken before and after the VHSv regulations

	Average	Before	After
Travel Cost ($)	41.96	39.27	42.67
Distance (mi)	75.80	70.23	77.27
Income	68,910	67,391	69,312
Per mile costs	0.29	0.29	0.29*
N		1345	1457

*Average per mile costs from 2009-2012 (AAA)

1.4.2 Fishing Site Characteristics

The site characteristics vector $\boldsymbol{q_j}$ from the indirect utility function (5) includes three dummy variables: Highway, Bayorseaway, and Urban. Highway is a variable intended to measure the remoteness of a site, which receives a value of one if the site is located next to a highway and zero otherwise. Bayorseaway captures preferences for fishing in warmer, safer areas of a lake and equals one if the site is located in a bay or seaway. Urban is a dummy variable that indicates whether the alternative lies in an area that the Census 2010 defined as at least partially urban and is used as a proxy for amenities at a site.

Monthly catch rates ($\boldsymbol{CR_{jnt}}$) were derived from Michigan DNR creel survey data (DNR, n.d.). The catch rates were estimated for six fish species across all available Great Lakes sites using a series of 84 Tobit regressions (updating and extending the catch models of Melstrom and

Lupi, 2013).[1] Each model includes per-hour catch rate data for 14 geographical Great Lake regions, excluding the Lake St. Clair system (summarized in Table D-2) (Appendix D). We include monthly dummies and site-specific effects that are representative of the particular region and species. To capture catch rate changes that may be due to VHSv, we also included yearly fixed effects in the Tobit regressions. We used the estimated monthly average catch rates for each site and species in the first stage of the linked model. Data was limited for sites in the St. Clair system, so we used simple averages for the monthly estimates.

Table 1-3: Predicted hourly catch rates for Great Lake sites

	Michigan	Superior	Huron	Erie	St. Clair System*
Number of Regions	5	2	6	1	1
Number of Tobit Models+	30	12	36	6	0
Catch Rate Estimates^					
Chinook Salmon	0.065	0.011	0.026	0.000	0.000
Coho Salmon	0.012	0.069	0.006	0.000	0.000
Lake Trout	0.030	0.131	0.106	0.000	0.000
Rainbow Trout	0.031	0.020	0.020	0.001	0.000
Walleye	0.017	0.009	0.068	0.109	0.119
Yellow Perch	0.373	0.057	0.205	1.252	0.711

*Due to limited data, these were simple averages from 2002-2004
+Month and year fixed effects with a p-value under .20 were included in each model.
^Hourly catch rates were averaged over months with available data.

[1] The estimated catch rates from Melstrom and Lupi (2013) included per-hour DNR creel data through 2009. We use creel data through 2013.

1.4.3 Participation Model and Angler Characteristics

In the participation model, we included several angler-specific characteristics that might influence the fishing trip decision. In addition to variables for age, dummy variables were used to measure whether the angler is male, employed full-time, retired, graduated from college and lives with their spouse. Angler income level dummies were included to identify which income group(s) may be more or less inclined to participate. Employment status proxied for how much leisure time an angler had available. Finally, we controlled for changing fishing conditions by incorporating seasonal dummy variables. Each season consists of three months.

The angler survey data contains information about the number of days fished during a calendar month, rather than number of trips. To convert days into trips, we first calculated the average number of days spent on a single fishing trip for each month and year, which comes from the site choice section of the survey. We then calculated the total days fished for each angler in the sample over the average days per trip, which resulted in an estimate of the number of trips each angler takes in a month (Appendix B). If an angler did not circle any days in the calendar, they were assigned a zero and are considered to be non-participants. The estimated monthly trips include all types of fishing (e.g. Great Lakes, inland lakes, rivers) for any length of time. Therefore, we scaled down the estimates to represent single day trips for Great Lakes fishing. Note that this method returns non-integer values for monthly trips, making a Tobit specification appropriate for our model.

The participation model contains monthly trip data on 24,482 anglers, consisting of 13,561 non-participants and 10,921 participants. There are 6,242.09 estimated monthly trips used in the model. This data is distinct from the fishing destination data in the site choice model allowing us to utilize the maximum amount of available data, including the data for anglers who did not take trips. In particular, the estimated inclusive value index from the site choice model is calculated at the participation level for all cases in the participation dataset, regardless of whether they were observed as Great Lakes anglers.

1.5 Results

1.5.1 Linked Model

The site choice and participation models were estimated using Stata 12 (StataCorp, 2011). The results of these models are presented in Tables 1.4 and 1.5. The results of the site choice model (Table 1.5) indicate that the travel cost variable had a significant negative impact on site choice for all models, as expected. If the cost to travel to a fishing site increases, the angler is less likely to choose that site. All site characteristics were positive and statistically significant at the 0.05 level in the site choice model. We find that anglers prefer sites that have high catch rates with highway access and are located in a protected area of a lake. The dissimilarity parameter (θ_n) is significantly less than one, which is consistent with utility-maximizing behavior (Hunt et al, 2007; Herriges et al, 1999) and indicates that the model is preferred to a conditional logit that does not allow any correlation among the unmeasured characteristics of sites within the regional nests.[2]

The two VHSv effects are negative and significant, suggesting that regardless of the stringency level, the presence of the disease and the accompanying regulations reduces the probability that a site is visited (Table 1.5). Furthermore, the effect of the positive management area is significantly greater than the effect of the surveillance management area, indicating that anglers are least likely to visit a fishing site if it is subject to the most stringent VHSv and

[2] A model where the three nests have different parameters resulted in nesting parameters estimates for the north, east and west of 0.42, 0.59 and 0.79. Overall though, all other parameters were quite similar.

disease regulations. We also find that controlling for the other variables in the model, on average anglers are more likely to visit fishing sites located along the lower peninsula of the state than sites located along the shore of Lake Superior.

Table 1-4: Site choice model results

Variables	Coefficient	Robust Standard Errors
Travel Cost	-0.0271^{***}	0.002
D_{jnt}^{P}	-1.774^{***}	0.436
D_{jnt}^{S}	-0.749^{*}	0.389
E	1.437^{***}	0.344
W	0.747^{**}	0.326
CR chinook	7.481^{***}	0.889
CR coho	5.452^{***}	1.336
CR lake trout	1.452^{***}	0.475
CR rainbow trout	3.484^{***}	1.297
CR walleye	2.500^{***}	0.268
CR yellow perch	0.510^{***}	0.053
Bayorseaway	0.218^{***}	0.054
Highway	0.375^{**}	0.161
Urban	0.405^{***}	0.063
θ_n	0.625^{***}	0.048
N	2802	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1-5: Participation model results

Variables	Coefficient	Robust Standard Errors
IV	0.048***	0.011
Male	0.241***	0.024
Age	0.015***	0.0036
Age^2	-0.0002***	0.000037
Employed	-0.076***	0.024
College	-0.123***	0.021
Married	0.022	0.023
Retired	-0.024	0.030
Income1[a]	-0.062	0.054
Income2	-0.041	0.047
Income3	-0.061	0.046
Income4	-0.085*	0.048
Income5	-0.057	0.049
Spring	0.702***	0.030
Summer	0.840***	0.031
Fall	0.191***	0.032
Constant	-0.961***	0.096
Standard Error (σ)	0.816***	0.015
N	24482	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[a] Annual incomes ($) categories are defined as: 0-24,999; 25,000-49,000; 50,000-74,999; 75,000-99,999; 100,000-150,000; Incomes> 150,000 were used as the baseline.

At the participation level, our results are consistent with previous findings (Table 1.6). The inclusive value coefficient is both positive and significant. As the value of Great Lakes fishing increases to an individual angler, they are expected to increase the number of trips taken per month. We find that on average male anglers take more trips per month, while anglers who are employed full-time, earn $75,000 to $100,000 and/or are highly educated take fewer fishing trips per month. The positive and negative effects of the age variables suggest that, holding all else constant, anglers fish the Great Lakes more often each year until they are about 38 years of age, and thereafter they fish less each year with the effect of age becoming negative at age 76 or greater. Conditional on age, retirement status does not have a significant effect on the number of trips taken for Great Lakes fishing. All seasonal dummy variables are significant relative to the omitted winter category; anglers take more trips in the spring, summer and fall, with the most trips occurring in the summer season.

Table 1-6: Predicted average monthly Great Lakes trips with and without VHSv and regulations

Site Location	Base ($D_{jnt}^{P} \neq D_{jnt}^{S}$)	Counterfactual ($D_{jnt}^{P} = D_{jnt}^{S} = 0$)
East	0.074	0.102
West	0.062	0.057
North	0.047	0.035
Total	0.183	0.194

1.5.2 Counterfactual Scenario

We can use the model estimates to predict the change in the number of trips taken in a region with and without the disease regulations to further illustrate the effects of the VHSv regulations on trip behavior (Table 1.6). These predictions were made by setting the regulation variables to zero in the site choice models and predicting new site choice probabilities for each angler. Then, the counterfactual inclusive value indices were computed and used within the Tobit participation model to predict changes in total trips per angler. The overall trip estimates for any site are then the product of the predicted site choice probabilities and the predicted total trips from the participation model. These site demands are averaged across anglers and summed regionally in Table 1.6. The results indicate that trips declined in the Lower Peninsula, particularly along the eastern shore, when the disease and the regulations were present. Conversely, trips to sites along Lake Superior increased after the regulations went into effect. Sites in the VHSv surveillance area along the western shore experienced a shift in trips, suggesting that these sites became more favorable as the quality of the VHSv positive sites diminished. The shift in trips can be attributed in part to the fact that anglers were constrained to choose sites that were feasible day trips; all other sites beyond that limit were unavailable to the angler. For many anglers, the sites that were unaffected by the regulations were excluded from the anglers choice set for day trips. The shifts from eastern to western sites suggest that day trip anglers were willing to substitute to sites with a relatively lower impact from VHSv. Overall, the results show that anglers react differently (spatially) according to the presence of the virus and the stringency of the regulations.

Table 1.7 presents the predicted average monthly loss in welfare for each year of the regulations. The model shows that the average loss per Great Lakes angler per month is $7.30, with the greatest loss of $7.63 occurring in the first year the regulations went into effect. There are about 300,000 resident anglers in Michigan that fish the Great Lakes, and about 70% of their trips are single day, suggesting an average welfare loss exceeding $18 million statewide from the impacts of VHSv and the regulations. Put differently, the loss with VHSv and the regulations would be about $8.40 per Great Lakes trip.

Table 1-7: Average welfare loss from VHSv and regulations per angler per month

	2009	2010	2011	2012	Mean
Upper Bound	-$7.03	-$6.87	-$6.52	-$6.52	-$6.73
Lower Bound	-$8.27	-$8.10	-$7.68	-$7.67	-$7.92
Mean	-$7.65	-$7.49	-$7.10	-$7.09	-$7.33

1.6 Conclusion

Policy makers and fisheries managers often have to make assumptions about the impacts of proposed regulations on behavior. Understanding how anglers respond to regulations is therefore crucial in protecting or enhancing the value of a fishery. Similarly, improved understanding of the impacts of invasive species and diseases on angler behavior and welfare is important to contemporary fisheries management and policy. The goal of this paper was to investigate and quantify the behavioral impacts of an invasive disease and the associated agency regulations for a recreational fishery by estimating a linked participation-site choice demand model. The results suggest that Michigan anglers responded to disease presence and disease regulations, and they significantly altered their behavior at both the site choice and participation levels. We find that the disease regulations implemented by the Michigan DNR to slow the spread of VHSv have had an impact on angler behavior for areas where the virus is present and regulated. Anglers have reduced the number of monthly trips to regions considered to be VHSv positive and regulated, reflecting a loss in welfare. Moreover, anglers responded to the regulations in a spatial manner that varied with the intensity of the regulations; the more stringently regulated area had a larger effect on angler behavior and welfare loss.

To be clear, we cannot explicitly distinguish among two possible effects driving these results: the influence of VHSv on resource quality and the influence of the regulations on angler actions per se within the disease management zones. Our model does not establish a link from VHSv to changes in the per hour catch rates that may have occurred during the regulation period. Moreover, we cannot measure the extent to which the regulations have prevented what might have been further damage to the fishery by limiting the spread of VHSv. Further, the changes in risks of VHSv are to some extent endogenous with human behavioral choices (Horan et al, 2008;

Barbier and Shogren, 2004; Perrings et al, 2002). Therefore, we cannot explicitly measure changes in risk as anglers choose to fish alternate waterbodies over time. In future work, it would be desirable to expand the analysis to include multiple day trips, non-resident anglers, and inland effects from VHSv and the regulations. Additional useful extensions would be to update the model with additional years of data should VHSv conditions and regulations change in the future, explicitly link VHSv to catch rates, and consider incorporating a stated preference component that accounts for some of the unobservables in our model, but these are beyond the scope of this paper.

Our investigation into the effects of fishing regulations was made possible by a statewide multi-year surveying effort. Both spatial and temporal dimensions were used to identify the spatial effects of new fishing regulations on angler behavior. To our knowledge, this is the first study to exploit such a natural experiment and apply a multi-dimensional database to modeling the effect of invasive species and disease regulations on an ecosystem service such as recreation.

CHAPTER 2

Angler Participation and Site Choices: A Linked Model for Inland Lake Fishing in Michigan

2.1 Introduction

Climate change is a growing concern among fisheries managers, as the composition of fish species is changing from increasing water temperatures and competition from invasive organisms. Summer stratification in lakes may increase which can wipe out key fish species or make the water unsuitable for use by human communities through toxic algal blooms and bad-tasting drinking water (Christie and Bostwick, 2012). Inland lakes ecosystems are especially sensitive to these environmental changes and can result in significant shifts in the ranges of targeted fish which may also leave behind local businesses such as resorts, restaurants and fishing equipment retailers that depend on the revenue generated from fishing these species (Ficke et al, 2007). Outdoor recreation is considered to be one of the strongest drivers for the protection and conservation of waterbodies (Söderqvist, 1998; Vesterinen et al, 2009), but also holds the potential to exacerbate the detrimental effects of climate change by putting pressure on freshwater systems. Therefore, it is increasingly important that fisheries managers are able to adapt to changing lake ecosystems and understand the impacts of changes in fishing quality on recreational anglers and the places they fish in order to sustain a healthy freshwater fishery.

Economically efficient natural resource policy requires comprehensive management of discrete opportunities over a complete system of sites (Ward et al, 1997). Demand systems are powerful tools that can aide state regulatory agencies to efficiently manage ecosystem services. Nevertheless, many of the demand systems and valuation studies that are available to inform management measure the impacts changes in ecosystem services by utilizing a subset of the options available to recreational anglers. This limitation results in an incomplete understanding of how anglers value the fishery and how they might alter their behavior as the state of the fishery changes.

Natural resource agencies use revenues primarily generated from license fees to implement fishery management policies, yet the number of anglers is in a long-run decline (Arlinghaus, Tillner, and Bork, 2014). The social and environmental impacts of this decline are not limited to the natural resource agencies and businesses that cater to recreational fishing; fewer anglers and decreasing revenues from license sales reduces the capacity of managers to protect natural systems, which many non-anglers regularly enjoy (Aas and Arlinghaus, 2009). Previous work has shown that shifts in recreational fishing behavior are linked to changes in fishing quality (Hunt et al, 2007; Cowx et al, 2010) and that agencies must manage both the quality and participation levels to maintain a sustainable fishery (Aprahamian et al, 2009). Therefore, a demand model that accounts for variation in trip frequency would provide agencies with a useful tool that could improve management decisions and retain the vital angler population.

Assessing changes in angler behavior requires an understanding of not only angler characteristics but also the desirability of fishing sites themselves. However, many site choice studies develop models tailored to a specific policy or quality change that shifts demand using a narrow collection of alternatives, rather than analyzing the effect in a broad demand system (Ward et al, 1997). Expanding the analyses through demand systems can encompass dynamic effects of quality changes from multiple aspects of a recreational fishery, at the participation and site choice levels. Therefore, it would be beneficial to develop a comprehensive demand model that is (1) consistent with known indicators that shift angler demand in the literature and (2) includes a broad spectrum of fishing site characteristics (e.g. catch measures, landscape features) for thousands of fishing sites across the landscape. State natural resource agencies would benefit from a comprehensive analysis because they can better understand anglers' fishing preferences and behavior and construct effective policies to sustain the resource.

This paper utilizes a linked participation-site choice model to capture the effects of a quality change on site choice and participation for Michigan recreational fishing. Modeling recreational fishing demand as a site choice problem alone is insufficient because such models implicitly assume that there will be a redistribution of anglers at the various alternatives when a change in site quality might provide enough disutility that the angler would choose not to participate in the activity. This paper develops a complex demand model linked to species-specific biomasses for upwards of one thousand inland lake fishing sites in Michigan. Since climate change is expected to differentially affect species abundances (Wehrly et al, 2013), we apply the model to understand the effects of changes in biomass on the type of sites visited and how often anglers fish.

2.2 Contributions

The model developed in this paper is unique in the detail of alternatives, breadth and inclusion of an extensive range of inland lake fishing available to recreational anglers. Additionally, we have extended the analysis to include a participation component, a detail that is sometimes excluded from other recreational demand models in the literature.

Studies in recreational fishing demand tend to limit the scope of their analysis in a variety of ways such as only site choices instead of both site and participation choices or by only using sites within a limited region (Murdock, 2006; Jakus et al, 1997; Whitehead et al, 2013).

The models that incorporate vast spatial variation frequently have a narrow range of defined choices that analyze only single day trips (Johnstone and Markandya, 2006; Melstrom and Lupi, 2013)   or a single species (Pierce, 2011). Studies that cover larger scale areas often include large aggregate sites (Hoehn, Tomasi, Lupi and Chen, 1996; Jones and Lupi, 1999) or restrict the types of fishing (Morey Rowe and Waston, 1993). We attempt to alleviate this issue by including in our choice set both single and multiple day trips for a broad region with sites defined on a fine scale. Additionally, we add detail to the model by using explicit linkages to species-specific fish biomass variables for all of the sites in the choice set. Few studies include fishing quality measures to this degree.

This study also contributes to the fisheries management literature by using the scope of the choice sets and by incorporating a complete linkage of participation to angler demographics and site quality. Our specification and broad dataset allows for a comprehensive understanding of how biological changes can shift demand to (from) sites. Furthermore, this model is suitable for analyzing changes in angler behavior and welfare in response to a multitude of ecosystem change scenarios, including the impacts due to invasive species, climate change, and changes in water quality and quantity.

2.3 Demand model

A linked participation site choice model was used to assess the effects of a quality change on Michigan anglers' fishing participation and site location decision (Hausman, Leonard, and McFadden, 1995; Andrews, 1996). Linked models are an extension of the travel cost method that allows the analyst to incorporate a substantial number of recreation sites without having to resort to extensive amounts of site aggregation, as would be needed for alternative approaches such as

Kuhn-Tucker demand systems (Herriges et al, 1999). Our model measured participation and site choice in two stages that were linked by an inclusive value index, the relative value of fishing for each angler in the sample. The first stage consisted of a random utility maximization (RUM) model, which was used to estimate the probability that an angler visited a specific fishing site based on the known characteristics of sites. The parameters from the RUM were used to compute the inclusive value index, which was used as an explanatory variable in the second stage of the analysis, the trip frequency model (Hausman et al, 1995; Parsons et al, 1999).

2.3.1 Site choice model

The location choice determines the utility, or benefit, that an angler experiences when they go fishing. Angler i's utility function for visiting site j is as follows:

$$U_{ijt} = U(z_i, q_{jt}, \varepsilon_{ijt}) \tag{1}$$

where z_i represents other goods or activities that the angler could consume besides fishing at site j, q_{jt} represents a vector of time variant and invariant observable attributes such as site amenities, and ε_{ijt} is a random element for all unobservable characteristics of the angler and site. It is assumed that on a given fishing trip, each angler chooses to fish the single site that results in the highest utility over all the other fishable alternatives. While each rational angler strives to maximize their utility when they choose where to fish, they are limited by their budget, represented by the following constraint:

$$\max_j U_{ijt}$$

$$s.t. \quad tc_{ijt} y_{ijt} + z_{it} \leq M_{it} \tag{2}$$

where M_i represents the angler's annual income. Anglers choose to spend their income on travelling to the fishing site at a price (tc_{ijt}), and on other goods or activities (z_i). y_{ijt} captures the angler's decision to travel to site j or not, where $y_{ijt} = 1$ for the chosen site and $y_{ijt} = 0$ otherwise. Conditional on this choice, the constraint in (2) can be rearranged and substituted into the utility function (1) as $z_{it} = M_{it} - tc_{ijt}$. Assuming that ε_{ijt} is additively separable from observed utility, this results in the following conditional indirect utility function:

$$v_{ijt} = v\left(M_{it} - tc_{ijt}, q_{jt}\right) + \varepsilon_{ijt} \tag{3}$$

We assumed that ε_{ijt} was independently and identically distributed Generalized Extreme Value (GEV) (McFadden, 1981) to produce a jointly estimated two-level site choice model (Haab & McConnell, 2002) in which the top level was a grouping of sites, or nests, and the bottom level consisted of the sites themselves. This structure allows the model to control for unobservable similarities between grouped sites.

We applied the model to inland lake fishing in Michigan, and grouped the alternatives by three geographic regions: western Lower Peninsula, eastern Lower Peninsula and the Upper Peninsula. We specified the indirect utility function for the site choice model as:

$$v_{ijnt} = \beta_{tc} tc_{ijnt} + \boldsymbol{\beta}_{IL}' \boldsymbol{CR}_{jn}^{IL} + \beta_q \boldsymbol{q}_{jn} + \varepsilon_{ijnt} \tag{4}$$

where tc_{ijn} is the travel cost variable for each angler i to site j in nest n. The term $\boldsymbol{CR}_{jn}^{IL}$ is a vector of gamefish biomass specific to each site and species. The variable $\boldsymbol{q}_{jn}$ is a vector of several physical features of sites that are expected to play a role in site choice.

The conditional predicted probability that angler i chooses site j can be specified using the GEV error distribution as:

$$P_{ijnt}(y_{ijn} = 1) = \Pr\,(v_{ijnt} > \forall v_{iknt}) = \frac{\exp\left(\frac{v_{ijnt}}{\theta_n}\right)\left[\sum_{k=1}^{Jn} \exp\left(\frac{v_{iknt}}{\theta_n}\right)\right]^{\theta_n - 1}}{\sum_{m=1}^{N}\left[\sum_{k=1}^{Jm} \exp\left(\frac{v_{ikmt}}{\theta_m}\right)\right]^{\theta_n}} \qquad (5)$$

where v_{ijnt} is the deterministic portion of the angler's indirect utility function from (4). The parameter θ_n represents a measure of the site dissimilarities within the nest compared to those that are outside the nest. Typically, a model is said to be consistent with utility-maximization when $0 < \theta_n < 1$. As the dissimilarity parameter approaches 1, the nested logit model simplifies to a conditional logit model, while values closer to 0 imply higher levels of correlation within nests (Phaneuf and Smith, 2004). P_{ijnt} is estimated using the following maximum likelihood estimation:

$$L = \prod_{n=1}^{N} \prod_{j=1}^{J_n} P_{ijnt}{}^{y_{ijn}} \qquad (6)$$

where $y_{ijn} = 1$ if the angler visits site j in nest n and $= 0$ otherwise. N represents the total number of anglers in the sample and J_n is the number of available alternatives in each angler's choice set.

Equation (6) can be used to calculate the expected value of a Michigan fishing trip over each angler in the sample, defined as:

$$IV_{it} = \ln\left[\sum_{n=1}^{N}\left(\sum_{j=1}^{Jn} \exp\left(\frac{v_{ijnt}}{\theta_n}\right)\right)^{\theta_n}\right] \qquad (7)$$

where IV_{it} is an index of the expected maximum utility of taking a fishing trip to all the alternatives in each regional group (Carson, Hanemann, and Wegge, 2009; Haab and McConnell, 2002). Once each inclusive value is calculated it is used as an independent variable in the participation stage and becomes the linking mechanism between the two models.

2.3.2 Participation model

Trips taken by anglers are unlikely to remain constant as fishing conditions change throughout the year; therefore, it is necessary to estimate each angler's trip frequency over each month. The inclusive value index can be used as the linkage to site choices in a model predicting the mean number of trips occurring over each month in our sample. We used a Tobit model to estimate trip frequency because it allows for a large occurrence of zeroes in the dependent variable as anglers choose to participate in a given month. The generalized Tobit model is:

$$T_{it} = \max(0, T_{it}^*) \tag{8}$$

$$T_{it}^* = \boldsymbol{\beta}'\boldsymbol{X_{it}} + \mu_{it} \tag{9}$$

where T_{it}^* is a latent variable and T_{it} is the observed number of trips taken by angler i in month t. Anglers with $T_{it} = 0$ are considered to be non-participants. It is assumed that anglers will optimize the number of trips taken per month over a vector of characteristics ($\boldsymbol{\beta}'\boldsymbol{X_{it}}$), which includes angler demographics, the site utility index, and the time of year. Specifically:

$$T_{it}^* = \alpha + \alpha_t \boldsymbol{S_t} + \boldsymbol{\beta_Z Z}_i + \beta_{IV} IV_{it} + \mu_{it} \tag{10}$$

where $\boldsymbol{S_t}$ is a vector of seasonal dummy variables that capture preferences for specific seasons, $\boldsymbol{Z}_i$ represents a vector of angler characteristics, and IV_{it} is the estimated inclusive value measure from the site choice model. μ_{it} is a random error term that is assumed to be independently distributed with a mean of zero and constant variance, σ^2. The Tobit likelihood function is:

$$L = \prod_{i=1}^{N} \left[1 - F\left(\frac{\boldsymbol{\beta}'\boldsymbol{X_{it}}}{\sigma}\right)\right]^{1-I(T_{it})} \left[\frac{1}{\sigma} f\left(\frac{T_{it} - \boldsymbol{\beta}'\boldsymbol{X_{it}}}{\sigma}\right)\right]^{I(T_{it})} \tag{11}$$

where f and F are standard normal probability and cumulative density functions, respectively, and $I(T_{it})$ is an indicator function equaling one if angler i fishes in month t and zero otherwise.

2.3.3 Welfare Estimation

The results of the linked model can be used to estimate the change in angler welfare from increasing fish biomass for several species across the inland lake alternatives. The increase in biomass will change anglers expected maximum utility from taking trips. This conditional on a trip willingness to pay (WTP) measure is estimated by using the site choice model to take the difference from the expected utility before and after the quality change and normalizing by the marginal utility of income (Haab and McConnell, 2002):

$$WTP_{trip,i} = \frac{1}{-\beta_{tc}}[IV_{it}^{1} - IV_{it}^{0}]$$

(12)

where IV_{it}^{1} and IV_{it}^{0} are the inclusive value parameters from (7). $WTP_{trip,i}$ as defined in (12) provides a per-trip estimate conditional upon taking a Michigan inland lakes fishing trip.

The Tobit model can be used to predict the number of trips taken by each angler in the sample with and without the quality change which can also be used in computing bounds for changes in welfare. Let $E(T_{it}^{1})$ be the expected number of trips taken by angler i in month t with increased fishing site quality and $E(T_{it}^{0})$ be the expected trips with current fishing site quality. The true WTP measure for each scenario will exist in the range (Haab and McConnell, 2002):

$$E(T_{it}^{0}) * WTP_{trip,i} \leq true\ welfare\ effect \leq E(T_{it}^{1}) * WTP_{trip,i} \quad (13)$$

The average of these bounds on the welfare measure accounting for changes in trips becomes:

$$\frac{E(T_{it}^{1})+E(T_{it}^{0})}{2} * WTP_{trip,i} = \overline{WTP_{\iota t}} \quad (14)$$

The welfare measure from (14) can be used to estimate the monthly benefits per angler from changes in site quality.

2.4 The Michigan Recreational Angler Survey

Data for the model was collected using the Michigan Recreational Angler Survey (MRAS). This survey was designed to gather information on the status and distribution of angling effort for all of Michigan's recreational fisheries (Simoes, 2009). The MRAS sample population consists of anglers who purchased a Michigan fishing license for the given year during or before the sampled month. Data was collected beginning in 2008 by drawing a simple random sample of anglers each month from the Michigan DNR Retail Sales System Database.

The MRAS uses a monthly mail questionnaire following protocol adapted from Dillman (2007). The initial mail packet included a four page questionnaire in booklet form, a personalized cover letter, and a self-addressed, postage-paid reply envelope (Simoes, 2009). The survey respondents were contacted four times over a two month period. Five days after the initial contact, a reminder postcard was sent to the respondent. After one month, those anglers who had not yet responded were sent a new packet with a revised cover letter, replacement survey, and reply envelope. Approximately two weeks following the third contact, a final postcard was mailed thanking them for their participation as well as stating that they will no longer be contacted regarding this project. Over five years of surveying, the average monthly response rate has been 48%. A copy of the MRAS is included in Appendix A.

The MRAS questionnaire asks respondents about their fishing activity over the previous month, as well as the details of their most recent and second most recent fishing trips. Respondents are questioned about the number of fishing trips taken, where they fished, what species they targeted and caught, the method of fishing, and household demographics.

2.4.1 Travel Cost

The MRAS surveys returned from July 2008 through December 2012 were used to model site choice and participation effects for Michigan anglers. Survey data were weighted to adjust for differences over time in the total number of surveys sent in each month as well as angler characteristics including age, gender, and license type (Appendix C).

The site choice model uses data from the section of the survey where anglers reported details of a fishing trip. Data was selected for anglers who took trips to any inland lake fishing site in Michigan with the primary purpose of fishing [3](these two factors represented 40% and 77% of the trips, respectively). As a result, the site choice model was estimated with 11,092 fishing trips to Michigan inland lake sites. The choice set includes 1,615 inland lakes per angler. Only lakes larger than 10 acres that had at least one visit were used in the analysis.

Each of these alternatives has varying travel costs depending on the angler's distance, income and year of trip (summarized in Table D-7). The average cost per mile was calculated using annual AAA estimates for a medium-sized sedan (AAA, 2008-2012). These values were used in accordance with each angler's round trip distance to estimate driving cost to each alternative. Distance traveled from the angler's home to the fishing site was calculated using the PC*Miler software (ALK Technologies , 2010). Income range was a demographic question included in the survey and was used to calculate a wage rate for each individual by taking the midpoint from each range and dividing by 2000 (approximate number of hours worked in one year). Any angler's income that was not reported was proxied by the Census 2012 ZCTA household median income. Unemployed anglers were assigned the Michigan minimum wage of $7.40. The time cost was calculated as one-third of the estimated wage rate multiplied by time

[3] See Appendix E for a detailed description on the data selected for the site choice model.

spent driving. We used one third of the hourly wage rate because it has been generally accepted as the lower bound by the recreation demand literature as the value of travel time (Parsons, 2003). The average driving speed was assumed to be 45 mph.

2.4.2 Fish Biomass

We use species-specific biomass estimates to reflect fishing quality at each of our inland lake sites (Esselman, unpublished data). The biomass measures were estimated for all lakes in our model by applying the methods of Esselman et al (2014). Biomass was obtained from the fish sampling data described in Wehrly et al (2012). The estimation used boosted regression trees to define non-linear functions that predicted biomass at a lake as a function of lake characteristics (e.g., temperature, size, morphology, nutrients) and of landscape-scale characteristics for the areas around the lake (e.g., land cover, coarse geology, hydrologic connectivity measures). Our model included biomass estimates for the following four specie groups: panfish, bass, yellow perch, and walleye. Only sites visited by the respondents were included in the model choice set which includes 1,615 inland lakes.

2.4.3 Fishing Site Characteristics

Several site characteristics $(\boldsymbol{q_{jn}})$ were chosen as potential influential factors to be used in the RUM model. Size, measured in thousand acres, is an indicator of the quantity of the resource and of fishing access at particular inland lakes sites. Additionally, we included seven locational dummy variables for sites that share similar ecosystem characteristics such as hydrologic regime, climate, landscape features, and zoogeographic history. These indicators are based on Michigan’s Ecological Drainage Units (EDUs) as defined by Higgins et al (2005). EDUs are based on watersheds provide a more effective framework for aquatic ecosystems and species distributions (Derosier and Badra, 2007). The Central Upper Peninsula Drainage Unit was used as the base case for the dummy variables. Descriptive statistics are summarized in Table D-6.

2.4.4 Participation model angler characteristics

In the participation model, we included several angler-specific characteristics known to influence the fishing trip decision. In addition to a variable for age, dummy variables were used to measure whether the angler is male, employed full-time, retired, graduated from college and lives with their spouse. Angler income level dummies were included to identify which income group(s) may be more or less inclined to participate. Employment status proxied for how much leisure time an angler had available. Finally, we controlled for changing fishing conditions by incorporating seasonal dummy variables. Each season consisted of three months.

The MRAS contains information about the number of days fished during a calendar month, rather than number of trips. To convert days into trips, we first calculate the average number of days spent on a single fishing trip for each month and year, which comes from the site choice section of the survey (see Appendix A). We then calculate the total days fished for each angler in the sample over the average days per trip, resulting in an estimate of the number of trips each angler takes in a month (Appendix B). If an angler did not circle any days in the calendar, they were assigned a zero and are considered to be non-participants. The estimated monthly trips were scaled to represent only the proportion of inland lake trips (Table B-5). Note that this method returns non-integer values for monthly trips, making a Tobit specification appropriate for our model.

The participation model contained monthly trip data on 24,482 anglers, which consisted of 13,561 non-participants and 10,921 participants. There were 17,846 estimated monthly trips used in the model. This data was housed separately from the location data in the site choice model to utilize the maximum amount collected through MRAS. So, the estimated inclusive value index from the site choice model was imputed at the participation level across all cases in the participation dataset, regardless of whether they indicated the location of their trip.

2.5 Model Estimation

2.5.1 Linked Model

The model was estimated using Stata 12 (StataCorp, 2011). Table 2.1 displays the results of the site choice model. The significant negative travel cost variable indicates that, all else equal, anglers are less likely to travel to a Michigan inland lakes fishing site that has a higher price (i.e. is further away). Anglers are more likely to visit a larger lake perhaps because there is more access or because there are other desirable features to larger lakes. All of the EDU dummies are significant, with the desirable features of sites that are not captured by the size and biomass variables being greater for sites located in the Upper Peninsula than for sites in the Lower Peninsula. All species biomass coefficients are positive and significant at the 0.01 level, suggesting, not surprisingly, that anglers in general are willing to travel further to access sites where there are more fish. The biomass coefficients indicate that walleye and yellow perch were preferred to bass and panfish. The dissimilarity parameter (θ_n) is significantly less than one, which indicates that there is correlation among the unmeasured characteristics for sites grouped within a particular regional nest.

Table 2-1: Site Choice Nested Logit Model Results

Site Choice Variables	Coefficient	Clustered Standard Error
Travel Cost	-0.021^{***}	0.001
Lake Size (1,000 acres)	0.110^{***}	0.006
Target Species Biomass		
CR_Bass	0.769^{***}	0.149
CR_Panfish	0.333^{***}	0.028
CR_Walleye	2.955^{***}	0.199
CR_Yellow Perch	1.947^{***}	0.358
Ecological Region		
SLM	-3.074^{***}	0.206
SB	-2.992^{***}	0.208
MIP	-3.278^{***}	0.221
MHS	-2.046^{***}	0.167
WPK	0.450^{***}	0.128
EUP	-0.529^{***}	0.098
WLE	-3.068^{***}	0.271
θ_n	0.646^{***}	0.028
Trips	8245	
Rows of Data	13315675	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

At the participation level, our results are consistent with findings of previous recreation demand studies (Table 2.2). The inclusive value coefficient is both positive and significant. As the value of inland lakes fishing increases to an individual angler, they are expected to increase the number of trips taken per month. We find that on average older, male anglers take more trips per month, while anglers who are employed full-time earning less than $150,000 and are highly educated are expected to take fewer fishing trips per month. Conditional on the age of an angler, retirement status does not have a significant effect on the number of trips. All seasonal dummy variables are significant relative to the omitted winter category, suggesting that anglers take more trips in the spring, summer and fall, with the most trips occurring in summer.

Table 2-2: Participation Model Results

Single Day Trip Variables	Coefficient	Robust Standard Error
IV	0.139^{***}	0.027
Male	0.465^{***}	0.046
Age	0.029^{***}	0.007
Age^2	-0.0004^{***}	0.0001
Employed	-0.160^{***}	0.046
College	-0.246^{***}	0.039
Spouse	0.021	0.044
Retired	-0.062	0.057
Income1[a]	-0.312^{***}	0.108
Income2	-0.165^{*}	0.096
Income3	-0.192^{**}	0.092
Income4	-0.223^{**}	0.094
Income5	-0.140	0.093
Spring	1.352^{***}	0.057
Summer	1.654^{***}	0.057
Fall	0.405^{***}	0.059
Constant	-1.974^{***}	0.188
Standard Error (σ)	1.552^{***}	0.029
N	24482	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[a] Annual incomes ($) dummy variable categories 1 to 5 are defined as: 0-24,999; 25,000-49,000; 50,000-74,999; 75,000-99,999; 100,000-149,999; Incomes≥ 150,000 were used as the baseline.

2.5.2 Angler Welfare from Biomass Increase

To assess the effects that changes in species composition would have on recreational angler trip demand, we developed two scenarios as if the biomass for a species was increased by 50% (Table 2.3). The two scenarios are repeated for each species. The first scenario applies the increase for all inland lake sites, and the second only applies it to sites located within the Lower Peninsula (LP). By taking the average of the results across the four species, we see that for an increase in biomass to all sites, trips are expected to increase by 6.1%, with an increase in trips of 5.5% if the biomass change is only at LP sites. We find that anglers who target walleye are expected to increase monthly trips by 13.6%, whereas anglers that target other species are expected to take 3.5% more trips per month for a statewide increase in abundance. Overall, there is a minimal difference between the statewide and the LP-only scenarios, which is largely attributable to the fact that most anglers live in the southern part of the LP.

Table 2-3: Predicted monthly trips from a 50% increase biomass

Variables	All Sites	Lower Peninsula
Baseline	0.264	
Increase in Walleye	0.300	0.296
Increase in Bass	0.273	0.273
Increase in Panfish	0.274	0.273
Increase in Yellow Perch	0.273	0.272
Average	0.280	0.279

Taking the average of the values across the four species, we find that the predicted average change in welfare from an increase in species abundance is $5.09 per month per

Michigan angler for all inland lakes sites (Table 2.4). If the increase occurs only in the Lower Peninsula, the value is predicted to be $4.60 per angler. Thus, we find that anglers are willing to pay about 11% more for biomass increases across all sites compared to an increase at only the LP sites. The model suggests that anglers are willing to pay the most for changes in walleye biomass. The least valuable specie group in both scenarios is yellow perch.

Table 2-4: WTP from increased biomass per inland lakes angler per month

	50% Biomass Increase for All Sites			50% Biomass Increase for Lower Peninsula Sites Only		
Variables	Lower Bound	Upper Bound	Mean	Lower Bound	Upper Bound	Mean
Bass	$2.68	$2.78	$2.73	$2.43	$2.51	$2.47
Walleye	$9.55	$10.86	$10.21	$8.61	$9.76	$9.19
Panfish	$2.84	$2.96	$2.90	$2.64	$2.75	$2.70
Yellow Perch	$2.61	$2.70	$2.66	$2.32	$2.40	$2.36
Average	$4.86	$5.31	$5.09	$4.40	$4.79	$4.60

To put the values in perspective, we can compare them to widely used values per fishing day from the benefits transfer literature (Loomis, 2005). By dividing the average welfare measures by predicted change in trips, we can estimate the average gain per trip. In the scenario where the species-specific biomasses increase by 50%, average gain per trip to an inland lake site is $18.17. In the alternate scenario regarding Lower Peninsula sites, average gain per trip is $16.51. These per trip estimates, which are only for a site quality change and not for an entire day, amount to about one-half the value of a recreational fishing day reported in the benefits transfer literature (Loomis, 2005).

2.6 Conclusion

Demand system models are useful tools for measuring the impacts of complex environmental problems on recreational angling on a large scale. A model of this scope can provide natural resource agencies with the mechanism to understand angler preferences and behavior. Our demand model utilized comprehensive data on Michigan anglers across a large range of inland lakes fishing opportunities. Furthermore, we allowed anglers to take single and multiple day trips, providing us with a more robust analysis. Understanding how sensitive anglers are to environmental changes can aid agencies in making more informed management decisions on how where they can allocate resources to benefit the fishery.

The site choice model results demonstrate that anglers are sensitive to biomasss for each species, but prefer walleye the most. Furthermore, we find that anglers have heterogeneous preferences to changes in the abundance levels for different fish species. This result is useful for policy makers as they strive to maintain healthy fish populations. However, we found little difference between the statewide and the Lower Peninsula only scenarios. This suggests that it may be almost as beneficial to increase species in portions of the state that are visited more frequently than over the entire geographical area.

In sum, we were able to measure participation and site choice and analyze the impacts of an ecosystem collapse on monthly trip demand angler using a complex demand model. This model was made possible through the statewide multi-year surveying effort, assistance from the Institute of Fisheries Research in Ann Arbor, Michigan, and funding from the Michigan Department of Natural Resources. Ideally, this demand system will be used to measure angler demand for a variety of applications in the future.

APPENDICES

APPENDIX A

SURVEY INSTRUMENT

The Michigan Recreational Angler Survey Data Process

Monthly samples for the survey originated from the Michigan Department of Natural Resources, Retail Sales System database. The sample consisted of only anglers aged 18 and older that purchased a fishing license during the year surveyed. Once the sample was received, the researcher reviewed and cleaned the list by checking for any pertinent missing information such as the angler's name or address. Any addresses outside of the United States and Canada were removed from the sample. Each angler was assigned a unique project identification number (Angler ID) which was used for the duration of the project.

An outside vendor was contracted to conduct all outgoing mail procedures. The vendor conducts a National Change of Address (NCOA) check of licensees, mail merge, prints and packages all components of the mailings and applies the appropriate postage to all mailings. The completed packages are then pre-sorted and mailed First-Class through the United States Postal Service. Each business reply envelope contains the unique angler identification number assigned to each individual in the sample. After conducting the NCOA, but prior to printing, packaging and mailing materials, the vendor contacts the researcher for a proof approval.

All returned survey data was keyed by technicians into a Microsoft Access database form developed specifically for the project. Any unusual responses or inconsistencies were reviewed by the researcher.

Copies of key survey materials contained in this appendix include the survey questionnaire (Figure A-1), and front and back pages of the two survey follow up letters (Figure A-2). The postcards from waves two and four mailings are omitted for brevity.

MICHIGAN STATE UNIVERSITY

MICHIGAN FISHING SURVEY

PART A: YOUR MICHIGAN FISHING DURING THE PAST 12 MONTHS

Please complete and return this questionnaire **even if you did not** go fishing in the past 12 months.

1. In the past 12 months, did you go fishing in Michigan?

☐ No (skip to **PART D, question 9**)
☐ Yes

2. In the past 12 months, how many times have you gone fishing in Michigan?

☐ 1 time
☐ 2 or 3 times
☐ 4 or 5 times
☐ 6 to 9 times
☐ 10 to 19 times
☐ 20 or more times

3. In the past 12 months, what types of water bodies did you fish at in Michigan?
(check all that apply)

☐ Michigan rivers
☐ Michigan inland lakes
☐ Great Lakes and connecting waterways

4. In the past 12 months, have you competed in any fishing events in Michigan?

☐ No
☐ Yes ➔ (If Yes) How many events?
_______ fishing events

5. For each of the types of fish listed below, indicate which methods, if any, you used to try catching that type of fish in Michigan in the past 12 months.
(check all that apply)

Method of fishing

Type of fish	Natural Bait	Artificial Bait	Trolling	Casting from boat	Casting from shore/pier	Fly fishing	Ice fishing	Other method
Bass	☐	☐	☐	☐	☐	☐	☐	☐
Catfish	☐	☐	☐	☐	☐	☐	☐	☐
Panfish	☐	☐	☐	☐	☐	☐	☐	☐
Pike	☐	☐	☐	☐	☐	☐	☐	☐
Salmon	☐	☐	☐	☐	☐	☐	☐	☐
Suckers	☐	☐	☐	☐	☐	☐	☐	☐
Trout	☐	☐	☐	☐	☐	☐	☐	☐
Walleye	☐	☐	☐	☐	☐	☐	☐	☐
Other ______	☐	☐	☐	☐	☐	☐	☐	☐

PART B: YOUR MICHIGAN FISHING IN MAY 2012

6. Did you go fishing in Michigan during the month of MAY 2012?

☐ No (skip to **PART C, question 7**)
☐ Yes ➔

(If Yes) Circle the days that you fished in MAY

MAY 2012						
S	M	T	W	T	F	**S**
		1	2	3	4	**5**
6	7	8	9	10	11	**12**
13	14	15	16	17	18	**19**
20	21	22	23	24	25	**26**
27	28	29	30	31		

Figure A-1: Image of Michigan Recreational Angler Survey

Figure A-1 (cont'd)

PART C: YOUR TWO MOST RECENT MICHIGAN FISHING TRIPS

For the purposes of this survey, a fishing trip is **any time you went fishing**, **no matter where or how long** you fished.

		7. Your Most Recent Michigan Fishing Trip			8. Your Second Most Recent Michigan Fishing Trip		
Trip Characteristics		↓			↓		
Date		month:________ year:_ _ _ _			month:________ year:_ _ _ _		
Was fishing the main purpose of the trip?		☐Yes ☐No			☐Yes ☐No		
Was it an overnight trip?		☐Yes ☐No			☐Yes ☐No		
How many days did you fish on this trip?		_____ day(s)			_____ day(s)		
Did you fish at multiple rivers or lakes?		☐Yes ☐No			☐Yes ☐No		
Main Trip Location (where most time was spent)		↓			↓		
River or Lake (check one)		☐River ☐Lake			☐River ☐Lake		
Name of River or Lake		Name:____________________			Name:____________________		
Nearest city/town/village		City:____________________			City:____________________		
County		County:____________________			County:____________________		
Please mark the general location on the map		Put an "X" on the map			Put an "X" on the map		
Primary Fishing Mode (check one)		↓			↓		
Primarily from the shoreline		☐			☐		
Primarily wading		☐			☐		
Primarily from a boat (trailered to site)		☐			☐		
Primarily from a boat (already at site)		☐			☐		
Charter boat		☐			☐		
Ice fishing		☐			☐		
Fish Species You Targeted, Caught or Released (check all that apply)		Targeted	Number Caught	Number Released	Targeted	Number Caught	Number Released
Bass	Largemouth	☐	___ fish	___ fish	☐	___ fish	___ fish
	Smallmouth	☐	___ fish	___ fish	☐	___ fish	___ fish
Carp	Common Carp	☐	___ fish	___ fish	☐	___ fish	___ fish
Catfish	Bullhead, Channel and Flathead	☐	___ fish	___ fish	☐	___ fish	___ fish
Pikes	Muskie/Muskellunge	☐	___ fish	___ fish	☐	___ fish	___ fish
	Pike	☐	___ fish	___ fish	☐	___ fish	___ fish
Panfish	Yellow Perch	☐	___ fish	___ fish	☐	___ fish	___ fish
	White Perch or White Bass	☐	___ fish	___ fish	☐	___ fish	___ fish
	Bluegill/ Pumpkinseed/Sunfish	☐	___ fish	___ fish	☐	___ fish	___ fish
	Black/White Crappie	☐	___ fish	___ fish	☐	___ fish	___ fish
	Rock Bass	☐	___ fish	___ fish	☐	___ fish	___ fish
Salmon & Trout	Chinook/King Salmon	☐	___ fish	___ fish	☐	___ fish	___ fish
	Coho/Silver Salmon	☐	___ fish	___ fish	☐	___ fish	___ fish
	Rainbow Trout (Steelhead)	☐	___ fish	___ fish	☐	___ fish	___ fish
	Brook/Speckled Trout	☐	___ fish	___ fish	☐	___ fish	___ fish
	Brown Trout	☐	___ fish	___ fish	☐	___ fish	___ fish
	Lake Trout	☐	___ fish	___ fish	☐	___ fish	___ fish
	Lake Whitefish/Whitefish	☐	___ fish	___ fish	☐	___ fish	___ fish
Suckers	Longnose, Redhorse and White	☐	___ fish	___ fish	☐	___ fish	___ fish
Walleye	Walleye	☐	___ fish	___ fish	☐	___ fish	___ fish
Other Species	Name:__________	☐	___ fish	___ fish	☐	___ fish	___ fish
	Name:__________	☐	___ fish	___ fish	☐	___ fish	___ fish
	Name:__________	☐	___ fish	___ fish	☐	___ fish	___ fish

Figure A-1 (cont'd)

Use this map to help answer questions in **PART C** regarding your **TWO MOST RECENT MICHIGAN FISHING TRIPS**. A fishing trip is **any time you went fishing**, **no matter where or how long** you fished.
Place X's near the locations of your **two most recent** fishing trips.

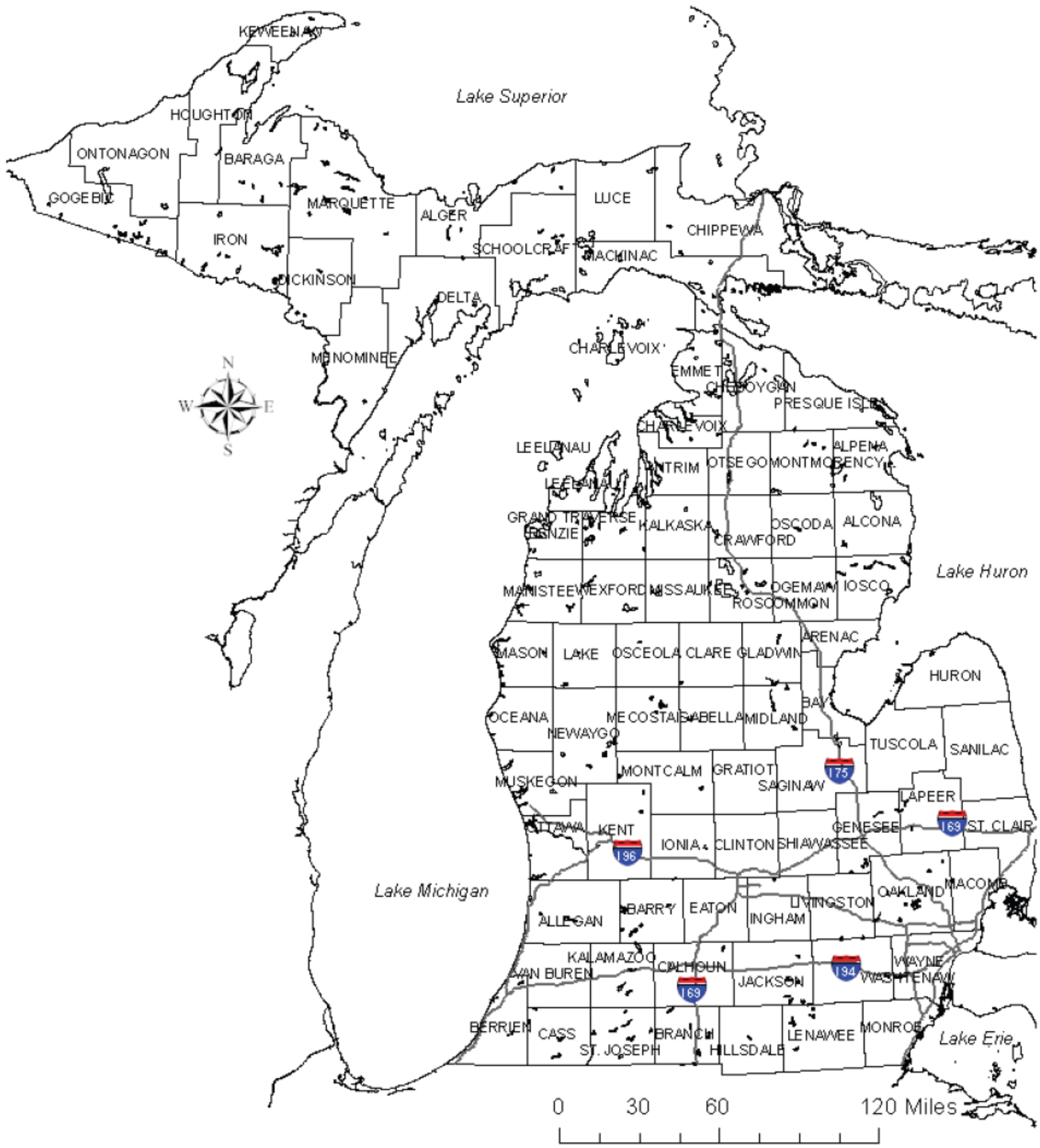

Figure A-1 (cont'd)

PART D: YOUR USUAL FISHING ACTIVITIES AND BACKGROUND

Summaries of the following questions help us represent the fishing activities of all types of anglers. Individual answers are CONFIDENTIAL.

9. About how old were you the first time you went fishing? (even if you did not catch a fish)
_______ years old

10. How many years have you fished in Michigan?
________ years

11. Do any of the following live in your household? (check all that apply)
- ☐ Spouse or significant other
- ☐ Children age 5 and under
- ☐ Children age 6 to 17 years old
- ☐ Other immediate family
- ☐ Extended family members or other adults
- ☐ None of these

12. How many people in your household have a current fishing license, including yourself?
_______ people

13. Which of the following best describes who you usually fish with? (check one)
- ☐ No one else
- ☐ Friends
- ☐ Family / relatives
- ☐ Other _______

14. Do you own a boat that you use for fishing?
- ☐ No
- ☐ Yes ➔ (if Yes) Check all that apply
  - ☐ Motor boat
  - ☐ Canoe/kayak
  - ☐ Other _______

15. When you go fishing, what do you usually do with the legal size fish you catch? (check one)
- ☐ Mostly keep my catch
- ☐ Keep some, release some
- ☐ Mostly catch and release

16. Do you use a computer to access the internet for personal use?
- ☐ No
- ☐ Yes

17. In the past 12 months, have you fished in other countries or in other states, besides Michigan?
- ☐ No
- ☐ Yes

18. Which of the following best describes your employment status? (check one)
- ☐ Employed fulltime
- ☐ Part-time
- ☐ Retired
- ☐ Un-employed
- ☐ Other _______

19. What is your highest level of education? (check one)
- ☐ Less than High School degree
- ☐ High School degree or GED
- ☐ Some post High School or some college
- ☐ Bachelor's Degree
- ☐ Graduate Degree

20. What is your race or ethnic background? (check all that apply)
- ☐ Asian
- ☐ American Indian or Alaska Native
- ☐ Black or African American
- ☐ Native Hawaiian or Pacific Islander
- ☐ Hispanic, Latino or Spanish Origin
- ☐ White, non-Hispanic
- ☐ Other

21. Which of the following best describes your annual household income? (check one)
- ☐ $0- 24,999
- ☐ $75,000-99,999
- ☐ $25,000-49,999
- ☐ $100,000-149,999
- ☐ $50,000-74,999
- ☐ $150,000 or more

Comments:

If you have misplaced your postage-paid envelope, please return this survey to: Frank Lupi, Department of Fisheries and Wildlife, Michigan State University, 13 Natural Resources Building, East Lansing, MI 48824-1222. THANK YOU!

Contact Letters for the Michigan Recreational Angler Survey

<DATE>

<Name>
<Address>
<City, State, Zip>

We need your help with a study of fishing for the Michigan Department of Natural Resources, Fisheries Division. The results will help agencies make fisheries management decisions that better reflect the needs of people that fish in Michigan.

You are part of a small sample of people being asked about their fishing activities. *Your* input is essential to ensure the results accurately represent the people who fish in Michigan.

No matter how often you fish, *your input is important*. Please let us know what you think by completing the enclosed questionnaire and returning it in the prepaid envelope.

Your answers are strictly confidential. If you have any questions about this study, please contact me at 13 Natural Resources Building, East Lansing, MI 48824; 517-355-1692, MIstudy@msu.edu.

Thank you for your help with this important survey.

{signature image omitted}

Sincerely,
Professor Frank Lupi
Enclosure

Answers to Frequently Asked Questions

How was I selected?
A computer program was used to randomly select names and addresses from fishing licenses in Michigan. You are part of a small group selected to participate in the survey about your fishing activities.

Will I be contacted about other surveys from you?
No, this is the only survey we will ask you to take. We know that you are busy and greatly appreciate your help with this important research project.

Why does this survey matter?
Natural resource agencies need scientifically sound information about anglers and their fishing in Michigan. The information this survey gathers will facilitate fact-based management of Michigan's fisheries.

Why do you want me to do the survey?
We need your help because you are part of a small, scientifically selected sample, designed to be representative of all Michigan anglers. Some anglers fish frequently, and others do not. Either way, we need to hear from everyone selected to ensure the accuracy of our results.

Who sees my answers?
Your responses are saved directly into a database that does not contain your name or address. Personal information is only used to manage the mailing of survey invitations.

How is my privacy protected?
Your answers are kept separately from our mailing list. Our mailing list and data are stored on password protected computers in locked offices. Everyone who works on the survey has completed training and signed an oath saying that they will not share any private information they see working on the survey.

How can I return the survey without the pre-paid envelope?
If you misplace your pre-paid return envelope, you can mail the survey to us at Department of Fisheries and Wildlife, Michigan State University, 13 Natural Resources Building, East Lansing, MI 48824.

Why is my fishing background important?
Your fishing background provides a greater understanding of the anglers that fish Michigan waters and demographic trends that may affect fisheries. This information helps managers develop policies that protect resources and benefit anglers like you.

Figure A-2 (Cont'd)

<DATE>

<Name>
<Address>
<City, State, Zip>

I recently sent you a survey about your fishing activities in Michigan. To the best of my knowledge, I have not heard from you.

I am writing to you again because **your input is vital!** You are part of a small sample of people who are being asked about their fishing activities.

Your input is needed to help ensure the results accurately represent the people who fish in Michigan. *Your input* will help natural resource agencies make management decisions that better reflect the needs of people that fish in Michigan.

Please take a few minutes to share your viewpoint by filling out this short survey.

Your answers are strictly confidential. If you have any questions about this study, please contact me at 13 Natural Resources Building, East Lansing, MI 48824; 517-355-1692, MIstudy@msu.edu.

Thank you for your help with this important survey.

Sincerely,

{signature image omitted}

Professor Frank Lupi
Enclosure

Answers to Frequently Asked Questions

How was I selected?
A computer program was used to randomly select names and addresses from fishing licenses in Michigan. You are part of a small group selected to participate in the survey about your fishing activities.

Will I be contacted about other surveys from you?
No, this is the only survey we will ask you to take. We know that you are busy and greatly appreciate your help with this important research project.

Why does this survey matter?
Natural resource agencies need scientifically sound information about anglers and their fishing in Michigan. The information this survey gathers will facilitate fact-based management of Michigan's fisheries.

Why do you want me to do the survey?
We need your help because you are part of a small, scientifically selected sample, designed to be representative of all Michigan anglers. Some anglers fish frequently, and others do not. Either way, we need to hear from <u>everyone selected</u> to ensure the accuracy of our results.

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Your responses are saved directly into a database that does not contain your name or address. Personal information is only used to manage the mailing of survey invitations.

How is my privacy protected?
Your answers are kept separately from our mailing list. Our mailing list and data are stored on password protected computers in locked offices. Everyone who works on the survey has completed training and signed an oath saying that they will not share any private information they see working on the survey.

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Why is my fishing background important?
Your fishing background provides a greater understanding of the anglers that fish Michigan waters and demographic trends that may affect fisheries. This information helps managers develop policies that protect resources and benefit anglers like you.

APPENDIX B

CONVERTING CALENDAR DATA ON DAYS PER MONTH INTO TRIPS PER MONTH

The survey data collected included information on the number of days a person fished during the month and questions on the two most recent trips taken. In this form, we cannot use this data to measure changes in participation because we do not know exactly how many trips the angler took in the month surveyed. This appendix describes how the monthly trips variable T_{it} was estimated for the linked participation model.

During the data collection period, 31,732 anglers returned completed surveys. A survey is considered complete if the respondent answers at least one question on the survey, most commonly the first question. Of these anglers, 95% responded to Part B (the section with the question about fishing in the month along with the calendar), and 75% responded to Part C (the section with details of two most recent trips). This is expected because it is easier to circle a few days on a calendar than recall exact details for two trips. Some anglers do not circle days on the calendar because they did not fish in the month they are being asked about. For Part B for fishing in the month, 54% answered "no" and they correctly did not circle any days on the calendar, 41% answered "yes" and circled days on the calendar, which leaves 5% that either answered "no" but did cirle days or answerd "yes" and did not circle days. Looking across both parts B and C, 36% of the sample population checked "yes" for fishing during the month and circled days on the calendar and answered part C. 7% skipped both questions.

Prior to constructing the trips variable, responses from the two trips questions were compared for consistency by observing if the date indicated for their most recent trips matches the survey period (summarized in Table B-1). Because the surveys are mailed out after the month specified on their calendar, it is possible that an angler's recent trips could have been taken after the month being asked about in the survey. Also, the dates for the most recent trips that are reported by anglers might precede the month being asked about in the calendar section of the survey. Of all the responses to the most recent trip questions, 94% match the year surveyed.

Only responses with exact matches (+) were used in the site choice models. An entry is considered to be an "exact match" if the respondent's recent trip was in the same year and within one month of the survey, as indicated in Table B-1 with a (+) in both columns. Those entries in B-1 marked as "Others" are not necessarily errors, since it includes trips that occurred more than one month before the month for the calendar.

Table B-1:Summary of Response Matches (+) and Others (-)

Year	Month	Percent of Total
+	+	38%
+	-	56%
-	-	6%

We performed an error check to confirm that respondents are consistent within the same question. In Part B of the survey, 0.198% of anglers checked "No" that they did not fish in the month but they also circled days in the calendar; that is, only a small percent indicated that they did not fish in the month being asked about but then went on to circle days. Thus, very few anglers mismarked the calendar when they indicated that they didn't participate that month.

Of the exact matches from Table B-1, 60% of the answers for the trips in Part C were for anglers that indicated they fished one day or fewer while the proportion of non-overnight trips was 62%. Among the responses where the years successfully matched, there is slightly larger variation between single day trips and non-overnight responses: 66% of the responses were one day or fewer, while 69% of the responses were non-overnight trips.

Over the sample of respondents, 45% participated in recreational fishing in their survey month for an average of 2.1 days (from section B of the survey). From section C, 30% of respondents traveled to a Great Lakes site, 45% to inland lakes, and 25% fished along rivers. Resident anglers represent 85% of the sample.

Table B-2 shows the average number of days per trip calculated from questions 7-8 and used as the denominator for trips conversion on the calendar. Only anglers who indicated that their two recent trips occurred either during or after the survey month were included in the calculation of monthly trips. No data is recorded prior to July 2008 because it is before the data collection period. This table was used as an input into the construction of the dependent variable for the participation component of the analyses.

Table B-2: Average Days per Trip

	2008	2009	2010	2011	2012	Monthly Average
January	-	1.7	1.5	1.2	1.5	1.5
February	-	1.7	1.5	1.1	1.3	1.4
March	-	1.5	1.7	1.6	1.8	1.6
April	-	1.8	1.6	1.6	1.7	1.7
May	-	1.8	1.7	1.7	1.9	1.8
June	-	1.7	1.7	1.7	1.7	1.7
July	2.7	2.0	2.2	1.9	2.2	2.2
August	2.3	1.9	2.0	2.2	1.9	2.0
September	1.8	2.1	1.7	2.1	2.0	2.0
October	1.8	1.7	1.7	1.7	1.9	1.8
November	1.4	1.6	1.3	2.3	1.4	1.6
December	1.4	1.7	1.2	2.9	1.3	1.7
Yearly Average	**1.9**	**1.8**	**1.7**	**1.8**	**1.7**	**1.8**

Table B-3 indicates the average number of days fished in a year during month t. This was calculated by summing the total days anglers fished in a month (from the calendar) and dividing by the number of days available in that month. Anglers fish the most during the summer months and have the fewest days during the winter months. Average days fished peaked in 2010 with 2.3

days in a month and has declined to 1.9 in 2012. No data is recorded prior to July 2008 because it is before the data collection period.

Table B-3: Average Days Fished

	2008	2009	2010	2011	2012	Monthly Average
January	-	0.9	1.4	1.0	0.6	1.0
February	-	0.6	1.0	0.8	0.6	0.7
March	-	0.9	2.6	2.4	2.3	2.0
April	-	2.6	2.6	2.3	2.6	2.6
May	-	3.5	3.4	2.7	3.1	3.4
June	-	3.7	3.7	3.9	3.6	3.7
July	3.8	3.7	3.7	4.4	4.0	3.8
August	3.0	3.2	2.8	2.6	2.9	3.1
September	1.2	2.2	3.2	2.3	1.9	1.9
October	1.2	1.1	1.4	0.9	1.0	1.1
November	0.4	0.7	0.5	0.7	0.3	0.5
December	0.6	0.7	0.7	0.5	0.4	0.6
Yearly Average	**2.2**	**2.0**	**2.3**	**2.1**	**1.9**	**2.1**

To derive trips per month from the two sources of data, we form the following index. The numerator is the sum of days fished for each angler in the month they were surveyed (from the calendar). If they indicated that they did not fish in the survey month, they were assigned zero for their days fished. $\overline{Days_t}$ represents the average number of days fished per trip calculated from Table 2. Using the formula below, we can estimate the number of trips taken for each angler.

$$\frac{Total\ Days_{it}}{\overline{Days_t}} = T_{it}$$

Where T_{it} represents the estimated trips taken for angler i during month t. This is the starting point for the dependent variable used in the second stage of the linked participation models. The survey data includes all trip types for all waterbody types. Therefore, these values must be adjusted appropriately to be used in each chapter.

In Chapter 1, we constrained the model to include only anglers who participated in a single day trip. In the data, single day trips represent 70% of the sample population. Therefore, T_{it} was adjusted to reflect this constraint. Table B-4 shows the Average number of single day trips taken per month and across 5 years. The results indicate that anglers take the most trips in June and the fewest trips in November. 2010 had the highest frequency of monthly trips. The distribution of trips is shown in Figure B-1. In Chapter 1, the estimated trips were further adjusted down by 30% to represent Great Lakes trips (not shown in Table B-4).

Table B-4: Average Estimated Single Day Trips per Angler

	2008	2009	2010	2011	2012	Monthly Average
January	-	0.4	0.6	0.6	0.3	0.5
February	-	0.2	0.4	0.5	0.3	0.4
March	-	0.4	1.1	1.1	0.9	0.9
April	-	1.0	1.2	1.0	1.1	1.1
May	-	1.4	1.4	1.1	1.1	1.3
June	-	1.5	1.5	1.6	1.5	1.5
July	1.0	1.3	1.2	1.7	1.3	1.3
August	0.9	1.2	1.0	0.8	1.1	1.0
September	0.5	0.7	1.3	0.8	0.7	0.8
October	0.5	0.4	0.6	0.4	0.4	0.4
November	0.2	0.3	0.2	0.2	0.2	0.2
December	0.3	0.3	0.4	0.1	0.2	0.3
Yearly Average	0.6	0.8	0.9	0.8	0.8	0.8

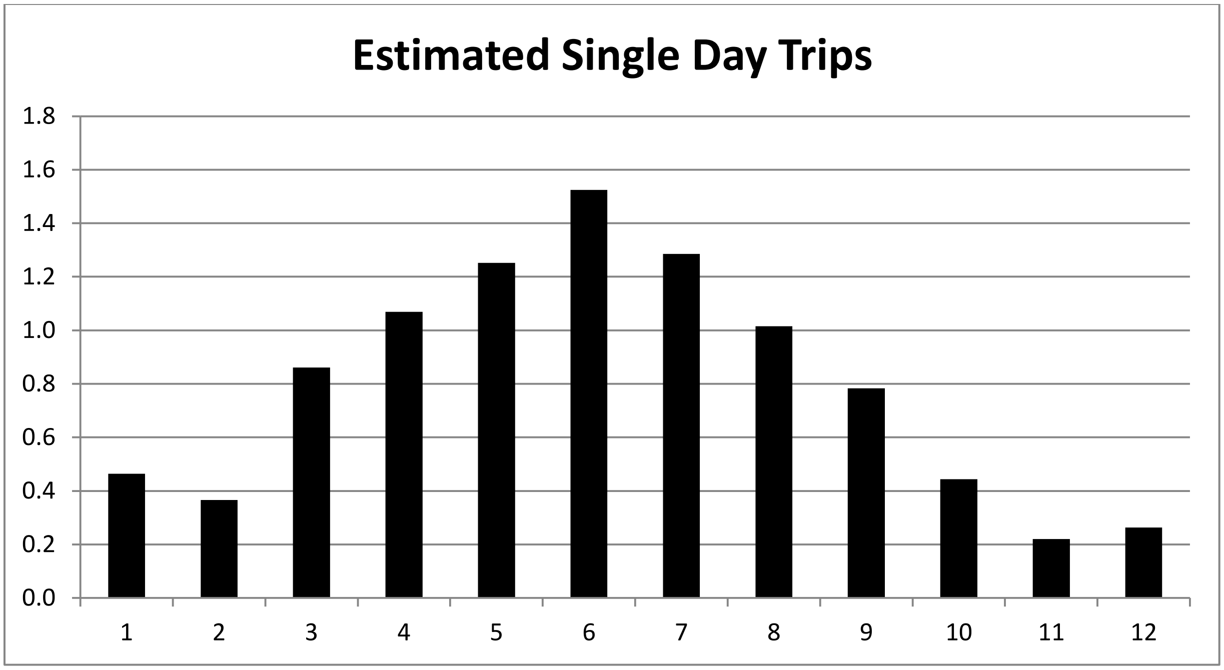

Figure B- 1: Distribution of estimated single day fishing trips per month across 5 years of sample data.

Chapter 2 used multiple day trips for inland lake sites, rather than single day trips. To estimate monthly trips for this model, we multiplied T_{it} from above by 40%, which represents the sample proportion of inland lake trips in our data (Table B-5).

Table B-5: Average Estimated Inland Lake Trips per Angler

	2008	2009	2010	2011	2012	Monthly Average
January	-	0.2	0.4	0.3	0.2	0.3
February	-	0.1	0.3	0.3	0.2	0.2
March	-	0.2	0.6	0.6	0.5	0.5
April	-	0.6	0.7	0.6	0.6	0.6
May	-	0.8	0.8	0.6	0.6	0.7
June	-	0.9	0.8	0.9	0.9	0.9
July	0.6	0.7	0.7	1.0	0.8	0.7
August	0.5	0.7	0.6	0.5	0.6	0.6
September	0.3	0.4	0.7	0.4	0.4	0.4
October	0.3	0.3	0.3	0.2	0.2	0.3
November	0.1	0.2	0.1	0.1	0.1	0.1
December	0.2	0.2	0.2	0.1	0.1	0.2
Yearly Average	0.3	0.4	0.5	0.5	0.4	0.5

APPENDIX C

DATA WEIGHTS

Post-stratification weights

Post-stratification weights were used to match the respondent characteristics to the sample characteristics (Holt and Smith 1979). Previous work done on a subsample of this data has shown significant differences in the mean age, license type, and gender. In order to reduce any potential response bias, the sample was jointly weighted over 26,194 resident respondents.

Table C-1: Joint Age, Gender, and License Type Distribution from the Random Sample*

	Male		Female	
Age Category	Restricted	All Species	Restricted	All Species
18-24	4.6%	3.0%	1.7%	0.6%
25-34	7.4%	6.1%	2.6%	1.0%
35-44	8.0%	7.0%	2.5%	0.9%
45-54	9.2%	8.4%	3.2%	1.3%
55-64	7.2%	7.2%	2.4%	0.9%
65 and Over	5.4%	7.3%	1.6%	0.7%
Total	41.7%	39.1%	13.9%	5.3%

*Includes the resident sample characteristics only (*N*= 58,706).

Table C-2: Joint Age, Gender, and License Type Distribution for Resident Anglers*

	Male		Female	
Age Category	Restricted	All Species	Restricted	All Species
18-24	2.4%	2.0%	1.1%	0.4%
25-34	4.4%	5.0%	1.7%	0.8%
35-44	5.6%	6.6%	2.1%	0.9%
45-54	8.3%	9.7%	3.6%	1.6%
55-64	8.5%	10.1%	3.2%	1.2%
65 and Over	6.8%	10.8%	2.2%	0.9%
Total	36.1%	44.1%	14.0%	5.8%

*Includes the respondent sample used for the model (*N*= 26,194).

Table C-3: Post-Stratification Weights Based on Joint Distribution of Age, Gender, and License Type for Resident Anglers*

	Male		Female	
Age Category	Restricted	All Species	Restricted	All Species
18-24	1.908	1.496	1.555	1.456
25-34	1.656	1.221	1.473	1.184
35-44	1.418	1.066	1.196	1.040
45-54	1.100	0.870	0.885	0.804
55-64	0.852	0.719	0.740	0.713
65 and Over	0.794	0.677	0.725	0.715
N	9454	11557	3658	1525

*The weights were determined by dividing the proportion of Table C-1 by the proportion of Table C-2. Calculated weights may not be exact due to rounding.

Stratification weights

The sample was also adjusted for the month that was sampled. Differences in budgets over time means that the monthly sample sizes differed over the course of the sample. In addition, some months and years receive a higher response rate. Stratification weights were developed to ensure each month sampled would receive the same weight, and hence equally represent all months.

Table C-4: Number of Survey Respondents

	2008	2009	2010	2011	2012
January		1128	581	141	194
February		1112	531	180	185
March		1081	720	260	198
April		1272	591	225	198
May		1164	449	202	222
June		1102	472	196	164
July	2420	857	182	175	166
August	2695	1036	163	190	157
September	695	1038	199	171	172
October	1053	1072	212	170	210
November	1035	1172	175	183	190
December	1117	564	210	217	192
N	9015	12598	4485	2310	2248

Table C-5: Sampling Distribution of Survey Respondents

	2008	2009	2010	2011	2012
January		3.68%	1.90%	0.46%	0.63%
February		3.63%	1.73%	0.59%	0.60%
March		3.53%	2.35%	0.85%	0.65%
April		4.15%	1.93%	0.73%	0.65%
May		3.80%	1.46%	0.66%	0.72%
June		3.59%	1.54%	0.64%	0.53%
July	7.89%	2.80%	0.59%	0.57%	0.54%
August	8.79%	3.38%	0.53%	0.62%	0.51%
September	2.27%	3.39%	0.65%	0.56%	0.56%
October	3.43%	3.50%	0.69%	0.55%	0.69%
November	3.38%	3.82%	0.57%	0.60%	0.62%
December	3.64%	1.84%	0.69%	0.71%	0.63%

Table C-6: Stratification Weights across Respondent Month and Year

	2008	2009	2010	2011	2012
January		0.503	0.977	4.026	2.926
February		0.511	1.069	3.154	3.069
March		0.525	0.788	2.183	2.867
April		0.446	0.961	2.523	2.867
May		0.488	1.264	2.810	2.557
June		0.515	1.203	2.896	3.462
July	0.235	0.662	3.119	3.244	3.420
August	0.211	0.548	3.483	2.988	3.616
September	0.817	0.547	2.853	3.320	3.301
October	0.539	0.530	2.678	3.339	2.703
November	0.549	0.484	3.244	3.102	2.988
December	0.508	1.007	2.703	2.616	2.957
N	9015	12598	4485	2310	2248

Final Weights for Analysis

The demographic post-stratification weights and calendar stratification weights were combined to form the final weights used in the models using the following method:

$$W_D * W_C = W_S$$

where W_S is calculated for each angler in the sample population.

APPENDIX D

DATA USED IN MODEL ESTIMATION

Site Characteristic Data

The fishing quality and other variables that describe fishing sites in the economic models are summarized in this section. Great Lakes per-hour catch rates for chinook, coho, walleye, yellow perch, steelhead, and lake trout were estimated using 84 Tobit models; each with specific monthly and yearly dummy variables for several regions of each Great Lake (summarized in tables D-2 and D-3). The resulting catch rates used in the site choice models for the six fish species were to the months and and sites, since anglers can only observe catch rates in the months they choose to fish.

Data for the models came from the Michigan Department of Natural Resources Creel survey spanning from 2007 through 2013 (T. Kolb, personal correspondence, May 8, 2014). We identified 66 usable fishing locale zones along Michigan's coastline, which were grouped into regions. Each of the six species was estimated by region. Due to limited data for the St. Clair system, catch rates were estimated using averaged of the observed catch rates, across one to three years, depending on the month.

An example of one of the Tobit models is presented in table D-1. In all there are models for 14 regions and 6 species models per region resulting in 84 tobit models. In addition, the St. Clair system forms another region but data limitations did not support tobit models so simple averages were used.

Table D-1: Results from One of the Catch Rate Tobit Models – Region: South Lake Michigan; Species: Chinook Salmon

	Coefficient	Standard Error	P-value
Catch Rate			
May	0.089	0.025	0.001
June	0.065	0.025	0.010
July	0.080	0.025	0.002
August	0.074	0.025	0.004
September	0.067	0.025	0.009
2009	-0.046	0.026	0.077
2010	-0.070	0.026	0.007
2011	-0.098	0.027	0.000
2012	-0.077	0.026	0.004
2013	-0.075	0.022	0.001
_Constant	0.042	0.018	0.022
Standard Error (σ)	0.077	0.006	
N	106		

Table D-2: Predicted hourly catch rates for Great Lake sites

	Michigan	Superior	Huron	Erie	St. Clair System*
Number of Regions	5	2	6	1	1
Number of Tobit Models+	30	12	36	6	0
Catch Rate Estimates^					
Chinook Salmon	0.065	0.011	0.026	0.000	0.000
Coho Salmon	0.012	0.069	0.006	0.000	0.000
Lake Trout	0.030	0.131	0.106	0.000	0.000
Rainbow Trout	0.031	0.020	0.020	0.001	0.000
Walleye	0.017	0.009	0.068	0.109	0.119
Yellow Perch	0.373	0.057	0.205	1.252	0.711

*Due to limited data, these were simple averages from 2002-2004
+Month and year fixed effects with a p-value under .20 were included in each model.
^Hourly catch rates were averaged over months with available data.

Table D-3: Average Hourly Great Lakes Catch Rates by year

	2007*	2008	2009	2010	2011	2012	2013	Total
Chinook Salmon	0.042	0.039	0.035	0.032	0.035	0.042	0.021	0.036
Coho Salmon	0.015	0.018	0.014	0.015	0.014	0.017	0.017	0.016
Lake Trout	0.038	0.044	0.051	0.049	0.051	0.056	0.045	0.047
Rainbow Trout	0.017	0.018	0.020	0.024	0.022	0.024	0.022	0.021
Walleye	0.059	0.053	0.054	0.051	0.051	0.055	0.063	0.055
Yellow Perch	0.492	0.467	0.533	0.467	0.591	0.531	0.508	0.511

*2007 and 2013 data were used in the Tobit models to supplement the years of fishing behavior data in the economic model.

Table D- 4: Inland lake fish biomass estimates using the methods of Esselman et al (2014) on inland lakes data. These are time invariant measures.

	Mean	Std. Deviation
Bass	0.448	0.113
Panfish	1.183	0.603
Yellow Perch	0.174	0.047
Walleye	0.376	0.100
N	1615	

Table D-5: Additional Time Invariant Site Characteristics for Site Choice Model

Variable	Mean	Standard Deviation	Range
Great Lake (n=144)			
Bayorseaway	0.431	0.497	0,1
Highway	0.833	0.374	0,1
Urban	0.444	0.499	0,1
Inland Lakes (n=1615)			
Size (acres)	349.87	1356.86	10.05 – 20,075.12
SLM	0.302	0.459	0,1
SB	0.108	0.311	0,1
MIP	0.116	0.321	0,1
MHS	0.369	0.483	0,1
WLE	0.004	0.066	0,1
WKP	0.023	0.149	0,1
EUP	0.048	0.213	0,1
CUP	0.034	0.181	0,1

*Ecological Drainage Units are defined as follows: Southeast Lake Michigan (SLM); Saginaw Bay (SB); Southeast Michigan Interlobate and Lake Plain (MIP); Northern Lake Michigan, Lake Huron, and Straits of Mackinac (MHS); Western Lake Erie (WLE); Western Upper Peninsula and Keweenaw Peninsula (WPK); Eastern Upper Peninsula (EUP); Central Upper Peninsula (CUP). CUP was used as the baseline.

Angler Characteristics

Sites were chosen based on data availability. Each option has at least one angler visit. We use two datasets for the model in order to utilize the maximum amount of available data. The site choice model consists of anglers who responded to the survey with useable fishing locations regarding their recent trips. The second dataset is comprised of anglers who indicated whether they participated in recreational fishing or not.

Table D-6: Summary of Weighted Travel Cost Components for Inland Lakes Anglers[a] (for Chapter 1 data, see Table 1.2)

	Mean	Std. Deviation	Min	Max
Travel Cost ($)	66.27	107.27	0	1,164.23
Distance (mi)[*]	124.93	183.72	0	1,263.60
Income ($)	59,144.88	40,179.05	12,500	200,000
Per mile costs[+]	0.286			
N	11092			

[a]For the chosen alternative in each angler's choice set.
[*]Distances are measured as round trip.
[+]Per mile costs were calculated from AAA for each year (2008-2012): 0.289; 0.264; 0.282; 0.287; 0.306

Table D-7: Selected Weighted Angler Characteristics*

	Chapter 1 Site Choice Model	Chapter 2 Site Choice Model	Participation Model	
			Participants (trips>0)	Non-participants (trips=0)
Age (mean)	44.77	46.12	45.44	47.32
Income (mean)	68,910.44	59,144.88	59,182.75	59,512.28
Male	85.2%	80.4%	84.71%	78.62%
Employed full-time	67.7%	57.0%	57.65%	54.33%
Retired	12.2%	17.4%	12.74%	14.39%
Bachelors or Higher	33.1%	26.2%	27.01%	29.67%
Spouse		-	72.67%	73.46%
Purpose is Fishing	95.7%	76.8%	N/A	N/A
Days per Trip	1	1.69	N/A	N/A
N	3681	11092	10921	13561

*Note: The participation dataset includes data for all types of waterbodies and was used for both models.

APPENDIX E

SITE CHOICE DATA PROCESSING

Look Up Lake Names (LULN) Program:

Data collected on the locations of respondents' recent fishing trips needed to be cleaned and processed in order to be usable for the linked model. The survey asked for the waterbody type, name, nearest city, and county the angler visited. Respondents may not completely answer the questions provided, or they might misspell the names of cities or waterbodies, or they might answer inconsistently. Processing this information required interpreting angler responses by checking for consistency and misspellings in order to standardize the data for use in analyses.

The Institute for Fisheries Research (IFR) in Ann Arbor, Michigan, developed a program to process the data regarding recent trips known as *Look Up Lake Names* (LULN), written in Python (Python Software Foundation, 2011). The program analyzes thousands of angler responses in a consistent manner to reduce human error in the cleaning process. When data is run through LULN, it first identifies acceptable responses. A line is considered a "non-response" if the angler did not identify a waterbody and city, a waterbody and county, or left the question blank. These are removed due to insufficient identifying information. The acceptable responses are first sorted by waterbody type (i.e, between rivers and lakes). Once sorted, the waterbody name, city, and county are compared using IFR databases. LULN confirms those that are perfect matches (i.e. the name of the lake is consistent with the city and county indicated) and separates those that are not. If the lake or river is misspelled, the program searches for a match using a dictionary file. If a match is located, LULN corrects the misspelling and updates other information associated with that waterbody such as city and county. If a lake or stream shares a common name (e.g. Mud Lake) the program uses the city indicated as a reference point to confirm the lake or stream. LULN calculates the distance from the city to the lake or stream. Lake locations are measured from the center of the waterbody. Streams are separated by segments determined by the United States Geographical Survey because one river could span multiple counties. The stream distances are calculated by segment. The distance calculated from the waterbody to the city is used when the results are reviewed as an indicator if LULN correctly matched the response. All of the confirmed lake and river names are standardized to simplify the reviewing process after run in LULN. Great Lakes are identified separately and given a special tag and DNR creel code based on the city and county provided.

After the data is processed by LULN, it is reviewed by analysts on the project. First, all of the matches are reviewed. They are sorted by distance calculated. Shorter distances have a higher probability of being correctly matched. As the distances between the waterbody and city increases, the probability decreases. Any responses that were not correctly matched were manually reviewed and matched where possible. Any remaining unmatched responses were also manually processed for possible matches. LULN is a continually developing program, and might not have all of the possible misspellings of a given lake or stream. Furthermore, if the angler misclassifies the waterbody, it may be processed as unmatched and needs to be corrected. For these cases each unmatched responses is reviewed and matched, if it exists. New misspellings are then added to the program. All responses that were updated by the reviewer are rerun through LULN to get distance calculations, creel codes, and waterbody IDs.

Once the data is processed, verified entries were separated and used to construct the respective choice sets in the first stage of the linked participation-site choice models in chapters 1 and 2. The creel codes, lake IDs, and river segment IDs are used to determine the sites to include in the models and to link attribute data to the sites (e.g., size, catch rates).

REFERENCES

REFERENCES

AAA. (2008-2012). Your Driving Costs. AAA. Retrieved from http://newsroom.aaa.com/wp-content/uploads/2012/04/YourDrivingCosts2012.pdf

Aas, O., & Arlinghaus, R. (2009). New Markets for Recreational Fishing. In *Wildlife and society: The science of human dimensions* (pp. 229-243). Island Press.

ALK Technologies . (2010). PC*MILER|BatchPro. Version 24. Princeton, NJ: ALK Technologies, Inc.

Andrews, T. P. (1996). *Management Alternatives and Trout Angler Benefits in Pennsylvania.* PhD Dissertation, Temple University.

Aphis Veternary Services. (2006). *Viral Hemorrhagic Septicemia in the Great Lakes Region.* http://www.aphis.usda.gov/publications/animal_health/content/printable_version/ia_VHS_Great_Lakes.pdf.

Aprahamian, M., Hickley, P., Shields, B. A. & Mawle, G. W. (2010). Examining changes in participation in recreational fisheries in England and Wales. *Fisheries Management and Ecology* **17,** 93–105.

Arlinghaus, R., Mehner, T., & Cowx, I. G. (2002). Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on europe. *Fish and Fisheries, 3*, 261-316.

Arlinghaus, R., Tillner, R., and Bork, M. (2014). Explaining participation rates in recreational fishing across industrialized countries. *Fisheries Management and Ecology*.

Barbier, E. B., & Shogren, J. F. (2004). Growth with endogenous risk of biological invasion. *Economic Inquiry*, *42*(4), 587-601.

Beardmore, B., Dorow, M., Haider, W., & Arlinghaus, R. (2011). The elasticity of fishing effort response and harvest outcomes to altered regulatory policies in eel (Anguilla anguilla) recreational angling. *Fisheries Research, 110*(1), 136–148.

Bowser, P. R. (2009). Fish diseases: viral hemorrhagic septicemia (VHS). *Northern Regional Aquaculture Publication*, (201-2009).

Buhle, E. R., Margolis, M., & Ruesink, J. L. (2005). Bang for buck: cost-effective control of invasive species with different life histories. *Ecological Economics*, *52*(3), 355-366.

Carson, R. T., Hanemann, W. M., & Wegge, T. C. (2009). A Nested Logit Model of Recreational Fishing Demand in Alaska. *Marine Resource Economics*, *24*(2), 101-129.

Christie, J., & Bostwick, P. (2012, September). Climate Change Adaptation Plan for Coastal and Inland Wetlands in the State of Michigan. The Association of Wetland Managers, Inc.

Cocklin, C., Craw, M., and McAuley, I.(1998). Marine reserves in New Zealand: Use rights, public attitudes, and social impacts. *Coastal Management,26*, 213-131.

Cornell University. (n.d.). *Viral Hemorrhagic Septicemia.* Retrieved Feb 16, 2012, from New York Invasive Species: http://www.nyis.info/index.php?action=invasive_detail&id=28

Cowx I.G., Arlinghaus R.A. & Cooke S.J. (2010) Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters. *Journal of Fish Biology* 76 (9), 2194–2215.

Creel, M., & Loomis, J. (1992). Recreation Value of Water to Wetlands in the San Joaquin Valley: Linked Multinomial Logit and Count Data Trip Frequency Models. *Water Resources Research, 28*(10), 2597-2606.

Davis, A. & Moeltner, K. (2006). Valuing the prevention of an infestation: The threat of the New Zealand mud snail in northern Nevada. *Agricultural and Resource Economics Review, 39*(1), 56-74.

Decker, D. J., Brown, T. L., & Siemer, W. F. (Eds.) (2001). *Human Dimensions of Wildlife Management in North America*. Bethesda, MD: The Wildlife Society.

Derosier, A. L., & Badra, P. J. (2007). Incorporating aquatic ecological classification units as Elements Of Biodiversity In The Biotics Database.

Dillman, D. A. (2007). *Mail and Internet Surveys, The Tailored Design Method*. Hoboken, New Jersey: John Wiley & Sons, Inc.

DNR. (2009). *Fish Disease Control FO-245.09.*Lansing, MI. Michigan Department of Natural Resources.

DNR. (n.d.). *Great Lakes Creel Survey Program.* Charlevoix, MI. Charlevoix Fisheries Research Station, Michigan Department of Natural Resources; Retrieved November 6, 2014, from http://www.michigan.gov/dnr/0,4570,7-153-10364_52259_10951_11301-97829--,00.html.

Dillman, D. A. (2007). Mail and Internet Surveys, The Tailored Design Method. Hoboken, New Jersey: John Wiley & Sons, Inc.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z., Knowler, D.J., Leveque, C., Naiman, R.J., Prieur-Richard, A., Soto, D., Stiassney, M.L.J. & Sullivan, C.A. (2006). Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews, 81*(2), 163-182.

Eiswerth, M. E., & Johnson, W. S. (2002). Managing nonindigenous invasive species: insights from dynamic analysis. *Environmental and resource economics*, *23*(3), 319-342.

Esselman, P., Stevenson, R. J., Lupi, F., Wiley, M. J., and Riseng, C. M. (2014). Landscape prediction and mapping of game fish standing crops—a highly-valued ecosystem service of Michigan rivers. In Press, *North American Journal of Fisheries Management*.

Faisal M, Shavalier M, Kim RK, Millard EV, Gunn MR, Winters AD, Schulz CA, Eissa A, Thomas MV, Wolgamood M, Whelan GE, Winton J. Spread of the Emerging Viral Hemorrhagic Septicemia Virus Strain, Genotype IVb, in Michigan, USA. Viruses. 2012; 4(5):734-760.

Ficke, A. D., Myrick, C. A., & Hansen, L. J. (2007). Potential impacts of global climate change on freshwater fisheries. *Reviews in Fish Biology and Fisheries*, *17*(4), 581-613.

Fiske, S. J. (1992). Sociocultural aspects of establishing marine protected areas. *Ocean & Coastal Management*, *17*(1), 25-46.

Haab, T., & McConnell, K. (2002). *Valuing Environmental and Natural Resources: The Econometrics of Non-market Valuation.* Northhampton: Edward Elgar Publishing, Inc.

Hausman, J. A., Leonard, G. K., & McFadden, D. (1995). A utility-consistent, combined discrete choice and count data model assessing recreational use losses due to natural resource damage. *Journal of Public Economics*, *56*, 1-30.

Herriges, J. A., Kling, C. L., & Phaneuf, D. J. (1999). Corner Solution Models of Recreation Demand: A Comparison of Competing Frameworks. In J. A. Herriges, & C. L. Kling, *Valuing Recreation and the Environment: Revealed Preference Methods in Theory and Practice* (pp. 163-197). Edward Elgar Publishing.

Higgins, J. V., Bryer, M. T., Khoury, M. L., & Fitzhugh, T. W. (2005). A freshwater classification approach for biodiversity conservation planning. *Conservation Biology*, *19*(2), 432-445.

Hoehn, J. P., Tomasi, T., Lupi, F., & Chen, H. Z. (1996). An economic model for valuing recreational angling resources in Michigan. *Michigan State University, Report to the Michigan Department of Environmental Quality*.

Holt, D., & Smith, T.M.F. (1979). Post-stratification. *Journal of the Royal Statistical Society* *142*(1):33-46.

Horan, R. D., Shogren, J. F., & Gramig, B. M. (2008). Wildlife conservation payments to address habitat fragmentation and disease risks. *Environment and Development Economics*, *13*(03), 415-439.

Hunt, L. M., Boots, B. N., & Boxall, P. C. (2007). Predicting Fishing Participation and Site Choice While Accounting for Spatial Substitution, Trip Timing, and Trip Context. *North American Journal of Fisheries Management*, *27*(3), 832-847.

Jakus, P. M., Downing, M., Bevelhimer, M. S., & Fly, J. M. (1997). Do sportfish consumption advisories affect reservoir anglers' site choice? *Agricultural and Resource Economics Review*, *26*, 196-204.

Johnstone, C., and Markandya, A. (2006). Valuing river characteristics using combined site choice and participation travel cost models. *Journal of Environmental Management*, *80*(3), 237-247.

Jones, C. A., & Lupi, F. (1999). The effect of modeling substitute activities on recreational benefit estimates. *Marine Resource Economics*, *14*(4), 357-374.

Loomis, J. B. (2005). Updated outdoor recreation use values on national forests and other public lands.

Lovell, S. J., Stone, S. F., & Fernandez, L. (2006). The economic impacts of aquatic invasive species: a review of the literature. *Agricultural and Resource Economics Review*, *35*(1), 195.

Lupi, F., Hoehn, J. & Christie, G. 2003. Using an economic model of recreational fishing to evaluate benefits of Sea Lamprey (*Petromyzon marinus*) control. *Journal of Great Lakes Research*, 29(Suppl. 1), 742-754.

Manfredo, M., Vaske, J., & Teel, T. (2003). The potential for conflict index: A graphic approach to practical significance of human dimensions research. *Human Dimensions of Wildlife*, *8*(3), 219-228.

McFadden, D. (1981). Econometric Models of Probabilistic Choice Models. In C. F. Manski, & D. McFadden, *Structural Analysis of Discrete Data with Applications.* Cambridge: MIT Press.

Melstrom, R. M., & Lupi, F. (2013). Valuing Recreational Fishing in the Great Lakes. *North American Journal of Fisheries Management*, *33*(6), 1184-1193.

Michigan Department of Natural Resources. (n.d.) DNR - About the DNR. Retrieved October 17, 2014, from http://www.michigan.gov/dnr/0,4570,7-153-10366---,00.html

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-Being: Biodiversity Synthesis, World Resources Institute, Washington D.C.

Missouri Census Data Center. (2012). American Community Survey Data 2008-2012. Retrieved from http://mcdc2.missouri.edu/applications/uexplore.shtml#acs

Montgomery, M., & Needelman, M. (1997). The Welfare Effects of Toxic Contamination in Freshwater Fish. *Land Economics, 73*(2), 211-223.

Morey, E. R., Rowe, R. D., & Watson, M. (1993). A repeated nested-logit model of Atlantic salmon fishing. *American Journal of Agricultural Economics, 75*(3), 578-592.

Morey, E. R., and Waldman, D. M. (1998). Measurement error in recreation demand models: the joint estimation of participation, site choice, and site characteristics. *Journal of Environmental Economics and Management, 35*(3), 262-276.

Murdock, J. (2006). Handling unobserved site characteristics in random utility models of recreation demand. *Journal of Environmental Economics and Management, 51*(1), 1-25.

Nunes, P.A.L.D. & van den Bergh, J.C.J.M. (2004). Can people value protection against invasive marine species? Evidence from a joint TC-CV survey in the Netherlands. *Environmental and Resource Economics, 28*(4), 517-532.

Parsons, G. R. (2003). The Travel Cost Model . In *A Primer on Nonmarket Valuation* (Vol. 3). Boston and London: Kluwer Academic Publishers, Netherlands.

Parsons, G. R., Jakus, P. M., & Tomasi, T. (1999). A Comparison of Welfare Estimates from Four Models Linking Seasonal Recreational Trips to Multinomial Models of Site Choice. *Journal of Environmental Economics and Management, 38*(2), 143-157.

Perrings, C., Williamson, M., Barbier, E. B., Delfino, D., Dalmazzone, S., Shogren, J., Simmons P., and Watkinson, A. (2002). Biological invasion risks and the public good: an economic perspective. *Conservation Ecology, 6*(1), 1.

Phaneuf, D. J., and Smith, V. K. (2005). Recreation demand models. *Handbook of environmental economics, 2*, 671-761.

Pierce, R. B. (2011). Long-Term Evaluations of Length Limit Regulations for Northern Pike in Minnesota. *North American Journal of Fisheries Management, 30*(2), 412-432.

Pimentel, D., Zuniga, R., & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological economics, 52*(3), 273-288.

Provencher, B., Lewis, D.J. & Anderson, K. (2012). Disentangling preferences in stated preference analysis with respondent uncertainty: The case of invasive species prevention. *Journal of Environmental Economics and Management, 64*(2), 169-182.

Python Software Foundation. (2011). *Version 2.7.*

Ricciardi, A. & Rasmussen, J.B. (1999). Extinction rates of North American freshwater fauna. *Conservation Biology, 13*(5), 1220-1222.

Salz, R. J., & Loomis, D. K. (2005). Recreation specialization and anglers’ attitudes towards restricted fishing areas. *Human Dimensions of Wildlife*, *10*(3), 187-199.

Simoes, J. C. (2009). *Recreational Angler Surveys: Their Role and Importance Nationally and the 2008 Michigan Angler Survey.* Michigan State University.

Söderqvist, T. (1998). Why Give up Money for the Baltic Sea?–Motives for People's Willingness (or Reluctance) to Pay. *Environmental and Resource Economics*, *12*(2), 249-254.

StataCorp. (2011). *Stata Statistical Software: Release 12.* College Station, TX: StataCorp LP.

Strayer, D.L. & Dudgeon, D. (2010). Freshwater biodiversity conservation: Recent progress and future challenges. *Journal of the North American Benthological Society*, *29*(1), 344-358.

Timar, L. & Phaneuf, D.J. (2009). Modeling the human-induced spread of an aquatic invasive: The case of the zebra mussel. *Ecological Economics*, *68*(12), 3060-3071.

Vesterinen, J., Pouta, E., Huhtala, A., & Neuvonen, M. (2010). Impacts of changes in water quality on recreation behavior and benefits in Finland. *Journal of Environmental Management*, *91*(4), 984-994.

Ward, F. A., Cole, R. A., Deitner, R. A., and Green-Hammond, C. A. (1997). Limiting environmental program contradictions: a demand systems application to fishery management. *American Journal of Agricultural Economics*, *79*(3), 803-813.

Wehrly, K. E., Breck, J. E., Wang, L., and Szabo-Kraft, L. (2012). A Landscape-Based Classification of Fish Assemblages in Sampled and Unsampled Lakes. *Transactions of the American Fisheries Society*, *141*(2), 414-425.

Wehrly, K.E., J.E. Breck, Z. Su, and L. Wang, 2013. Modeling the Effects of Climate Change on Growth and Abundance of Lake Fishes in Michigan, working paper, presented at American Fisheries Society, September 12, 2013. Little Rock, AK.

Whelan, G. (2007). *VHS - The Viral Invaders.* Ann Arbor, MI: Great Lakes Commission.

Whitehead, J. C., Dumas, C. F., Landry, C. E., and Herstine, J. (2013). A recreation demand model of the North Carolina for-hire fishery: a comparison of primary and secondary purpose anglers. *Applied Economics Letters*, *20*(16), 1481-1484.

Whitehead, J. C., Groothuis, P. A., and Southwick, R. (2007, May 25). Linking Recreation Demand and Willingness to Pay with the Inclusive Value: Valuation of Saginaw Bay Coastal Marsh. Presented at US Environmental Protection Agency Workshop.

Zhang, C. & Boyle, K.J. (2010). The effect of an aquatic invasive species (Eurasian watermilfoil) on lakefront property values. *Ecological Economics*, *70*(2), 394-404.