DISCRETE CHOICE MODELS OF HUNTING AND FISHING IN MICHIGAN

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ABSTRACT

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In this dissertation I employ multiple discrete choice modeling methods and data collection approaches to make both methodological and empirical contributions which focus on a variety of management-relevant programs and policies. In dissertation chapter 1, I examine the potential for researchers to estimate recreation demand models using widely available secondary data on recreation site choice that lacks some income and trip details. I find that substituting zip-code median income for individual-reported income, and constructing estimates of trips based on days spent hunting and the distance of the hunting site from the individual's residence, generate welfare estimates that are similar to results using individual-reported information on income and trips. This research indicates potential for utilizing a wide range of previously ignored recreation site choice data for recreation demand modeling purposes. Dissertation chapters 2 and 3 are supported by the procedure developed in dissertation chapter 1. Dissertation chapter 2 estimates a discrete choice model of ruffed grouse hunting in Michigan with the objective of estimating both the economic benefits of all publicly accessible hunting land in Michigan for ruffed grouse hunters and the potential changes to ruffed grouse hunter economic benefits as a result of a proposal to ban the use of firearms in approximately 67,000 acres of national forest wilderness area. Economic benefits of publicly accessible hunting land for ruffed grouse hunters in Michigan was estimated to be about $30 million in 2008, with economic benefits of the 67,000 acres of national forest

wilderness area to ruffed grouse hunters estimated at about $45,000. Dissertation chapter 3 estimates the economic benefits of the USDA Conservation Reserve Program for pheasant hunters in Michigan by linking a previously developed spatially explicit, landscape based model of pheasant sightings to a discrete choice model of pheasant hunter site choice. Chapter 3 also estimates the potential economic benefits generated through the initiation of a multi-agency and stakeholder pheasant habitat restoration plan. Results show that economic benefits for pheasant hunters depend critically on restoration site selection. Dissertation chapter 4 uses a choice experiment survey of Michigan trout anglers to examine the willingness of anglers to make tradeoffs between changes in driving distance to a fishing site and changes in attributes available at fishing sites. On average, trout anglers prefer higher catch rates, shorter travel distances to a fishing site, and are highly averse to strict fishing regulations such as catch-and-release only and artificial flies only regulations. However, there is evidence of preference heterogeneity within the trout angler population for these regulations, with some anglers preferring (all else equal) to fish in areas with these restrictions. This distribution of angler preferences is used to examine the proportion of anglers who can be made better off when strict regulations induce catch-related quality improvements at a fishing site.

To Rebecca

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KEY TO ABBREVIATIONS

AAA	American Automobile Association
Ag	Agriculture
BBS	Breeding Bird Survey
CFA	Commercial Forest Act
CRP	Conservation Reserve Program
CS	Consumer Surplus
Diff	Difference
ha	hectare
IJI	Interspersion and Juxtaposition Index
LWCF	Land and Water Conservation Fund
Max	Maximum
MDNR	Michigan Department of Natural Resources
Min	Minimum
MPRI	Michigan Pheasant Restoration Initiative
MPS	Mean Patch Size
NGO	Non Governmental Organization
NLCD	National Land Cover Dataset
Obs	observations
OLS	Ordinary Least Squares
Stats	Statistics

USDA	United States Department of Agriculture
USDOI	United States Department of Interior
WTP	Willingness to Pay

INTRODUCTION

Hunting and fishing are popular outdoor recreational activities in the United States, with 33.1 million people fishing and 13.7 million people hunting at least once in 2011 (USDOI 2013). The quality of these recreational experiences is affected by resource manager decisions regarding the allocation of scarce budgetary dollars across various management activities to sustain viable fish and wildlife populations. Understanding individual preferences for aspects of hunting and fishing experiences is critical for enabling state and federal fisheries and wildlife management agencies to identify management actions which would provide the greatest benefit to hunters and anglers. Characterizing these preferences in terms of the monetary tradeoffs individuals are willing to make for quality changes in hunting and fishing site attributes can improve resource allocation and facilitate cost-benefit analysis.

The primary objective of this dissertation is to utilize discrete choice statistical modeling tools to examine the preferences of hunters and anglers for different aspects of hunting and fishing experiences. Through the discrete choice approach, a researcher can examine hunter or angler preferences and tradeoffs for attributes of hunting and fishing locations by analyzing the choice of a hunting or fishing site from a choice set of two or more sites, with each site described by relevant site characteristics (e.g., travel cost, public land, catch/harvest rate). There are two primary types of discrete choice approaches – revealed preference and stated preference – with both approaches used in this dissertation. The revealed preference discrete choice approach involves analyzing preferences by using individuals' actual choices (observed or reported), whereas the stated preference discrete choice approach is a survey-based approach which elicits preferences through individuals' selection of a preferred alternative from a set of alternatives, with each alternative's attributes described explicitly within the choice format.

The discrete choice analysis within this dissertation begins in chapter 1 with a methodological contribution in which a procedure is developed to utilize previously collected data to estimate revealed preference discrete choice models of hunter site choice. Federal and state fisheries and wildlife management agencies routinely administer surveys to collect information on wildlife harvest, and such data offers substantial potential for cost-effectively using revealed preference approaches to examine hunter preferences and estimate economic benefits associated with hunting site attributes. The analysis in dissertation chapter 1 provides evidence that travel cost model welfare estimates obtained through the use of assumptions necessary to overcome wildlife harvest data limitations are comparable to welfare estimates obtained when using data which does not require such assumptions. In dissertation chapters 2, 3, and 4, I focus on using discrete choice approaches to address pressing and critical aspects of management concern: Access, catch/harvest rate, habitat management, and regulations. Abundant game or fish species in a particular location is of little benefit to hunters or anglers if they are unable to access the land or a body of water. Correspondingly, abundant access for hunting and fishing matters little if fish and game species are not present in sufficient numbers to make targeting them a worthwhile endeavor. Finally, hunting and fishing regulations act as potential constraints to interactions hunters and anglers have with fish and wildlife resources. Below, I provide background and detail the rationale for understanding hunter and angler preferences for a) access, b) habitat management & catch/harvest rate, and c) regulations, and I briefly describe the contribution of this dissertation with respect to these three categories.

ACCESS

Access to both publicly-owned and privately-owned lands has been identified as two of the most important issues facing hunting today. A 2002 survey of licensed hunters nationwide reported that 22% and 18% of hunters identified access to public land and private land, respectively, as being one of the two most important issues facing hunting today (Duda et al. 2004). Actions at both the national and state level have been undertaken to facilitate access to public and private lands. At the national level, the United States Department of Agriculture's Voluntary Public Access and Habitat Incentive Program provided grants to 25 states totaling $17.8 million to encourage private landowners to make their land available to the public for hunting. Further, President Obama launched the America's Great Outdoors initiative in 2010, which recommends full funding of $900 million per year (by 2014) for the Land and Water Conservation Fund, a federal funding program which over the past 40 years has enabled the purchase of about 3 million acres of recreation lands and the funding of over 29,000 projects to develop basic recreational facilities on public lands. In Michigan, publicly-owned hunting access options include State Forest (1.5 million ha), National Forest (1.2 million ha), State Game and Wildlife areas (200,000 ha), State Parks and Recreation areas (107,000 ha), two National Lakeshores (52,000 ha), and United States Fish and Wildlife Service Land (47,000 ha). Additionally, about 890,000 ha of privately-owned, publicly accessible land is available to hunters through Michigan's Commercial Forest Act (CFA), which provides tax incentives for private landowners (predominantly timber harvesting companies) to allow hunting and angling on their land.

Given the importance to hunters of being able to access lands and the high importance natural resource managers are currently placing on facilitating access, there has been a surprising lack of attention in the published literature regarding the relationship of hunting access to hunter site choice and the economic benefits hunters derive from this access. Research within examines the economic benefits of publicly accessible hunting lands for ruffed grouse hunters in Michigan, helping to fill this gap in the literature while building on my previous research on the economic benefits of publicly accessible lands for deer hunters (Knoche and Lupi 2012). Within this dissertation, I use the revealed preference travel cost method to estimate economic benefits with respect to ruffed grouse hunting in Michigan for the three main types of publicly accessible hunting land: Federally-owned land, State-owned land, and privately-owned, publicly accessible CFA land. Additionally, I perform a management-relevant policy analysis by examining the implications to ruffed grouse hunters from the closing of a portion of federally-owned land to firearm hunters.

HABITAT MANAGEMENT AND GAME/FISH POPULATIONS

Natural resource managers employ habitat and fish/game management strategies to produce satisfactory catch/harvest outcomes from participating in hunting and fishing activities. Duda et al. (2004) found that 18% of hunters identified loss of habitat as being one of two most important issues facing hunting today, whereas 13% of hunters identified game management as being one of two most important issues. Extensive and expensive habitat restoration and conservation approaches which have the potential to improve catch/harvest outcomes desired by hunters and anglers are undertaken by federal, state, local and non-profit organizations. According to Bernhardt et al. (2005), between 14 and 15 billion dollars were spent on over 37,000 river/stream restoration projects in the continental U.S. from 1990 to 2003, many of which have the potential to improve fisheries. The United States Department of Agriculture (USDA) Conservation Reserve Program (CRP) has provided farmers and landowners with rental payments and cost-share assistance to engage in beneficial land management practices totaling over $41.3 billion since the CRP was signed into law in 1985 (USDA 2013). CRP land has been shown by a number of researchers (see, e.g., Gould and Jenkins 1993, Kantrud 1993, Riley 1995, Nielson et al. 2008 and Schroeder and Vander Haegen 2011) to be beneficial for wildlife species pursued by hunters. Fish propagation and stocking is a commonly used tool used by state and federal agencies to improve catch-related attributes for recreational fishing, such as catch rate and availability of particular species. In 2004, state and federal agencies reported stocking an estimated 1.75 billion fish in the waters of the U.S. (Halverson 2008).

Allocating budgetary resources across management alternatives with the objective of maximizing benefits to hunters and anglers requires an understanding of hunter and angler preferences for catch-related aspects of hunting and fishing activities. Research within this dissertation links a spatially explicit landscape-based ecological production function of pheasant abundance to a revealed-preference discrete-choice model of pheasant hunters' site choices providing valuable information on the economic benefits of USDA Conservation Reserve Program Land to pheasant hunters in Michigan. The economic benefits of all CRP land to pheasant hunters in Michigan's lower peninsula is estimated (relative to all CRP land being eliminated), and a management-relevant analysis is also provided through the estimation of the economic benefits accruing to pheasant hunters through plausible restoration scenarios occurring through the implementation of the Michigan Pheasant Restoration Initiative (MPRI).

Additionally, this dissertation explores the aspects of the Michigan stream trout fishing experience which are most important to anglers. Through the use of a stated preference choice experiment, I analyze angler fishing site choice as a function of the attributes available at different possible fishing locations. Characterizing angler preferences for fishing site attributes by using distance as a common trade-off metric facilitates the comparison of angler preferences for these attributes. Understanding relative preferences for catch attributes can help fisheries managers more effectively allocate limited budgetary resources to stocking programs and habitat management actions likely to improve the catch-related aspects of the stream trout fishing experience most preferred by anglers.

REGULATIONS

Natural resource managers implement and enforce a variety of regulations with the objective of limiting excessive impacts to fish and wildlife populations and resulting reductions in the quality of recreational opportunities for a wide variety of stakeholders. Fisheries and wildlife managers regulate hunters and anglers through restrictions on harvest, species targeted, and gear/method which vary along spatial and temporal dimensions. Hunters and anglers may have different levels of tolerance for such regulations. For anglers with slightly or moderately negative preferences for regulations, regulation-induced improvements in catch and harvest may make some of these anglers better off than a scenario in which regulations are relaxed but catch/harvest rates are low. Additionally, managers of publicly-owned lands may be confronted with recreational use conflicts between different user groups and thus consider restricting outdoor recreation by user groups (e.g., firearm hunters) at specific locations. An informed decision regarding whether or not to implement such restrictions would involve examining the impacts to all user groups affected (both positively and negatively) from such restrictions.

It is important for resource managers to understand the potential impacts of regulations on hunter and angler site choice and their enjoyment of hunting and fishing activities. Research within this dissertation explores stream trout angler preferences for fishing site attributes and estimates the proportion of anglers who have positive and negative preferences for restrictions on trout harvest and tackle restrictions. This then allows for an examination of whether and to what extent trout anglers negatively impacted by regulations can be made better-off through regulation-induced improvements in catch-related attributes. Finally, this dissertation examines the potential welfare impacts to hunters from a recreational use conflict which results in the loss of hunting rights. Drawing upon a recent contentious debate over firearm hunting in Michigan National Forest Wilderness areas, I examine the impact to ruffed grouse hunters from eliminating 67,000 acres of National Forest land as a hunting option.

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CHAPTER 1: WELFARE IMPLICATIONS OF USING IMPERFECT SECONDARY DATA TO ESTIMATE RECREATION DEMAND MODELS

1.1 Introduction

Economists, through the application of non-market valuation methods, contribute to the efficient management of environmental goods and services by providing resource managers and policy makers with economic benefits estimates associated with changes in environmental quality. For environmental catastrophes such as a major oil spill, the potential for substantial reductions in economic welfare resulting from area closures and/or environmental quality changes can easily justify costly non-market valuation studies to obtain accurate and precise willingness-to-pay estimates used to inform compensation decisions and support litigation efforts. Outside of the public spotlight, however, resource managers are routinely making lower-visibility budgetary allocation decisions to improve environmental quality characteristics, while often lacking the funds necessary to inform these decisions through a full-scale study of stakeholder preferences and economic benefits. It is incumbent upon applied economists working within the natural resource management field to find cost-effective ways to contribute meaningfully to this decision-making process. In some situations, the benefits transfer approach can be a simple and cost-effective way to contribute to the discussion – however, spatial and/or temporal differences between the initial study and the intended area of application may be too great to apply this method with a reasonable degree of confidence. As a third alternative, utilizing “secondary data” collected by resource managers may be an attractive option, providing up-to-date, location-specific information on individual preferences for recreation sites, while avoiding the high costs associated with primary data collection.

Resource managers concerned with the sustainable management of natural resources often collect spatially explicit information regarding the nature and intensity of recreational use to quantify user impact on a resource. Such information is regularly collected by state and federal agencies through hunter harvest and angler creel surveys, and may also be available for mountain biking, hiking, white-water rafting and other outdoor recreational activities where user-impacts and congestion are issues of management concern. In particular, hunter harvest surveys appear to be a particularly robust source of spatially explicit recreation site choice data. Through the Pittman-Robertson Wildlife Restoration Act (1937), each state in the U.S. has the primary responsibility and authority over the hunting of wildlife within state boundaries, and many of these states administer regular wildlife harvest surveys that help monitor game populations and assist in the development of hunting regulations. While the specifics of these hunter harvest surveys vary across states and game species of interest, the surveys generally collect data on the hunting site choice (e.g., county or game management unit) of hunters, the number of days spent hunting, and quantity of targeted species harvested. For example, in Oregon, each hunter is required to report harvest and effort information (i.e., number of days hunted and location hunted) for each hunting tag purchased. The Michigan Department of Natural Resources (MDNR) surveys big game hunters (e.g., deer, elk, bear) and small game hunters (e.g., ruffed grouse, pheasant, rabbit, and squirrel) to estimate hunter participation, harvest, and hunting effort. Colorado Division of Wildlife conducts surveys of big game and small game hunters regarding hunting area, species harvested, and number of days spent hunting. While states have the primary authority over managing resident wildlife, the U.S. Federal government has the ultimate responsibility for developing regulations regarding migratory bird hunting. Migratory bird hunters are required by federal law to register with the Migratory Bird Harvest Information Program; hunters are then randomly selected and mailed surveys (survey return is voluntary). The survey asks hunters to provide information regarding their migratory bird hunting experience, such as the locations hunted and the number of days spent hunting at each location.

At first glance, secondary data that captures individuals' recreation site selection decisions during some time period (e.g., calendar year, hunting/fishing season) would seem suitable for analysis using a revealed preference non-market valuation approach such as the multiple-site random utility travel cost model. However, as this data collection is generally designed to understand the nature and extent of user-impacts on natural resources, rather than to understand the motivations of recreationists, this can result in challenging data measurement and data omission issues from the perspective of a researcher seeking to apply non-market valuation techniques. A common limitation of such recreational site use data is the measurement of site choice in terms of the number of days spent at a site during a particular time period, rather than the number of trips taken to the site. If it cannot be reasonably assumed that all trips are single day trips, but instead that a day at a recreation site may be a component of a multiple day trip of undetermined length, constructing the travel cost variable (generally considered to be a function of trip-level expenses such as driving costs and opportunity costs of time) becomes problematic. Another common limitation faced by researchers who might consider using secondary data to estimate a travel cost model is a lack of information regarding the income of the individual. The opportunity cost of time associated with traveling to and from a site is considered to be key component of the price of a trip, and this is generally estimated as a fraction of an individual's wage rate (Parsons 2003).

The research within examines the possibility of making available a large body of imperfect site choice data for use by recreation demand modelers on limited budgets to estimate economic benefits associated with popular outdoor recreational activities such as hunting (13.7 million U.S. hunters; 282 million days hunting [USDOI 2011]). I examine the potential to overcome two common limitations of secondary data sets with respect to estimating travel cost models of recreational site choice – 1) missing information on individual income, and 2) site choice information measured in days rather than trips. Using data from a 2003 survey of Michigan deer hunters (response rate = 68%), I estimate a travel cost model of deer hunter site choice using complete data on hunter income and trips and compare the economic benefits from this baseline model to economic benefits when the model is re-estimated using a variety of variable proxies as substitutes for the missing data on income and trips. The empirical strategy is as follows. First, baseline travel cost models of firearm and archery hunting are estimated using all available data (i.e., hunter-reported income and hunter-reported trips). Next, variable proxies for individual income and the number of trips (measurements which would be missing in much of secondary data) are constructed and these proxies are used in model re-estimation. The proxy for income is constructed by assigning each individual the U.S. Census-based median household income for their zip code of residence. Proxies for missing trips are constructed using a variety of possible functional relationships between the number of trips to a hunting site and both the number of days spent at the hunting site and the distance from the individual's residence to the hunting site. The impacts on economic benefits resulting from assumptions on income and trips are compared to the impacts from researcher best-judgments and assumptions commonly employed by recreation demand modelers.

1.2 Literature Review

To provide context to the research findings regarding the differences in economic benefits resulting from the use of proxy variables, it is helpful to examine the existing literature to understand the welfare implications of researcher-imposed best-judgments and assumptions. First, though it is fairly common within the recreation demand literature to assign an individual the mean or median U.S. Census income of a geopolitical region when lacking individual-specific data on income (see, e.g., Heberling and Templeton 2009, Knoche and Lupi 2007, Knoche and Lupi 2012, Knoche and Lupi 2013, Whitehead et al. 2009, Henderson et al. 1999, Jakus et al. 1997, Cameron 1992), I am aware of no studies which examine the welfare implications of this assumption. Additionally, there does not appear to be any literature which examines the potential for making use of a large body of outdoor recreation participation data which measures recreation site use in terms of days rather than trips.

Table 1.1. Peer-reviewed literature examining impacts of assumptions regarding the opportunity cost of time, driving costs, and the nature of trips, on welfare estimates

Authors	Baseline	Comparison	Estimates	CS Diff.
Opportunity Cost of Time (fraction of wage rate)				
Cesario (1976)	0	1/3	11	15% to 35%
Bishop and Heberlein (1979)	0	1/4	1	143%
		1/2	1	300%
Wilman and Pauls (1987)	1/3	1	6	15% to 101%
Rockel and Kealy (1991)	3/10	3/5	7	10% to 20%
Bowker et al. (1996)	0	1/4	4	2% to 52%
		1/2	4	43% to 127%
Layman et al. (1996)	0	3/10	48	-14% to 67%
		3/5	48	34% to 163%
		1	48	81% to 193%
Zawaki et al. (2000)	0	1/4	4	13% to 104%
		1/2	4	41% to 259%
Bin et al. (2005)	1/3	1/4	14	-38% to 17%
		1	14	17% to 391%
Hynes et al. (2009)	0	1	4	29% to 85%
Edwards et al. (2011)	0	1/3	2	101% to 120%
		1	2	349% to 450%
Driving Costs				
Bowker et al. (1996)	Imputed	Reported	4	5% to 50%
English and Bowker (1996)	Imputed	Reported	12	-21% to 570%
	$0.15/mile	$0.25/mile	2	61% to 64%
		$0.35/mile	2	123% to 130%
Layman et al. (1996)	Imputed	Reported	64	7% to 113%
Prayaga et al. (2010)	Imputed	Reported	2	-66% to -56%
Nature of Trips				
Mendelsohn et al. (1992)	Multi-Destination Excluded	Multi-Destination Included	2	65% to 77%
Parsons and Wilson (1997)	Incidental Excluded	Incidental Included	2	4% to 8%
Loomis et al. (2000)	Incidental Excluded	Incidental Included	1	72%
Loomis (2006)	Multi-Destination Excluded	Single Destination Excluded	1	1516%
		All Trips Included	1	137%

Notes: CS diff. is difference in consumer surplus between the baseline & comparison model assumptions, imputed costs are per-mile driving cost estimates, reported costs are travel costs reported by individuals, & Estimates is the number of comparisons between baseline & comparison model.

The effect of many other researcher-imposed best-judgments and assumptions on coefficient estimates and welfare measures have been examined within the recreation demand literature, and meta-analyses within this literature (see Zandersen and Tol 2009, Shrestha and Loomis 2003, Rosenberger and Loomis 2001, Walsh et al. 1992, and Smith and Kaoru 1990 a,b) report that researcher decisions and modeling assumptions can substantively impact welfare estimates. Table 1.1 provides a survey of the literature on the welfare impacts from various assumptions (though this is not intended to be an exhaustive list). Numerous studies were identified which provide information on the welfare impacts resulting from assumptions on components of the travel cost variable, with many researchers reporting ranges of welfare estimates resulting from using different percentages of an individual's wage rate to calculate their opportunity cost of time. For example, researchers commonly compare welfare estimates obtained through valuing the opportunity cost of travel time at 0% of wage rate (i.e., there is no time cost to the traveler), 100% of wage rate, and some fraction of the wage rate. In general, researchers find that the percentage selected can have a substantial impact on welfare estimates. When using 0% of the wage rate as the baseline estimate, valuing opportunity cost of time at 100% of an individual's wage rate results in welfare differences that are generally greater than 100%, and as high as 490%. Also well-examined in the literature are the welfare impacts associated with different approaches for estimating an individual's transportation costs. Decisions on whether to use individual-reported travel cost vs. imputed travel costs (imputed costs generally incorporate per-mile estimates of driving costs obtained from American Automobile Association), and which per-mile rate to apply to miles traveled when using imputed travel costs also produce a wide range of welfare estimates.

Another area of research examining the impact of researcher-imposed best-judgments and assumptions involves the treatment of recreational trips also consisting of incidental or intended trips to another location. The specific issue is that for such trips, it is generally not possible to apportion travel costs amongst different activities. As such, many studies (see Englin et al. 2008, Bin et al. 2005, Chakraborty and Keith 2000, Fix and Loomis 1998, Bowker et al. 1996, and Beal 1995) drop multiple-destination and/or multiple-purpose trips from their analysis. However, Freeman (1993) notes that dropping such trips can result in an underestimate of consumer surplus. As such, researchers use their best judgment in deciding whether to drop trip observations that are suspected to involve incidental or intended trips to another location. The decision whether to drop such trips can have a large impact on welfare estimates.

1.3 Methods

1.3.1 Economic Theory

Random Utility Maximization (RUM) is the theoretical framework underlying the recreation demand model used in this research. The utility an individual realizes from recreating at a particular site (site *i*) is expressed mathematically in equation 1.

1) $$v_{ni} = \beta_{tc} tc_{ni} + \beta_q q_i + e_{ni}$$

The utility individual *n* receives from visiting site *i* is v_{ni}, tc_{ni} is the trip cost for reaching site *i*, q_i is a vector of site characteristics, e_{ni} is a random error term capturing unmeasured characteristics associated with site *i*, and βs are parameters (Haab and McConnell 2002; Parsons 2003).

An individual chooses the option which offers the highest utility. Thus, site *k* would be chosen from the set of all possible sites *i* when

2) $$\beta_{tc}tc_{nk} + \beta_q q_k + e_{nk} \geq \beta_{tc}tc_{ni} + \beta_q q_i + e_{ni} \ for \ all \ i \ in \ C$$

where *C* is the set of possible recreation sites in an individual's choice set.

A conditional logit model (which is derived from a random utility model with extreme value type 1 - distributed random components) is used to estimate the probability individual n chooses site k .

3) $$\mathrm{Prob}(nk) = \exp(\beta_{tc}tc_{nk} + \beta_q q_k / \sum_{i=1}^{C} \exp(\beta_{tc}tc_{ni} + \beta_q q_i)$$

Parameter estimation proceeds via maximum likelihood estimation by estimating the log of the likelihood function in equation 4, where $\mathrm{Prob}(ni)$ is the logit form from equation 3 and r_{in} is equal to one if site *i* is chosen by individual *n*, and equal to zero otherwise (Parsons 2003).

4) $$L = \prod_{n=1}^{N} \prod_{i=1}^{C} \mathrm{Prob}(ni)^{r_{in}}$$

The analysis focuses on examining how economic benefits estimates differ when proxies for trips and income are used in place of trips and income obtained from survey responses. To this end, equation 5 is used to estimate the change in per-trip economic benefits ($\hat{S}_n$) resulting from a quality change at one or multiple sites ($\acute{q_\iota}$) , and with estimated parameters ($\hat{\beta}$).

5) $$\hat{S}_n = [\ln\{\sum_{i=1}^{C} \exp(\hat{\beta}_{tc} tc_{ni} + \hat{\beta}_q \acute{q_\iota})\} - \ln\{\sum_{i=1}^{C} \exp(\hat{\beta}_{tc} tc_{ni} + \hat{\beta}_q q_i)\}]/-\hat{\beta}_{tc}$$

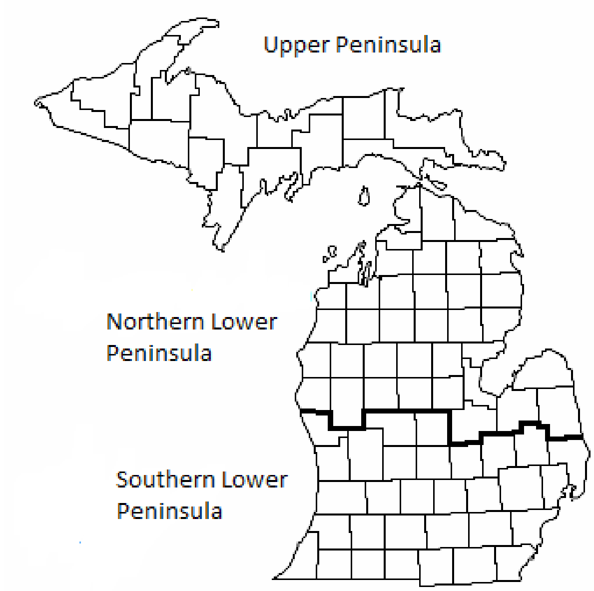
1.3.2 Empirical Model

Our empirical modeling strategy is designed to explore the potential for using researcher-based best judgments to overcome data limitations when estimating recreation demand models. To accomplish this, economic benefits estimates derived from travel cost models which utilize hunter-reported data on income and trips (from a 2002 survey of Michigan deer hunters) are contrasted with economic benefits derived from models re-estimated using a variety of proxies for trips and income. The per-trip and seasonal economic benefits from the existence of publicly accessible hunting land (relative to all publicly accessible land being eliminated) are used as a basis for comparing the baseline models to the re-estimated proxy-based models. Sections 1.3.3 – 1.3.5 proceed as follows. First, I describe the formulation of two “Baseline” travel cost models which incorporate hunter-reported trips and hunter-reported income in models which predict the selection of a hunting site as a function of a travel cost variable and other hunting site attributes. Then, I describe the approach for constructing proxies for income and trips, which allows for model re-estimation and subsequent economic benefits comparison.

1.3.3 Baseline Travel Cost Models - Archery Hunting and Firearm Hunting

This analysis uses data from a 2003 survey of Michigan deer hunters. This survey data contains information on the number of hunting trips taken and the number of days spent hunting at each hunting location during the 2002 hunting season for two methods of deer hunting: shotgun/rifle and archery. Separate baseline travel cost models for the shotgun/rifle (henceforth firearm) and archery seasons are estimated using hunter-reported trips to a Michigan county to construct the site choice variable and hunter-reported income to construct the relevant component of the travel cost variable. Estimating separate travel cost models for different types of hunting activities helps identify the extent to which differences in economic benefits resulting from the use of proxy variables for income and trips may be contingent upon the nature of the recreational experience.

Figure 1.1. Michigan hunting site choices



In the baseline archery and firearm travel cost models, the probability of site choice is estimated as a function of the following hunting site attributes: travel cost, acreage of the three types of publicly accessible hunting land, deer population, and two regional categorical variables indicating whether the county is located in the Upper Peninsula or Northern Lower Peninsula of Michigan (see Figure 1.1 for the delineation between these regions). The three types of publicly accessible hunting land are federally-owned land, state-owned land, and privately-owned, publicly accessible Commercial Forest Act (CFA) land. Federally-owned land in Michigan consists of National Forest land, U.S. Fish and Wildlife Service land, and National Lakeshore land, and State-owned land consists of State Forest land, State Parks and Recreation Areas, and State Game and Wildlife Areas. The CFA provides tax incentives to private landowners who retain and manage forest for long-term timber production; enrollees are required to make this land available for hunters and anglers.

The variable *Price* is calculated as the sum of round-trip driving costs and the opportunity cost of time associated with traveling to and from a hunting site. The round-trip driving costs were obtained by multiplying the per-mile cost of operating a vehicle (31 cents; AAA 2002) by the total estimated round-trip mileage. Round-trip mileage is estimated by calculating the driving distance between the hunter's residence and the centroid of the county to which the trip was taken. The opportunity cost of time was estimated to be 1/3 of the individual's hourly wage rate (Parsons 2003), multiplied by the estimated number of hours the individual spent traveling to and from the hunting site (estimated via PC Miler® software). For the baseline firearm and archery models, the individual's reported income was used to estimate the opportunity cost of time. Deer population in the county was obtained from estimates via the Michigan Department of Natural Resources.

1.3.4 Model Re-Estimation Using Proxy for Income

As noted in the review of the literature, some researchers confronted with missing data for individual income assign individuals aggregate U.S. Census level income estimates based on geopolitical regions such as zip code of residence. To examine the welfare implications of such income proxies, a proxy for individual income is constructed by assigning each individual the 2000 U.S. Census estimate of median household income for their zip code of residence. Economic benefits estimates from the baseline archery and firearm models are then compared to benefits estimates from re-estimated archery and firearm models which substitute the census-based income proxy into the relevant component of the travel cost variable.

1.3.5 Model Re-Estimation Using Proxy for Trips

Travel cost model estimation is problematic when site choice information is measured by the number of days spent at a recreation site as opposed to the number of trips taken to the recreation site. However, the number of trips taken to a recreation site might reasonably be assumed to be a function of non-missing data such as the number of days spent at the recreation site and the distance from the individual's residence to the recreation site. I hypothesize that individuals hunting in areas further from their residence would spend more days hunting at a recreation site per trip, due to the higher costs associated with traveling to these further sites (see McConnell 1992 for a similar argument). Prior to constructing proxy variables for trips, I empirically examine the relationship between the number of days spent hunting per hunting trip and the distance from their residence to the hunting location.

Figure 1.2. Average number of days spent hunting per firearm and archery (bow) hunting trip by distance from residence

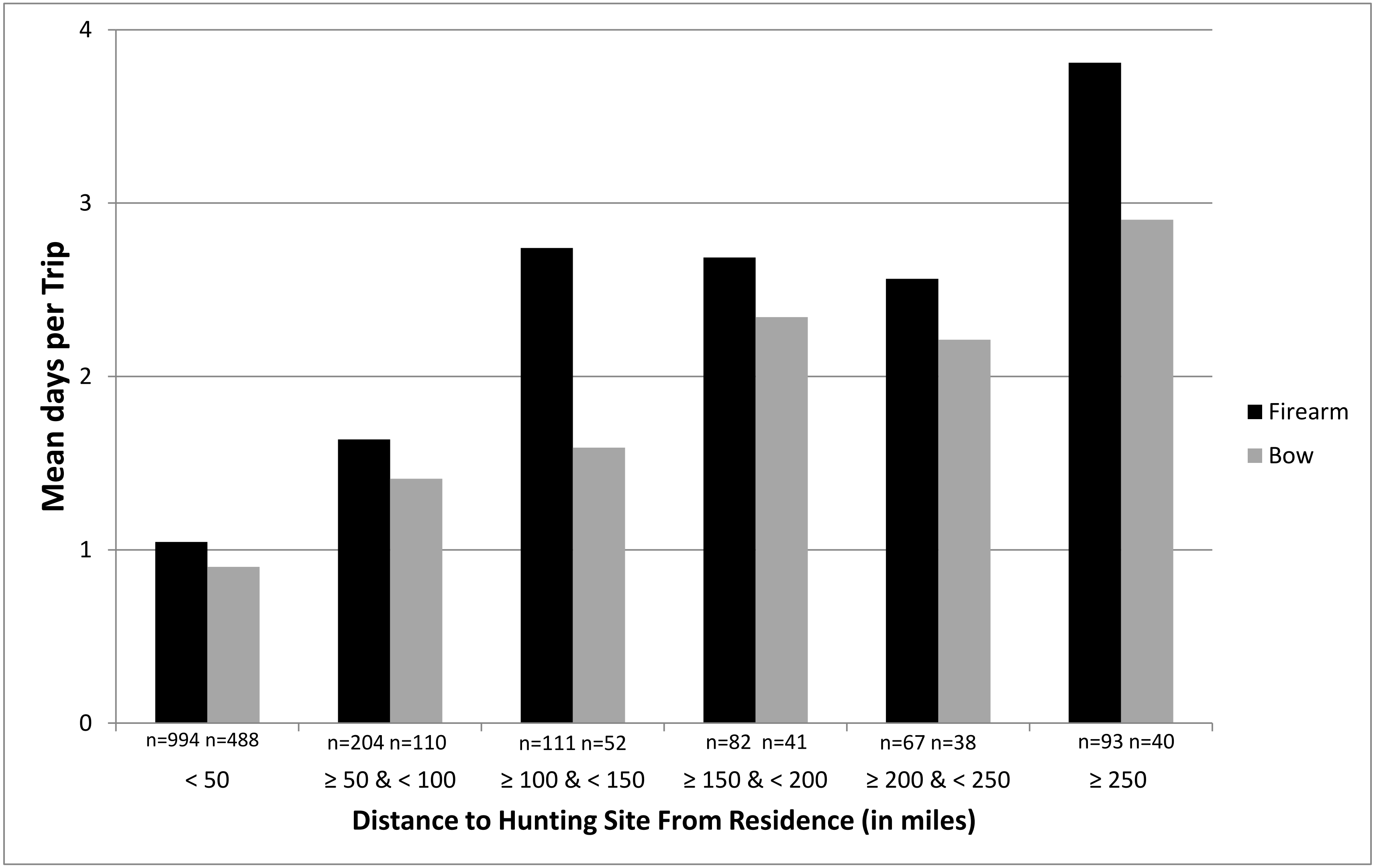


Figure 1.2 provides evidence of an increasing relationship between the number of days the individual spends hunting per trip and the distance of the hunting site from the individual's residence for both archery and firearm hunters. Archery and firearm hunters spend approximately one day hunting per hunting trip for hunting sites under 50 miles from their residence, whereas for long distance trips (>250 miles), archery hunters spend close to three days hunting per hunting trip and firearm hunters report spending close to four days hunting per hunting trip.

This assumption of increasing days per hunting trips as a function of distance is tested through the use of Ordinary Least Squares (OLS) regression for both firearm and archery hunters (specified below).

6) $$Trips_{ij} = \alpha_0 + \beta_1 Days_{ij} + \beta_2 Distance_{ij} + \varepsilon_{ij}, \text{ for all } Trips_{ij} \geq 1$$

In equation 6, $Trips_{ij}$ is the number of trips taken by individual *i* to hunting site *j* during the 2002 hunting season, $Days_{ij}$ is the number of days spent hunting site *j* during the 2002 season, $Distance_{ij}$ is the (one-way) distance in miles from the individual *i*'s residence to hunting site *j*, and ε_{ij} is an error term.

Table 1.2. OLS regression of the number of hunting trips taken to the site during the season on the number of days taken to the site during the season and the distance to the hunting site from the individual's residence

Independent Variables	**Firearm Model**		**Archery Model**	
	Coefficient	P-Value	Coefficient	P-Value
Days	0.323	P<0.01	0.941	P<0.01
Distance	-0.021	P<0.01	-0.026	P<0.01
Constant	5.252	P<0.01	2.183	P<0.01
Model Statistics				
# of Obs.	1551 hunters		769 hunters	
R-squared	0.269		0.718	

OLS regression results in Table 1.2 are consistent with Figure 1.2 – individuals economize on costs when hunting far-away sites by spending more days hunting per hunting trip. This trend is evident in both the Firearm and Archery OLS models, with the coefficient on *Distance* being negative and statistically significant (P<0.01) for both of these models. In summary, the greater the distance traveled from an individual's residence to a hunting site, holding days spent at a recreation site constant, the fewer trips taken to that hunting site.

In the analysis supported by Figure 1.2 and Table 1.2 above, I avoided a more in-depth analysis of the relationship between trips, days, and distance – desiring simply to confirm the hypothesized direction of the relationship. Armed with the general information presented above, seven ad-hoc relationships (see Table 1.3) were constructed which relate the number of hunting trips taken to a site to the number of hunting days reported by the individual and the distance required to travel to that site. Then, using the same interval scheme as with the ad-hoc calculations, seven empirically-based proxies for the number of trips were constructed by calculating the mean trips-per-day ratio for a given distance interval level (obtained through the survey data) and multiplying this ratio by the number of days reported hunting in the survey. These empirically-based trip proxies will be used to serve as a basis of comparison for the ad-hoc assumptions. As these proxies incorporate actual information on hunter-reported trips/days ratio (rather than relying on ad-hoc formulations of this relationship), economic benefits estimates from these empirically-based proxies are expected to more closely approximate benefits estimates from the baseline models.

Table 1.3. Ad-hoc trips proxy and empirically-based trips proxy variables

Site Choice Proxy Variable		Ad-hoc Trips Proxy	Empirically-based Trips Proxy
7)	*Trips_A*	$=\begin{cases} Days, & Distance < 50 \\ \frac{Days}{2}, & Distance \geq 50 \end{cases}$	$=\begin{cases} Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance < 50\right], & Distance < 50 \\ Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance \geq 50\right], & Distance \geq 50 \end{cases}$
8)	*Trips_B*	$=\begin{cases} Days, & Distance < 100 \\ \frac{Days}{2}, & Distance \geq 100 \end{cases}$	$=\begin{cases} Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance < 100\right], & Distance < 100 \\ Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance \geq 100\right], & Distance \geq 100 \end{cases}$
9)	*Trips_C*	$=\begin{cases} Days, & Distance < 150 \\ \frac{Days}{2}, & Distance \geq 150 \end{cases}$	$=\begin{cases} Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance < 150\right], & Distance < 150 \\ Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance \geq 150\right], & Distance \geq 150 \end{cases}$
10)	*Trips_D*	$=\begin{cases} Days, & Distance < 75 \\ \frac{Days}{2}, & 75 \leq Distance < 150 \\ \frac{Days}{3}, & Distance \geq 150 \end{cases}$	$=\begin{cases} Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance < 75\right], & Distance < 75 \\ Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert 75 \leq Distance < 150\right], & 75 \leq Distance < 150 \\ Days * \left[\frac{\sum Trips}{\sum Days}\middle\vert Distance \geq 150\right], & Distance \geq 150 \end{cases}$

Table 1.3. (cont'd)

Site Choice Proxy Variable	**Ad-hoc Trips Proxy**	**Empirically-based Trips Proxy**
11) *Trips_E*	$= \begin{cases} Days, & Distance < 100 \\ \frac{Days}{2}, 100 \leq & Distance < 200 \\ \frac{Days}{3}, & Distance \geq 200 \end{cases}$	$= \begin{cases} Days * \left[\frac{\sum Trips}{\sum Days} \middle\| Distance < 100\right], & Distance < 100 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| 100 \leq Distance < 200\right], & 75 \leq Distance < 200 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| Distance \geq 200\right], & Distance \geq 200 \end{cases}$
12) *Trips_F*	$= \begin{cases} Days, & Distance < 75 \\ \frac{Days}{2}, 75 \leq & Distance < 150 \\ \frac{Days}{3}, 150 \leq & Distance < 225 \\ \frac{Days}{4}, & Distance \geq 225 \end{cases}$	$= \begin{cases} Days * \left[\frac{\sum Trips}{\sum Days} \middle\| Distance < 75\right], & Distance < 75 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| 75 \leq Distance < 150\right], & 75 \leq Distance < 150 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| 150 \leq Distance < 225\right], & 75 \leq Distance < 225 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| Distance \geq 225\right], & Distance \geq 225 \end{cases}$
13) *Trips_G*	$= \begin{cases} Days, & Distance < 100 \\ \frac{Days}{2}, 100 \leq & Distance < 200 \\ \frac{Days}{3}, 200 \leq & Distance < 300 \\ \frac{Days}{4}, & Distance \geq 300 \end{cases}$	$= \begin{cases} Days * \left[\frac{\sum Trips}{\sum Days} \middle\| Distance < 100\right], & Distance < 100 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| 100 \leq Distance < 200\right], & 100 \leq Distance < 200 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| 200 \leq Distance < 200\right], & 200 \leq Distance < 300 \\ Days * \left[\frac{\sum Trips}{\sum Days} \middle\| Distance \geq 300\right], & Distance \geq 300 \end{cases}$

Equations 7 through 13 (*Trips_A* through *Trips_G*) generate ad-hoc and empirically-based proxy estimates for individual trips to a hunting site using days spent hunting and distance to the hunting site. For example, the Ad-Hoc Trips Proxy for equation 9 (*Trips_C*) is calculated using the assumption that each day spent hunting less than 50 miles from the individuals residence resulted in one trip, whereas for days spent hunting at a location greater than or equal to 50 miles from the hunters residence, two days spent hunting resulted in one trip being taken. The Empirically-based Trips Proxy is calculated by first calculating the mean trips – days ratio for each distance interval, then multiplying this ratio by the number of days spent hunting by the individual within the distance interval. For example, the Empirically-based Trips Proxy for equation 9 (*Trips_C*) is calculated by first estimating the mean trips/days ratio for all hunters taking a trip to a county within 50 miles of their residence, with this ratio then multiplied by the number of days reported hunting by each individual taking a trip within this distance interval. Standard rounding procedures (i.e., ≥ 0.5 rounds up to nearest integer, < 0.5 rounds down to nearest integer) were used. When an individual reported hunting one day (regardless of distance), that was considered to be a single trip.

1.4 Results

Table 1.4 provides the baseline model estimates for both the firearm and archery travel cost models. Coefficient signs are generally as expected – *Price* is negative and *Deer* (deer population) is positive for both models, and these coefficients are statistically significant

(P<0.001). The three types of publicly accessible hunting land (Federal, State, and CFA) are positive and statistically significant (P<0.001) in each model.

Table 1.4. Baseline Firearm and Archery model results using hunter-reported information on trips and income

	Firearm Baseline Model	**Archery Baseline Model**
Independent Variables		
Price	-0.0324*	-0.0376*
Deer(10,000 deer)	0.2217*	0.1502*
Federal (10,000 acres)	0.0352*	0.0598*
State(10,000 acres)	0.0779*	0.0845*
CFA(10,000 acres)	0.1046*	0.0898*
Size(100 sq. miles)	-0.1396*	-0.1019*
UP_Dum	2.4177*	1.6627*
NLP_Dum	0.5778*	0.5200*
Model Statistics		
Log-Likelihood	-30,850	-27,245
Observations	654	1355

Notes: A * indicates statistical significance at the P<0.001 level. Null hypothesis that all parameters equaled 0 was rejected for both models (P<0.0001)

Using economic benefits from the existence of publicly accessible hunting land as the basis of comparison, I compare the economic benefits from the firearm and archery baseline models to re-estimated firearm and archery models in which hunter-reported income is replaced by the zip code level U.S. Census estimate of median household income. Welfare estimates from these re-estimated models closely approximate the welfare estimates derived from baseline firearm and archery models in which hunter-reported income are used (see Table 1.5). Per-trip and seasonal estimates of the economic benefits of publicly accessible hunting land for both firearm and archery hunters in Michigan varies by about 3 percent depending on whether individual-reported income is used (as in the baseline models) or median zip code income is substituted for individual-reported income (as in the re-estimated models).

Table 1.5. Differences in per-trip and seasonal welfare estimates for publicly accessible hunting land between baseline models estimated using hunter reported income and models re-estimated using aggregate census data for income

		Baseline Models	**Re-estimated Models Using Census-based Median Income Proxy**	**% difference**
Per-Trip	Firearm	$15.18	$14.74	-2.9%
	Archery	$12.88	$12.43	-3.5%
Seasonal	Total	$81,226,000	$78,717,000	-3.1%

Next, I compare the welfare estimates using the empirically-based and ad-hoc trip proxies with welfare estimates obtained via the baseline models. Per-trip and seasonal welfare estimates for publicly accessible hunting land are obtained by re-estimating the firearm and archery models using 14 different proxies for trips for each model (seven ad-hoc proxies and seven empirically-based proxies) and then estimating the economic benefits of publicly accessible hunting land. The 14 model re-estimations using ad-hoc trip proxies and the 14 model re-estimations using the empirically-based proxies all generated coefficient estimates with the same sign as the baseline models using individual-reported information for income and trip, and all results were statistically significant (P<0.001).[1]

For the firearm and archery models re-estimated using the ad-hoc and empirically-based proxies for hunter trips, Table 1.6 shows that as the number of distance intervals increases, welfare estimates for these trip proxies more closely approximate results from the baseline models. Welfare estimates using the empirically-based proxies for trips differ from baseline estimates by 1% - 31%, generally more closely approximating baseline estimates than the ad-hoc estimates (which has differences ranging from 3% - 44%). This is expected, as the empirically-based trip proxies utilize estimates of the trips-days ratio calculated from survey responses, whereas the ad-hoc proxies do not use such information. At the three and four distance interval level, welfare measures obtained when using ad-hoc and empirically-based proxies more closely align with welfare estimates from the baseline model. The four ad-hoc assumptions for both the firearm and archery models produce welfare estimates that are within 10% of the baseline models welfare estimates.

[1] See Appendix A, Table A.1. and Table A.2. for coefficient estimates and model statistics for the 28 model estimations.

Table 1.6. Per-trip and economic benefits for firearm hunters and archery hunters for empirically-based and ad-hoc proxies for the number of hunting trips

	Baseline Model	Trip Proxies	Two Intervals			Three Intervals		Four Intervals	
			Trips_A	*Trips_B*	*Trips_C*	*Trips_D*	*Trips_E*	*Trips_F*	*Trips_G*
Per-Trip Firearm Hunter Economic Benefits from Public Land	$15.18	Empirically-based	$17.53 (15.48%)	$15.01 (-1.12%)	$19.91 (31.16%)	$15.57 (2.57%)	$15.13 (-0.33%)	$15.47 (1.91%)	$14.91 (-1.78%)
		Ad-hoc	$20.07 (32.21%)	$19.55 (28.79%)	$21.86 (44.01%)	$15.38 (1.32%)	$16.57 (9.16%)	$14.55 (-4.15%)	$16.04 (5.66%)
Per-Trip Archery Hunter Economic Benefits from Public Land	$12.88	Empirically-based	$15.55 (20.73%)	$14.29 (10.95%)	$15.35 (19.18%)	$14.00 (8.70%)	$14.13 (9.70%)	$14.15 (9.86%)	$14.07 (9.24%)
		Ad-hoc	$15.65 (21.51%)	$15.56 (20.81%)	$17.14 (33.07%)	$13.04 (1.24%)	$13.92 (8.07%)	$12.65 (-1.79%)	$13.86 (7.61%)
Total Seasonal Economic Benefits for Firearm and Archery Hunters From Public Land (millions)	$81.2	Empirically-based	$95.2 (17.16%)	$83.5 (2.74%)	$103.4 (27.33%)	$84.9 (4.53%)	$83.6 (2.88%)	$84.8 (4.45%)	$82.6 (1.75%)
		Ad-hoc	$104.6 (28.79%)	$102.5 (26.23%)	$114.1 (40.51%)	$82.3 (1.29%)	$88.4 (8.81%)	$78.5 (-3.39%)	$86.3 (6.29%)

1.5 Discussion

This research examines the welfare impacts associated with operationalizing imperfect data sets for the purposes of estimating travel cost models of recreation demand. I show that employing assumptions on hunter trips and income when faced with missing data produces welfare estimates that closely approximate welfare measures produced by travel cost models that use individual-reported information on income and trips. Additionally, substituting census-based income measures for individual-reported income impacts welfare measures by about 3-4%. Relative to the welfare implications of researcher assumptions and best judgments detailed in Table 1.1, using a census-based income proxy in place of individual-reported income has little effect. When assessing whether it is appropriate to assign an individual a census-based median income proxy based on their geographic region of residence, it may be helpful to search for and review information that compares socio-demographics of the group of interest to the general population. Research by the National Shooting Sports Foundation (2010) found that median hunter income was within 5% of state median income for 12 of 17 states examined, further supporting the use of aggregate income measures when valuing hunting experiences in different states. Given that survey item non-response to income questions is typically between 20% and 40% (Moore et al. 1997, Juster and Smith 1997, and Yan et al. 2005), the availability of aggregate census data on individual income may allow researchers to utilize a large proportion of survey responses in which individuals choose not to answer income-related questions.

The ad-hoc assumptions regarding the relationship between the number of days spent hunting per trip and the distance of the site from an individual's residence produced welfare estimates that were increasingly close to baseline model estimates as the number of distance intervals increased. The large positive differences of hunter welfare for the two interval scenarios, relative to estimates from the baseline model, is likely due to these ad-hoc assumptions failing to account for the propensity of individuals hunting far from their residence to spend longer than two days hunting during a trip. As with the proxy for income, using ad-hoc proxies for trips, particularly at the three or four interval level, resulted in welfare differences from the baseline model which are much smaller than the differences identified in Table 1.1. Ultimately, when assessing the feasibility of using secondary data measuring site choice in terms of days rather than trips, researchers should keep in mind that other commonly used researcher assumptions generally have a much larger impact on welfare measures.

The applicability of these findings to other hunting activities (and potentially to other types of outdoor recreation) depends on whether individuals participating in other types of hunting activities similarly adjust the number of hunting days per trip based on the distance to a hunting site. Comparing welfare estimates between the firearm and archery models may provide insight into whether this is the case, as there are potentially important differences in the nature of the archery and firearm deer hunting experiences. An obvious difference is that firearm and archery hunters use different weapons, which may require different levels of sophistication and practice to attain a skill level sufficient to harvest an animal. Miller and Graefe (2000) compared the degree of hunter specialization across seven different hunting experiences (rifle deer, muzzleloader deer, archery deer, waterfowl, pheasant, grouse and turkey) finding that the activity with the highest degree of specialization was archery deer hunting, twice the mean degree of specialization of rifle deer hunting, which had the lowest mean specialization of the seven hunting activities examined. Furthermore, Miller and Graefe (2001) found dissimilarities in satisfaction models across rifle, archery, and muzzleloader deer hunters, which the researchers interpreted as underlying difference in orientation towards hunting between hunters in these three groups. Finally, the nature of recruitment into archery hunting suggests that archery deer hunters are a distinctive subset of firearm deer hunters who are seeking additional and/or different hunting experiences. According to Duda and Bisell (2001), 82 percent of archery hunters actively hunted with firearms prior to taking up bow hunting, with bow hunters having on average 12 years of experience in firearm hunting before taking up bow hunting.

These differences in firearm and archery hunters and their respective hunting experiences, along with the similarity of welfare measures between the archery and firearm models, suggests that tradeoffs between trips and days as a function of distance may be similar across different types of outdoor recreation experiences. It is important to note that different assumptions on the cost and nature of recreational trips (as outlined in Table 1.1) have considerably more impact on welfare estimates then do the assumptions on trips and individual income. The wealth of wildlife harvest data available from the federal government and state wildlife management agencies provides the opportunity to use similar assumptions to those used within this dissertation chapter to estimate travel cost models for recreational hunting experiences in different regions and for different species. Furthermore, the finding that individuals facing high costs of reaching a site will take fewer trips while spending more days on site per-trip might reasonably applied to other types of outdoor recreational experiences as well. While care must be taken in each situation, this research supports the use of assumptions on income and trips similar to those used in this paper to estimate travel cost models using widely available but imperfect secondary data on recreation site choice.

APPENDIX

Table 1. Deer hunting travel cost model results using seven empirically-based estimates of trips as a function of days and distance

	TRIPS_A		**TRIPS_B**		**TRIPS_C**		**TRIPS_D**		**TRIPS_E**		**TRIPS_F**		**TRIPS_G**	
Vars	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**
Price	-0.028	-0.034*	-0.030	-0.035	-0.026	-0.035	-0.030	-0.037	-0.30	-0.036	-0.030	-0.037	-0.030	-0.036
Pop	0.223	0.173*	0.234	0.187	0.255	0.208	0.237	0.182	0.236	0.187	0.236	0.182	0.233	0.185
Size	-0.154	-0.131*	-0.136	-0.125	-0.169	-0.151	-0.152	-0.134	-0.142	-0.129	--0.152	-0.133	-0.139	-0.127
CFA	0.106	0.110*	0.102	0.104	0.109	0.103	0.107	0.104	0.102	0.101	0.106	0.105	0.096	0.096
NAT	0.041	0.067*	0.041	0.065	0.044	0.068	0.044	0.067	0.041	0.066	0.043	0.067	0.040	0.066
State	0.065	0.079*	0.059	0.078	0.071	0.088	0.064	0.086	0.062	0.081	0.064	0.085	0.066	0.083
UP	2.746	1.701*	2.792	1.763	2.506	1.665	2.794	1.747	2.787	1.691	2.790	1.773	2.619	1.623
NLP	0.653	0.624*	0.736	0.692	0.802	0.706	0.695	0.674	0.768	0.709	0.699	0.664	0.795	0.714
Stats														
Log L	-27,987	-32,483	-26,546	-31,585	-32,778	-32,260	-26,480	-30,425	-26,507	-31,174	-26,432	-30,609	-26,395	-31,105
Obs	654	654	654	654	654	654	654	654	654	654	654	654	654	654

Table 2. Deer hunting travel cost model results using seven assumption-based estimates of trips as a function of days and distance

	TRIPS_A		**TRIPS_B**		**TRIPS_C**		**TRIPS_D**		**TRIPS_E**		**TRIPS_F**		**TRIPS_G**	
Vars	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**
Price	-0.025	-0.033	-0.025	-0.033	-0.024	-0.031	-0.031	-0.040	-0.031	-0.037	-0.033	-0.041	-0.036	-0.045
Pop	0.227	0.175	0.236	0.193	0.252	0.208	0.237	0.178	0.237	0.189	0.237	0.177	0.252	0.212
Size	-0.155	-0.131	-0.145	-0.128	-0.108	-0.147	-0.152	-0.128	-0.152	-0.129	-0.154	-0.129	-0.198	-0.175
CFA	0.105	0.111	0.104	0.106	0.108	0.107	0.106	0.097	0.106	0.094	0.104	0.098	0.117	0.106
NAT	0.041	0.068	0.041	0.065	0.043	0.064	0.043	0.068	0.043	0.0662	0.045	0.068	0.048	0.070
State	0.062	0.079	0.059	0.077	0.068	0.083	0.065	0.089	0.065	0.086	0.070	0.089	0.085	0.108
UP	2.609	1.744	2.587	1.751	2.455	1.622	2.773	1.670	2.773	1.530	2.697	1.640	3.230	2.018
NLP	0.667	0.615	0.738	0.677	0.781	0.683	0.710	0.675	0.710	0.722	0.743	0.680	0.995	0.928
Stats														
Log L	-31,978	-29,414	-33,710	-31,474	-35,938	-33,594	-27,973	-26,690	-29,973	-28,937	-26,759	-26,117	-28,301	-28,406
Obs	654	654	654	654	654	654	654	654	654	654	654	654	654	654

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CHAPTER 2: ESTIMATING THE ECONOMIC BENEFITS OF PUBLICLY ACCESSIBLE LAND FOR RUFFED GROUSE HUNTERS[2]

2.1 Introduction

Hunting small game is a popular outdoor recreational activity in the United States, with 4.5 million people spending about 51 million days and $2.5 billion hunting rabbit, squirrel, pheasant, grouse, and other small mammals and birds in 2011 (U.S. Department of the Interior [USDOI] 2011). Monetary expenditures incurred by small game hunters on trips and equipment have the potential to generate substantial economic impacts to local communities, with many of these benefits accruing to rural economies of particular concern and interest to politicians and policy makers. As a result, much attention has been paid to these retail expenditures and resulting economic impacts, which include multiplier effects (initial spending and recirculation of those expenditures throughout an economy) and the jobs generated by the initial spending and re-spending of these dollars. From 2000–2003, retail sales related to small game hunting in the United States averaged $443 million annually, generating annual multiplier effects of about $1.2 billion and over 10,100 full and part-time jobs (Southwick Associates 2007).

Economic impacts such as those detailed above are widely available and can be useful for characterizing the importance of outdoor recreational activities such as small game hunting

[2] A version of this chapter was published as "Knoche, S., and F. Lupi. 2013. Economic Benefits of Publicly Accessible Land for Ruffed Grouse Hunters. *Journal of Wildlife Management* 77: 1294-1300.". In that publication, welfare measures from the sample were extrapolated to the population by computing per-trip willingness to pay measures, which were then averaged across sample members and multiplied by the number of resident ruffed grouse hunters. Here, consistent with the other dissertation chapters, welfare measures were extrapolated using weighted average per-trip willingness to pay where the weights were each person's trips, which was multiplied by the number of resident ruffed grouse hunters.

to regional or local economies. However, economic impacts figures are not appropriate for analyzing alternative management regimes within a cost-benefit context. For example, were small game hunting not an option, individuals would spend their money on other activities and these expenditures would still generate economic impact, just to different industries likely affecting different regions and different people. Thus, such expenditures simply reflect monetary transfers, and are not appropriate for use in informing the deployment of scarce management resources to improve the welfare of outdoor recreationists. Estimating the economic benefits (i.e., maximum willingness to pay minus total costs) accruing to outdoor recreation participants from aspects of the recreational experience is the appropriate approach for evaluating the net benefits of costly alternative management regimes. Estimating the economic benefits associated with aspects of outdoor recreation requires the use of non-market valuation techniques, which have often been used to estimate economic benefits associated with big game hunting (e.g., white-tailed deer (*Odocoileus virginianus*)[Schwabe et al. 2001; Knoche and Lupi 2007, 2012], elk (*Cervus Canadensis*) [Fried et al. 1995], moose (*Alces alces*) [Sarker and Surry 1998], and pronghorn antelope (*Antilocapra americana*) [Boxall 1995]). However, other than ring-necked pheasant (*Phasianus colchicus*) hunting (see Shulstad and Stoevener 1978, Adams et al. 1989, Remington et al. 1996, Hansen et al. 1999), little research has been conducted on the economic benefits associated with the small game hunting experience. In particular, the popularity of hunting ruffed grouse (*Bonasa umbellus*) on public land relative to many other small game species (Frawley 2012) offers a unique opportunity for economic valuation and policy analysis.

Wildlife managers and policy makers at both the federal and state levels have enacted programs to increase and enhance the provision of publicly accessible lands for hunting and other types of outdoor recreation. Helland (2006) reports that 11 states (primarily west of the Mississippi) have Walk-In Hunting Access (WIHA) programs that facilitate access to private land. According to Benson (2001), 40% of state wildlife management agencies have a program that assists hunters and landowners with access-related issues for hunted and/or non-hunted species, with 96% of agency administrators reporting that access to private land is important for their organizations' objectives. At the federal level, President Obama launched the America's Great Outdoors initiative in 2010, which recommends full funding of $900 million per year (by 2014) for the Land and Water Conservation Fund (LWCF), a federal government funding program which over the past 40 years has enabled the purchase of 1.2 million hectares of recreation lands and the funding of over 29,000 projects to develop basic recreational facilities on public lands. In 2012, the LWCF distributed more than $42 million in grants for land acquisition and recreation development purposes, which subsequently leveraged an additional $48 million from state, local, and private sources. Hunting-specific federal initiatives such as the United States Department of Agriculture's Public Access and Habitat Incentive Program (VPA-HIP) provided grants to 25 states totaling $17.8 million to encourage private landowners to make their land available to the public for hunting.

Despite efforts by state and federal governments to 1) improve or increase access to publicly-owned recreation land, and 2) to implement programs that incentivize landowners to allow public hunting access on their privately owned lands, few research efforts (other than Knoche and Lupi [2012]) have examined the economic benefits accruing to hunters as a result of changing amounts of publicly accessible land for hunters. To address these gaps in the literature, the travel cost valuation method was used to determine which site attributes (e.g., harvest rate, public land acreage) influence a ruffed grouse hunter's site selection decision. Economic benefits to ruffed grouse hunters were then estimated for each type of publicly accessible hunting land that is a statistically significant predictor of hunter site selection. This method allowed the estimation of economic benefits of publicly accessible land to grouse hunters by examining the tradeoffs individuals make between the amount and nature of publicly accessible land at a hunting site and the cost incurred in traveling to that hunting site.

2.2 Study Area

The ruffed grouse is the most popular upland game bird in the upper Great Lakes region, with about 193,000 hunters spending over 1.5 million days hunting ruffed grouse in Michigan and Wisconsin in 2007, compared to 116,000 hunters spending about 800,000 days hunting pheasant in these two states (Dhuey 2008, Frawley 2008). Ruffed grouse hunting participation and harvest can vary substantially, as ruffed grouse in this region, as well as in Alaska and much of Canada, have approximately 10-year cycles of abundance (Rusch et al. 1999), with hunter numbers and ruffed grouse harvest fluctuating with respect to the population cycle (Dessecker et al. 2006). During cyclic highs, about three million ruffed grouse are harvested evenly across Minnesota, Wisconsin, and Michigan, with about 900,000 harvested during cyclic lows (Dessecker and McCauley, 2001). Our survey uses data from the 2008 ruffed grouse hunting season, during which ruffed grouse populations were rebounding from population lows documented during 2004–2005 (Frawley and Stewart 2009).

In 2008 in the state of Michigan, an estimated 88,300 resident hunters spent 624,000 days harvesting 301,000 ruffed grouse (Frawley 2012). For the purposes of delineating ruffed grouse population areas of interest in Michigan (see Figure 1.1 in dissertation chapter 1), the Upper Peninsula and much of the Northern Lower Peninsula of Michigan (along with northern portions of Wisconsin and Minnesota, and portions of southern Canada) are considered to be part of the Boreal Transition Forest area, defined as a transitional forest landscape between deciduous-dominated forests to the south and coniferous-dominated forests to the north (Dessecker 2006). The remaining southern portion of the Lower Peninsula of Michigan, along with the southern two-thirds of Wisconsin and Central Minnesota, are defined to be part of the Prairie Hardwood Transition, a transitional landscape between prairies to the west and south and deciduous-dominated forests to the east and north (Stewart et al. 2006). All forested landscapes in these regions can support populations of ruffed grouse. However, mature forests generally support only low-density populations of ruffed grouse, whereas ruffed grouse are most prolific in young (early-successional) forests. The Michigan portion of the Boreal Transition Forest area has a substantial amount of ruffed grouse habitat, with about 4.1 million hectares of large-diameter forest (>12.7 cm) and 1.3 million hectares of small-diameter forest (≤12.7 cm; Dessecker 2006). The southern portion of the Lower Peninsula of Michigan, which has been heavily affected by humans via agricultural use and urban or suburban development, has about one million hectares of large-diameter and 400,000 hectares of small-diameter forest (Dessecker 2006).

Forests in both regions described above contain productive ruffed grouse habitat. Additionally, much of this forest acreage is located on publicly accessible land, available to all Michigan hunters for free access or for a small entrance fee. Publicly-owned hunting options in Michigan include State Forest (1.5 million ha), National Forest (1.2 million ha), State Game and Wildlife areas (200,000 ha), State Parks and Recreation areas (107,000 ha), 2 National Lakeshores (52,000 ha), and United States Fish and Wildlife Service Land (47,000 ha). Additionally, about 890,000 million ha of privately-owned, publicly accessible land is available to hunters through Michigan's Commercial Forest Act (CFA), which provides tax incentives for private landowners (predominantly timber companies) to allow hunting and angling on their land. Federally-owned land, state-owned land, and CFA land are the three major types of publicly accessible hunting lands in Michigan, and serve as the focal point of this analysis (see Knoche and Lupi 2012 for greater detail relating to publicly accessible hunting lands in Michigan).

2.2.1 Policy Scenario

Currently, the vast majority of federally-owned and state-owned land in Michigan is open to recreational hunting. However, national forests are legally responsible for providing for a variety of uses and benefits by the Multiple Use and Sustained Yield Act (1960), which states that *"…it is the policy of Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes."* Managing land for multiple uses can result in stakeholder conflict when one stakeholder's use of the resource is affected by, or incompatible with, the use of the resource by another stakeholder. Conflict between recreational users of national forest land (e.g., hikers, birdwatchers, and snowshoers vs. gun hunters and snowmobilers) is at the heart of a recent court ruling requiring the United States Forest Service to consider closing 14 semi-primitive areas containing about 27,000 ha of the approximately 400,000 ha Huron-Manistee National Forest to recreational gun hunting. The Huron-Manistee National Forest is popular with outdoor recreationists (with about 4 million estimated visits during 2007), and recreational hunting is one of the most popular recreational activities, with about 25% of Huron-Manistee National Forest visits being for the primary purpose of hunting (U.S. Department of Agriculture [USDA] 2009). Closing portions of this National Forest to gun hunting has the potential to negatively affect hunters pursuing a multitude of game species found on these lands, including white-tailed deer, black bear (*Ursus americanus*), wild turkey (*Meleagris gallopavo*), and ruffed grouse. In a 27 January 2012 decision, the USDA Forest Service officially selected a management alternative detailed within the Final Supplemental Environmental Impact Statement (USDA 2012) that will continue to allow gun hunting at these 14 areas; however, this decision has since been appealed and may not be settled for some time. This particular user conflict scenario provides a useful setting for examining how economic benefits accruing to a particular user group would be affected when access privileges are reduced or eliminated.

2.3 Methods

2.3.1 Data

To examine how the location of hunter trips are influenced by the different levels of attributes at potential hunting sites, I first describe the various hunting site options within the hunter's choice set. For the purposes of this study, each of the 83 counties in Michigan is defined as being a hunting site alternative (see figure 1.1 in dissertation chapter 1). Developing a predictive model of hunter site selection and ultimately estimating the economic benefits to hunters from hunting site attributes requires information on hunter site choice and trip frequency to each site, and the levels of attributes available at each hunting site (e.g., harvest rate of game species, amount of publicly accessible hunting land).

Information on hunter site choice and site visitation frequency is obtained from the Michigan 2008–2009 Upland Game Harvest Report survey (Michigan Department of Natural Resources 2009) administered by the Michigan Department of Natural Resources (MDNR). This was a mail survey sent to 9,987 randomly selected people who were eligible to hunt small game in Michigan, with up to two follow-up questionnaires sent to non-respondents. Questionnaires were undeliverable to 242 people and were returned by 5,532 people, yielding a 57% response rate. For this analysis, only Michigan residents who hunted ruffed grouse in Michigan (n = 1,280) are included. Information on the number of trips to a site is generally required to estimate a travel cost model, however, the Upland Game Harvest Survey provides data on the number of days spent hunting, as opposed to the number of trips. To convert the reported number of days hunted into an estimate of hunting trips, I relied on relationships between hunting trips, hunting days, and travel distance that were identified using data from a 2003 survey of Michigan deer hunters. Using this data to estimate multiple travel cost models in which both reported trips and estimated trips are used as the dependent variable, I identified several plausible formulations of this relationship that generated economic benefits estimates that closely approximated benefits estimates obtained when using hunter-reported trips (see dissertation chapter 1). The best formulation was used to convert grouse hunting days into grouse hunting trips. Using this formulation converted 12,006 days hunting into 9,666 trips, which is about 1.24 days per hunting trip.

The variable *Price* was computed to reflect the round-trip time costs and driving costs from each hunter's residence to each of the 83 different counties. For each survey respondent, PC*Miler software was used to calculate the driving distance from the individual's zip code of residence to the zip code that is closest to the geographic center of each hunting site. Driving cost was computed by multiplying the per-mile vehicle operating cost by the distance traveled. The per-mile operating costs, excluding fixed costs such as insurance, were 40.2 cents per mile based on data published annually by the American Automobile Association (2008). The other component of travel costs was the opportunity cost of the time the individual spent to travel to the site. For this, the individual's address was used in conjunction with ArcGIS® software to assign each individual the United States Census Bureau median household income for their census tract of residence (Cameron 1992, Kahn 1998). Some individual's addresses were not identifiable; for these cases, individuals were assigned the median household income for their zip code of residency. These Census-based median household income figures were used as proxies for individuals' annual wage rates. Using the same data and travel cost modeling approach as described in the previous paragraph, I found that for two different types of hunting, substituting median household income estimates (based on zip code of residence) for individual-reported income had a negligible effect on economic benefits estimates (see dissertation chapter 1). Though some debate continues regarding the appropriate portion of an individuals' wage rate to attribute to the time component of travel cost, the recreation literature has generally accepted that the opportunity cost of time spent driving ranges from a third of the hourly wage rate to the full wage rate (Parsons 2003). For this analysis, one-third of the wage rate was used. Wage rate was computed by dividing the Census-based median income figure by the number of work hours per year. Travel time was calculated using an average trip speed of approximately 64 km (40 miles) per hour.

Data on seasonal ruffed grouse harvest data was obtained from the Michigan Upland Game Harvest Report surveys implemented by the MDNR. In Michigan, the ruffed grouse hunting season is approximately three months long, beginning 15 September and lasting through 1 January, with the exception that ruffed grouse hunting is not permitted during the firearm deer season (15–30 Nov). Using hunter survey responses from the 2006–2007, 2007–2008, and 2008–2009 Michigan Upland Game Harvest Report surveys, a per-day ruffed grouse harvest rate, averaged over three years, was produced for each county in Michigan.

2.3.2 Economic Model

The travel cost method is commonly used to estimate economic benefits associated with outdoor recreation (Parsons 2003). Understanding the relationship between the cost (price) of a recreational trip and the number of trips taken allows the construction of a demand relationship between these two variables, which then can be used to estimate economic benefits. Economic benefits, as defined in this paper, represent the difference between the greatest amount an individual would be willing to pay to participate in the activity and the trip-related expenses actually incurred to participate. If an individual participates in the recreational activity, then the activity must be worth at least as much as the cost incurred to participate. The individual realizes an economic benefit when the amount the individual would be willing to pay for the recreational experience exceeds the cost of the experience.

As my primary research interest was to estimate economic benefits associated with publicly accessible hunting land, I used a multiple-site approach known as the random utility travel cost model (Freeman 1993, Grijalva et al. 2002, Knoche and Lupi 2007). The random utility travel cost model allows the estimation of the economic benefits of site attributes by comparing the attribute levels to the costs of traveling to those hunting sites (Haab and McConnell 2002, Lupi et al. 2003, Parsons 2003, Kotchen et al. 2006). The modeling of hunter site choice, estimation of site attribute parameters, and calculation of economic benefits for publicly accessible land within this paper closely follows the economic theory and econometric methods described in detail in dissertation chapter 1, section 1.3.1.

2.4 Results

Despite the Upper Peninsula having only about 3% of Michigan's residents, 27.4% of Michigan ruffed grouse hunters live in the Upper Peninsula (Table 2.1). Likewise, about 13.5%

of Michigan residents reside in the Northern Lower Peninsula but 31.8% of ruffed grouse hunters live in this region. The Southern Lower Peninsula has the majority of Michigan's ruffed grouse hunters but comprises a smaller share of the total population of their regions than do the northern regions. Regional trends are also evident regarding hunting site selection. Upper Peninsula residents are more likely to hunt in the county they live in and are more likely to hunt in two or more counties, and they also drive the shortest distance to hunting sites. Southern Lower Peninsula residents are least likely to hunt in their county of residence or hunt in two or more counties, and they drive the furthest distance to hunting sites, whereas hunting site selection figures of Northern Lower Peninsula residents lie between the other two regions. Comparing Michigan ruffed grouse hunter demographics to Michigan hunters in general, we see that the mean age of Michigan hunters (for all species) is 42, and percent male composition of hunters is 92% (Frawley 2006), both of which are below the ruffed grouse hunter age and gender statistics for all 3 regions in Michigan. However, care should be taken with these demographic comparisons as Frawley's figures are from the 2005 hunting seasons, and the ruffed grouse figures for use in this analysis are from the 2008 hunting season.

Table 2.1. Michigan ruffed grouse hunter demographics and hunting site choices by region of residence, 2008–2009

REGION OF RESIDENCE	PUBLICLY ACCESSIBLE HUNTING LAND BY REGION (1000S HA)			HUNTER DEMOGRAPHICS AND HUNTING SITE CHOICES					
	Federal	State	CFA	% living in each region	Avg. Age	% male	% hunting in county of residence	% hunting in ≥2 counties	Avg. distance from residence to site hunted (km)
Upper Peninsula	724	699	887	27.4	47.3	94.9	87.2	29.3	52.5 km
Northern Lower Peninsula	888	989	17	31.8	49.0	96.6	64.6	27.8	108.6 km
Southern Lower Peninsula	6	155	2	40.8	48.3	98.3	12.5	21.6	307.4 km
Statewide	1,617	1,842	905		48.2	96.8	49.5	25.7	174.3 km

For the economic model of hunter site choices, the *Price* variable represents the implicit price an individual hunter pays to hunt at a particular site. With most goods purchased in the marketplace, as price of the good increases, holding all else constant, the quantity of the good purchased decreases. The same holds true here; price had a negative effect on number of trips taken by a hunter to a specific county ($P<0.001$), meaning that increases in travel cost to a hunting site, all else equal, result in fewer hunting trips to that hunting site (Table 2.1). As expected, the 3-year average of ruffed grouse harvested per day (*Harvest*) and amount of the 3 types of publicly accessible hunting land per county (*CFA*, *Federal*, and *State*) had a positive effect on number of trips taken by a hunter to a specific county ($P<0.001$). The region-specific dummy variables for the Upper Peninsula and the Northern Lower Peninsula both had a positive effect on number of trips to a county ($P<0.001$). Because of the non-linearity of the conditional logit model, the precise value of a single coefficient does not have a straightforward interpretation. However, when comparing across variables measured by the same metric (e.g., hectares of the different types of publicly accessible hunting land), the relative magnitude of these coefficients indicates the importance of a marginal increase in the level of a hunting site attribute in generating economic benefits to hunters.

Table 2.2. Conditional logit results for a travel cost model of ruffed grouse hunting in Michigan

Variable[a]	Coefficient	SE	P-Values
Price	−0.029	0.0003	P<0.001
Harvest (an additional ruffed grouse)	1.373	0.086	P<0.001
Federal (10,000 ha)	0.072	0.0044	P<0.001
State (10,000 ha)	0.169	0.0066	P<0.001
CFA (10,000 ha)	0.148	0.0071	P<0.001
Size (100 sq. km)	−0.049	0.003	P<0.001
Upper Peninsula	4.502	0.098	P<0.001
Northern Lower Peninsula	2.475	0.057	P<0.001
Statistics			
Log likelihood		−23,237	
Observations		1,280 hunters	

[a] *Price* = travel costs; *Harvest* = 3-year average of grouse hunted per day; *Federal*, *State*, and *CFA* = area of land in the county that is federally-owned land, state-owned land, and publicly accessible, privately-owned Commercial Forest Act, respectively; size = area of county; *Upper Peninsula* and *Northern Lower Peninsula* represent region-specific dummy variables (reference region is Southern Lower Peninsula).

Seasonal economic benefits for the three types of publicly accessible land individually in this model are estimated to be about $14.0 million for state-owned land, $11.1 million for CFA land, and $4.4 million for federally-owned land, with a total of $29.9 million in economic benefits annually to ruffed grouse hunters from the existence of publicly accessible hunting lands in Michigan. Average per hectare economic benefits for publicly accessible land are greatest for CFA land ($12.29/ha), followed by state-owned land ($7.61/ha) and federally-owned land ($3.94/ha). I also examined the effects of different assumptions regarding the percentage of wage rate and driving costs, as these assumptions will affect the economic benefits estimates detailed above (e.g., English and Bowker 1996, Layman et al. 1996, Bin et al. 2005, Edwards et al. 2011). Relative to using 1/3 wage rate, economic benefits are reduced by 7% when using 1/4 of wage rate, whereas using 2/5 of wage rate increases economic benefits by 6%. Similarly, decreasing the travel rate by approximately 16 km (10 miles) per hour reduces economic benefits by 10%, whereas increasing the travel rate by approximately 16 km (10 miles) per hour increases economic benefits by 6%.

The vast majority of publicly accessible hunting land is in the Upper Peninsula and Northern Lower Peninsula of Michigan, with public lands in these areas generating substantial economic benefits for ruffed grouse hunters. The approximately 2.3 million ha of publicly owned and privately-owned, publicly accessible hunting land in the Upper Peninsula of Michigan generates about $24.1 million in annual economic benefits for ruffed grouse hunters, and the approximately 1.4 million ha of publicly accessible hunting land in the Northern Lower Peninsula generates about $4.8 million in annual economic benefits. Publicly accessible land in the Southern Lower Peninsula generates about $160,000 in annual economic benefits. The Upper Peninsula generates the greatest amount of average annual economic benefits per hectare ($10.45/ha) followed by the Northern Lower Peninsula ($3.42/ha). Despite the relative scarcity of publicly accessible hunting land in the Southern Lower Peninsula, combined with the proximity of this public land to high population centers (e.g., Metropolitan Detroit, Lansing, and Grand Rapids) where many hunters live, an average hectare of publicly accessible hunting land in this region is valued at $0.82/ha, less than an average hectare in the Upper Peninsula or Northern Lower Peninsula.

The above results illustrate the annual economic benefits to ruffed grouse hunters from the existence of the current levels of publicly accessible hunting land, relative to each type of publicly accessible hunting land (or all publicly accessible hunting land in each region) being completely eliminated. Although obtaining a clearer picture of the total economic benefits from publicly accessible hunting land allows managers to compare and contrast hunter economic benefits to state and federal land management costs, it does not provide insight into the extent marginal changes to the amount of publicly accessible hunting land would impact economic benefits from ruffed grouse hunting. Estimating hunter economic benefits from marginal changes in publicly accessible hunting land allows managers to better account for the benefits and costs of more realistic policy scenarios in which hunters compete with other stakeholders within the political and legal systems for preferential access to federal and state-owned lands. Eliminating approximately 27,000 hectares of National Forest land contained within 14 semi-primitive areas in Michigan is estimated to reduce economic benefits to ruffed grouse hunters by about $45,000 annually.

2.5 Discussion

Although the economic impacts of small game hunting generated by hunter retail expenditures have been well documented, almost no insight exists into the economic benefits small game hunters derive from their hunting experiences. This is surprising, given the popularity of small game hunting for species such as squirrel (1.7 million hunters, 21 million days), rabbit (1.5 million hunters, 17 million days spent hunting), quail (841,000 hunters, 9 million days), and grouse (812,000 hunters, 8 million days) (USDOI 2011). This research helps to address this gap in the literature by estimating economic benefits hunters realize from the use of publicly accessible hunting lands for ruffed grouse hunting.

Furthermore, this research is easily compared and contrasted with research by Knoche and Lupi (2012), which provides estimates of the annual economic benefits of public land accruing to firearm and archery deer hunters in Michigan. Annual economic benefits from publicly accessible hunting land to the average Michigan resident ruffed grouse hunter is estimated to be $338.98, which is about 310% and 280% greater than the annual economic benefits for the average Michigan firearm deer hunter ($82.94) and archery deer hunter ($88.71), respectively (Knoche and Lupi 2012). These results are intuitive within the context of the use of public land by deer and ruffed grouse hunters, given that 79% of ruffed grouse hunters hunted on public land at least once during the 2009 hunting season (Frawley 2012), compared to 41% for deer hunters during the 2006 hunting season (Frawley and Rudolph 2008). Additionally, increasing levels of public access variables, *Federal*, *State*, and *CFA*, were statistically significant and positive predictors of hunter site selection for both the ruffed grouse travel cost model presented in this paper as well as the two deer hunting travel cost models (Knoche and Lupi 2012). Both studies provide evidence that hunters for deer and grouse have stronger preferences for state-owned land and CFA land, relative to preferences for federally-owned land. Specifically, coefficients on Federal variables are markedly lower than State and CFA coefficients in the three models described above, with State and CFA coefficients being between 107% and 187% greater than the coefficients for Federal in the ruffed grouse model and firearm deer hunting model results, and between 43% and 46% greater than Federal in the archery deer hunting model results. State and CFA coefficients are relatively comparable, with the greatest coefficient difference in the firearm model where the CFA coefficient was 26% greater than the State coefficient. The multiple types of state land (e.g., state forests, recreation areas, game/wildlife areas) may offer enhanced access opportunities through more developed facilities and increased access points with CFA land offering similar access benefits via access points and roads built and maintained to facilitate timber management. In contrast, much of Michigan's federally-owned land consists of large, contiguous blocks of national forest land, which may present access challenges to recreational hunters.

Finally, despite the estimate that annual economic benefits to ruffed grouse hunters would be reduced by about $45,000 as a result of the proposed policy to ban hunting on approximately 27,000 hectares of national forest land, this amount is only a portion of the lost annual economic benefits from such a policy. This land, which is located in the Northern Lower Peninsula of Michigan, offers additional, diverse hunting opportunities including (but not limited to) white-tailed deer, black bear, wild turkey, and small game species such as rabbit and squirrel. The approximately 88,300 resident ruffed grouse hunters in Michigan are only a small portion of the 753,000 people that hunted in Michigan in 2006 (USDOI 2006), suggesting that reductions in economic benefits to all hunters might be many times the lost economic benefits to ruffed grouse hunters. A rigorous cost-benefit analysis of this policy would need to include these reduced benefits to these other hunters as result of the closure, as well as any changes in economic benefits to individuals whose outdoor recreational experiences are positively affected from the closure to hunting.

2.6 Management Implications

The results within are relevant to wildlife managers and policy makers who are considering whether to increase or enhance access for ruffed grouse hunters to both publicly-owned and privately-owned, publicly accessible hunting land. When faced with difficult decisions on how to best allocate limited public funds to provide the greatest benefit to hunters, anglers, and other outdoor recreationists, policy makers can look at this research and note that a relatively small group of outdoor recreationists (about 88,300 resident ruffed grouse hunters) derive about $30 million in annual economic benefits from the availability of publicly accessible hunting land. With the annual economic benefits associated with publicly accessible land for deer hunting in Michigan estimated to be over $80 million (Knoche and Lupi 2012), along with the economic benefits of this land for hunting other game species in Michigan (e.g., wild turkey, pheasant, waterfowl, black bear) and for participating in other types of outdoor recreation (e.g., angling, hiking, camping, mountain biking, cross country skiing) still unaccounted for, total economic benefits accruing to users of public lands in Michigan is hundreds of millions of dollars per year. The large economic benefits of state-owned land relative to federally-owned land and CFA land takes on more importance with the Governor of Michigan recently signing into law Senate Bill No. 248 (2012) which caps the amount of land the State of Michigan can own at 4.65 million acres (~1.88 million ha) until the legislature approves a strategic plan for buying and selling land. Although when (or if) the Michigan legislature will develop and approve a strategic plan is not clear, in the meantime the state is faced with sharp constraints on acquiring land for outdoor recreation purposes, land that this analysis shows to be quite valuable to a single segment of outdoor recreationists. Finally, this analysis also indicates that a policy proposal to close about 27,000 ha of national forest land from hunting would result in an annual loss of over $45,000 in economic benefits to ruffed grouse hunters in Michigan. Given the relatively stronger preferences for state-owned and CFA land over federally-owned land, it would be expected that similar management actions undertaken on these lands would result in greater losses of economic benefits to ruffed grouse hunters. Regardless, with the roughly 648,000 days spent hunting ruffed grouse in Michigan (Frawley 2012) being a small percentage of the estimated 11.9 million days spent hunting in Michigan in 2006 (USDOI 2006), reduced economic benefits to ruffed grouse hunters would likely comprise only a small portion of the losses realized by all hunters.

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CHAPTER 3: HARVESTING BENEFITS FROM HABITAT RESTORATION – THE INFLUENCE OF LANDSCAPE POSITION ON ECONOMIC BENEFITS TO PHEASANT HUNTERS

3.1 Introduction

The precarious state of the world's ecosystems has been well documented, with the Millennium Ecosystem Assessment (2005) characterizing 15 out of 24 ecosystem services as either being in decline or being used unsustainably. Substantial efforts focused on halting and reversing these declines have emerged, as evidenced by the tremendous growth of the ecological restoration and conservation biology research disciplines (Young 2000, Suding 2011) and the substantial financial resources dedicated to restoration and conservation efforts. According to Bernhardt et al. (2005), between 14 and 15 billion dollars were spent on over 37,000 river/stream restoration projects in the continental U.S. from 1990 to 2003. The United States Department of Agriculture (USDA) Conservation Reserve Program (CRP) has provided farmers and landowners with rental payments totaling approximately $43 billion between the years 1987 to 2014 (USDA 2014). Given the high cost of restoration and conservation efforts and the limited budgets available to achieve objectives, it is critical to develop a better understanding of whether and to what extent restoration and conservation efforts impact human well-being. Establishing and accounting for key linkages between basic biophysical structures and processes of the natural environment, the production of ecosystem functions and services, and finally, benefits to humans can allow researchers to characterize and quantify human benefits associated with costly habitat management actions (Haines-Young and Potchin 2010, de Groot et al. 2002). Characterizing the change in human well-being in monetary terms facilitates a cost-benefit analysis of potential restoration projects, and estimating the economic values of ecosystem services has been identified as a critical research area (Millennium Ecosystem Assessment 2005, Carpenter et al. 2006, Carpenter et al. 2009).

Ecological restoration actions have the potential to generate economic benefits to outdoor recreationists such as recreational hunters and anglers through improved catch or harvest rates at hunting or fishing locations. Several research efforts have involved estimating the economic benefits of changes in water quality for recreational anglers by establishing and accounting for the linkages between water quality, angler catch rate, and economic benefits. Lipton and Hicks (1999, 2003) and Massey et al. (2006) estimate the economic benefits resulting from changes in water quality to recreational anglers in the Mid-Atlantic region by linking expected catch models incorporating dissolved oxygen to recreation demand models of angling site choice. Another area of research involves estimating the economic benefits of water temperature mitigation strategies by linking water temperature, fish population/expected catch, and angler economic benefits. Huang et al. (2012) estimate the net economic benefits to recreational anglers from altered water releases and diversions designed to mitigate stream temperatures, and Johnson and Adams (1988) use a contingent valuation survey in conjunction with a fish production model to estimate the economic benefits to recreational anglers associated with increased streamflow.

The effect of restoration siting decisions and land use change on ecosystem service provision is receiving increasing attention from researchers with respect to a variety of ecosystems, including wetlands (see, e.g., White and Fennessy 2005, Lesta 2009, Moreno-Mateos et al. 2010), marine reserves (Leslie et al. 2003), alpine environments (Fontana et al.

2009) and floodplain/riparian environments (Oetter et al. 2004, Johnson et al. 2007). Researchers are also beginning to explore how spatial variability across landscapes affects the economic values of ecological outputs (Barbier 2012, Barbier et al. 2008, Sanchirico and Mumby 2009), and recreation demand modelers have begun incorporating landscape metrics such as landscape patch shape complexity, path variation, and total edge directly in recreation demand models (see Bestard and Font 2009). However, there is a lack of research linking such spatially explicit information regarding the provision of ecosystem services to outdoor recreationist (e.g., hunter, angler) behavior in order to evaluate economic benefits across a range of ecological restoration. This is surprising, given that the increasingly sophisticated spatially explicit ecological production functions which use landscape metrics to predict species abundance and richness measures for small mammals (Gibson et al. 2004), large mammals (Maier et al. 2005), avian species (Radford et al. 2005, Nielson et al. 2008), and fish and aquatic invertebrates (Pess et al. 2002, Arbuckle and Downing 2002) could be adapted to generate region-specific species abundance estimates for use in discrete choice recreation demand models of popular outdoor recreation activities such as away-from-home wildlife viewing (22.5 million participants), recreational fishing (33.1 million participants), and recreational hunting (13.7 million participants) (USDOI 2011). The discrete choice recreation demand approach is well-suited for incorporating spatially explicit outputs generated by an ecological production function as site quality attributes entering into the individual’s recreation demand decision, thereby allowing a tracing of economic benefits back to the original restoration actions. Accounting for these linkages could help improve targeting of restoration efforts of existing large-scale conservation programs such as the USDA CRP (Claassen et al. 2008) by providing resource managers with a greater understanding of the spatial distribution of landscape characteristics that would generate the largest conservation "bang for the buck".

In this chapter, I estimate the economic benefits of CRP land for pheasant hunters in Michigan by linking a spatially explicit model of pheasant sightings as a function of landscape characteristics developed by Nielson et al. (2008) (henceforth referred to as the Nielson Model) to a recreation demand model of pheasant hunting in Michigan. Further, I focus special attention on the extent to which economic benefits accruing to hunters are contingent upon the site-selection for CRP conservation actions. Agricultural landscapes have the potential to provide a wide variety of valuable ecosystem services (Swinton et al. 2007, Knoche and Lupi 2007), and provision of ecosystem services on such landscapes can be aided by targeted CRP conservation/restoration efforts on these lands. Researchers have found that CRP conservation generate benefits for sought-after games species, including white-tailed deer (Gould and Jenkins 1993) but especially for avian species such as waterfowl (Kantrud 1993, Reynolds 1994, Reynolds 2001), sage grouse (Schroeder and Vander Haegen 2011), northern bobwhite (Riffell et al. 2008) and ring-necked pheasant (Riley 1995, King and Savidge 1995, Haroldson et al. 2006, Nielson et al. 2008). However, despite the cost of the CRP and the documented relationship of CRP land to species populations sought by hunters and wildlife-watchers, efforts to estimate the economic benefits of CRP land to outdoor recreationists have been sparse. One exception is Hansen et al. (1999), who use a recreation demand model to estimate that the economic value of CRP land to pheasant hunters is about $80 million annually. Hansen et al. (1999) use a reduced form approach in which landscape characteristics presumed to influence pheasant population enter directly into the pheasant hunter site decision problem. While reduced form approaches are often employed by economists when information is lacking regarding the relationship between the biophysical structure/processes of an ecosystem and ecosystem service outputs (see, e.g., Hicks, 2004), such approaches do not fully characterize the complex nature of the ecological production process in which ecosystem services are generated through the underlying biophysical structure/processes. Furthermore, Newbold and Massey (2010) show that reduced form models can produce biased estimates of willingness to pay and recommend caution when using such models for ecosystem valuation. The availability of the ecological production function via the Nielson model overcomes the limitations associated with the reduced form approach and permits the construction of region-specific pheasant sightings which are a function of the amount and spatial distribution of relevant landscape characteristics such as agricultural land and CRP. This enables the examination of how hunter economic benefits vary contingent upon the selection of different geographic areas for CRP-related restoration.

3.2 Methodology

3.2.1 Ecological Production Function

Equation 1 illustrates the ecological production function referred to as the Nielson Model, which predicts pheasant sightings on a North American Breeding Bird Survey(BBS)[3] route *j* as a function of a time trend (yr), vector of landscape characteristics (ch_j), a vector of landscape size and distribution metrics (m_j) within a 1000m buffer of BBS route *j*:

[3] See Sauer et al. (2011) for summary of the North American Breeding Bird Survey and survey results and analysis from 1966 – 2010.

1) $Pheasant\ Sightings_j = \exp\left[\alpha_0 + \alpha_{yr}yr + \alpha_{ch}ch_j + \alpha_m m_j\right].$

The Nielson Model uses a Bayesian hierarchical modeling approach, fitting the model using Markov-chain Monte Carlo methods to model BBS counts of pheasants as overdispersed Poisson counts, with deviance information criterion (DIC) used as a guide to identify the most parsimonious model. For further details on developing and estimating the Nielson Model see the Nielson et al. (2008) paper; details relating to the adaptation and replication of the Nielson model for use as a site quality variable for this analysis are presented in Section 3.1.

3.2.2 Discrete Choice Recreation Demand Model

The discrete choice recreation demand model approach is well-suited for incorporating spatially explicit outputs generated by an ecological production function as site quality inputs into the individual's recreation demand decision, thereby allowing a tracing of economic benefits back to the original restoration actions. Estimating changes in economic benefits resulting from changes in recreation site attributes proceeds by examining the tradeoffs individuals make between the levels of quality attributes available at recreation sites and the costs associated with traveling to those sites (Parsons 2003, Haab and McConnell 2002). The behavioral foundation for the discrete choice recreation demand model is random utility theory, which posits that the indirect utility individual *n* receives from visiting a recreational site *j* (v_{nj}) is a function of travel cost (tc_{nj}) which varies by respondents as well as by recreational site, a vector of site quality characteristics (q_j), which vary only by recreational site, and e_{nj}, which is a random error term capturing unmeasured characteristics associated with a recreational site:

2) $$v_{nj} = \beta_{tc}tc_{nj} + \beta_q q_j + e_{nj}.$$

In equation 2, the larger a site quality parameter β_q is in absolute value, the greater the degree the site quality characteristic influences the indirect utility of individual *n*, whereas the sign on the parameter reveals whether the site characteristic has a positive or negative impact on individual *n*'s indirect utility. Economic theory suggests that indirect site utility decreases with increases in travel costs, and increases with site characteristics thought to be desirable, such as game species population.

Within random utility theory, an individual chooses to visit the site which offers the highest indirect utility. Thus, site *k* would be chosen over all other possible sites *j* when equation 3 holds, with *C* identifying the set of possible recreation sites in an individual's choice set:

3) $$\beta_{tc}tc_{nk} + \beta_q q_k + e_{nk} \geq \beta_{tc}tc_{nj} + \beta_q q_j + e_{nj} \; for\ all\ j\ in\ C.$$

Since the indirect utility function described in equation 2 contains an error term which captures un-measurable site characteristics (characteristics known by the individual but unobserved by the researcher), equation 4 is used to estimate the probability individual *n* chooses site *k*:

4) $$\text{Prob}\left(\beta_{tc}tc_{nk} + \beta_q q_k + e_{nk} \geq \beta_{tc}tc_{nj} + \beta_q q_j + e_{nj}\right) \text{for all } j \text{ in C.}$$

These probability functions can be interpreted as the expected demand functions for the sites. A 2-level nested logit model is used, with equation 5 defining the probability an individual chooses site k in nest l from the *J* possible sites, where θ_m are distributional parameters to be estimated (Haab and McConnell 2002).

$$5)\qquad \mathrm{Prob}(k,l) = \frac{\exp(\frac{v_{kl}}{\theta_l})[\sum_{j=1}^{J_l}\exp(\frac{v_{jl}}{\theta_l})]^{\theta_l - 1}}{\sum_{m=1}^{L}[\sum_{j=1}^{J_m}\exp(\frac{v_{jm}}{\theta_m})]^{\theta_m}}.$$

The probability individual *n* takes a trip to site *k* in nest l is a function of indirect utility v associated with site *k* in nest l, as well as the indirect utility associated with substitute sites. This form allows sites within a nest to have error terms that are more correlated with other sites within the nest than with sites in a different nest. Maximum likelihood estimation was used to identify the values for the coefficients which maximize the likelihood function, *Li*, defined in equation 6. In equation 6, $r_{kl} = 1$ if individual *n* visited site *k* in nest l and equals zero otherwise, and $\mathrm{Prob}(k,l)$ is the nested logit form from equation 5:

$$6)\qquad Li = \prod_{l=1}^{L}\prod_{k=1}^{J_l}\mathrm{Prob}(k,l)^{r_{kl}}.$$

3.2.3 Estimating Economic Benefits for Site Quality Changes

Once parameters in the indirect utility function have been estimated, it is then possible to estimate the changes in economic benefits resulting from changes in the levels of recreational site attributes or changes in available sites. The economic benefits associated with a change at a particular site or sites is given by the difference in the expected maximum utility with and without changes in the levels of site attributes and/or site access, and this difference is divided by the marginal utility of income. When the site probability functions take the nested logit form, this measure of economic benefits is defined in equation 7:

7) $$WTP = \frac{1}{\beta_{tc}} \ln \frac{\sum_{m=1}^{L} [\sum_{j=1}^{J'_m} \exp(\frac{v'_{jl}}{\theta_l})]^{\theta_m}}{\sum_{m=1}^{L} [\sum_{j=1}^{J_m} \exp(\frac{v_{jl}}{\theta_m})]^{\theta_m}}.$$

In equation 7, *WTP* denotes the change in per-trip economic benefits resulting from a quality and/or access change at one or multiple sites; v are the indirect utilities for sites in the original state and v' are the indirect utilities for sites after the quality and/or access changes (Haab and McConnell 2002). This is a "per-trip" measure in the sense that it's units refer to trips to all sites in the choice set. An estimate of the seasonal economic benefits to recreationists from a quality change is obtained by multiplying *WTP* by the total number of trips individuals made to the recreational sites within the choice set within the season of interest.

3.3 Survey and Attribute Data

Information on pheasant hunter site choice and site visitation frequency was obtained from the 2008–2009 Michigan Upland Game Harvest Report mail survey (MDNR, 2009) administered by the Michigan Department of Natural Resources (MDNR) (n=9,987; 57% response rate)[4]. The analysis included only individuals (*n* = 682) who reported: a) hunting pheasant during the 2008 Michigan pheasant hunting season, b) the county (or counties) in

[4] Even though the survey achieved a reasonably high response rate, we do not have access to the data on nonrespondents and a nonresponse study was not conducted.

which they hunted pheasant, and c) the number of days spent hunting in each county. Consistent with the spatial resolution of the survey data, hunting sites are defined at the county level. This survey provides hunting site choice information for 682 hunters who reported spending a total of 3265 days hunting pheasant during the pheasant hunting season.

For each hunter, the survey data contains the number of days hunted at each county visited by the hunter. To run the site choice model it was necessary to convert these days into trips per county. If days were converted into trips using a simple mean number of days per trip, it would cause difficulties if trips to farther sites are more likely to be multiple day trips. Instead a distance-based conversion was used which was developed using data for other hunting activities where both days and trips were known (see dissertation chapter 1). Dissertation chapter 1 estimated travel cost models for multiple hunting activities and compared welfare estimates using hunter-reported trips with estimates using a variety of plausible relationships between trips, days and distance to hunting sites. That analysis found many distance-based conversions that closely approximated those using hunter-reported trips and found one that only had an approximately 1% difference. The latter conversion (also described and applied in dissertation chapter 2) was applied to this data, generating a total estimate of 3070 pheasant hunting trips for the 682 pheasant hunters in the model.

To account for multiple trips from the same individual when estimating the discrete choice model, the frequency weighting procedure was used in Stata® to weight each observed site choice by the estimated number of trips an individual took to the site. Individuals who took trips to multiple sites have a choice set for each unique site visited, weighted by its respective number of visits. The clustered-robust standard errors procedure is used to account for the correlated error terms across different site choices by the same individual.

The vast majority of pheasant hunting in Michigan takes place in Michigan's Lower Peninsula. Of the 2008-2009 Upland Game Harvest Survey respondents reporting hunting pheasant during the 2008-2009 Michigan pheasant hunting season (n=871), only 45 (5.2%) lived in the Upper Peninsula. Further, only four of the 45 individuals living in the Upper Peninsula reported hunting a county in the Lower Peninsula (8.9%) and only five of the 826 individuals living in the Lower Peninsula reported hunting a county in the Upper Peninsula (0.6%). Thus, it appears likely that most hunters do not consider counties outside their peninsula of residence when evaluating potential pheasant hunting site options. Finally, the majority of the Upper Peninsula is closed to pheasant hunting – 10 out of 15 counties in the Upper Peninsula have no legal pheasant hunting season, with only one county in the Upper Peninsula having all of its land open to pheasant hunting. Given both the limited pheasant hunting in Michigan's Upper Peninsula and limited travel between the Upper and Lower Peninsulas for the purpose of pheasant hunting, only hunters and counties in Michigan's Lower Peninsula are included in the choice model. Because there are also likely to be regional differences within Michigan's Lower Peninsula, with similarities between hunting sites within regions and differences between hunting sites across regions, two nests are defined in this nested logit model of pheasant hunting. The first nest, called the *No_Extended_Season* nest, consists of counties in the Northern Lower Peninsula and counties located in the western portion of the Southern Lower Peninsula which do not have sizeable portions with the extended December pheasant hunting season (MDNR 2008). The other nest, called the *Extended_Season* nest, contains the other counties in Michigan's Lower Peninsula. See Figure 3.2 for the delineation of nest membership.

County attributes used as independent variables in the nested logit model include the travel cost (time cost + vehicle operating cost) associated with traveling to and from a county, the amount of publicly accessible hunting land in the county, the size of the county, and the pheasant sightings estimate from the Nielson Model summed across all landscape parcels in the county. The variable *Price* is computed to reflect the round-trip travel costs from each hunter's residence to each of the 68 counties in Michigan's Lower Peninsula. PC*Miler® software was used to calculate the driving distance from each individual's zip code of residence to the zip code that is closest to the geographic center of each hunting site. Vehicle operating cost was computed by multiplying the per-mile vehicle operating cost by the distance traveled. Per-mile vehicle operating costs, which includes average per-mile costs for gas, maintenance and tires, was 17.0 cents in 2008 (AAA 2008). Per-mile depreciation rates were calculated using 15,000 miles driven annually as a reference point, with 10,000 and 20,000 miles driven resulting in decreased deprecation and increased depreciation of about 3.5 cents per mile and 3.8 cents per mile (AAA 2008), respectively. The midpoint of these two estimates (3.65 cents) is added to per-mile operating costs of 17.0 cents to obtain a per-mile vehicle operating cost of 20.65 cents. The other component of travel costs is time cost, which is the opportunity cost of the time required for round-trip travel to the site. To estimate an opportunity cost of time for each individual, the individual's address is used in conjunction with ArcGIS® software to assign each individual the United States Census Bureau median household income for their census tract of residence.[5] Individuals whose addresses were not recoverable using ArcGIS software (4.3% of the population) were assigned the median household income for their zip code of residency. To value the time component of travel cost, I follow the many studies in the recreation literature by using one-third of the wage rate (Parsons 2003). Wage rate was computed by dividing median income by the number of work hours per year (2080). An estimate of travel time was computed using an average trip speed of approximately 64 km (40 miles) per hour.

Other county attributes in the model include the variable *Public_Access*, consisting of the total number of acres of publicly accessible hunting land in each county. This includes federally-owned land, state-owned land, and privately-owned land that is publicly accessible to hunters through Michigan's Commercial Forest Act program. Finally, the variable *Size* reflects the geographic area of each county. In models using aggregate sites such as the 68 counties in this choice set, many studies include a measure of group size to mitigate potential differences in site heterogeneity (Haener et al. 2004). However, unlike some recreation such as fishing at lakes (Lupi and Feather 1998), pheasant hunting takes place at myriad places across the landscape, and therefore does not have easily defined access points. Never the less, differences in the amount of potential hunting locations across counties is controlled for by including the variables for publicly accessible land and geographic size of a county.

[5] When lacking survey data on individual income, recreation demand modelers often assign individuals a proxy for income via aggregate measures which characterize income at a geographic scale, such as median household income for census areas or zip codes (see, e.g., Heberling and Templeton (2009), Whitehead et al. (2009), Henderson et al. (1999), and Jakus et al. (1997)). This approach is based on the tendency of individuals to cluster geographically by socioeconomic status. If membership in the sub-group of interest (in this case, pheasant hunters) is correlated with higher (or lower) median incomes compared to others in their census tract, then welfare estimates could be biased downwards (upwards).

3.3.1 Computing Pheasant Sightings using the Nielson Model

For the *Pheasant_Sightings* variable, the Nielson Model ecological production function is used which predicts pheasant sightings obtained from the BBS as a function of landscape characteristics obtained from the National Land Cover Dataset (NLCD) and the USDA. To develop this model, Nielson et al. (2008) estimated pheasant sightings associated with landscape characteristics of 3,888 BBS routes. Equation 8 is Nielson et al.'s (2008) study area-wide model (which I refer to as the Nielson Model), which estimates the number of pheasants counted along a survey route in year *i*.

8) $$\begin{aligned} T_i = \exp[&1.5451 - 0.0059(\text{year}_i - 1996) + 0.2748(\text{NLCD Woody Vegetation}) \\ &+ 0.7040(\text{NLCD Herbaceous Vegetation}) \\ &+ 1.4949(\text{NLCD Agricultural Field}) - 0.6584(N\text{LCD Agricultural Field})^2 \\ &+ 0.1991(C\text{RP Herbaceous Vegetation}) - 0.0526(\text{Mean Patch Size}) \\ &- 0.1702(\text{Interspersion and Juxtaposition Index})] \end{aligned}$$

The Nielson Model was originally fit using landscape characteristic data from the 1992 NLCD and USDA CRP data, and landscape metrics Mean Patch Size (MPS) and Interspersion and Juxtaposition Index (IJI). Four NLCD landscape characteristic categories are included in the model: NLCD Woody Vegetation (includes NLCD classifications of shrubland and orchards/vineyards), NLCD Herbaceous Vegetation (grassland/herbaceous and pasture/hay), NLCD Agricultural Field (row crops, small grains, and fallow) and CRP Herbaceous Vegetation (14 types of herbaceous CRP enrollment classifications). Finally, two landscape patch metrics –

MPS and IJI – are included in the model as well and were computed using FRAGSTATS v4 (McGarigal et al. 2012). Variables in equation 8 were calculated using a 1000m buffer around the BBS route. Assuming a straight BBS route, this corresponds to an area of 19,487 acres. Nielson et al. (2008) also estimated the model using buffers of 400m and 700m, however, 1000m was used for the final model as this approach yielded the lowest deviance information criterion and the fewest variables.

In replicating the Nielson Model to estimate site-specific pheasant sightings estimates in Michigan, I closely followed the approach described in Nielson et al. (2008) while taking advantage of recently available landscape characteristic data. Using 2006 NLCD and Michigan USDA CRP geolocation data[6], a fishnet procedure was employed using ArcGIS software to construct a grid consisting of 19,487 acre landscape parcels which overlays Michigan's Lower Peninsula (see Figure 3.1). Landscape characteristic data for each of these parcels was used in equation 8 to produce a pheasant sightings estimate for that parcel. Pheasant sightings estimates for each parcel were used to construct total pheasant sightings for each county. For landscape parcels which overlap two or more counties, the pheasant sightings estimate for that landscape parcel was proportionally allocated to each county.

[6] Access to otherwise protected USDA CRP data was granted through a USDA Section 1619 Cooperator Memorandum of Understanding issued by the Farm Service Agency. This agreement prohibits the disclosure of the geospatial USDA CRP data, and as such, we do not map Michigan-level USDA CRP data in our figures or otherwise provide information on USDA CRP location within this paper.

Figure 3.1. Michigan lower peninsula counties and landscape parcels used to estimate pheasant sightings

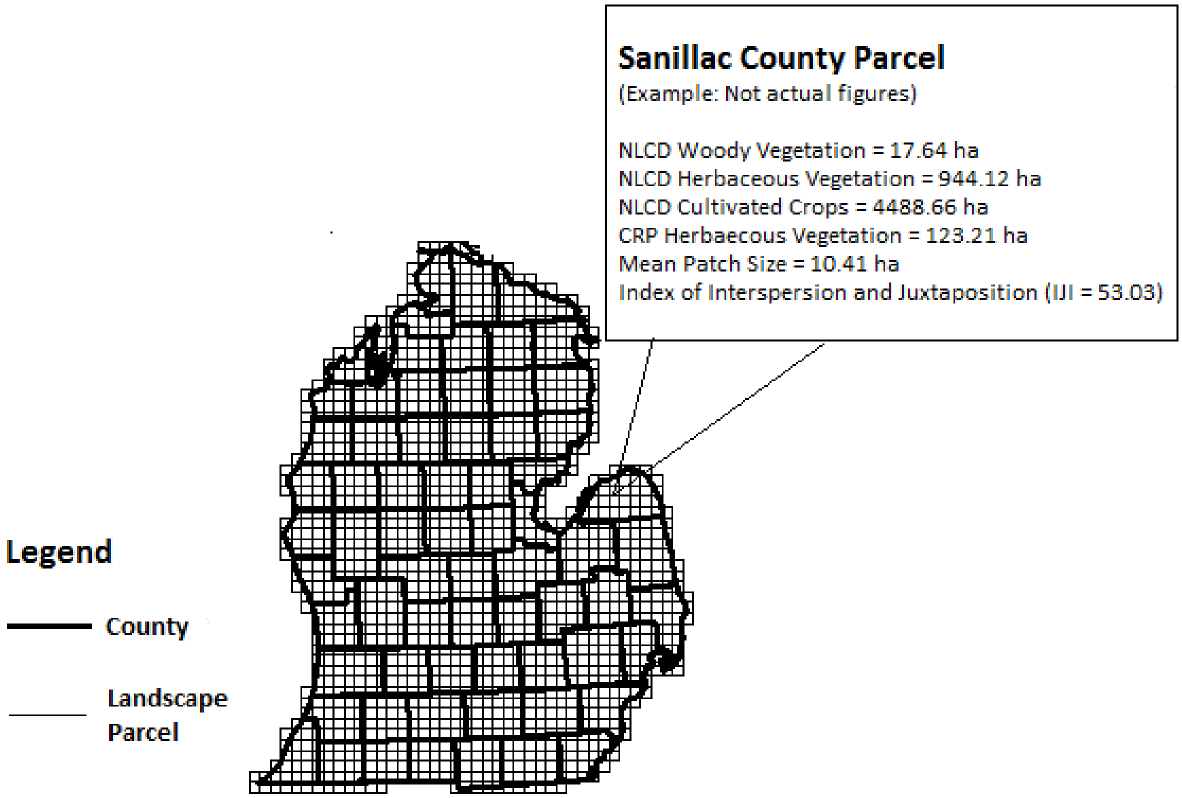


Figure 3.2 compares the county-level pheasant sightings predicted by the Nielson Model to county-level pheasant brood observations through MDNR mail carrier surveys. The MDNR mail carrier survey is an annual survey conducted during the summer months in which cooperating rural mail carriers within 43 southern Michigan counties record the number of pheasant broods observed during the survey period. The 43 counties were selected for the mail carrier survey based on the potential of habitat in that county to support wild pheasant populations - 41 of these 43 counties were identified in the 2013 National Wild Pheasant Conservation Plan (Association of Fish and Wildlife Agencies 2013) as having wild pheasant range. Further, MDNR has found the mail carrier data to be a good predictor of pheasant

abundance and fall harvest (Luukkonen 1998). In Figure 3.2, the MDNR mail carrier survey estimates reflect the total brood observations in each county for the previous ten surveys (2004 – 2013). To facilitate comparison of MDNR mail carrier survey brood observations and the pheasant sightings estimates from the Nielson Model, only Nielson Model estimates for the counties surveyed via the MDNR mail carrier survey are included in Figure 3.2. County-level estimates for the MDNR mail carrier survey and the Nielson Model are segmented into quartiles to further aid comparison.

Figure 3.2. County-level estimates of pheasant abundance from the Nielson model and a MDNR mail carrier pheasant brood survey and the delineation between regional nests in nested logit model

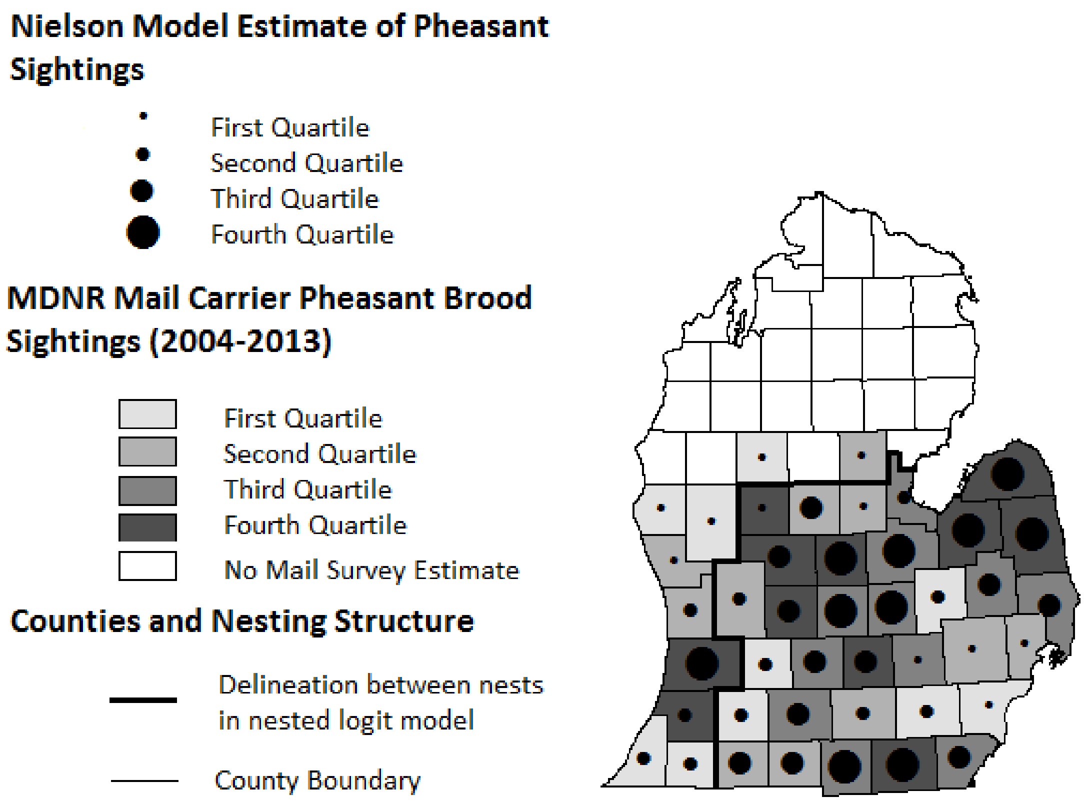


Figure 3.2 illustrates similarities between the Nielson Model pheasant sightings estimates and pheasant sightings estimated via the MDNR mail carrier surveys. The pearson correlation coefficient is used to characterize the relationship between the Nielson Model sightings predictions and MDNR mail carrier brood observations. The estimated pearson correlation coefficient of + 0.62 indicates a positive correlation between MDNR mail carrier pheasant brood observations over a ten year period and the county-level pheasant sightings obtained from application of the Nielson Model.

3.4 Results

The nested logit model results are displayed in Table 3.1. *Price* is statistically significant and negative, meaning that as the cost of traveling to a hunting site increases, the utility associated with that site (and the probability of selecting that hunting site) decreases. As the number of pheasant sightings and the amount of publicly accessible hunting land increases at a hunting site, the utility associated with that hunting site increases. Dissimilarity parameters represent the interdependence of unobserved utility in each nest; a dissimilarity parameter of one indicates that there is no correlation in unobserved utility between sites in a given nest. In the model, *Extended_Season* and *No_Extended_Season* are statistically signficant and different than one, meaning that counties within each respective nest are similar in unobserved utility to other sites in that nest.

Table 3.1. Nested logit model of pheasant hunting in Michigan

Independent Variables	**Coefficient**	**Clustered Robust SE**	***P Value***
Price	-0.053	0.005	P<0.01
Pheasant_Sighting	0.013	0.002	P<0.01
Public_Access (10,000 acres)	0.040	0.017	P<0.01
Size (100 sq. miles)	-0.022	0.031	P = 0.48
Dissimilarity Parameters[a]			
Extended_Season	0.603	0.063	P<0.01
No_Extended_Season	0.621	0.069	P<0.01
Model Statistics			
Log-Likelihood		-5966.6	
Wald chi2(4)		103.51 (P<0.0001)	
Observations		682 individuals; 3070 choice occasions	

[a] P values for the dissimilarity coefficients are estimated against the null hypothesis that the coefficient is equal to one.

3.4.1 Pheasant Hunter Benefits of CRP Land

Economic benefits of CRP land to Michigan pheasant hunters are estimated by examining how hunter welfare changes when all 213,674 acres of CRP land is converted to the 2006 NLCD cultivated crops landscape characteristic[4]. First, the per-trip economic benefits of

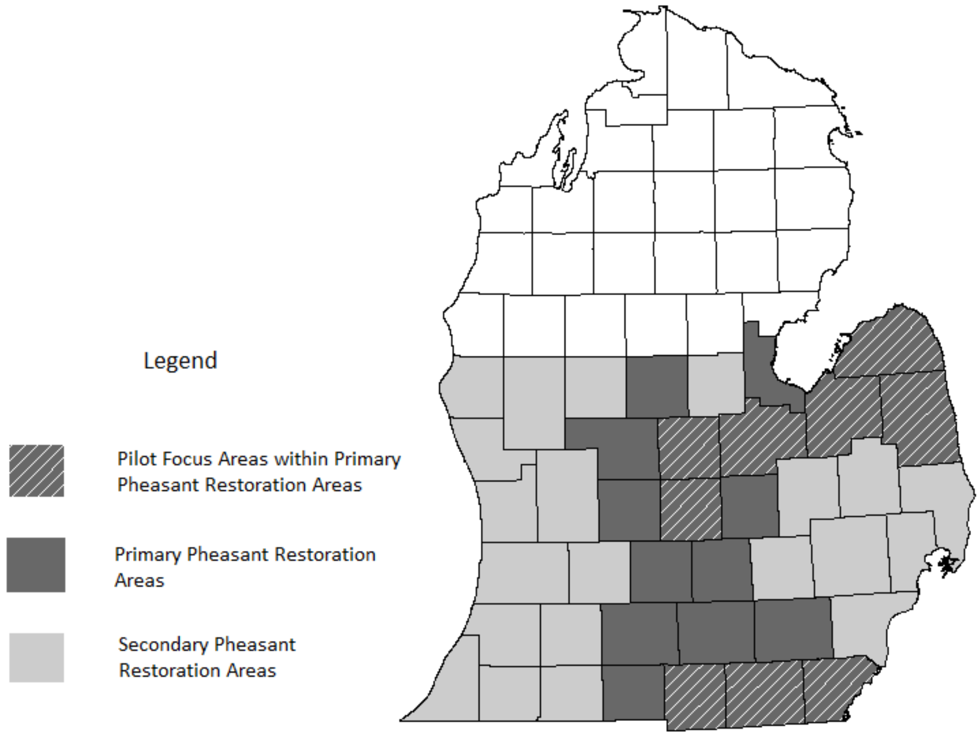
[4] We use recently available 2006 NLCD data to estimate pheasant sightings using the Nielson Model, while Nielson et al. (2008) used 1992 NLCD data. For our purposes, the primary difference between 1992 NLCD agricultural field category and the 2006 NLCD cultivated crops category is that 2006 NLCD cultivated crops includes land used for orchards and vineyards, while the 1992 NLCD data separately accounts for orchards and vineyards. The Nielson et al. (2008) model includes orchards/vineyards in the NLCD woody vegetation category. We felt the benefits from using 2006 NLCD data vastly outweighed this minor discrepancy in how orchards/vineyards were categorized within the 1992 and 2006 NLCD datasets.

CRP land for pheasant hunters in Michigan are estimated (equation 7). The conversion of all CRP land to NLCD cultivated crops results in a per-trip welfare loss of about $1.82. To obtain an estimate of the reduction of seasonal economic welfare from this conversion, this per-trip welfare loss was multiplied by the estimated number of trips taken in the season for all pheasant hunters represented in the model. The estimate of the total number of trips (183,081) is obtained by multiplying the total number of pheasant hunters (43,144) by the percentage of these hunters both living in the Lower Peninsula and not hunting in the Upper Peninsula (94.3%) and by the estimated number of hunting trips per person (4.5). Thus, the total seasonal welfare loss to hunters from this conversion is estimated to be about $332,600 which yields a mean per acre CRP value for pheasant hunters of $1.56.

3.4.2 Michigan Pheasant Restoration Initiative (MPRI) Policy Scenario

The MDNR has partnered with the U.S. Fish and Wildlife Service, Michigan Department of Agriculture, and non-governmental organizations such as Pheasants Forever and Michigan United Conservation Clubs to implement the Michigan Pheasant Restoration Initiative (MPRI). The stated objective of the MPRI is to establish 10 cooperatives (roughly 10,000 acres in size) in Michigan throughout 3 pilot areas (see Figure 3) and restore 1,200 – 2,000 acres of pheasant habitat in each of these cooperatives.

Figure 3.3 MPRI priority pheasant restoration areas within Michigan's lower peninsula



To estimate the economic benefits to pheasant hunters associated with achieving the MPRI restoration goal, it is assumed that the high-quality pheasant habitat restored via the MPRI will have the same characteristics as land enrolled under the USDA herbaceous CRP category. To ensure that the policy analysis within is consistent with the Nielson Model, it is assumed that each of the nine counties in the MPRI pilot focus area will have one cooperative consisting of a single 19,487 acre landscape parcel. The midpoint of the MPRI cooperative level restoration goal is selected, thereby assuming that 1,600 acres of herbaceous CRP land is restored within a single 19,487 acre landscape parcel in each county, for a total restoration of 14,400 herbaceous CRP acres across the nine counties. For each landscape parcel which is completely within the borders of an MPRI pilot focus area county, a new pheasant sightings estimate for that landscape is generated by converting 1,600 acres of cultivated crops within that landscape to herbaceous CRP land. These new pheasant sightings estimates are used to estimate the economic benefits associated with multiple policy scenarios in which different landscape parcels are selected for location of the MPRI cooperatives. These policy scenarios provide important insights regarding the extent to which economic benefits accruing to hunters vary depending on ecological restoration siting decisions.

For the previous analysis regarding the seasonal economic benefits of CRP land to pheasant hunters in Michigan, information on the size and location of CRP patches enabled the accounting of changes in landscape metrics MPS and IJI resulting from the conversion of these patches to cultivated crops. However, such precision with MPS and IJI is not possible in the MPRI analysis due to uncertainties regarding the size and location of the cultivated crop patches converted to herbaceous CRP land. For insight into how this conversion might impact MPS (and hence impact pheasant sightings measures and hunter welfare), three assumptions are used regarding the patch size of the cultivated crops land area converted to CRP. First, the change in hunter welfare is estimated using the assumption that the 1,600 acres of restored CRP land in each landscape parcel has a mean patch size equal to the mean patch size of all herbaceous CRP patches throughout Michigan (6.3 acres), and that these patches are not directly adjacent to other CRP patches. This results in 254 patches of herbaceous CRP added to the landscape parcel. Second, given the potential of the cultivated crop conversion to occur on land currently adjacent to herbaceous CRP land, hunter welfare is estimated using the assumption that 50% of the herbaceous CRP patches are placed adjacent to existing patches. This results in an addition of 127 patches to the landscape. Finally, the welfare implications of restoration was examined under the assumption that all restored herbaceous CRP is adjacent to existing herbaceous CRP, thus creating zero new patches and resulting in no change in MPS in that landscape parcel.

It is more challenging, however, to develop plausible scenarios for how the conversion of cultivated crops to herbaceous CRP land would affect the IJI variable. As IJI depends on the relative proportion of patch adjacencies, the direction and the extent that IJI would be impacted as a result of the conversion of cultivated crops is ambiguous. Welfare estimates in Table 3.2 can thus be taken to be reflective of an "average" landscape parcel in which IJI does not change with the conversion of the cultivated crops to herbaceous CRP. Additonal examination revealed that a +/- one standard deviation change in IJI results in a change to hunter welfare (relative to the results in Table 3.2) of approximately +/- 20%.

In Table 3.2, three assumptions on MPS and the assumption of constant IJI are used to examine how economic benefits accruing to pheasant hunters from the MPRI vary across three different restoration siting scenarios. The change in pheasant sightings in each landscape (across the nine MPRI pilot focus areas) resulting from the conversion of 1600 acres of agricultural land to herbaceous CRP was computed, and the landscape with the minimum, median, and maximum pheasant sightings increases in each county was identified. In the first scenario, "Minimum", it is assumed that for each of the nine counties, the conversion occurs within the landscape parcel in each county that realizes the smallest increase in pheasant sightings as a result of the conversion. Essentially, the policy-relevant analogy is that the MPRI managers selected the worst possible landscape parcel to locate the cooperative in each of the nine counties. In the second scenario, "Median" it is assumed that the conversion occurs within the landscape parcel in each county that realizes the median increase in pheasant sightings in that county, and in the third scenario, “Maximum” it is assumed that conversion occurs within the landscape parcel in each county that realizes the largest increase in pheasant sightings in that county. In this “Maximum” scenario, the policy analogy is that MPRI managers have complete freedom to locate the additional 1600 acres of CRP land in the landscape that provides the greatest increase in pheasant sightings. The seasonal welfare per acre in Table 2 is the seasonal welfare estimate in Table 3.2 divided by the total number of acres of agricultural land converted to herbaceous CRP (14,400 acres) in the MPRI restoration siting scenario.

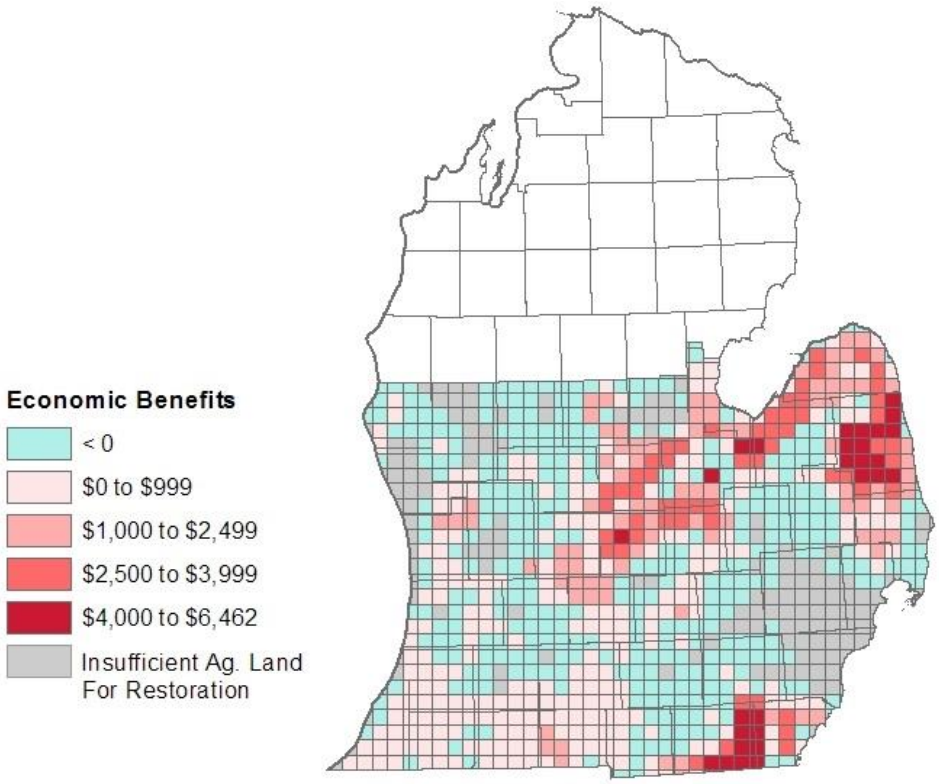
Table 3.2. Seasonal welfare and per-acre welfare of MPRI restoration siting scenarios

Restoration Siting Scenarios		% Change in Pheasant Sightings in Restoration Area	Seasonal Welfare	Seasonal Welfare per acre	Welfare Difference (Median as Baseline)
No Patch Increase	*Minimum*	-2.9%	$-900	-$0.06	-107%
	Median	+24.9%	$12,700	$0.88	Baseline
	Maximum	+52.9%	$30,100	$2.09	+ 137%
50% New Patches	*Minimum*	-1.5%	-$400	-$0.03	-103%
	Median	+27.4%	$13,900	$0.97	Baseline
	Maximum	+63.0%	$34,200	$2.38	+145%
All New Patches	*Minimum*	-0.4%	-$100	-$0.01	-101%
	Median	+33.0%	$14,900	$1.04	Baseline
	Maximum	+69.7%	$37,000	$2.57	+148%

Table 3.2 illustrates the critical role restoration siting decisions play in generating economic benefits to pheasant hunters. Choosing the least productive landscape in each county for restoration of 1,600 acres of herbaceous CRP essentially results in zero economic benefits to hunters from the 14,400 acres of restored land. For a different perspective, interpret the “Median” scenario as being a situation in which a manager, facing no constraints on restoration site selection but also possessing no information on the benefits of restoration on different landscapes, selects the landscape with the median increase in economic benefit from restoration in each county. Relative to this scenario, a manager able to identify and select for restoration landscapes with the largest increase in economic benefits (the “Maximum”

scenario) in each county are able to achieve an increase in economic benefits to hunters of about 140%.

Figure 3.4. Parcel-level economic benefit estimates from converting 1,600 acres of agricultural land to CRP herbaceous land



The above analysis demonstrates the importance of restoration site selection in generating economic benefits. To further illustrate, Figure 3.4 shows the economic benefits for each landscape parcel within the primary and secondary MPRI restoration areas in Michigan's Souther Lower Peninsula. For each parcel 1,600 acres of the agricultural land within that parcel was converted to CRP hebaceous land, under the assumption that 50% of the converted patches are adjacent to existing CRP patches and 50% are new patches (holding all other landscape characteristics within and across parcels constant). Restoration parcel hot spots which produce economic benefits are scaled using shades of red – the darker the color, the greater the economic benefit of restoring that parcel. Parcels which lacked sufficient agricultural land for the restoration scenario (less than 1,600 acres) are indicated in grey. Some parcels, shaded in blue, had small negative economic benefit estimates (mean losses for those parcels = -$126; median = -$108) due to the non-linearities and spatial juxtiposition of agricultural lands within the pheasant sightings equation (equation 8).

3.5 Discussion

The objective of this paper is to explore the extent to which restoration site selection affects economic benefits for a user group whose outdoor recreational experience is directly affected by ecosystem services generated through ecological restoration efforts. Examining the linkages between CRP restoration, pheasant abundance, and willingness to pay for increases in pheasant abundance by Michigan pheasant hunters, it is clear that the level of economic benefits realized by pheasant hunters depend dramatically on restoration site selection. An important factor affecting the levels of economic benefits across different possible restoration sites is that the ecosystem service output desired by pheasant hunters (i.e., increases in pheasant) is affected by a highly non-linear ecological production function. In particular, diminishing returns to agricultural land results in the economic benefits from CRP restoration (via the conversion of agricultural land to CRP land) being highly sensitive to the amount of agricultural land within the landscape selected for restoration. In the extreme, the worst restoration site selection scenarios generate effectively zero economic benefits. In contrast, an informed resource manager can select restoration sites in a manner that increases the returns on economic benefits by about 140% relative to a baseline scenario in which the manager possesses no spatially explicit information. Such non-linear relationships between landscapes and human well-being have also been identified in Kopmann and Rehdanz (2013). Additionally, this result conforms with the finding of Newbold and Massey (2010), who showed that poorly targeted environmental improvements can lead to welfare decreases. These analyses suggest that managers should be particularly concerned with landscape heterogeneity and spatial dependencies when the landscape characteristic targeted for restoration provides positive but diminishing returns within the ecological production function.

The parcel-level economic benefits estimates illustrated in Figure 4 produce key information for governmental and non-governmental organizations seeking to maximize return on restoration dollars when a key objective is to increase benefits for pheasant hunters. Restoration hotspots as indicated in Figure 3.4 align closely with the nine MPRI pilot focus area counties (see Figure 3.3) targeted for initial restoration efforts, suggesting a well-targeted restoration focus. Even within these nine counties there is evidence of hotspots which provide the most economic benefits. Moreover, if restoration activities could target conversion of agricultural lands to habitat types and locations that are even more beneficial to pheasants than generic CRP herbaceous lands, then the economic benefits would be even greater.

While site selection for CRP restoration plays an important role in the relative amount of economic benefits accruing to pheasant hunters, both the Michigan CRP as a whole as well as the MPRI generate modest aggregate economic benefits to these hunters. A limiting and conservative assumption within the MPRI restoration scenario analysis is that restoration occurring through this program is through the conversion of agricultural land to generic herbaceous CRP land. In contrast, restoration actions via the MPRI program would likely focus on restoring distinct herbaceous CRP classification subcategories which are the most beneficial to pheasant (and are not represented in the sightings model), such as upland bird habitat buffers. Restoration efforts targeted at the most beneficial habitat types would result in greater increases in pheasant abundance, and thus greater economic benefits to pheasant hunters. An additional limitation of the survey data and analysis is that the total number of pheasant hunter trips is held constant despite increases in the pheasant. This assumption becomes less valid with large changes in pheasant populations. If such quality improvements resulted in latent pheasant hunters rejoining the active hunter population or if active pheasant hunters increased their number of hunting trips, the estimates within would understate economic benefits.

Although methodological differences complicate direct comparison to the Hansen et al. (1999) study, the temporal and regional differences between these studies help explain the comparatively smaller economic benefits estimated in this analysis. For example, the number of Michigan pheasant hunters has declined by 63% over the previous two decades (Moritz, 1992; Frawley, 2012) - scaling up the aggregate economic benefits estimates within this paper under the assumption of a 1991 level of pheasant hunters yields a per-acre CRP value of about \$3.93/acre/year. Finally, opportunities and preferences for different types of hunting in Michigan appear to have changed over the previous two decades, with increasing interest in and availablility of deer hunting and sharply declining participation small game hunting (Frawley, 2006). This substitution away from pheasant hunting and towards deer hunting (especially archery hunting, for which the season is open throughout the Michigan pheasant hunting season) likely results in lower willingness to pay for increases in pheasant hunting quality relative to the past.

In summary, while this analysis reveals relatively modest economic benefits to pheasant hunters from CRP land, the level of economic benefits from habitat restoration efforts varies considerably depending on restoration site selection. These results illustrate how managers can leverage spatially explicit ecological data and the site choices of outdoor recreationists to enhance the return on conservation investments.

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CHAPTER 4: A DISCRETE CHOICE EXPERIMENT APPROACH EXAMINING TROUT ANGLER PREFERENCES FOR FISHING SITE ATTRIBUTES

4.1 Introduction

Trout fishing is a popular outdoor recreational activity in the U.S., with about 7.2 million anglers spending 76 million days pursuing species such as brown trout (*Salmo Trutta*), brook trout (*Salvelinus fontinalis*), rainbow trout (*Onchorhynchus mykiss*), and cutthroat trout (*Onchorhynchus mykiss*) in U.S. waters (excluding the Great Lakes) in 2011 (USDOI 2013). To generate and sustain high-quality trout fishing experiences, fisheries managers undertake costly management actions such as trout stocking, pollution mitigation, and stream and riparian restoration. Further, fisheries managers seek to prevent the over-exploitation of trout fisheries through the implementation of site and season-specific regulations which restrict trout harvest and permissible fishing gear. Achieving the improvements in the fishery desired by anglers while both staying within budget and being cognizant of angler tolerance for regulations requires an in-depth understanding of the types of trout fishing experiences preferred by anglers. Characterizing mean angler preferences for trout fishing site attributes in terms of the willingness to incur increased costs (such as increased travel distance to reach a fishing destination) to obtain fishing site quality improvements provides a convenient and relevant metric for comparing angler preferences for different site attributes. Moreover, management decision-making can be greatly aided by information on how these preferences for fishing site attributes vary across the population of anglers. For example, fisheries managers seeking to achieve catch-related improvements through the implementation of more restrictive regulations such as higher minimum size, lower daily harvest limit, and restrictions on certain types of fishing gear would do well to understand how heterogeneous angler preferences for regulations affect whether and to what extent anglers are made better off via regulation-induced catch-related improvements.

To examine angler preferences and preference heterogeneity for fishing site attributes, I use the survey-based stated preference discrete choice experiment approach. This approach allows for the identification of angler preferences through observing the choice of a preferred fishing site from a set of two hypothetical fishing sites, with each site consisting of different catch rates, regulations, and travel distance. Angler choice of a fishing site is statistically analyzed via the mixed logit model, which produces both mean and standard deviation parameter estimates that characterize the distribution of preferences for fishing site attributes across the angling population. This provides insight into angler preference heterogeneity for fishing site attributes, thus providing an additional dimension of analysis relative to the widely used conditional logit model which only provides information on mean preferences. Mean parameter estimates are used to examine the willingness of anglers to accept greater travel distances in exchange for changes in catch and regulations at trout fishing locations. Standard deviation parameter estimates are used in conjunction with mean parameter estimates to characterize the distribution of angler preferences with respect to fishing regulations. Subsequently, I examine the extent to which trout anglers switch from being negatively impacted by trout regulations to being positively impacted when these regulations generate catch-related improvements in the trout fishery. Finally, I describe the potential use of these results in guiding fisheries management decisions.

4.2 Study Area

There are approximately 12,500 miles of coldwater trout streams in Michigan, with the majority of these waterways distributed throughout Michigan's Upper Peninsula and Northern Lower Peninsula (see Figure 4.3). Trout fishing opportunities are more limited in the south-central and southeastern portions of the Lower Peninsula. However, this region is the most populous, with the nine-county Detroit-Ann Arbor-Flint combined statistical area constituting more than half of the state's total population. Brown Trout and Brook Trout comprise the majority of the wild, non-anadromous trout population, though there are some localized, non-anadromous populations of wild Rainbow Trout (Bryan Burroughs, pers. comm.).

Throughout these coldwater trout fishing streams, fisheries managers utilize a variety of regulations to protect and enhance trout fishing experiences. The Michigan Department of Natural Resources (MDNR) classifies the majority of Michigan trout streams (~1,600 streams) into four different regulations categories, with each category having a regulations regime which can vary by fishing season, possession season, and minimum size lengths.

Figure 4.1. Major categories of Michigan trout fishing regulations

All types of natural and artificial baits may be used on stream Types 1-4			Minimum Size Limit (inches)			Daily Possession Limit
Stream Type (Colors below are indicated accordingly on the maps online.)	Fishing Season	Possession Season	Brook Trout	Brown Trout	Atlantic, Chinook, Coho & Pink Salmon, Lake Trout, Rainbow Trout (Steelhead), Splake	All Trout and Salmon
1 (Approx. 1,400 streams)	Last Sat. in Apr. - Sep. 30	Last Sat. in Apr. - Sep. 30	7"	8"	10"	5 fish, but no more than 3 trout 15" or greater
2 (14 streams)	Last Sat. in Apr. - Sep. 30	Last Sat. in Apr. - Sep. 30	10"	12"		
3 (60 streams)	Open All Year	Open All Year	15"	15"		
4 (130 streams)	Open All Year	Last Sat. in Apr. - Sep. 30 for Brook Trout, Brown Trout, and Atlantic Salmon Open all year for all other Trout and Salmon	8"	10"		

Source: 2013 Michigan Fishing Guide (Michigan Department of Natural Resources)

Per Figure 4.1, trout fishing and trout possession seasons are either a) the last Saturday in April – September 30, or b) open all year. Minimum size regulations for brook trout (brown trout) range from 7” to 15” (8” to 15”). At all locations within the possession season, the daily harvest limit is five trout and salmon with only three trout greater than 15”.

On some sections of trout streams, however, the MDNR has implemented special regulations restricting the use of natural bait/artificial lures and the number of trout that may be harvested. On three stream sections totaling 21.8 miles, catch and release is required during the standard trout fishing season (i.e., last Saturday in April through September 30). A two trout harvest limit is imposed on ten sections of stream totaling 105.4 miles. Michigan trout anglers also face restrictions on the types of lures/baits that may be used on certain portions of streams. Trout anglers fishing in eight stream sections totaling 78.2 miles are restricted to the use of artificial flies, while anglers fishing in seven stream sections totaling 53.4 miles are restricted to using artificial lures (including artificial flies). Additionally, five stream sections totaling 34.6 miles have restrictions on lures/bait which vary throughout the year.

Special harvest and gear restrictions during the standard fishing season occur on about 260 miles of trout streams, only about 2% of the 12,500 miles of coldwater trout streams in Michigan. The most widespread regulation, mandatory catch and release for brown trout and brook trout outside of the standard trout fishing season, occurs on about 8% of trout streams in Michigan. However, these regulations exist on highly regarded trout streams which receive substantial fishing pressure, such as the Au Sable, Manistee, and Pere Marquette rivers. This includes an 8.7 mile stretch of the Au Sable referred to many fly anglers as the "Holy Waters" (Bain 1987, Gigliotti 1989), a highly regulated (artificial flies only and catch & release only) portion of the Au Sable renowned for its trout fishing.

Privately and publicly funded stocking and habitat restoration efforts are used to enhance trout fisheries in Michigan. Excluding Great Lakes and Great Lakes connecting waterways (i.e., Detroit River and St. Clair River), about 1.5 million brown trout and about 100,000 brook trout were stocked in rivers/streams in Michigan in 2012 (MDNR 2012). The MDNR Fisheries Division undertakes numerous habitat restoration projects that benefit coldwater species such as trout – in 2011 the MDNR Fisheries Division reported carrying out 17 dam removal projects resulting in 167 miles of rehabilitated stream habitat, and ten additional restoration projects which reconnected and improved 161 miles of streams and rivers (MDNR 2011). The MDNR Fisheries Division also manages a habitat restoration and research fund which is funded from penalties levied on hydropower operators due to damages from dam operation. This fund supports habitat restoration and research efforts on major trout fishing rivers/streams in Michigan such as the Au Sable and Manistee rivers. In 2011, these mitigation funds helped fund the removal of six dams, facilitated three woody habitat improvement structures, and helped reduce sedimentation via two road-stream crossing projects (MDNR 2011).

4.3 Material and Methods

4.3.1 Discrete Choice Method

Discrete choice methods employed within a recreational fisheries context utilize information on an angler's choice of a fishing site from a set of potential fishing sites to identify angler preferences for fishing site attributes. This information on angler preferences may be obtained via revealed preference approaches in which actual or reported fishing site choices of anglers are used, or through stated preference survey-based approaches in which individuals are presented with multiple hypothetical fishing sites within a choice scenario and asked to choose a preferred alternative. Early discrete choice modeling efforts focusing on recreational fishing used revealed preference methods (Milon 1988a, Milon 1988b, Bockstael et al. 1989), and until recently, a large majority of peer-reviewed research consisted of revealed preference approaches (Hunt 2005). There have been numerous revealed preference discrete choice studies which examine aspects of coldwater trout and salmon fishing experiences, with several studies specifically focusing on the site choice of stream trout anglers (see, e.g., Ahn et al. 2000, Morey et al. 2002, and Timmins and Murdock 2007).

The reliance on individuals' observed or reported behavior is an attractive feature of revealed preference approaches for many researchers. However, it may be difficult and costly to obtain reasonably precise information on the location of trout angler fishing trips. Further, even if information on trout angler site choice exists or can readily be obtained, site attribute tradeoff analysis requires the measurement of site-specific attributes such as angler catch rate. In many cases insufficient data exists to quantify angler catch rate or other attributes at potential fishing locations. Such measurement problems can be mitigated through survey-based stated preference approaches which elicit angler preferences through choice scenarios which explicitly and quantitatively define attributes levels available at fishing site alternatives. Stated preference discrete choice approaches may also be advantageous if fishing site attributes levels are correlated across fishing sites, which can make it difficult to identify relationships between attribute levels and site choice, or if there is an interest in examining angler preferences for attributes (or attribute levels) that currently do not exist at fishing sites. There has been substantial growth in the use of stated preference discrete choice modeling efforts to examine angler preferences for recreational fishing attributes. Whereas the Hunt (2005) study identified three stated preference approaches which examine aspects of recreational fishing, I identified over 20 peer-reviewed research papers using the stated preference approach since Hunt's 2005 publication. Three research efforts have focused specifically on the stream trout fishing experience. Ahn et al. (2000) examined angler preferences for catching brown trout and grayling in Norway, while Beville and Kerr (2008) and Beville and Kerr (2009) examined angler preferences and preference heterogeneity for New Zealand stream trout fishing attributes.

4.3.2 Stated Preference Discrete Choice Survey

A stated preference discrete choice experiment of trout anglers in Michigan was developed and implemented to examine angler preferences for aspects of a stream trout fishing experience. The choice experiment was a component of a larger survey which examined Michigan coldwater angler opinions, preferences, and participation, as well as associated economic impacts of coldwater fishing in Michigan (see Appendix B for survey). To filter survey respondents with a history of trout fishing in Michigan to the choice experiment section of the survey, the following skip question was used (also see Appendix B, Figure B.2.):

"During the previous 5 years, have you fished for Brown Trout and/or Brook Trout in a Michigan river or stream?"

Individuals who responded "No" to this question were skipped past all choice experiment-supporting questions, including warm up questions (Appendix B, Figure B.3.), information treatments (Appendix B, Figure B.4.), and trout fishing-related supporting questions (Appendix B, Figure B.9.). Respondents who answered "Yes" to this question were directed to the choice experiment (and the aforementioned choice experiment-related questions), which consists of four choice scenarios with each scenario consisting of two stream trout fishing locations described by the attribute levels available at each location. These fishing site locations were described by the same seven attributes listed in Figure 4.2, while the attribute levels varied across different fishing site options. For each choice scenario, the survey respondent was asked to first compare the different fishing site options by the attribute levels associated with each option, and then identify the location he/she would prefer to go fishing at. Figure 4.2 is an example of a choice scenario that was included in the survey[7].

[7] The survey is a split-sample survey which presented one-half of the sample with the choice experiment binary format seen in Figure 4.2., and one-half of the sample with a choice experiment ranking format seen in Appendix D, Figure D.1. Each format presents two trout fishing site options described by fishing site attributes and varying attribute levels; however, the ranking format includes a third option "go fishing at another location", and asks individuals to rank these three options within this format. For this analysis, we only consider angler preferences with respect to the two described trout fishing sites for the binary and ranking formats.

Figure 4.2. Example Michigan stream trout fishing site choice scenario

ATTRIBUTES		Option A	Option B
REGULATIONS	*Possession Limit*	5 trout	2 trout
	Lure/Bait Restrictions	None	None
BROWN TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 30 minutes	1 trout per 4 hours
	Typical Angler Catch Size	25% under 7" 50% 7" to 9" 25% over 9"	25% under 8" 50% 8" to 16" 25% over 16"
BROOK TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 2 hours	1 trout per 15 minutes
	Typical Angler Catch Size	25% under 6" 50% 6" to 7" 25% over 7"	25% under 8" 50% 8" to 9" 25% over 9"
TRAVEL	*Travel Distance (One Way)*	100 miles	35 miles

7.	**Where would you prefer to go fishing? (Please check one)**	Option A ☐	Option B ☐

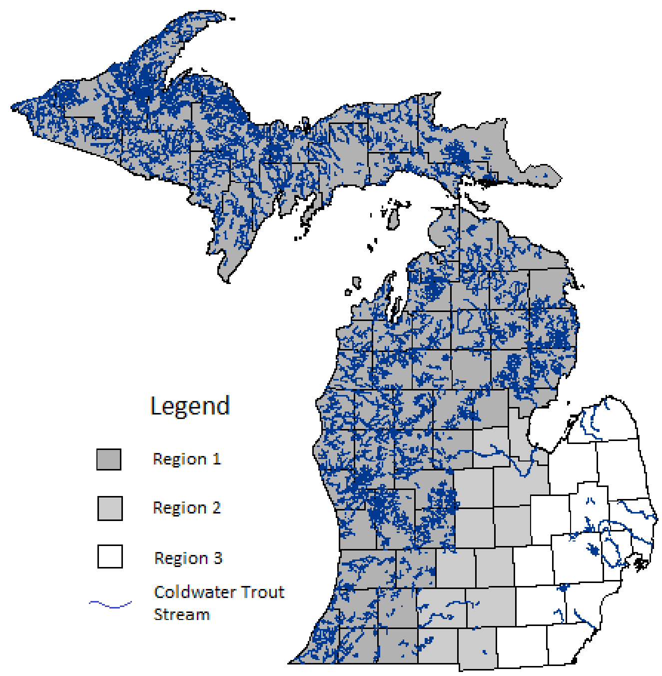
The process of identifying management-relevant attributes for use in describing Michigan stream trout fishing locations began with a comprehensive review of peer-reviewed literature, grey literature, and additional materials which could provide insight into important aspects of the recreational fishing experience. Reviewing 50 discrete choice analyses of recreational fishing, Hunt (2005) found the following site attributes to influence an individual's fishing site selection decision; a) costs relating to travel or access, b) fishing quality (e.g., size, catch rate, and species availability), c) environmental quality, d) facility development, e) encounter levels (with anglers and other individuals), and f) regulations. These attributes were used as starting points in the search for management-relevant attributes which might influence stream trout fishing site choice in Michigan. The 2013 Michigan Fishing Guide (MDNR 2013) was useful in understanding the different types of regulations faced by Michigan trout anglers. Discussions with personnel from the MDNR and Trout Unlimited (a coldwater fisheries NGO) helped identify fishing site attributes which might influence a trout angler's selection of a fishing site and also provided guidance regarding realistic attribute levels for different fishing site attributes. Ultimately, seven stream trout fishing site attributes were identified as being management-relevant and potentially important drivers of fishing site choice. These attributes and the range of potential attribute levels are detailed in Table 4.1 below.

Table 4.1. Fishing site attribute levels for choice experiment

CATEGORY	ATTRIBUTE	# OF LEVELS	ATTRIBUTE LEVELS					
Regulations	Possession Limit	3	Catch and Release 2 Trout 5 Trout					
	Lure/Bait Restrictions	3	None Artificial Lures & Flies Only Flies Only					
Brown Trout Catch Attributes	Typical Angler Catch Size	9	25% under 7”,50% 7” to 9”, 25% over 9” 25% under 7”, 50% 7” to 11”, 25% over 11” 25% under 7”, 50% 7” to 15”, 25% over 15” 25% under 8”, 50% 8” to 10”, 25% over 10” 25% under 8”, 50% 8” to 12”, 25% over 12” 25% under 8”, 50% 8” to 16”, 25% over 16” 25% under 10”, 50% 10” to 12”, 25% over 12” 25% under 10”, 50% 10” to 14”, 25% over 14” 25% under 10”, 50% 10” to 18”, 25% over 18”					
	Typical Angler Catch Rate	6	1 trout per 15 minutes 1 trout per 30 minutes 1 trout per hour			1 trout per 2 hours 1 trout per 4 hours 1 trout per 8 hours		
Brook Trout Catch Attributes	Typical Angler Catch Size	9	25% under 6”, 50% 6” to 7”, 25% over 7” 25% under 6”, 50% 6” to 8”, 25% over 8” 25% under 6”, 50% 6” to 11”, 25% over 11” 25% under 7”, 50% 7” to 8”, 25% over 8” 25% under 7”, 50% 7” to 9”, 25% over 9” 25% under 7”, 50% 7” to 12”, 25% over 12” 25% under 8”, 50% 8” to 9”, 25% over 9” 25% under 8”, 50% 8” to 10”, 25% over 10” 25% under 8”, 50% 8” to 13”, 25% over 13”					
	Typical Angler Catch Rate	6	1 trout per 15 minutes 1 trout per 30 minutes 1 trout per hour			1 trout per 2 hours 1 trout per 4 hours 1 trout per 8 hours		
Travel	Travel Distance	6	*Region 1 (miles)*	10 20 35 50 75 100	*Region 2 (miles)*	60 70 85 100 125 150	*Region 3 (miles)*	100 110 125 140 165 190

Most anglers living in the south-central or southeastern portion of Michigan's Lower Peninsula do not have stream trout fishing locations within close proximity to their residence. To ensure that travel distance levels in the choice experiment reflected realistic travel distances an angler might face on an actual trout fishing trip, anglers were separated into three distinct geographic regions by region of residence (see Figure 4.3.). Trout anglers residing in the Northern Lower Peninsula or the Upper Peninsula of Michigan likely have nearby stream trout fishing options, and thus might see travel distances as low as 10 miles in choice scenarios, whereas anglers living in southeastern Michigan likely have few or no nearby stream trout fishing options, and thus do not see travel distances less than 100 miles.

Figure 4.3. Coldwater trout streams in Michigan



Experimental design procedures allow for the control of factors within a choice experiment which affect parameter estimation, model flexibility, and the statistical efficiency of estimated parameters (Johnson et al. 2007). The software package NGENE 1.0 (Choice Metrics) was used to generate stream fishing site choice sets, with each choice set consisting of two fishing site alternatives which vary by attribute levels. To obtain an experimental design consisting of trout fishing site choice sets which enable the estimation of parameters with the lowest possible standard errors, an algorithm was used to search for an experimental design which would minimize D-error. Insights into likely signs of attribute parameters were sought from the published literature and directional priors were incorporated into the design search to improve the efficiency of the experimental design. Hunt et al. (2005) found that parameters on cost and gear restrictions within a discrete choice recreational fishing context were mostly negative, while parameters on catch attributes such as catch size and catch rate were generally positive. These findings were followed with respect to assigning priors for use in the design search. A total of seventy-two choice scenarios were identified by NGENE for use in the surveys.[8]

To evaluate angler comprehension of the survey prior to actual survey implementation, individuals with a history of fishing in Michigan were recruited to participate in one-hour survey pretesting sessions which incorporated internet meeting software along with phone discussion (following the approach of Weicksel [2012]). GatherPlace® screen sharing software was used which allowed individuals to take the survey while progress was monitored visually from a remote location. A phone connection was maintained throughout the process to address immediate comments, questions or concerns an individual might have regarding specific aspects of the survey instrument. A thorough assessment of respondent comprehension occurred after the survey was completed, with each individual asked a series of questions designed to identify potential issues with survey instrument design or content. Survey instrument pretesting consisted of 15 anglers associated with the Trout Unlimited organization and seven individuals recruited for a previous Michigan fishing survey - a total of 22 people completed the survey pretesting sessions. Individuals from Trout Unlimited were not compensated for their time, whereas the 7 other individuals were each paid $20. Though no major issues were identified in the pretesting process, helpful comments and suggestions were received which facilitated the improvement of various aspects of the survey layout and design.

[8] See Appendix F for attribute levels for each choice scenario, Appendix G for Pearson Product Moment Correlations for attributes within and across choice scenarios, and Appendix H for the choice scenarios in the different 120 mail survey versions and 108 internet survey versions.

The Coldwater Resources Steering Committee of the MDNR, which includes various representatives of the agency and the angling public, also reviewed a draft survey and their feedback was incorporated into the final version of the questionnaire.

Survey recipients consisted of a randomly drawn sample of 4,099 Michigan residents who purchased an “Unrestricted” fishing license (which allows for the holder to target trout and salmon) for the 2012-2013 Michigan fishing season. A mixed mode internet and mail survey approach was used with up to four contacts for each potential respondent (see Appendix A for description of mailings timeline). The first three contacts consisted of an envelope with letter (first contact) and two postcards (second and third contacts) which explained the nature and purpose of the survey and provided a website address which the individual could type into their web browser to access the survey (see Appendix D). Individuals who did not attempt to complete the online version of the survey were sent a fourth contact, which included both the website address as well as a printed 12-page questionnaire (see Appendix B for survey and Appendix D for 4^{th} mailing contact letter). A total of 1038 individuals completed the internet survey and 743 individuals completed the mail survey, for a total response of 1781 individuals (response rate of 44.6%; see Appendix A, Table A.1. for disposition table further detailing survey response). The chi-square procedure was used to test for statistically significant differences ($P<0.01$) in response rates by age, gender, and region of residence. Statistically significant ($P<0.01$) differences in response rate were found for age, with the trend of response rate increasing as age increased. In model estimation, survey results were weighted accordingly (see Appendix A, Table A.2. for weights).

4.3.3 Random Utility Theory and Model Estimation

Random utility theory (McFadden 1974) is the underlying behavioral theory supporting this discrete choice analysis of stream trout fishing site selection. According to random utility theory, an individual selects the fishing location which maximizes his/her indirect utility. In equation 1, V_{ij} is the indirect utility associated with individual *i* at site *j*, x_{ij} is a vector of site attributes for individual *i* at site *j*, β is a vector of parameters associated with these site attributes, and ε_{ij} is the stochastic error term unobservable to the researcher.

1) $$V_{ij} = \bar{V}(x_{ij}, \beta) + \varepsilon_{ij}$$

The indirect utility function in equation 1 consists of the fishing site attribute variables defined and described in Table 4.2 below.

Table 4.2. Fishing site attributes variables in indirect utility function

Fishing Site Attribute Variables	**Fishing Site Attribute Variable Definition**	**Variable Type**	**Min, Max**
Distance	One-way distance from individual's residence (in miles)	Continuous	10, 190
Catch&Release	All trout caught must be released	Categorical	0,1
Harvest_2	Harvest limit of two trout	Categorical	0,1
Lures&Flies_Only	Only lures and flies may be used; no natural bait	Categorical	0,1
Flies_Only	Only flies may be used; no other lures or natural bait	Categorical	0,1
Brown_Rate	# of Brown Trout caught per hour by a Typical Angler	Continuous	0.125, 4
Brook_Rate	# of Brook Trout caught per hour by a Typical Angler	Continuous	0.125, 4
Brown_25	25^{th} percentile of Brown Trout catch length (in inches)	Continuous	7,10
Brown_75	75^{th} percentile of Brown Trout catch length (in inches)	Continuous	9,18
Brook_25	25^{th} percentile of Brook Trout catch length (in inches)	Continuous	6,8
Brook_75	75^{th} percentile of Brook Trout catch length (in inches)	Continuous	7,13

4.3.4 Mixed Logit Model

The mixed logit modeling approach accounts for preference heterogeneity of individuals via the estimation of parameter distributions for specified random variables (Train 2009). While the mixed logit has been applied to discrete choice analysis since the early 1980s (see Boyd and Mellman 1980, Cardell and Dunbar 1980), the first application to recreational fishing was by Train (1998), who examined angler preferences and estimated economic benefits associated with trout fishing in Montana rivers. Other mixed logit modeling approaches examining preferences for angling site attributes include McConnell and Tseng (1999), Breffle and Morey (2000), Provencher and Bishop (2004), Massey et al. (2006), Oh and Ditton (2006) and Wielgus et al. (2009). Kerkvliet and Nowell (2000) use a mixed logit model to examine angler preferences and demand for stream trout fishing experiences in Yellowstone National Park.

In the mixed logit model, the probability that an angler i chooses site j is estimated by integrating standard logit probabilities (McFadden 1974) over a density of β parameters (Train 2009).

2) $$P_{ij} = \int \frac{\exp(V_{ij})}{\exp(V_{iA}) + \exp(V_{iB})} f(\beta) d(\beta)$$

Mixed logit estimation proceeds with the objective of estimating mean and standard deviation parameters for the parameters specified to have a random distribution. To aid in the calculation of willingness to pay the parameter on distance is assumed to be fixed (Revelt and Train 2000, Eggert and Olsson 2009); parameters on all other attributes are assumed to be random. The researcher makes distributional assumptions for random parameters – commonly assumed distributions include normal and lognormal distributions. Random parameters in this model are assumed to be normally distributed with mean *b* and standard deviation *s* characterizing the probability distribution$f(\beta)$. Parameters are estimated via maximum simulated likelihood estimation, in which mixed logit probabilities in equation 2 are approximated by repeating draws of a value β from $f(\beta|\theta)$, where θ refers to the mean and covariance of the distribution (Train 2009).

4.3.5 Estimating Willingness to Pay and Preference Heterogeneity

Once the mixed logit model has been used to estimate mean and standard deviation parameters for fishing site attributes, I examine the willingness of stream trout anglers to make tradeoffs between the distance traveled to reach a fishing site and the attributes available at that fishing site. To do this, equation 3 below is used to estimate the mean willingness to pay of trout anglers to obtain different levels of fishing site attributes.

3) $$WTP_{miles} = -\hat{b}_q / \hat{b}_{distance}$$

The estimated mean parameter $\hat{b}_q$ in equation 3 refers to a fishing site attribute other than distance, and $\hat{b}_{distance}$ is the estimated parameter associated with the distance attribute. This WTP_{miles} metric reflects the willingness of trout angler to drive further distances to obtain quality improvements at a trout fishing site. For example, if $\hat{b}_q$ = hourly catch rate = 5 and $\hat{b}_{distance}$ = -1, an individual would be willing to drive up to an additional 5 miles to obtain an increase in the hourly catch rate by one fish per hour.

Finally, when the mean and standard deviation on the normally distributed random variables are both statistically significant ($P<0.05$), the proportion of individuals who derive positive and negative utility from these site attributes is calculated. Subsequently, the change in the proportion of individuals deriving positive and negative utility from a regulation is estimated given a regulation-induced improvement in catch-related attributes such as catch size and catch rate.

4.4 Results

Table 4.3 provides mixed logit model results for the stream trout fishing choice model. As expected, the *Distance* coefficient is negative and statistically significant, meaning that the utility an individual receives from a site decreases as the distance to the site increases. As the parameter on *Distance* is assumed to be fixed, there is a single mean parameter estimate for this variable. For the other variables, normal distributions are assumed with mean and standard deviation coefficients estimated. Mean coefficient estimates for the most restrictive regulation levels in the gear and harvest regulation categories were also negative and highly significant. All else equal, trout anglers are less likely to select fishing sites where trout cannot be harvested (*Catch&Release*) relative to sites where there is a harvest limit of five trout. Similarly, sites where only artificial flies may be used (*Flies_Only*) are less likely to be chosen than sites where there are not restrictions on natural bait or artificial lures. Restricting anglers to harvesting two trout (*Harvest_2*) or prohibiting the use of natural bait (*Lures&Flies_Only*) are both negative - *Harvest_2* is statistically significant at the 5% level, whereas *Lures&Flies_Only* is not statistically significant at conventional levels of measurement. As expected, anglers prefer to fish at locations where catch rates are higher - this result is statistically significant (P<0.01) for both brown and brook trout catch rates. While anglers prefer higher catch rates of both trout species, the mean coefficient on *Brown_Rate* is close to double that of the mean coefficient on *Brook_Rate*, indicating a stronger preference for catching brown trout. On average, anglers do not appear to have strong preferences for increasing the first quartile of trout size for either species; mean coefficients on *Brown_25* and *Brook_25* are negative but not statistically significant at conventional measurement levels. Finally, results indicate a preference for larger brown trout size relative to larger brook trout size.

The standard deviation coefficients in Table 4.3 identify angler preference heterogeneity associated with a fishing site attribute. The estimated standard deviations for *Catch&Release* and *Flies_Only* regulations are statistically significant (P<0.01), indicating heterogeneous preferences for these regulations across the population of stream trout anglers in Michigan. Statistically significant (P<0.01) preference heterogeneity is identified for both *Brown_25* and *Brook_25* variables, while the null hypothesis that mean coefficients for *Brown_25* and *Brook_25* are equal to zero cannot be rejected. The combination of a statistically significant standard deviation and the inability to reject the null hypothesis that the mean is different than zero suggests that the preferences for changes in the 25^{th} percentile size vary throughout the angler population.

Table 4.3. Mixed logit model results for Michigan trout fishing choice experiment

	Coefficient	Robust Standard Error	P-Values
Mean			
Distance (Fixed)	-0.013	0.002	P<0.01
Catch&Release	-1.759	0.192	P<0.01
Harvest_2	-0.235	0.112	P=0.04
Lures&Flies_Only	-0.170	0.105	P=0.11
Flies_Only	-1.064	0.155	P<0.01
Brown_Rate	0.224	0.034	P<0.01
Brown_25	-0.020	0.044	P=0.65
Brown_75	0.060	0.017	P<0.01
Brook_Rate	0.120	0.034	P<0.01
Brook_25	0.024	0.067	P=0.73
Brook_75	0.040	0.028	P=0.15
Standard Deviation			
Catch&Release	1.570	0.261	P<0.01
Harvest_2	0.014	0.071	P=0.84
Lures&Flies_Only	0.078	0.084	P=0.35
Flies_Only	1.409	0.264	P<0.01
Brown_Rate	0.074	0.137	P=0.59
Brown_25	0.321	0.099	P<0.01
Brown_75	0.002	0.008	P=0.83
Brook_Rate	0.149	0.136	P=0.28
Brook_25	0.521	0.161	P<0.01
Brook_75	0.176	0.073	P=0.02
Model Statistics			
Log-Likelihood	1572.899		
Wald chi2(21)	140.84		
Observations	634 individuals; 2535 choice occasions		

The WTP figures in Table 4.4 are interpreted as the number of miles an individual would be willing to travel to obtain a change in fishing site quality attribute. For the two most restrictive regulations, there are very large negative estimates of mean WTP, implying that individuals would travel large distances to avoid these regulations. With respect to brown trout catch-related attributes, an angler would be willing to travel an additional 16.6 miles to increase trout catch rate by one brown trout per hour, and travel an additional 4.5 miles to increase the length of each brown trout caught by 1”. Together, the WTP for *Brown_Rate* and *Brown_75* indicate that an angler would be roughly indifferent to a change in brown trout catch of one per hour and a change in the length of each brown trout caught of 3.5”. Regarding brook trout catch attributes, Table 4.4 shows that the average angler would be willing to drive an additional 8.9 miles to catch one more brook trout every hour. Comparing WTP for both brown trout and brook trout attributes, it appears that anglers have a stronger preference for increases in brown trout attributes relative to brook trout attributes.

Table 4.4. Per-trip willingness to pay for statistically significant (P<0.05) fishing site attribute variables

Fishing Site Attribute Variables	**WTP with respect to Distance (in miles)**
Catch&Release	-130.4
Harvest_2	-17.5
Flies_Only	-78.9
Brown_Rate (Catch increase of 1 Brown Trout/hour)	16.6
*Brown_*75 (Increase in 4th quartile Brown Trout catch size by 1")	4.5
Brook_Rate (Catch increase of 1 Brook Trout/hour)	8.9

4.4.1 Management Regulation Policy Scenarios

The proportion of the angling population supporting restrictive regulations such as mandatory catch & release and artificial flies only may be influenced by the effectiveness of these regulations in improving catch-related angling outcomes. To understand the potential for changes in angler support for regulations resulting from regulation-induced catch improvements at fishing sites, I examine the change in the proportion of anglers who benefit from a regulation when the regulation occurs along with a catch-related quality change. Take, for example, the mandatory catch and release regulation. Some anglers who realize low to moderate disutility with respect to mandatory catch and release may derive positive utility from a scenario in which mandatory catch and release is accompanied by catch-related quality improvements. That is, these anglers go from being worse off with the regulation to being better off with both the regulation and the catch improvements.

Table 4.5 examines regulation-induced fishing site quality change scenarios involving the three catch-related variables that have mean coefficients which are statistically significant ($P<0.01$); Brown_*75*, *Brown_Rate*, and *Brook_Rate*. In Table 4.5, "better for" refer to the proportion of anglers for whom the scenario makes them better off (i.e., generates positive utility for the angler) while "worse for" refers to the proportion of anglers for whom the scenario makes them worse off (i.e., generates negative utility for the angler). The scenarios described in Table 4.5 show that regulation-induced catch-quality improvements increase the proportion of anglers who receive positive utility, relative to the scenario in which regulations are not accompanied by catch-quality improvements. These results also indicate that catch-related improvements occurring from the artificial flies only gear restriction makes more anglers better off than compared to when catch improvements result from the mandatory catch and release restriction.

Table 4.5. Current proportion of anglers receiving positive utility from regulations (scenario 1) and the proportion of anglers receiving positive utility when the regulation is accompanied by a catch-related site quality improvement (scenarios 2-4).

		REGULATIONS	
		Mandatory Catch and Release	**Artificial Flies Only**
Scenario 1: Add regulations to a site without catch-related site quality improvements	*better for* *worse for*	13.2% 86.8%	22.5% 77.5%
Scenario 2: size increase: Add regulations to a site with an increase in 4th quartile length of 3" for brown trout	*better for* *worse for*	15.8% 84.2%	26.5% 73.5%
Scenario 3: catch rate increase: Add regulations to a site with an increase in catch rate of 1 brown trout/hour and 1 brook trout/hour	*better for* *worse for*	18.4% 81.6%	30.5% 69.5%
Scenario 4: size & catch rate increase: Add regulations to a site with increase in 3rd quartile length of 3" for brown trout and increase in catch rate of 1 brown trout/hour and 1 brook trout/hour	*better for* *worse for*	21.6% 78.4%	35.1% 64.9%

4.5 Discussion

Results of this discrete choice study of stream trout fishing in Michigan generally conform with results identified in other discrete choice studies of recreational fishing. Similar to the review of recreational fishing discrete choice studies in Hunt et al. (2005), this analysis reveals that on average, anglers prefer larger fish, higher catch rates, less restrictive regulations, and lower travel distances. In particular, the average angler is substantially and negatively impacted by the most highly restrictive regulations, with the average angler willing to drive many miles to avoid mandatory catch and release and artificial flies only fishing regulations at trout fishing sites. Importantly, results show that the less strict harvest regulations (two trout per day) and gear restrictions (artificial lures and flies permitted; no natural bait) have less impact on trout angler site choice. Managers desiring to mitigate negative impacts on the fishery while minimizing impacts to anglers should consider implementing such less strict regulations. Further, the literature on hooking mortality has largely confirmed that the use of natural baits leads to greater fish mortality than the use of artificial lures (see Taylor 1992 meta-analysis), while more limited and equivocal evidence exists regarding a reduction in trout mortality through the use of artificial flies as opposed to artificial lures (Wydoski 1977, Schisler and Bergersen 1996, and Risley and Zydlewski 2010) find evidence for such a mortality reduction whereas Mongillo (1984) does not]. This suggests that the greatest reductions in fish mortality with least impact to anglers can be achieved by banning the use of natural baits, whereas mortality reductions achieved by mandating the use of artificial flies are more uncertain and would have negative impacts on a large percentage of trout anglers.

Despite these strongly negative mean preferences for the most restrictive regulations, the results show that even while holding all other site characteristics (such as catch-related attributes) constant, 22.5% of anglers (13.2% of anglers) prefer fishing in areas with flies only gear restrictions (mandatory catch and release). Table 4.5 shows that regulation-induced quality changes have the potential to further increase the number of anglers better off with such regulations. In effect, this table illustrates the proportion of anglers who “switch” from being made worse off through the implementation of strict regulations, to being made better off through regulations accompanied by catch improvements. Though the comparison is not perfect, it is worth noting that the proportions of anglers preferring these regulations (with or without catch-related quality improvements) are far greater than the proportion of coldwater trout streams in Michigan having mandatory catch and release (0.2%) and artificial flies only restrictions (0.6%) throughout the trout fishing season. Given this imbalance, increasing the number of trout fishing sites with mandatory catch & release and artificial flies only regulations to provide additional opportunities to these anglers may be advisable from an equity standpoint.

Despite the potential to make some anglers better off as a result of regulation-induced improvements in catch quality, the mean angler is likely sufficiently negatively impacted by regulations such that regulations are unlikely to generate the level of catch-related improvements necessary to fully compensate these anglers. For example, Table 4.3 shows that an increase in brown trout catch rate (brook trout catch rate) of 7.9 brown trout (14.7 brook trout) per hour would be necessary to fully compensate for the mean angler for implementing catch and release harvest regulations, whereas an increase in brown trout catch rate (brook trout catch rate) of 4.8 brown trout (8.9 brook trout) per hour would be necessary to fully compensate for the implementation of flies only gear restrictions. These increases in catch rates are beyond the highest attribute level of hourly trout catch rates in the choice experiment (four trout per hour) and may not be a realistic fisheries outcome from implementing regulations. Such strong negative mean angler preferences for strict regulations will likely ensure that fisheries managers are confronted with disproportionate angler opposition to proposed new regulations. However, such regulation changes are possible and may require operating within the state political structure. For example, gear-restricted streams in Michigan were legislatively capped at 212 miles in 2002 (PA 434 2002), an increase from the 100 miles limit in 1994 (PA 451 1994).

Our research also sheds light on angler preferences with respect to catch rate and catch size for brown trout and brook trout. While anglers' benefit from an improvement in catch rates for both species, stronger mean preferences are evident for brown trout. This result suggests greater benefits for anglers from stocking and habitat management programs which improve brown trout catch rate. Results of this analysis indicate that Michigan trout anglers have stronger positive preferences for increases in the 75th percentile of brown trout size distribution, while there is less evidence that the mean angler is concerned with upper end brook trout size. This difference may be due to angler preferences for the challenge of the fight associated with catching a large brown trout (which can reach lengths of up to 30 inches) relative to brook trout (for which 13 inches would be considered particularly large). However, standard deviation is statistically significant at the 5% level for upper end brook trout size, indicating varying preferences for changes in this variable throughout the angler population. Finally, preference heterogeneity at the 1% significance level has been identified for the 25th percentile of the size distribution for both brook trout and brown trout. To speculate, this may have to do with varying angler preferences for trout reaching the minimum size for harvest. In the majority of trout river/streams in Michigan, minimum size limit for brook trout is 7", whereas the minimum size limit for brown trout is 8". These minimum size limits are also the median of the 1st quartile size distributions for both brook trout (6", 7", and 8") and brown trout (7", 8", and 10") attribute levels that an individual could encounter in the choice experiment. This preference heterogeneity may result from harvest-oriented anglers selecting fishing sites perceived to have a greater number of legal-sized trout, while other non-harvest-oriented anglers may be unconcerned with trout at the lower end of the distribution reaching a minimum size.

Ultimately, effective management of stream trout fisheries in Michigan involves allocating scarce budgetary funds to management actions which provide the greatest benefit to anglers. The results of this analysis provide important insights into angler preferences for stream trout fishing attributes such as catch size, catch rate, and gear and harvest regulations. Further, this analysis provides managers with information on how angler support for regulations changes when regulations are accompanied by catch-related site quality improvements. The research within can lead to improved resource allocation by allowing managers to direct resources to the improvement of attributes most preferred by anglers and thus improve the quality of stream trout fishing experiences.

APPENDICES

APPENDIX A

APPENDIX A: SURVEY MAILING TIMELINE AND RESPONSE RATE

ASAP Printing company (Okemos, Michigan) was used for the printing and mailing of surveys and contact materials. The following bullets illustrate the timeline for survey mailing.

- First Wave Mailing: May 7, 2013

  This wave consisted of a 2-sided 8.5" by 11" document (see Figure D.1 and Figure D.2 in Appendix D). The front of the document contained information about the purposes of the survey and a website address to access the survey. The back of the document contained answers to common questions individuals often have about the nature and purpose of the survey. The mailing envelope contained a survey logo we developed which consisted of an outline of the state of Michigan overlayed with an outline of a trout (see Figure D.3 in Appendix D).

- Second Wave Mailing: May 16, 2013

  This wave consisted of a 2-sided 5.5" by 4.25" postcard (see Figure D.4 and Figure D.5 in Appendix D). The front of the postcard consisted of a brief request to complete the survey, the link to the survey website, and a color image of the survey logo. The back of the postcard contained rationale for the survey and contact information.

- Third Wave Mailing: May 29, 2013

  This wave consisted of a 2-sided 8.5" by 5" postcard (see Figure D.6 and Figure D.7 in Appendix D). The front of the postcard consisted of a brief request to complete the survey, the link to the survey website, and a color image of the survey logo. The back of the postcard contained rationale for the survey and contact information.

- Fourth Wave Mailing: July 2, 2013 –

  This wave contained a 2-sided 8.5" by 11" document (see Figure D.8 and Figure D.9 in Appendix D). This wave also contained a 12 page survey (see Figures B.1 – B.12 in Appendix C) consisting of three 17" by 11" pages folded over to create a booklet. The page containing the front and back of the survey was of slightly heavier weight. Finally, this wave contained a 9" by 12" business reply mail envelope. These materials were mailed in a 9" by 12" envelope which contained the same image and text as the first outgoing envelope in Figure D.3 in Appendix D.

To reduce undeliverable mail, ASAP Printing company cross-checked the individuals' mailing addresses with the National Change of Address list. A total of 192 individuals were identified as having changed addresses, and the addresses were updated accordingly. This list of changed addresses included out-of state addresses for 13 individuals. Throughout the survey mailing process, a total of 92 surveys were returned as undeliverable. For calculating the effective response rate, the 13 individuals who moved out of state and the 92 undeliverable surveys were removed from the calculation, yielding an effective sample size of 3,994.

The internet nature of the survey, combined with the uncertainty associated with the date that a respondent received a mailing, complicates calculating the precise survey response by wave. However, we provide an estimate of response rate by mailing below.

- First Wave Response – 420 internet surveys
- Second Wave Response – 348 internet surveys
- Third Wave Response – 218 internet surveys
- Fourth Wave Response – 743 valid mail surveys and 87 internet surveys

For the internet survey, there were 4 people who logged on but did not answer a question, and 10 people have 2 survey entries. These individuals were eliminated from our analysis and subtracted from total internet survey responses listed above, leaving a total of 1038 valid internet survey respondents. Below is the equation for the effective response rate.

$$Effective\ Response\ Rate = \frac{Valid\ Internet\ Surveys + Valid\ Mail\ Surveys}{Survey\ Sample\ Size - Undeliverables - NCOA\ out\ of\ State}$$

$$= \frac{1038 + 743}{4099 - 92 - 13} = 44.6\%$$

Table A.1. Summary of trout angler survey response and disposition

Initial Sample Size	4,099
Undeliverable	92
Total Responses	1781
Wave 1 Responses (internet survey)	420
Wave 2 Responses (internet survey)	313
Wave 3 Responses (internet survey)	218
Wave 4 Responses (mail and internet survey)	830
Wave 4 Mail Survey	743
Wave 4 Internet Survey	87
Out of State	13
Refusals	2

Table A.2. Survey weighting

Birth_year	**Survey Weighting**
Birth year ≥ 1979	1.44222
Birth year ≥ 1969 and ≥ 1978	1.25939
Birth year ≥ 1959 and ≥ 1968	1.02139
Birth year ≥ 1949 and ≥ 1958	0.87668
Birth year ≥ 1939 and ≥ 1948	0.73865
Birth year < 1939	0.79386

APPENDIX B

Figure B.1. Mail survey page 1

Michigan Trout and Salmon Fisheries Management Survey

We need your help!

Please complete the Michigan Trout and Salmon Fisheries Management Survey and return it in the postage-paid envelope.

YOUR input is needed even if you did not fish for trout or salmon.

MICHIGAN STATE
UNIVERSITY

If you have misplaced your postage-paid envelope, please return survey to:

Professor Frank Lupi
Department of Fisheries and Wildlife
Michigan State University
480 Wilson Road
13 Natural Resources Box 1
East Lansing, MI 48824

THANK YOU!

Figure B.2. Mail survey page 2

Trout, Steelhead, and Salmon Fishing in Michigan

In questions 1 & 2 below, we will ask you about your fishing activity relating to five specific types of trout, steelhead, and salmon fishing in Michigan.

For questions 1 & 2, we are ONLY interested in your fishing activity during the 2012-2013 Michigan fishing license season (4/1/2012 through 3/31/2013).

For each specific type of fishing, we are interested in the number of multiple-day fishing trips you took, and the number of times you went fishing for one day or less. These are defined below.

1) Total number of multiple-day fishing trips:

This refers to the number of fishing trips you took which DID INVOLVE staying overnight at a location other than your primary residence. Regardless of whether you stayed overnight for a single night or for many nights during the trip, please consider the period away from your primary residence one multiple-day trip.

2) Total number of times you went fishing for a single day or less:

This refers to the number of times you went fishing that DID NOT INVOLVE staying overnight at a location other than your primary residence. Please count each time you went fishing for a day or less, even times when you may have fished only a few minutes.

1. Please enter the number of multiple-day fishing trips you took during the 2012-2013 Michigan fishing license season (4/1/2012 through 3/31/2013), for each type of fishing listed below.

(If you did not participate in a type of fishing, please enter a "0".)

	Trips
Fishing for **brown trout and/or brook trout** in a Michigan river/stream	
Fishing for **steelhead** in a Michigan river/stream	
Fishing for **trout** in a Michigan inland lake	
Fishing for **salmon** in a Michigan river/stream or on the Michigan Great Lakes shoreline	
Fishing for **trout, steelhead, and/or salmon** out of a boat on the Michigan Great Lakes	
All Other Types of Fishing Not Listed Above (such as fishing for bass, panfish, walleye, catfish, etc.)	

2. Please enter the number of times you went fishing for a single day or less during the 2012-2013 Michigan fishing license season (4/1/2012 through 3/31/2013), for each type of fishing listed below.

(If you did not participate in a type of fishing, please enter a "0".)

	Times
Fishing for **brown trout and/or brook trout** in a Michigan river/stream	
Fishing for **steelhead** in a Michigan river/stream	
Fishing for **trout** in a Michigan inland lake	
Fishing for **salmon** in a Michigan river/stream or on the Michigan Great Lakes shoreline	
Fishing for **trout, steelhead, and/or salmon** out of a boat on the Michigan Great Lakes	
All Other Types of Fishing Not Listed Above (such as fishing for bass, panfish, walleye, catfish, etc.)	

3. During the previous 5 years, have you fished for Brown Trout and/or Brook Trout in a Michigan river or stream?

☐ No ⟶ ***If No, Skip to Question 16.***

☐ Yes ⟶ ***If Yes, go to the next question.***

Figure B.3. Mail survey page 3

4. When fishing for brown trout and brook trout in rivers/streams in Michigan, please indicate how much you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I select a river/stream trout fishing location based on how many trout I expect to catch	☐	☐	☐	☐	☐
The availability of a specific species of trout affects my choice of river/stream to go trout fishing	☐	☐	☐	☐	☐
At a given river/stream trout fishing location, I catch more and/or larger trout than the typical angler	☐	☐	☐	☐	☐
I am willing to fish for trout in a river/stream where all trout caught must be released	☐	☐	☐	☐	☐
Having the option to keep a few trout if I want to is an important part of my fishing	☐	☐	☐	☐	☐
I select a river/stream trout fishing location based on the size of trout I expect to catch	☐	☐	☐	☐	☐
The distance from my home to a river/stream affects how often I go trout fishing at that location	☐	☐	☐	☐	☐

Lure/Bait Restrictions refers to restrictions on the type of lures and bait you are legally allowed to use when fishing for trout at a particular location in a river/stream in Michigan. For the purposes of this survey, we define three different types of lures and bait:

1) NATURAL BAIT – Refers to live bait and dead/preserved bait. Example of live bait and dead/preserved bait include minnows, worms, aquatic nymphs and larvae, and salmon eggs.

2) ARTIFICIAL LURES – Refers to a man-made lure that imitates natural bait. Examples of artificial lures include spoons, spinners, crankbaits/plugs, and soft plastic baits.

3) FLIES – Refers to wet and dry flies, streamers and nymphs. Flies lack spinners, spoons, lips, or attached baits or lures.

5. When fishing for trout in a Michigan river or stream, what type of lure/bait do you prefer to use?

☐ Natural Bait
☐ Artificial Lures (not including Flies)
☐ Flies

6. How often does the presence or absence of a lure/bait restriction affect where you decide to go river/stream trout fishing?

☐ Always
☐ Sometimes
☐ Never

Figure B.4. Mail survey page 4

Where Would You Go Trout Fishing?

On the following pages, you will be asked to identify the river/stream trout fishing location where YOU would prefer to go fishing.

You may choose one of two options: Option A or Option B. Both of these options are described by the attributes associated with each fishing location. Assume that attributes not listed in the table are the same for both Option A and Option B.

The table below is an EXAMPLE of a choice you will be asked to make on the following pages. Please review this table and the text boxes to the left. **Do not select a trip for this example** - simply go to the next page when you are finished reviewing.

Step 1: Compare trout fishing regulations.

Step 2: Compare catch rate and catch size for each type of trout.

Step 3: Compare distance from your home.

ATTRIBUTES		Option A	Option B
REGULATIONS	*Possession Limit*	5 trout	Catch & Release Only
	Lure/Bait Restrictions	None	Flies only
BROWN TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 15 minutes	1 trout per hour
	Typical Angler Catch Size	25% under 8" 50% 8" to 12" 25% over 12"	25% under 10" 50% 10" to 14" 25% over 14"
BROOK TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 30 minutes	1 trout per 2 hours
	Typical Angler Catch Size	25% under 6" 50% 6" to 8" 25% over 8"	25% under 8" 50% 8" to 12" 25% over 12"
TRAVEL	*Travel Distance (One Way)*	35 miles	15 miles

Step 4: Identify the option you would prefer to go fishing at.

Ex 1. Where would you prefer to go fishing?
(Please check one)

Option A ☐ Option B ☐

EXAMPLE

Figure B.5. Mail survey page 5

Choice #1 of 4: Where Would You Go Trout Fishing?

Option A and Option B are two river/stream trout fishing locations. Each option is described by the attributes associated with each fishing location. Assume that attributes not listed in the table are the same for both Option A and Option B.

Suppose you are going trout fishing for a day or less at a Michigan river or stream. **Which river/stream location would you prefer to go trout fishing at?**

ATTRIBUTES		Option A	Option B
REGULATIONS	*Possession Limit*	5 trout	2 trout
	Lure/Bait Restrictions	None	None
BROWN TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 30 minutes	1 trout per 4 hours
	Typical Angler Catch Size	25% under 7" 50% 7" to 9" 25% over 9"	25% under 8" 50% 8" to 16" 25% over 16"
BROOK TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 2 hours	1 trout per 15 minutes
	Typical Angler Catch Size	25% under 6" 50% 6" to 7" 25% over 7"	25% under 8" 50% 8" to 9" 25% over 9"
TRAVEL	*Travel Distance (One Way)*	100 miles	35 miles

7. **Where would you prefer to go fishing? (Please check one)**

Option A ☐ Option B ☐

8. **Which would you prefer?**

☐ Going trout fishing at the Option you selected in the previous question
☐ Going trout fishing at a river or stream location other than Option A or Option B

Figure B.6. Mail survey page 6

Choice #2 of 4: Where Would You Go Trout Fishing?

Option A and Option B are two river/stream trout fishing locations. Each option is described by the attributes associated with each fishing location. Assume that attributes not listed in the table are the same for both Option A and Option B.

Suppose you are going trout fishing for a day or less at a Michigan river or stream. **Which river/stream location would you prefer to go trout fishing at?**

ATTRIBUTES		Option A	Option B
REGULATIONS	*Possession Limit*	Catch & Release Only	5 trout
	Lure/Bait Restrictions	Flies Only	Artificial Lures & Flies Only
BROWN TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 4 hours	1 trout per 30 minutes
	Typical Angler Catch Size	25% under 7" 50% 7" to 11" 25% over 11"	25% under 7" 50% 7" to 9" 25% over 9"
BROOK TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 4 hours	1 trout per 8 hours
	Typical Angler Catch Size	25% under 6" 50% 6" to 7" 25% over 7"	25% under 8" 50% 8" to 13" 25% over 13"
TRAVEL	*Travel Distance (One Way)*	20 miles	10 miles

9. Where would you prefer to go fishing? (Please check one)

Option A ☐ Option B ☐

10. Which would you prefer?

☐ Going trout fishing at the Option you selected in the previous question
☐ Going trout fishing at a river or stream location other than Option A or Option B

Figure B.7. Mail survey page 7

Choice #3 of 4: Where Would You Go Trout Fishing?

Option A and Option B are two river/stream trout fishing locations. Each option is described by the attributes associated with each fishing location. Assume that attributes not listed in the table are the same for both Option A and Option B.

Suppose you are going trout fishing for a day or less at a Michigan river or stream. **Which river/stream location would you prefer to go trout fishing at?**

ATTRIBUTES		Option A	Option B
REGULATIONS	*Possession Limit*	Catch & Release Only	Catch & Release Only
	Lure/Bait Restrictions	Artificial Lures & Flies Only	Flies Only
BROWN TROUT CATCH	*Typical Angler Catch Rate*	1 trout per hour	1 trout per 30 minutes
	Typical Angler Catch Size	25% under 7" 50% 7" to 9" 25% over 9"	25% under 7" 50% 7" to 15" 25% over 15"
BROOK TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 15 minutes	1 trout per 4 hours
	Typical Angler Catch Size	25% under 6" 50% 6" to 11" 25% over 11"	25% under 6" 50% 6" to 8" 25% over 8"
TRAVEL	*Travel Distance (One Way)*	20 miles	35 miles

11. Where would you prefer to go fishing? (Please check one)

Option A ☐ Option B ☐

12. Which would you prefer?

☐ Going trout fishing at the Option you selected in the previous question

☐ Going trout fishing at a river or stream location other than Option A or Option B

Figure B.8. Mail survey page 8

Choice #4 of 4: Where Would You Go Trout Fishing?

Option A and Option B are two river/stream trout fishing locations. Each option is described by the attributes associated with each fishing location. Assume that attributes not listed in the table are the same for both Option A and Option B.

Suppose you are going trout fishing for a day or less at a Michigan river or stream. **Which river/stream location would you prefer to go trout fishing at?**

ATTRIBUTES		Option A	Option B
REGULATIONS	*Possession Limit*	5 trout	Catch & Release Only
	Lure/Bait Restrictions	Artificial Lures & Flies Only	Artificial Lures & Flies Only
BROWN TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 2 hours	1 trout per 30 minutes
	Typical Angler Catch Size	25% under 7" 50% 7" to 9" 25% over 9"	25% under 8" 50% 8" to 10" 25% over 10"
BROOK TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 4 hours	1 trout per 30 minutes
	Typical Angler Catch Size	25% under 7" 50% 7" to 12" 25% over 12"	25% under 7" 50% 7" to 9" 25% over 9"
TRAVEL	*Travel Distance (One Way)*	100 miles	50 miles

13. Where would you prefer to go fishing? (Please check one) Option A ☐ Option B ☐

14. Which would you prefer?

☐ Going trout fishing at the Option you selected in the previous question

☐ Going trout fishing at a river or stream location other than Option A or Option B

Figure B.9. Mail survey page 9

15. Indicate the degree to which you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fishing locations where natural bait is allowed are more crowded with anglers	☐	☐	☐	☐	☐
Fishing locations in rivers/streams where brook trout are abundant have a more scenic natural environment	☐	☐	☐	☐	☐
The natural environment is less scenic in rivers/streams where brown trout populations are low	☐	☐	☐	☐	☐
Fishing locations where brook trout are abundant are less crowded with anglers	☐	☐	☐	☐	☐
Fishing locations where natural bait is not allowed have a more pristine natural environment	☐	☐	☐	☐	☐
There are less anglers fishing trout rivers/streams where brown trout abundance is low	☐	☐	☐	☐	☐
The natural environment is more degraded at fishing locations where natural bait is allowed	☐	☐	☐	☐	☐
Fishing locations where anglers may keep trout have more appealing natural scenery	☐	☐	☐	☐	☐
River/streams with low levels of brook trout are less visually appealing	☐	☐	☐	☐	☐
Fishing locations where catch & release is required have a less pristine natural environment	☐	☐	☐	☐	☐
Catch & release regulations reduce the chances of encountering other anglers on the river/stream	☐	☐	☐	☐	☐
Low brook trout abundance in a trout river/stream is a sign that anglers frequent this river/stream	☐	☐	☐	☐	☐
Fishing locations where brown trout are abundant are more crowded with anglers	☐	☐	☐	☐	☐
Where brown trout are abundant, the natural scenery is more visually appealing	☐	☐	☐	☐	☐

16. Did you fish for trout, steelhead and/or salmon in Michigan during the 2012-2013 Michigan fishing license season (4/1/2012 through 3/31/2013)?

☐ No ⟶ ***If No, Skip to Question 31.***

☐ Yes ⟶ ***If Yes, go to the next question.***

Figure B.10. Mail survey page 10

Trout and Salmon Fishing Trip Questions

17. **We are interested in the <u>FIRST TIME</u> you went fishing for trout, steelhead, and/or salmon during the 2012-2013 Michigan fishing license season (4/1/2012 through 3/31/2013). Which specific type of fishing <u>best describes</u> the type of fishing you did during this trip?** ***(Check one)***

- ☐ Fishing for **brown trout** and/or **brook trout** in a Michigan river/stream
- ☐ Fishing for **steelhead** in a Michigan river/stream
- ☐ Fishing for **trout** in a Michigan inland lake
- ☐ Fishing for **salmon** in a Michigan river/stream or on the Michigan Great Lakes shoreline
- ☐ Fishing for **trout, steelhead, and/or salmon** <u>out of a boat</u> on the Michigan Great Lakes

Questions 18 to 30 ask about this first time you fished for trout, steelhead, and/or salmon in the 2012-2013 fishing license season.

18. **During which month was this trip (*this first time in 2012-2013*)?** ______________

19. **What is the name of the lake, river or stream where you fished (*this first time in 2012-2013*)?** __________________

20. **What is the name of the city/town/village that is closest to the location where you fished?** __________________

21. **How many other people accompanied you on this trip?** ***(do not include yourself)*** ________

22. **Which fishing method(s) did you use on this trip?** ***(Check all that apply)***

- ☐ Live/Natural Bait
- ☐ Artificial Lures (not including Flies)
- ☐ Flies
- ☐ From Boat/Canoe
- ☐ From Shore/Pier
- ☐ Wading
- ☐ Trolling

23. **Which species did you target during this trip?** ***(Check all that apply)***

- ☐ Brown Trout
- ☐ Brook Trout
- ☐ Rainbow Trout/Steelhead
- ☐ Lake Trout
- ☐ Chinook (King) Salmon
- ☐ Coho Salmon
- ☐ Pink Salmon
- ☐ Other ________________

24. **Was this time you went fishing during a multiple-day fishing trip?**

☐ No ⟶ ***If No, Skip to Question 29.***

☐ Yes ⟶ ***If Yes, go to the next question.***

Figure B.11. Mail survey page 11

25. How many nights were you away from home during this trip? __________

26. On how many days did you fish during this trip? __________

27. Where did you stay during this trip? (*Check all that apply*)

- ☐ Campground
- ☐ Rental lodging or hotel
- ☐ Lodging you own
- ☐ Stayed with friends, family or other no cost lodging
- ☐ Other (Please specify) __________________

28. Was fishing for trout, steelhead and/or salmon the primary purpose of this trip?

- ☐ Yes
- ☐ No

29. Expenditures YOU made Within 35 Miles of the Trip Destination

For the same trip as above, please enter the dollar amount of expenditures YOU made within 35 miles of the trip destination. Do this for each category below. Please be as accurate as possible - If unsure, provide your best estimate.
If you made no expenditures for a particular spending category, please enter a "0".

Transportation (for example, fuel/oil)	$
Boat Expenses (for example, fuel/oil and launch fees)	$
Lodging	$
Restaurant/Bars	$
Groceries/Take-Out Food/Drinks	$
Entertainment (for example, gambling)	$
Natural Bait, Lures, Flies, and other Fishing Tackle	$
Guide/Charter Fees	$
Other	$

30. Expenditures YOU made Outside 35 Miles of the Trip Destination

For the same trip as above, please enter the dollar amount of expenditures YOU made outside 35 miles of the trip destination. Do this for each category below. Please be as accurate as possible - If unsure, provide your best estimate.
If you made no expenditures for a spending category, please enter a "0".

Transportation (for example, fuel/oil)	$
Boat Expenses (for example, fuel/oil and launch fees)	$
Lodging	$
Restaurant/Bars	$
Groceries/Take-Out Food/Drinks	$
Entertainment (for example, gambling)	$
Natural Bait, Lures, Flies, and other Fishing Tackle	$
Guide/Charter Fees	$
Other	$

Please complete the questions on the back cover →

Figure B.12. Mail survey page 12

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

31. Who is filling out this survey?
- ☐ The person the invitation was addressed to
- ☐ Another household member
- ☐ Someone else

32. What is your gender?
- ☐ Male
- ☐ Female

33. In what year were you born? __________

34. What is your race/ethnicity?
- ☐ White
- ☐ Black/African American
- ☐ Hispanic/Latino
- ☐ Asian
- ☐ American Indian
- ☐ Other __________

35. What is the highest level of schooling you have completed?
- ☐ Less than High School
- ☐ High School or equivalent
- ☐ Some College, no degree
- ☐ Associate's degree
- ☐ Bachelor's degree
- ☐ Graduate or Professional degree

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

37. What is your approximate annual household income? (*Check one*)
- ☐ Less than $25,000
- ☐ $25,000 to $34,999
- ☐ $35,000 to $49,999
- ☐ $50,000 to $74,999
- ☐ $75,000 to $99,999
- ☐ $100,000 to $149,999
- ☐ $150,000 to $199,999
- ☐ $200,000 or more

Comments:

APPENDIX C

Figure C.1. Choice experiment format #2

Where Would You Go Trout Fishing?

On the following pages, you will be asked to rank the river/stream trout fishing locations where YOU would prefer to go fishing, from most to least preferred.

There are three options for you to rank. Options A & B are described by the attributes associated with each river/stream trout fishing location. Assume that attributes not listed in the table are the same for both Option A and Option B. Option C is a river/stream trout fishing location other than Option A or Option B.

The table below is an EXAMPLE of a choice you will be asked to make on the following pages. Please review this table and the text boxes to the left. **Do not select a trip for this example** - simply go to the next page when you are finished reviewing.

***Step 1:* Compare trout fishing regulations.**

***Step 2:* Compare catch rate and catch size for each type of trout.**

***Step 3:* Compare distance from your home.**

ATTRIBUTES		Option A	Option B	Option C
REGULATIONS	*Possession Limit*	5 trout	Catch & Release Only	I would go fishing somewhere else
	Lure/Bait Restrictions	None	Flies only	
BROWN TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 15 minutes	1 trout per hour	
	Typical Angler Catch Size	25% under 8" 50% 8" to 12" 25% over 12"	25% under 10" 50% 10" to 14" 25% over 14"	
BROOK TROUT CATCH	*Typical Angler Catch Rate*	1 trout per 30 minutes	1 trout per 2 hours	
	Typical Angler Catch Size	25% under 6" 50% 6" to 8" 25% over 8"	25% under 8" 50% 8" to 12" 25% over 12"	
TRAVEL	*Travel Distance (One Way)*	35 miles	15 miles	

***Step 4:* Identify the option you would prefer to go fishing at.**

Ex 1. Where would you prefer to go fishing?

	Option A	Option B	Option C
Most Preferred Option	☐	☐	☐
Second Most Preferred Option	☐	☐	☐
Least Preferred Option	☐	☐	☐

EXAMPLE

APPENDIX D

Figure D.1. First mail contact (front)

MICHIGAN STATE
UNIVERSITY

DEPARTMENT OF FISHERIES AND WILDLIFE

Frank Lupi
Professor

13 Natural Resources Bldg.
East Lansing, MI 48824

517-355-1692
MIstudy@msu.edu

May 2, 2013

<NAME1>
<STREET1>
<CITY1>, MI <ZIP1>

Dear <NAME1>:

We need your help with a survey about trout and salmon fishing in Michigan.

By taking a few minutes to share your thoughts and opinions you will be helping us out a great deal. The results will be used by managers to protect and enhance Michigan's trout and salmon fisheries.

No matter how often you fish, your input is essential to ensure the accuracy of our results. Your answers are strictly confidential.

The survey is being conducted on the internet. To access the survey, please type the following address into your web browser:

Web address: <web address>

If you have any questions about this study, contact me at 13 Natural Resources Bldg., Michigan State University, East Lansing, MI 48824; 517-355-1692, MIstudy@msu.edu.

Sincerely,

Professor Frank Lupi

MSU is an affirmative-action, equal-opportunity employer

Figure D.2. First mail contact (back)

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 trout and salmon fishing.

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?
Managers need scientifically sound information about anglers' opinions on the management of trout and salmon fisheries. The information this survey gathers on anglers' preferences will facilitate fact-based management of Michigan's trout and salmon 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 trout and salmon 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 do I get help with web survey access or other problems?
If you have trouble accessing the web survey or if you have other technical issues you should contact our research team by email (MIstudy@msu.edu) or by phone (517-355-1692). One of our research assistants will help you.

How can I see the results?
Contact our research team by email (MIstudy@msu.edu) or by phone (517-355-1692) and request a copy of the results which should be available in about six months.

Figure D.3. Envelope for first mail contact

MICHIGAN STATE
UNIVERSITY

Michigan Trout and Salmon Fishing Survey
Professor Frank Lupi
Department of Fisheries and Wildlife
Room 13 Natural Resources Bldg.
East Lansing, MI 48824

Figure D.4. Second mail contact (postcard front)

MICHIGAN STATE
UNIVERSITY

We need your help!

Please complete the trout and salmon fishing survey:

Survey Website:
www.research.net/s/trout120?c=11

<NAME1>
<STREET1>
<CITY1>, MI <ZIP1>

Figure D.5. Second mail contact (postcard back)

Recently, I contacted you about a web survey on trout and salmon fishing.

If you have already answered the survey, ***thank you very much!***

If you have not filled out the survey, we still need your help. You are part of a small scientific sample, and your answers help us represent all anglers in Michigan.

To access the survey, please use the web address printed on the other side of this card.

If you have questions about the survey, email: mistudy@msu.edu
or call: 517-355-1692.

Thank you very much for your help with this important study!

Sincerely,

Frank Lupi, Professor

Figure D.6. Third mail contact (postcard front example)

MICHIGAN STATE
UNIVERSITY

We need your help to better manage trout and salmon fisheries in Michigan!

Please complete the following survey:

Survey Website:
www.research.net/s/trout120?c=11

<NAME>
<ADDRESS>
<CITY, STATE, ZIP>

Figure D.7. Third mail contact (postcard back)

Recently, I contacted you about a web survey on trout and salmon fishing in Michigan.

If you have already answered the survey, ***thank you very much!***

If you have not completed the survey, we still need your help. You are part of a small scientific sample, and your answers help us represent all anglers in Michigan. Survey results will help guide future trout and salmon fisheries management decisions.

The web address for the survey is printed on the other side of this card.

If you have questions about the survey, email: mistudy@msu.edu or call: 517-355-1692.

Thank you very much for your help with this important research study!

Sincerely,

Frank Lupi, Professor

Figure D.8. Fourth mail contact (letter front)

MICHIGAN STATE
UNIVERSITY

June 21, 2013

<NAME1>
<STREET1>
<CITY1>, MI <ZIP1>

Dear <NAME1>:

We have recently contacted you about a web survey on trout and salmon fishing in Michigan. Although we have received completed surveys from many people, to the best of our knowledge, we have not heard from you.

I am writing to you one last time because your input is vital! You are part of a small sample that represents all Michigan anglers.

No matter how often you fish, your input is essential to ensure the accuracy of our results.

The results will help fisheries managers make decisions that better reflect the needs of people that fish in Michigan. Your answers are strictly confidential.

Please visit the website below OR return your completed survey in the postage paid return envelope.

Web address: <web address>

If you have any questions about this study, contact me at 13 Natural Resources Bldg., Michigan State University, East Lansing, MI 48824; 517-355-1692, MIstudy@msu.edu.

Sincerely,

Professor Frank Lupi

DEPARTMENT OF FISHERIES AND WILDLIFE

Frank Lupi
Professor

13 Natural Resources Bldg.
East Lansing, MI 48824

517-355-1692
MIstudy@msu.edu

MSU is an affirmative-action, equal-opportunity employer

Figure D.9. Fourth mail contact (letter back)

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 trout and salmon fishing.

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?
Managers need scientifically sound information about anglers' opinions on the management of trout and salmon fisheries. The information this survey gathers on anglers' preferences will facilitate fact-based management of Michigan's trout and salmon 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 trout and salmon 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.

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 do I get help with web survey access or other problems?
If you are having trouble accessing the web survey, be sure that you are typing the trout web address into the address bar (usually located at top of screen) and <u>not</u> a search bar. Look for web address in address bar that begins with <u>http://</u>, and type the trout web address over this. If you are still having trouble accessing the web survey or you are having other technical issues please contact our research team by email (MIstudy@msu.edu) or by phone (517-355-1692). One of our research assistants will help you.

How can I see the results?
Contact our research team by email (MIstudy@msu.edu) or by phone (517-355-1692) and request a copy of the results which should be available in about six months.

APPENDIX E

Table E.1. Paired choice alternatives and attribute levels

Choice Scenarios		*Dist*	*Hvst*	*Gear*	*Brwn catch*	*Brwn 25*	*Brwn 75*	*Brk catch*	*Brk 25*	*Brk 75*
1	a	75	0	1	2	7	15	2	7	9
	b	35	0	2	2	10	14	0.25	8	13
2	a	100	0	1	8	7	9	0.25	7	9
	b	10	5	0	8	7	11	1	8	13
3	a	100	2	0	2	8	16	1	8	13
	b	35	0	2	0.25	10	18	2	7	9
4	a	75	2	0	8	8	10	2	8	13
	b	10	5	0	1	7	15	8	7	9
5	a	35	0	1	0.5	8	16	0.25	8	13
	b	10	2	2	4	8	12	1	7	12
6	a	50	0	1	0.25	8	12	0.5	8	13
	b	20	5	1	2	7	11	0.5	7	12
7	a	50	2	0	4	7	15	0.5	7	9
	b	50	2	2	4	8	16	8	8	10
8	a	35	2	0	2	7	11	0.25	7	9
	b	75	5	1	2	7	15	4	8	10
9	a	35	5	0	1	10	14	2	7	8
	b	35	2	2	0.25	7	9	8	7	12
10	a	50	5	0	0.25	10	18	1	7	8
	b	10	5	1	1	8	10	2	7	12
11	a	50	0	2	8	8	12	1	6	8
	b	100	2	2	0.25	7	15	1	6	7
12	a	35	0	2	2	8	16	2	6	8
	b	50	5	1	1	8	16	0.25	6	7
13	a	75	5	0	4	8	10	0.25	6	8
	b	50	5	2	2	10	12	4	6	11
14	a	100	5	0	2	8	16	0.5	6	8
	b	75	0	0	4	7	9	8	6	11
15	a	100	0	2	0.5	10	12	0.5	7	8
	b	50	5	2	0.25	10	18	4	7	8
16	a	75	0	2	0.25	10	18	0.25	7	8
	b	75	0	0	0.5	7	15	8	7	8
17	a	75	5	2	1	10	18	0.5	6	11
	b	35	5	1	2	8	12	8	8	10
18	a	100	5	2	0.25	10	14	0.25	6	11
	b	10	2	2	8	7	11	2	8	10
19	a	100	2	1	1	7	15	0.25	8	9
	b	100	5	1	2	8	10	1	6	7

Table E.1. (cont'd)

Choice Scenarios		*Dist*	*Hvst*	*Gear*	*Brwn catch*	*Brwn 25*	*Brwn 75*	*Brk catch*	*Brk 25*	*Brk 75*
	a	75	2	1	0.25	7	11	0.5	8	9
20	b	50	2	2	8	7	9	0.25	6	7
	a	35	5	2	0.5	7	15	1	8	9
21	b	50	0	0	0.25	7	11	0.5	6	8
	a	50	5	2	0.25	7	9	2	8	9
22	b	75	5	2	0.5	10	14	1	6	8
	a	50	2	1	4	10	18	2	6	11
23	b	10	0	0	0.25	7	9	0.5	8	9
	a	35	2	1	2	10	12	1	6	11
24	b	20	5	2	0.5	10	12	1	8	9
	a	10	5	0	4	10	14	8	8	13
25	b	10	5	1	4	7	15	1	6	7
	a	20	5	0	2	10	18	4	8	13
26	b	20	2	2	2	8	16	0.5	6	7
	a	20	0	2	4	7	11	4	6	7
27	b	10	5	1	0.5	7	9	8	8	13
	a	10	0	2	2	7	15	8	6	7
28	b	20	2	2	0.25	8	10	4	8	13
	a	75	5	0	1	7	11	1	6	7
29	b	20	0	1	8	10	18	0.5	8	9
	a	100	5	0	0.5	7	9	2	6	7
30	b	35	2	0	4	8	16	0.25	8	9
	a	100	0	2	8	10	14	2	8	13
31	b	75	0	1	8	10	12	4	6	11
	a	75	0	2	4	10	12	1	8	13
32	b	100	2	0	4	8	10	2	6	11
	a	75	2	2	0.25	8	10	8	8	10
33	b	10	0	1	0.5	8	12	4	8	9
	a	100	2	2	0.5	8	12	4	8	10
34	b	20	2	0	0.25	10	14	8	8	9
	a	100	5	1	2	7	9	4	7	12
35	b	50	0	1	0.5	8	10	0.5	7	9
	a	75	5	1	4	7	11	8	7	12
36	b	75	2	0	0.25	10	12	1	7	9
	a	10	2	2	8	7	15	1	7	12
37	b	75	2	1	4	7	11	2	7	8
	a	20	2	2	4	7	11	2	7	12
38	b	100	5	2	8	8	12	4	7	8
	a	20	5	1	1	8	16	2	8	10
39	b	75	2	1	0.5	7	9	2	8	10

Table E.1. (cont'd)

Choice Scenario		*Dist*	*Hvst*	*Gear*	*Brwn catch*	*Brwn 25*	*Brwn 75*	*Brk catch*	*Brk 25*	*Brk 75*
	a	10	5	1	0.5	8	12	1	8	10
40	b	100	5	0	1	8	10	4	8	10
	a	10	2	1	0.25	8	12	2	7	8
41	b	10	2	0	4	10	18	4	6	11
	a	20	2	1	0.5	8	10	1	7	8
42	b	20	0	1	2	8	16	8	6	11
	a	20	0	0	0.25	10	14	1	6	8
43	b	50	2	0	4	10	14	0.5	7	9
	a	10	0	0	0.5	10	12	2	6	8
44	b	75	0	1	2	8	12	1	7	9
	a	75	2	1	1	10	14	4	6	8
45	b	75	5	2	0.5	8	16	0.25	7	12
	a	100	2	1	0.5	10	18	8	6	8
46	b	100	2	1	1	7	15	0.5	7	12
	a	100	0	0	8	8	12	8	7	8
47	b	20	5	2	0.5	8	12	0.25	6	8
	a	75	0	0	4	8	16	4	7	8
48	b	35	2	1	1	7	11	0.5	6	8
	a	35	2	2	2	8	10	0.5	6	7
49	b	20	2	0	8	8	10	0.5	7	9
	a	50	2	2	4	8	12	0.25	6	7
50	b	35	0	1	4	10	12	0.25	7	9
	a	50	5	1	8	10	12	0.25	7	9
51	b	20	2	0	1	8	12	4	6	7
	a	35	5	1	4	10	14	0.5	7	9
52	b	35	0	1	0.5	10	14	2	6	7
	a	10	2	2	0.25	10	12	4	7	9
53	b	35	5	0	2	7	9	0.25	6	8
	a	20	2	2	1	10	18	8	7	9
54	b	10	0	2	8	10	12	1	6	8
	a	20	5	1	2	8	10	8	6	7
55	b	100	5	0	2	7	11	2	7	8
	a	10	5	1	8	8	16	4	6	7
56	b	50	0	2	8	10	14	8	7	8
	a	10	0	1	0.5	7	15	0.5	6	11
57	b	20	5	0	1	10	18	2	6	8
	a	20	0	1	1	7	9	0.25	6	11
58	b	35	0	2	0.5	7	15	4	6	8
	a	20	2	0	4	10	18	0.25	8	9
59	b	75	5	0	1	10	14	0.25	8	13

Table E.1. (cont'd)

Choice Scenario		*Dist*	*Hvst*	*Gear*	*Brwn catch*	*Brwn 25*	*Brwn 75*	*Brk catch*	*Brk 25*	*Brk 75*
60	a	10	2	0	8	10	12	0.5	8	9
	b	100	0	2	0.5	7	11	0.5	8	13
61	a	35	0	1	2	10	14	4	8	9
	b	100	0	0	8	8	16	8	8	10
62	a	50	0	1	0.25	10	12	8	8	9
	b	50	2	1	2	10	18	2	8	10
63	a	50	2	0	0.25	7	11	8	6	11
	b	100	0	0	1	8	12	8	6	11
64	a	35	2	0	1	7	9	4	6	11
	b	50	2	1	0.25	10	14	2	6	11
65	a	35	0	0	0.5	7	9	8	8	10
	b	20	0	2	8	7	9	2	7	8
66	a	50	0	0	1	7	15	4	8	10
	b	35	5	0	4	10	12	4	7	8
67	a	50	5	2	0.5	8	10	4	7	12
	b	75	0	2	8	7	15	0.25	8	13
68	a	35	5	2	1	8	16	8	7	12
	b	100	5	0	4	10	18	0.5	8	13
69	a	10	0	0	0.25	8	10	0.25	7	12
	b	100	2	1	1	10	12	1	8	9
70	a	20	0	0	1	8	12	0.5	7	12
	b	50	0	0	0.25	8	10	0.25	8	9
71	a	20	5	2	2	7	9	0.5	8	10
	b	35	2	1	1	10	18	1	7	12
72	a	20	5	2	2	7	9	0.5	8	10
	b	10	0	0	0.25	8	16	0.25	7	12

APPENDIX F

Table F.1. Pearson product moment correlations for attributes within and across choice alternatives in choice pairs

		Site A									**Site B**								
		Dist	*Hvst*	*Gear*	*Brwn catch*	*Brwn 25*	*Brwn 75*	*Brk catch*	*Brk 25*	*Brk 75*	*Dist*	*Hvst*	*Gear*	*Brwn catch*	*Brwn 25*	*Brwn 75*	*Brk catch*	*Brk 25*	*Brk 75*
Site A	*Dist*	1.00	0.00	0.00	0.02	0.00	0.00	-0.01	0.00	0.00	-0.01	0.00	0.04	0.05	0.00	0.00	0.05	0.00	0.00
	Hvst	0.00	1.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00
	Gear	0.00	0.00	1.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.11	0.00	0.00	-0.01	0.00	0.00
	Brwn catch	0.02	-0.01	0.02	1.00	-0.01	-0.04	-0.10	0.05	0.02	-0.01	-0.01	0.02	0.06	-0.10	-0.02	0.04	-0.10	0.03
	Brwn 25	0.00	0.00	0.00	-0.01	1.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	-0.04	0.00	0.00	0.00	0.00	0.00
	Brwn 75	0.00	0.00	0.00	-0.04	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.04	0.00	0.00	0.05	0.00	0.00
	Brk catch	-0.01	0.00	0.00	-0.10	0.00	0.00	1.00	0.00	0.00	0.03	0.00	0.02	0.02	0.00	0.00	-0.02	0.00	-0.01
	Brk 25	0.00	0.00	0.00	0.05	0.00	0.00	0.00	1.00	0.00	0.02	0.00	-0.04	0.00	0.00	0.00	-0.05	0.00	0.00
	Brk 75	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	1.00	0.02	0.00	0.01	0.01	0.00	0.00	-0.09	0.00	0.00
Site B	*Dist*	-0.01	0.00	0.02	-0.01	0.02	0.00	0.03	0.02	0.02	1.00	0.02	-0.08	-0.03	-0.05	0.00	0.00	0.02	0.03
	Hvst	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.02	1.00	-0.04	-0.15	0.00	0.00	-0.06	0.00	0.00
	Gear	0.04	-0.04	0.00	0.02	0.01	0.01	0.02	-0.04	0.01	-0.08	-0.04	1.00	0.10	0.01	0.04	-0.08	-0.04	0.01
	Brwn catch	0.05	0.00	0.11	0.06	-0.04	-0.04	0.02	0.00	0.01	-0.03	-0.15	0.10	1.00	0.00	-0.05	0.00	0.05	-0.05
	Brwn 25	0.00	0.00	0.00	-0.10	0.00	0.00	0.00	0.00	0.00	-0.05	0.00	0.01	0.00	1.00	0.00	-0.08	0.00	0.00
	Brwn 75	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	-0.05	0.00	1.00	0.06	0.00	0.00
	Brk catch	0.05	0.00	-0.01	0.04	0.00	0.05	-0.02	-0.05	-0.09	0.00	-0.06	-0.08	0.00	-0.08	0.06	1.00	0.05	0.06
	Brk 25	0.00	0.00	0.00	-0.10	0.00	0.00	0.00	0.00	0.00	0.02	0.00	-0.04	0.05	0.00	0.00	0.05	1.00	0.00
	Brk 75	0.00	0.00	0.00	0.03	0.00	0.00	-0.01	0.00	0.00	0.03	0.00	0.01	-0.05	0.00	0.00	0.06	0.00	1.00

APPENDIX G

Table G.1. Mail survey choice scenario groupings by survey number

Region 1				Region 2				Region 3			
#	Binary Order	#	Ranking Order	#	Binary Order	#	Ranking Order	#	Binary Order	#	Ranking Order
1	30-27-58-35	21	30-27-58-35	41	30-27-58-35	61	30-27-58-35	81	30-27-58-35	101	30-27-58-35
2	9-16-28-67	22	9-16-28-67	42	9-16-28-67	62	9-16-28-67	82	9-16-28-67	102	9-16-28-67
3	41-50-12-55	23	41-50-12-55	43	41-50-12-55	63	41-50-12-55	83	41-50-12-55	103	41-50-12-55
4	15-68-62-38	24	15-68-62-38	44	15-68-62-38	64	15-68-62-38	84	15-68-62-38	104	15-68-62-38
5	59-2-65-57	25	59-2-65-57	45	59-2-65-57	65	59-2-65-57	85	59-2-65-57	105	59-2-65-57
6	42-3-20-14	26	42-3-20-14	46	42-3-20-14	66	42-3-20-14	86	42-3-20-14	106	42-3-20-14
7	1-10-8-29	27	1-10-8-29	47	1-10-8-29	67	1-10-8-29	87	1-10-8-29	107	1-10-8-29
8	70-21-44-66	28	70-21-44-66	48	70-21-44-66	68	70-21-44-66	88	70-21-44-66	108	70-21-44-66
9	36-47-40-4	29	36-47-40-4	49	36-47-40-4	69	36-47-40-4	89	36-47-40-4	109	36-47-40-4
10	18-61-60-23	30	18-61-60-23	50	18-61-60-23	70	18-61-60-23	90	18-61-60-23	110	18-61-60-23
11	53-24-51-71	31	53-24-51-71	51	53-24-51-71	71	53-24-51-71	91	53-24-51-71	111	53-24-51-71
12	37-13-56-69	32	37-13-56-69	52	37-13-56-69	72	37-13-56-69	92	37-13-56-69	112	37-13-56-69
13	17-52-25-34	33	17-52-25-34	53	17-52-25-34	73	17-52-25-34	93	17-52-25-34	113	17-52-25-34
14	32-45-48-63	34	32-45-48-63	54	32-45-48-63	74	32-45-48-63	94	32-45-48-63	114	32-45-48-63
15	5-19-54-26	35	5-19-54-26	55	5-19-54-26	75	5-19-54-26	95	5-19-54-26	115	5-19-54-26
16	72-43-11-39	36	72-43-11-39	56	72-43-11-39	76	72-43-11-39	96	72-43-11-39	116	72-43-11-39
17	46-49-7-64	37	46-49-7-64	57	46-49-7-64	77	46-49-7-64	97	46-49-7-64	117	46-49-7-64
18	31-22-33-6	38	31-22-33-6	58	31-22-33-6	78	31-22-33-6	98	31-22-33-6	118	31-22-33-6
19	17-29-10-64	39	17-29-10-64	59	17-29-10-64	79	17-29-10-64	99	17-29-10-64	119	17-29-10-64
20	14-68-20-58	40	14-68-20-58	60	14-68-20-58	80	14-68-20-58	100	14-68-20-58	120	14-68-20-58

Table G.2. Internet survey choice scenario groupings by survey number

Region 1				Region 2				Region 3			
#	Binary Order	#	Ranking Order	#	Binary Order	#	Ranking Order	#	Binary Order	#	Ranking Order
1	30-27-58-35	19	30-27-58-35	37	30-27-58-35	55	30-27-58-35	73	30-27-58-35	91	30-27-58-35
2	9-16-28-67	20	9-16-28-67	38	9-16-28-67	56	9-16-28-67	74	9-16-28-67	92	9-16-28-67
3	41-50-12-55	21	41-50-12-55	39	41-50-12-55	57	41-50-12-55	75	41-50-12-55	93	41-50-12-55
4	15-68-62-38	22	15-68-62-38	40	15-68-62-38	58	15-68-62-38	76	15-68-62-38	94	15-68-62-38
5	59-2-65-57	23	59-2-65-57	41	59-2-65-57	59	59-2-65-57	77	59-2-65-57	95	59-2-65-57
6	42-3-20-14	24	42-3-20-14	42	42-3-20-14	60	42-3-20-14	78	42-3-20-14	96	42-3-20-14
7	1-10-8-29	25	1-10-8-29	43	1-10-8-29	61	1-10-8-29	79	1-10-8-29	97	1-10-8-29
8	70-21-44-66	26	70-21-44-66	44	70-21-44-66	62	70-21-44-66	80	70-21-44-66	98	70-21-44-66
9	36-47-40-4	27	36-47-40-4	45	36-47-40-4	63	36-47-40-4	81	36-47-40-4	99	36-47-40-4
10	18-61-60-23	28	18-61-60-23	46	18-61-60-23	64	18-61-60-23	82	18-61-60-23	100	18-61-60-23
11	53-24-51-71	29	53-24-51-71	47	53-24-51-71	65	53-24-51-71	83	53-24-51-71	101	53-24-51-71
12	37-13-56-69	30	37-13-56-69	48	37-13-56-69	66	37-13-56-69	84	37-13-56-69	102	37-13-56-69
13	17-52-25-34	31	17-52-25-34	49	17-52-25-34	67	17-52-25-34	85	17-52-25-34	103	17-52-25-34
14	32-45-48-63	32	32-45-48-63	50	32-45-48-63	68	32-45-48-63	86	32-45-48-63	104	32-45-48-63
15	5-19-54-26	33	5-19-54-26	51	5-19-54-26	69	5-19-54-26	87	5-19-54-26	105	5-19-54-26
16	72-43-11-39	34	72-43-11-39	52	72-43-11-39	70	72-43-11-39	88	72-43-11-39	106	72-43-11-39
17	46-49-7-64	35	46-49-7-64	53	46-49-7-64	71	46-49-7-64	89	46-49-7-64	107	46-49-7-64
18	31-22-33-6	36	31-22-33-6	54	31-22-33-6	72	31-22-33-6	90	31-22-33-6	108	31-22-33-6

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