GREAT LAKES FISHERY COMMISSION

Project Completion Report[1]

The Recreational Fishing Value of Sea Lamprey Control

Part 1: Project Overview
Part 2: A Partial Benefit-Cost Analysis of Sea Lamprey Treatment Options on the St. Marys River
Part 3: Trout and Salmon Catch Rates at Michigan Great Lakes Sites, 1986 to 1995
Part 4: A Preliminary Valuation of Lake Trout Using the Existing Michigan Recreational Angling Demand Model

by:

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Michigan State University
East Lansing, MI 48824-1039

July 1998

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The Recreational Fishing Value of Sea Lamprey Control: Project Overview

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Research summary submitted to the Great Lakes Fishery Commission

July, 1998

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The Recreational Fishing Value of Sea Lamprey Control: Project Overview

The purpose of this document is to summarize research that was conducted as part of a grant from the Great Lakes Fishery Commission (GLFC) to Michigan State University (MSU) entitled "The Recreational Fishing Value of Sea Lamprey Control." Drs. John P. Hoehn and Frank Lupi of the Department of Agricultural Economics, MSU, were the principal investigators. Throughout the course of the project, we have worked closely with Gavin Christie, Integrated Management Specialist at the GLFC.[1]

One of the aims of the project was to estimate some of the economic value that recreational anglers in Michigan place on changes in populations of lake trout. The value estimates were derived from a model of the demand for recreational fishing in Michigan that was developed at Michigan State University, the "MSU model." The MSU model relates *where* and *how often* anglers go fishing to the travel costs and the catch rates of alternative fishing sites in Michigan. This relationship serves as estimate of anglers' willingness to trade costs (money) for catch rates. The estimated relationship between travel costs and catch rates was used to estimate some of the economic values associated with changes in catch rates.

What does the model measure? Since the model is based on anglers *use* of fishing resources, it can only be used to estimate "use-values." That is, the model can only capture changes in economic value that affect anglers' use of fishery resources, and it cannot measure values that do not affect use. For example, the model cannot be used to assess general values the public might attach to the rehabilitation of native stocks of fish. In

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[1] Douglas B. Jester of the Michigan Department of Natural Resources was instrumental in initiating the project and has provided valuable input throughout the course of the project. Dr. Heng Z. Chen, formerly at MSU and now with American Express, also contributed to the initial phases of the project.

addition, the model applies only to Michigan resident anglers and does not capture use-values that might accrue to anglers in other jurisdictions. Finally, what is measured and reported here is the *net* economic value associated with *changes* in the quality of fishing. By net economic value we mean the difference between willingness-to-pay and actual expenditures. Thus, we are not estimating the economic impact (measured in terms of jobs and incomes) that fishing expenditures may have on the economy. Instead, we are estimating the difference between anglers' willingness-to-pay for fishing quality minus what they actually spend which is an appropriate measure of benefits for use in benefit cost assessments of resource management alternatives.

A complete discussion of the original model and survey data is contained in Hoehn *et al.*[2] The Hoehn *et al.* model and survey data serve as the starting point for the current project. The current project had 3 main parts which are discussed below. The methods and results of each part of the project are documented and presented in three separate reports also submitted to the Great Lakes Fishery Commission.

- Lupi, Frank, and John P. Hoehn, *A Preliminary Valuation of Lake Trout Using the Michigan Recreational Angling Demand Model*, report to the Great Lakes Fishery Commission, October 1997.
- Lupi, Frank, John P. Hoehn, and Douglas B. Jester, *Trout and Salmon Catch Rates at Michigan Great Lakes Sites, 1986 to 1995*, report to the Great Lakes Fishery Commission, March, 1998.
- Lupi, Frank, and John P. Hoehn, *A Partial Benefit-Cost Analysis of Sea Lamprey Treatment Options On the St. Marys River*, report to the Great Lakes Fishery Commission, July 1998.

[2] Hoehn, John P., Theodore Tomasi, Frank Lupi, and Heng Z. Chen, *An Economic Model for Valuing Recreational Angling Resources in Michigan*, Report submitted to the Michigan Department of Environmental Quality and Michigan Department of Natural Resources, Department of Agricultural Economics, Michigan State University, December 1996.

Part I: Values-per-fish (VPF)

The first part of the project is documented in: *A Preliminary Valuation of Lake Trout Using the Michigan Recreational Angling Demand Model*, as referenced above. This report discusses and assesses methods for using the MSU model to develop basin-specific estimates of the value-per-fish for lake trout at Lakes Michigan, Huron, and Superior. The report also discusses alternative means of applying the MSU model to the task of estimating economic values associated with changes in the population of lake trout.

Why values-per-fish (VPF)? There are several reasons why it would be useful to be able to express anglers' values for changes in lake trout populations in per-fish units. VPF estimates are easy to use, and they facilitate comparisons between recreational and commercial fishing values. Moreover, VPF "fit" into existing frameworks for modeling fishery problems -- see for example the framework for setting sea lamprey control targets developed by Koonce *et al.*[3] Perhaps the most important reason for developing VPF estimates is that they are amenable to benefits transfer. This means that VPF estimates can be used to represent economic values for all the anglers living in and around a particular Great Lake whereas the MSU model can only capture values for Michigan residents.

Key findings from Part I:

1. *Limited support for turning economic values from the complex models into VPF*

   The MSU model was used to derive average values per fish for lake trout at each of lakes Michigan, Superior and Huron. Average values per fish for lake trout were derived

[3] Koonce, Joseph F., Randy L. Eshenroder, and Gavin Christie, "An Economic Injury Level Approach to Establishing the Intensity of Sea Lamprey Control in the Great Lakes," *North American Journal of Fisheries Management*, 13(1):1-14, 1993.

by dividing an estimate of total lake trout value by an estimate of the number of lake trout caught by anglers. The total lake trout value was estimated by setting lake trout catch rates to zero and using the economic model to value this reduction in catch rates. The total lake trout catch was estimated by using the economic model to derive predictions of fishing effort at each site and then multiplying by catch rates at each site.

The approach for estimating average values-per-fish was examined to see how sensitive the results would be to the following: (a.) changes in the assumptions used to translate fishing trips and catch rates into estimated harvest of lake trout; (b.) different assumptions regarding the relative baseline level of catch rates at the Great Lake where lake trout policies were being examined; and (c.) different assumptions regarding the relative baseline level of catch rates at Great Lakes *other* than the lake where lake trout policies were being examined (that is, the fishing quality at potential substitute fishing sites).

For several reasons, the results of these inquiries were not encouraging for the use of a value per fish approach. First, the values per fish obtained from this approach were *very* sensitive to plausible alternative methods of using the model to estimate harvest of lake trout (as examined in a. above). Second, the estimated values per fish were shown to be moderately sensitive to the baseline levels of quality used to derive the estimates (as examined in b. above). In some cases the average value per fish was 50% larger when calculated from a different level of initial quality. Third, in some cases the average value per fish estimates differed by over a factor of two across the Great Lakes. Finally, related research[4] suggests that setting the lake trout catch rates to zero will not

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[4] Lupi, Frank, "Increasing at an Increasing Rate: The Convexity of Discrete-Choice Welfare Measures," Agricultural Economics Staff Paper 98-xx; paper presented at American Agricultural Economics Association's annual meeting, Salt Lake City, Utah, August 2, 1998.

adequately capture the total use-value of lake trout fishing. This limitation affects the usefulness of the estimated average values per fish. All of these results suggest that the average VPF estimates are too sensitive to the context in which they are derived to support broad use of the VPF estimates for benefit transfer purposes, thereby undermining the key advantage of the value-per-fish approach.

2. *The MSU model can be used to directly evaluate changes in lake trout populations*

The report also discusses the fact that there is no direct need to rely on VPF to get values for the Michigan population. The MSU model can be used to directly evaluate policies if a relationship between catch rates and lake trout population levels is assumed, e.g., a proportional relationship between catch rates and fish population. While this approach limits both the ease of use of the economic values and the transferability of the results, it does not present a significant hurdle to the use of the model.

3. *Economic values for changes in catch rates at one Great Lake can be treated as if they are independent of possible changes in the conditions at other Great Lakes*

An examination of a range of hypothetical scenarios revealed that the estimated recreational fishing values for changes in lake trout catch rates at an entire Great Lake were relatively insensitive to the assumed levels of fishing quality at alternative Great Lakes (as examined in c. above). This result provides strong support for using the economic model to evaluate policies for one Great Lake without worrying about possible changes in the quality of other lakes. This greatly simplifies the task of performing economic assessments of changes in fish populations. For example, in conducting an assessment of potential changes over time in lake trout populations at Lake Huron, one can proceed *as if* fish populations at other Great Lakes remain at their baseline levels.

Part II: Catch rate estimation

The Hoehn et al. version of the recreational fishing model is based on Great Lake catch rates that were estimated in the late 1980s. The catch rates vary by site, species, and month. The second phase of the current project was devoted to updating these catch rate estimates so that the recreational demand model could be re-estimated using catch rates estimates more in line with the 1994 survey data on anglers' fishing site choices. This part of the project is documented in *Trout and Salmon Catch Rates at Michigan Great Lakes Sites, 1986 to 1995*, as cited above.

In this phase of the research, an extensive set of catch rate models that are novel and of potentially broader use were developed. Negative binomial regression models were used to estimate catch-per-hour for recreational anglers fishing for trout and salmon in Michigan waters of the Great Lakes. Dependent variables were observations on catch and hours fished for angler parties interviewed in Michigan creel surveys from 1986 to 1995. The estimated models relate catch rates to independent variables for year, month, and fishing location. Interactions between months and locations are included to permit a rich array of spatial and temporal variation in estimated catch rates. Additional variables control for charter boat use, angler party size, and extent of species targeting (e.g., fishing for "salmon" versus "chinook"). Separate models are estimated for nine combinations of species and Great Lakes. While lake trout is treated as a separate species, chinook and coho salmon are grouped together as are rainbow and brown trout. The estimation results indicate significant relationships between catch rates and most independent variables, including large positive effects for charter boats and targeting, positive but declining effects for increases in fishing party size, and significant spatial and temporal differences.

By utilizing the annual data, the catch rate modeling approach provided predictions of the

1994 catch rates that were specific to specie targeted, lake, site, month, and year -- even for combinations of specie, site, and month where any one year contained to few observations to estimate the combined effect. These predictions serve as inputs to the final stage of the research project.

Part III: Economic model re-estimation and policy evaluations

The final phase of the project involved re-estimating the recreational demand model using the new catch rate data and applying the revised model to some potential lake trout rehabilitation scenarios. A complete description of the re-estimated model is contained in *A Partial Benefit-Cost Analysis of Sea Lamprey Treatment Options On the St. Marys River*, as cited above.

Re-estimated model results: Re-estimation of the recreational angling demand model using the updated catch rates revealed some interesting results. A general finding after estimating under a variety of model specifications was that the parameters on the catch rates for individual species were fairly unstable and were often insignificant. For example, some model specifications resulted in the lake trout parameter being insignificant and sometimes even negative, while other specifications resulted in the salmon catch rate being very low and insignificant. Interestingly, in almost all specifications examined, we could not reject the restriction that all the species of Great Lakes trout and salmon had the same parameter. One possible explanation for this result is that the specie-specific catch rates are significantly correlated with one another which complicates attempts to identify their separate effects. Another possible explanation is that anglers who are targeting a specific trout or salmon species may not care about the catch rates of other species when they make their site choices. The implication of the result that the catch rate variables have the same parameter is that each of the species is equally important to anglers and equally valuable. Put differently, it means that when making a Great Lakes trout and salmon fishing site choice, anglers prefer high catch rates, and there were not significant differences in this preference among trout and salmon species.

Perhaps the biggest caveat associated with the model re-estimation phase is that a close inspection of the data revealed a fairly thin data set for the types of trips of interest for this application. Specifically, of the more than 4,000 trips that were used in the original Hoehn et al. model, less than 10% are fishing trips where Great Lakes trout and salmon were being sought. Thus, while we were successful in estimating an economic model that predicts where anglers will take Great Lake trout and salmon fishing trips, the available data on trout and salmon fishing limits our ability to capture potentially important trade-offs anglers might make in their choice of which trout and salmon species to target on a fishing trip.

Policy evaluation: To illustrate how the recreational demand model can be used, the model was applied to the evaluation of alternative lamprey treatment options at the St. Marys river. The complete results are presented in *A Partial Benefit-Cost Analysis of Sea Lamprey Treatment Options On the St. Marys River*. We refer to this as a "partial" benefit-cost analysis to emphasize that only a portion of the economic values associated with the treatment options can be captured by the MSU economic model. A more complete set of caveats is presented in the report.

Three alternative policies for sea lamprey treatment were evaluated against the annual baseline associated with not undertaking additional treatment on the St. Marys river. The three policies are: A = annual trapping and sterile male release; C = annual trapping and sterile male release with granular bayer applications every five years; and E = annual trapping and sterile male release with one granular bayer application. Research results provided by the GLFC linked each treatment option to long run changes in lamprey populations and lake trout populations by age class. Treatment option A results in the slowest growth in the lake trout populations while option results in the fastest growth. Both options A and E converge to the same long run lake trout populations while option C converges on a somewhat larger population level. All three options result in substantially larger long run lake trout populations than would occur were the St. Marys not treated.

The time series of changes in the age 8+ lake trout population by region of Lake Huron that were projected for each policy were translated into a time series of proportional changes in lake trout populations by regions of Lake Huron. These proportional changes in regional lake trout populations were then used to proportionally change the lake trout portion of the catch rate variable at the sites within each region in the recreational demand model. The outcome was a time path of changes in regional lake trout catch rates for each of the three treatment options, as well as a time path for baseline lake trout catch rates. The economic model is then used to estimate the value to anglers of the change in catch rates for each year along the time path of changes in catch rates.

The evaluation of the St. Marys treatment options builds on the research results of the first two phases of the project. For example, the linkages between the economic model and the lake trout population changes is based on the conclusions from the first part of the research project (as outlined above in finding 2). Moreover, when the time paths of Lake Huron lake trout catch rates are being evaluated in the economic model, the possible changes in catch rates at other lakes are assumed to remain at their baseline levels. This assumption permits a substantial reduction in the computational burden required to evaluate the Lake Huron scenarios and the results of part one suggest that this simplification has little impact on the estimated values for the changes in catch rates at Lake Huron (see finding 3 above). In addition, the model from this phase of the project is entirely dependent on the catch rate modeling that was done in part two.

Before presenting an evaluation of the entire time path of changes in the regional lake trout catch rates, we will examine the estimated benefits in the year 2015. The *un-discounted* estimates of the economic use-values associated with each of the policy options in the year 2015 are: $2,617,000 for Option A; $4,742,000 for Option C; and $3,333,000 for Option E. These are estimates of the economic use-values accruing to Michigan resident anglers, and they are denominated in 1994 US dollars. The estimates reveal that each of these options yield substantial benefits in future years. Note that in these scenarios, the northern portions of the lake experience much larger changes in population than do the southern portions. However, it is the southern portion of the lake that lies closest to the bulk of the Michigan population. Not surprisingly then, if the lake wide average changes in lake trout population for policy A were used to change catch rates at all sites (instead of breaking them out by regions), the estimated values for option A would be over 3 times larger. The implication is that the spatial distribution of the changes in fish population matters.

Just looking at the estimated economic benefits for the different treatment options in the year 2015 only reveals part of the picture since the costs of the policies differ, as does the timing of the costs and benefits for each policy. In such situations economists often argue for comparing the "net present value" of the alternative investment options. The net present value is the difference between the present value of the stream of benefits minus the present value of the stream of costs. Present values are the values in some future year multiplied by a discount rate. Discount rates reflect the fact that capital is productive so that investments in one activity mean one forgoes the opportunity to invest in other activities. Thus, discount rates are inversely proportional to the interest rates that one assumes are available on alternative investments (such as putting money in a bank account). If the interest rate is r, the discount rate for some benefit, B_t, in year t is $d_t=(1+r)^{-t}$, and the present value of the benefit that occurs in year t is $B_t \times d_t = B_t/(1+r)^t$. Thus, the larger is the interest rate, the lower is the net present value of a benefit or a cost that occurs in year t.

The get the stream of benefits for the alternative St. Marys treatment options, the regional changes in catch rates were evaluated for the years 1999 to 2030 with the regional lake trout populations in future years assumed to stay at the 2030 levels. The stream of costs was estimated by the GLFC to be about $300,000 per year for trapping and sterile male release, and about 5 million dollars per granular bayer treatment. The net present value of the streams of benefits minus cost was calculated for each option using a variety of discount rates and are reported in Table 1. The columns of the table represent the results for the different treatment options, and the rows show the sensitivity of the results to alternative discount rates.

The results presented in Table 1 show that all three treatment options are estimated to have positive net present values at reasonable discount rates.[5] In addition, treatment Option E which involves the one time granular bayer application combined with lamprey trapping and release of sterile males is best in the sense that it yields the largest net present values, (except at very high discount rates). Also, option C is better than option A at lower discount rates (<6%) with the converse holding at higher discount rates. The economic value of the

[5] In "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," (Circular No. A-94-Revised, October 29, 1992) the US Office of Management and Budget recommends using an interest rate of 7%. However, the OMB circular states that guidance for water resource projects is found in "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" which recommends use of a discount rate of xx ** traditionally around 3% -- double check latest version **

Table 1: Net Present Value of the St. Marys River treatment policies under alternative interest rates (The economic values in table are in $1,000 units)†

interest rate	Option A (SMRT only)	Option C (SMRT + G.B. every 5 yrs.)	Option E (SMRT + G.B. only once)
	(thousand $)	(thousand $)	(thousand $)
3.0%	93,340	96,470	192,110 *
5.0%	40,410	40,730	81,910 *
7.0%	21,030	19,800	40,520 *
10.0%	9,200	6,680	14,510 *
12.5%	4,940 *	1,840	4,820
15.0%	2,690 *	(740)	(380)
25.0%	(40)	(3,730)	(6,730)

† Negative numbers in parentheses (based on partial benefits estimate, measures only the use-value that accrues to Michigan resident anglers as a result of the changes in lake trout catch rates).

* Option with largest net present value (present value of Michigan angling benefits minus present value of treatment costs).

Future research possibilities

Additional model applications: The brief review of the St. Marys River application illustrates one of the ways that the economic model developed for this project can be used. The model can continue to be applied to the St. Marys case if alternative assumptions regarding lake trout were to be developed. For example, the model could be used to evaluate the range in benefits that might be associated with different ranges of uncertainty in the lake trout growth scenarios. Naturally, the model is of broader applicability than illustrated.

Another area that the model might be applied is in examining lamprey control targets at each Great Lake. Using part of the framework developed by Koonce *et al.*,[6] alternative lamprey control levels can be linked to lake trout population levels. The changes in lake trout population levels can then be evaluated with the economic model by applying the methodology developed in phase one of this project and illustrated in St. Marys River case study.

Research issues: Several important research issues have been raised in the course of this project. A key issue regards anglers' preferences for alternative species of trout and salmon. In the model applied here, we lacked enough data to identify potential differences in anglers' preferences for various trout and salmon species. As a consequence, the model treats all these species as equally valuable and implicitly holds the allocation of fishing effort constant across species. There are many possible research steps that might shed more light on this issue. One approach would be to incorporate more data into further refinements of the recreational angling model. This might be accomplished by using a larger data source on recreational species choices such as the Michigan Creel survey. The additional data might

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[6] See note 3.

permit the modeling of anglers specie target decisions in addition to their site choices.

Another possibility would be to use a new survey to directly question anglers about their species preferences. In such a survey, it would also be possible to elicit anglers' preferences for alternative lake management plans. In this way, valuable information could be acquired about anglers' specie preferences as well as their preferences regarding the lake community objectives. While survey methods are commonly used to collect information about anglers' activities and opinions, specific formulations of these questions are suitable for estimating economic benefits associated with lake management plans. Finally, there is nothing that prevents the collection of preference information from the general public, as opposed to just anglers.

GREAT LAKES FISHERY COMMISSION

Project Completion Report[1]

The Recreational Fishing Value of Sea Lamprey Control

Part 2: A Partial Benefit-Cost Analysis of Sea Lamprey Treatment Options on the St. Marys River

by:

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A Partial Benefit-Cost Analysis of Sea Lamprey Treatment Options on the St. Marys River

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A report submitted to the Great Lakes Fishery Commission, July 1998

The research reported here reflects a work in progress; Feedback welcome & encouraged.

Please direct any comments or questions to Lupi *<lupi@pilot.msu.edu>*

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1. Purpose

The purpose of this report is to document an economic model of recreational fishing in Michigan and illustrate how the model can be used to estimate some of the economic benefits associated with fisheries management decisions.[1] The illustration presents estimates of some of the economic benefits associated with sea lamprey control on the St. Marys River. An economic model of recreational anglers demand for fishing in Michigan is used to estimate the economic benefits that accrue to Michigan's recreational anglers as a result of lake trout recovery scenarios that are linked to lamprey management options on the St. Marys River. These benefits are then compared to the costs of the alternative management options. Since no attempt has been made to document all possible economic benefits, we refer to this as a "partial" benefit-cost analysis. Even though not all the benefits are quantified here, the results provide important evidence about the benefits that readers should bear in mind. First, assuming the scenario descriptions being valued are reasonable characterizations of the effects of lamprey treatments, the estimated benefits presented here serve as a lower bound on the total benefits since many important potential benefits have not been quantified. Second, the benefits to Michigan anglers are likely a major portion of the benefits associated with changes in lamprey control. The results suggest that all of the lamprey treatment options yield substantial economic benefits to Michigan anglers, and the portion of benefits that are estimated here exceed the program costs.

2. Sea Lamprey Background[2]

The sea lamprey is a non-indigenous aquatic nuisance specie in the Great Lakes. The lamprey likely made its way into the Great Lakes through shipping canal following 1829 construction of the Welland Canal around Niagara Falls. Sea lamprey prey on lake trout and other species of Great Lakes fish. Lamprey are credited, along with over-fishing, for the collapse of the lake trout populations in the Great Lakes. The presence of lamprey in the Great Lakes led to the creation of the Great Lakes Fishery Commission (GLFC) which is jointly funded by Canada and the United States. The GLFC oversees lamprey control in the Great Lakes.

Ongoing chemical and barrier lamprey control efforts have successfully reduced populations of lamprey in Lake Superior and most of Lake Michigan. This has allowed for the

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[1] The research reported here was conducted as part of a grant from the Great Lakes Fishery Commission (GLFC) to Michigan State University (MSU) entitled "The Recreational Fishing Value of Sea Lamprey Control." Drs. John P. Hoehn and Frank Lupi of the Department of Agricultural Economics, MSU, were the principal investigators. Throughout the course of the project, we have worked closely with Gavin Christie, Integrated Management Specialist at the GLFC. We have also benefitted from discussions with Douglas B. Jester of the Michigan Department of Natural Resources.

[2] The material in this section is drawn the St. Marys River Control Task Force report (see "SMRCS" in the references), and from the following fact sheets prepared by the Great Lakes Fishery Commission: Fact sheet 1, "The Great Lakes Fishery Commission: History, Structure, and Mandate," Fact sheet 3, "Sea Lamprey: A Great Lakes Invader," and Fact sheet 9, "International Sea Lamprey Management on the St. Marys River."

restoration of lake trout populations in Lake Superior and some more limited success in Lake Michigan. Efforts to achieve restoration of lake trout on Lake Huron and northern Lake Michigan have been hampered by the large numbers of lamprey that spawn in the St. Marys River, the channel connecting Lake Superior and Lake Huron. The sea lamprey population in northern Lake Huron is estimated to be larger than in all of the other Great Lakes combined (SMRCS). The primary means of controlling lamprey is by treating streams in the Great Lakes basin with the lapricide TFM (3-trifluoromethyl-4-nitrophenol). TFM kills larval lamprey before they can migrate to the Great Lakes. However, due to the flow volume and depth of the St. Marys River, TFM treatment would require substantial funds and would be of reduced effectiveness. This has led the GLFC to search for other potential control options for the St. Marys river. Were it not for the difficulties associated with the treatment of the St. Marys river, it is estimated that sea lamprey abundance in Lake Huron would be about 50,000 (approximately the levels of Lakes Superior and Michigan) rather than 400,000 (SMRCS). The large number of lamprey in northern Lake Huron (and Lake Michigan) coincide with vast areas of critical spawning habitat for lake trout. Increasing lake trout populations in the critical spawning areas in northern Lake Huron is crucial for achieving self sustaining stocks of lake trout -- a goal laid out in the Fish-Community Objectives for Lake Huron (DesJardine et al).

3. Recreation Demand Models for Michigan

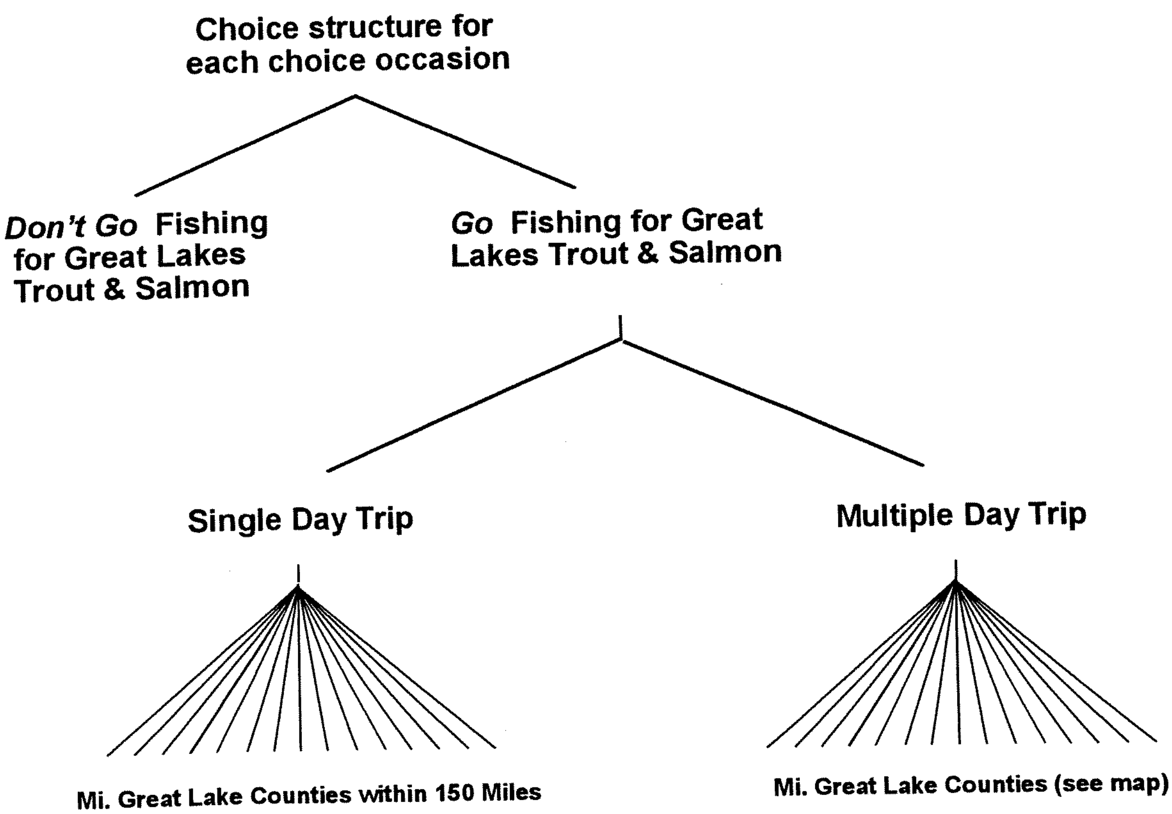
An economic model of recreational fishing in Michigan is used to estimate the economic benefits to recreational anglers in Michigan of increases in lake trout populations in Lake Huron. The economic model is based on the travel cost method. The basic idea behind the travel cost method is that anglers must spend time and money to travel to and from recreation sites. These travel costs can then be used to estimate anglers' willingness to pay for recreation sites. A complete discussion of the travel cost method and what it does and does not measure is provided in chapter 2 of Lupi and Hoehn (also see Freeman or Bockstael et al, 1991 for recent technical reviews of the travel cost method). The model and data used here draws on the work of previous research conducted at Michigan State University and documented in Hoehn *et al.*

The type of travel cost model employed by the Michigan State University team is referred to as a random utility model (RUM).[3] RUMs use data on individual trips and advanced statistical techniques to explain anglers' fishing site choices and relate these choices to the costs and characteristics of alternative fishing sites. As discussed below, it is through this linkage that RUMs can be used to value changes in site characteristics such as environmental quality. Since possible fishing destinations differ in their travel costs and characteristics, anglers must make a trade-offs between travel costs and site characteristics. The RUM approach assumes that anglers pick the site that they consider to be best. Anglers' choices reveal their relative preferences for

[3] For general texts on the RUM, see Train or Ben-Akiva and Lerman. For early applications of the RUM to recreation site choices, see Bockstael *et al.* (1984) and Bockstael *et al.* (1989). Recent applications include Feather *et al.* and Hausman *et al.*, while Jones and Sung represents an earlier application of the RUM to fishing in Michigan.

site characteristics and travel costs, i.e., the anglers' willingness to trade travel costs (or money) for site characteristics. By combining data on anglers' fishing site choices with the costs and characteristics of all alternative sites, statistical methods can be used to estimate these relationships.

Figure 1: Choice Structure for Repeated Random Utility Model of Recreational Fishing in Michigan for Great Lakes Trout and Salmon.



As noted above, the basic RUM model describes site choice. In a *repeated* RUM such as the Michigan model, the season is divided into a series of choice occasions. In each occasion, anglers decide whether to take a trip, and if so, where to fish.[4] In the Michigan model, the choice structure depicted in Figure 1 is repeated twice-weekly over the course of the season.

[4] For applications of the repeated-RUM, see Morey *et al.*, 1991 and 1993, and Chen *et al.* Morey provides a thorough review of repeated RUM models in the context of modeling seasonal recreation demand and site choices.

Consequently, the repeated RUM can explain site choices as well as the number of trips (i.e., where and how often anglers fish). All other fishing and non-fishing activities are reflected in the "don't go" alternative.

The data describing where and how often anglers go fishing in Michigan was collected in an extensive telephone panel survey that followed anglers during the course of the 1994-95 fishing year. The panel members were recruited from the general population of Michigan residents to ensure that the results would be representative of the general population. Computer assisted telephone interviewing was used to streamline all interviews and improve response accuracy. Techniques to ensure response accuracy included a large pilot survey, fishing logs as memory aides, bounded recall to avoid double counting of trips across panel interviews, and providing multiple opportunities to revise trip counts. To balance the need to collect timely and accurate data against the burden of the interviews, frequent anglers were called more often than infrequent anglers -- panel interview frequencies ranged from eight interviews for the most avid anglers to three interviews for the least avid anglers. A complete description of the data and methods is found in Hoehn et al.

Here, the survey data is used in two stages. In the first stage, fishing location choices are modeled using the survey data for anglers who took a fishing trip to the Great Lakes and fished for trout or salmon. In the second stage, the number of Great Lakes trout and salmon fishing trips is modeled. The second stage estimates the propensity of all the anglers in the panel to participate in Great Lakes trout and salmon fishing trips.

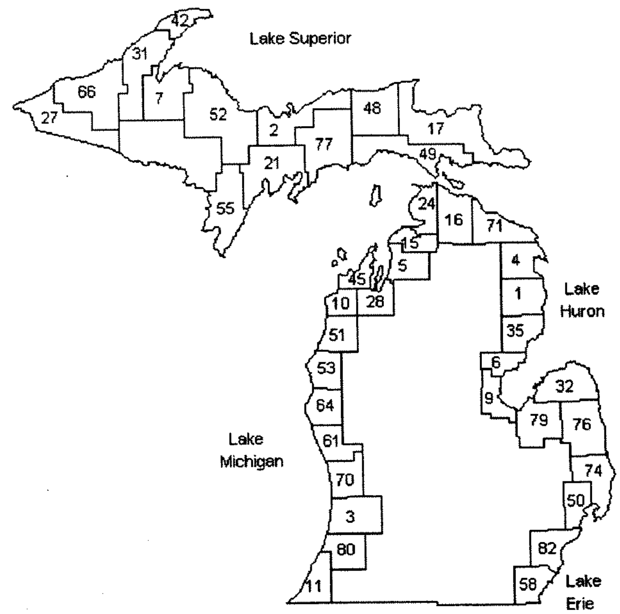
There are 1902 potential anglers in the panel data sample; 1080 of these took some type of fishing trips in 1994 during the April to October open-water fishing season. Of these participants, 90 individuals took Great Lake trout and salmon trips for a total of 312 trips. Of these trips, 70 are multiple day trips and 242 are single day trips. There are 9 choice occasions per month from April to October.

The fishing sites are characterized by their travel costs and catch rates. Travel costs are defined as the sum of driving costs, lodging costs, and time costs. Driving costs are the round trip travel distance multiplied by the estimated per mile driving cost for each sample member. Time costs are defined as each individual's estimated time costs times the travel time for each trip. The individual specific time cost and driving cost regressions, as well as the lodging cost calculations are documented in detail in Appendix 1 of Hoehn et al.

In the recreational fishing model, the fishing sites are each characterized by the catch rates for each of the following species: salmon, lake trout, and other trout. These catch rates are specific to each county and vary on a monthly basis over the open water season (April to October). These catch rates are based on an analysis of the Michigan creel survey party interview data (described in the next section). The spatial and temporal variation in the catch rates reflects seasonal differences across sites in the abundance of salmon and trout.

Figure 2: Michigan's Great Lake County Numbers and Names

1 Alcona
2 Alger
3 Allegan
4 Alpena
5 Antrim
6 Arenac
7 Baraga
9 Bay*
10 Benzie
11 Berrien
15 Charlevoix
16 Cheboygan*
17 Chippewa
21 Delta
24 Emmet
27 Gogebic
28 Grand Traverse
31 Houghton
32 Huron
35 Iosco
42 Keweenaw
45 Leelanau
48 Luce
49 Mackinac
50 Macomb*
51 Manistee
52 Marquette
53 Mason
55 Menominee
58 Monroe*
61 Muskegon
64 Oceana
66 Ontonagon
70 Ottawa
71 PresqueIsle
74 St. Clair
76 Sanilac
77 Schoolcraft
79 Tuscola*
80 Van Buren
82 Wayne*



* Counties that do not enter the model as destination sites for Great Lakes trout and salmon fishing.

Destination sites (fishing locations) are defined by the stretch of Great Lake shoreline within a county (see Figure 2). There are 41 Great Lake counties in Michigan. However, not all 41 counties provide access to trout an salmon fishing. For example, the counties bordering Lake Erie, Lake St. Clair and some of the Saginaw Bay counties are excluded because the warmer water does not provided substantive opportunities to catch Great Lakes trout and salmon.[5] Feasible sites that enter anglers' choice sets for single day trips include all Great Lake counties in Michigan within 150 miles of an individuals permanent residence. For multiple day trips, all the sites enter the choice sets.

The recreational angling model that is estimated here is specified statistically as a nested logit with the participation level nested above the site choice level. Since an extensive discussion of this type of statistical model and its economic underpinnings is given in Lupi and Hoehn, only a

[5] The following Great Lake counties were not included in the analysis: Monroe, Wayne, Macomb, Tuscola, Bay, and Cheboygan. With the exception of Cheboygan, these are warm-water areas where trout or salmon fishing is essentially non-existent (these counties had no more than a handful of trout or salmon anglers in ten years of creel survey data). Cheboygan County was not included because no angler in the sample fished there and because in 10 years of creel survey data there were no trout or salmon observations from Cheboygan Co. However, unlike the other excluded counties, it is possible to catch trout or salmon from the waters off Cheboygan.

brief explanation is presented here (see also McFadden or Morey). In the nested logit model formulation, the probability of selecting a site conditional on taking a trip is given by

$$Prob(j|go) = \pi_{j|go} = \frac{\exp(\beta X_j)}{\sum_j \exp(\beta X_j)} \tag{1}$$

where go refers to taking a trip, j refers to the possible sites, X_j is a vector of characteristics describing the sites, and β is a vector of parameters to be estimated. X_j will include site characteristics such as travel costs and catch rates. The index βX_j is referred to as the indirect utility of taking a trip to site j. The relative value of the elements of the estimated β are estimates of anglers preference for different site characteristics.

The probability that an angler chooses to take a trip on any given occasion is given by

$$Prob(go) = \pi_{go} = \frac{\exp(\theta IV + \gamma Z)}{1 + \exp(\theta IV + \gamma Z)} \tag{2}$$

where Z is a vector of characteristics of the angler, γ is a vector of parameters to be estimated, IV stands for "inclusive value" and θ is the estimated parameter on the inclusive value. The inclusive is a summary index that describes the estimated utility of the recreation site choices, and it is given by

$$IV = \ln\left(\sum_j \exp(\beta X_j)\right) \tag{3}$$

The use of the inclusive value as a variable is a way of introducing potential correlation in the error terms associated with sites. If θ, the estimated parameter on IV, is less than one, then the model estimates suggest that the indirect utilities associated with the alternative fishing sites are more correlated with one another than they are with the "don't go fishing" alternative (McFadden). The IV formula is also used in the calculation of the economic value (benefits or costs) associated with any changes in the site characteristics, X_j (Small and Rosen; McFadden; Morey). Even though the present model differs, the procedures for calculating economic benefits and extrapolating these to the Michigan population are the same as those described in detail in chapter 3 of Lupi and Hoehn (also see Lupi and Hoehn, 1998, for additional details regarding welfare measurement).

4. Catch Rate Modeling

Part of the research project was devoted to updating the Great Lake trout and salmon catch rate estimates so that the recreational demand model could be re-estimated using catch rates estimates more in line with the 1994 survey data on anglers' fishing site choices. Specifically, the Hoehn *et al* version of the recreational fishing model is based on Great Lake catch rates that were estimated by MDNR personnel using data from the mid to late 1980s. The catch rates vary by site, species, and month. However, since the angler survey data is from 1994, there is the possibility that the catch rate data does not reflect the status for the Great Lakes fisheries in the year that anglers made their fishing site choices. For example, in the very late 1980s through the early 1990s, salmon on Lake Michigan suffered substantial mortality due to bacterial kidney disease (known as BKD). Because of potentially important changes in these fisheries, we went back to the raw data and re-estimated the catch rates to include more recent years. The catch rate estimation was a core task of the GLFC project, and is fully documented in Lupi, Hoehn, and Jester.

This phase of the research developed an extensive set of catch rate models that are novel and of potentially broader use. Negative binomial regression models were used to estimate catch-per-hour for recreational anglers fishing for trout and salmon in Michigan waters of the Great Lakes. Dependent variables were observations on catch and hours fished for angler parties interviewed in Michigan creel surveys from 1986 to 1995. The estimated models relate catch rates to independent variables for year, month, and fishing location. Interactions between months and locations are included to permit a rich array of spatial and temporal variation in estimated catch rates. Additional variables control for charter boat use, angler party size, and extent of species targeting (e.g., fishing for "salmon" versus "chinook"). Separate models are estimated for nine combinations of species and Great Lakes. While lake trout is treated as a separate species, chinook and coho salmon are grouped together as are rainbow and brown trout. The estimation results indicate significant relationships between catch rates and most independent variables, including large positive effects for charter boats and targeting, positive but declining effects for increases in fishing party size, and significant spatial and temporal differences.

By utilizing the annual data, the catch rate modeling approach provides predictions of the 1994 catch rates that are specific to specie targeted, lake, site, month, and year -- even for combinations of specie, site, and month where any one year might contain few observations. The estimates of catch rates for 1994 serve as independent variables describing sites in the recreational fishing model. The complete set of estimated catch rates for all species and lakes in given in Lupi et al. These estimated monthly 1994 lake trout catch rates for Lake Huron are presented in Table 1. Notice that the catch rates at Lake Huron for lake trout are very low in September and are zero in April and October. This is a direct reflection of the regulations on the fishing season that apply to Lakes Huron and Michigan.

Table 1: Predicted 1994 catch rates for lake trout by county and month.[†]

Counties along Lake Huron		Monthly catch rate per 100 hours						
#	Name	April	May	June	July	Aug.	Sept.	Oct.
17	Chippewa	0	1	1	3	1	0	0
49	Mackinac*	0	1	1	3	1	0	0
71	Presque Isle	0	28	31	27	4	~0	0
4	Alpena	0	8	11	9	5	0	0
1	Alcona	0	12	34	34	20	11	0
35	Iosco	0	8	24	19	11	1	0
6	Arenac*	0	1	2	5	2	0	0
32	Huron	0	22	29	32	24	13	0
74	St. Clair*	0	1	2	5	2	0	0
76	Sanilac	0	1	2	5	2	0	0
11	Berrien	0	11	10	10	9	2	0

† Based on an angler party size of one that is targeting the species.

* In Lupi *et al* and in the estimation of the current model, these sites had zero catch rates for lake trout. For policies, these sites were given small positive lake trout catch rates similar to a nearby county so that the catch rates could grow slightly over time as reported in the above table. The baseline policy also was assigned the catch rates in the table.

5. Estimated Model Parameters

The nested-logit recreational fishing model was estimated sequentially by applying maximum likelihood techniques to the site choice and participation levels of the model. The choice probability functions used at the two stages of estimation are given above by equation (1) for the site choice level and equation (2) for the participation level. The sequential estimation method produces consistent estimates of the model parameters (Morey; McFadden). The model parameters and their t-statistics are presented in Table 2.

As shown in Table 2, The estimated parameters on the travel cost variables are negative and significantly different than zero. These estimates reflect that all else equal, anglers would prefer sites that have lower travel costs. The catch rate variables are positive. The single day trip catch rate parameter is significantly different than zero at the 2% level, but not at the 1% level. Notice that the travel cost parameter for multiple day trips is lower than the travel cost parameter for single day trips, and the catch rate parameter for multiple day trips is larger than for single day trips. This means that catch rates are relatively more important and travel costs are relatively less important determinants of where anglers take multiple day trips than they are for single day trips. This suggests that any changes in catch rates will be more valuable for anglers taking a multiple day trip than for anglers taking a single day trip.

Table 2 also presents the estimated parameters on the Lake Superior and Lake Michigan constants for both single and multiple day trips. The Lake Superior and Lake Michigan constants for the single and multiple day trips are dummy variables that take the value of 1 if a site lies on the lake and a value of 0 otherwise. Including these constants in the model assures that, on average, the estimated model will predict that the share of trips will match that in the survey data.

The third part of the table presents the participation level results. The inclusive value parameter is a coefficient associated with the nested logit distribution. If the parameter is less than one, then the fishing alternatives are more correlated with one another than they are with the "not fishing" alternative in the repeated nested logit. The IV parameter is significantly different than zero at the 10% level, but not at the 5% level. However, the parameter is significantly less than one indicating that the nested logit is a significant improvement of the multinomial logit formulation. Roughly speaking, the inclusive value parameter estimate implies that the Great Lakes trout and salmon fishing sites are closer substitutes for each other than they are to the "don't go" alternative. This suggests that, relative to an un-nested version of the model, the total number of Great lakes trout and salmon fishing trips will be less responsive to changes in fishing quality than will be the allocation of trips across sites.

In addition to the inclusive value parameter, Table 2 also presents several other parameter estimates for variables that entered the model at the participation level. Males, older individuals, and more educated individuals are more likely to take Great lakes trout and salmon fishing trips. Conversely, individuals with more adults or more children living in their household are less likely to take great Lakes trout and salmon fishing trips (though the effect of adults is not significantly different than zero at conventional criteria). In addition, individuals who do not have a paying job are less likely to take Great Lakes trout and salmon fishing trips.

Re-estimated model results: Re-estimation of the recreational angling demand model using the updated catch rates revealed some interesting results. Recall that the catch rate models reported in Lupi, Hoehn, and Jester (and discussed in the previous section) estimated catch rates specific to three specie groups: lake trout, salmon, and other trout. The combined catch rate variable used in the economic model as presented in Table 2 was derived by taking the sum of these three catch rates at each site in each month. That is, the catch rate for trout and salmon at site j in time t is given by

$$CR_{j,t}^{T+S} = CR_{j,t}^{lake\ trt} + CR_{j,t}^{salmon} + CR_{j,t}^{other\ trt} \qquad (4)$$

where the subscript j,t represents site j at time t, and the superscripts represent the specie groups with T+S meaning "trout and salmon." Several preliminary models were estimated using the three separate catch rate variables, one for each of the specie groups. A general finding after estimating under a variety of model specifications was that the parameters on the catch rates for individual species were fairly unstable and were often insignificant. For example, some model specifications resulted in the lake trout parameter being insignificant and sometimes even negative, while other specifications resulted in the salmon catch rate being very low and insignificant. Interestingly, in almost all specifications examined, we could not reject the restriction that all the species of Great Lakes trout and salmon had the same parameter. One possible explanation for this result is that the specie-specific catch rates are significantly correlated with one another which complicates attempts to identify their separate effects. Another possible explanation is that anglers who are targeting a specific trout or salmon species may not care about the catch rates of other species when they make their site choices. The implication of the result that the catch rate variables have the same parameter is that each of the species is equally important to anglers and equally valuable. Put differently, it means that when making a Great Lakes trout and salmon fishing site choice, anglers prefer high catch rates, and there were not significant differences in this preference among trout and salmon species. This result has potentially important implications for the current analysis as well as for any future analyses of anglers preferences regarding fish-community objectives. Whether the result accurately characterizes the general population of anglers or whether it may be due to present data limitations is recommended as an area for future research.

Table 2: Estimated Model Parameters.

Single day trip, site choice level		
variables	**parameter**	**t-stat**
Travel cost/100	-5.70	-16.6
Catch rate	1.89	2.51
Lake Superior constant	1.04	1.36
Lake Michigan constant	1.89	4.99

Multiple day trip, site choice level		
variables	**parameter**	**t-stat**
Travel cost/100	-0.81	-5.77
Catch rate	4.60	5.19
Lake Superior constant	0.15	0.27
Lake Michigan constant	1.37	4.19
Trip constant	-5.89	-10.0

Participation Level		
variables	**parameter**	**t-stat**
Inclusive value	0.17	1.93
Participation constant	-17.2	-8.00
Male	1.56	6.57
Ln(age)	1.74	5.34
Ln(education)	1.81	3.16
Adults in hhd.	-0.11	-1.21
Children in hhd.	-0.20	-2.78
No job	-0.71	-3.47

Log likelihood values at site choice level, -510; and at participation level, -1493.

6. Three St. Marys River Treatment Options

To illustrate how the recreational demand model can be used, the model was applied to the evaluation of alternative lamprey treatment options at the St. Marys river. We examine three sea lamprey control options for the St. Marys river. The three options consist of combinations of two treatments: sterile male release and trapping (SMRT) and granular bayer applications (GB). The sterile male release and trapping program involves the trapping of lamprey, the sterilization of the males, and the release of the sterile males. Uncertainty associated with the long run effectiveness of SMRT is larger than the uncertainty associated with the long run effectiveness of granular bayer. One reason for this increased uncertainty is the possibility of enhanced growth and reduced mortality of larval lamprey at lower spawning rates (a compensatory response). Granular bayer is a chemical treatment that is effective in killing larval lamprey. Spot treatments with the bottom toxicant granular bayer do not appear to cause significant mortality in non-target organisms (SMRCS). It is produced in a granular form so that it can sink to the river bed where the larval lamprey are located. GB is applied by helicopters to larval lamprey "hot spots" identified based on a mapping and sampling of lamprey spawning areas in the river.

In sum, the three treatment options being considered in this analysis are as follows: The first option is an ongoing program sterile male release (SMRT only). The second option includes the ongoing sterile male release program along with applications of granular bayer every five years (SMRT + GB). The third option includes the ongoing sterile male release program along with a one time applications of granular bayer (SMRT + GB 1.x).

Estimated annual costs for the three scenarios: Granular bayer is much more expensive than sterile male release. Applications of granular bayer cost just under 5 million dollars (US) per application. The sterile male release and trapping program costs about three hundred thousand dollars a year. The cost estimates were provided by Gavin Christie, GLFC. Exact costs used in the evaluation of the treatment options are presented later in the report.

7. Linking the Treatments to Economic Values

In order to use the recreational angling demand model to value changes in the fishery, we need to establish a link between the treatment options and variables that enter the economic model. The obvious variable in the recreational demand model would be catch rates. The following diagram illustrates the steps involved in linking the two.

Figure 3: Steps required to link treatment options to economic value.

```
                Step                Step              Step              Step
                 1                   2                 3                 4

Treatment          Changes in          Changes in         Changes            Benefits
options    -->      lamprey      -->   lake trout   -->   in catch     -->   to Mi.
                   population          population         rates              anglers

        linkages between treatment                    assumed              from the
| <-- options, lamprey & lake trout  --> |<-- proportional -->|<--   economic   -->|
        from Sitar (and Bence?)                                             model
```

The diagram emphasizes that a complex chain of information is needed in order to evaluate the treatment options. First, the effect that the treatment options will have on lamprey populations needs to be established. Second, the changes in lamprey populations must be linked to changes in the population of lake trout. Third, one needs to map the changes in lake trout population levels into changes in lake trout catch rates. Finally, the economic model can be used to estimate the economic value that accrues to anglers as a result of increased catch rates. Basically, the diagram illustrates one pathway in which changes in management actions result in changes in economic value. Anderson refers to this as marginal analysis to emphasize that we seek to identify how economic benefits change in response to some management action.

Projections of lamprey and lake trout populations associated with the three treatment options as well as the no treatment option were derived from the models of Şitar et al (the first two linkages in Figure 3). That study models the relationship between lamprey populations in Lake Huron and lake trout populations. These are linked to the control options using assumptions provided by the GLFC (possibly resulting from Bence's research?). Thus, for each treatment option as well as for the no treatment option, the GLFC has provided a time series of lake trout population levels for various regions of Lake Huron (Christie). The projected age 8+ lake trout population levels in the three regions are presented in Figures 5 and 6. The three regions of Lake Huron are shown on the map in Figure 4.

The third step in Figure 3 involves relating lake trout populations to the catch rates that are used in the recreational angling model. To relate changes in lake trout populations to changes in catch rates, we will assume that a proportional relationship holds for each site. Thus, an X% increase in the lake trout population associated with a site will increase the lake trout portion of the catch variable for that site by X%. This relationship is discussed further in Lupi, Hoehn, and Jester. Referring back to equation x, when Lake Huron lake trout populations increase by X%, only $CR^{lake\ trt}$ is increased by X%. Since only the lake trout portion of the catch rate variable in the recreational angling model is adjusted, the overall catch variable will not increase by X%. This linkage between lamprey levels and the recreational fishing model was developed and discussed in detail in Lupi and Hoehn, 1997. To develop the other steps, we will rely on research conducted by colleagues at Michigan State University, the Great Lakes Fishery Commission, and the Michigan Department of Natural Resources.

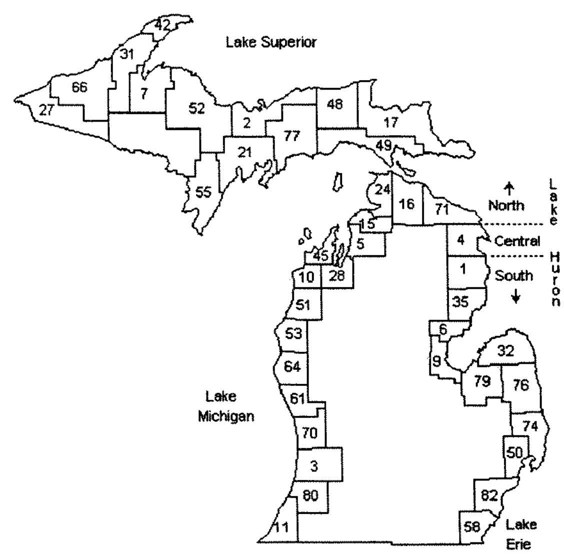
The regional lake trout population estimates were translated into proportional changes in regional lake trout populations by dividing by the regions lake trout population levels in 1994. The proportional changes over time in the populations of mature lake trout for each region are presented in figures 5 to 6. For each county in the recreational demand model, a time series of catch rate changes is derived by multiplying the 1994 catch rate for lake trout by the proportional change in lake trout population for the region associated with the site. This approach preserves the spatial variation in catch rates that existed in 1994.

The scenarios to be evaluated with the recreational demand model require the comparison of catch rates in the baseline (absent any of the St. Marys river treatment options) with catch rates under the treatment option for each year from 1998 forward. In the projected time series for lake trout populations, population peaks and levels off by the year 2030 for all of the policies. In our analysis, we use the year 2030 population levels for all years beyond 2030.

Figure 4: Map of Lake Huron Regions

[-- insert map 2 here --]

North -	lake trout management area MH-1 (Presque Isle Co. and north)
Central -	lake trout management area MH-2 - Alpena County)
South -	lake trout management areas MH-3,4,5 (Alcona Co. and south).



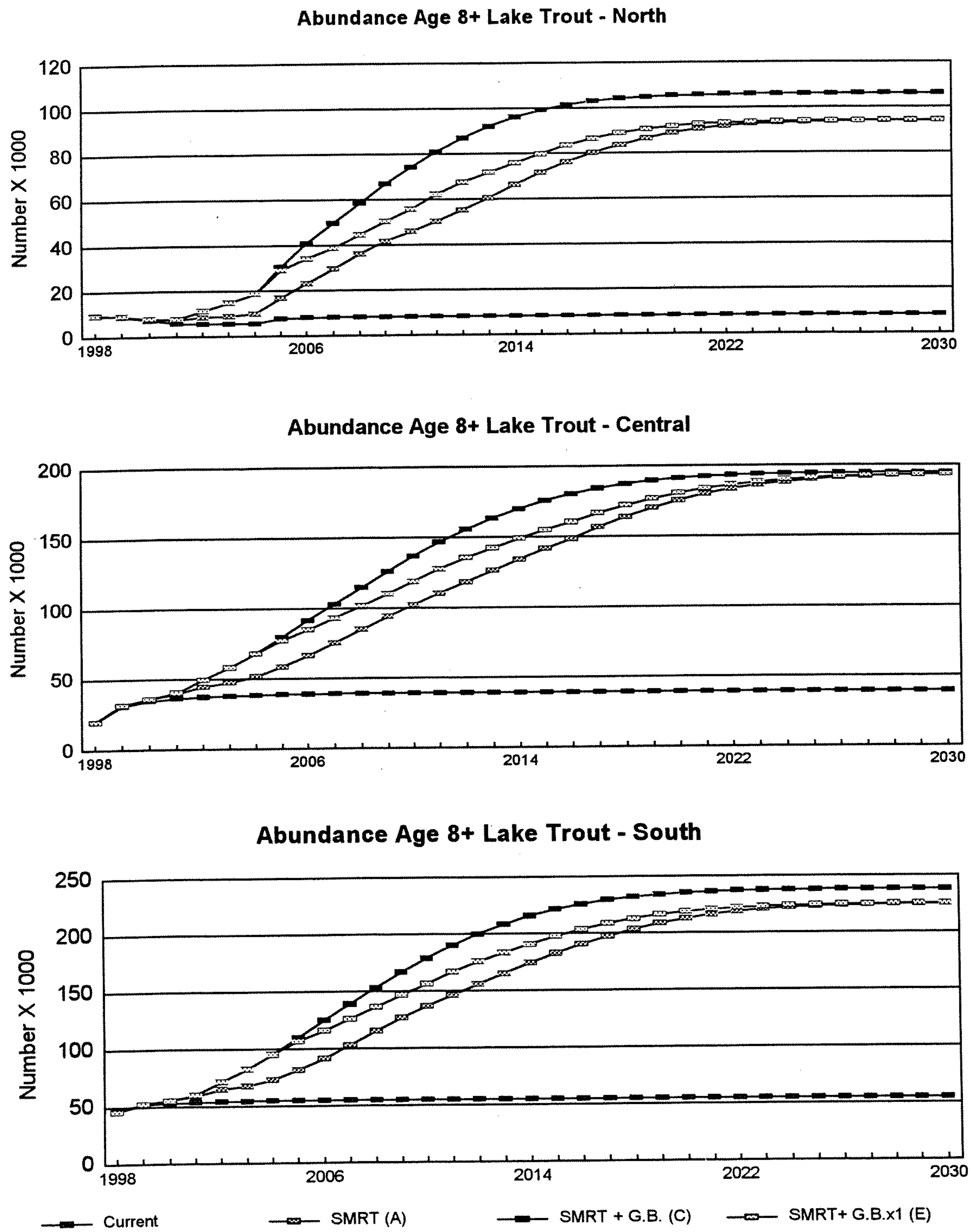


Figure 5: ***Absolute Change*** **in Estimated Annual Abundance of Mature Lake Trout by Regions of Lake Huron for each Treatment Option.**

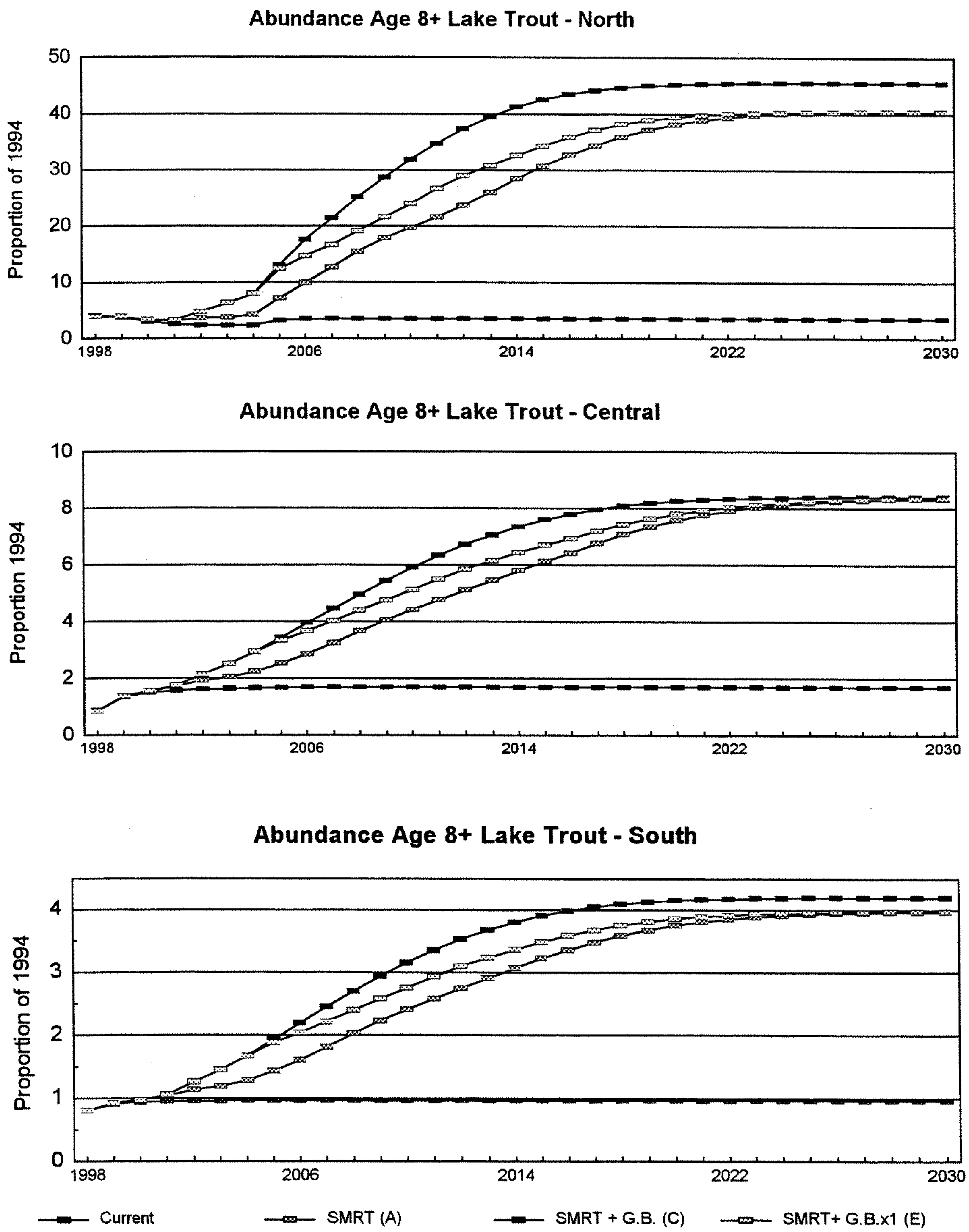


Figure 6: ***Proportional Change*** **in Estimated Annual Abundance of Mature Lake Trout by Regions of Lake Huron for each Treatment Option**

8. Valuation Results

Before presenting an evaluation of the entire time path of changes in the regional lake trout catch rates, we will examine the estimated benefits in the year 2015. The *un-discounted* estimates of the economic use-values associated with each of the policy options in the year 2015 are: $2,617,000 for Option A; $4,742,000 for Option C; and $3,333,000 for Option E (see Figure 7 and Table 3). These are estimates of the economic use-values accruing to Michigan resident anglers, and they are denominated in 1994 US dollars. The estimates reveal that each of these options yield substantial benefits in future years.

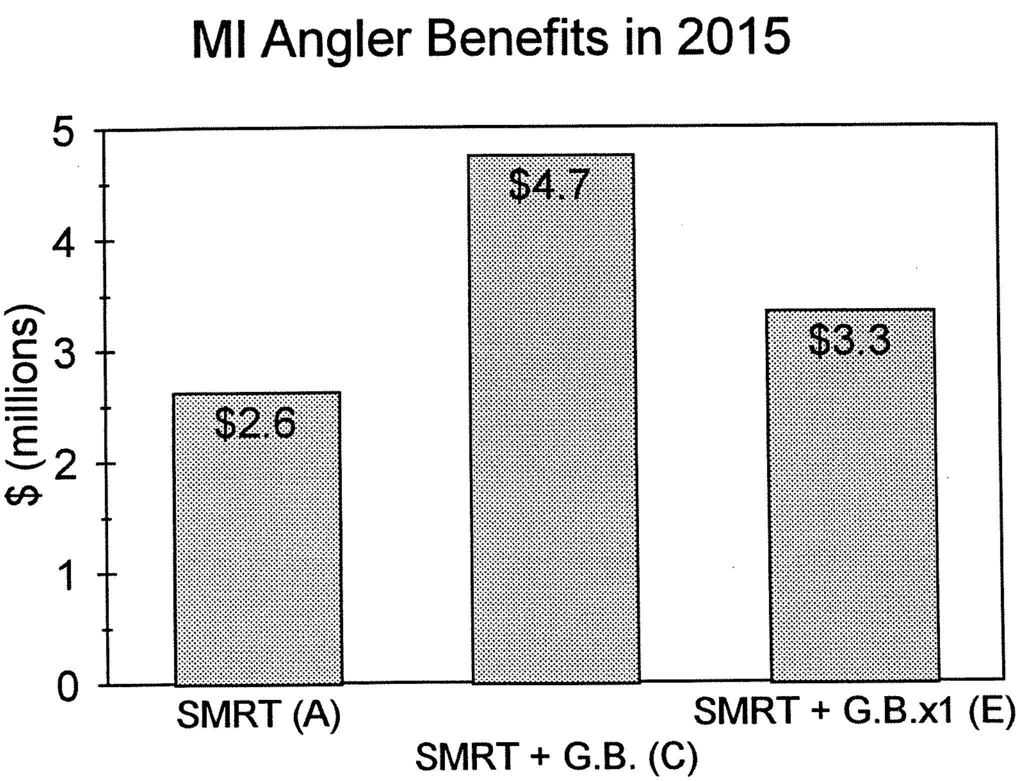


Table 3: Estimated recreational angling benefits for the projected lake trout populations in 2015 for each St. Marys river treatment options.

	Option 1 (A) SMRT only	Option 2 © SMRT + GB	Option 3 (E) SMRT + GB 1.x
Estimated benefits to Michigan anglers in 2015	$2.62 mil	$4.74 mil	$3.33 mil
Estimated population increase (absolute)†			
Northern region	62,000	90,000	71,000
Central region	122,000	156,000	135,000
Southern region	137,000	175,000	152,000
Lake Huron (total)	321,000	421,000	357,000
Estimated population increase (proportional)‡			
Northern region	30.8	42.6	34.3
Central region	6.1	7.6	6.7
Southern region	3.2	3.9	3.5
Lake Huron§	4.8	6.0	5.3

† Estimated absolute increase in mature lake trout population for each region.
‡ Projected factor increase in estimated mature lake trout population for each region (regional population in 2015/regional population in 1994).
§ Projected factor increase in estimated mature lake trout population for all of Lake Huron (lake population in 2015/lake population in 1994).

Summary of Table 3 Results

- o The table shows the estimated annual use value that would accrue to Michigan's recreational anglers if lake trout catch rates were to increase by the factors in the table. These are in 1994 dollars. This is a change in angler's consumer surplus associated with recreational fishing site choices.

- o The table also shows that, as one would expect, the treatment options that yield the largest lake trout population increases have the largest benefits.

- o Dividing the estimated value by the change in fish yield an estimated value per fish added to the lake of about $8.16, $11.21, and $9.33 (this compares reasonably well to the lowest estimated values per fish reported in Lupi and Hoehn; it is also consistent with the conclusion in Lupi and Hoehn that the value per fish estimates are not constant over a broad range of population changes).

- o The absolute changes in population are largest in the southern region and smallest in the northern region. However, since the current population level in the northern regions is so low, the proportional increases in population are much larger in the north than in the south.

Does the spatial pattern of changes in fish population matter?

In the above scenarios the proportional changes in catch rates are much larger in the northern region than in the other regions. The spatial (regional) composition of the catch rates changes makes a substantial difference for the estimated economic values. If the average lakewide change in population were applied to all sites at Lake Huron, then the estimated benefits of option A would be about $8 million. The reason for this is that the southern portions of the lake that are closer to population centers get much larger catch rate changes when the average lake trout population change for the lake is used instead of the catch rate change by region. This results reflects the economic result that, all else equal, changes in fishing quality will be more valuable the closer they are to users. This is a reflection of the use values that are being measured by the travel cost method.

The time path of angler benefits and treatment costs

As explained above, the time series of proportional changes in lake trout populations in each region (as depicted in Figure 6) were used to change regional catch rates for lake trout. Each years changes in lake trout catch rates were evaluated with the economic model of recreational fishing. For each treatment option, this resulted in an estimate of the economic value of the catch rate change for each year in the time series. The estimated values are tabulated in

Table 4. The table contains rows for each year from 1998 to 2030 with a final row representing values for all years beyond 2030. The table presents columns for the estimated angler benefits for each of the three treatment options and columns for the estimated costs for each of the three treatment options.

Consider the cost estimates first. The estimated annual costs for sterile male release and trapping program is $298,000. This cost occurs under all three of the treatments considered. The estimated costs for the granular bayer treatments under option C are $4,873,500 every fifth year with the exception of the first treatment where some of the costs are spread over two years. Option E has only one GB treatment so after the first two years the costs are the same as for option A. All of these cost estimates are presented in 1998 real dollars. The cost estimates were provided by Gavin Christie, GLFC.

The estimated benefits in Table 4 represent the estimated economic use-values that accrue to Michigan's resident anglers as a result of the increases in lake trout catch rates. Notice that the benefits are very low initially and grow over time as the catch rates increase. The estimates indicate that the added long run population associated with treatment option C is worth, in future years, almost a million dollars more than the long run population associated with treatment options A or E. Recall from figures x that the long run lake trout population levels are highest for option C due to the ongoing granular bayer treatments. Of course, this added lake trout population levels comes at the cost of almost a million dollars a year. Moreover, these costs and benefits accrue well into the future. Now compare the annual estimated benefits of options E and A. The benefits grow faster for E than A due to the initial application of GB.

Table 4: Annual Estimated Benefits to Michigan Anglers and Annual Program Costs for Each Treatment Option.

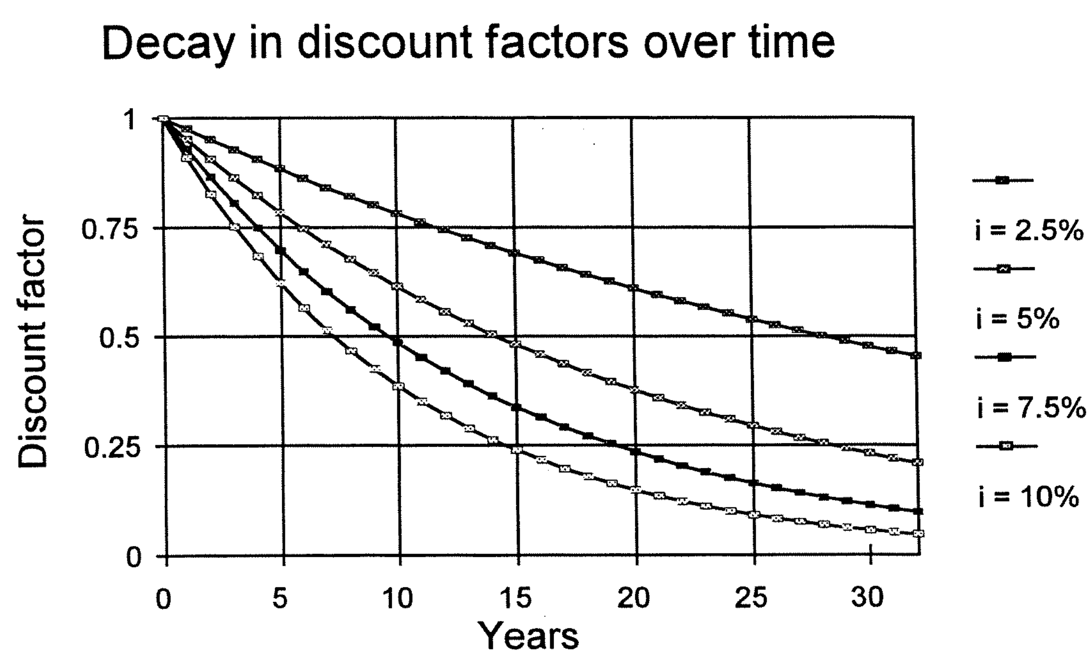
year	Annual Mi. Angler Benefits			Annual Costs		
	Option A (SMRT only)	Option C (SMRT + G.B. every 5 yrs.)	Option E (SMRT + G.B. only once)	Option A (SMRT only)	Option C (SMRT + G.B. every 5 yrs.)	Option E (SMRT + G.B. only once)
	(thous $)	(thous $)	(thous $)	(thous $)	(thous $)	(thous $)
1998	0	0	0	298	754	754
1999	6	6	6	298	4,165	4,165
2000	13	13	13	298	298	298
2001	30	37	37	298	298	298
2002	63	112	112	298	298	298
2003	83	204	204	298	298	298
2004	121	335	335	298	5,172	298
2005	193	535	492	298	298	298
2006	296	803	636	298	298	298
2007	433	1,117	811	298	298	298
2008	623	1,510	1,048	298	298	298
2009	834	1,970	1,311	298	5,172	298
2010	1,061	2,443	1,599	298	298	298
2011	1,311	2,961	1,949	298	298	298
2012	1,581	3,454	2,324	298	298	298
2013	1,908	3,931	2,642	298	298	298
2014	2,255	4,378	2,988	298	5,172	298
2015	2,617	4,742	3,333	298	298	298
2016	2,988	5,048	3,672	298	298	298
2017	3,333	5,325	3,964	298	298	298
2018	3,640	5,487	4,202	298	298	298
2019	3,931	5,653	4,413	298	5,172	298
2020	4,202	5,736	4,558	298	298	298
2021	4,413	5,821	4,705	298	298	298
2022	4,558	5,864	4,818	298	298	298
2023	4,705	5,907	4,855	298	298	298
2024	4,780	5,907	4,932	298	5,172	298
2025	4,855	5,907	4,970	298	298	298
2026	4,932	5,950	4,970	298	298	298
2027	4,970	5,950	5,009	298	298	298
2028	4,970	5,950	5,009	298	298	298
2029	5,009	5,950	5,009	298	5,172	298
2030	5,009	5,950	5,009	298	298	298
2030+	5,009	5,950	5,009	298	298*	298

* 298 plus an additional 4,874 every fifth year.

Net Present Values:

Just looking at the estimated economic benefits for the different treatment options in the year 2015 only reveals part of the picture since the costs of the policies differ, as does the timing of the costs and benefits for each policy. In such situations economists often argue for comparing the "net present value" of the alternative investment options. The net present value is the difference between the present value of the stream of benefits minus the present value of the stream of costs. Present values are the values in some future year multiplied by a discount rate. Discount rates reflect the fact that capital is productive so that investments in one activity mean one forgoes the opportunity to invest in other activities. Thus, discount rates are inversely proportional to the interest rates that one assumes are available on alternative investments (such as putting money in a bank account).

If the interest rate is r, the discount rate for some benefit, B_t, in year t is $d_t=(1+r)^{-t}$, and the present value of the benefit that occurs in year t is $B_t \times d_t = B_t/(1+r)^t$. Thus, the larger is the interest rate, the lower is the net present value of a benefit or a cost that occurs in year t. Figure 8 illustrate how the discount factors decrease over time for several different discount rates. The figure shows the discount factor applied to dollar values for years along the horizontal axis at different discount rates. For example, at a 10% discount rate, a dollar in 30 years is worth x cents today, yet at a 3% discount rate, a dollar in 30 years is worth xx% today. Therefore, the higher the interest rate that can be earned on alternative investments, the less weight that gets placed on future benefits and costs.



The specific formula employed to calculate net present value is

$$\begin{matrix}Net\\Present\\Value\end{matrix} = \sum_{t=0}^{T} \frac{1}{(1+rate)^t} \times \{Benefits(t) - Costs(t)\}.$$

where t indicates time periods and rate if the interest rate. The get the stream of annual benefits, the regional changes in catch rates were evaluated for the years 1999 to 2030 with the populations in future years assumed to stay at the 2030 levels. Figure 9 graphs the annual stream of net benefits (benefits to Michigan anglers minus costs). From Figure 9, for the treatment options involving granular bayer, there are large downward spikes that reflect the large costs of the granular bayer treatments in those years. One can also see from Figure 9 that net benefits of each policy are negative for the initial years following the initiation of each of the treatment options. Then, in later years, as the lake trout population begins to grow, net benefits become positive. The net present value of benefits minus cost was calculated for each option using a variety of discount rates (see Table 5).

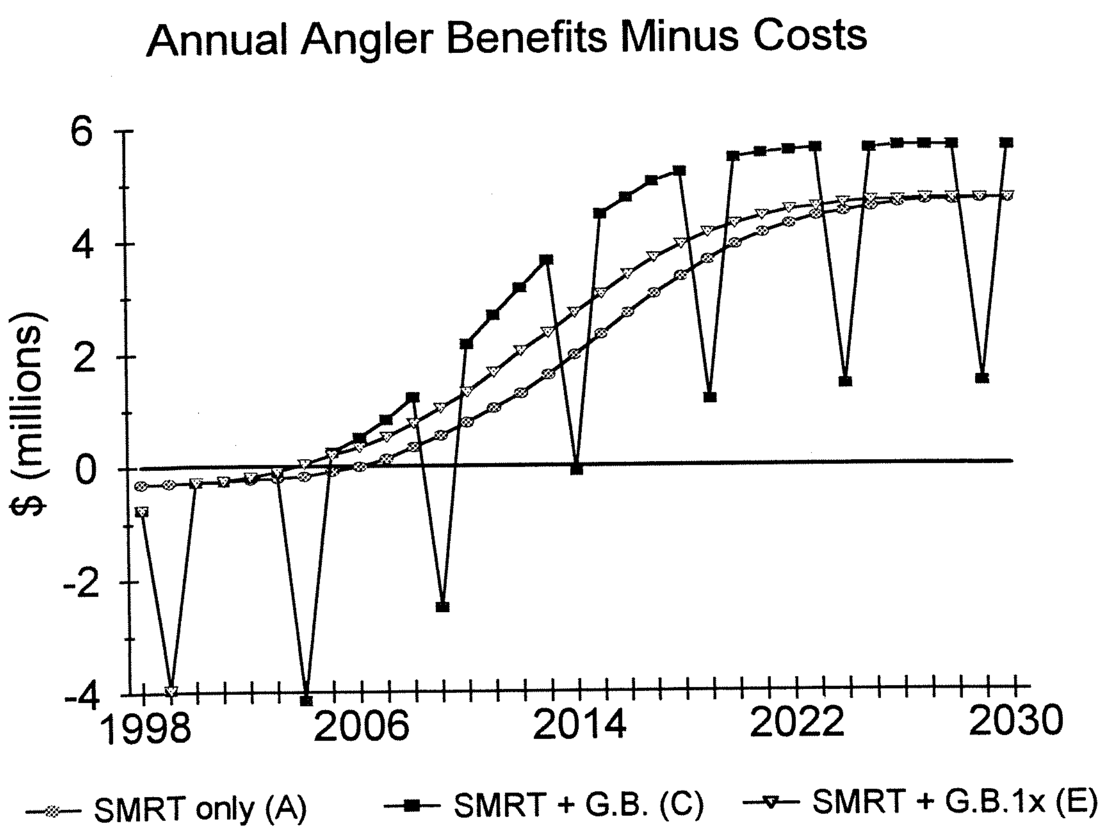


Table 5: **Net Present Value of the St. Marys river policies under alternative interest rates** (The economic values in table are in $1,000 units)

interest rate	Option A (SMRT only)	Option C (SMRT + G.B. every 5 yrs.)	Option E (SMRT + G.B. only once)	Option C-A (which is better?)
1.0%	394,030	406,210	804,720*	12,180
2.0%	165,700	171,530	340,510*	5,820
3.0%	93,340	96,470	192,110*	3,130
4.0%	59,370	60,860	121,700*	1,480
5.0%	40,410	40,730	81,910*	320
6.0%	28,720	28,160	57,070*	(550)
7.0%	21,030	19,800	40,520*	(1,230)
8.0%	15,730	13,970	28,980*	(1,760)
9.0%	11,960	9,780	20,660*	(2,180)
10.0%	9,200	6,680	14,510*	(2,520)
12.5%	4,940*	1,840	4,820	(3,100)
15.0%	2,690*	(740)	(380)	(3,430)
25.0%	(40)*	(3,730)	(6,730)	(3,690)

† Negative numbers in parentheses (based on partial benefits estimate, measures only the use-value that accrues to Michigan resident anglers as a result of the changes in lake trout catch rates).

* Option with largest net present value (present value of Michigan angling benefits minus present value of treatment costs).

The results presented in Table 1 show that all three treatment options are estimated to have positive net present values at reasonable discount rates.[6] In addition, treatment Option E which involves the one time granular bayer application combined with lamprey trapping and

[6] In "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," (Circular No. A-94-Revised, October 29, 1992) the US Office of Management and Budget recommends using an interest rate of 7%. However, the OMB circular states that guidance for water resource projects is found in "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" which recommends use of a discount rate of xx ** traditionally around 3% -- double check latest version **

release of sterile males is best in the sense that it yields the largest net present values, (except at very high discount rates). Referring back to Table 4, the net present value results imply that the accumulated difference in benefits between options C and A are enough to offset the added GB application cost that occurs up front -- except at extremely high discount rates. Also, option C is better than option A at lower discount rates (<6%) with the converse holding at higher discount rates. The economic value of the three treatment options differs for several reasons. While option C grows fastest and leads to a larger lake trout population, it also has large recurring costs. Alternatively, option A has the lowest costs, but it also has the slowest growth in lake trout populations. The best alternative, option E, suggests the faster initial growth provided by the first treatment of granular bayer is beneficial, but continued granular bayer treatments do not yield enough additional growth to offset the large application costs.

It is important to bear in mind some of the caveats associated with the numbers reported in table 5. For instance, the estimated benefits used to calculate the net benefits are based only on the estimated recreational use-value accruing to Michigan recreational anglers. There are likely other economic benefits associated with the treatment options that have not been measured. Potentially important benefits that have not been measured include such things as: benefits to non-resident anglers that fish in Michigan; benefits to anglers that fish in Canadian portions of the lake; benefits due to possible increases in catch rates in northern Lake Michigan; potential reductions in stocking costs; and values that the general public might have for rehabilitation of native fish stocks. Moreover, the changes in lake trout catch rates are based on changes in the growth of age 8+ lake trout which likely over-states the growth in the population of lake trout entering the recreational fishery (about age 5+). In addition, the analysis does not take account for uncertainties associated with the projected lake trout growth for each scenario, nor does the analysis account for any uncertainties associated with the economic value estimates. Finally, a sensitivity analysis of the physical and economic assumptions underlying the results has not been conducted. A list of some of the key assumptions underlying the analysis follows:

- Used the yearly proportional changes for the age 8+ year classes and these were applied only to lake trout (no changes in other species are assumed);

- all changes in catch rates are proportional to the 1994 values (so sites with very low baseline catch rates tend to stay low);

- the above table uses the complete stream of benefits and costs into perpetuity;

- annual benefits are only comprised of the use-value estimates from the recreational demand model where all trout and salmon species where equally desirable;

- the benefits only apply to Michigan resident recreational anglers and do not include non-use values;

- there is no accounting for any savings in fish stocking costs or benefits to commercial or tribal fishers;

- the season for lake trout is held at its current level (May to early Sept);
- recreation model values travel time at the full opportunity cost;
- there is no accounting for any increases in lake trout that could be due to reductions in lamprey populations in northern Lake Michigan;
- there is no accounting for the uncertainty associated with the economic model estimates;
- nor is there any accounting for the degree of uncertainty associated with population projections for each of the options, etc.

Could the un-quantified benefits alter the project rankings? One major benefit that has not been quantified would relate to any future savings in stocking costs. Given the growth trajectories in figures xx to xx, these are likely very similar across the three treatment options so they are unlikely to change the project rankings. There are also benefits that accrue to anglers who are not Michigan residents. If these other use related benefits are proportional to the benefits estimated here (e.g., reductions in stocking costs and benefits to anglers living outside Michigan), then they too will not alter the rankings. Finally, there may be non-use benefits associated with the restoration of lake trout populations. However, since each of the treatment options leads to stock recovery, these non-use benefits are also unlikely to alter the ranking of the project.

10. Future research

Additional model applications: The brief review of the St. Marys River application illustrates one of the ways that the economic model developed for this project can be used. The model can continue to be applied to the St. Marys case if alternative assumptions regarding lake trout were to be developed. For example, the model could be used to evaluate the range in benefits that might be associated with different ranges of uncertainty in the lake trout growth scenarios. Naturally, the model is of broader applicability than illustrated.

Another area that the model might be applied is in examining lamprey control targets at each Great Lake. Using part of the framework developed by Koonce *et al.*, alternative lamprey control levels can be linked to lake trout population levels. The changes in lake trout population levels can then be evaluated with the economic model by applying the methodology developed in phase one of this project and illustrated in St. Marys River case study.

Research issues: Several important research issues have been raised in the course of this project. A key issue regards anglers' preferences for alternative species of trout and salmon. In the model applied here, we lacked enough data to identify potential differences in anglers' preferences for various trout and salmon species. As a consequence, the model treats all these species as equally valuable and implicitly holds the allocation of fishing effort constant across species. There are many possible research steps that might shed more light on this issue. One approach would be to incorporate more data into further refinements of the recreational angling model. This might be accomplished by using a larger data source on recreational species choices such as the Michigan Creel survey. The additional data might permit the modeling of anglers specie target decisions in addition to their site choices.

Another possibility would be to use a new survey to directly question anglers about their species preferences. In such a survey, it would also be possible to elicit anglers' preferences for alternative lake management plans. In this way, valuable information could be acquired about anglers' specie preferences as well as their preferences regarding the lake community objectives. While survey methods are commonly used to collect information about anglers' activities and opinions, specific formulations of these questions are suitable for estimating economic benefits associated with lake management plans. Finally, there is nothing that prevents the collection of preference information from the general public, as opposed to just anglers.

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GREAT LAKES FISHERY COMMISSION

Project Completion Report[1]

The Recreational Fishing Value of Sea Lamprey Control

Part 3: Trout and Salmon Catch Rates at Michigan Great Lakes Sites, 1986 to 1995

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July 1998

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[1]Project completion reports of Commission-sponsored research are made available to the Commission's Cooperators in the interest of rapid dissemination of information that may be useful in Great Lakes fishery management, research, or administration. The reader should be aware that project completion reports have not been through a peer review process and that sponsorship of the project by the Commission does not necessarily imply that the findings or conclusions are endorsed by the Commission.

Trout and Salmon Catch Rates at Michigan Great Lakes Sites, 1986 to 1995

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Trout and Salmon Catch Rates at Michigan Great Lakes Sites, 1986 to 1995

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Tables and Figures

1. Purpose

This report documents the estimation of catch rates for trout and salmon in Michigan waters of the Great Lakes. The purpose of the research was to update and further develop indicators of fishing quality that could be used in the Michigan recreational angling demand model that has been developed by researchers at Michigan State University (Hoehn et al.). We will refer to this demand model as the "MSU demand model." The MSU demand model seeks to establish the relationship between when, where, and how often anglers go fishing and the quality of fishing sites.

Our goal here is to estimate monthly catch rates for trout and salmon in 1994 for Great Lake counties in Michigan. 1994 is the same year as the angler trip data used to estimate the MSU demand model. The county level is chosen to match the definition of sites in the MSU demand model. The variation over fishing sites and months is important for determining the trade-offs anglers make between the costs and qualities of alternative fishing sites.

In this report, we develop and document statistical models for predicting these catch rates. The specification of the models seeks to preserve the "species/site/month" variation in catch rates while making best use of available data. We also develop and document an explicit linkage between fish populations and the MSU demand model. This linkage can be utilized to value changes in fish populations via the MSU demand model (e.g., changes in fish populations change catch rates which affect angler behavior and result in changes economic value).

In the models presented here, lake trout (Lat) is treated as a separate species to facilitate the valuation of lake trout for use in setting sea lamprey control targets. Because of data limitations discussed in detail in later sections of this report, other trout species are grouped into a generic "trout" (Trt) catch rate model and all salmon are grouped into a generic "salmon" (Sal) catch rate model. Each of these three specie groups are modeled separately for Lakes Huron (Hu), Superior (Su), and Michigan (Mi). As a result, this research documents *nine* distinct catch rate models that will be referred to using the following shorthand: Lat Su, Lat Hu, Lat Mi, Sal Su, Sal Hu, Sal Mi, Trt Su, Trt Hu, and Trt Mi.

The catch rate models estimated here are based upon the party interview data from the Michigan creel surveys for the years 1986 through 1995. For the past 10 years, the Michigan Department of Natural Resources has conducted angler contact creel surveys on the Great Lakes. The creel surveys consist of two types of observations. The first type are party interviews conducted on-shore with randomly selected fishing parties. These interviews collect basic information about the fishing party including hours fished, species targeted, species caught, method, mode, and party size. The second type of observations are counts of fishing pressure. These data are combined by the MDNR to estimate total catch and total effort. For the catch rate models estimated here, only the party interview data are used.

Most Great Lakes counties in Michigan contain an index port that is regularly sampled under the creel survey. Over the past ten years, there are over 300,000 party interviews in the Michigan creel survey data. Of course, not all of these angler parties were fishing for trout and salmon. Though the creel survey coverage is broad and there are a large number of data points over the years, in any given year not all sites are sampled. Moreover, even with ten years of data, there are some species/month/site combinations where data gets thin. The catch rate models developed here are one way to control for potentially thin data while at the same time enabling predictions of monthly catch rates in 1994 for Great Lakes counties for the three species groups: lake trout, other trout, and salmon.

Another important feature of the catch rate models presented here is that we are estimating targeted catch rates. That is, the catch rates are tailored to those anglers that are actually targeting the species being modeled. The targeted catch rates are likely to provide a better indicator of resource quality than untargeted catch rates (by untargeted catch rates we mean catch rate estimates that do not distinguish angler effort by the species sought by the angler). The issues surrounding the targeted catch rates are discussed in more detail in section 3.5 of this report.

This report is organized as follows: the next (second) chapter reports on the statistical methods and models used to estimate catch rates; the third chapter reports on the creel survey data used to estimate the models and details the specification of the statistical models; the fourth chapter presents selected results from the estimated models including the 1994 predicted monthly catch rates by Great Lake counties for each of three species. More complete details on the underlying data, model specifications, estimation results are left to the appendices.

2. Statistical Models for Catch-Per-Unit-Effort

In this research, we estimate the statistical relationship between catch rates for trout and salmon and fishing site and month. The catch rate analysis abstracts from issues related to recruitment, growth, and survival. Instead, we focus on estimated catch-per-unit-effort without specifying size or other characteristics of the fish being caught. This level of abstraction fits the level of detail contained in the best available data, the Michigan creel survey, which does not record the size or quality of fish that are caught. The approach also allows us to take a first step toward linking the catch rate models to the MSU recreational angling demand model.

The basic setup for the catch rate model builds on two common frameworks: a proportional model of catch and Poisson processes for catching fish. In the proportional model of catch, total catch is assumed to be proportional to effort and to fish density. The catch function is given by

$$C=qED, \tag{1}$$

where C represents total catch, E represents total effort, and D represents fish density. The remaining term, q, is a proportionality term indicating the share of the stock that is caught per-unit-effort. The proportionality parameter q is often referred to as the catchability coefficient. Here, the catch rate or the catch-per-unit-effort can be expressed as

$$C/E = qD. \tag{2}$$

Thus, catch rates (qD) are proportional to fish density, and the number of fish caught is proportional to the fishing effort.

This framework is readily extended to allow for differences in catch by sites and by months. For example, catch at a particular site may vary by months because of changes in water temperature and subsequent migration of species (changes in D over time). In addition, catch may vary across sites due to differences in habitat and food availability (D varying over sites). Catch can also vary because effort (E) varies over time and space. In what follows we describe the statistical models that will be used to estimate the catch rates.

2.1 The Poisson distribution

The number of fish that an angler catches over some period of time can be treated as a random variable that takes on discrete values. Let C_i be the number of fish caught by angler i. Following the proportionality model described above, the number of fish caught by angler i in E_i units of time can be treated as a random variable taking discrete values ($C_i = 0,1,2,3,...$) with rate parameter λ=qD. Such data is often referred to as "count" data.

A common statistical model for count data is the Poisson. Under the Poisson model, the probability of catching C_i fish in E_i units of time is given by

$$\text{Prob}(C_i \mid \lambda, E_i) = (\lambda E_i)^{Ci} \exp(-\lambda E_i)/(C_i!) \quad (3)$$

In the Poisson, λE_i is both the mean and the variance of the random variable C_i. Here λ is the expected number of fish caught in a unit interval of time. If effort (time) is measured in hours, λ is the mean catch per hour, the catch rate. A complete derivation and description of the Poisson distribution can be found in most introductory statistics books (for example, Lindgren).

The statistical model allows one to estimate the rate parameter using a sample of observations on anglers' catch and effort (hours spent fishing). With the sample data and the distributional assumption implicit in the probabilities (3), the underling rate parameter λ can be estimated by maximum likelihood estimation (MLE) methods. The log likelihood function corresponding to the Poisson probabilities in (3) is

$$\Sigma_i \log L_i = \Sigma_i \log\{\text{Prob}(C_i \mid \lambda, E_i)\} = \Sigma_i C_i \log(\lambda E_i) - \Sigma_i \lambda E_i - \Sigma_i \log(C_i!). \tag{4}$$

The MLE estimator of λ is found by maximizing this likelihood function with respect to λ. The MLE estimator of λ (call this r) is given by the sum of the fish caught divided by the sum of the hours spent fishing,

$$\hat{\lambda}^{MLE} = r = \Sigma_i C_i / \Sigma_i E_i. \tag{5}$$

This estimator is a statistically unbiased, consistent, and efficient estimator of the Poisson catch rate, λ.

In the literature on angler creel surveys, this estimator is sometimes referred to as the "ratio-of-means" estimator (Jones *et al.*; Lockwood). An alternative estimator would be the mean of the individual catch rates, $\Sigma_i (C_i / E_i)/N$. This estimator can be referred to as the "mean-of-ratios" estimator, and it is also a consistent estimator of the Poisson rate parameter. The two estimators are trivially the same if all anglers spend the same amount of time fishing. However, if the time spent fishing varies over individuals, the "mean-of-ratios" estimator is statistically *strictly inferior* to the MLE estimator since it has a larger variance.

In a Poisson model, the expected number of fish caught in E_i units of time is λE_i. If all anglers face the same rate, then expected total catch is given by λE where E represents the total time spent fishing by all anglers. Since the underling rate parameter represents qD, the Poisson model of the catch of individual anglers is perfectly compatible with a proportionality model for total catch.

It is common in Poisson models to parameterize λ by letting log(λ)=βX. For example, X might include variables that capture the effects of q and D. The parameters β can also be estimated by maximum likelihood techniques. By the Slutzky theorem, if x is a random variable, the MLE estimator of F(x) is equal to the function F evaluated at the MLE estimator for x. Therefore, the MLE estimator of λ is exp(BX) where B is the MLE estimator of β. We will make use of this property when the predicted catch rates are estimated.

2.2 *The negative binomial distribution*

The basic Poisson model can be extended to allow the rate parameter to vary across anglers. The extension permits anglers to face differing catch rates due to differing skill, experience and other factors that might not be controlled for. If the rate parameter is assumed to vary randomly over anglers following a Gamma distribution, the resulting model of the catch process is called a negative binomial. The negative binomial is a generalization of the Poisson which permits the variance of C_i to differ from the expected value of C_i. The negative binomial is then the result of letting $\log(\lambda)=\rho+\varepsilon$ where ε is distributed gamma with mean one and variance α. This model is discussed in Greene (1995, p. 545).

With the negative binomial, the expected catch in E is given by ρE, and the predicted catch rate per unit time is given by ρ. The result mirrors that of the Poisson model. Thus, the parallels to the proportional catch model remain even if the underlying mean rate parameter is allowed to vary over the population. However, the negative binomial model differs from the Poisson in that the variance, which is $\rho E+(\rho E)^2\alpha$, is strictly greater than the expected catch, ρE. In the negative binomial, the parameter α is referred to as the dispersion parameter. Low values of α indicate lower dispersion of catch rates around the mean while high values of α indicate high dispersion of catch around the mean. In the negative binomial model, the "overdispersion" rate is $Var[C_i]/E[C_i] = 1+\alpha E[C_i] = 1+\alpha\rho E$.

To simplify the presentation of the model, let $\theta=1/\alpha$. With the negative binomial model, the probability of catching C fish in E hours is given by

$$Prob(C \mid \rho,E) = [\rho E/(\theta+\rho E)]^C \; [\theta/(\theta+\rho E)]^\theta \; \Gamma(\theta+C)/[C!\Gamma(\theta)], \tag{6}$$

where the subscripts for i have been suppressed for C and E. Consequently, under the negative binomial, the log likelihood function value for individual i is

$$\begin{aligned} \log L_i &= \log[Prob(C_i \mid \rho, E_i)] \\ &= C_i \log[\rho E_i/(\theta+\rho E_i)] + \theta\log[\theta/(\theta+\rho E_i)] + \log[\Gamma(\theta+C_i)/\{C_i!\Gamma(\theta)\}]. \end{aligned} \tag{7}$$

The log likelihood function for the sample is simply $\Sigma_i \log L_i$. The MLE's for ρ and θ are found by maximizing the function in (7) with respect to ρ and θ.

As with the Poisson, it is common to parameterize the rate by assuming $\rho=\exp(\beta X_i)$. Again, the parameters β and $\theta=1/\alpha$ can be estimated by maximum likelihood (MLE). The Poisson MLE estimates of β will be consistent, but not efficient estimators for this distribution. The catch rate models presented here will be based on the negative binomial model, and the parameters will be estimated by MLE.

Two major advantages of using the above count models for estimating catch rates are that they make use of the available data, and they are compatible with the proportional model of catch formulated above. With the catch models, joint effects of qD can be thought of as being related to a number of available proxy variables X. The exact catchability coefficients and species density by sites/month/species need not be measured. Rather variables which are thought to proxy q and D can be included in the catch rate models. The underlying catch rate, qD, can then be proxied by $\exp(\beta X)$. Under this formulation, a 10% increase in D will result in a 10% increase in the catch rate. Thus, if the proportional model of catch is deemed appropriate, then for policy purposes, catch rates are explicitly linked to fish density at various Great Lakes locations. The MSU demand model can then be used to link angler behavior to catch rates.

2.3 Asymptotic variance of the prediction

The catch rate models will be used to predict the monthly and site specific catch rates for trout and salmon. This section discusses how we will estimate the variance of the predicted catch rates. The variance is used to derive the standard errors of the predictions for use in constructing confidence intervals and testing hypotheses. This section draws on the discussion in Greene (1995) -- especially the discussions on pages 677 and 645.

The above mentioned MLE parameter estimates are random variables with known asymptotic distributions. Since the predicted rates are functions of estimated parameters, the predictions themselves are random variables. The derivation of the variance of the predicted catch rates is complicated by the fact that the predicted rates are nonlinear functions of the estimated parameters. Because of this nonlinearity, a first order Taylor's series expansion is used to approximate the asymptotic variance of each predicted catch rate.

To explain the Taylor's series expansion, consider some general notation. Let B be the MLE estimator of β and let V be the MLE covariance matrix for B. Let F be a function of β, and let f denote the derivative of F with respect to β. A first order Taylor's series approximation of the asymptotic variance of F is given by

$$\text{Asy. Var}\,[F(B)] \approx f(B)'\ V\ f(B) \tag{8}$$

which is an estimate of the variance of F and all functions are evaluated at the estimated parameter B. As discussed above, with the Poisson or the negative binomial, the rate is commonly parameterized by $\lambda = \exp(\beta X) = F(\beta)$. Here, the vector of partial derivatives with respect to β is given by $f = \lambda X$. Given this formulation, the predicted catch rate, r, will be a nonlinear function of the estimated parameters, i.e., $r = \exp(BX) = F(B)$. Thus, the asymptotic variance of the predicted λ is

$$\text{Asy. Var}[r] = \exp(BX)^2\ X'VX. \tag{9}$$

This is the formula used in later sections of the report. Note that this is the variance of the predicted expected value of catch rates, not the estimated variance of the underlying negative binomial. As mentioned above, the variance of the underlying catch rates in the negative binomial is estimated with $\lambda(1+\alpha\lambda)$ or $r(1+ar)$ where $r=\exp(BX)$ and B and a are the MLE estimates of β and α.

A final note on the asymptotic variance is in order. When the rate is parameterized by explanatory variables, the form $\lambda=\exp(\beta X)$ makes the likelihood function and estimators easier to derive. Observe that

$$\lambda = \exp(\beta X) = \exp(\beta_1 X_1+\beta_2 X_2+...+\beta_K X_K) = \exp(\beta_1 X_1)\times\exp(\beta_2 X_2)\times...\times\exp(\beta_K X_K). \qquad (10)$$

In this form, the individual elements of β (the β_k's) will have a increasing (decreasing) effect on the overall rate if they are positive (negative). What will generally be of interest is the $\exp(B_k X_k)$ rather than estimated B_k. For example, if X_k is a dummy variable, then $\exp(B_k)$ can be interpreted as the factor increase or decrease that X_k has on the catch rate. Once again using the Slutzky theorem, $\exp(B_k)$ is the consistent and efficient estimator of $\exp(\beta_k)$. When B_k is significantly different than zero, $\exp(B_k)$ will generally be significantly different than 1 -- though this is not an exact test of the hypothesis that $\exp(\beta_k)=1$. Drawing on the above discussion, the Taylor's series approximation for the asymptotic standard error of exp(B) is $\exp(B)\times S_B$, where S_B is the MLE estimated standard error for the parameter B. For example, an approximate asymptotic 95% confidence interval for exp(B) would be $1.96\times\exp(B)\times S_B \pm \exp(B)$. That is,

$$\text{Prob}[\ \{1.96\times S_B\times[1-\exp(B)]\} < \exp(B) < \{1.96\times\exp(B)\times S_B + \exp(B)\}\ ] \approx 0.95 \qquad (11)$$

We will use this result in tables providing the estimated exponentiated parameter effects presented later in the report.

2.4 The link to the proportional model of catch

We will use the negative binomial model as the basis for our estimates of catch rates for trout and salmon at Great Lakes fishing sites in Michigan. In our application, we take D to vary by species, lakes, sites within a lake, and months of the year. Accordingly, predicted catch rates will then vary by species, lakes, locations within a lake, and months of the year. Predicted catch rates will then be used to update the MSU demand model.

In our application of the negative binomial model presented above, the catch rate will be parameterized by covariates which proxy possible components of qD. There are independent variables describing fishing method, fishing modes, charter boating, angler party size, and species being targeted. For example, anglers targeting lake trout may be more successful than anglers targeting a broader group such as salmon and trout. There will be a complete set of variables to distinguish among sites fished at, the year of the interview, and monthly effects. A broad set of month-site interaction terms will also be included to allow for complex spatial and temporal patterns of catch rates. Where data becomes too thin to support the month-site interactions, the sites are grouped into zones and zonal-month interactions are included to preserve the variation in the underlying data.

Recall from equation (1) that the proportional model of catch can be written as C = qED where C equals the fish caught at some location in E hours fished, D equals the fish density at the location fished at, and q is a catchability coefficient. We can then parameterize the catch rates qD as follows:

$$\begin{aligned} E &= \text{effort} = \text{time spent fishing} = T \\ q &= \text{catchability} = f(\text{mode, method, target, party size, ...}) = \exp(\beta_1 X_1) \qquad (12) \\ D &= \text{density} = h(\text{location, season, year, lake, species}) = \exp(\beta_2 X_2) \end{aligned}$$

Using these definitions, the models estimated here can be considered as a parameterization of the process of catching fish that yields:

$$C = TqD = T\lambda = T\times\exp(\beta_1 X_1)\times\exp(\beta_2 X_2)\times\exp(\text{error}) \qquad (13)$$

where λ is the rate parameter. With the negative binomial, exp(error) is a generalized error to capture dispersion around the mean rate; it is gamma distributed with mean 1 and variance alpha. In the models estimated here, the variables proxying catchability effects, X_1, consist of the following:

Mode variables: boat use, charter are distinguished from those not engaging in such modes.

Method variables: trolling is distinguished from not trolling.

Targeting group variables: dummies distinguishing the degree that the species was targeted; for example, in the lake trout equations, there are dummies for individuals targeting groups that include lake trout such as "trout" and "salmon and trout" so that these can be differentiated from cases specifically naming "lake trout" as the target species.

Angler party size variables: dummies for the number of anglers in a party (1,2,3,4 and 5 or more).

The variables proxying density effects, X_2, will consist of year effects, site variables, month variables, and site/month interaction terms. Future availability of data that can proxy D or q (e.g., habitat characteristics by locations) could also be built into this framework.

3. Creel Survey Data and Model Specifications

The basic statistical model is one of C fish caught in E hours. The statistical model we will use was described in Chapter 2. Left unanswered were practical questions regarding the definitions of C, E and a discussion of the exact data used in the models. For example, should the catch rates be species specific? Should they apply only to those targeting the species of interest? Since the catch data is based on the party, how should the effort be measured? How should the effects of party size be controlled for? The section addresses these issues.

Before proceeding, it is useful to reiterate that the catch rate models are developed to predict catch rates for use in the MSU demand model. This raises the question of why the models are needed; that is, why not just average the 1994 creel data for each site/month/species? The simple answer is that there is not enough data in 1994 to get the level of detail desired for the MSU demand model. As mentioned above, reasons for thin data included the fact that not all sites were sampled in each month of 1994. One option would be to use more years of data for each site/month/species combination and just average these catch rates. This raises questions of which years of data to use and whether all of the years can be treated equally? Moreover, even with several years of data there are still combinations of site/month/species where there are few observations to reliably estimate the 1994 site/month/species specific catch rates that are needed for the MSU demand model. The models "smooth" the data, and allow us to predict the 1994 site/month/species specific catch rates. With the catch models, all the available years of data enter the models, and explanatory variables are used to control for the effects of different years, different sites, and different months.

Table 1: Basic Data Collected in Creel Survey Party Interviews (Trip, Catch, and Angler Files)

Description of Creel Survey Question/Data	File location
Date of interview	Trip
Interview Site	Trip
Fishing Site	Trip
Fishery Type: Great Lakes proper or Anadromous stream.	Trip
Mode: Charter boat, Private boat, Shore, etc.	Trip
Hours Fished	Trip
Number of Anglers in Party	Trip
For each angler in party: Sex; Age; Residence; Fishing method (cast, troll, etc.).	Angler
Target species for the party	Trip
Party catch data: Species caught and kept Number kept of each species.	Catch

3.2 *Overview of "data selection" by variables*

Date: The creel survey interview data from the years 1986 through 1995 are used in this research. Only observations from April through October are used; this is the definition of the open-water season that was used in the MSU demand model.

Sites: Creel survey data is clustered around key ports, but there are observations from sites that are not major ports. All such observations are used in the catch rate models. Recall that the catch rate

3.1 The Michigan creel survey

The Michigan creel survey consists of two basic types of data: on-shore creel interviews of fishing parties and counts of fishing pressure. The catch rate models estimated here use the data collected in the on-shore party interviews. Table 1 presents a brief listing of the questions asked (data collected) in the party interviews of the creel surveys. The complete party interview form is presented in Appendix E.

To provide a feel for the organization of the creel survey data, Table 1 also indicates the data files where each of the variables is stored. All the data in the "trip" files refer to the entire party of anglers, and there is one "line" of data for each party that was interviewed. The data in the "angler" files refer to each member of each party so there can be multiple "lines" of data for each party that gets interviewed. The data in the "catch" files refer to each species caught and kept by the party, so there can be multiple lines of data for each party. Parties that did not catch and keep any fish will not have any "lines" of data in the "catch" files.

Because the basic creel survey data on catch and effort is collected for parties (rather than individuals), we need to make a decision on how to define the C and E for the statistical models. Since there is no obvious method of allocating the effort and catch across party members, we will define catch and effort at the party level and include explanatory variables in each model to control for the effects of party size.

Also note that the structure of the data collection makes it difficult to use the individual specific data for party members as explanatory variables in the catch rate models. Since the catch and effort data is collected at the party level, use of the angler characteristics is complicated by differences in party size. For example, if a party has two anglers, should age be the average age of the party, the minimum, etc. The final models presented here do not include any of the individual characteristics of the anglers.

models are estimated separately for each lake. Naturally, each catch rate model only uses the observations for the creel sites associated with that lake.

For each catch rate model, dummy variables were created for the county that a site lies in. The county level variables are used to identify fishing site effects in the catch rate models. The county level matches the site definitions in the MSU demand model. In most cases, each catch rate model contains month, county, and month/county interaction variables to preserve the variation in the raw data. However, in some cases the data was "too" thin to reliably identify such variables. In general, month/county interaction variables that would have less than 30 observations were combined with another dummy to define a common effect. In such situations, two adjacent counties or months would be given common month/county interactions variables.

There are fishing sites in Michigan where there are not any on-site creel survey observations. For reference, this section provides a brief listing of places without data or with limited data:

> Lake Superior: There are no observations at all in Luce County; all observations from Chippewa are at the St. Marys River; there are very few observations in Houghton County. (As a result, in each of the Superior catch rate models, sites in Houghton and Keweenaw County were assigned a common site dummy variable).

> Lake Michigan: There are no observations in the Lake Michigan waters of Mackinac County; there are no lake trout in the Lake Michigan waters of the Upper Peninsula (Menominee, Delta, and Schoolcraft Counties); all the observations in Antrim County were at Elk Rapids just few miles from Grand Traverse County. (As a result, in each of the Michigan catch rate models, sites in Antrim and Grand Traverse County were assigned a common site dummy variable).

> Lake Huron: There are no observations from Cheboygan County, and there were very few or no observations for anglers targeting cold species in Bay and Tuscola Counties. In addition, there are not any angler parties targeting lake trout for Arenac County.

<u>Fishery Type</u>: Only observations for parties that were fishing in the Great Lakes proper were used in the catch rate models.

Number of Anglers in Party: The size of the party is controlled for by creating variables for parties with multiple anglers and including these as explanatory variables in the catch rate models.

Mode: All modes are considered valid for the catch rate models estimated here. Charter boat is used as a shifter variable in the model to control for charter boat effects. Earlier regressions included a variable to distinguish boat use (see Appendix F), but these variables were not used in the final models.

Method: All methods are considered valid for the catch rate models estimated here. Early versions of the catch rate models included variables for boat use (mode) and for trolling (method). These variables were not included in the final models presented here to make the predicted rates most compatible with the MSU demand model. The MSU demand model does not distinguish fishing trips by modes and methods, so these effects were not maintained. The effects were generally significant and are summarized in Appendix F.

General data selection: In summary, the data used in the catch rate models includes the creel survey party interview data from 1986 to 1995 that met the following criterion:

- The month of the fishing trip was between April and October; this definition matches the open-water season used in the MSU demand model.
- The fishing took place on the Great Lakes proper rather than on an anadromous stream; i.e., fishery type=Great Lake.
- The target species was valid for the model being estimated; (this criteria is discussed in the next section, at the end of this chapter, and in Table 4).
- The fishing sites were at the lake for the model being estimated; i.e., observations where the fishing site is on Lake Superior are only used in the "SU" models.

3.3 Creel survey data summaries

Table 2 presents the breakdown of the species or groups of species anglers were targeting. The breakdown is based on the raw creel survey data files. Since there were relatively few coho salmon observations at Lake Huron and few brown trout observations at Lake Superior, some species were combined in order to estimate the catch rate models. All salmon were grouped into a "salmon" catch rate, and rainbow and brown trout were combined into a "trout" catch rate. This yields three catch rate models: lake trout catch rates, "salmon" catch rates, and "trout" catch rates. The models were run separately for each of the three species groups, and for each lake. Thus, there were a total of nine catch rate models.

The creel survey asks anglers what they were fishing for (targeting) as well as what they caught. Responses to these questions were coded as specific species. Appendix E presents the form for coding species targeted and species caught. The following groups of species are also valid responses for species targeted: *anything*; *salmon and trout*; *salmon*; *trout*; and several warm water species groups. The data on anglers indicating they targeted "anything" were not used in any of the catch rate models.

For any given species group, the observations used in the catch rate models consisted of those cases specifically targeting that species or targeting a group that could include that species. Table 4 indicates which responses were used in each of the three catch rate models. For example, those parties indicating they targeted "salmon and trout" were included in the model for each species. The data for anglers targeting the group "trout" were used in both the lake trout and trout models, yet they were not used in the salmon model. Similarly, the data for anglers targeting the group "salmon" were only used in the salmon model.

Table 2: Summaries of Creel Survey Cold Species Targeting Response Data for Each Lake.

Target Codes	Definition	Lake Superior #	Lake Superior %	Lake Huron #	Lake Huron %	Lake Michigan #	Lake Michigan %
SAT*	"Salmon & trout"	3,803	25.1	22,592	42.2	25,401	42.4
TRT*	"Trout"	969	6.4	2,091	3.9	6,106	10.2
SAL*	"Salmon"	2,781	18.4	22,537	42.1	12,145	20.3
LAT	Lake trout	4,815	31.8	537	1.0	1,913	3.2
CHS	Chinook salmon	517	3.4	3,913	7.3	3,245	5.4
COH	Coho salmon	1,870	12.3	33	0.1	913	1.5
ATL	Atlantic salmon	--		126	0.2	--	
PKS	Pink salmon	134	0.9	529	1.0	21	0
RBT	Rainbow trout	216	1.4	391	0.7	4,923	8.2
BKT	Brown trout	6	0.0	416	0.8	5,230	8.7
BNT	Brook trout	18	0.1	2	0	2	0
SPL	Splake	23	0.2	23	0	3	0
	Totals	15,152	100	53,520	100	59,902	100

* group of species as defined in creel survey.

Table 3: Summaries of Creel Survey Targeting Response Data for Each Lake (All Species).

Target Codes	Definition	Lake Superior #	%	Lake Huron #	%	Lake Michigan #	%
ANY*	"Anything"	2,852	15	7,382	6.5	8,140	8.0
cold	All "cold" species	15,623	80	54,029	47.8	61,598	60.5
warm	All "warm" species	1,008	5	51,598	45.7	32,065	31.5
	Totals	19,483	100	113,009	100	101,803	100

* group of species as defined in creel survey.

cold = defined as the cold species listed in table 2 plus whitefish.
warm = the residual of cold species less "ANY"; includes perch, walleye, etc.

Note that the bulk of the angler parties interviewed at Lake Superior are targeting cold species (80%). Angler parties interviewed at Lakes Michigan and Huron have much larger shares of anglers targeting warm species (32% and 46%, respectively).

Appendix G presents more extensive summary statistics for the creel survey data for each of the three lakes: Superior, Michigan, and Huron.

Table 4: Targeting Response Codes and the Catch Rate Model the Targets Appear in.

Creel Survey Specie Codes	Definition	Targets appearing in each catch rate model		
		LAT	SAL	TRT
SAT*	"Salmon & trout"	x	x	x
TRT*	"Trout"	x		x
SAL*	"Salmon"		x	
LAT	Lake trout	x		
CHS	Chinook salmon		x	
COH	Coho salmon		x	
ATL	Atlantic salmon		x	
PKS	Pink salmon		x	
RBT	Rainbow trout			x
BKT	Brown trout			x
BNT	Brook trout			x
SPL	Splake			x

* group of species as defined in creel survey.

A more complete discussion of the targeting is discussed in the last section of this chapter.

3.4 Model specifications

Table 5 presents some definitions of variables used in the models.

Table 5: Definitions of Variables Used in Catch Rate Models.

Chart	dummy variable equals one if party used a charter boat.
Ang2	dummy variable for two anglers in party (default is none)
Ang3	dummy variable for three anglers in party
Ang4	dummy variable for four anglers in party
Ang5	dummy variable for five or more anglers in party
Year#	dummy variable for year; equals one if year is #=1986 to 1995, 1994 is default.
"Months"	dummy variable for month of trip (april, may, june, july, august, september, october); omitted month is the default.
C*x*M*y*	interaction term for county *x* in month *y*; e.g., C80M6 is a dummy variable for Van Buren County in June. These second order effects are above and beyond the separate county and month effects.
Loghours	variable with coefficient fixed at one to control for different fishing hours across parties.
α	dispersion parameter in the negative binomial model.

Catch rate models are estimated separately for each lake, and for each of the three major species groups (lake trout, other trout, and salmon). One might ask why we estimate separate models for each lake rather than estimate a pooled model with lakes as control variables. The short answer is the model size. If a pooled model were estimated for each lake, the number of variables would exceed the limits of our desired statistical estimation software. There would be little gained by pooling the models (where the data is thin is in terms of the month/county interaction variables).

Table 6 shows the total number of observations and the total number of variables that appear in each model. The number of cases (observations) that appears in each model range from about 5,000 to almost 50,000. The number of variable ranges from 36 to 110. Thus, the models generally have a very large number of variables and observations.

Table 6: The Number of Observations and Variables in Each of the Catch Rate Models.

	Lake Trout			Other Trout			Salmon		
	Lake Huron	Lake Superior	Lake Michigan	Lake Huron	Lake Superior	Lake Michigan	Lake Huron	Lake Superior	Lake Michigan
Cases	20,612	9,522	23,215	25,290	5,004	40,025	49,346	8,939	40,405
Variables	47	76	55	67	36	96	74	57	110

3.5 Why targeted catch rates?

In this section, we briefly discuss the choice between models that only use observations for parties "targeting" the species versus using all observations. A potential difficulty with the tabulated catch and effort data published by the MDNR is that they report predictions of total effort for all species and total catch for individual species by month and by ports. We refer to these as *un*targeted catch rates because there is no breakdown of effort by species. Thus, in ports that support diverse species, the catch rate of some species may appear very low simply because most of the fishing effort is directed at other species. This type of information is well suited to estimating total catch because the catch rates are combined with effort estimates where there is no possibility of distinguishing effort by the targeted species.

However, untargeted catch rate information can give misleading indications of the quality of a site. For example, suppose there is a site where the catch rate of species A is high and species B is medium. Since A is high, most anglers fish for A at the site. If the non-targeted catch rates are used (the effort from A is used in the model of the catch rate for B), then the catch rate for B will be understated. Now suppose the fishery for species A collapses and fishery B stays the same. If anglers switch to B, it will now appear as if the catch rates for B went up, though this is simply due to the reduction in the hours spent fishing for A. This potential problem with the MDNR catch rates is noted in the reports (Rakoczy and Lockwood). Alternatively, this would not be a problem if "targeted" catch rates are calculated. In our catch rate models, the observations for the catch rate of species j only include anglers targeting j, or targeting a broader group which might contain j. For example, in the model of lake trout catch rates, anglers targeting "lake trout" are included as are anglers targeting the group "salmon and trout." However, anglers targeting the group "perch and walleye" are not included. The different levels of target groups that might get included in a model are distinguished and controlled for during estimation. The end result are models capable of predicting *targeted* catch rates for each species. The targeted catch rates are likely to be a better indicator of the underlying quality of a fishery.

We feel that derivation of targeted catch rates are more indicative of underlying resource quality than "untargeted" catch rates. For example, in a port where there are substantial fisheries for perch and salmon, one would expect that anglers targeting perch will be more successful at catching perch than would anglers targeting salmon. However, an untargeted catch rate for perch would include the hours spent salmon fishing in the estimate of total effort for perch. If there were some change in the targets of anglers, it might look like perch catch rates rise simply because effort of perch increased relative to effort for other species.

Consider a hypothetical example where anglers fishing for perch catch 100 perch in 100 hours and anglers fishing for salmon catch 20 salmon in 100 hours. Total effort at the port is 200 hours. The untargeted estimates of the hourly catch rates are 0.5 for perch (100/200) and 0.1 for salmon (20/200). Targeted catch rates per hour would be 1 for perch (100/100) and 0.2 for salmon. If there is a shift in the species targeted by anglers with no change in resource quality, the untargeted catch rates can send mixed signals. For example, suppose now that anglers catch 50 perch in 50 hours spent fishing for perch and 30 salmon in 150 hours spent fishing for salmon. The targeted catch rates remain unchanged, yet the untargeted catch rates are now 0.25 for perch (50/200) and 0.15 for salmon (30/200). Now suppose the perch fishery is closed for some reason. Further suppose that salmon effort goes up by 50 hours (because some of the anglers stop fishing or switch sites, and some switch species). Now, 30 salmon are caught in 150 hours spent fishing for salmon. Now the untargeted rate for salmon is 0.15. Based on the untargeted catch rates, it appears as if the salmon catch rates have improved simply because of the change in the definition of effort. Thus, when comparing catch across sites, the untargeted catch rates are confounded by use of total fishing effort in the denominator.

In the MDNR creel survey reports, total harvest is estimated by combining untargeted catch rates at each port with estimates of total fishing pressure at a port. The estimates of total fishing pressure come from the creel survey "count" interviews where it is not known what the anglers are fishing for. Absent knowledge of fishing pressure by species targeted, the targeted catch rates reported here will not be well-suited to predicting the total harvest of each species. While it would be difficult to predict total catch using the targeted catch rates reported here, the targeted catch rates are well aligned with our interest in developing an indicator of fishing quality.

4. Estimation Results

The complete estimation results are presented in Appendix A.

4.1 Exponentiated effects

Recall that the rate parameters of the negative binomial models are parameterized by variables that appear within an exponential -- see equation (9). Thus, the specific parameter estimates are likely to be of less interest than the exponent of the parameter estimate. Since most of the variables are dummy variables, the exponent of the parameter estimate can be interpreted directly as the factor increase or decrease that the variable has on catch rates. For example, if the parameter estimate for some dummy variable X_k is B_k=0.69, then $\exp(B_k)\approx 2.0$. Thus, when the variable k takes a value of 1, catch rates are twice as high as when X_k takes a value of 0. Similarly, if the parameter estimate for some dummy variable X_j is B_j=-1.1, then $\exp(B_k)\approx 0.33$. Thus, when X_j=1, catch rates are one-third as high as when X_j=0 -- this variable has a negative effect on catch rates. Variables with positive (negative) parameter estimates will have increase (decrease) on the predicted catch rates.

Table 7 presents some of the exponentiated parameter estimates. The month, county, and county/month interaction terms are not presented. These later effects are difficult to interpret independently of one another.

All of the models exhibit significant variability in the estimated catch rates, as evident by the significance of the dispersion parameter for the negative binomial models. Thus, all of the models are significant improvements over the simple Poisson. From the table, the estimated dispersion parameter (α) is generally highest for the TRT models. This may be due to the combination of brown and rainbow trout that make up the "other trout" models.

Table 7: Select Exponentiated Parameter Effects and Approximate Asymptotic Significance Levels.

	LAT			TRT			SAL		
	HU	SU	MI	HU	SU	MI	HU	SU	MI
CHART	4.86 ***	2.38 ***	3.11 ***	0.75	24.62	2.01 ***	2.08 ***	2.72 *	2.60 ***
Party size									
ANG2	1.40 ***	1.73 ***	1.74 ***	1.16 ***	0.79 *	1.41 ***	1.16 ***	1.35 ***	1.69 ***
ANG3	1.77 ***	2.10 ***	2.27 ***	1.25 ***	0.66 **	1.74 ***	1.36 ***	1.73 ***	2.11 ***
ANG4	2.10 ***	2.43 ***	2.67 ***	1.23 ***	0.28 ***	1.99 ***	1.48 ***	1.55 ***	2.26 ***
ANG5	2.43 ***	2.85 ***	3.30 ***	1.24 **	0.04 ***	2.32 ***	1.63 ***	1.92 **	2.37 ***
Targeting									
TRT	0.88	0.82 ***	0.41 ***	0.65 ***	0.18 ***	0.76 ***	n/a	n/a	n/a
SAL	n/a	n/a	n/a	n/a	n/a	n/a	0.93 ***	0.92	0.78 ***
SAT	0.29 ***	0.36 ***	0.41 ***	0.42 ***	0.41 ***	0.47 ***	0.84 ***	0.50 ***	0.66 ***
Year									
Y86	0.94	1.38 **	0.75 ***	0.10 ***	0.80	0.74 ***	0.89 **	1.95 **	2.53 ***
Y87	1.51 ***	1.32 ***	1.07	0.63 ***	0.80	0.69 ***	1.21 ***	0.89	2.27 ***
Y88	1.41 ***	0.99	1.16 **	0.31 ***	1.75 *	0.74 ***	1.01	1.31 ***	1.49 ***
Y89	0.96	2.13 ***	1.39 ***	0.24 ***	1.75 *	0.68 ***	0.92	0.93	1.50 ***
Y90	0.94	1.31 ***	1.09	0.07 ***	1.64	0.81 ***	0.55 ***	0.97	1.42 ***
Y91	1.17 *	1.16 ***	1.30 ***	0.44 ***	1.00	0.92 *	1.03	1.08	1.49 ***
Y92	0.93	1.33 ***	0.78 ***	0.76 ***	0.93	0.97	0.81 ***	0.90	1.31 ***
Y93	0.58 ***	1.09 *	1.00	1.11 *	1.10	0.97	0.95 *	0.86 **	1.32 ***
Y95	1.44 ***	1.04	1.11 **	1.08	1.45	0.74 ***	1.30 ***	0.76 ***	1.43 ***
Dispersion α	1.67 ***	0.72 ***	1.14 ***	1.6 ***	3.1 ***	1.5 ***	1.04 ***	1.16 ***	1.02 ***

* Significantly different than 1 at the 10% level.
** Significantly different than 1 at the 5% level.
*** Significantly different than 1 at the 1% level.

Charter boat variable: Table 7 shows that anglers fishing from a charter boat tend to have catch rates that are higher by a factor of 2 to 3. In general, chartering seems to be most effective for lake trout (LAT) and least effective for other trout (TRT). The chartering effect for the TRT SU model is huge, but it is not significant. Also, note that most of the chartering trips are taken by multi-angler parties, but these party effects are controlled for through the ang# variables. So, chartering effect is over and above the effect of party size; but not over and above effects of boat use and method.

Angler Party Size: There is a general pattern that having more anglers in a party will increase catch. However, the effect of additional anglers is less than proportional to the increase in the number of anglers. The TRT equation for Lake Superior actually shows a decrease in catch as party size increases (which in part reflects the decreased catch of trt at superior with a boat/troll). In addition, the trout equation for Huron plateaus at a party size of three anglers.

Targeting: The default is anglers targeting the specific species. The dummies for those targeting broader species groups consistently show that catch rate is lower; and the catch rate for those targeting the most general group (salmon and trout) is usually less than more specific groups. Exceptions: LAT at MI where trt will likely mean trouts other than lake trout; and TRT SU where trt is more likely to mean lake trout than other trt.

Years: There are some discernable year effects. For example, with the SAL MI model, the year effects are all significant and show a clear decline in the catch rates for salmon from 1986 into the nineties with a rebound in 1995. SAL at HU do not show a clear upward or downward trend and they fall in a fairly tight range. SAL at SU are not significantly different in most years and appear to be lower in the later years. For TRT at Lake Superior the year effects are also mostly insignificant. Catch for TRT at MI appears to rise into the early nineties with a drop again in 1995; these year effects exhibit the smallest range. TRT at Huron appear to be significantly better in recent years. The year effects for LAT at SU indicate some slight decline in the later years of the data. The results for LAT at MI show no clear pattern. For LAT at HU, there does appear to be some increase following the significant decline in 1993.

4.2 Predicted rates

The predicted monthly catch rates per 100 hours are presented in Tables 8 to 10. The catch rates for lake trout appear in Table 8, while the catch rates for salmon and other trout appear in tables 9 and 10, respectively. The predictions for each of the nine combinations of species and lake are based on the catch rate model developed for that combination. The predictions are based on an angling party of one, that is targeting the specific species within the group, that is not using a charter boat, and is fishing in the year 1994.

In the tables, months are shown in the columns, and counties are shown in rows. The counties are grouped by lake. Within each set of rows for a lake, the rows are ordered so that adjacent counties on a map are adjacent rows in the table -- see Figure 1 for a map of Great lake counites. Thus, the tables attempt to preserve the spatial ordering of the counties to facilitate any comparisons of catch rates across counties and months.

Almost all of the predicted catch rates in table 8 to 10 are significantly different than zero.[1] The tables also reveal that there are cases where the predicted catch rates have been set at 0. These are due to counties and/or months that were not modelled for a particular species. In some cases, this is due to a complete lack of data at some sites as discussed above. For example, the lake trout catch rates for the Upper Peninsula counties of Lake Michigan are all set at zero because there are no party interviews where

[1] Table X in appendix X presents asymptotic standard errors associated with each of the predicted catch rates. These standard errors use the Taylor's series approximation presented in equation (9). The overwhelming majority of the predicted catch rates are significantly greater than 0 at the 1% level. Only six cases are not significantly greater than 0 at the 10% level.

lake trout were targeted at these sites. In another example, catch rates for lake trout at Lakes Michigan and Huron are set at zero in the months of April and October because of fishing regulations.

Add discussion of the tables...

Table 8: Predicted 1994 catch rates for *lake trout* by county and month.

Counties along each lake		Monthly catch rate per 100 hours						
#	Name	April	May	June	July	Aug.	Sept.	Oct.
Lake Superior								
27	Gogebic	9	11	35	38	31	20	10
66	Ontonagon	6	20	31	26	38	24	7
42	Keweenaw	5	30	20	22	23	21	27
7	Baraga	7	22	20	29	22	19	20
52	Marquette	13	25	30	31	41	43	43
2	Alger	7	23	23	30	32	27	40
Lake Huron								
17	Chippewa		1	1	3	1	0-	
71	Presque Isle		28	31	27	4	0'	
4	Alpena		8	11	9	5	0	
1	Alcona		12	34	34	20	11	
35	Iosco		8	24	19	11	1	
32	Huron		22	29	32	24	13	
76	Sanilac		1	2	5	2	0-	
Lake Michigan								
24	Emmet		34	32	29	27	15	
15	Charlevoix		36	28	30	26	8	
5,28	Antrim & Grand Traverse		21	17	22	12	3	
45	Leelanau		28	25	12	8	1	
10	Benzie		18	19	19	8	1	
51	Manistee		7	10	10	7	0'	
53,64	Mason & Oceana		10	17	16	6	1	
61	Muskegon		9	11	10	5	1	
70	Ottawa		8	16	20	8	2	
3	Allegan		21	19'	21'	4	2'	
80	Van Buren		17	17	21	19	3	
11	Berrien		11	10	10	9	2	

Table 9: Predicted 1994 catch rates for *salmon* by county and month.

Counties along each lake #	Name	Monthly catch rate per 100 hours April	May	June	July	Aug.	Sept.	Oct.
Lake Superior								
27	Gogebic	10	27	19	10	5	12	15
66	Ontonagon	3	24	6	3	4	6	4
42	Keweenaw	18	16	15	18	12	10	7
7	Baraga	38	32	24	14	12	15	14
52	Marquette	35	22	11	7	5	9	11
2	Alger	33	29	18	22	22	20	48
Lake Huron								
17	Chippewa	0	2	8	12	37	56	29
49	Mackinac	0	2	11	15	38	36	22
71	Presque Isle	0	2	8	19	19	24	22
4	Alpena	0	3	12	23	30	14	17
1	Alcona	0	6	11	13	17	16	28
35	Iosco	6	13	7	8	10	7	4
6	Arenac	0	7	1	3	4	8	4
32	Huron	17	12	11	12	10	10	12
76	Sanilac	17	16	19	13	6	5	10
74	St. Clair	34	15	17	12	5	5	9
Lake Michigan								
55	Menominee	0	0	6	11	9	7	3
21	Delta	0	0	8	14	5	6	7
77	Schoolcraft	0	0	3	7	8	11	12
24	Emmet	0	0	1	3	4	3	3
15	Charlevoix	0	0	1	6	8	10	15
28	Grand Traverse	23	17	2	4	5	6	5
45	Leelanau	0	0	5	9	11	14	11
10	Benzie	2	4	4	6	11	11	5
51	Manistee	5	9	5	7	9	7	4
53	Mason	6	11	8	8	11	7	6
64	Oceana	9	10	5	14	9	7	1
61	Muskegon	3	10	6	7	6	5	2
70	Ottawa	6	9	5	6	6	4	3
3	Allegan	8	11	4	7	6	7	0
80	Van Buren	10	9	4	3	5	2	0
11	Berrien	27	14	7	5	5	3	2

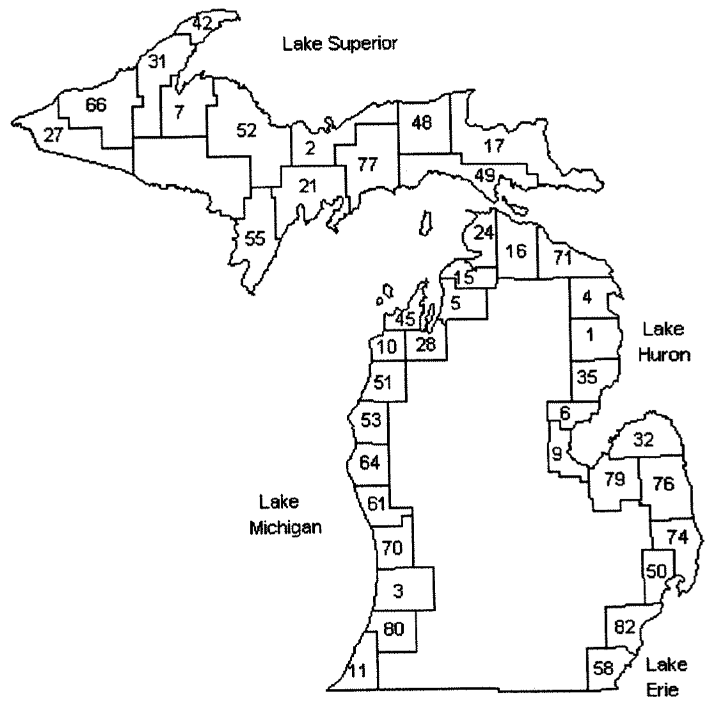
Table 10: Predicted 1994 catch rates for *"other" trout* by county and month.

Counties along each lake		Monthly catch rate per 100 hours						
#	Name	April	May	June	July	Aug.	Sept.	Oct.
Lake Superior								
27	Gogebic	0	16	6	1	3	4	4
66	Ontonagon	0	8	3	0	1	2	2
42	Keweenaw	0	5	2	0	1	1	1
7	Baraga	9	9	3	0	1	1	15
52	Marquette	10	10	4	0	1	1	17
2	Alger	22	25	4	10	3	8	16
Lake Huron								
17	Chippewa	0	40	20	57	34	28	45
49	Mackinac	0	25	13	32	19	16	27
71	Presque Isle	31	13	4	7	4	2	46
4	Alpena	41	21	11	15	9	5	8
1	Alcona	3	2	4	9	11	5	46
35	Iosco	17	10	4	16	11	10	29
6	Arenac	13	7	3	5	3	2	3
32	Huron	22	11	4	10	10	17	31
76	Sanilac	21	15	13	24	14	10	14
74	St. Clair	12	6	3	4	3	2	2
Lake Michigan								
55	Menominee	47	18	20	41	33	19	13
21	Delta	21	34	7	7	15	15	21
77	Schoolcraft	22	35	8	7	15	16	21
24	Emmet	15	4	1	2	3	8	35
15	Charlevoix	11	5	3	6	2	2	9
28	Grand Traverse	22	10	7	6	4	3	18
45	Leelanau	8	4	2	18	1	1	7
10	Benzie	18	13	19	16	10	12	23
51	Manistee	20	16	26	17	15	12	19
53	Mason	19	15	11	17	21	24	19
64	Oceana	15	11	8	13	15	18	14
61	Muskegon	11	8	6	11	9	11	14
70	Ottawa	10	11	3	8	4	8	11
3	Allegan	18	8	5	5	3	3	15
80	Van Buren	17	8	5	5	3	3	14
11	Berrien	11	8	11	11	9	4	10

Michigan's Great Lake County Numbers and Names

1 Alcona
2 Alger
3 Allegan
4 Alpena
5 Antrim
6 Arenac
7 Baraga
9 Bay
10 Benzie
11 Berrien
15 Charlevoix
16 Cheboygan
17 Chippewa
21 Delta
24 Emmet
27 Gogebic
28 Grand Traverse
31 Houghton
32 Huron
35 Iosco
42 Keweenaw
45 Leelanau
48 Luce
49 Mackinac
50 Macomb
51 Manistee
52 Marquette
53 Mason
55 Menominee
58 Monroe
61 Muskegon
64 Oceana
66 Ontonagon
70 Ottawa
71 PresqueIsle
74 St. Clair
76 Sanilac
77 Schoolcraft
79 Tuscola
80 Van Buren
82 Wayne

Figure 1: Great Lake Counties in Michigan.



Summary/Conclusions?

Negative binomial regression models were used to estimate catch-per-hour for recreational anglers fishing for trout and salmon in Michigan waters of the Great Lakes. Dependent variables were observations on catch and hours fished for angler parties interviewed in Michigan creel surveys from 1986 to 1995. The estimated models relate catch rates to independent variables for year, month, and fishing location. Interactions between months and locations were included to permit a rich array of spatial and temporal variation in estimated catch rates. Additional variables controlled for charter boat use, angler party size, and extent of species targeting (e.g., fishing for "salmon" versus "chinook"). Separate models were estimated for nine combinations of species (lake trout, salmon, and "other" trout) and Great Lakes (Superior, Huron, and Michigan). The models use 5,000 to 50,000 observations and have 36 to 110 variables. The results indicate significant relationships between catch rates and most independent variables. In particular, there were large positive effects for charter boats and targeting, positive but declining effects for increased party size, and significant spatial and temporal differences. By utilizing the annual data, the modeling approach can provide predictions of catch rates that are specific to species, lake, site, month, and year -- even for combinations of specie, site, and month where any one year might contain few observations.

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Others?

Appendix A

Abridged *LIMDEP*™ Output for Negative Binomial Models of Catch-Per-Hour

Codes Used in Report:

```
LAT = Lake Trout
SAL = Salmon, mostly Chinook and Coho
TRT = Other Trout, mostly Rainbow and Brown

HU  = Lake Huron
SU  = Lake Superior
MI  = Lake Michigan

There are nine equations:

LAT_HU, LAT_SU, LAT_MI
SAL_HU, SAL_SU, SAL_MI
TRT_HU, TRT_SU, TRT_MI
```

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Estimation output for LAT HU

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	20612
Iterations completed	47
Log likelihood function	-14774.57

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-2.9274	0.18820	-15.555	0.00000	
CHART	1.5806	0.14703	10.750	0.00000	0.9461E-02
ANG2	0.33525	0.70543E-01	4.752	0.00000	0.4207
ANG3	0.56848	0.72724E-01	7.817	0.00000	0.2629
ANG4	0.74202	0.77080E-01	9.627	0.00000	0.1444
ANG5	0.88980	0.94698E-01	9.396	0.00000	0.4517E-01
TRT	-0.12727	0.92858E-01	-1.371	0.17050	0.5691E-01
SAT	-1.2509	0.88726E-01	-14.098	0.00000	0.9175
Y86	-0.59877E-01	0.19386	-0.309	0.75742	0.4900E-02
Y87	0.41336	0.74080E-01	5.580	0.00000	0.7292E-01
Y88	0.34396	0.68913E-01	4.991	0.00000	0.1198
Y89	-0.36297E-01	0.97130E-01	-0.374	0.70863	0.2833E-01
Y90	-0.63494E-01	0.87165E-01	-0.728	0.46634	0.4934E-01
Y91	0.15657	0.80546E-01	1.944	0.05191	0.8393E-01
Y92	-0.67502E-01	0.68810E-01	-0.981	0.32660	0.9839E-01
Y93	-0.53750	0.72457E-01	-7.418	0.00000	0.1321
Y95	0.36352	0.58618E-01	6.202	0.00000	0.2645
MAY	-1.9685	0.20387	-9.656	0.00000	0.1488
JUNE	-0.94162	0.29700	-3.170	0.00152	0.1571
AUG	-1.0412	0.31272	-3.330	0.00087	0.2534
SEPT	-4.8698	0.50978	-9.553	0.00000	0.1052
C1	1.8570	0.16348	11.359	0.00000	0.9980E-01
C4	0.54445	0.15175	3.588	0.00033	0.4087
C17	-0.44345	0.24158	-1.836	0.06642	0.6307E-02
C32	1.7899	0.17095	10.471	0.00000	0.9339E-01
C35	1.2858	0.16098	7.988	0.00000	0.1734
C71	1.6105	0.15746	10.228	0.00000	0.1280
C1M5	0.89877	0.27977	3.213	0.00132	0.6258E-02
C1M6	0.92091	0.31653	2.909	0.00362	0.1722E-01
C1M8	0.50847	0.33026	1.540	0.12366	0.3144E-01
C1M9	3.7013	0.58016	6.380	0.00000	0.4852E-02
C4M5	1.7985	0.23882	7.531	0.00000	0.2790E-01
C4M6	1.1325	0.30717	3.687	0.00023	0.4046E-01
C4M8	0.34527	0.32137	1.074	0.28265	0.1192
C32M5	1.6070	0.23259	6.909	0.00000	0.2620E-01
C32M6	0.84684	0.31883	2.656	0.00791	0.2731E-01
C32M8	0.74771	0.34470	2.169	0.03007	0.1174E-01
C32M9	3.9512	0.62881	6.284	0.00000	0.2911E-02
C35M5	1.0896	0.22588	4.824	0.00000	0.3610E-01
C35M6	1.1679	0.31025	3.765	0.00017	0.4012E-01
C35M8	0.45751	0.32855	1.392	0.16377	0.3653E-01
C35M9	2.1573	0.61063	3.533	0.00041	0.1329E-01
C71M5	2.0146	0.22531	8.942	0.00000	0.1203E-01
C71M6	1.0856	0.31567	3.439	0.00058	0.1630E-01
C71M8	-0.98822	0.32582	-3.033	0.00242	0.4129E-01
LOGHOURS	1.0000	........(Fixed	Parameter)	....	1.546
α	1.6738	0.53624E-01	31.214	0.00000	

Estimation output for LAT SU

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	9522
Iterations completed	60
Log likelihood function	-15699.14

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-0.97525	0.10659	-9.150	0.00000	
CHART	0.86673	0.19093	4.540	0.00001	0.5356E-02
ANG2	0.54639	0.38191E-01	14.307	0.00000	0.4849
ANG3	0.74430	0.43673E-01	17.042	0.00000	0.1762
ANG4	0.88730	0.55767E-01	15.911	0.00000	0.5776E-01
ANG5	1.0476	0.95135E-01	11.012	0.00000	0.1890E-01
TRT	-0.19959	0.50420E-01	-3.959	0.00008	0.1007
SAT	-1.0126	0.33669E-01	-30.075	0.00000	0.3973
Y86	0.31920	0.10956	2.913	0.00358	0.1775E-01
Y87	0.27620	0.69133E-01	3.995	0.00006	0.6564E-01
Y88	-0.50398E-02	0.54030E-01	-0.093	0.92568	0.1037
Y89	0.75426	0.12208	6.178	0.00000	0.1365E-01
Y90	0.27173	0.57842E-01	4.698	0.00000	0.8024E-01
Y91	0.15083	0.52270E-01	2.886	0.00391	0.1226
Y92	0.28613	0.53158E-01	5.383	0.00000	0.1128
Y93	0.83390E-01	0.48534E-01	1.718	0.08576	0.1545
Y95	0.42530E-01	0.47265E-01	0.900	0.36821	0.1558
APRIL	-1.4450	0.13019	-11.099	0.00000	0.4652E-01
MAY	-1.2258	0.17125	-7.158	0.00000	0.1573
JUNE	-0.63052E-01	0.13601	-0.464	0.64294	0.2117
AUG	-0.19585	0.14862	-1.318	0.18758	0.2023
SEPT	-0.62469	0.12645	-4.940	0.00000	0.1255
OCT	-1.3176	0.32078	-4.108	0.00004	0.6606E-01
C2	-0.24309	0.10971	-2.216	0.02671	0.1818
C7	-0.28103	0.14410	-1.950	0.05115	0.7477E-01
C42	-0.53825	0.13236	-4.067	0.00005	0.9221E-01
C52	-0.19643	0.10118	-1.942	0.05220	0.4607
C66	-0.36853	0.11984	-3.075	0.00210	0.1239
C2M5	0.97806	0.19113	5.117	0.00000	0.4495E-01
C2M6	-0.19051	0.16348	-1.165	0.24389	0.3424E-01
C2M8	0.26926	0.17698	1.521	0.12816	0.2510E-01
C2M9	0.54333	0.16700	3.253	0.00114	0.2069E-01
C2M10	1.6210	0.42607	3.805	0.00014	0.3361E-02
C7M5	0.94398	0.22435	4.208	0.00003	0.1470E-01
C7M6	-0.30261	0.19155	-1.580	0.11415	0.1806E-01
C7M8	-0.57581E-01	0.21102	-0.273	0.78496	0.1680E-01
C7M9	0.21763	0.23066	0.944	0.34542	0.7876E-02
C7M10	0.95909	0.45861	2.091	0.03650	0.1995E-02
C42M5	1.5362	0.22545	6.814	0.00000	0.1019E-01
C42M6	-0.15371E-01	0.18575	-0.083	0.93405	0.1869E-01
C42M8	0.23446	0.19882	1.179	0.23830	0.2100E-01
C42M9	0.59666	0.18754	3.182	0.00146	0.1806E-01
C42M10	1.5364	0.36377	4.223	0.00002	0.5776E-02
C52M4	0.60687	0.16052	3.781	0.00016	0.2436E-01
C52M5	1.0004	0.18523	5.401	0.00000	0.5482E-01
C52M6	0.43961E-01	0.14860	0.296	0.76735	0.9011E-01
C52M8	0.46718	0.16059	2.909	0.00362	0.1019
C52M9	0.94363	0.14654	6.439	0.00000	0.5451E-01
C52M10	1.6379	0.32877	4.982	0.00000	0.5114E-01
C66M5	0.95593	0.21494	4.447	0.00001	0.2352E-01
C66M6	0.24834	0.17206	1.443	0.14893	0.3823E-01
C66M8	0.57028	0.18603	3.066	0.00217	0.2625E-01
C66M9	0.53298	0.21092	2.527	0.01151	0.6721E-02
LOGHOURS	1.0000	........(Fixed Parameter).......			1.365
α	0.72429	0.24585E-01	29.460	0.00000	

Estimation output for LAT MI

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	23215
Iterations completed	75
Log likelihood function	-20168.90

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-2.2939	0.11228	-20.431	0.00000	
CHART	1.1361	0.76201E-01	14.909	0.00000	0.2162E-01
ANG2	0.55117	0.45989E-01	11.985	0.00000	0.4263
ANG3	0.82134	0.48991E-01	16.765	0.00000	0.2044
ANG4	0.98054	0.54511E-01	17.988	0.00000	0.9959E-01
ANG5	1.1927	0.68147E-01	17.502	0.00000	0.3937E-01
TRT	-0.88771	0.59702E-01	-14.869	0.00000	0.1034
SAT	-0.89581	0.55026E-01	-16.280	0.00000	0.8156
Y86	-0.28962	0.65391E-01	-4.429	0.00001	0.7504E-01
Y87	0.70614E-01	0.58675E-01	1.203	0.22879	0.8671E-01
Y88	0.14577	0.56491E-01	2.580	0.00987	0.8994E-01
Y89	0.33216	0.59777E-01	5.557	0.00000	0.7163E-01
Y90	0.85792E-01	0.64213E-01	1.336	0.18153	0.7258E-01
Y91	0.25959	0.55421E-01	4.684	0.00000	0.1114
Y92	-0.24379	0.59874E-01	-4.072	0.00005	0.9752E-01
Y93	-0.36453E-02	0.53924E-01	-0.068	0.94610	0.1178
Y95	0.10728	0.51716E-01	2.074	0.03804	0.1428
MAY	0.37720E-01	0.97398E-01	0.387	0.69855	0.1994
JUNE	-0.65149E-01	0.10991	-0.593	0.55337	0.1776
AUG	-0.10644	0.11301	-0.942	0.34627	0.2472
SEPT	-1.8331	0.15532	-11.803	0.00000	0.1542
C3	0.75186	0.45455	1.654	0.09811	0.5255E-02
C10	0.60446	0.95923E-01	6.302	0.00000	0.1885
C15	1.0898	0.12412	8.781	0.00000	0.5393E-01
C24	1.0668	0.11692	9.124	0.00000	0.6466E-01
C28	0.75544	0.11121	6.793	0.00000	0.9171E-01
C45	0.14343	0.16495	0.870	0.38456	0.1309E-01
C51	0.12089E-01	0.11402	0.106	0.91557	0.1126
C53	0.48854	0.11528	4.238	0.00002	0.1031
C61	0.19572E-01	0.15969	0.123	0.90245	0.5772E-01
C70	0.67186	0.12658	5.308	0.00000	0.1340
C80	0.73366	0.16352	4.487	0.00001	0.4122E-01
C3M5	-0.77234E-01	0.54793	-0.141	0.88790	0.1895E-02
C3M6	-0.73056E-01	0.64343	-0.114	0.90960	0.1077E-02
C3M8	-1.6189	0.59096	-2.739	0.00616	0.1292E-02
C10M5	-0.80262E-01	0.13140	-0.611	0.54132	0.2063E-01
C10M6	0.71599E-01	0.13494	0.531	0.59571	0.2964E-01
C10M8	-0.69313	0.13322	-5.203	0.00000	0.6130E-01
C10&45M9	-0.76771	0.22121	-3.471	0.00052	0.2421E-01
C15M5	0.14910	0.19530	0.763	0.44520	0.6332E-02
C15M6	-0.12517E-01	0.16423	-0.076	0.93925	0.1620E-01
C15M8	-0.35378E-01	0.17345	-0.204	0.83838	0.1409E-01
C15M9	0.47853	0.26847	1.782	0.07468	0.4092E-02
C24M5	0.11611	0.16072	0.722	0.47002	0.8917E-02
C24M6	0.14259	0.15716	0.907	0.36425	0.1848E-01
C24M8	0.27017E-01	0.17129	0.158	0.87467	0.1335E-01
C24M9	1.1688	0.24057	4.859	0.00000	0.5083E-02
C28M5	-0.77750E-01	0.14658	-0.530	0.59581	0.1809E-01
C28M6	-0.15044	0.15883	-0.947	0.34356	0.1568E-01
C28M8	-0.46078	0.15925	-2.893	0.00381	0.2050E-01
C28M9	-0.20568	0.26182	-0.786	0.43211	0.1198E-01
C45M5	0.82715	0.33692	2.455	0.01409	0.8615E-03
C45M6	0.81415	0.26050	3.125	0.00178	0.2369E-02
C45M8	-0.25574	0.21246	-1.204	0.22870	0.4868E-02

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
C51M5	-0.39260	0.16031	-2.449	0.01433	0.1801E-01
C51M6	0.76882E-01	0.16378	0.469	0.63877	0.1900E-01
C51M8	-0.25514	0.16207	-1.574	0.11542	0.2839E-01
C51M9	-1.5762	0.53879	-2.926	0.00344	0.1684E-01
C53M5	-0.52014	0.15754	-3.302	0.00096	0.2016E-01
C53M6	0.10597	0.16643	0.637	0.52432	0.1391E-01
C53M8	-0.83728	0.16413	-5.101	0.00000	0.2933E-01
C53M9	-1.0520	0.28095	-3.745	0.00018	0.1633E-01
C61M5	-0.13703	0.21422	-0.640	0.52236	0.1219E-01
C61M6	0.12419	0.23367	0.531	0.59510	0.8615E-02
C61M8	-0.71172	0.22899	-3.108	0.00188	0.1689E-01
C61M9	-1.1998	0.47790	-2.510	0.01206	0.1142E-01
C70M5	-0.96646	0.15210	-6.354	0.00000	0.4010E-01
C70M6	-0.17197	0.17045	-1.009	0.31301	0.1938E-01
C70M8	-0.80339	0.17267	-4.653	0.00000	0.2567E-01
C3&70M9	-0.66701	0.22727	-2.935	0.00334	0.3261E-01
C80M5	-0.24037	0.24679	-0.974	0.33006	0.6978E-02
C80M6	-0.12142	0.22592	-0.537	0.59096	0.8184E-02
C80M8	-0.71289E-03	0.21680	-0.003	0.99738	0.9950E-02
C80M9	-0.22607	0.31428	-0.719	0.47194	0.8874E-02
LOGHOURS	1.0000	........(Fixed	Parameter)	....	1.387
α	1.1437	0.38080E-01	30.033	0.00000	

Estimation output for TRT HU

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	25290
Iterations completed	57
Log likelihood function	-14377.67

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-1.9325	0.11118	-17.382	0.00000	
CHART	-0.28238	0.25858	-1.092	0.27481	0.7513E-02
ANG2	0.14763	0.50031E-01	2.951	0.00317	0.4053
ANG3	0.22249	0.55657E-01	3.997	0.00006	0.2370
ANG4	0.20922	0.62506E-01	3.347	0.00082	0.1258
ANG5	0.21195	0.80926E-01	2.619	0.00882	0.3828E-01
TRT	-0.42932	0.10403	-4.127	0.00004	0.8217E-01
SAT	-0.87835	0.96873E-01	-9.067	0.00000	0.8850
Y86	-2.2969	0.51925	-4.423	0.00001	0.5338E-02
Y87	-0.46586	0.83542E-01	-5.576	0.00000	0.8015E-01
Y88	-1.1630	0.72738E-01	-15.989	0.00000	0.1149
Y89	-1.4169	0.17042	-8.314	0.00000	0.2811E-01
Y90	-2.5960	0.19130	-13.571	0.00000	0.4334E-01
Y91	-0.82450	0.82730E-01	-9.966	0.00000	0.7556E-01
Y92	-0.27692	0.60955E-01	-4.543	0.00001	0.9960E-01
Y93	0.10065	0.52126E-01	1.931	0.05350	0.1367
Y95	0.79209E-01	0.48171E-01	1.644	0.10011	0.2618
APRIL	1.0345	0.70167E-01	14.743	0.00000	0.1137
MAY	0.35484	0.11143	3.184	0.00145	0.1199
JUNE	-0.31070	0.91560E-01	-3.393	0.00069	0.1175
AUG	-0.51434	0.58134E-01	-8.848	0.00000	0.2113
SEPT	-1.0919	0.11527	-9.473	0.00000	0.9130E-01
OCT	-0.60253	0.10537	-5.718	0.00000	0.7121E-01
C1	-0.51729	0.12248	-4.224	0.00002	0.8011E-01
C6	-1.1631	0.29727	-3.913	0.00009	0.3796E-02
C17	1.3654	0.30231	4.516	0.00001	0.6445E-02
C32	-0.38207	0.13159	-2.904	0.00369	0.8323E-01
C35	0.66470E-01	0.91352E-01	0.728	0.46684	0.1927
C49	0.77711	0.21846	3.557	0.00037	0.1257E-01
C71	-0.76441	0.13174	-5.803	0.00000	0.9648E-01
C74	-1.1877	0.45634	-2.603	0.00925	0.2096E-02
C76	0.51073	0.15395	3.317	0.00091	0.1202
C1S	-1.9887	0.64063	-3.104	0.00191	0.6129E-02
C1M6	-0.45587	0.33004	-1.381	0.16719	0.1020E-01
C1M8	0.75028	0.17979	4.173	0.00003	0.2562E-01
C1M9	0.60653	0.44179	1.373	0.16979	0.3954E-02
C1M10	2.2773	0.30634	7.434	0.00000	0.2214E-02
C17SP	-0.71097	0.36116	-1.969	0.04900	0.3598E-02
C17F	0.37324	0.74736	0.499	0.61749	0.9095E-03
C49SP	-0.58458	0.38511	-1.518	0.12903	0.2017E-02
C49F	0.44120	0.29509	1.495	0.13488	0.6564E-02
C32M4	-0.21598	0.23955	-0.902	0.36727	0.4666E-02
C32M5	-0.23211	0.20356	-1.140	0.25417	0.2135E-01
C32M6	-0.48983	0.22499	-2.177	0.02947	0.2183E-01
C32M8	0.49075	0.24116	2.035	0.04186	0.9648E-02
C32M9	1.6096	0.31037	5.186	0.00000	0.2610E-02
C32M10	1.7536	0.37080	4.729	0.00000	0.2570E-02

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
C35M4	-0.92507	0.14438	-6.407	0.00000	0.2365E-01
C35M5	-0.82457	0.17417	-4.734	0.00000	0.3009E-01
C35M6	-1.0614	0.19259	-5.511	0.00000	0.3124E-01
C35M8	0.18378	0.14507	1.267	0.20522	0.3171E-01
C35M9	0.68443	0.25584	2.675	0.00747	0.1159E-01
C35M10	1.2277	0.16191	7.582	0.00000	0.2384E-01
C71M4	0.49301	0.31880	1.546	0.12199	0.1977E-02
C71M5	0.32002	0.32636	0.981	0.32680	0.5061E-02
C71M6	-0.23814	0.30687	-0.776	0.43773	0.7750E-02
C71M8	0.17288E-01	0.17804	0.097	0.92265	0.3365E-01
C71M9	-0.26223	0.23372	-1.122	0.26187	0.1957E-01
C71M10	2.5307	0.32106	7.883	0.00000	0.1621E-02
C76M4	-1.1710	0.17989	-6.510	0.00000	0.3551E-01
C76M5	-0.86413	0.20808	-4.153	0.00003	0.3116E-01
C76M6	-0.29310	0.21695	-1.351	0.17670	0.1123E-01
C76M8	-0.98302E-02	0.23576	-0.042	0.96674	0.1000E-01
C76M9	0.20421	0.22731	0.898	0.36897	0.1190E-01
C76M10	0.56100E-01	0.24500	0.229	0.81889	0.1111E-01
LOGHOURS	1.0000	........(Fixed	Parameter)	....	1.471
α	1.5966	0.63903E-01	24.984	0.00000	

Estimation output for TRT SU

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Negative Binomial Regression
Maximum Likelihood Estimates
Dependent variable                    KEPT
Number of observations                5004
Iterations completed                    37
Log likelihood function          -1330.511
```

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-5.9205	0.67856	-8.725	0.00000	
CHART	3.2036	2.2047	1.453	0.14619	0.2998E-02
ANG2	-0.23918	0.14649	-1.633	0.10254	0.4622
ANG3	-0.42060	0.21943	-1.917	0.05526	0.1517
ANG4	-1.2723	0.49127	-2.590	0.00960	0.4636E-01
ANG5	-3.1044	2.4603	-1.262	0.20703	0.1279E-01
TRT	-1.7060	0.28986	-5.886	0.00000	0.1916
SAT	-0.90333	0.23554	-3.835	0.00013	0.7560
Y8687	-0.22882	0.36300	-0.630	0.52847	0.4416E-01
Y8889	0.55897	0.25395	2.201	0.02773	0.9592E-01
Y90	0.49250	0.30146	1.634	0.10232	0.9353E-01
Y91	-0.29846E-02	0.23834	-0.013	0.99001	0.1129
Y92	-0.73009E-01	0.24618	-0.297	0.76679	0.1047
Y93	0.94723E-01	0.21353	0.444	0.65732	0.1711
Y95	0.37406	0.21756	1.719	0.08555	0.1439
APRIL	3.6038	0.66359	5.431	0.00000	0.1049
MAY	3.6468	0.64759	5.631	0.00000	0.1992
JUNE	2.5943	0.66223	3.918	0.00009	0.1721
AUG	1.3022	0.63668	2.045	0.04082	0.1485
SEPT	1.4935	0.61973	2.410	0.01596	0.1705
OCT	4.1422	0.64465	6.425	0.00000	0.6315E-01
C2	3.6297	0.76628	4.737	0.00000	0.1996
C7	-0.14324	0.28291	-0.506	0.61265	0.7914E-01
C27	1.1038	0.41243	2.676	0.00744	0.1111
C42	-0.17762	0.61079	-0.291	0.77120	0.8633E-01
C66	0.36117	0.47599	0.759	0.44798	0.1661
Z1S	-0.64349	0.47452	-1.356	0.17507	0.1515
Z1M10	-2.4929	0.75526	-3.301	0.00096	0.1499E-01
C2M4	-2.8187	0.83498	-3.376	0.00074	0.4197E-01
C2M5	-2.7597	0.79295	-3.480	0.00050	0.5675E-01
C2M6	-3.6088	0.88998	-4.055	0.00005	0.2658E-01
C2M8	-2.6576	0.96406	-2.757	0.00584	0.2098E-01
C2M9	-1.7619	0.80965	-2.176	0.02955	0.3157E-01
C2M10	-3.6929	1.0649	-3.468	0.00052	0.6994E-02
LOGHOURS	1.0000	........(Fixed	Parameter)	....	1.285
α	3.0995	0.46476	6.669	0.00000	

Estimation output for TRT MI

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	40025
Iterations completed	87
Log likelihood function	-32313.62

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-3.1116	0.11430	-27.222	0.00000	
CHART	0.69785	0.78645E-01	8.873	0.00000	0.1267E-01
ANG2	0.34055	0.28545E-01	11.930	0.00000	0.4035
ANG3	0.55476	0.32844E-01	16.891	0.00000	0.1782
ANG4	0.69052	0.39852E-01	17.327	0.00000	0.8087E-01
ANG5	0.84066	0.60215E-01	13.961	0.00000	0.2773E-01
TRT	-0.27686	0.37152E-01	-7.452	0.00000	0.1477
SAT	-0.75304	0.30853E-01	-24.407	0.00000	0.6143
APRIL	1.3207	0.11790	11.201	0.00000	0.1966
MAY	0.55402	0.13675	4.051	0.00005	0.1508
JUNE	0.12059	0.15426	0.782	0.43434	0.1023
AUG	-0.44114	0.15333	-2.877	0.00401	0.1607
SEPT	-0.54084	0.17243	-3.137	0.00171	0.1029
OCT	1.1498	0.12683	9.066	0.00000	0.1270
C3	0.48864E-01	0.14172	0.345	0.73025	0.5272E-02
C10	1.2938	0.11573	11.179	0.00000	0.1902
C11	0.94350	0.13329	7.079	0.00000	0.1406
C15	-0.45028	0.17177	-2.621	0.00875	0.2304E-01
C24	-0.77835	0.26537	-2.933	0.00336	0.2831E-01
C28	0.25567	0.87857E-01	2.910	0.00361	0.5209E-01
C45	-0.72638	0.32506	-2.235	0.02544	0.7121E-02
C51	1.3562	0.12674	10.701	0.00000	0.1527
C53	1.3405	0.13957	9.605	0.00000	0.9666E-01
C61	0.90353	0.21337	4.235	0.00002	0.5022E-01
C64	1.0529	0.18693	5.633	0.00000	0.7445E-02
C70	0.52032	0.16503	3.153	0.00162	0.1200
C21	0.37821	0.30656	1.234	0.21731	0.4472E-02
C55	2.2200	0.11966	18.552	0.00000	0.7685E-01
C77	0.41025	0.32214	1.274	0.20283	0.3773E-02
Y86	-0.29801	0.46272E-01	-6.440	0.00000	0.7708E-01
Y87	-0.37575	0.48010E-01	-7.826	0.00000	0.8470E-01
Y88	-0.29512	0.46248E-01	-6.381	0.00000	0.9057E-01
Y89	-0.39263	0.49029E-01	-8.008	0.00000	0.7448E-01
Y90	-0.21539	0.50203E-01	-4.290	0.00002	0.7058E-01
Y91	-0.84898E-01	0.46027E-01	-1.845	0.06510	0.9302E-01
Y92	-0.33729E-01	0.46870E-01	-0.720	0.47176	0.8867E-01
Y93	-0.31525E-01	0.41645E-01	-0.757	0.44905	0.1255
Y95	-0.30160	0.40336E-01	-7.477	0.00000	0.1418
C10M4	-1.2437	0.13655	-9.109	0.00000	0.2636E-01
C10M5	-0.74936	0.15746	-4.759	0.00000	0.2316E-01
C10M6	0.40468E-01	0.17082	0.237	0.81273	0.2146E-01
C10M8	-0.30110E-01	0.16977	-0.177	0.85923	0.3675E-01
C10M9	0.21476	0.19822	1.083	0.27860	0.1559E-01
C10M10	-0.78762	0.14263	-5.522	0.00000	0.3138E-01
C11M4	-1.3983	0.15295	-9.142	0.00000	0.3625E-01
C11M5	-0.92530	0.17246	-5.365	0.00000	0.2658E-01
C11M6	-0.20364	0.19141	-1.064	0.28737	0.1621E-01
C11M8	0.18612	0.19717	0.944	0.34518	0.1374E-01
C11M9	-0.45754	0.21804	-2.098	0.03587	0.1339E-01
C11M10	-1.2435	0.18049	-6.890	0.00000	0.1509E-01

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
C2177M4	-0.14704	0.34830	-0.422	0.67291	0.2998E-02
C2177M5	1.0898	0.39656	2.748	0.00599	0.1574E-02
C2177M8	1.2423	0.51255	2.424	0.01536	0.6496E-03
C2177M9	1.3744	0.48031	2.861	0.00422	0.1224E-02
C24M4	0.63760	0.55515	1.149	0.25076	0.4997E-03
C24M5	0.11081	0.36836	0.301	0.76355	0.3848E-02
C24M6	-0.81088	0.38612	-2.100	0.03572	0.5846E-02
C24M8	0.80318	0.36220	2.218	0.02659	0.6346E-02
C24M9	1.9116	0.40346	4.738	0.00000	0.2723E-02
C24M10	1.7016	0.40183	4.235	0.00002	0.7495E-03
C51M4	-1.1812	0.14335	-8.240	0.00000	0.3583E-01
C51M5	-0.61521	0.16250	-3.786	0.00015	0.2721E-01
C51M6	0.30060	0.18588	1.617	0.10584	0.1577E-01
C51M8	0.27805	0.18496	1.503	0.13277	0.1689E-01
C51M9	0.20596	0.20850	0.988	0.32326	0.1177E-01
C51M10	-1.0828	0.15478	-6.995	0.00000	0.2621E-01
C5364M4	-1.1878	0.16323	-7.277	0.00000	0.2089E-01
C5364M5	-0.70324	0.17817	-3.947	0.00008	0.1874E-01
C5364M6	-0.55400	0.20726	-2.673	0.00752	0.8395E-02
C5364M8	0.62885	0.19091	3.294	0.00099	0.1774E-01
C5364M9	0.87125	0.21439	4.064	0.00005	0.1074E-01
C5364M10	-1.0527	0.17740	-5.934	0.00000	0.1367E-01
C55M4	-1.1833	0.14242	-8.309	0.00000	0.2159E-01
C55M5	-1.3829	0.19648	-7.038	0.00000	0.5047E-02
C55M6	-0.85507	0.21564	-3.965	0.00007	0.4122E-02
C55M8	0.22726	0.17756	1.280	0.20057	0.1524E-01
C55M9	-0.20556	0.22042	-0.933	0.35103	0.6821E-02
C55M10	-2.2940	0.29201	-7.856	0.00000	0.1999E-02
C61M4	-1.2936	0.24866	-5.202	0.00000	0.1112E-01
C61M5	-0.88636	0.28914	-3.066	0.00217	0.7445E-02
C61M6	-0.81216	0.29711	-2.734	0.00627	0.5047E-02
C61M8	0.27944	0.27010	1.035	0.30085	0.9869E-02
C61M9	0.49334	0.27717	1.780	0.07509	0.6796E-02
C61M10	-0.92199	0.27813	-3.315	0.00092	0.4822E-02
C70M4	-1.0002	0.18747	-5.335	0.00000	0.2311E-01
C70M5	-0.13417	0.19758	-0.679	0.49710	0.2453E-01
C70M6	-0.92299	0.24621	-3.749	0.00018	0.1152E-01
C70M8	-0.21807	0.24030	-0.907	0.36414	0.1509E-01
C70M9	0.54787	0.22909	2.391	0.01678	0.1939E-01
C70M10	-0.79136	0.19970	-3.963	0.00007	0.1686E-01
C15M7	0.76474	0.24231	3.156	0.00160	0.5921E-02
C45M7	2.1157	0.35196	6.011	0.00000	0.2923E-02
C1545SP	0.37599E-01	0.28864	0.130	0.89636	0.2623E-02
C1545F	0.11912E-01	0.48807	0.024	0.98053	0.2324E-02
LOGHOURS	1.0000	........(Fixed	Parameter)	....	1.292
α	1.5280	0.34910E-01	43.769	0.00000	

Estimation output for SAL HU

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	49346
Iterations completed	76
Log likelihood function	-58190.91

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-1.4924	0.48066E-01	-31.048	0.00000	
CHART	0.73223	0.81372E-01	8.998	0.00000	0.7316E-02
ANG2	0.15227	0.24770E-01	6.148	0.00000	0.4452
ANG3	0.30677	0.26574E-01	11.544	0.00000	0.2373
ANG4	0.39365	0.30730E-01	12.810	0.00000	0.1122
ANG5	0.48955	0.40888E-01	11.973	0.00000	0.3354E-01
SAL	-0.77783E-01	0.28899E-01	-2.692	0.00711	0.4547
SAT	-0.17033	0.31547E-01	-5.399	0.00000	0.4533
Y86	-0.11338	0.60062E-01	-1.888	0.05906	0.2464E-01
Y87	0.19306	0.30554E-01	6.319	0.00000	0.1373
Y88	0.13854E-01	0.31342E-01	0.442	0.65846	0.1326
Y89	-0.82110E-01	0.53509E-01	-1.535	0.12490	0.2592E-01
Y90	-0.59787	0.46323E-01	-12.906	0.00000	0.3554E-01
Y91	0.32540E-01	0.31873E-01	1.021	0.30729	0.1030
Y92	-0.20562	0.31937E-01	-6.438	0.00000	0.1169
Y93	-0.49499E-01	0.29354E-01	-1.686	0.09174	0.1366
Y95	0.26040	0.28569E-01	9.115	0.00000	0.1553
APRIL	-4.3641	0.28411	-15.361	0.00000	0.5482E-01
MAY	-2.0039	0.10918	-18.354	0.00000	0.7855E-01
JUNE	-0.60974	0.58415E-01	-10.438	0.00000	0.7054E-01
AUG	0.27724	0.36662E-01	7.562	0.00000	0.2522
SEPT	-0.49401	0.60004E-01	-8.233	0.00000	0.2620
OCT	-0.26097	0.72464E-01	-3.601	0.00032	0.8530E-01
C1	-0.57091	0.56614E-01	-10.084	0.00000	0.1142
C76	-0.53397	0.87173E-01	-6.125	0.00000	0.1363
C6	-2.1472	1.1144	-1.927	0.05400	0.6687E-02
C17	-0.60722	0.11984	-5.067	0.00000	0.2782E-01
C32	-0.61982	0.68364E-01	-9.067	0.00000	0.1289
C35	-1.0162	0.59651E-01	-17.035	0.00000	0.1606
C49	-0.43140	0.84826E-01	-5.086	0.00000	0.1749E-01
C71	-0.15845	0.42827E-01	-3.700	0.00022	0.1834
C74	-0.65191	0.22775	-2.862	0.00421	0.2938E-02
C1M5	1.2761	0.24678	5.171	0.00000	0.2371E-02
C1M6	0.43424	0.13224	3.284	0.00102	0.5593E-02
C1M8	0.39064E-01	0.78567E-01	0.497	0.61904	0.2553E-01
C1M9	0.73706	0.86305E-01	8.540	0.00000	0.4590E-01
C1M10	1.0616	0.98764E-01	10.749	0.00000	0.1844E-01
C6M5	3.0194	1.2358	2.443	0.01456	0.4053E-03
C6M9	1.5822	1.1259	1.405	0.15996	0.3668E-02
C6M10	0.70980	1.1350	0.625	0.53173	0.2371E-02
C17M6	0.13179	0.44738	0.295	0.76832	0.7295E-03
C17M8	0.82904	0.12744	6.506	0.00000	0.1111E-01
C17M9	2.0186	0.13839	14.586	0.00000	0.1153E-01
C17M10	1.1066	0.26789	4.131	0.00004	0.8511E-03
C49M6	0.30877	0.27371	1.128	0.25929	0.8309E-03
C49M8	0.68273	0.11322	6.030	0.00000	0.5208E-02
C49M9	1.3944	0.11205	12.445	0.00000	0.7275E-02
C49M10	0.67112	0.21418	3.133	0.00173	0.1621E-02
C32M4	4.7072	0.31069	15.150	0.00000	0.3182E-02
C32M5	2.0116	0.13841	14.533	0.00000	0.1733E-01
C32M6	0.53830	0.10499	5.127	0.00000	0.1327E-01
C32M8	-0.44875	0.93482E-01	-4.800	0.00000	0.1970E-01
C32M9	0.27428	0.96285E-01	2.849	0.00439	0.4260E-01
C32M10	0.20734	0.10974	1.889	0.05884	0.1913E-01

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
C35M4	3.9818	0.37799	10.534	0.00000	0.1641E-02
C35M5	2.4511	0.13192	18.580	0.00000	0.1696E-01
C35M6	0.46590	0.10128	4.600	0.00000	0.1585E-01
C35M8	-0.12045	0.77853E-01	-1.547	0.12183	0.3743E-01
C35M9	0.32005	0.90726E-01	3.528	0.00042	0.5668E-01
C35M10	-0.35537	0.13152	-2.702	0.00689	0.1161E-01
C71M5	-0.28940	0.69552	-0.416	0.67734	0.6080E-03
C71M6	-0.27824	0.15503	-1.795	0.07269	0.4458E-02
C71M8	-0.29295	0.55391E-01	-5.289	0.00000	0.8631E-01
C71M9	0.69786	0.75877E-01	9.197	0.00000	0.4280E-01
C71M10	0.39707	0.22143	1.793	0.07294	0.1135E-02
C76M4	4.6410	0.29849	15.548	0.00000	0.2677E-01
C746M5	2.2250	0.14307	15.552	0.00000	0.2924E-01
C746M6	0.97164	0.11859	8.194	0.00000	0.1242E-01
C746M8	-1.1024	0.13032	-8.459	0.00000	0.1196E-01
C746M9	-0.40587	0.11767	-3.449	0.00056	0.3174E-01
C746M10	-0.62484E-01	0.12846	-0.486	0.62667	0.1708E-01
C74M4	5.4171	0.37406	14.482	0.00000	0.1986E-02
LOGHOURS	1.0000	........(Fixed	Parameter)	....	1.431
α	1.0352	0.17514E-01	59.104	0.00000	

Estimation output for SAL SU

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	8939
Iterations completed	56
Log likelihood function	-9114.012

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
Constant	-2.3134	0.21280	-10.872	0.00000	
CHART	1.0024	0.36701	2.731	0.00631	0.2797E-02
ANG2	0.29753	0.47438E-01	6.272	0.00000	0.4473
ANG3	0.54978	0.58526E-01	9.394	0.00000	0.1369
ANG4	0.43533	0.11076	3.930	0.00008	0.3211E-01
ANG5	0.65411	0.20797	3.145	0.00166	0.9509E-02
SAL	-0.88016E-01	0.58426E-01	-1.506	0.13195	0.3035
SAT	-0.68625	0.56935E-01	-12.053	0.00000	0.4232
Y86	0.66733	0.20927	3.189	0.00143	0.1208E-01
Y87	-0.11495	0.10257	-1.121	0.26244	0.4643E-01
Y88	0.27196	0.79278E-01	3.430	0.00060	0.7260E-01
Y89	-0.75628E-01	0.44703	-0.169	0.86565	0.3244E-02
Y90	-0.27850E-01	0.10573	-0.263	0.79224	0.7014E-01
Y91	0.79750E-01	0.67404E-01	1.183	0.23674	0.1731
Y92	-0.10243	0.73606E-01	-1.392	0.16406	0.1398
Y93	-0.14579	0.78448E-01	-1.858	0.06312	0.1575
Y95	-0.27801	0.70128E-01	-3.964	0.00007	0.1662
MAY	1.0002	0.24463	4.089	0.00004	0.1872
JUNE	0.64854	0.25256	2.568	0.01023	0.1105
AUG	-0.73273	0.30138	-2.431	0.01505	0.9900E-01
SEPT	0.14799	0.22462	0.659	0.51001	0.1892
OCT	0.39221	0.37812	1.037	0.29961	0.6164E-01
C2	0.80254	0.27071	2.965	0.00303	0.2082
C7	0.36021	0.29284	1.230	0.21868	0.1288
C42	0.57004	0.45165	1.262	0.20691	0.2640E-01
C52	-0.37389	0.27386	-1.365	0.17217	0.4592
C66	-1.2455	0.31743	-3.924	0.00009	0.1005
C2M4	0.39239	0.20706	1.895	0.05809	0.6992E-01
C2M5	-0.72666	0.31937	-2.275	0.02289	0.5504E-01
C2M6	-0.86962	0.33862	-2.568	0.01023	0.1902E-01
C2M8	0.72605	0.39388	1.843	0.06528	0.9733E-02
C2M9	-0.26661	0.31305	-0.852	0.39440	0.4139E-01
C2M10	0.37432	0.49808	0.752	0.45234	0.5370E-02
C7M4	0.99528	0.25432	3.913	0.00009	0.2204E-01
C7M5	-0.19248	0.33597	-0.573	0.56670	0.4508E-01
C7M6	-0.13944	0.35090	-0.397	0.69110	0.2215E-01
C7M8	0.55572	0.44219	1.257	0.20884	0.7943E-02
C7M9	-0.70736E-01	0.35146	-0.201	0.84049	0.1130E-01
C7M10	-0.41406	0.48019	-0.862	0.38853	0.1163E-01
C42M5	-1.1030	0.71395	-1.545	0.12236	0.1678E-02
C42M6	-0.82206	0.68866	-1.194	0.23259	0.2237E-02
C42M8	0.37161	0.70279	0.529	0.59697	0.3468E-02
C42M9	-0.68477	0.55035	-1.244	0.21341	0.1007E-01
C42M10	-1.3558	0.70250	-1.930	0.05361	0.6600E-02
C52M4	1.6332	0.20218	8.078	0.00000	0.1905
C52M5	0.18060	0.32233	0.560	0.57528	0.5593E-01
C52M6	-0.15213	0.36358	-0.418	0.67564	0.2461E-01
C52M8	0.37611	0.38660	0.973	0.33061	0.4520E-01
C52M9	0.10685	0.31108	0.343	0.73125	0.9117E-01
C52M10	0.10993	0.44756	0.246	0.80598	0.3378E-01
C66M5	1.1228	0.38014	2.954	0.00314	0.1958E-01
C66M6	0.62256E-01	0.39579	0.157	0.87501	0.3121E-01
C66M8	1.1116	0.45568	2.439	0.01471	0.2014E-01
C66M9	0.62698	0.44658	1.404	0.16033	0.8055E-02
C66M10	-0.10115E-01	1.5167	-0.007	0.99468	0.1007E-02
LOGHOURS	1.0000	........(Fixed Parameter).......			1.142
α	1.1573	0.51951E-01	22.276	0.00000	

Estimation output for SAL MI

Negative Binomial Regression	
Maximum Likelihood Estimates	
Dependent variable	KEPT
Number of observations	40405
Iterations completed	95
Log likelihood function	-44286.10

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
C3M4	-1.7429	0.45144	-3.861	0.00011	0.1411E-02
C3M5	-1.0462	0.42278	-2.475	0.01334	0.1633E-02
C3M6	0.50378E-01	0.48111	0.105	0.91660	0.6435E-03
C3M8	-0.44661	0.37581	-1.188	0.23468	0.1732E-02
C3M9	-0.52544	0.56821	-0.925	0.35511	0.4455E-03
C10M4	-3.1376	0.69083	-4.542	0.00001	0.7672E-03
C10M5	-2.0133	0.23644	-8.515	0.00000	0.7276E-02
C10M6	0.39592	0.22916	1.728	0.08404	0.1386E-01
C10M8	0.47845	0.11430	4.186	0.00003	0.6477E-01
C10M9	0.25408	0.13349	1.903	0.05700	0.5477E-01
C10M10	-0.40634	0.18545	-2.191	0.02844	0.1322E-01
C11M4	-0.14437	0.26565	-0.543	0.58681	0.4945E-01
C11M5	-0.46972	0.23020	-2.040	0.04130	0.3368E-01
C11M6	0.97611	0.23176	4.212	0.00003	0.1366E-01
C11M8	-0.88344E-01	0.13919	-0.635	0.52563	0.1638E-01
C11M9	-0.90464	0.15609	-5.796	0.00000	0.2245E-01
C11M10	-0.99501	0.19918	-4.996	0.00000	0.9850E-02
C15M6	-1.2003	0.30856	-3.890	0.00010	0.2549E-02
C15M8	0.14477	0.16561	0.874	0.38202	0.1297E-01
C15M9	0.11113	0.16909	0.657	0.51105	0.2346E-01
C15M10	0.77729	0.26698	2.911	0.00360	0.1831E-02
C24M6	-0.61110	0.61641	-0.991	0.32150	0.1312E-02
C24M8	0.26368	0.20269	1.301	0.19330	0.8737E-02
C24M9	-0.22350	0.24399	-0.916	0.35965	0.4529E-02
C24M10	-0.68770E-01	0.44922	-0.153	0.87833	0.4702E-03
C51M4	-2.1181	0.34523	-6.135	0.00000	0.1633E-02
C51M5	-1.1933	0.23605	-5.055	0.00000	0.9826E-02
C51M6	0.40311	0.23852	1.690	0.09102	0.1069E-01
C51M8	0.18360	0.12387	1.482	0.13829	0.4648E-01
C51M9	-0.34934	0.14392	-2.427	0.01521	0.3203E-01
C51M10	-0.66679	0.19525	-3.415	0.00064	0.8588E-02
C53M4	-1.9687	0.30754	-6.401	0.00000	0.1757E-02
C53M5	-1.0963	0.23366	-4.692	0.00000	0.1336E-01
C53M6	0.79190	0.23639	3.350	0.00081	0.9034E-02
C53M8	0.18266	0.12603	1.449	0.14725	0.4198E-01
C53M9	-0.42644	0.14514	-2.938	0.00330	0.2760E-01
C53M10	-0.44433	0.20054	-2.216	0.02671	0.5074E-02
C61M4	-2.7226	0.31684	-8.593	0.00000	0.6534E-02
C61M5	-1.0851	0.25446	-4.264	0.00002	0.7351E-02
C61M6	0.64958	0.26954	2.410	0.01595	0.5346E-02
C61M8	-0.27586	0.16714	-1.650	0.09884	0.1086E-01
C61M9	-0.59133	0.18023	-3.281	0.00103	0.1101E-01
C61M10	-1.5403	0.54143	-2.845	0.00444	0.2005E-02
C64M4	-2.2331	0.51889	-4.304	0.00002	0.4950E-03
C64M5	-1.7970	0.32019	-5.612	0.00000	0.3044E-02
C64M6	-0.30454	0.42384	-0.719	0.47243	0.8415E-03
C64M8	-0.55212	0.25902	-2.132	0.03304	0.3440E-02
C64M9	-1.0917	0.30562	-3.572	0.00035	0.2178E-02
C64M10	-2.6400	0.47247	-5.588	0.00000	0.1534E-02
C70M4	-1.8753	0.27947	-6.710	0.00000	0.1629E-01
C70M5	-1.1473	0.23681	-4.845	0.00000	0.2512E-01
C70M6	0.40480	0.24400	1.659	0.09711	0.1178E-01
C70M8	-0.13002	0.15035	-0.865	0.38716	0.1671E-01
C70M9	-0.78551	0.16054	-4.893	0.00000	0.2683E-01
C70M10	-1.0067	0.22872	-4.401	0.00001	0.7474E-02

Variable	Coefficient	Standard Error	z=b/s.e.	P[|Z|≥z]	Mean of X
C80M4	-0.66578	0.29549	-2.253	0.02425	0.7153E-02
C80M5	-0.41918	0.27294	-1.536	0.12458	0.5445E-02
C80M6	0.82989	0.29379	2.825	0.00473	0.4876E-02
C80M8	0.34670	0.17269	2.008	0.04469	0.7697E-02
C80M9	-0.76957	0.23148	-3.325	0.00089	0.7450E-02
CUPM5	0.85685E-01	0.27183	0.315	0.75260	0.1534E-02
C55M8	-0.34559	0.13237	-2.611	0.00903	0.1146E-01
C55M9	-0.85357	0.19177	-4.451	0.00001	0.5173E-02
C55M10	-1.3316	0.68828	-1.935	0.05303	0.7177E-03
C21M8	-1.2481	0.28457	-4.386	0.00001	0.1683E-02
C21M9	-1.2774	0.31793	-4.018	0.00006	0.1435E-02
C21M10	-0.89471	0.50022	-1.789	0.07367	0.3960E-03
C77M8	0.39950E-01	0.16705	0.239	0.81099	0.4727E-02
C77M9	0.13224	0.15430	0.857	0.39144	0.5989E-02
C77M10	0.43279	0.27064	1.599	0.10979	0.9405E-03
Constant	-3.2624	0.99804E-01	-32.688	0.00000	
APRIL	1.8101	0.25395	7.128	0.00000	0.8642E-01
MAY	1.4901	0.21489	6.934	0.00000	0.1078
JUNE	-0.68033	0.21161	-3.215	0.00130	0.7808E-01
AUG	0.15103	0.99635E-01	1.516	0.12957	0.2694
SEPT	0.40042	0.12078	3.315	0.00092	0.2399
OCT	0.16346	0.16372	0.998	0.31808	0.5851E-01
C3	0.64765	0.30607	2.116	0.03434	0.6707E-02
C10	0.42448	0.10047	4.225	0.00002	0.1874
C11	0.28143	0.11423	2.464	0.01375	0.1565
C15	0.43099	0.13884	3.104	0.00191	0.4740E-01
C24	-0.33155	0.16976	-1.953	0.05082	0.2119E-01
C45	0.86371	0.99681E-01	8.665	0.00000	0.9826E-02
C51	0.54017	0.10795	5.004	0.00000	0.1312
C53	0.67700	0.11010	6.149	0.00000	0.1170
C61	0.52980	0.13225	4.006	0.00006	0.4871E-01
C64	1.2718	0.21722	5.855	0.00000	0.1309E-01
C70	0.48505	0.12472	3.889	0.00010	0.1139
C80	-0.16891	0.15525	-1.088	0.27661	0.3997E-01
C21	1.2672	0.16764	7.559	0.00000	0.5816E-02
C55	1.0438	0.10611	9.837	0.00000	0.3121E-01
C77	0.55409	0.11816	4.689	0.00000	0.2232E-01
CHART	0.95370	0.59057E-01	16.149	0.00000	0.2015E-01
ANG2	0.52643	0.25686E-01	20.494	0.00000	0.4243
ANG3	0.74615	0.27685E-01	26.951	0.00000	0.2100
ANG4	0.81379	0.32395E-01	25.121	0.00000	0.1024
ANG5	0.86312	0.44821E-01	19.257	0.00000	0.3512E-01
SAL	-0.24872	0.31559E-01	-7.881	0.00000	0.2946
SAT	-0.41148	0.30014E-01	-13.710	0.00000	0.6058
Y86	0.92825	0.39565E-01	23.462	0.00000	0.9840E-01
Y87	0.81777	0.36407E-01	22.462	0.00000	0.1371
Y88	0.39803	0.38275E-01	10.399	0.00000	0.1169
Y89	0.40721	0.39786E-01	10.235	0.00000	0.8793E-01
Y90	0.35128	0.43170E-01	8.137	0.00000	0.7440E-01
Y91	0.39594	0.39697E-01	9.974	0.00000	0.8803E-01
Y92	0.26677	0.43494E-01	6.134	0.00000	0.7729E-01
Y93	0.27697	0.38332E-01	7.225	0.00000	0.9863E-01
Y95	0.35629	0.38573E-01	9.237	0.00000	0.1142
LOGHOURS	1.0000	........(Fixed Parameter).......			1.367
α	1.0233	0.19882E-01	51.466	0.00000	

Note: Variable order for this model reflects *LIMDEP*™s 100 variable limits on matrix sizes; the above variables > 100 were not needed to estimate standard errors for the 1994 predicted rates.

Appendix B

Estimated Asymptotic Standard Errors of the Predicted Catch Rates

Estimated Asymptotic Standard Errors of the Predicted Catch Rates

The predicted monthly catch rates per hours are presented in Table B.1. There are columns for each of the specie groups and rows for counties and months for each county. The predictions are based on an angling party of one, that is targeting the specific species within the group, that is not using a charter boat, and is fishing in the year 1994. In Table B.1, the approximate asymptotic standard errors (a.s.e.) associated with each of the predicted catch rates are also reported. These standard errors are based on the Taylor's series approximation presented in equation (9) of the main report. Inspection of the table shows that the vast majority of the predicted catch rates are significantly different than 0 at the 1% level. There are only six cases where the predicted rates fail to be significantly different than 0 at the 10% level.

The table also reveals that there are cases where the predicted catch rates have been set at 0. These are due to counties and/or months that were not modelled for a particular species. In some cases, this is due to a complete lack of data at some sites as discussed above. For example, the lake trout catch rates for the Upper Peninsula counties of Lake Michigan are all set at zero because there are no party interviews where lake trout were targeted at these sites. In another example, catch rates for lake trout at Lakes Michigan and Huron are set at zero in the months of April and October because of fishing regulations.

Table B.1: Predicted Catch Rates (CR) and Standard Errors by Species, Counties, and Months.

			Lake Trout (LAT)		Salmon (SAL)		Other Trout (TRT)	
County	Month	Lake	CR	a.s.e. †	CR	a.s.e. †	CR	a.s.e. †
1 Alcona	4	Hu	0.000	0.000 0	0.002	0.001 **	0.033	0.021 *
1 Alcona	5	Hu	0.118	0.026 ***	0.061	0.014 ***	0.017	0.011 *
1 Alcona	6	Hu	0.336	0.049 ***	0.107	0.012 ***	0.040	0.013 ***
1 Alcona	7	Hu	0.343	0.047 ***	0.127	0.009 ***	0.086	0.014 ***
1 Alcona	8	Hu	0.201	0.029 ***	0.174	0.011 ***	0.109	0.018 ***
1 Alcona	9	Hu	0.107	0.031 ***	0.162	0.008 ***	0.053	0.023 **
1 Alcona	10	Hu	0.000	0.000 0	0.283	0.016 ***	0.461	0.123 ***
2 Alger	4	Su	0.070	0.009 ***	0.327	0.030 ***	0.222	0.068 ***
2 Alger	5	Su	0.231	0.018 ***	0.290	0.029 ***	0.246	0.066 ***
2 Alger	6	Su	0.230	0.019 ***	0.177	0.026 ***	0.037	0.018 **
2 Alger	7	Su	0.296	0.023 ***	0.221	0.047 ***	0.101	0.045 **
2 Alger	8	Su	0.318	0.028 ***	0.219	0.041 ***	0.026	0.017 *
2 Alger	9	Su	0.273	0.027 ***	0.196	0.024 ***	0.077	0.030 ***
2 Alger	10	Su	0.401	0.112 ***	0.475	0.127 ***	0.159	0.120 *
3 Allegan	4	Mi	0.000	0.000 0	0.078	0.019 ***	0.175	0.025 ***
3 Allegan	5	Mi	0.206	0.065 ***	0.114	0.025 ***	0.081	0.014 ***
3 Allegan	6	Mi	0.186	0.086 **	0.039	0.013 ***	0.053	0.008 ***
3 Allegan	7	Mi	0.214	0.097 **	0.073	0.022 ***	0.047	0.008 ***
3 Allegan	8	Mi	0.038	0.015 ***	0.055	0.012 ***	0.030	0.005 ***
3 Allegan	9	Mi	0.018	0.009 **	0.065	0.031 **	0.027	0.005 ***
3 Allegan	10	Mi	0.000	0.000 0	0.000	0.029 0	0.148	0.024 ***
4 Alpena	4	Hu	0.000	0.000 0	0.003	0.001 ***	0.407	0.049 ***
4 Alpena	5	Hu	0.078	0.012 ***	0.030	0.004 ***	0.207	0.030 ***
4 Alpena	6	Hu	0.112	0.014 ***	0.122	0.008 ***	0.106	0.014 ***
4 Alpena	7	Hu	0.092	0.011 ***	0.225	0.011 ***	0.145	0.016 ***
4 Alpena	8	Hu	0.046	0.006 ***	0.297	0.016 ***	0.087	0.010 ***
4 Alpena	9	Hu	0.001	0.000 ***	0.137	0.010 ***	0.049	0.007 ***
4 Alpena	10	Hu	0.000	0.000 0	0.173	0.013 ***	0.079	0.011 ***
6 Arenac	4	Hu	0.000	0.000 0	0.000	0.000 0	0.127	0.039 ***
6 Arenac	5	Hu	0.000	0.000 0	0.073	0.038 **	0.065	0.020 ***
6 Arenac	6	Hu	0.000	0.000 0	0.014	0.016 n	0.033	0.011 ***
6 Arenac	7	Hu	0.000	0.000 0	0.026	0.029 n	0.045	0.014 ***
6 Arenac	8	Hu	0.000	0.000 0	0.035	0.039 n	0.027	0.009 ***
6 Arenac	9	Hu	0.000	0.000 0	0.078	0.012 ***	0.015	0.005 ***
6 Arenac	10	Hu	0.000	0.000 0	0.041	0.009 ***	0.025	0.008 ***

County	Month	Lake	LAT CR	LAT a.s.e.	SAL CR	SAL a.s.e.	TRT CR	TRT a.s.e.
7 Baraga	4	Su	0.067	0.012 ***	0.384	0.051 ***	0.085	0.031 ***
7 Baraga	5	Su	0.215	0.025 ***	0.318	0.039 ***	0.089	0.031 ***
7 Baraga	6	Su	0.198	0.020 ***	0.236	0.034 ***	0.031	0.012 ***
7 Baraga	7	Su	0.285	0.035 ***	0.142	0.034 ***	0.002	0.002 n
7 Baraga	8	Su	0.221	0.026 ***	0.119	0.030 ***	0.009	0.005 **
7 Baraga	9	Su	0.190	0.033 ***	0.153	0.029 ***	0.010	0.005 **
7 Baraga	10	Su	0.199	0.063 ***	0.139	0.031 ***	0.146	0.057 ***
10 Benzie	4	Mi	0.000	0.000 0	0.016	0.010 *	0.175	0.011 ***
10 Benzie	5	Mi	0.177	0.018 ***	0.035	0.003 ***	0.134	0.010 ***
10 Benzie	6	Mi	0.186	0.017 ***	0.044	0.004 ***	0.191	0.013 ***
10 Benzie	7	Mi	0.185	0.016 ***	0.059	0.004 ***	0.162	0.010 ***
10 Benzie	8	Mi	0.083	0.008 ***	0.110	0.006 ***	0.101	0.007 ***
10 Benzie	9	Mi	0.014	0.002 ***	0.113	0.006 ***	0.117	0.011 ***
10 Benzie	10	Mi	0.000	0.000 0	0.046	0.004 ***	0.233	0.015 ***
11 Berrien	4	Mi	0.000	0.000 0	0.268	0.014 ***	0.106	0.007 ***
11 Berrien	5	Mi	0.105	0.010 ***	0.141	0.008 ***	0.079	0.006 ***
11 Berrien	6	Mi	0.095	0.010 ***	0.068	0.005 ***	0.105	0.010 ***
11 Berrien	7	Mi	0.101	0.011 ***	0.051	0.004 ***	0.114	0.010 ***
11 Berrien	8	Mi	0.091	0.010 ***	0.054	0.004 ***	0.089	0.009 ***
11 Berrien	9	Mi	0.016	0.002 ***	0.031	0.003 ***	0.042	0.005 ***
11 Berrien	10	Mi	0.000	0.000 0	0.022	0.002 ***	0.104	0.011 ***
15 Charlevoix	4	Mi	0.000	0.000 0	0.000	0.000 0	0.110	0.027 ***
15 Charlevoix	5	Mi	0.362	0.056 ***	0.000	0.000 0	0.051	0.012 ***
15 Charlevoix	6	Mi	0.278	0.028 ***	0.009	0.002 ***	0.032	0.005 ***
15 Charlevoix	7	Mi	0.300	0.034 ***	0.059	0.007 ***	0.061	0.009 ***
15 Charlevoix	8	Mi	0.260	0.030 ***	0.079	0.007 ***	0.018	0.003 ***
15 Charlevoix	9	Mi	0.077	0.016 ***	0.098	0.007 ***	0.017	0.008 **
15 Charlevoix	10	Mi	0.000	0.000 0	0.151	0.028 ***	0.091	0.044 **
17 Chippewa	4	Hu	0.000	0.000 0	0.002	0.001 **	0.000	0.000 0
17 Chippewa	5	Hu	0.005	0.001 ***	0.017	0.003 ***	0.397	0.092 ***
17 Chippewa	6	Hu	0.013	0.005 ***	0.076	0.033 **	0.204	0.052 ***
17 Chippewa	7	Hu	0.034	0.008 ***	0.123	0.015 ***	0.567	0.181 ***
17 Chippewa	8	Hu	0.012	0.005 ***	0.370	0.020 ***	0.339	0.109 ***
17 Chippewa	9	Hu	0.000	0.000 0	0.563	0.032 ***	0.276	0.196 *
17 Chippewa	10	Hu	0.000	0.000 0	0.285	0.067 ***	0.451	0.313 *
21 Delta	4	Mi	0.000	0.000 0	0.000	0.000 0	0.210	0.037 ***
21 Delta	5	Mi	0.000	0.000 0	0.000	0.000 0	0.336	0.121 ***
21 Delta	6	Mi	0.000	0.000 0	0.075	0.017 ***	0.073	0.024 ***
21 Delta	7	Mi	0.000	0.000 0	0.136	0.020 ***	0.065	0.020 ***
21 Delta	8	Mi	0.000	0.000 0	0.045	0.010 ***	0.145	0.065 **
21 Delta	9	Mi	0.000	0.000 0	0.057	0.015 ***	0.150	0.069 **
21 Delta	10	Mi	0.000	0.000 0	0.065	0.030 **	0.205	0.064 ***

County	Month	Lake	LAT		SAL		TRT	
			CR	a.s.e.	CR	a.s.e.	CR	a.s.e.
24 Emmet	4	Mi	0.000	0.000 0	0.000	0.000 0	0.145	0.071 **
24 Emmet	5	Mi	0.342	0.042 ***	0.000	0.000 0	0.040	0.010 ***
24 Emmet	6	Mi	0.317	0.032 ***	0.008	0.004 **	0.010	0.003 ***
24 Emmet	7	Mi	0.293	0.031 ***	0.028	0.004 ***	0.020	0.005 ***
24 Emmet	8	Mi	0.271	0.033 ***	0.042	0.005 ***	0.029	0.007 ***
24 Emmet	9	Mi	0.151	0.027 ***	0.033	0.005 ***	0.081	0.022 ***
24 Emmet	10	Mi	0.000	0.000 0	0.030	0.012 ***	0.354	0.105 ***
27 Gogebic	4	Su	0.089	0.015 ***	0.099	0.021 ***	0.000	0.000 0
27 Gogebic	5	Su	0.111	0.018 ***	0.269	0.047 ***	0.163	0.059 ***
27 Gogebic	6	Su	0.354	0.042 ***	0.189	0.038 ***	0.057	0.023 ***
27 Gogebic	7	Su	0.377	0.040 ***	0.099	0.021 ***	0.008	0.005 *
27 Gogebic	8	Su	0.310	0.041 ***	0.048	0.012 ***	0.030	0.014 **
27 Gogebic	9	Su	0.202	0.022 ***	0.115	0.017 ***	0.036	0.016 **
27 Gogebic	10	Su	0.101	0.033 ***	0.146	0.050 ***	0.042	0.029 *
28 GrandTrav	4	Mi	0.000	0.000 0	0.234	0.057 ***	0.215	0.016 ***
28 GrandTrav	5	Mi	0.206	0.021 ***	0.170	0.034 ***	0.100	0.011 ***
28 GrandTrav	6	Mi	0.173	0.018 ***	0.019	0.004 ***	0.065	0.009 ***
28 GrandTrav	7	Mi	0.215	0.021 ***	0.038	0.004 ***	0.058	0.006 ***
28 GrandTrav	8	Mi	0.122	0.014 ***	0.045	0.004 ***	0.037	0.005 ***
28 GrandTrav	9	Mi	0.028	0.006 ***	0.057	0.005 ***	0.034	0.005 ***
28 GrandTrav	10	Mi	0.000	0.000 0	0.045	0.007 ***	0.182	0.020 ***
32 Huron	4	Hu	0.000	0.000 0	0.171	0.020 ***	0.224	0.049 ***
32 Huron	5	Hu	0.223	0.031 ***	0.122	0.009 ***	0.112	0.017 ***
32 Huron	6	Hu	0.292	0.040 ***	0.113	0.008 ***	0.044	0.009 ***
32 Huron	7	Hu	0.321	0.046 ***	0.121	0.009 ***	0.099	0.016 ***
32 Huron	8	Hu	0.239	0.040 ***	0.102	0.008 ***	0.097	0.022 ***
32 Huron	9	Hu	0.128	0.049 ***	0.097	0.006 ***	0.166	0.046 ***
32 Huron	10	Hu	0.000	0.000 0	0.115	0.008 ***	0.312	0.107 ***
35 Iosco	4	Hu	0.000	0.000 0	0.056	0.014 ***	0.173	0.022 ***
35 Iosco	5	Hu	0.080	0.012 ***	0.127	0.009 ***	0.097	0.014 ***
35 Iosco	6	Hu	0.243	0.033 ***	0.071	0.005 ***	0.039	0.007 ***
35 Iosco	7	Hu	0.194	0.026 ***	0.081	0.006 ***	0.155	0.019 ***
35 Iosco	8	Hu	0.108	0.015 ***	0.095	0.006 ***	0.111	0.016 ***
35 Iosco	9	Hu	0.013	0.005 ***	0.068	0.004 ***	0.103	0.024 ***
35 Iosco	10	Hu	0.000	0.000 0	0.044	0.005 ***	0.289	0.038 ***
42 Keweenaw	4	Su	0.052	0.009 ***	0.175	0.074 ***	0.000	0.000 0
42 Keweenaw	5	Su	0.300	0.040 ***	0.158	0.085 **	0.045	0.027 **
42 Keweenaw	6	Su	0.204	0.022 ***	0.147	0.074 **	0.016	0.009 **
42 Keweenaw	7	Su	0.220	0.024 ***	0.175	0.074 ***	0.002	0.002 n
42 Keweenaw	8	Su	0.229	0.025 ***	0.122	0.060 **	0.008	0.005 *
42 Keweenaw	9	Su	0.214	0.025 ***	0.102	0.031 ***	0.010	0.006 **
42 Keweenaw	10	Su	0.274	0.043 ***	0.067	0.029 **	0.012	0.009 *

County	Month	Lake	LAT CR	a.s.e.	SAL CR	a.s.e.	TRT CR	a.s.e.
45 Leelanau	4	Mi	0.000	0.000 0	0.000	0.000 0	0.084	0.033 ***
45 Leelanau	5	Mi	0.277	0.080 ***	0.000	0.000 0	0.039	0.015 ***
45 Leelanau	6	Mi	0.246	0.051 ***	0.046	0.010 ***	0.024	0.008 ***
45 Leelanau	7	Mi	0.116	0.019 ***	0.091	0.010 ***	0.179	0.024 ***
45 Leelanau	8	Mi	0.081	0.012 ***	0.106	0.011 ***	0.014	0.004 ***
45 Leelanau	9	Mi	0.009	0.002 ***	0.136	0.019 ***	0.013	0.006 **
45 Leelanau	10	Mi	0.000	0.000 0	0.107	0.019 ***	0.069	0.030 **
49 Mackinac	4	Hu	0.000	0.000 0	0.002	0.001 **	0.000	0.000 0
49 Mackinac	5	Hu	0.000	0.000 0	0.020	0.003 ***	0.250	0.079 ***
49 Mackinac	6	Hu	0.000	0.000 0	0.108	0.028 ***	0.129	0.043 ***
49 Mackinac	7	Hu	0.000	0.000 0	0.146	0.014 ***	0.315	0.076 ***
49 Mackinac	8	Hu	0.000	0.000 0	0.381	0.032 ***	0.188	0.046 ***
49 Mackinac	9	Hu	0.000	0.000 0	0.359	0.025 ***	0.164	0.037 ***
49 Mackinac	10	Hu	0.000	0.000 0	0.220	0.042 ***	0.268	0.067 ***
51 Manistee	4	Mi	0.000	0.000 0	0.048	0.011 ***	0.199	0.011 ***
51 Manistee	5	Mi	0.072	0.009 ***	0.088	0.008 ***	0.163	0.010 ***
51 Manistee	6	Mi	0.103	0.012 ***	0.050	0.005 ***	0.263	0.022 ***
51 Manistee	7	Mi	0.102	0.011 ***	0.066	0.005 ***	0.173	0.014 ***
51 Manistee	8	Mi	0.071	0.008 ***	0.092	0.005 ***	0.147	0.013 ***
51 Manistee	9	Mi	0.003	0.002 *	0.069	0.004 ***	0.124	0.013 ***
51 Manistee	10	Mi	0.000	0.000 0	0.040	0.004 ***	0.185	0.013 ***
52 Marquette	4	Su	0.134	0.013 ***	0.349	0.027 ***	0.099	0.029 ***
52 Marquette	5	Su	0.247	0.018 ***	0.222	0.021 ***	0.103	0.033 ***
52 Marquette	6	Su	0.304	0.018 ***	0.112	0.021 ***	0.036	0.013 ***
52 Marquette	7	Su	0.310	0.020 ***	0.068	0.014 ***	0.003	0.002 *
52 Marquette	8	Su	0.406	0.025 ***	0.048	0.008 ***	0.010	0.005 **
52 Marquette	9	Su	0.426	0.033 ***	0.088	0.010 ***	0.012	0.005 ***
52 Marquette	10	Su	0.427	0.031 ***	0.113	0.017 ***	0.169	0.052 ***
53 Mason	4	Mi	0.000	0.000 0	0.064	0.011 ***	0.194	0.014 ***
53 Mason	5	Mi	0.102	0.012 ***	0.112	0.009 ***	0.147	0.011 ***
53 Mason	6	Mi	0.171	0.020 ***	0.084	0.008 ***	0.110	0.012 ***
53 Mason	7	Mi	0.164	0.018 ***	0.075	0.006 ***	0.170	0.017 ***
53 Mason	8	Mi	0.064	0.008 ***	0.105	0.006 ***	0.205	0.017 ***
53 Mason	9	Mi	0.009	0.002 ***	0.073	0.005 ***	0.237	0.024 ***
53 Mason	10	Mi	0.000	0.000 0	0.057	0.006 ***	0.188	0.018 ***
55 Menominee	4	Mi	0.000	0.000 0	0.000	0.000 0	0.470	0.036 ***
55 Menominee	5	Mi	0.000	0.000 0	0.000	0.000 0	0.179	0.025 ***
55 Menominee	6	Mi	0.000	0.000 0	0.060	0.010 ***	0.197	0.029 ***
55 Menominee	7	Mi	0.000	0.000 0	0.109	0.008 ***	0.410	0.030 ***
55 Menominee	8	Mi	0.000	0.000 0	0.090	0.007 ***	0.331	0.028 ***
55 Menominee	9	Mi	0.000	0.000 0	0.069	0.010 ***	0.194	0.026 ***
55 Menominee	10	Mi	0.000	0.000 0	0.034	0.023 *	0.131	0.034 ***

County	Month	Lake	LAT CR	a.s.e.		SAL CR	a.s.e.		TRT CR	a.s.e.	
61 Muskegon	4	Mi	0.000	0.000	0	0.026	0.004	***	0.113	0.014	***
61 Muskegon	5	Mi	0.093	0.014	***	0.098	0.010	***	0.079	0.014	***
61 Muskegon	6	Mi	0.109	0.019	***	0.063	0.009	***	0.055	0.010	***
61 Muskegon	7	Mi	0.103	0.016	***	0.065	0.007	***	0.110	0.021	***
61 Muskegon	8	Mi	0.045	0.007	***	0.057	0.006	***	0.094	0.012	***
61 Muskegon	9	Mi	0.005	0.002	***	0.054	0.005	***	0.105	0.013	***
61 Muskegon	10	Mi	0.000	0.000	0	0.016	0.008	**	0.138	0.023	***
64 Oceana	4	Mi	0.000	0.000	0	0.090	0.037	***	0.146	0.021	***
64 Oceana	5	Mi	0.102	0.012	***	0.101	0.014	***	0.110	0.015	***
64 Oceana	6	Mi	0.171	0.020	***	0.051	0.016	***	0.083	0.014	***
64 Oceana	7	Mi	0.164	0.018	***	0.137	0.028	***	0.128	0.021	***
64 Oceana	8	Mi	0.064	0.008	***	0.092	0.013	***	0.154	0.023	***
64 Oceana	9	Mi	0.009	0.002	***	0.068	0.014	***	0.178	0.025	***
64 Oceana	10	Mi	0.000	0.000	0	0.012	0.005	***	0.141	0.022	***
66 Ontonagon	4	Su	0.062	0.010	***	0.029	0.008	***	0.000	0.000	0
66 Ontonagon	5	Su	0.199	0.023	***	0.238	0.039	***	0.078	0.026	***
66 Ontonagon	6	Su	0.314	0.028	***	0.058	0.010	***	0.027	0.010	***
66 Ontonagon	7	Su	0.261	0.025	***	0.029	0.008	***	0.004	0.003	*
66 Ontonagon	8	Su	0.379	0.037	***	0.042	0.010	***	0.014	0.007	**
66 Ontonagon	9	Su	0.238	0.038	***	0.062	0.020	***	0.017	0.009	**
66 Ontonagon	10	Su	0.070	0.023	***	0.042	0.061	n	0.020	0.015	*
70 Ottawa	4	Mi	0.000	0.000	0	0.058	0.005	***	0.103	0.008	***
70 Ottawa	5	Mi	0.078	0.008	***	0.088	0.006	***	0.114	0.009	***
70 Ottawa	6	Mi	0.156	0.018	***	0.047	0.005	***	0.034	0.005	***
70 Ottawa	7	Mi	0.198	0.024	***	0.062	0.006	***	0.075	0.010	***
70 Ottawa	8	Mi	0.080	0.009	***	0.064	0.005	***	0.039	0.006	***
70 Ottawa	9	Mi	0.016	0.003	***	0.042	0.003	***	0.076	0.007	***
70 Ottawa	10	Mi	0.000	0.000	0	0.027	0.004	***	0.107	0.010	***
71 PresqueIsle	4	Hu	0.000	0.000	0	0.002	0.001	**	0.311	0.084	***
71 PresqueIsle	5	Hu	0.281	0.035	***	0.019	0.013	*	0.132	0.039	***
71 PresqueIsle	6	Hu	0.310	0.037	***	0.079	0.011	***	0.039	0.011	***
71 PresqueIsle	7	Hu	0.268	0.031	***	0.192	0.010	***	0.067	0.011	***
71 PresqueIsle	8	Hu	0.035	0.005	***	0.189	0.009	***	0.041	0.007	***
71 PresqueIsle	9	Hu	0.002	0.001	**	0.235	0.011	***	0.017	0.003	***
71 PresqueIsle	10	Hu	0.000	0.000	0	0.220	0.046	***	0.464	0.128	***
74 St.Clair	4	Hu	0.000	0.000	0	0.336	0.035	***	0.124	0.057	**
74 St.Clair	5	Hu	0.000	0.000	0	0.146	0.032	***	0.063	0.030	**
74 St.Clair	6	Hu	0.000	0.000	0	0.168	0.037	***	0.032	0.015	**
74 St.Clair	7	Hu	0.000	0.000	0	0.117	0.027	***	0.044	0.021	**
74 St.Clair	8	Hu	0.000	0.000	0	0.051	0.011	***	0.026	0.012	**
74 St.Clair	9	Hu	0.000	0.000	0	0.048	0.011	***	0.015	0.007	**
74 St.Clair	10	Hu	0.000	0.000	0	0.085	0.019	***	0.024	0.011	**

County	Month	Lake	LAT CR	a.s.e.		SAL CR	a.s.e.		TRT CR	a.s.e.	
76 Sanilac	4	Hu	0.000	0.000	0	0.174	0.010	***	0.211	0.026	***
76 Sanilac	5	Hu	0.008	0.001	***	0.164	0.009	***	0.145	0.020	***
76 Sanilac	6	Hu	0.021	0.006	***	0.189	0.014	***	0.132	0.022	***
76 Sanilac	7	Hu	0.054	0.010	***	0.132	0.012	***	0.241	0.044	***
76 Sanilac	8	Hu	0.019	0.006	***	0.058	0.006	***	0.143	0.029	***
76 Sanilac	9	Hu	0.000	0.000	0	0.054	0.004	***	0.099	0.016	***
76 Sanilac	10	Hu	0.000	0.000	0	0.095	0.007	***	0.140	0.027	***
77 Schoolcraft	4	Mi	0.000	0.000	0	0.000	0.000	0	0.217	0.075	***
77 Schoolcraft	5	Mi	0.000	0.000	0	0.000	0.000	0	0.347	0.092	***
77 Schoolcraft	6	Mi	0.000	0.000	0	0.034	0.008	***	0.076	0.026	***
77 Schoolcraft	7	Mi	0.000	0.000	0	0.067	0.006	***	0.067	0.022	***
77 Schoolcraft	8	Mi	0.000	0.000	0	0.081	0.010	***	0.150	0.069	**
77 Schoolcraft	9	Mi	0.000	0.000	0	0.114	0.008	***	0.155	0.051	***
77 Schoolcraft	10	Mi	0.000	0.000	0	0.121	0.025	***	0.212	0.068	***
80 VanBuren	4	Mi	0.000	0.000	0	0.102	0.009	***	0.167	0.017	***
80 VanBuren	5	Mi	0.172	0.033	***	0.094	0.011	***	0.078	0.009	***
80 VanBuren	6	Mi	0.174	0.027	***	0.038	0.006	***	0.050	0.007	***
80 VanBuren	7	Mi	0.210	0.033	***	0.032	0.005	***	0.045	0.005	***
80 VanBuren	8	Mi	0.189	0.026	***	0.053	0.004	***	0.029	0.004	***
80 VanBuren	9	Mi	0.027	0.007	***	0.022	0.004	***	0.026	0.004	***
80 VanBuren	10	Mi	0.000	0.000	0	0.000	0.000	0	0.141	0.012	***

† Codes indicate significance levels based on a one-tailed test of the hypothesis that the predicted rate equals zero.

0 = No test performed due to an imposed catch rate of 0,
n = Not significantly different than 0 at the 1, 5, or 10 percent levels,
* = Significantly different than 0 at the 10 percent level,
** = Significantly different than 0 at the 5 percent level,
*** = Significantly different than 0 at the 1 percent level.

Appendix C

Creel Survey Party Interview Instructions and Forms

Appendix D

LIMDEP™ Command Files for Negative Binomial Models of Catch-Per-Hour

Codes Used in Report:

```
LAT = Lake Trout
SAL = Salmon, mostly Chinook and Coho
TRT = Other Trout, mostly Rainbow and Brown

HU  = Lake Huron
SU  = Lake Superior
MI  = Lake Michigan

There are nine equations:

LAT_HU, LAT_SU, LAT_MI
SAL_HU, SAL_SU, SAL_MI
TRT_HU, TRT_SU, TRT_MI
```

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A note on model estimation

The Poisson and negative binomial models of catch rates were estimated in the software package *LIMDEP*™ (Greene, 1995). The estimators in Limdep are formulated assuming E_i (effort) is the same across all individuals. However, in our data E_i varies over individuals. This feature of *LIMDEP* can be overcome by including $\log(E_i)$ as an explanatory variable and restricting the coefficient on $\log(E_i)$ to equal one. Specifically, consider a combined Poisson (or negative binomial) rate parameter $\mu = \lambda E_i$ (this follows the discussion in the amin report). Letting λ be parameterized such that $\log(\lambda) = \beta X$, one can write

$$\mu = \lambda E_i = \exp(\beta X) E_i = \exp(\beta X)\exp(\log E_i) = \exp(\beta X + \log E_i). \qquad \text{(xx)}$$

The underlying model parameters (the β's) can then be appropriately estimated with the usual X and with the $\log(E_i)$ as a variable whose parameter is fixed at one. In *LIMDEP*, this is accomplished by using the "Rst" command to restrict parameter values. This approach applies to both the Poisson and negative binomial models.

Limdep command file: TRT HU

```
READ;      Names = kept, fhr, mode, troll, angcnt,
           year, month, county, target;    Nvar = 9;
           Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
           File = c:\limdep7\glfc\trt_ahu.dat $
?
CREATE;    Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
           Y89 = year = 89; Y90 = year = 90; Y91 = year = 91;
           Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
           C6 = county = 6; C74 = county = 74; C49=county=49;
           C17 = county = 17; C76 = county = 76;
           C1 = county = 1; C4 = county = 4; C32 = county = 32;
           C35 = county = 35; C71 = county = 71; loghours = log(fhr);
           ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
           ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
           april = month = 4; oct = month = 10;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month = 9;
           TRT = target = 62; SAT = target = 63$
?
Create;    c1m4=c1*april; c1m5=c1*may; c1m6=c1*june; c1m8=c1*aug;
           c1m9=c1*sept; c1m10=c1*oct;
           c4m4=c4*april; c4m5= c4*may; c4m6= c4*june;
           c4m8= c4*aug; c4m9=c4*sept; c4m10=c4*oct;
           c17m5=c17*may; c17m6=c17*june; c17m8=c17*aug;
           c17m9=c17*sept; c17m10=c17*oct;
           c49m5=c49*may; c49m6=c49*june; c49m8=c49*aug;
           c49m9=c49*sept; c49m10=c49*oct$

create;    c32m5= c32*may; c32m6= c32*june; c32m8= c32*aug;
           c32m4= c32*april; c32m9= c32*sept; c32m10= c32*oct;
           c35m5= c35*may; c35m6= c35*june; c35m8= c35*aug;
           c35m4= c35*april; c35m9= c35*sept; c35m10= c35*oct;
           c71m5= c71*may; c71m6= c71*june; c71m8= c71*aug;
           c71m4=c71*april; c71m9= c71*sept; c71m10= c71*oct;
           c76m5= c76*may; c76m6= c76*june; c76m8= c76*aug;
           c76m4=c76*april; c76m9= c76*sept; c76m10= c76*oct$
?
Create;    if (mode>3) noboat=1; (else) noboat=0$
Create;    if (mode=2) noboat=1$
?
create;   c1s=c1m4+c1m5$
create;   c17sp=c17*(may+june); c17f=c17*(sept+oct);
          c49sp=c49*(may+june); c49f=c49*(sept+oct)$
?
Namelist; X = one, CHART, ANG2, ANG3, ANG4, ANG5, trt,
           SAT, Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95,
           April, MAY,  JUNE,  AUG,   SEPT,  Oct,
           C1, C6, C17, C32, C35, C49, C71, C74, c76,
           c1s, C1M6, C1M8, C1m9, C1m10,
           c17sp, c17f, c49sp, c49f,
           c32m4, c32m5, c32m6, c32m8, c32m9, c32m10,
           c35m4, c35m5, c35m6, c35m8, c35m9, c35m10,
           c71m4, c71m5, c71m6, c71m8, c71m9, c71m10,
           c76m4, c76m5, c76m6, c76m8, c76m9, c76m10$
?
Poisson;   LHS = kept; RHS = X, loghours; RST = 65_b, 1;
           tlf; tlb $  Permits gradient convergence only.
?
Negbin;    LHS = kept; RHS = X, loghours; RST = 65_b, 1, a;
           Maxit = 100; tlf; tlb $
?
Matrix;    V=VARB; beta=B $
?
?  File for calculating the predictions and variance of predictions.
?
APPEND; file = c:\limdep7\glfc\salhupre.dat;  Nvar = 2;
         Nobs = 70; ? 10 counties*7 months for all.
         Names = County, Month $
?
```

```
Sample; all$
Reject; fhr>-999$
?
?  Leave fhr as -999 so that it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, trt, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
CREATE;    C6 = county = 6; C74 = county = 74; C49=county=49;
           C17 = county = 17; C76 = county = 76;
           C1 = county = 1; C4 = county = 4; C32 = county = 32;
           C35 = county = 35; C71 = county = 71;
           april = month = 4; oct = month = 10;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month = 9 $
Create;    c1m4=c1*april; c1m5=c1*may; c1m6=c1*june; c1m8=c1*aug;
           c1m9=c1*sept; c1m10=c1*oct;
           c4m4=c4*april; c4m5= c4*may; c4m6= c4*june;
           c4m8= c4*aug; c4m9=c4*sept; c4m10=c4*oct;
           c17m5=c17*may; c17m6=c17*june; c17m8=c17*aug;
           c17m9=c17*sept; c17m10=c17*oct;
           c49m5=c49*may; c49m6=c49*june; c49m8=c49*aug;
           c49m9=c49*sept; c49m10=c49*oct$
create;    c32m5= c32*may; c32m6= c32*june; c32m8= c32*aug;
           c32m4= c32*april; c32m9= c32*sept; c32m10= c32*oct;
           c35m5= c35*may; c35m6= c35*june; c35m8= c35*aug;
           c35m4= c35*april; c35m9= c35*sept; c35m10= c35*oct;
           c71m5= c71*may; c71m6= c71*june; c71m8= c71*aug;
           c71m4=c71*april; c71m9= c71*sept; c71m10= c71*oct;
           c76m5= c76*may; c76m6= c76*june; c76m8= c76*aug;
           c76m4=c76*april; c76m9= c76*sept; c76m10= c76*oct$
create;   c1s=c1m4+c1m5; c17sp=c17*(may+june); c17f=c17*(sept+oct);
          c49sp=c49*(may+june); c49f=c49*(sept+oct)$
?
?  Matrix derivation of asy var of predicted values.
?  Square root is the estimated standard error of the predicted rate.
?
Namelist; z = x, loghours $
Create;  ratehat  = exp(Beta'Z) $
Create;  rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;  ratease  = rateavar^(0.5) $
?
reject; county = 17 & month =4$
reject; county = 49 & month =4$
?
write;  county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\trt_HUy.rat $
```

Limdep command file: TRT SU

```
READ;      Names = kept, fhr, mode, troll, angcnt,
           year, month, county, target;   Nvar = 9;
           Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
           File = c:\limdep7\glfc\trt_asu.dat$
?
CREATE;    Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
           Y89 = year = 89; Y90 = year = 90; Y91 = year = 91;
           Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
           y8687=y86+y87; y8889=y88+y89;
           ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
           ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
           C2 = county = 2; C7 = county = 7; C27 = county = 27;
           Cc31 = county = 31; Cc42 = county = 42; C42 = Cc31+Cc42;
           C52 = county = 52; C66 = county = 66; april = month = 4;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month = 9; oct = month = 10;
           TRT = target = 62; SAT = target = 63; loghours = log(fhr)$
?
```

```
create;   c2m4=c2*april; c2m5=c2*may; c2m6=c2*june; c2m8=c2*aug;
          c2m9=c2*sept; c2m10=c2*oct;
          c7m4=c7*april; c7m5=c7*may; c7m6=c7*june; c7m8=c7*aug;
          c7m9=c7*sept; c7m10=c7*oct;
          c52m4=c52*april; c52m5=c52*may; c52m6=c52*june;
          c52m8=c52*aug; c52m9=c52*sept; c52m10=c52*oct$
?
create;   z1m5=(c27+c42+c66)*may; z1m6=(c27+c42+c66)*june;
          z1m10=(c27+c42+c66)*oct;  z1s = z1m6+z1m5  $
?
Namelist; X= one, CHART, ANG2, ANG3, ANG4, ANG5,
          TRT, SAT, Y8687, Y8889, Y90, Y91, Y92, Y93, Y95,
          April, MAY, JUNE, AUG, SEPT, Oct,
          C2, C7, C27, C42, C66, ? C52,
          Z1s,  z1m10,
          C2m4, C2m5, C2m6, C2m8, C2m9, C2m10 $
?
Poisson;  LHS = kept; RHS = X, loghours; RST = 34_b, 1;
          maxit =100; tlf; tlb $  Permits gradient convergence only.
?
Negbin;   LHS = kept; RHS = X, loghours; RST = 34_b, 1, a;
          Maxit = 100; tlf; tlb $
?
Matrix;   V=VARB; beta=B $
?
?  Get file for calculating predictions & asy. S.E.'s of predictions.
?
APPEND; file = c:\limdep7\glfc\latsupre.dat;  Nvar = 2;
        Nobs = 42; ? 6 counties*7 months for all.
        Names = County, Month $
?
sample; all$
Reject; fhr>-999$
?
?  Leave fhr as -999 so it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, TRT, SAT,
        Y8687, Y8889, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
CREATE;   C2 = county = 2; C7 = county = 7; C27 = county = 27;
          Cc31 = county = 31; Cc42 = county = 42; C42 = Cc31+Cc42;
          C52 = county = 52; C66 = county = 66; april = month = 4;
          may = month = 5; june = month =6; july = month = 7;
          aug = month = 8; sept = month = 9; oct = month = 10$
create;   c2m4=c2*april; c2m5=c2*may; c2m6=c2*june; c2m8=c2*aug;
          c2m9=c2*sept; c2m10=c2*oct;
          c7m4=c7*april; c7m5=c7*may; c7m6=c7*june; c7m8=c7*aug;
          c7m9=c7*sept; c7m10=c7*oct;
          c52m4=c52*april; c52m5=c52*may; c52m6=c52*june;
          c52m8=c52*aug; c52m9=c52*sept; c52m10=c52*oct$
create;   z1m5=(c27+c42+c66)*may; z1m6=(c27+c42+c66)*june;
          z1m10=(c27+c42+c66)*oct;  z1s = z1m6+z1m5  $
?
?  Matrix derivation of asy var of predicted values.
?  Square root is the estimated standard error of the predicted rate.
?
namelist;  z=x, loghours $
Create;  ratehat  = exp(Beta'Z) $
Create;  rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;  ratease  = rateavar^(0.5) $
reject; c27=1 & month=4$
reject; c42=1 & month=4$
reject; c66=1 & month=4$
?
write;  county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\trt_suy.rat $
```

Limdep command file: TRT MI

```
READ;      Names = kept, fhr, mode, troll, angcnt,
           year, month, county, target;   Nvar = 9;
           Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
           File = c:\limdep7\glfc\trt_ami.dat$
?
CREATE;    Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
           Y89 = year = 89; Y90 = year = 90; Y91 = year = 91;
           Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
           ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
           ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
           C3 = county = 3; C10 = county = 10; C11 = county = 11;
           C15 = county = 15; C24 = county = 24; C28 = county = 28;
           C45 = county = 45; C51 = county = 51; C53 = county = 53;
           C61 = county = 61; C70 = county = 70; C80 = county = 80;
           C21 = county = 21; C55 = county = 55; C77 = county = 77;
           C64 = county = 64; april = month = 4;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month = 9; oct = month = 10;
           trt = target = 62; SAT = target = 63; loghours = log(fhr)$
create;    c10m5=c10*may; c10m6=c10*june; c10m8=c10*aug;
           c10m9=c10*sept; c10m10=c10*oct; c10m4=c10*april;
           c70m5=c70*may; c70m6=c70*june; c70m8=c70*aug;
           c70m9=c70*sept; c70m10=c70*oct; c70m4=c70*april $
create;    c11m5=c11*may; c11m6=c11*june; c11m8=c11*aug;
           c11m9=c11*sept; c11m10=c11*oct; c11m4=c11*april;
           c61m5=c61*may; c61m6=c61*june; c61m8=c61*aug;
           c61m9=c61*sept; c61m10=c61*oct; c61m4=c61*april;
           c64m5=c64*may; c64m6=c64*june; c64m8=c64*aug;
           c64m9=c64*sept; c64m10=c64*oct; c64m4=c64*april;
           c51m5=c51*may; c51m6=c51*june; c51m8=c51*aug;
           c51m9=c51*sept; c51m10=c51*oct; c51m4=c51*april;
           c53m5=c53*may; c53m6=c53*june; c53m8=c53*aug;
           c53m9=c53*sept; c53m10=c53*oct; c53m4=c53*april;
           c28m5=c28*may; c28m6=c28*june; c28m8=c28*aug;
           c28m9=c28*sept; c28m10=c28*oct; c28m4=c28*april $
create;    c15m7=c15*july; c45m7=c45*july;
           C1545sp=(c15+c45)*(april+may); C1545f=(c15+c45)*(sept+oct);
           c24m4=c24*april; c24m6=c24*june; c24m8=c24*aug;
           c24m5=c24*may;   c24m9=c24*sept; c24m10=c24*oct;
           c2177m4=(c21+c77)*april; c2177m5=(c21+c77)*may;
           c2177m8=(c21+c77)*aug; c2177m9=(c21+c77)*sept;
           c2177m10=(c21+c77)*oct;
           c55m4=c55*april; c55m5=c55*may; c55m6=c55*june;
           c55m8=c55*aug; c55m9=c55*sept; c55m10=c55*oct$
?
create;    c5364m4=c53m4+c64m4; c5364m5=c53m5+c64m5;
           c5364m6=c53m6+c64m6; c5364m8=c53m8+c64m8;
           c5364m9=c53m9+c64m9; c5364m10=c53m10+c64m10 $
?
Namelist; X3= c10m4, c10m5, c10m6, c10m8, c10m9, c10m10,
           c11m4, c11m5, c11m6, c11m8, c11m9, c11m10,
           c2177m4, c2177m5, c2177m8, c2177m9, ? c2177m10,
           c24m4, c24m5, c24m6, c24m8, c24m9, c24m10,
           c51m4, c51m5, c51m6, c51m8, c51m9, c51m10,
           c5364m4, c5364m5, c5364m6, c5364m8, c5364m9, c5364m10,
           c55m4, c55m5, c55m6, c55m8, c55m9, c55m10,
           c61m4, c61m5, c61m6, c61m8, c61m9, c61m10,
           c70m4, c70m5, c70m6, c70m8, c70m9, c70m10,
           c15m7, c45m7, c1545sp, c1545f $
Namelist; X= one, CHART,
           ANG2, ANG3, ANG4, ANG5, trt, SAT,
           April, MAY, JUNE, AUG, SEPT, Oct,
           C3, C10, C11, C15, C24, C28,
           C45, C51, C53, C61, C64, C70, ?C80,
           C21, C55, C77,
           Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95,
           x3$
?
Poisson;   LHS = kept; RHS = X, loghours; RST = 94_b, 1;
           maxit =100; tlf; tlb $  Permits gradient convergence only.
?
```

```
Negbin ; LHS = kept; RHS = X, loghours;
         RST = 94_b, 1, a; Maxit = 100; tlf; tlb $
?
Matrix;   V=VARB; beta=b  $
?
?  Get file for calculating predictions & asy. S.E.'s of predictions.
?
APPEND; file = c:\limdep7\glfc\trtmipre.dat;  Nvar = 2;
        Nobs = 112; ? 16 counties*7 months for all.
        Names = County, Month $
?
sample; all$
Reject; fhr>-999$
?
?  Leave fhr as -999 so it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, trt, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
CREATE; C3 = county = 3; C10 = county = 10; C11 = county = 11;
          C15 = county = 15; C24 = county = 24; C28 = county = 28;
          C45 = county = 45; C51 = county = 51; C53 = county = 53;
          C61 = county = 61; C70 = county = 70; C80 = county = 80;
          C21 = county = 21; C55 = county = 55; C77 = county = 77;
          C64 = county = 64; april = month = 4;
          may = month = 5; june = month =6; july = month = 7;
          aug = month = 8; sept = month = 9; oct = month = 10$
create;   c10m5=c10*may; c10m6=c10*june; c10m8=c10*aug;
          c10m9=c10*sept; c10m10=c10*oct; c10m4=c10*april;
          c70m5=c70*may; c70m6=c70*june; c70m8=c70*aug;
          c70m9=c70*sept; c70m10=c70*oct; c70m4=c70*april $
create;   c11m5=c11*may; c11m6=c11*june; c11m8=c11*aug;
          c11m9=c11*sept; c11m10=c11*oct; c11m4=c11*april;
          c61m5=c61*may; c61m6=c61*june; c61m8=c61*aug;
          c61m9=c61*sept; c61m10=c61*oct; c61m4=c61*april;
          c64m5=c64*may; c64m6=c64*june; c64m8=c64*aug;
          c64m9=c64*sept; c64m10=c64*oct; c64m4=c64*april;
          c51m5=c51*may; c51m6=c51*june; c51m8=c51*aug;
          c51m9=c51*sept; c51m10=c51*oct; c51m4=c51*april;
          c53m5=c53*may; c53m6=c53*june; c53m8=c53*aug;
          c53m9=c53*sept; c53m10=c53*oct; c53m4=c53*april;
          c28m5=c28*may; c28m6=c28*june; c28m8=c28*aug;
          c28m9=c28*sept; c28m10=c28*oct; c28m4=c28*april $
create;   c15m7=c15*july; c45m7=c45*july;
          C1545sp=(c15+c45)*(april+may); C1545f=(c15+c45)*(sept+oct);
          c24m4=c24*april; c24m6=c24*june; c24m8=c24*aug;
          c24m5=c24*may;   c24m9=c24*sept; c24m10=c24*oct;
          c2177m4=(c21+c77)*april; c2177m5=(c21+c77)*may;
          c2177m8=(c21+c77)*aug; c2177m9=(c21+c77)*sept;
          c2177m10=(c21+c77)*oct;
          c55m4=c55*april; c55m5=c55*may; c55m6=c55*june;
          c55m8=c55*aug; c55m9=c55*sept; c55m10=c55*oct$
create;   c5364m4=c53m4+c64m4; c5364m5=c53m5+c64m5;
          c5364m6=c53m6+c64m6; c5364m8=c53m8+c64m8;
          c5364m9=c53m9+c64m9; c5364m10=c53m10+c64m10 $
?
namelist;  z=x, loghours $
Create;  ratehat  = exp(Beta'Z) $
Create;  rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;  ratease  = rateavar^(0.5) $
?
write;  county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\trt_miy.rat $
```

Limdep command file: SAL HU

```
READ;     Names = kept, fhr, mode, troll, angcnt,
          year, month, county, target;   Nvar = 9;
```

```
APPEND; file = c:\limdep7\glfc\salhupre.dat;  Nvar = 2;
        Nobs = 70; ? 10 counties*7 months (no tusc, bay or cheb).
        Names = County, Month $
?
Sample; all$
Reject; fhr>-999$
?
?  Leave fhr as -999 so that it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, SAL, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
CREATE;    C6 = county = 6; C74 = county = 74; C49=county=49;
           C17 = county = 17; C76 = county = 76;
           C1 = county = 1; C4 = county = 4; C32 = county = 32;
           C35 = county = 35; C71 = county = 71;
           april = month = 4; oct = month = 10;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month = 9$
Create;    c1m5=c1*may; c1m6=c1*june; c1m8=c1*aug;
           c1m9=c1*sept; c1m10=c1*oct;
           c76m4=c76*april; c76m5= c76*may; c76m6= c76*june;
           c76m8= c76*aug; c76m9=c76*sept; c76m10=c76*oct;
           c6m9=c6*sept; c6m10=c6*oct;
           c17m6=c17*june; c17m8=c17*aug; c17m9=c17*sept;
           c17m10=c17*oct;
           c49m6=c49*june; c49m8=c49*aug; c49m9=c49*sept;
           c49m10=c49*oct;
           c32m5= c32*may; c32m6= c32*june; c32m8= c32*aug;
           c32m4= c32*april; c32m9= c32*sept; c32m10= c32*oct;
           c35m5= c35*may; c35m6= c35*june; c35m8= c35*aug;
           c35m4= c35*april; c35m9= c35*sept; c35m10= c35*oct;
           c71m5= c71*may; c71m6= c71*june; c71m8= c71*aug;
           c71m9= c71*sept; c71m10= c71*oct;
           c74m4= c74*april $
?
?  Give St. Clair the same temporal pattern as Sanilac, except for M4.
create;    c746m5=(c74+c76)*may; c746m6=(c74+c76)*june;
           c746m8=(c74+c76)*aug;
           c746m9=(c74+c76)*sept; c746m10=(c74+c76)*oct $
create;    c6m5=c6*may$
?
Namelist; z = x, loghours $
Create;  ratehat  = exp(Z'beta) $      predicted rate.
Create;  rateavar = ratehat*ratehat*Qfr(z,V) $
Create;  ratease  = rateavar^(0.5) $   asy s.e. of predicted rate.
?
write;   county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
         file=c:\limdep7\glfc\sal_HUy.rat $
```

Limdep command file: SAL SU

```
READ;      Names = kept, fhr, mode, troll, angcnt,
           year, month, county, target;   Nvar = 9;
           Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
           File = c:\limdep7\glfc\sal_asu.dat$
?
Sample;    all $
REJECT;    fhr <= 0 $
Reject;    county = 17$
?
CREATE;    Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
           Y89 = year = 89; Y90 = year = 90; Y91 = year = 91;
           Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
           ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
           ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
           C2 = county = 2; C7 = county = 7; C27 = county = 27;
           Cc31 = county = 31; Cc42 = county = 42; C42 = Cc31+Cc42;
```

```
          C52 = county = 52; C66 = county = 66; april = month = 4;
          may = month = 5; june = month =6; july = month = 7;
          aug = month = 8; sept = month = 9; oct = month = 10;
          SAL = target = 61; SAT = target = 63; loghours = log(fhr)$
create;   c2m4=c2*april; c2m5=c2*may; c2m6=c2*june; c2m8=c2*aug;
          c2m9=c2*sept; c2m10=c2*oct;
          c7m4=c7*april; c7m5=c7*may; c7m6=c7*june; c7m8=c7*aug;
          c7m9=c7*sept; c7m10=c7*oct;
          c52m4=c52*april; c52m5=c52*may; c52m6=c52*june;
          c52m8=c52*aug; c52m9=c52*sept; c52m10=c52*oct;
          c27m5=c27*may; c27m6=c27*june; c27m8=c27*aug;
          c27m9=c27*sept; c27m10=c27*oct;
          c42m5=c42*may; c42m6=c42*june; c42m8=c42*aug;
          c42m9=c42*sept; c42m10=c42*oct;
          c66m5=c66*may; c66m6=c66*june; c66m8=c66*aug;
          c66m9=c66*sept; c66m10=c66*oct $
?
Namelist; X= one, CHART, ANG2, ANG3, ANG4, ANG5,
          SAL, SAT, Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95,
          ?April,
          MAY, JUNE, AUG, SEPT, Oct,
          C2, C7, ?C17, ?C27,
          C42, C52, C66,
          c2m4, c2m5, c2m6, c2m8, c2m9,  c2m10,
          c7m4, c7m5, c7m6, c7m8, c7m9,  c7m10,
          c42m5, c42m6, c42m8, c42m9,  c42m10,
          c52m4, c52m5, c52m6, c52m8, c52m9, c52m10,
          c66m5, c66m6, c66m8, c66m9, c66m10 $
?
REJECT;   fhr < 0 $
?
Poisson;  LHS = kept; RHS = X, loghours; RST = 55_b, 1;
          maxit =100; tlf; tlb $  Permits gradient convergence only.
?
Negbin;   LHS = kept; RHS = X, loghours; RST = 55_b, 1, a;
          Maxit = 100; tlf; tlb $
?
Matrix;   V=VARB; beta=B $
?
?  Get file for calculating predictions & asy. S.E.'s of predictions.
?
APPEND; file = c:\limdep7\glfc\salsupre.dat;  Nvar = 2;
        Nobs = 49; ? 7 counties*7 months for all -- with C17.
        Names = County, Month $
?
sample; all$
Reject; fhr>-999$
?
CREATE;   C2 = county = 2; C7 = county = 7; C27 = county = 27;
          Cc31= county = 31; Cc42= county = 42; C42= Cc31+Cc42;
          C52= county = 52; C66= county = 66; C17=county=17;
          april = month = 4;
          may= month = 5; june = month =6; july = month = 7;
          aug= month = 8; sept = month = 9; oct = month = 10;
          SAL= target = 62; SAT= target = 63; loghours= log(fhr)$
create;   c2m4=c2*april; c2m5=c2*may; c2m6=c2*june; c2m8=c2*aug;
          c2m9=c2*sept; c2m10=c2*oct;
          c7m4=c7*april; c7m5=c7*may; c7m6=c7*june; c7m8=c7*aug;
          c7m9=c7*sept; c7m10=c7*oct;
          c52m4=c52*april; c52m5=c52*may; c52m6=c52*june;
          c52m8=c52*aug; c52m9=c52*sept; c52m10=c52*oct;
          c27m5=c27*may; c27m6=c27*june; c27m8=c27*aug;
          c27m9=c27*sept; c27m10=c27*oct;
          c42m5=c42*may; c42m6=c42*june; c42m8=c42*aug;
          c42m9=c42*sept; c42m10=c42*oct;
          c66m5=c66*may; c66m6=c66*june; c66m8=c66*aug;
          c66m9=c66*sept; c66m10=c66*oct $
?
create; If (mode>3) noboat=1; (else) noboat=0 $
create; If (mode=2) noboat=1$
?
```

```
?  Leave fhr as -999 so it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, SAL, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
namelist;  z=x, loghours $
Create;  ratehat  = exp(Beta'Z) $
Create;  rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;  ratease  = rateavar^(0.5) $
?
write;  county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\sal_suy.rat $
```

Limdep command file: SAL MI

```
READ;      Names = kept, fhr, mode, troll, angcnt,
           year, month, county, target;   Nvar = 9;
           Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
           File = c:\limdep7\glfc\sal_ami.dat$
?
?REJECT;    county = 49 $  there are no obs. from here.
?
Sample;    all $
REJECT;    county = 21 & month < 6 $  UP counties
REJECT;    county = 55 & month < 6 $
REJECT;    county = 77 & month < 6 $
REJECT;    county = 24 & month < 6 $  Upper LP counties
REJECT;    county = 15 & month < 6 $
REJECT;    county = 45 & month < 6 $
reject;    kept>100$
reject;    fhr>40$
?
CREATE;    Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
           Y89 = year = 89; Y90 = year = 90; Y91 = year = 91;
           Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
           ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
           ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
           C3 = county = 3; C10 = county = 10; C11 = county = 11;
           C15 = county = 15; C24 = county = 24; C28 = county = 28;
           C45 = county = 45; C51 = county = 51; C53 = county = 53;
           C61 = county = 61; C70 = county = 70; C80 = county = 80;
           C21 = county = 21; C55 = county = 55; C77 = county = 77;
           C64 = county = 64; april = month = 4;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month =9; oct = month = 10;
           SAL = target = 61; SAT = target = 63; loghours = log(fhr)$
create;    c3m4=c3*april; c3m5=c3*may; c3m6=c3*june; c3m8=c3*aug;
           c3m9=c3*sept;
           c10m5=c10*may; c10m6=c10*june; c10m8=c10*aug;
           c10m9=c10*sept; c10m10=c10*oct; c10m4=c10*april;
           c70m5=c70*may; c70m6=c70*june; c70m8=c70*aug;
           c70m9=c70*sept; c70m10=c70*oct; c70m4=c70*april;
           c80m5=c80*may; c80m6=c80*june; c80m8=c80*aug;
           c80m9=c80*sept; c80m4=c80*april$
create;    c11m5=c11*may; c11m6=c11*june; c11m8=c11*aug;
           c11m9=c11*sept; c11m10=c11*oct; c11m4=c11*april;
           c61m5=c61*may; c61m6=c61*june; c61m8=c61*aug;
           c61m9=c61*sept; c61m10=c61*oct; c61m4=c61*april;
           c64m5=c64*may; c64m6=c64*june; c64m8=c64*aug;
           c64m9=c64*sept; c64m10=c64*oct; c64m4=c64*april;
           c51m5=c51*may; c51m6=c51*june; c51m8=c51*aug;
           c51m9=c51*sept; c51m10=c51*oct; c51m4=c51*april;
           c53m5=c53*may; c53m6=c53*june; c53m8=c53*aug;
           c53m9=c53*sept; c53m10=c53*oct; c53m4=c53*april;
           c28m5=c28*may; c28m6=c28*june; c28m8=c28*aug;
           c28m9=c28*sept; c28m10=c28*oct; c28m4=c28*april $
create;    c15m6=c15*june; c15m8=c15*aug;
           c15m9=c15*sept; c15m10=c15*oct;
```

```
          c24m6=c24*june; c24m8=c24*aug;
          c24m9=c24*sept; c24m10=c24*oct;
          c77m8=c77*aug; c77m9=c77*sept; c77m10=c77*oct;
          c21m8=c21*aug; c21m9=c21*sept; c21m10=c21*oct;
          c55m8=c55*aug; c55m9=c55*sept; c55m10=c55*oct;
          cupm5=(c55+c21)*june$
?
Namelist; X1= one, April, MAY, JUNE, AUG, SEPT, Oct,
          C3, C10, C11, C15, C24, ?C28,
          C45, C51, C53, C61, C64, C70, C80,
          C21, C55, C77,
          CHART, ANG2, ANG3, ANG4, ANG5, SAL, SAT,
          Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95$
Namelist; X3= one,
          April, MAY, JUNE, AUG, SEPT, Oct,
          C3, C10, C11, C15, C24, ?C28,
          C45, C51, C53, C61, C64, C70, C80,
          C21, C55, C77,
          CHART, ANG2, ANG3, ANG4, ANG5, SAL, SAT,
          Y86$ , Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95$
Namelist; X2= c3m4,  c3m5,  c3m6, c3m8,  c3m9,
          c10m4, c10m5, c10m6, c10m8, c10m9, c10m10,
          c11m4, c11m5, c11m6, c11m8, c11m9, c11m10,
          c15m6, c15m8, c15m9, c15m10,
          c24m6, c24m8, c24m9, c24m10,
          c51m4, c51m5, c51m6, c51m8, c51m9, c51m10,
          c53m4, c53m5, c53m6, c53m8, c53m9, c53m10,
          c61m4, c61m5, c61m6, c61m8, c61m9, c61m10,
          c64m4, c64m5, c64m6, c64m8, c64m9, c64m10,
          c70m4, c70m5, c70m6, c70m8, c70m9, c70m10,
          c80m4, c80m5, c80m6, c80m8, c80m9,
          cUPm5, c55m8, c55m9, c55m10,
          c21m8, c21m9, c21m10,
          c77m8, c77m9, c77m10 $  108 vars.
?
REJECT;   fhr < 0 $
?
Poisson;  LHS = kept; RHS = X2,X1, loghours;
          RST = 99_b, c1,c2,c3,c4, c5,c6,c7,c8, c9, 1;
          maxit =100; tlf; tlb $  Permits gradient convergence only.
?
Negbin ; LHS = kept; RHS = X2,X1, loghours;
         RST = 99_b, c1,c2,c3,c4, c5,c6,c7,c8, c9, 1, a;
         Maxit = 100; tlf; tlb $
?
Matrix;   V=VARB; beta= part(B,1,100) $
?
?  Get file for calculating predictions & asy. S.E.'s of predictions.
?
APPEND; file = c:\limdep7\glfc\salmipre.dat;  Nvar = 2;
        Nobs = 112; ? 16 counties*7 months for all -m4,m5 for 6.
        Names = County, Month $
?
sample; all$
Reject; fhr>-999$
?
?  Leave fhr as -999 so it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, SAL, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
CREATE;   C3 = county = 3; C10 = county = 10; C11 = county = 11;
          C15 = county = 15; C24 = county = 24; C28 = county = 28;
          C45 = county = 45; C51 = county = 51; C53 = county = 53;
          C61 = county = 61; C70 = county = 70; C80 = county = 80;
          C21 = county = 21; C55 = county = 55; C77 = county = 77;
          C64 = county = 64; april = month = 4;
          may = month = 5; june = month =6; july = month = 7;
          aug = month = 8; sept = month = 9; oct = month = 10$
create;   c3m4=c3*april; c3m5=c3*may; c3m6=c3*june; c3m8=c3*aug;
```

```
            c3m9=c3*sept;
            c10m5=c10*may; c10m6=c10*june; c10m8=c10*aug;
            c10m9=c10*sept; c10m10=c10*oct; c10m4=c10*april;
            c70m5=c70*may; c70m6=c70*june; c70m8=c70*aug;
            c70m9=c70*sept; c70m10=c70*oct; c70m4=c70*april;
            c80m5=c80*may; c80m6=c80*june; c80m8=c80*aug;
            c80m9=c80*sept; c80m4=c80*april$
create;     c11m5=c11*may; c11m6=c11*june; c11m8=c11*aug;
            c11m9=c11*sept; c11m10=c11*oct; c11m4=c11*april;
            c61m5=c61*may; c61m6=c61*june; c61m8=c61*aug;
            c61m9=c61*sept; c61m10=c61*oct; c61m4=c61*april;
            c64m5=c64*may; c64m6=c64*june; c64m8=c64*aug;
            c64m9=c64*sept; c64m10=c64*oct; c64m4=c64*april;
            c51m5=c51*may; c51m6=c51*june; c51m8=c51*aug;
            c51m9=c51*sept; c51m10=c51*oct; c51m4=c51*april;
            c53m5=c53*may; c53m6=c53*june; c53m8=c53*aug;
            c53m9=c53*sept; c53m10=c53*oct; c53m4=c53*april;
            c28m5=c28*may; c28m6=c28*june; c28m8=c28*aug;
            c28m9=c28*sept; c28m10=c28*oct; c28m4=c28*april $
create;     c15m6=c15*june; c15m8=c15*aug;
            c15m9=c15*sept; c15m10=c15*oct;
            c24m6=c24*june; c24m8=c24*aug;
            c24m9=c24*sept; c24m10=c24*oct;
            c77m8=c77*aug; c77m9=c77*sept; c77m10=c77*oct;
            c21m8=c21*aug; c21m9=c21*sept; c21m10=c21*oct;
            c55m8=c55*aug; c55m9=c55*sept; c55m10=c55*oct;
            cupm5=(c55+c21)*june$
?
namelist;  z=x2,x3 $
Create;   ratehat  = exp(Beta'Z) $
Create;   rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;   ratease  = rateavar^(0.5) $
?
write;  county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\sal_miy.rat $
```

Limdep command file: LAT HU

```
READ;       nobs=25190 ;  Names = kept, fhr, mode, troll, angcnt,
            year, month, county, target;   Nvar = 9;
            Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
            File = c:\limdep7\glfc\lat_ahu.dat $
?
Sample;     all $
REJECT;     county = 0 $
REJECT;     fhr <= 0 $
?
CREATE;     Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
            Y89 = year = 89 ; Y90 = year = 90; Y91 = year = 91;
            Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
            C1 = county = 1; C4 = county = 4; C32 = county = 32;
            C6 = county = 6; C9 = county = 9; C6and9 = C6 + C9;
            C17 = county = 17; C49 = county = 49; C17and49 = C17+C49;
            C35 = county = 35; C71 = county = 71; C74 = county =74;
            ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
            ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
            may = month = 5; june = month =6; july = month = 7;
            aug = month = 8; sept = month = 9; loghours = log(fhr);
            TRT = target = 62; SAT = target = 63$
create;     c1m5= c1*may; c1m6= c1*june; c1m8= c1*aug;
            c4m5= c4*may; c4m6= c4*june; c4m8= c4*aug;
            c32m5= c32*may; c32m6= c32*june; c32m8= c32*aug;
            c35m5= c35*may; c35m6= c35*june; c35m8= c35*aug;
            c71m5= c71*may; c71m6= c71*june; c71m8= c71*aug;
            c1m7= c1*july; c4m7= c4*july; c32m7= c32*july;
            c35m7= c35*july; c71m7= c71*july; c1m9=c1*sept;
            c32m9=c32*sept; c35m9=c35*sept$
?
Namelist; X = one, CHART, ANG2, ANG3, ANG4, ANG5, TRT,
```

```
          SAT, Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95,
          MAY, JUNE, AUG, SEPT,
          C1, C4, C17, C32, C35, C71,
          C1M5, C1M6, C1M8, C1M9, C4M5, C4M6, C4M8,
          C32M5, C32M6, C32M8, C32M9,
          C35M5,C35M6,C35M8,C35M9, C71M5,C71M6,C71M8$
?
REJECT;   fhr < 0 $
reject;   month<5 $
reject;   month>9 $
reject;   c6   =1 $
reject;   c9   =1 $
reject;   c49  =1 $
reject;   c74  =1 $
?
Poisson;  LHS = kept; RHS = X, loghours; RST = 45_b, 1;
          maxit =100; tlf; tlb $  Permits gradient convergence only.
?
Negbin;   LHS = kept; RHS= X, loghours; RST= 45_b,1,a;
          Maxit = 100; tlf; tlb $
?
Matrix;   V=VARB; beta=B $
?
?  Get file for calculating predictions & asy. S.E.'s of predictions.
?
APPEND; file = c:\limdep7\glfc\lathupre.dat;  Nvar = 2;
        Nobs = 65; ? 13 counties*5 months for all.
        Names = County, Month $
?
sample; all$
Reject; fhr>-999$
?
Create; MAY = month =5; JUNE= month =6; JULY = month =7; AUG= month =8;
        SEPT = month =9; C1= county =1;  C4=county =4; C32= county =32;
        C35 =county=35; C71 =county= 71; C6=county= 6; C17 =county= 17;
        c1m5= c1*may; c1m6= c1*june; c4m7= c4*july; c1m8= c1*aug;
        c4m5= c4*may; c4m6= c4*june; c1m7= c1*july; c4m8= c4*aug;
        c32m5=c32*may; c32m6=c32*june; c32m7=c32*july; c32m8=c32*aug;
        c35m5=c35*may; c35m6=c35*june; c35m7=c35*july; c35m8=c35*aug;
        c71m5=c71*may; c71m6=c71*june; c71m7=c71*july; c71m8=c71*aug;
        c1m9=c1*sept; c32m9=c32*sept; c35m9=c35*sept$
?
?  Leave fhr as -999 so that it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, TRT, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
namelist;  z=x, loghours $
Create;  ratehat  = exp(Beta'Z) $
Create;  rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;  ratease  = rateavar^(0.5) $
?
reject; county =  6$
reject; county =  9$
reject; county = 16$
reject; county = 49$
reject; county = 74$
reject; county = 79$
?
write;  county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\lat_huy.rat $
```

Limdep command file: LAT SU

```
READ;     Names = kept, fhr, mode, troll, angcnt,
          year, month, county, target;    Nvar = 9;
          Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
          File = c:\limdep7\glfc\lat_asu.dat$
```

```
?
Sample;    all $
REJECT;    county = 0 $
REJECT;    fhr <= 0 $
Reject;    county = 17$
?
CREATE;    Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
           Y89 = year = 89; Y90 = year = 90; Y91 = year = 91;
           Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
           ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
           ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
           C2 = county = 2; C7 = county = 7; C27 = county = 27;
           Cc31 = county = 31; Cc42 = county = 42; C42 = Cc31+Cc42;
           C52 = county = 52; C66 = county = 66; april = month = 4;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month = 9; oct = month = 10;
           TRT = target = 62; SAT = target = 63; loghours = log(fhr)$
create;    c2m4=c2*april; c2m5=c2*may; c2m6=c2*june; c2m8=c2*aug;
           c2m9=c2*sept; c2m10=c2*oct;
           c7m4=c7*april; c7m5=c7*may; c7m6=c7*june; c7m8=c7*aug;
           c7m9=c7*sept; c7m10=c7*oct;
           c52m4=c52*april; c52m5=c52*may; c52m6=c52*june;
           c52m8=c52*aug; c52m9=c52*sept; c52m10=c52*oct;
           c27m5=c27*may; c27m6=c27*june; c27m8=c27*aug;
           c27m9=c27*sept; c27m10=c27*oct;
           c42m5=c42*may; c42m6=c42*june; c42m8=c42*aug;
           c42m9=c42*sept; c42m10=c42*oct;
           c66m5=c66*may; c66m6=c66*june; c66m8=c66*aug;
           c66m9=c66*sept; c66m10=c66*oct $
?
Namelist; X= one, CHART, ANG2, ANG3, ANG4, ANG5,
           TRT, SAT, Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95,
           April, MAY, JUNE, AUG, SEPT, Oct,
           C2, C7, ?C27,
           C42, C52, C66, c2m5, c2m6, c2m8, c2m9,  c2m10,
           c7m5, c7m6, c7m8, c7m9,  c7m10,
           c42m5, c42m6, c42m8, c42m9,  c42m10,
           c52m4, c52m5, c52m6, c52m8, c52m9, c52m10,
           c66m5, c66m6, c66m8, c66m9 $
?
Poisson;   LHS = kept; RHS = X, loghours; RST = 53_b, 1;
           maxit =100; tlf; tlb $  Permits gradient convergence only.
?
Negbin;    LHS = kept; RHS = X, loghours; RST = 53_b, 1, a;
           Maxit = 100; tlf; tlb $
?
Matrix;    V=VARB; beta=B $
?
?  Get file for calculating predictions & asy. S.E.'s of predictions.
?
APPEND; file = c:\limdep7\glfc\latsupre.dat;  Nvar = 2;
        Nobs = 42; ? 6 counties*7 months for all.
        Names = County, Month $
?
sample; all$
Reject; fhr>-999$
?
CREATE;    C2 = county = 2; C7 = county = 7; C27 = county = 27;
           Cc31= county = 31; Cc42= county = 42; C42= Cc31+Cc42;
           C52= county = 52; C66= county = 66; april = month = 4;
           may= month = 5; june = month =6; july = month = 7;
           aug= month = 8; sept = month = 9; oct = month = 10$
create;    c2m4=c2*april; c2m5=c2*may; c2m6=c2*june; c2m8=c2*aug;
           c2m9=c2*sept; c2m10=c2*oct;
           c7m4=c7*april; c7m5=c7*may; c7m6=c7*june; c7m8=c7*aug;
           c7m9=c7*sept; c7m10=c7*oct;
           c52m4=c52*april; c52m5=c52*may; c52m6=c52*june;
           c52m8=c52*aug; c52m9=c52*sept; c52m10=c52*oct;
           c27m5=c27*may; c27m6=c27*june; c27m8=c27*aug;
           c27m9=c27*sept; c27m10=c27*oct;
           c42m5=c42*may; c42m6=c42*june; c42m8=c42*aug;
```

```
          c42m9=c42*sept; c42m10=c42*oct;
          c66m5=c66*may; c66m6=c66*june; c66m8=c66*aug;
          c66m9=c66*sept; c66m10=c66*oct $
?
?  Leave fhr as -999 so it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, TRT, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
namelist;  z=x, loghours $
Create;  ratehat   = exp(Beta'Z) $
Create;  rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;  ratease   = rateavar^(0.5) $
?
write;   county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\lat_suy.rat $
```

Limdep command file: LAT MI

```
READ;      Names = kept, fhr, mode, troll, angcnt,
           year, month, county, target;   Nvar = 9;
           Format = (f3.0,f4.1,f1.0,f1.0,f1.0,f2.0,f2.0,f2.0,f2.0);
           File = c:\limdep7\glfc\lat_ami.dat$
?
Sample;    all $
REJECT;    fhr <= 0 $
?
REJECT;    county = 21 $  UP counties
REJECT;    county = 49 $
REJECT;    county = 55 $
REJECT;    county = 77 $
Reject;    month  < 5 $
Reject;    month  > 9 $
?
CREATE;    Y86 = year = 86; Y87 = year = 87; Y88 = year = 88;
           Y89 = year = 89; Y90 = year = 90; Y91 = year = 91;
           Y92 = year = 92; Y93 = year = 93; Y95 = year = 95;
           ANG2 = angcnt = 2; ANG3 = angcnt = 3; ANG4 = angcnt = 4;
           ANG5 = angcnt > 4; Chart = mode = 3; NoTroll = troll = 0;
           C3 = county = 3; C10 = county = 10; C11 = county = 11;
           C15 = county = 15; C24 = county = 24; C28 = county = 28;
           C45 = county = 45; C51 = county = 51; C53 = county = 53;
           C61 = county = 61; C70 = county = 70; C80 = county = 80;
           may = month = 5; june = month =6; july = month = 7;
           aug = month = 8; sept = month = 9;
           TRT = target = 62; SAT = target = 63; loghours = log(fhr)$
create;    c3m5=c3*may; c3m6=c3*june; c3m8=c3*aug;
           c3m9=c3*sept;
           c10m5=c10*may; c10m6=c10*june; c10m8=c10*aug;
           c10m9=c10*sept;
           c11m5=c11*may; c11m6=c11*june;
           c11m8=c11*aug; c11m9=c11*sept;
           c15m5=c15*may; c15m6=c15*june; c15m8=c15*aug;
           c15m9=c15*sept;
           c24m5=c24*may; c24m6=c24*june; c24m8=c24*aug;
           c24m9=c24*sept;
           c28m5=c28*may; c28m6=c28*june; c28m8=c28*aug;
           c28m9=c28*sept;
           c45m5=c45*may; c45m6=c45*june; c45m8=c45*aug;
           c45m9=c45*sept$
create;    c51m5=c51*may; c51m6=c51*june; c51m8=c51*aug;
           c51m9=c51*sept;
           c53m5=c53*may; c53m6=c53*june; c53m8=c53*aug;
           c53m9=c53*sept;
           c61m5=c61*may; c61m6=c61*june; c61m8=c61*aug;
           c61m9=c61*sept;
           c70m5=c70*may; c70m6=c70*june; c70m8=c70*aug;
           c70m9=c70*sept;
```

```
          c80m5=c80*may; c80m6=c80*june; c80m8=c80*aug;
          c80m9=c80*sept$
?
Create; c3&70m9 = c3m9+c70m9; c10&45m9 = c45m9+c10m9 $
? 90% of Leelanau Fsites are outside of GT bay.
?
Namelist; X= one, CHART, ANG2, ANG3, ANG4, ANG5,
          TRT, SAT, Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95,
          MAY, JUNE, AUG, SEPT,
          C3, C10, ?C11,
          C15, C24, C28, C45, C51, C53, C61, C70, C80,
          c3m5,  c3m6,  c3m8,
          c10m5, c10m6, c10m8, c10&45m9,
          c15m5, c15m6, c15m8, c15m9,
          c24m5, c24m6, c24m8, c24m9,
          c28m5, c28m6, c28m8, c28m9,
          c45m5, c45m6, c45m8,
          c51m5, c51m6, c51m8, c51m9,
          c53m5, c53m6, c53m8, c53m9,
          c61m5, c61m6, c61m8, c61m9,
          c70m5, c70m6, c70m8, c3&70m9,
          c80m5, c80m6, c80m8, c80m9$
?
Poisson;  LHS = kept; RHS = X, loghours; RST = 74_b, 1;
          maxit =100; tlf; tlb $  Permits gradient convergence only.
?
Negbin;   LHS = kept; RHS = X, loghours; RST = 74_b, 1, a;
          Maxit = 100; tlf; tlb $
?
Matrix;   V=VARB; beta=B $
?
?  Get file for calculating predictions & asy. S.E.'s of predictions.
?
APPEND; file = c:\limdep7\glfc\latmipre.dat;  Nvar = 2;
        Nobs = 60; ? 12 counties*5 months for all.
        Names = County, Month $
?
sample; all$
Reject; fhr>-999$
?
CREATE;   C3 = county = 3; C10 = county = 10; C11 = county = 11;
          C15 = county = 15; C24 = county = 24; C28 = county = 28;
          C45 = county = 45; C51 = county = 51; C53 = county = 53;
          C61 = county = 61; C70 = county = 70; C80 = county = 80;
          may= month = 5; june = month =6; july = month = 7;
          aug= month = 8; sept = month = 9$
create;   c3m5=c3*may; c3m6=c3*june; c3m8=c3*aug;
          c3m9=c3*sept;
          c10m5=c10*may; c10m6=c10*june; c10m8=c10*aug;
          c10m9=c10*sept;
          c11m5=c11*may; c11m6=c11*june;
          c11m8=c11*aug; c11m9=c11*sept;
          c15m5=c15*may; c15m6=c15*june; c15m8=c15*aug;
          c15m9=c15*sept;
          c24m5=c24*may; c24m6=c24*june; c24m8=c24*aug;
          c24m9=c24*sept;
          c28m5=c28*may; c28m6=c28*june; c28m8=c28*aug;
          c28m9=c28*sept;
          c45m5=c45*may; c45m6=c45*june; c45m8=c45*aug;
          c45m9=c45*sept$
create;   c51m5=c51*may; c51m6=c51*june; c51m8=c51*aug;
          c51m9=c51*sept;
          c53m5=c53*may; c53m6=c53*june; c53m8=c53*aug;
          c53m9=c53*sept;
          c61m5=c61*may; c61m6=c61*june; c61m8=c61*aug;
          c61m9=c61*sept;
          c70m5=c70*may; c70m6=c70*june; c70m8=c70*aug;
          c70m9=c70*sept;
          c80m5=c80*may; c80m6=c80*june; c80m8=c80*aug;
          c80m9=c80*sept$
Create; c3&70m9 = c3m9+c70m9; c10&45m9 = c45m9+c10m9 $
```

```
?
?  Leave fhr as -999 so it can be used to "select" prediction rows.
?
Recode; CHART, ANG2, ANG3, ANG4, ANG5, TRT, SAT,
        Y86, Y87, Y88, Y89, Y90, Y91, Y92, Y93, Y95, loghours;
        -999=0 $
?
namelist;  z=x, loghours $
Create;  ratehat  = exp(Beta'Z) $
Create;  rateavar = ratehat*ratehat*Qfr(Z,V) $
Create;  ratease  = rateavar^(0.5) $
?
write;  county, month, ratehat, ratease; format=(2F3.0, 2(1x,F6.4));
        file=c:\limdep7\glfc\lat_miy.rat $
```

Appendix E

Summaries of Michigan Creel Survey Party Interview Data

Codes Used in Report:

LAT = Lake Trout
SAL = Salmon, mostly Chinook and Coho
TRT = Other Trout, mostly Rainbow and Brown

HU = Lake Huron
SU = Lake Superior
MI = Lake Michigan

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Frequencies of Creel Data are Organized as Follows:

1. Frequencies of key variables about trips for each lake
   a. Superior
   b. Michigan
   c. Huron

2. Crosstabs "Mode" and "Method" variables*
   a. Superior
   b. Michigan
   c. Huron

   * Method: the party level method is defined as trolling if any member of the party was trolling.

3. Frequencies of species caught for each lake
   a. Superior
   b. Michigan
   c. Huron

All output is based on creel survey interviews from 1986 to 1996 and are based on observations where the "fishery type" was Great Lakes proper (not Anadromous streams). The results for Lake Erie are excluded since there are virtually no cold species.

MODE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Boat	1	15598	79.3	79.3	79.3
Shore	2	2859	14.5	14.5	93.9
Charter	3	101	.5	.5	94.4
Open Ice	4	529	2.7	2.7	97.1
Shanty Ice &/or Pier	5	549	2.8	2.8	99.9
	6	26	.1	.1	100.0
		-------	-------	-------	
	Total	19662	100.0	100.0	

TROLL

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	0	6571	33.4	33.5	33.5
	1	13015	66.2	66.5	100.0
	.	76	.4	Missing	
		-------	-------	-------	
	Total	19662	100.0	100.0	

MONTH

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	3	151	.8	.8	.8
	4	3353	17.1	17.1	17.8
	5	3338	17.0	17.0	34.8
	6	3064	15.6	15.6	50.4
	7	2538	12.9	12.9	63.3
	8	2716	13.8	13.8	77.1
	9	2940	15.0	15.0	92.1
	10	1534	7.8	7.8	99.9
	11	28	.1	.1	100.0
		-------	-------	-------	
	Total	19662	100.0	100.0	

YEAR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	86	278	1.4	1.4	1.4
	87	1273	6.5	6.5	7.9
	88	1972	10.0	10.0	17.9
	89	581	3.0	3.0	20.9
	90	1364	6.9	6.9	27.8
	91	3046	15.5	15.5	43.3
	92	2535	12.9	12.9	56.2
	93	2805	14.3	14.3	70.5
	94	2788	14.2	14.2	84.6
	95	3020	15.4	15.4	100.0
		-------	-------	-------	
	Total	19662	100.0	100.0	

```
-> GET FILE='C:\GLFC\SAV\TRP_THU.SAV'.
-> FREQUENCIES VARIABLES= target tar_type angcnt county mode troll month year .
```

TARGET

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
ATL	1	126	.1	.1	.1
BKT	2	2	.0	.0	.1
BNT	3	416	.4	.4	.5
CHS	4	3913	3.5	3.5	3.9
COH	5	33	.0	.0	4.0
LHR	6	330	.3	.3	4.3
LAT	7	537	.5	.5	4.7
LWF	8	372	.3	.3	5.1
PKS	9	529	.5	.5	5.5
RBT	10	391	.3	.3	5.9
RWF	11	137	.1	.1	6.0
SPL	12	23	.0	.0	6.0
SMT	13	93	.1	.1	6.1
WAE	15	14132	12.5	12.5	18.6
YEP	16	27810	24.6	24.6	43.2
WHB	17	90	.1	.1	43.3
WHP	18	3	.0	.0	43.3
NOP	19	1371	1.2	1.2	44.5
MUS	20	6	.0	.0	44.5
BCR	22	273	.2	.2	44.8
BLG	23	35	.0	.0	44.8
LMB	25	318	.3	.3	45.1
LSF	26	1	.0	.0	45.1
OSF	27	1	.0	.0	45.1
PSF	28	14	.0	.0	45.1
RSF	29	51	.0	.0	45.1
RKB	30	114	.1	.1	45.2
SMB	31	669	.6	.6	45.8
WCR	33	123	.1	.1	45.9
BLB	34	17	.0	.0	46.0
BRB	35	24	.0	.0	46.0
CCF	36	2405	2.1	2.1	48.1
YLB	37	9	.0	.0	48.1
CAR	38	63	.1	.1	48.2
LNS	40	2	.0	.0	48.2
CWS	43	156	.1	.1	48.3
BUR	45	4	.0	.0	48.3
DRU	46	19	.0	.0	48.3
GAR	47	1	.0	.0	48.3
OTH	51	2	.0	.0	48.3
ANY	60	7380	6.5	6.5	54.9
SAL	61	22537	19.9	19.9	74.8
TRT	62	2091	1.9	1.9	76.7
SAT	63	22592	20.0	20.0	96.6
PAW	64	3794	3.4	3.4	100.0
		-------	-------	-------	
	Total	113009	100.0	100.0	

TAR_TYPE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Cold	1.00	54029	47.8	47.8	47.8
Warm	2.00	51598	45.7	45.7	93.5
Any	3.00	7382	6.5	6.5	100.0
		-------	-------	-------	
	Total	113009	100.0	100.0	

ANGCNT

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	1	23247	20.6	20.6	20.6
	2	51799	45.8	45.8	66.4
	3	23731	21.0	21.0	87.4
	4	10842	9.6	9.6	97.0
	5	2529	2.2	2.2	99.2
	6	861	.8	.8	100.0
		-------	-------	-------	
	Total	113009	100.0	100.0	

COUNTY

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Alcona	1	6115	5.4	5.4	5.4
Alpena	4	12702	11.2	11.2	16.7
Arenac	6	8892	7.9	7.9	24.5
Bay	9	10782	9.5	9.5	34.1
Chippewa	17	4606	4.1	4.1	38.2
Huron	32	20328	18.0	18.0	56.2
Iosco	35	18117	16.0	16.0	72.2
Mackinac	49	4626	4.1	4.1	76.3
Presque Isle	71	9884	8.7	8.8	85.1
Saginaw	73	561	.5	.5	85.6
St Clair	74	1075	1.0	1.0	86.5
Sanilac	76	9572	8.5	8.5	95.0
Tuscola	79	5653	5.0	5.0	100.0
	.	96	.1	Missing	
	Total	113009	100.0	100.0	

MODE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Boat	1	80744	71.4	71.4	71.4
Shore	2	19065	16.9	16.9	88.3
Charter	3	438	.4	.4	88.7
Open Ice	4	85	.1	.1	88.8
Shanty Ice &/or Pier	5	12676	11.2	11.2	100.0
	6	1	.0	.0	100.0
	Total	113009	100.0	100.0	

TROLL

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	0	55128	48.8	49.1	49.1
	1	57231	50.6	50.9	100.0
	.	650	.6	Missing	
	Total	113009	100.0	100.0	

MONTH

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	3	11	.0	.0	.0
	4	12429	11.0	11.0	11.0
	5	13655	12.1	12.1	23.1
	6	13167	11.7	11.7	34.7
	7	22876	20.2	20.2	55.0
	8	22835	20.2	20.2	75.2
	9	18865	16.7	16.7	91.9
	10	9005	8.0	8.0	99.9
	11	166	.1	.1	100.0
	Total	113009	100.0	100.0	

YEAR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	86	6448	5.7	5.7	5.7
	87	18381	16.3	16.3	22.0
	88	13449	11.9	11.9	33.9
	89	5680	5.0	5.0	38.9
	90	2102	1.9	1.9	40.8
	91	13718	12.1	12.1	52.9
	92	14035	12.4	12.4	65.3
	93	14478	12.8	12.8	78.1
	94	12429	11.0	11.0	89.1
	95	12289	10.9	10.9	100.0
	Total	113009	100.0	100.0	

```
-> GET FILE='C:\GLFC\SAV\TRP_TMI.SAV'.
-> FREQUENCIES VARIABLES=target tar_type angcnt county mode troll month year .
```

TARGET

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
BKT	2	2	.0	.0	.0
BNT	3	5230	5.1	5.1	5.1
CHS	4	3245	3.2	3.2	8.3
COH	5	913	.9	.9	9.2
LAT	7	1913	1.9	1.9	11.1
LWF	8	897	.9	.9	12.0
PKS	9	21	.0	.0	12.0
RBT	10	4923	4.8	4.8	16.8
RWF	11	799	.8	.8	17.6
SPL	12	3	.0	.0	17.6
SMT	13	6	.0	.0	17.6
WAE	15	6326	6.2	6.2	23.8
YEP	16	22218	21.8	21.8	45.7
WHB	17	7	.0	.0	45.7
WHP	18	4	.0	.0	45.7
NOP	19	389	.4	.4	46.1
BCR	22	109	.1	.1	46.2
BLG	23	86	.1	.1	46.3
LMB	25	22	.0	.0	46.3
PSF	28	4	.0	.0	46.3
RSF	29	1	.0	.0	46.3
RKB	30	35	.0	.0	46.3
SMB	31	1472	1.4	1.4	47.8
WCR	33	5	.0	.0	47.8
BLB	34	1	.0	.0	47.8
CCF	36	120	.1	.1	47.9
CAR	38	26	.0	.0	47.9
LNS	40	1	.0	.0	47.9
RHS	42	1	.0	.0	47.9
CWS	43	3	.0	.0	47.9
BUR	45	14	.0	.0	47.9
DRU	46	35	.0	.0	48.0
STR	50	1	.0	.0	48.0
ANY	60	8140	8.0	8.0	56.0
SAL	61	12145	11.9	11.9	67.9
TRT	62	6106	6.0	6.0	73.9
SAT	63	25401	25.0	25.0	98.8
PAW	64	1179	1.2	1.2	100.0
	Total	101803	100.0	100.0	

TAR_TYPE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Cold	1.00	61598	60.5	60.5	60.5
Warm	2.00	32065	31.5	31.5	92.0
Any	3.00	8140	8.0	8.0	100.0
	Total	101803	100.0	100.0	

ANGCNT

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	1	29910	29.4	29.4	29.4
	2	43928	43.2	43.2	72.5
	3	18031	17.7	17.7	90.2
	4	7475	7.3	7.3	97.6
	5	1730	1.7	1.7	99.3
	6	729	.7	.7	100.0
	Total	101803	100.0	100.0	

COUNTY

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Allegan	3	510	.5	.5	.5
Antrim	5	294	.3	.3	.8
Benzie	10	13770	13.5	13.5	14.3
Berrien	11	13470	13.2	13.2	27.5
Charlevoix	15	2827	2.8	2.8	30.3
Delta	21	10626	10.4	10.4	40.8
Emmet	24	2466	2.4	2.4	43.2
Grand Traverse	28	5189	5.1	5.1	48.3
Leelanau	45	607	.6	.6	48.9
Manistee	51	12859	12.6	12.6	61.5
Mason	53	10586	10.4	10.4	71.9
Menominee	55	5057	5.0	5.0	76.9
Muskegon	61	3995	3.9	3.9	80.8
Oceana	64	891	.9	.9	81.7
Ottawa	70	11538	11.3	11.3	93.0
Schoolcraft	77	1356	1.3	1.3	94.3
Van Buren	80	5762	5.7	5.7	100.0
		-------	-------	-------	
	Total	101803	100.0	100.0	

MODE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Boat	1	64439	63.3	63.3	63.3
Shore	2	4352	4.3	4.3	67.6
Charter	3	933	.9	.9	68.5
Open Ice	4	6	.0	.0	68.5
Shanty Ice &/or Pier	5	32073	31.5	31.5	100.0
		-------	-------	-------	
	Total	101803	100.0	100.0	

TROLL

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	0	52520	51.6	52.2	52.2
	1	48134	47.3	47.8	100.0
	.	1149	1.1	Missing	
		-------	-------	-------	
	Total	101803	100.0	100.0	

MONTH

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	3	1056	1.0	1.0	1.0
	4	12342	12.1	12.1	13.2
	5	13564	13.3	13.3	26.5
	6	13934	13.7	13.7	40.2
	7	18035	17.7	17.7	57.9
	8	18718	18.4	18.4	76.3
	9	14427	14.2	14.2	90.4
	10	8967	8.8	8.8	99.3
	11	747	.7	.7	100.0
	12	13	.0	.0	100.0
		-------	-------	-------	
	Total	101803	100.0	100.0	

YEAR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	86	8515	8.4	8.4	8.4
	87	9831	9.7	9.7	18.0
	88	9348	9.2	9.2	27.2
	89	8207	8.1	8.1	35.3
	90	8090	7.9	7.9	43.2
	91	8732	8.6	8.6	51.8
	92	10780	10.6	10.6	62.4
	93	12433	12.2	12.2	74.6
	94	13586	13.3	13.3	87.9
	95	12281	12.1	12.1	100.0
		-------	-------	-------	
	Total	101803	100.0	100.0	

```
-> GET FILE='C:\GLFC\SAV\TRP_TSU.SAV'.
-> CROSSTABS
->   /TABLES=mode  BY troll
->   /FORMAT= AVALUE NOINDEX BOX LABELS TABLES
->   /CELLS= COUNT .
```

MODE by TROLL

Page 1 of 1

MODE	Count	TROLL 0	TROLL 1	Row Total
Boat	1	2637	12894	15531 79.3
Shore	2	2832	24	2856 14.6
Charter	3	2	93	95 .5
Open Ice	4	529		529 2.7
Shanty Ice &/or	5	545	4	549 2.8
	6	26		26 .1
	Column Total	6571 33.5	13015 66.5	19586 100.0

Number of Missing Observations: 76

0.1 % of cases have troll=1 and boat=0.

```
-> GET FILE='C:\GLFC\SAV\TRP_THU.SAV'.
-> CROSSTABS  /TABLES=mode BY troll
->     /FORMAT= AVALUE NOINDEX BOX LABELS TABLES   /CELLS= COUNT .
```

MODE by TROLL

Page 1 of 1

MODE	Count	TROLL 0	TROLL 1	Row Total
Boat	1	23674	56579	80253 71.4
Shore	2	18825	139	18964 16.9
Charter	3	33	402	435 .4
Open Ice	4	83	1	84 .1
Shanty Ice &/or	5	12512	110	12622 11.2
	6	1		1 .0
Column Total		55128 49.1	57231 50.9	112359 100.0

Number of Missing Observations: 650

0.2% of cases have troll=1 and boat=0.

```
-> GET FILE='C:\GLFC\SAV\TRP_TMI.SAV'.
-> CROSSTABS  /TABLES=mode BY troll
->    /FORMAT= AVALUE NOINDEX BOX LABELS TABLES   /CELLS= COUNT .
```

```
MODE  by  TROLL

                    TROLL        Page 1 of 1
            Count |
                  |
                  |              Row
                  |     0|     1| Total
MODE      --------+------+------+
                1 | 16928| 46751| 63679
  Boat            |      |      |  63.3
                  +------+------+
                2 |  4227|    63|  4290
  Shore           |      |      |   4.3
                  +------+------+
                3 |    23|   901|   924
  Charter         |      |      |    .9
                  +------+------+
                4 |     6|      |     6
  Open Ice        |      |      |    .0
                  +------+------+
                5 | 31336|   419| 31755
  Shanty Ice &/or |      |      |  31.5
                  +------+------+
           Column   52520  48134 100654
            Total    52.2   47.8  100.0

Number of Missing Observations:  1149
```

0.5% of cases have troll=1 and boat=0. For all 3 lakes, its less than 0.5%.

```
-> GET FILE='C:\GLFC\SAV\CATSU.SAV'.
-> FREQUENCIES VARIABLES=species .
```

SUPERIOR CATCH FILE:
SPECIES

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
ATL	1	25	.2	.2	.2
BKT	2	20	.1	.1	.3
BNT	3	220	1.5	1.5	1.8
CHS	4	1162	7.8	7.8	9.6
COH	5	3657	24.6	24.6	34.3
LHR	6	10	.1	.1	34.3
LAT	7	5964	40.2	40.2	74.5
LWF	8	342	2.3	2.3	76.8
PKS	9	251	1.7	1.7	78.5
RBT	10	631	4.3	4.3	82.8
RWF	11	318	2.1	2.1	84.9
SPL	12	287	1.9	1.9	86.8
SMT	13	111	.7	.7	87.6
SAU	14	2	.0	.0	87.6
WAE	15	407	2.7	2.7	90.3
YEP	16	221	1.5	1.5	91.8
NOP	19	42	.3	.3	92.1
BLG	23	1	.0	.0	92.1
LMB	25	2	.0	.0	92.1
RSF	29	59	.4	.4	92.5
RKB	30	10	.1	.1	92.6
SMB	31	17	.1	.1	92.7
WAR	32	1053	7.1	7.1	99.8
BLB	34	3	.0	.0	99.8
CAR	38	1	.0	.0	99.8
LNS	40	3	.0	.0	99.8
QIL	41	1	.0	.0	99.9
RHS	42	3	.0	.0	99.9
CWS	43	9	.1	.1	99.9
BUR	45	9	.1	.1	100.0
STR	50	1	.0	.0	100.0
	Total	14842	100.0	100.0	

```
-> GET FILE='C:\GLFC\SAV\CAT_HU.SAV'.
-> FREQUENCIES VARIABLES=species .
```

HURON CATCH FILE:

SPECIES

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
ATL	1	71	.1	.1	.1
BKT	2	15	.0	.0	.1
BNT	3	2636	3.6	3.6	3.7
CHS	4	19175	26.3	26.3	30.0
COH	5	849	1.2	1.2	31.2
LHR	6	237	.3	.3	31.5
LAT	7	5297	7.3	7.3	38.8
LWF	8	284	.4	.4	39.2
PKS	9	1540	2.1	2.1	41.3
RBT	10	3519	4.8	4.8	46.1
RWF	11	166	.2	.2	46.3
SPL	12	16	.0	.0	46.4
SMT	13	97	.1	.1	46.5
SAU	14	3	.0	.0	46.5
WAE	15	9052	12.4	12.4	58.9
YEP	16	20325	27.9	27.9	86.8
WHB	17	697	1.0	1.0	87.7
WHP	18	194	.3	.3	88.0
NOP	19	1038	1.4	1.4	89.4
MUS	20	5	.0	.0	89.4
TMU	21	3	.0	.0	89.4
BCR	22	152	.2	.2	89.7
BLG	23	164	.2	.2	89.9
GSF	24	9	.0	.0	89.9
LMB	25	193	.3	.3	90.2
LSF	26	6	.0	.0	90.2
OSF	27	19	.0	.0	90.2
PSF	28	323	.4	.4	90.6
RSF	29	85	.1	.1	90.7
RKB	30	908	1.2	1.2	92.0
SMB	31	573	.8	.8	92.8
WCR	33	65	.1	.1	92.9
BLB	34	136	.2	.2	93.1
BRB	35	487	.7	.7	93.7
CCF	36	2877	3.9	3.9	97.7
YLB	37	113	.2	.2	97.8
CAR	38	200	.3	.3	98.1
BUF	39	1	.0	.0	98.1
LNS	40	18	.0	.0	98.1
RHS	42	24	.0	.0	98.2
CWS	43	172	.2	.2	98.4
BOW	44	26	.0	.0	98.4
BUR	45	18	.0	.0	98.5
DRU	46	1111	1.5	1.5	100.0
GAR	47	11	.0	.0	100.0
GZS	48	3	.0	.0	100.0
	97	2	.0	.0	100.0
	Total	72915	100.0	100.0	

```
-> GET FILE='C:\GLFC\SAV\CATMI.SAV'.
-> FREQUENCIES VARIABLES=species .
```

MICHIGAN CATCH FILE:
SPECIES

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
ATL	1	15	.0	.0	.0
BKT	2	69	.1	.1	.1
BNT	3	6574	9.0	9.0	9.2
CHS	4	13702	18.8	18.8	28.0
COH	5	6558	9.0	9.0	37.0
LHR	6	9	.0	.0	37.0
LAT	7	8548	11.8	11.8	48.8
LWF	8	667	.9	.9	49.7
PKS	9	82	.1	.1	49.8
RBT	10	9654	13.3	13.3	63.1
RWF	11	762	1.0	1.0	64.1
SPL	12	515	.7	.7	64.8
SMT	13	46	.1	.1	64.9
SAU	14	1	.0	.0	64.9
WAE	15	4057	5.6	5.6	70.5
YEP	16	16522	22.7	22.7	93.2
WHB	17	23	.0	.0	93.2
WHP	18	36	.0	.0	93.3
NOP	19	614	.8	.8	94.1
BCR	22	131	.2	.2	94.3
BLG	23	141	.2	.2	94.5
GSF	24	1	.0	.0	94.5
LMB	25	58	.1	.1	94.6
LSF	26	2	.0	.0	94.6
OSF	27	3	.0	.0	94.6
PSF	28	127	.2	.2	94.8
RSF	29	30	.0	.0	94.8
RKB	30	434	.6	.6	95.4
SMB	31	1694	2.3	2.3	97.7
WAR	32	1	.0	.0	97.7
WCR	33	32	.0	.0	97.8
BLB	34	35	.0	.0	97.8
BRB	35	45	.1	.1	97.9
CCF	36	674	.9	.9	98.8
YLB	37	9	.0	.0	98.8
CAR	38	92	.1	.1	98.9
BUF	39	2	.0	.0	98.9
LNS	40	7	.0	.0	99.0
QIL	41	2	.0	.0	99.0
RHS	42	46	.1	.1	99.0
CWS	43	184	.3	.3	99.3
BOW	44	12	.0	.0	99.3
BUR	45	93	.1	.1	99.4
DRU	46	404	.6	.6	100.0
GAR	47	2	.0	.0	100.0
GZS	48	3	.0	.0	100.0
STR	50	15	.0	.0	100.0
	97	1	.0	.0	100.0
	Total	72734	100.0	100.0	

Appendix F

Summary of Models with Mode and Method Variables

Summary of Models with Mode and Method Variables

The following table provides a brief summary of initial modelling results that were obtained from versions of the catch rate models that included variables for trolling and boat use. These are presented in case they may be of interest to readers. These variables were dropped from the final models so that the predicted catch rates would be more compatible with the level of detail contained in the MSU recreational demand model of Hoehn et al.

In the table there is a row for each of the nine models. Recall that there is one model for each combination of the three specie groups (LAT: lake trout, SAL: salmon, and TRT: other trout) and the three Great Lakes (SU: Superior, MI: Michigan, and HU: Huron). The first column in Table X refers to the number of cases that were used in each model, (i.e., the number of observations on the dependent variable in each model). The second column presents the number of independent variables that appeared in each of the models. The next set of columns refers to the variables for those parties that did not troll and/or did not use a boat (no troll and no boat, respectively). Recall that not trolling means that no member of the fishing party trolled. For each of the no troll and no boat variables there are three columns. The first shows the percent of the cases that took a value of one (didn't troll or didn't use a boat), the second shows the estimated parameter for the variable, and the third gives exponentiated parameter to show the variables effect on catch rates. The later is interpreted as a multiplication factor by which catch rates would be increased or decreased (increased if the value is greater than one and decreased if it is less than one -- see Table X in the main text for a similar presentaion).

Table F.1: Summary of Models with "No Troll" and "No Boat" Variables

Model	# of cases	# of vars	No troll % of cases	No troll est. par.	No troll exp. effect	No boat % of cases	No boat est. par.	No boat exp. effect
LAT								
HU	19,550	46	0.7*	-0.69	0.50	0*		
MI	18,659	77	1.5*	-0.19+	0.83	0*		
SU	8,891	56	6.7*	-0.37	0.69	0*		
SAL								
HU	49,346	74	20.5	0.34	1.40	17.4	-0.16	0.85
MI	40,405	112	26.2	-0.56	0.57	25.9	-0.24	0.79
SU	8,939	59	34.3	0.56	1.75	22.3	-0.53	0.59
TRT								
HU	25,290	76	16.5	0.49	1.63	15.4	-0.45	0.64
MI	40,025	103	36.4	-0.13+	0.88	35.9	-0.13+	0.88
SU	5,004	40	23.0	1.64	5.16	16.2	-0.45	0.64

* Model didn't include boat observations because of convergance problems when the no boat variable was used.
+ Not significant at 5% (the p-values were between 0.09 na 0.11).

Appendix G

File and Programming Inventory

Creel Party Interview Files (*.DBF)

The creel data was recieved in DBF file format. The creel survey party interview data is organized by year and by lake. There are three files for each combination of year and lake.

Trip files	(party level observations, one line per party)
Angler files	(angler level observations, one line per angler in each party)
Catch files	(species kept by party, one line for each specie kept by each party; parties without catch data did not catch fish)

These files link together through the "key" and "year" variables. Each party interview gets a unique key, but these can repeat over years of data.

There is one of each of these files for each lake for each year.

SPSS File Inventory (*.SPS)

SPSS software was used to manage initial files and investigate frequencies and other properties of the data. The following are SPSS syntax file (programs) which were created to combine and "clean" the raw data files.

TRP_DBF	translates and codes the trip files, saves as spss files
COMB_TRP	combines trp files for each lake into 3 large files.
DUP_KEY	outputs dup_key ascii files for use with fortran program for identifying and deleting duplicate keys.
ANG_DBF	translates and combines the angler files, saves as spss files.
TROLL	recodes method into troll, writes ang_meth.dat files for use with the fortran programs, and then merges new troll into trip files.

SITES codes fish sites into counties and tar_type (target type: any, cold, warm)

CAT_DBF	translates, gives raw freqs, codes the catch files, saves as spss files, and combines files, deletes rows if species = oth.
SPEC_MIX	writes specmix.dat files for fortran program, reads specmix and merges into trip files.
CATLINES	reads files "lines_??.out" from spec_mix; a count of catch lines per party.
CAT_T	Catch file with trp data merged in, lines not in catch get a zero catch, lines not in trp get deleted.

FORTRAN File Inventory

Fortran programs were written to manipulate some of the data (since SPSS lacks a convient "do loop" command).

DUP_KEY	reads key (f11) & year (f2) from DUP_KEY.DAT, and if a duplicate key exists within any year the program outputs key(f12) & year (f2) to DUP_KEY.OUT. Duplicate keys cause SPSS file merges to fail.
ANG_METH	reads key (f11), troll (f1), & year (f2) from ANG_METH.DAT; codes troll variable for each party, and outputs key(f12), troll (f1) & year (f2) to ANG_METH.OUT thereby assigning a single troll variable to each party.
SPEC_MIX	reads key (f11), spec_typ (f1), & year (f2) from SPEC_MIX.DAT; codes specmix variable for catch of each party and computes # lines per party; outputs key(f12), specmix (f1) & year (f2) to SPEC_MIX.OUT and outputs key(f12), lines (f2) & year (f2) to CATLINES.OUT.
SALMON	reads key (f11), kept (f3), & year (f2) from SALMON.DAT; adds up numbers caught for each party and outputs key (f12), kept (f3), & year (f2) from SALMON.DAT; (also used to add up "other" trout).

Limdep files: See Appendix D.

GREAT LAKES FISHERY COMMISSION

Project Completion Report[1]

The Recreational Fishing Value of Sea Lamprey Control

Part 4: A Preliminary Valuation of Lake Trout Using the Existing Michigan Recreational Angling Demand Model

by:

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July 1998

[1]Project completion reports of Commission-sponsored research are made available to the Commission's Cooperators in the interest of rapid dissemination of information that may be useful in Great Lakes fishery management, research, or administration. The reader should be aware that project completion reports have not been through a peer review process and that sponsorship of the project by the Commission does not necessarily imply that the findings or conclusions are endorsed by the Commission.

D R A F T D R A F T D R A F T

A Preliminary Valuation of Lake Trout Using the Existing Michigan Recreational Angling Demand Model

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October, 1997

Draft report submitted to the Great Lakes Fishery Commission as part of the project entitled: *The recreational fishing value of sea lamprey control.*

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A Preliminary Valuation of Lake Trout Using the Existing Michigan Recreational Angling Demand Model

Table of Contents

Chapter 1
Purpose and Overview of Report

In the Great Lakes ecosystem, the sea lamprey is a non-indigenous nuisance species that preys on lake trout. Lake trout are a native species that are often targeted by recreational anglers. The Great Lakes Fishery Commission (GLFC) is faced with the task of setting target levels for sea lamprey control. Knowledge of the benefits of lamprey control at each Great Lake would aid the GLFC in the setting of lamprey control targets. Indeed, setting the lamprey control targets in an economically optimal manner involves balancing the costs of lamprey control against the benefits of lamprey control. Similarly, following integrated pest management principles requires balancing the damages of a pest (lamprey) against the cost of treatment (lamprey control costs). In this case, the damages of lamprey are the foregone value of improved lake trout populations (in numbers and quality).

This report documents efforts to estimate some of the economic benefits of lamprey control. The difficulty with such a task is that, while the costs can be measured by program expenditures, there are no readily observable measures of the benefits of lamprey control. In particular, recreational angling for lake trout is not a market good so there is no "market price" with which to gauge the benefits of lamprey control. Never the less, the benefits of lamprey control can be inferred through various non-market valuation techniques.

One way to estimate the some of the economic value associated with recreational fishing for lake trout is to relate the demand to the quality of lake trout fishing. To economists, demand refers to the relationship between price and quantity demanded. The travel cost method is a well established technique for estimating recreational demand for non-market goods. The travel cost method recognizes that going fishing requires time and money inputs, i.e., travel costs. The travel costs are a surrogate for the price of a recreational fishing trip, and quantity is usually thought of as the number of fishing trips. When deciding where and how often to fish, anglers make choices between fishing sites with different bundles of travel cost and fishing quality. These choices are used to relate the demand for fishing to measures of fishing quality at alternative sites. Such a linkage can be used to estimate the economic value of changes in fishing quality. For example, if fishing trips are related to lake trout catch rates, then changes in lake trout catch rates will affect the quantity of fishing trips resulting in a change in economic value. Thus, lamprey control can in part be valued through its effect on lake trout catch rates.

1.1 Objectives

Researchers at MSU have developed a travel cost model of the demand for fishing in Michigan (Hoehn *et al.*) which we will refer to as the "MSU model." The purpose of this report is to document preliminary estimates of the value of lake trout using the existing MSU model. The objectives of the research reported here are as follows:

1. Develop the valuation methodology for estimating basin specific values-per-fish for lake trout caught by recreational anglers in Michigan's waters of Lakes Michigan, Huron, and Superior.

2. Apply the valuation methodology to the existing MSU recreational demand model to provide preliminary estimates of the recreational use values associated with catching lake trout.

3. Provide *direct* valuations of changes in lake trout populations in Michigan's waters of the Great Lakes (direct, as opposed to translating benefits into value-per-fish estimates).

4. Explore the sensitivity of the value estimates to alternative patterns of lake quality in order to assess the validity of approximating the recreational benefits by constant values-per-fish.

5. Provide recommendations for future valuation efforts.

The report presents results of the first stage of a research project sponsored by the GLFC. That project involves adapting the MSU demand model to the lake trout valuation task. Additional efforts are underway to update the measures of lake trout catch rates and to re-estimate the MSU demand model using the updated catch rates. If these efforts are successful, the methods developed here will be applied to the "new" MSU demand model. Thus, the development and documentation of the methods is an important input into any further valuation efforts, and these methods can be reviewed even though the valuation is not being applied to the "new" MSU demand model.

In addition, the translation of the lake trout valuation estimates into values-per-fish greatly increases the usefulness and applicability of the valuation information for fisheries management, and the value-per-fish units fit the needs of the GLFC, as will be discussed below. However, most economic models of the benefits of lake trout fishing would not yield values that are amenable to being expressed as constant "values-per-fish". The current research seeks to examine the empirical sensitivity of the value-per-fish estimates to see if they can, for practical purposes, be treated as constants. The empirical investigation of the sensitivity of these values-per-fish will provide many results that will be robust to a broad range of potential changes in the parameter estimates of the MSU model.

1.2 Policy Setting

This section briefly describes the sea lamprey and its relationship to lake trout populations in the Great Lakes. The discussion draws on GLFC literature. The lake trout valuation policies (objective 4) and value-per-fish derivations (objectives 1 and 2) are motivated by the policy issues posed by the sea lamprey.

Sea lamprey first entered the Great Lakes sometime after the 1829 completion of the Welland Canal which provided a shipping route around the Niagara Falls. Lamprey are parasites that primarily prey upon lake trout. Lake trout are cold-water fish that weigh about 10 pounds as adults but can grow as large as 50 pounds. The lake trout are indigenous to the Great Lakes and are a target of recreational anglers. After attaching to a host, the lamprey feed on body fluids, thereby scarring, weakening, and often killing the host. Each adult lamprey kills about 40 pounds of fish during its lifetime. Lamprey predation is cited as the major cause of the collapse of naturally reproducing stocks of Lake Trout during the 1950's.

Lamprey spawn in the shallows of Great Lake tributaries, and they disperse widely once they leave the streams and enter the lake. Because there is currently no cost-effective control technology for adult lamprey already in the Great Lakes, the principal control practice is application of a lampricide in the streams so as to kill larval lamprey. Ancillary methods of control consist of structures that block the migration of spawning adult lamprey and the release of sterile adult males.

The Great Lakes Fishery Commission (GLFC), established by Canada and the US in 1956, is charged with managing sea lampreys and improving fisheries resources. The GLFC formulates annual lamprey control plans for each Great Lake. The GLFC pursues a progressive management strategy that attempts to minimize the cost of achieving lamprey population targets for any given Great Lake. The GLFC has developed a expert system to estimate the effectiveness of lampricide in streams with different morphologies (Koonce and

Locci-Hernandez). The GLFC uses the system to determine the least-cost mix of control strategies to meet annual lamprey targets for the lake.

Recent research has taken this whole process a step further by developing a model for optimally setting the lamprey target populations for each lake (Koonce *et al.*). The model incorporates biological relationships between lake trout populations, lake trout stocking, and sea lamprey populations. The goal is to determine the target level of lamprey population that balances the costs of controlling lamprey against the damages caused by lamprey. The damages foregone due to lamprey control can be considered benefits.

The damages caused by lamprey are measured as the value of lake trout harvest foregone because of mortality from lamprey predation. Koonce *et al.* assign each lake trout a constant value (a value per fish). Thus, the Koonce et al. model treats the total lake trout value as a linear function of the population level. Moreover, the total value of lake trout at a specific Great Lake is independent of the level of lake trout at other Great Lakes which are potential substitute fishing sites. This will be referred to as the value-per-fish approach. Because there is little information about theses values, Koonce *et al.* assume that the value per fish is 12 dollars (US) and examine the sensitivity of the resulting target levels to various parameters in the model. Perhaps not surprisingly, they find that the target levels are very sensitive to the assumed value per fish and conclude that more research is needed into the value of lake trout.

Developing the valuation methodology and providing preliminary estimates of the value per fish for lake trout are two of the objectives of this research (objectives 1 and 2). These value-per-fish estimates will be specific to three lakes: Lake Superior, Lake Huron, and Lake Michigan. The methods and results will help improve subsequent efforts to value

Great Lakes fish (objective 5). Since non-market value estimates are limited, the results also help to fill a void in the Great Lakes information base used by resource managers.

The "direct" values of lake trout derived for objective (3) will be used to derive the values-per-fish estimates for objective (2). The lake trout values must be translated into value-per-fish units because the MSU demand model yields benefit estimates that are in "per angler" units, not "per fish" units. This research also examines the appropriateness of treating the value per fish as a constant that is independent of the stock of fish across lakes (objective 4).

1.3 A Generic Benefits Function versus Value Per Fish

This section presents a generic benefits function to structure the investigation of the value-per-fish approach. The implications of value-per-fish approach are expressed as restrictions on a more general benefits function. When evaluating changes in quality at recreation sites, such a benefit function will usually be derived from a recreational demand model. Most benefit functions derived from recreational demand models will not satisfy these restrictions. So why bother translating the lake trout valuations into values-per-fish if the theory rejects such an approach? One reason is that the using the values-per-fish for broader ranges of policies *might* closely approximate the exact measure from a demand model. Moreover, there are many advantages to being able to express the values of lake trout in per-fish units. Therefore, the extent to which these restrictions are not met is an empirical matter and is explored in Chapter 4.

What are the advantages of VPF? First, a value-per-fish unit can be used directly in the Koonce *et al.* framework for setting economically optimal target levels of lamprey. Second, the value-per-fish estimates places the value information in a familiar context for fishery management purposes, and the values are expressed in a unit in which the costs of many fisheries programs are often accounted for. Reporting the values in per-fish units results in value information that is easily understood and can be used by a wide audience of decision makers. (Moreover, the value-per-fish approach avoids the need to link all policies to catch rates and then run the policy in the MSU demand model -- a point developed in more detail in later sections of the report).

Naturally, the benefits of any lamprey control policy accrue to anglers beyond those captured within any economic model of non-market values. Since there are few recent economic studies that can be drawn upon to establish the benefits of changes in lake trout populations, any comprehensive Great lakes assessment would require some means of transferring the values to all anglers in areas affected by lamprey control policies. Thus, another advantage of the value-per-fish approach is that the estimates are easy to transfer to other jurisdictions of a basin.

Finally, the value-per-fish approach is also amenable to more sophisticated dynamic models of fishery management that might include stocking in addition to lamprey control and fishing pressure. For example, expressing nonmarket values in value-per-fish units matches an established literature on economic models for commercial fisheries where benefits are often based on a fixed market price per pound or per fish.

What restrictions are implied by the VPF approach? A value-per-fish approach such as the existing GLFC model implies that the benefits to anglers of lake trout catch at lake i can be written as

$$B_i = VPF_i \times H_i, \tag{1.1}$$

where B_i is the benefits function at lake i, VPF_i is the value per fish at lake i, and H_i represents harvest at lake i. Total benefits across lakes would be given by the sum of the B_i's. This type of benefits function will be referred to as the "VPF approach."

A more general formulation of the benefits function would have the following properties,

$$
\begin{aligned}
&B = B(q_1,\ldots,q_J) \\
&\partial B/\partial q_i>0 \text{ for all } i \quad \text{and} \\
&\partial^2 B/\partial q_j \partial q_i \neq 0 \text{ for all } i,j.
\end{aligned}
\tag{1.2}
$$

where q_i refers to quality at lake i. The general function in (2) does not have the linearity embodied in the VPF approach in (1). The VPF approach is a special case of the general benefits function with the following restrictions:

$$
\begin{aligned}
&B(q_1,\ldots,q_J)= \textstyle\sum_i B(q_i); \\
&\partial B/\partial q_i = VPF_i\,; \\
&\partial B/\partial q_j=0; \text{ and} \\
&\partial^2 B/\partial q_i^2=0.
\end{aligned}
\tag{1.3}
$$

Here q_i is taken to be fish for purposes of structuring the VPF approach. Throughout this report, q_i will denote quality at site i and will often be referred to interchangeably as *fishing quality*, *site quality*, and *catch rate*. While the VPF approach does not yield a benefit function with the general properties in (2), it might closely approximate the more general function.

The implications and appropriateness of the VPF approach can be addressed in two separate questions.

VPF Question 1 (Linearity): *Are the benefits of quality changes at site i independent of the baseline level of quality at site **i** ("own" site)?*

The standard textbook formulation of an environmental benefits function usually specifies benefits as an increasing function of quality, but at a rate that is decreasing. Thus, when initial quality is low, the value of an increment in quality is greater than the value of the same increment from a higher initial level of quality. The VPF approach implies that all changes in catch rate are equally valuable regardless of the existing level of quality. Another implication of the VPF approach is that when the benefits function is linear in quality, marginal benefits are constant and equal to average benefits. (Lupi has shown that many common non-market valuation models yield benefit functions that do not have the textbook shape.) The linearity question will often be referred to as independence from *own* site quality levels, with the term *own* referring to the initial level of quality at the same site where quality is hypothesized to change.

VPF Question 2 (Separability): *Are the benefits of quality changes at site i independent of the baseline level of quality at sites **j** ("other" sites)?*

This question seeks to determine if the benefits function is separable so that $B = \mathbf{\Sigma}_i B_i$ where i indexes each of the Great Lakes. As it will be made clear in the later sections, demand for recreation sites will typically depend on the quality of substitute sites. Thus, the answer to this question is almost certainly no. The relevant point then becomes one of determining the sensitivity of the benefit measure for site i (e.g., VPF_i) to changes in quality at site j. The separability question will be sometimes be referred to as independence from *other* site quality levels, with the term *other* referring to the initial level of quality at substitute sites where quality is not hypothesized to change.

Value estimates from models such as the existing MSU valuation model are not independent of one another. The values are *relative* to the quality of substitute fishing opportunities that are in the model. The fact that theoretically appropriate values depend on substitute fishing opportunities is why it is important for travel cost models to include all relevant substitute fishing sites. Thus, the formulas for calculating value from such models cannot be expressed as in equations (1.1 or 1.3). For example, the values of recreational catch for any one basin will depend on the catch rates at other basins. Accounting for the interdependence of these values is an important step in performing theoretically valid valuation of multidimensional policies (Hoehn). In particular, when quality changes at many sites, the entire array of quality should be valued jointly. Such joint valuation is more complex than simply adding together separate values for changes at each lake. For example, suppose a value of fish estimate for one lake is used to set new target levels of sea lamprey control at that Great Lake. If the new target results in a substantially different catch rate for that Great Lake, then the value of fish estimates for the other Great Lakes will no longer be theoretically correct. The practical significance of such an effect is an empirical question that is closely related to VPF question 2. The question is germane because it is much easier for valuation and for management purposes to ignore the interdependencies involved in joint valuations of multidimensional changes in quality.

Answering the two VPF questions is one of the objectives of this research (objective 4). Empirical results of this inquiry are the subject of Chapter 4. Chapter 2 describes recreational demand models, and, in a general fashion, discusses the benefits function that can be derived from such models. The resulting benefits function will not satisfy the linearity and separability restrictions, but the extent to which it could be approximated by a VPF approach is an empirical question. Chapter 3 presents key details of the MSU model. In

Chapter 4, VPF estimates will be derived from the model described in Chapter 3, and these VPF estimates will then be examined under a variety of assumptions regarding the baseline level of quality at *own* and *other* substitute sites. The sensitivity of the VPF estimates will provide the empirical answers to VPF questions 1 and 2.

1.4 The MSU Model

The MSU model of the recreational demand for fishing in Michigan will be used to preform the lake trout valuations. The MSU model is the outcome of a team effort that included the authors (Hoehn *et al.*). The initial MSU model development was funded by the Michigan Department of Natural Resources and Michigan Department of Environmental Quality. The MSU model uses the travel cost method (TCM) to relate the demand for fishing to measures of fishing quality at various sites throughout the state. Because demand for fishing is related to site quality, the model is capable of predicting changes in demand associated with changes in fishing quality at any or all sites in the model. The demand model can also be used to determine the economic value of changes in fishing quality.

The type of TCM employed by the MSU team is referred to as a random utility model (RUM). RUMs explain the choice of a fishing site and relate this choice to the price and quality of alternative fishing sites. Through this linkage RUMs can be used to value changes in site quality. RUM approaches are considered the state-of-the-art methods for travel cost estimation of recreational demand when there are numerous substitute sites. The basic RUM choice model posits that on any occasion, anglers choose a fishing site from a set of alternative fishing sites. Since possible fishing destinations differ in their travel costs and quality, anglers must make a trade-off between travel costs (money) and site quality. The approach assumes that anglers pick the site that they consider to be best. Observations of angler's choices reveal their relative preference for site quality and money, i.e., the anglers' willingness to trade money for site quality.

The basic RUM model describes site choice. By repeating the site choice model over the course of a season, the model can explain complex site choices as well as total seasonal demand for fishing. In a *repeated* RUM such as the MSU model, the season is divided into a series of choice occasions. In each choice occasion, anglers decide whether to take a trip, and if they are taking a trip, they must decide where to fish.

In the RUM approach, researchers acknowledge that they can not measure all of the factors that are relevant to individual anglers when they make their choices. To handle this, error terms are introduced into the model, and the model becomes a statistical model. By combining actual data on anglers' choice of fishing site with the costs and quality of all alternative sites, the parameters of the statistical model can be estimated. The type of statistical specification used for the MSU model is referred to as a repeated nested logit model. The MSU model contains four levels of nesting and is estimated by full information maximum likelihood estimation. There are about 80 estimated parameters in the model.

The behavioral data describing where and how often anglers go fishing in Michigan was collected in an extensive panel survey. The survey was a telephone panel study which followed over 2000 anglers during the course of the 1994-95 fishing year. Computer assisted telephone interviewing was used to streamline interviews and improve response accuracy. Techniques to ensure response accuracy included a large pilot survey, fishing logs as memory aides, bounded recall to avoid double counting of trips across panel interviews, and providing multiple opportunities to revise trip counts. To balance the need to collect timely and accurate data against the burden of the interviews, frequent anglers were called more often than infrequent anglers -- panel interview frequencies ranged from eight interviews for the most avid anglers to three interviews for the least avid anglers.

In the MSU repeated RUM, trips are differentiated by trip durations (single versus multiple day trips), by water body fished at (Great Lakes, inland lakes, rivers/streams), and by species targeted ("warm" species such as bass, perch and walleye, versus "cold" species such as salmon and trout). In all, the MSU model contains over 850 distinct fishing opportunities in each choice occasion, and this set of opportunities is available for over 60 choice occasions for each sampled angler in the model.

For the Great Lakes, destination sites are defined by the stretch of Great Lake shoreline within a county. There are 41 Great Lake counties in each of two Great Lakes product lines, Great Lake warm and Great Lake cold. Great Lake warm refers to fishing trips targeting warm water species such as bass, walleye, and perch. Great Lake cold refers to trips that target trout and salmon. Within the Great Lake cold branch of the MSU model, sites are described by the catch rates for each of the following species: coho salmon, chinook salmon, lake trout, and rainbow trout. These catch rates are specific to each county and vary on a monthly basis over the open water season (April to October). These salmonid catch rates are based on an analysis of the Michigan creel survey party interview data and were used in earlier travel cost models for Michigan (Jones and Sung). The catch rate data used by Jones and Sung is from the mid to late 1980's. However, the MSU model is based on angler survey data collected in 1994.

Currently, research is underway to update and re-estimate the salmonid catch rates. Updating the catch rates will eliminate the mismatch between the dates of the angler behavior data and the catch rate data. The MSU model will then be re-estimated using the updated catch rates. Re-estimating the model will result in changes in the parameter estimates reported in Hoehn *et al.* The research reported here is "preliminary" in that it is based on the existing version of the MSU demand model that uses the same catch rate data as used in Jones and Sung, and in Hoehn *et al.*

1.5 Basin Specific Average Values Per Fish

To meet objectives (1) and (2), the results from the MSU model will be used to estimate average values per fish (AVPF) for lake trout at each of Michigan's Great Lakes. The goal was to derive value-per-fish estimates that are suitable for use in the existing sea lamprey control framework of Koonce *et al.* One method of calculating AVPF is to divide an estimate of the total recreational value of lake trout by an estimate of total recreational harvest of lake trout for each of Michigan's Great Lakes. An advantage of this approach is that it does not depend on knowledge of the biological relationship between lake trout catch rates and populations. Here we briefly describe the method used to calculate total catch and total value in order to derive basin-specific AVPF. The approach is described in detail in section 4.1 of chapter 4.

The MSU survey included questions about where anglers went on each trip, what they fished for on each trip, and how many hours they fished at each site. This information on can be used to calculate hours of fishing effort for lake trout by panel angler n at site j of Great Lake i during month m, E_{nijm}. This estimate of effort is is then multiplied by the creel survey estimate of lake trout catch rate at site j of Great Lake i during month m, (R_{ijm}) to estimate harvest (C_{nijm}). The result, $E_{nijm} \times R_{ijm} = C_{nijm}$ is then an estimate of panel angler n's catch (harvest) of lake trout at site j of Great Lake i during month m. Using the panel survey sample weights, the weighted average of the C_{nijm} over all anglers is calculated and multiplied by the estimated population of potential anglers (also from the panel survey data) to derive statewide estimates of the total catch at site j of Great Lake i during month m, C_{ijm}. We can then sum this over the months and over the j sites at i to derive an estimate of the total catch at Great Lake i.

The second basic step in estimating AVPF involves using the MSU model to estimate the total recreational value of lake trout for each Great Lake; call this value V_i. V_i is calculated by reducing the lake trout catch rates to zero for each site within Great Lake *i*. The MSU model is used to value this elimination of lake trout at Great Lake *i*. Catch rates for other species and for lake trout at other Great Lakes are held constant at their current levels when calculating V_i. Finally, the estimated V_i and C_i are used to derive the average value per fish for each Great Lake by dividing total value by total catch, i.e., $AVPF_i = V_i/C_i$. A key step in this approach is to define angler effort per trip in a manner that is consistent with the definition of the catch rates. As will be seen in the results, this estimate of AVPF depends directly on assumptions regarding how to derive angler effort per trip from the MSU survey.

1.6 Organization of Chapters

Chapter 2 provides a brief review of the type of travel cost model used in this research. The chapter is directed at readers who are not economists. The chapter begins with a brief discussion of what economists mean by "economic value." The basic concepts of the travel cost method are then discussed, as are the types of values that can be measured by the travel cost method. The next section presents the basic random utility model (RUM) of recreational site choice which is the basis for the MSU model. The aim of the presentation is to separate the statistical methodology of the model from the basic intuition underlying the discrete choices. These initial sections of Chapter 2 are based on material presented in the first three chapters of the Hoehn *et al.* report. In order to address the VPF questions, the final sections of Chapter 2 review the properties and shape of the RUM benefit measure. These properties will affect the degree to which the VPF estimates can be treated as constants.

Chapter 3 then presents the details of the MSU random utility model and its estimated parameters. Chapter 3 summarizes the key parts of the description of the MSU model that are found in Chapter 4 and the Appendices of the Hoehn *et al.* report, and it follows the presentation found in Lupi.

Chapter 4 describes the methodology used in the present study to derive estimates of the value of lake trout. It draws on the results initially presented in Lupi. It begins by explaining how the repeated RUM benefits function is used to derive estimates of the value per fish for lake trout from Lake Superior, from Lake Huron, and from Lake Michigan. To do so, the recreational demand model is used to estimate harvest at each lake, H_i in equation (1). The total benefits of lake trout at each lake can are then divided by H_i to estimate *average* VPF for each lake. The sensitivity of the resulting average values-per-fish to alternative estimates of total harvest is also examined in Chapter 4.

Chapter 4 precedes by examining the extent to which the value estimates can be treated *as if* they are independent of stocks at their own lake and at substitute lakes (objective 4; VPF questions 1 and 2). The chapter also presents valuation estimates for hypothetical changes in lake trout populations that are directly derived from the valuation model rather than being translated into values per fish (objective 3). Chapter 4 also presents the results of a query into an alternative method of translating the results into dollar values (discussed further below). Finally, Chapter 4 ends by presenting the results of a few scenarios that are more extreme than the lake trout valuation scenarios. Specifically, valuations resulting in decreases in all Great Lake trout and salmon are presented along with an estimate of the total surplus use-value of the trout and salmon fishery in the Great Lakes.

1.7 Overview of Results

Technical results of VPF questions: Recall that objective (4) is to explore the sensitivity of the VPF estimates to alternative reference levels of quality in order t assess the validity of translating the benefit estimates into "per fish" units. In section 1.3, this objective was expressed in the form of two questions: can the benefits be treated as if they are linear in "own" site quality (VPF question 1) and can the benefits be treated as if they are independent of "other" site quality (VPF question 2)? While these are technical questions that might seem to be of interest only to economists, the answers affect how the fish value information can and should be used for fisheries management purposes.

The empirical examination of the VPF questions posed above did not lend support to the VPF approach because the the degree of non-linearity was judged to be high. That is, the amount of non-linearity did not lend support to treating the values "as if" they were independent of the level of *own* site quality (not supporting VPF question 1). In particular, the value of an increment improvement in quality was in some cases over twice the value of an equivalent decrease in quality. Alternatively, the sensitivity results did support treating the values for any site "as if" they were independent of *other* site quality (supporting VPF question 2). Thus, the striking empirical result was that the degree of nonlinearity was high, yet the values for any site exhibited minimal dependence on the reference level of quality at substitute sites.

The insensitivity of the welfare measures bears on the appropriateness of conducting independent valuations. The total values for joint policies were remarkably well approximated by the sum of independent valuations (this is defined and discussed in detail in section 2.4 and 4.4). Importantly, the implication is that the Great Lakes could be valued independently, and these values could then be used for management purposes without worry over how they might be affected by the possibly changing reference levels of quality at substitute lakes. Taken at face value, this result seems to contradict the importance of including substitute sites in recreational demand models.

While interesting, the "near independence" of the Great Lake values should not be taken as evidence that the effects of changes in reference levels of quality at substitute sites are *always* negligible in travel cost models, nor should the results be interpreted to mean that one need not use multiple site travel cost models. In fact, the results are driven by the large amounts of substitution in the model and the limited opportunities to substitute across lakes. Therefore, the main qualification to the independence results is that they hold for the Great Lake polices examined here. The spatial separation of the Great Lakes in question inhibit substitution across Great Lakes for day trips for the bulk of Michigan anglers. Additionally, the policies examined were lakewide in scope, so each Great Lake is actually a collection of sites rather than an individual site. Moreover, the RUM used for the policy evaluations has an *extremely* large number of substitute fishing sites and activities. Since day-trip sites in the model were "almost" IIA (a property discussed in Chapters 2 and 3), the large number of substitute sites across the nests of the model were, *ceteris paribus*, nearly as good substitutes as the "other" Great Lakes where quality was being changed. Consequently, the separability results only apply to the valuations of lakewide policies on the Great Lakes; they are not expected to apply to individual sites located in close proximity to one another.

Fish values: The method used to derive the average VPF estimates is shown in Chapter 4 to be *very* sensitive to various plausible assumptions regarding how to estimate harvest at each lake. The alternative assumptions differ in their treatment of the fishing effort of those targeting various species and groups of species as well as those not targeting at all. Because of uncertainties regarding the appropriate treatment of the different types of targeting, the current translation of the value estimates into average values per fish is deemed to be too unreliable for policy purposes.

In contrast, the direct value estimates reveal some more robust policy implications. The direct values are the estimates derived from the model prior to being translated into values per fish. In particular, the relative values across lakes reveal that marginal changes in lake trout populations are most valuable at Lake Michigan followed by Lakes Huron and Superior, respectively. This is a direct reflection of the distribution of trips across these lakes. While the actual dollar amounts of the direct and marginal values are sensitive to changes in the parameter estimates, the patterns of value ought to be fairly robust to changes in the MSU model specification. Thus, these value results are more robust than the average VPF results.

MSU model: In the process of working with the Michigan repeated RUM, several potential limitations were identified. For example, some deficiencies in the existing models treatment of Great Lake trout and salmon sites were uncovered. In the existing MSU model, Great Lakes counties bordering Lakes Erie and St. Clair are included as feasible fishing sites for Great Lake trout and salmon fishing. Even though these sites were assigned catch rates of zero, the model predicted a large share of Great Lake trout and salmon trips to these sites (due to the importance of travel distance and the proximity of these sites to a large number of anglers). Thus, the current model under-predicts trips to Lakes Superior, Huron, and Michigan which leads to under-estimates of value for changes in lake trout at these lakes. Other examples are identified in Chapter 5, along with potential solutions to these limitations.

Chapter 5 also summarizes other lessons learned in this research which may aid any future valuation efforts aimed at Great Lakes fish.

Before proceeding, we note that it would be naive to take the values presented here as the final word on the value of lamprey control in the Great Lakes. For one, the values only apply to Michigan residents, yet the benefits of lamprey control spill over to other jurisdictions. In addition, without viable lake trout stocks to prey upon, the lamprey would increase predation on more valuable recreational and commercial species. Further, the valuation results presented here only measure use values. Thus, any non-use values related to the existence of native fish populations or negative non-use values relating to the existence of non-indigenous nuisance species are not measured. Moreover, the use values measured here only capture quantity effects (number of fish caught per hour), and do not capture qualitative effects such as the health of the fish (their fight) or the aesthetics of the fish (scarring or presence of attached lamprey). Finally, the use-values presented here are based on the existing MSU model and will change if the underlying data for catch rates for trout and salmon are altered to be more reflective of 1994 conditions.

Chapter 2
Economic Values and Travel Cost Methods

This chapter of the report provides a brief overview of the economic concept of value that the MSU model seeks to measure. There is a widespread conception that the value of something in the economic sense is *necessarily* related to a market price. While value in general terminology has many meanings, in mainstream economics value is precisely defined, and this definition need have nothing to do with market prices. The basic concept of economic value is broader than the concept of a market, and admits a wider array of measurement techniques than use of market prices. Non-market valuation techniques allow the valuation of goods not traded on markets, such as recreation experiences and environmental quality. Non-market measurement methods for values generated by recreational experiences are described in this section, as are methods for determining the impact of environmental quality changes on recreational values.

2.1 The Concept of Economic Value

Value theory begins by examining a person in a situation where he or she must make a choice and the choice involves a trade-off, i.e., where something must be given up to obtain something else. The logic of value theory can be applied to any object of choice. Objects of choice can be familiar market goods, like shoes, or more complex goods, like school desegregation plans or ecosystems. What matters is that people consider their options systematically, and choose the option they prefer. If one object is chosen over another by a rational individual weighing his or her options carefully, it means that the chosen object is at least as good (at least as *valuable* to the person) as what was given up. The value of the chosen object can then be denominated in terms of the object given up. If what is given up is money, then the value is measured in money terms. But the denomination need not be monetary; measurement in some other unit of account makes the value obtained no less "economic." What matters for calling a value "economic" is that carefully considered trade-offs are being made by rational individuals.

2.1.1 Money Measures of Value

If a trade is denominated in money, the unit of account represents a general group of other, unnamed goods. Money on its own holds no intrinsic value; willingness to give up (or get) money in an exchange situation represents the willingness to forego (or obtain) the other goods one would purchase with money. Which goods these would be depends on the person involved. What matters is the extra well-being the person can obtain with a little more money, called the marginal utility of income.

The existence of an organized market for a good provides one context for making trades; it allows people chances to make choices and for analysts to observe them. In a market economy (as opposed to one using barter) observed trades are denominated in money. If a person is observed to pay $100 for a pair of shoes, then one knows that the person is willing to give up $100 for the shoes. The $100 represents the consumer's the ability to buy a collection of alternative goods. The opportunity to use the $100 in an alternative manner is traded for the shoes, so the shoes must be worth *at least* $100 to that person. But the $100 price for the shoes is only a lower bound for value since the person might be willing to pay much more. The market here provides a convenient forum for observing choices and allows some information about values to be inferred.

There are several relevant points to make regarding the economic theory of value. First, the theory of value is specified at an *individual* level. There may be as many values for a good as there are people valuing it. To define some sort of "social" value requires some method of aggregating individual values. There is no one "correct" way to do this, and hence no "correct" social value of something. In benefit-cost type studies, it is common to aggregate values across people as a simple sum. This is the approach taken in the MSU model.

Second, there are no restrictions placed on *why* someone values a good. Economic values are anthropocentric notions based on situations of rational choice. Third, the actual mechanism of choice can vary. For example, choices might take place in a market, or they might be a negotiated through an explicit or implicit contract, or they might take place in a public referendum.

Fourth, items that can be valued are broad, not just final consumption goods. Thus, an object may have value because it produces something else of value. In this way, ecosystems and their elements might generate value either directly (e.g., pleasure from canoeing in wetlands), or because they, like a machine, generate something else that is valued directly (e.g., wetlands that are valued only for their provision of flood control).

Fifth, values are not fixed and context-independent. Value will depend on the circumstances of the trade presented to an individual. To decipher economic value, the economist ideally will know all the attributes and circumstances of the trade-offs to be made: the (perceived) characteristics of the object of choice, the good to be traded, the mechanism of the trade, and the and consequences of the trade. When the analyst is unaware of some of the characteristics of the choice situation, he or she must make assumptions about them. That, of course, is part of the challenge of the valuation task.

2.1.2 Willingness to Pay and Willingness to Accept

There basically are two ways that choice situations arise: one in which people give up something to obtain an object of choice (i.e., they pay for it) and one where they receive compensation in return for giving up an object of choice (i.e., they sell it). Which side of the transaction individuals find themselves on depends on the assignment of rights to the choice object. In the first case they do not have an assigned right to the good, and they must pay to obtain it. In the second case they have an assigned right to the good, and they must be compensated for giving it up.

The two alternative rights systems give rise to two concepts of value: willingness to pay (WTP) and willingness to accept compensation (WTA). The former, of course, is constrained by what one brings to the trade (e.g., income) as well as ones' tastes, while the latter is not constrained by individuals' incomes. Hence, WTP and WTA are expected to differ, and the amount to which they diverge can be large. The divergence between WTP and WTA depends upon (among other things) the ability to find a substitute for the object you give up among the things you can get when you sell it (Hanemann 1993). If the object is a unique natural resource with few good substitutes among goods you can buy with money, then its selling price will be high, while its purchase price will be substantially lower.

The valuation research problem is to determine the smallest amount of compensation an individual would require to sell a good, or the largest payment they would make to acquire it. A very simple model can be used to illustrate the concepts. Suppose for the sake of argument that the ability to achieve a level of economic well-being by an individual depends on three things: the amount of income they have, Y, the prices of market goods they face, P, and the level of an index of environmental quality, Q. Under baseline conditions, the index of environmental quality is at level Q^0, and the baseline level of well-being (called utility) is

V, and this can be written as $V(P,Y,Q^0)$.[1] Now, suppose that a management action reduces the index of environmental quality to a lower level, $Q^1 < Q^0$. Then, the individual's well-being falls to the level

$$V(P,Y,Q^1) < V(P,Y,Q^0) \tag{2.1}$$

That is, in (2.1), the individual is worse off (has a lower utility) with the management action than without it.

Willingness to pay in dollars is the amount of money that could be paid, ex-ante, to avoid the policy. It is an amount of income, WTP$, that could be given up by the person and leave them no worse off than they would be if the management action had occurred. Thus, WTP$ is defined by the equation

$$V(P,Y,Q^1) = V(P,Y - WTP\$,Q^0) \tag{2.2}$$

Reducing income by the amount WTP$ and maintaining the baseline level of environmental quality leaves the person just as well off as if the policy had occurred, but they retained their income.

Willingness to accept compensation in dollars is given by an amount of income, WTA$, which, if given to the person after the policy, would restore them to the level of well-being they would have achieved had the policy never occurred. Thus, WTA$ is defined by

$$V(P,Y + WTA\$,Q^1) = V(P,Y,Q^0) \tag{2.3}$$

Because WTP and WTA are measures of the effects that a policy has on an individual's well-being, WTP and WTA are referred to as welfare measures.

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[1] This notation V(x,y) can be read "V depends on the level of the variables x and y."

As discussed above, WTP$ does not generally equal WTA$. One circumstance in which these alternative measures of value are equal is when the extra well-being that can be obtained from having more income (the marginal utility if income) is a constant amount independent of the initial amount of income. In this case, the utility function can be written as

$$V(P,Y,Q) = \beta Y + f(P,Q), \tag{2.4}$$

where β is some fixed number (the marginal utility of income) and f(P,Q) is a function showing how well-being depends on prices and environmental quality. In the MSU model, it is assumed that a form such as (2.4) holds, and therefore WTP equals WTA in the model.

2.1.3 Recreational Use and Passive Use Values

There is nothing in value theory that restricts an individual's motivations for valuing a good. Thus, an individual may value a good even if he or she does not expect to use it directly. For example, an individual might be willing to pay to protect an endangered specie, irrespective of their intentions to ever view the specie. Accordingly, values have been classified into two broad groups: direct use values and passive (also called existence or nonuse) values. For the former, one potentially can observe behavioral choices related to use of the good. For the latter, the analyst can not observe choices related to the use of the good. However, the analyst can construct a choice situation to observe trade-offs that reveal passive values.

The notion of direct use has a history of being narrowly associated with on-site recreation activities, typically associated with "user days" of an activity such as birdwatching, fishing, or hiking. In fact, many direct uses will not be so closely related to on-site recreation. Individuals may have a number of contacts with the resource base that would be direct use, yet such contacts would not measured by on-site recreation value. For example, someone who lives near a river and crosses it as part of general travel is engaged in a direct use relationship with the resource. This activity will not be counted as user days of recreation, the value of which can be measured using a travel cost type model.

In the case of sea lamprey in the Great Lakes ecosystem, it may be that some individuals who do not fish in the Great Lakes would be willing to pay to control lamprey simply because the lamprey is a nonindigenous species. That is, the mere existence of exotics in the Great Lakes ecosysytem may be a negative sorce of value for some. Similarly, since lake trout are an indigenous species in the Great Lakes, there may be individuals who value healthy stocks of natuarally reproducing lake trout. In this sense, there may be people who hold existence values for naturally reproducing stocks of indigenous species such as lake trout and negative existince values for non-indigenous species such as lamprey.

This project focuses only on the direct *use* values for recreational angling, measured in dollars. Hence, it must be stressed that the model is intended to capture only a small portion of the values that people might attach to natural resources and environmental change.

2.2 Measurement of Value

There basically are two sets of ways to measure WTP or WTA. In the first, known as *indirect* or *revealed preference* methods, the analyst observes individuals' choices. The analyst then makes some assumptions about the context of that choice, and infers a value from a model of choice. In the second, known as *direct* methods, the analyst constructs a choice situation of known (to the analyst) design, places people in this choice situation, and observes either a choice (as in an experiment) or a statement about what choice would be made. Direct methods can be used to value either direct or passive use values, while indirect methods can only be used to value direct use losses.

To value recreational angling opportunities, this project uses a type of indirect valuation approach known as a travel cost model. Where and how often people go fishing is observed and used to infer the value to them of alternative fishing opportunities. The travel cost approach is very closely associated with the process of valuing goods that are traded on markets. The goal is to use market-like transactions to estimate either the WTP or WTA concept of value. The measurement concept is called consumer surplus because it refers to the "surplus" value that accrues to an individuals, i.e., total willingness to pay *net* of what has to be paid. Consumer surplus is an appropriate measure of value for any good for which a demand curve can be estimated.[2] In the next section, the measurement of consumer surplus is illustrated in the recreation context using a travel cost model.

2.2.1 The Travel Cost Method

The travel cost method is a way of deriving the demand curve for recreational use of a natural resource, such as fishing at a particular site. A demand curve is a relationship between the price of a good and the quantity of the good purchased. In economics, it is generally assumed that the first unit of a good is more highly valued than the n^{th} unit of the good. This concept is referred to as diminishing marginal utility. As a result, the demand curve will be downward sloping; that is, as the price of a good goes up, all else constant, the

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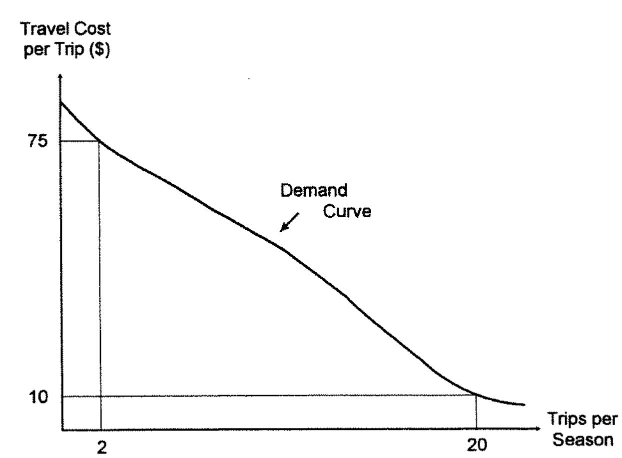
[2] Here, the term consumer surplus is used in a generalized sense to refer to the exact measures of welfare change defined earlier, WTP or WTA. Necessary conditions for the consumer surplus to be an exact measure welfare can be found in Freeman.

quantity purchased will fall. The travel cost method seeks to derive the demand curve by using travel costs as a proxy for the price of recreation.

To make this concrete, suppose that the good is fishing trips to Clear Lake. For this case, the quantity consumed is the number of visits to Clear Lake over some period of time, such as a summer. There is no market, and hence no market price, for fishing trips. However, the costs associated with travel to and from Clear Lake *function* as the price for Clear Lake since an individual must decide whether to incur travel and other access costs, when deciding whether to make a visit to Clear Lake. The costs include the costs of travel (gasoline, lodging, and time) as well as any costs of gaining access to the lake (parking fees, launch fees, etc.).

An example of a demand curve is illustrated in Figure 2.1. On the vertical axis is the cost of taking a trip, and on the horizontal axis is the number of trips taken. The demand curve shows the expected relationship of declining number of visits as travel costs increase. The exact position and shape of the demand curve will depend on a number of factors, including the person's tastes for lake recreation, income, the quality of the lake recreation site, including water quality, and the location of (and hence travel costs to) and quality of alternative, substitute lakes to visit.

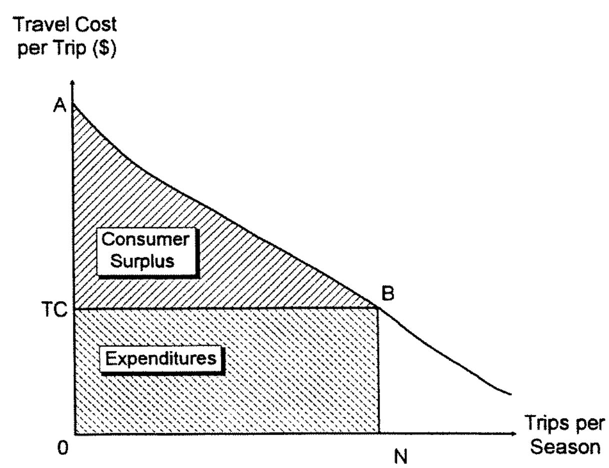
Figure 2.1: Travel Cost Demand Curve



For the Clear Lake example, the first fishing trip to Clear Lake is highly valued; the person is willing to pay quite a lot in travel costs for this first visit. However, their willingness to pay in travel costs per visit for the twentieth visit will be lower than it is for the first visit. This relationship is embodied in the downward sloping demand curve. Consequently, if the person's travel cost to the lake is very high, say a two hour drive costing $75, the person will make few visits to this lake, perhaps only twice per summer. If the travel distance is short, say a fifteen-minute drive costing $10, the person will go relatively frequently, perhaps twenty times over a summer. This is shown in Figure 2.1.

The essence of the travel cost method is to determine statistically the relationship between price (travel cost) and quantity (number of visits) to the site. In applying the travel cost model to fishing, the travel cost method is used to value the fishing experience *at a specific site*, not fishing in general.

Figure 2.2: Consumer Surplus



The travel cost demand curve for trips does double duty: it shows how many trips to the site will be taken at a given price, and, importantly, it also shows the amount this person is just willing to pay to take a certain number of trips per season to the site. By adding values for all the trips taken to the site, the total willingness to pay for trips to the site is obtained. In Figure 2.2, a demand curve is shown. When the travel cost is TC, N trips are take to the site. The total willingness to pay for the N trips is the area OABN (all the shaded areas in the figure). The amount actually spent on travel is the price per trip times the number of trips, or $TC × N (the area OTCBN labeled "expenditures").

Consumer surplus is the excess of total willingness to pay, over and above the amount that actually was paid. This is the cross-hatched area TCAB. If Clear Lake was closed for the season, the loss of economic well-being (economic value or economic welfare) for this person is measured by the consumer surplus.

When employing the travel cost method to derive a demand curve, it is important to take into account the availability of substitute fishing sites. If there are many good substitute lakes for Clear Lake, then a small increment in travel cost to Clear Lake will result in many fewer trips being taken there. In this case the demand curve will be relatively flat and little consumer surplus will be generated. Alternatively, if Clear Lake is relatively unique, an increment to access costs will have relatively little impact on visitation. In this instance, the demand curve will be relatively steep and a great deal of consumer surplus will exist. Therefore, to properly account for substitution possibilities, a model for any one site really must be a model of choice among a variety of angling experiences at alternative destinations. Such a model is described in section 2.3.

2.2.2 Economic Benefits Versus Economic Impacts

The measure of loss in economic benefits from closing Clear Lake for the season is the consumer surplus. To calculate this loss of benefits, the total amount spent traveling to the lake (OTCBN in Figure 2.2) is deducted from the total value of the lake (OABN) because when the lake is closed no travel takes place and the money otherwise spent on travel is available to purchase other goods. The money lost in travel expenditures is transferred elsewhere in the economy, and does not represent an overall loss of value. The consumer surplus (the remaining area TCAB) represents the value to this person of being able to go to Clear Lake as many times as desired at the travel price TC. The economic benefits (losses) that are appropriate for measuring use values, WTA and WTP, are measured by consumer surplus.

Often, attention is devoted to the economic *impacts* of a change in policy or management (e.g., changes in jobs and income in local economies). The economic impacts are related to the expenditure portion of Figure 2.2, represented by changes in the area OTCBN. While these impacts may be of interest for some policy and planning purposes, they are not measures of economic value. Value estimates are based on changes in consumer surplus, not in measures of economic impacts.[3]

Another point about economic benefits relates to benefit-cost analysis. Benefit-cost analysis consists of comparing the benefits of a policy or program to its costs. As mentioned above, the benefits of a policy which introduces a new recreation site are given by the consumer surplus for that site, not the expenditures or economic impacts. However, many policies of interest will involve changes in the consumer surplus of existing sites rather than creation or elimination of sites. For example, policy actions are unlikely to eliminate fishing at all Great Lakes, though policies could affect the price or quality of fishing at Great Lakes. In such cases, neither the total value of the resource, total consumer surplus, nor the economic impacts are desired measures of benefits. The relevant measure of benefits (costs) is the *change* in the consumer surplus that is associated with the policy.

2.2.3 Valuing Changes in Site Quality Using Recreation Demand

The quality characteristics of the possible choices of places to fish are key determinants of the demand for recreational fishing. Examples of quality characteristics are

[3] In some cases, economic impacts can be measures of economic value. For example, if the relevant population is the people of Michigan, then changes in income brought to Michigan by nonresidents would be a part of the measure of value change for Michiganders.

catch rates for various species, shoreline development, and contamination in fish. If one of these characteristics is altered, the demand for fishing trips to that site shifts, as does the demand at substitute fishing sites. In the earlier figures depicting hypothetical demand curves, such a quality change results in a shift or movement of the entire demand curve. For example, if the catch rate for a specie decreases at some site, the number of trips taken to that site at any given price will likely decrease, though trips may increase at other sites. That is, the decrease in quality would shift the demand curve for that site to the left. When the demand curve shifts, consumer surplus changes. The *change* in consumer surplus is the relavant measure of the economic benefits (losses) associatted with the cause of the demand shift.

When quality characteristics such as catch rates can be linked to management actions, the benefits of the management actions can be assessed using the travel cost method. For example, suppose that the demand for recreational angling depends on, among other things, the catch rate of a fish specie at the site. Suppose that a management action reduces sea lamprey populations, which leads to increases in fish populations. Suppose it can be determined what the catch rate would be with and without the lamprey control. Then, the travel cost method can be used to determine the extent to which the demand for fishing at the site would shift with the increase in the quality of fishing at the site. The change in consumer surplus for fishing at the site then measures the benefits to recreational anglers (increased use values) associated with the lamprey control action. In the general case of any quality changes, the change in consumer surplus is given by the area between the two travel cost demand curves for the site in question: one at the high level of quality, and one at the low level of quality.[4]

Thus, to use the travel cost model to value environmental quality, changes in environmental quality must be linked to changes in angler behavior. Typically, this is accomplished by including a measure of environmental quality as a variable in the travel cost model. In the case of valuing changes in lake trout populations, the inclusion of lake trout catch rates as a site characteristic in the model provides the linkage between catch rates and angler behavior. Changes in angler behavior map to changes in predicted trips and to changes in estimated surplus use-value accruing to recreational anglers. However, valuing environmental quality through the fish variables requires appropriate evidence from the physical sciences which links some change in environmental quality to changes in fish. This can be referred to as a "valuation pathway" (see Figure 2.3). For example, this pathway could be used to value lamprey control targets provided that changes in lamprey control can be mapped into changes in lake trout catch rates. One possible linkage between lake trout populations and lake trout catch rates would be to assume that lake trout rates are proportional to population levels. With the proportional catch assumption, a 10% increase in population levels results in a 10% increase in catch rates. This reaserch does not establish the entire valuation pathway. Rather, the MSU model is directed at the later portions of the pathway, as indicated in Figure 2.3.

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[4] Strictly speaking, this is true under a condition known as weak complementarity (see Mäler or Freeman). Weak complementarity holds between a market good and a public good if, when the market good is not being consumed, changes in provision of the public good do not change welfare. In the case of fishing, for example, the market good is travel to a recreation site, and the public good is water quality there. Weak complementarity holds if a person who does not travel to the site does not care about changes in water quality there.

Figure 2.3: Establishing a Pathway for Valuing Lamprey Control Through Catch Rates of Fish.

```
                                                                          Demand shift
Changes in          Changes         Changes        Changes     -->   (trips change)
sea lamprey   -->   in fish   -->   in catch  -->  in angler
control             stocks          rates          behavior    -->   Changes in
                                                                          value

|<--      linkages established        -->|<--      linkages based on the        -->|
          by physical sciences                      travel cost method
```

2.2.4 What Can and Cannot be Valued by Travel Cost Methods?

As mentioned, site quality changes that result in shifts in the travel cost demand curve can be used to measure some of the value of the change in site quality. Since the travel cost demand curve is a relationship between recreational *use* and the price and quality of a resource, it can only be utilized to measure *use-values*. The TCM demand curve tells us nothing about values that are not associated with recreational use of the resource. Moreover, for changes in the quality of a resource, value is measured by shifts in the TCM demand curve. Thus, only measures of quality that have been linked to the demand curve can be valued. This linkage is accomplished by including variables that describe site quality as potential shifter variables in a statistical model of demand. Because the linkage must be established statistically, there are a host of data issues involved in identifying this linkage. For example, the data must exist to describe (quantify) the quality measure; the data should exhibit sufficient variation across sites; the data cannot be highly correlated with other variables that influence site choice; and the range of the variation in the data should be sufficient to cover the range of policies to be examined. *Ultimately, any valuation of site quality is only as good as the statistical link between quality and the TCM demand curve.*

2.3 The Random Utility Model (RUM)

The type of travel cost model implemented for this project is known as a random utility model (RUM). The RUM was developed by McFadden (1974) and was first applied to recreation valuation by Hanemann (1978). Since then, it has been used for valuing aspects of recreation by several investigators. For a detailed description of the general approach, the reader is directed to descriptions of the RUM by Morey and by Bockstael et al (1991). This chapter presents an intuitive description of the basic logic of the RUM approach. More specific details about the RUM used for this project are provided in Chapter 4, while the complete technical details of the model are provided in Hoehn et al.

The RUM model is especially useful and applicable when there are many alternative recreational sites (i.e., fishing destinations). In such circumstances, any given angler will visit only one site on a given choice occasion and over the course of a season will visit only a few sites. In other words, the observed number of trips taken by any given angler will be zero for most sites. This is called a "generalized corner solution." While traditional demand models have been developed to estimate generalized corner solution models, and could be applied in the travel cost framework, these approaches are most useful for data sets where just a few goods (sites) are not consumed. In Michigan, there are hundreds of fishing sites and, for any individual angler there will be hundreds of sites that are not visited. The RUM can accommodate this type of data.

Moreover, the RUM is very useful in bringing a wide array of substitutes directly into the derivation and estimation of the demand model. In particular, when a RUM model is used, the demand for fishing at any site will be a function of the prices and qualities of *all* sites included in the analysis. As discussed earlier in this Chapter, it is important to include relevant substitutes in the analysis if accurate value estimates are to be obtained.

2.3.1 *The Basic Choice Model*

Suppose that one has information on where individuals go to fishing. Typically, anglers have available a number of alternative destinations for fishing. Each possible choice of a destination represents a combination of characteristics, such as the quality of the fishing at the site, as well as the price that must be paid to get to the site (i.e., the site's travel cost). Observations about where anglers fish reveal information about the trade-offs between travel costs (money) and site quality. That is, data on where people go provide information on their willingness to trade income for site quality. This is the essence of the model employed by the MSU team.

To begin the discussion of the basic model, divide the fishing season into small time periods, called choice occasions. On a choice occasion, an angler can either make one fishing trip, or she can decide to not go fishing. In the MSU model, choice occasions are ½ week intervals, of which there are about 60 in Michigan's "open water" fishing season.[5]

Suppose that an individual gets utility (i.e., pleasure) from visiting a recreation site, denoted by V, and that this utility depends on only two things: the quality characteristics of the site that gets visited (call these Q, for fishing quality, and S, for shoreline development), and the amount of a market good that can be consumed in addition to recreation (call this good M, for market). This is just for illustrative purposes; people of course care about more than this.[6]

[5] While the data include ice fishing trips, an ice fishing model in not estimated for this project.

[6] M is a composite commodity consumed with income not spent recreating. It is assumed that the relative prices of the components of this commodity do not change. Any other goods are assumed to be (weakly) separable from those consumed in the recreation "branch" of the utility function.

Suppose further (again for illustrative purposes) that the utility of a visit to the recreation site (site A) for individual (h) depends on the two measures of site quality (Q and S) and the market good (M) in the following fashion:[7]

$$V^{h,A} = \beta_1 [M] + \beta_2 [Q_A] + \beta_3 [S_A] + \epsilon_{h,A.} \qquad (2.8)$$

The parameters β_1, β_2, and β_3 are constants that describe the relative importance of the variables to h's overall utility. The parameter β_1 is a fixed number that measures the contribution of consuming the good M to utility, while β_2 and β_3 measure the contribution of trip quality at recreation site A to h's utility. For example, suppose that Q is a measure of fishing success, such as the catch rate. Then, if the catch rate is increased by one unit, the recreator's utility will increase by the amount β_2. Further, if she can consume one more unit of M, then utility goes up by β_1. If M is thought of as a composite good, representing all the other things the person can buy, then M is what is purchased with one's income and β_1 is the value of an increment to income. Thus, the ratio between these parameters (β_2/β_1) gives us the relative value to the individual of catch rates for fish and income, or the dollar value of a one unit change in catch rate.

It is assumed that all individuals have the same values for the β_i parameters. Individuals attach different utility values to trips to a site because people have different values for the variables included in the model. There are two ways that individual variation can be accounted for. The first is by including measured variables that act as demand shifters that vary across individuals, such as demographic variables. Individuals with different values for these measured variables will have different demands. The second way that individual

[7] This is a conditional indirect utility function, defined for one choice occasion. It is conditional on the choice occasion and on the choice of site A. It is assumed that goods consumed across choice occasions are separable from one another.

variation enters the model is through the term $\epsilon_{h,A}$. This is an individual-specific term representing variation in tastes across the population.[8] While M, Q_A, and S_A are observable, and the β parameters can be estimated statistically, the term $\epsilon_{h,A}$ is not observable by investigators. $\epsilon_{h,A}$ is known by individuals when they make travel choices on any given occasion, but it is unknown to analysts. Thus, it represents, in some sense, unavoidable errors introduced into the analysis since researchers cannot know all the relevant aspects of every person's decision problem.[9]

If the magnitude of the β_i parameters is known, a person's willingness to trade the quality of the recreation site for income could be assessed. That is, the value of a change in site quality could be established.

2.3.2 Estimating the Choice Model

The goal is to estimate the parameters (i.e., β_1, β_2, and β_3) of the utility function. This is done using statistical estimation procedures. The price index of the composite market good M can be set arbitrarily, so set it at one. Let the travel cost of going to a site be given by P. The travel cost consists of the money and time costs of gaining access to the site.

Suppose there are two sites available, A and B. These sites have qualities (Q_A ,S_A) and (Q_B ,S_B) and travel prices of P_A and P_B. Everyone who visits a site will experience the

---

[8] This also could represent variations in perceptions of the characteristics of goods by individuals relative to the measured levels of these characteristics.

[9] The error term may vary through time for individuals, so that the person does not always view the choices in the same way. It is assumed here that individuals know the value taken by their own error terms; it also is possible that there is a random component to choice.

same quality attributes (at least on average),[10] but each will face a different travel cost, since people live in different places. The prices P_A and P_B are personalized prices. Note that in the MSU model there are many more sites than just two.

A person has an amount of income (Y) that can be spent on fishing and on the market good. If a person chooses to visit a site, the travel price must be paid. Then, the person is able to consume an amount of the other good (M) equal to the available budget (Y), less the cost of the trip to the recreation site (P). This residual budget, (Y-P), is the amount of income left over for buying M after paying for recreating. Thus, if an individual chooses to go to site A, the person consumes the overall bundle: "a trip to A with site quality (Q_A,S_A) and good M in the amount [Y-P_A]." Similarly, if the person goes to B they consume "(Q_B,S_B) and [Y-P_B]." Thus, if the person goes to site A, the utility level that is achieved is (dropping the indicator h)

$$V_A = \beta_1 [Y - P_A] + \beta_2 Q_A + \beta_3 S_A + \epsilon_A$$

while if they go to site B, the utility level achieved is

$$V_B = \beta_1 [Y - P_B] + \beta_2 Q_B + \beta_3 S_B + \epsilon_B$$

Economic theory typically assumes that people choose among alternatives so as to maximize their utility given their budget. Thus, they go to the site that they think gives them the most enjoyment; otherwise, they would go somewhere else. Thus, a person will visit site A if

[10] Different people might experience the same quality attributes differently. For example, catch rates may be higher for those who know the lake. This is not considered in the MSU model which uses averages. Further, note that these are expected quality variables before the trip is taken; bad weather can lower catch rates, but this may not be known when it is decided where to go fishing.

$$V_A = \beta_1 [Y - P_A] + \beta_2 Q_A + \epsilon_A > \beta_1 [Y - P_B] + \beta_2 Q_B + \epsilon_B = V_B \, , \qquad (2.9)$$

and they will visit site B if the inequality is reversed and site B gives them more enjoyment. The inequality in (2.9) is exploited to estimate the parameters of the utility function (the β's).

Survey methods can be used to obtain data on where people go fishing. In addition, the cost of getting to the alternative fishing sites (the Ps), and the quality of the fishing at the sites (the Q's and S's) can be determined. What remains unknown are the values of the parameters β_1, β_2, and β_3, and the error terms (ϵ's).[11] To obtain these, statistical techniques are used to identify the combination of these parameters that makes it most likely to actually see the pattern of fishing visitation that is observed in the behavioral data. For example, suppose that β_1 is large and β_2 is small; then this indicates that people care relatively more about income than catch rates. In this case, one would expect to see people staying close to home and not driving really far to get to high quality sites. Conversely, if β_1 is small and β_2 is large, people care a lot about catch rates relative to money, and one would expect to see them incurring travel costs (paying a high price) to avail themselves good fishing sites. Additionally, the different measures of site attributes in Q and S play a role here; suppose that S is an index of whether there is contamination at a site. Then, if people really care about contaminated sites and stay away from them, one would expect β_3 to be a negative number.

Overall, for any distribution of the error terms, there is one set of parameters that best reproduces the observed pattern of behavior (i.e., the pattern of travel to sites with varying

[11] The income Y is the budget allocated to this choice occasion which typically is not observable. Since the MSU model is specified as linear in income, the income term (β_1Y) drops out because is does not vary across alternatives. In a RUM, variables that are constant across all choices drop out, since only utility differences matter for choice and estimation. The parameter β_1 can be estimated because the price term (travel cost) varies across choices.

quality). These best parameters are called the maximum likelihood estimates of the true parameters β_1, β_2 , and β_3.

The existence of the unobservable "error" term ϵ makes the problem uncertain from the analyst's viewpoint. Given the cost of getting to a site and its measured quality, the analyst can only calculate the *chance* that any given individual will find it the best site and go there. This chance depends on how likely it is that a particular value of ϵ arises. Large values of ϵ make a site more attractive while small or negative values make a site less attractive.

The term ϵ can take on one of any number of values, according to a statistical distribution; that is, some values of ϵ are more likely to be true than others. This is why the model is called a random utility model. The statistical distribution used determines the type of RUM, and hence the type of travel cost model. Details of the statistical theory of estimating these types of models can be found in Maddala; Ben Akiva and Lerman; and the references cited therein. The computer routines for implementing the MSU model estimation are provided in Appendix 1 of Heohn et al.

The important thing about taking account of the error term is that, from the analyst's viewpoint, there is only a *chance* that any person will find a particular site the most attractive. Even with knowledge of the β's, the personalized terms (the ϵ's) are not observable. If someone has a very large ϵ_A but a small ϵ_B, then they may visit site A, even though B looks better simply in terms of measured characteristics (travel cost and site quality). Thus, there is some *chance* that any person has a given ranking of sites, and therefore some *chance* that they find any given site best. The statistical model, in addition to providing estimates of the βs, also provides information on the individual's chances of visiting sites.

To illustrate this point, suppose that a number is picked for each of the ϵ terms. Conditional on these numbers being chosen, one can calculate which site is best, the site that provides maximal utility. But remember that there is only a probability that these numbers are the true ϵ's; the true error terms might be other numbers. Rearranging terms in the expression (2.9) above, the person will visit site A if

$$\epsilon_A - \epsilon_B > \{\beta_1 [Y-P_A] + \beta_2 Q_A + \beta_3 S_A\} - \{\beta_1 [Y-P_B] + \beta_2 Q_B + \beta_3 S_A\} = K.$$

The term on the right side of this inequality is, for given β's, just a number, call it K. Then this inequality says that if the random term ($\epsilon_A - \epsilon_B$) exceeds this number K, then the person visits site A. There is some chance that this person finds site A best, based on the statistical probability that ($\epsilon_A - \epsilon_B$) exceeds this number K. This probability is inherent in the statistical distribution of $\epsilon_A - \epsilon_B$. This can be expressed as

The probability A is the best site (π^A)	=	Probability $\{ V_A > V_B \}$	
π^A	=	Prob $\{ \epsilon_A - \epsilon_B > K \}$	(2.10)
π^A	=	Prob $\{\epsilon_A - \epsilon_B > [-\beta_1 P_A + \beta_2 Q_A + \beta_3 S_A] - [-\beta_1 P_B + \beta_2 Q_B + \beta_3 S_B] \}$	

Note that the income term has dropped out of this equation. So too would any term that did not vary across the choices. For example, if all sites have a fish consumption advisory, then one could not assess the impact of such advisories. Only differences in utility across choices matter in this theory.

The probability of choosing site A can then be interpreted as the "expected demand" for site A. Just as with the demand curves presented in figures 2.1 and 2.2, when the price of site A rises, the expected demand for site A falls; that is, as the price of site A rises, the probability of selecting site A as the best site falls.

Once a statistical distribution for the error term ϵ is selected, the β's can be estimated, and the chances that a person finds any particular site the best can be calculated. The model is slightly more complicated if there are many sites, but the basic idea is the same; the inequality in (2.9) must hold for all the other sites besides A if A is the best.

The form of the selected distribution for the error terms determines the type of RUM being estimated. For example, if the error terms, ϵ, are independent draws from an extreme value distribution, then a simple logit model results.[12] The extreme value distribution is one of many possible distributions. The relationships among random choice models, the types of choice probabilities, and the statistical distribution chosen for the individual-specific terms ϵ has been established by McFadden (1974, 1981).

The expression for the choice probabilities above, (2.10), states that an increase in any variable, like Q_A, that raises the utility of visiting site A, raises the chance that site A is visited. These chances or probabilities of visiting a site can be thought of as the expected demand for fishing at the site. Further, equation (2.10) makes it clear that the utility of visiting a site is being compared with the utilities of visiting *all* the other sites. Thus, substitution among sites is directly incorporated into the model.

2.3.3 Nested Models

As discussed above, there is an intimate tie between the structure of the choice model and assumptions about the form of the statistical distribution of the error terms, ϵ. One approach, called the simple logit model, assumes that the error terms have a Type 1 extreme value distribution and that each ϵ is an independent draw from this distribution. This treats all potential choices as equally close substitutes for one another, with none systematically

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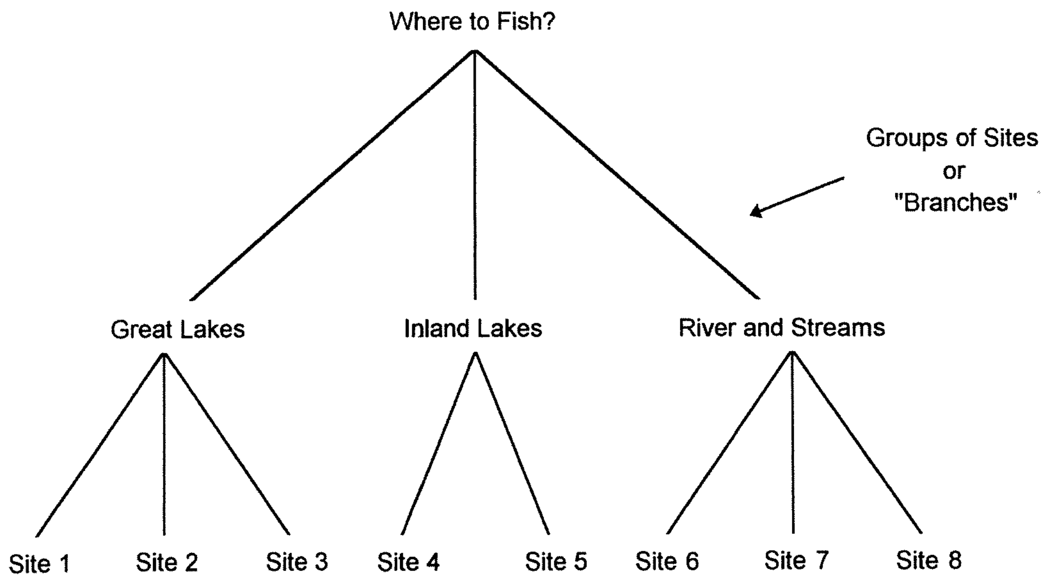
[12] In this case, the probability of visiting site j is $\exp[\beta X_j] / \Sigma_k \exp[\beta X_k]$ where $V_j = \beta X_j + \epsilon_j$.

Figure 3.2: Hypothetical Nesting Structure for a Nested RUM



more similar than others. Technically, this is known as the independence of irrelevant alternatives (IIA). The concept of independence means that knowledge of the ϵ for one choice tells us nothing about the magnitude of the ϵ for any other choice. The limitations of the IIA idea can be illustrated using a famous example from transportation choices.

Suppose a person has available three ways to get to work: a red bus, a blue bus, and a bicycle. Under the IIA assumption, the odds of choosing the red bus over the bicycle do not change if the blue bus becomes available. But this seems unreasonable. Clearly, any personalized factor that makes it likely to choose a red bus over a bicycle, also makes it likely that the blue bus would be chosen over a bicycle. Thus, knowledge that $\epsilon_{\text{red bus}}$ is large (relative to $\epsilon_{\text{bicycle}}$) provides information that $\epsilon_{\text{blue bus}}$ likely is large as well, contradicting the idea that these are independent of one another.

If it is thought that this IIA assumption is not a good one, that some choices are more similar than others, and hence that correlation among the errors is important, there is a more general approach. It comes from using a special case of the generalized extreme value (GEV) distribution, and is called a "nested" RUM. This approach was developed by McFadden.[13]

The nested version of the RUM divides the alternative choices into groups that are relatively more similar with alternatives in the same group than with alternatives in different groups. For example, to an angler interested in fishing for lake trout in the Great Lakes, all the Great Lake sites may be closer substitutes for one another then a Great Lake site and an inland stream site would be. Similarly, for a brook trout angler, two cold water stream sites may be better substitutes for one another than a stream site and an inland lake site would be.

What is sought, then, are groups of choices where the IIA assumption holds within the group, but not necessarily across groups. Hence, within each grouping of choices, the alternatives appear to be equally good substitutes. For example, suppose all the Great Lakes fishing sites are one group, and all the inland stream sites are another. Knowing that the ϵ for fishing out of Muskegon (a Lake Michigan site) is high for a person, makes it more likely that the ϵ for fishing out of Ludington (another Lake Michigan site) is high as well, at least compared to fishing on the Pigeon River.

To understand the estimation of a nested model, it is useful to think of an individual's decision of where to go as taking place sequentially. In fact, such decisions do not necessarily take place in this sequential manner, but this is a useful pedagogic device.

[13] The general form of the GEV distribution and its relationship to choice probabilities arising from random utility maximization and the IIA property is discussed by McFadden (1974, 1981), Morey, and Ben-Akiva and Lerman.

Suppose that the structure of choice is as follows: there are three types of fishing: Great Lakes (GL), inland lakes (IL), and rivers and streams (RS).[14] Within each of these groups there are several alternative destinations, among which IIA holds. The angler can be thought of as first choosing which type of fishing to engage in, and then, having made this choice, which specific site to visit. This decision structure can be pictured as in the Figure 3.1.

First, the angler chooses among the three basic types of fishing, and then, conditional on this choice, chooses a site. When deciding among sites within a "branch" of the decision tree, say among GL sites, an individual chooses the best available, exactly as described above for a non-nested model. But how should the person choose from among the three "water body type" branches GL, IL, and RS? What is needed is a summary variable which summarizes the choices available in each of the lower "branches" of the decision "tree." Such a summary variable is the "inclusive value index," denoted by IV.[15] There is one for each available branch; in this example, there would be one for the GL branch, one for the IL branch, and one for the RS branch. The inclusive value index gives the expected value of the highest utility the person would achieve if they chose that branch, not knowing exactly which site they would visit.[16] The inclusive value index for GL "summarizes" that choice in the sense that it measures the maximum expected utility from fishing at any GL site. Similarly, the inclusive value indices for the IL and RS branches summarize the expected maximum utility for sites in those branches. Then, choice among the three water body types

[14] In the MSU model there are twenty-four types of fishing: twelve for day trips and twelve for multiple-day trips. See Chapter 3 for details.

[15] The inclusive value index is given by $IV = \ln[\Sigma_{j \in L} \exp(\beta X_j)]$, where L is the set of sites available in a branch, and βX_j is the deterministic portion of the conditional indirect utility of visiting site j in L.

[16] The expected value of the maximum conditional indirect utility is the IV plus a constant. The constant drops out of measures of welfare changes, and in what follows, the constant term is ignored.

(branches) can be made based on the relative magnitudes of the inclusive value index across water bodies, as well as other variables that influence this choice.

Just as with the non-nested RUM, analysts can not know all there is about people and the characteristics of the choices they make. The ϵ terms capture these idiosyncracies, both within and across branches. Hence, there is some probability that the person chooses a particular site within a branch. For example, one can estimate $\pi_{GL,Muskegon}$ -- the probability that an angler chooses the GL branch, and the Muskegon site. This chance can be decomposed into the product of two terms: the chance of choosing a GL site (π_{GL}) and the chance of choosing Muskegon, *given* that one is going Great Lakes fishing ($\pi_{Muskegon|GL}$).

If some GL site is improved in quality, then the probability of visiting that site, given a GL choice goes up. Moreover, the overall utility for GL fishing, given by the inclusive value index for the GL branch, goes up as well. This, in turn, increases the probability of choosing Great Lakes fishing over other types. There may be many levels of such branches. For example, the GL, IL, and RS groups mentioned above may be further divided based on other characteristics of trips (e.g., trip duration) and/or characteristics of sites (e.g., geographical region).

2.3.4 Welfare Estimation

This section of the report, discusses how the model and estimated parameters can be used to determine WTP for a change in quality of recreation sites. First, there is an illustration of how to compute WTP per trip when the statistical/random utility nature of the problem is ignored. Next, there is a discussion of how to introduce this statistical uncertainty into the calculation of WTP per trip. This is done for the case of a non-nested model, since the logic is easier to see in this case; the extension to nested models is then briefly considered.

WTP per trip

This section addresses the issue of how the RUM model can be used to assess economic value for environmental quality associated with recreation. Consider first the case without the inclusion of the personalized ϵ terms. Suppose that the quality of the environment declines at a site, from Q^H ("high" quality) to a lower value Q^L ("low" quality). Then, for an individual who visits that site before and after the change, the value of V attained will fall as well; the person is worse off with Q^L. Let the measure S remain unchanged. In this case, the following inequality must hold

$$V^H = \beta_1 [Y-P] + \beta_2 Q^H + \beta_3 S > \beta_1 [Y-P] + \beta_2 Q^L + \beta_3 S = V^L. \qquad (2.11)$$

Equation (2.11) says that, holding constant the consumption of other goods (where M = Y-P, i.e., consumption of other goods equals income less the expenditure on travel to the site), the initial level of well-being, V^H, is higher than the level of well-being attained with a degraded environment, V^L.

To get willingness to pay to avoid this change in environmental quality, compute the amount of income that could be taken from the person when the quality of environment is at the baseline level Q^H to make them as well off as they would be when the environmental quality is at the low level Q^L, and they have their base income. The individual is using a high-quality recreational good, with quality Q^H, but income is subtracted until they attain level of well-being with the degraded environment. Denote the amount taken from income by WTP. This value of WTP satisfies

$$\beta_1 [Y\text{-}P - WTP] + \beta_2 Q^H + \beta_3 S = \beta_1 [Y\text{-}P] + \beta_2 Q^L + \beta_3 S\ .^{17} \tag{2.12}$$

Solving this equation for WTP, it can be seen that

$$WTP = (\beta_2/\beta_1)[Q^H - Q^L]. \tag{2.13}$$

The WTP in this case is the incremental value of the quality variable times the amount of quality change. Therefore, if there were no error terms (ϵ's) and values of the β parameters were known, the WTP measure of welfare for an individual could be easily computed. Of course, the true values of the β parameters are not known, but, as explained above, estimates of them can be obtained. An estimate of WTP is then obtained by inserting the estimated β's into formula (2.13) for WTP.[18]

Expected WTP

That the model has a random component means that the true measure of WTP for any individual is known only up to the personalized ϵ terms. To deal with this uncertainty, the statistical expectation of the potential true WTP measures is used. This works as follows. As before, the overall utility achieved by the individual from a visit to site A is

$$V_A = \beta_1 [Y - P_A] + \beta_2 Q_A + \beta_3 S_A + \epsilon_A.$$

[17] This derivation holds only if the site where quality changes remains the best site before and after a quality change. More generally, one seeks the reduction of income that would equate the indirect utility of the best site before a change in quality to the indirect utility of the best site after a change in quality. Thus, if the site where quality changes is not the best before or after the change, then there is no change in the individual's well-being.

[18] Since estimates of parameters are random variables, WTP is a random variable.

Given the error terms, there is only a chance that A is in fact the best site. Thus, the probability that the site truly is best and the probability that the computed WTP is the true WTP must be incorporated into the analysis.

The expected value of an uncertain thing is the best estimate of what the truth is, in light of the inherent uncertainty. It can be shown that the expected value of the maximum utility for the travel cost RUM is the inclusive value index, as defined earlier in Section 3.4. The essential thing about the inclusive value, IV, is that it gives the expected value of the highest utility the person would achieve. There is a different IV for each person, since each person has a different travel price to each site.

Now, in order to calculate an individual's WTP for a change in quality, find the amount that can be taken from income to equate the inclusive value index for that person before the change, IV^o, to his or her inclusive value after the change, IV^1. This can be shown to equal

$$WTP = (1/\beta_1)[IV^o - IV^1]. \tag{2.14}$$

The inclusive value IV^o is the individual's expected maximum utility with the baseline level of environmental quality at the recreation site, and IV^1 is their expected maximum utility with a degraded environment. The difference between the IV's is the change in the expected level of utility due to a change in quality at one or more sites. Equation (2.14) says that the change in the expected level of utility is converted to units of money by dividing by the parameter which shows how utility is related to income (β_1). This is the WTP per trip (or WTA per trip) for the change in recreational site quality.[19] It applies to every trip taken by the individual. In keeping with the notion of consumer surplus presented in section 2.2, the formula in (2.14) is equivalet to the change in the area under the probabilty functions where

[19] Footnote 18 applies here as well since the estimates of the β_i's are random variables.

site characteristics have changed; that is, the change in the areas under the expected demand functions.

Welfare measurement in the nested model

Welfare measurement in the nested RUM is similar to welfare measurement in the non-nested RUM. One computes the expected value of the maximal utility achieved in the choice situation. In the non-nested model, this is the inclusive value index. In the nested model, this is a more complex expression than the inclusive value, but the idea is the same. Call this index of maximum expected utility D. Accordingly, under baseline quality conditions, maximal expected utility is D^0 and under the altered conditions it is D^1. As a result, the welfare measure can be expressed

$$WTP = (1/\beta_1)[D^0 - D^1]. \qquad (2.15)$$

The details of computing D take account of the more complex nature of the statistical distribution for the error terms.[20] The measure in (2.15) can still be interpreted as changes in areas under expected demand curves for the sites where quality characteristics change.

Aggregation

The above measure of welfare change is computed at the individual level. What is desired is an aggregate measure, defined for the population as a whole. Exactly how one adds the individual measures up over people depends on the sampling scheme used in the survey to obtain information from anglers and on how one treats benefits to different anglers. In the MSU model, benefits to anglers are treated equally regardless of who the angler is or

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[20] A definition of "D" for the MSU model is provided in Chapter 3, see also Morey or McFadden.

where they live, that is, social benefits are the simple sum of individual benefits. Under such a scheme, if the survey sample is selected as a simple random sample, and the sample obtained appropriately represents the population of interest, then one can simply calculate the average welfare measures obtained for the sample and multiply by the size of the population sampled. If a more elaborate sampling plan is used, then appropriate weights must be attached to the sample observations before aggregation. For example, the MSU model is based on a stratified sample of individuals, where not every sampled person has the same likelihood of being drawn. A description how welfare measures were extrapolated from the sample to the population is contained in section 3.3.4 of Chapter 3.

2.3.5 Total Seasonal Demand

The RUM model described above, in either its nested or non-nested versions, addressed an individual's decision of where to go on an outing, *given* that one was going. It did not explicitly address the issue of *how many* outings to take. Hence, the welfare measure was WTP per trip, not the full measure of welfare change over all trips. After a change in the quality of some recreation sites, one might expect both the value per trip as well as the number of trips to change. In RUM type models, determining the number of trips to take is called the participation decision.

A number of proposals have been made in the literature about modeling the participation decision. Some have suggested that a *separate* model be estimated regarding the number of trips taken over a whole season, and that this model of how much to go could be linked to the RUM site choice model of where to go (e.g., Bockstael et al. 1987; Jones and Sung; Parsons and Kealy; Feather et al., Hausman et al.). However, a different tack, that taken here, is called the repeated RUM (Hanemann and Carson; Morey et al.). In the repeated model, the overall season is divided into distinct choice occasions, and the RUM site choice framework is repeated over the course of the season. By including the option of not taking a trip (don't go) in the set of feasible alternatives within each choice occasion, participation is directly incorporated in the RUM model.

The go/don't go decision is commonly treated as its own level in a nested model. If an angler does decide to fish within a choice occasion, then they choose the best site for them as described earlier. Again, the analyst does not know what level of well-being they achieve but the expected highest level of well-being from taking a trip to some site is the inclusive value index for the overall site choice model, IV. If they do not go fishing, they do not incur any travel costs, and so they get to consume all their income, M, but they do not get to enjoy fishing. The utility they achieve from this can be expressed as $\boldsymbol{\beta}_1$M. Thus, a comparison of going *versus* not going involves a comparison of the inclusive value index, IV, and $\boldsymbol{\beta}_1$M, perhaps as conditioned on other variables, say W. This is a nested RUM, where one branch is a choice about participation, and then, conditional on participation, one faces a choice of destination.

In estimation of this model, the probability of participating is obtained; call it $\boldsymbol{\pi}^P$. If there are T choice occasions in the season, the expected number of trips taken in a season is $N = \boldsymbol{\pi}^P \times T$. When a quality characteristic of a site changes, the inclusive value associated with participation is altered. As such, a change in the participation probability occurs which results in a change in the predicted number of trips. If quality characteristics vary over the season, as they do in the MSU model, then $\boldsymbol{\pi}^P$ will vary by choice occasion. The expected number of trips is then the sum of the participation probabilities over all the choice occasions in the season.

The welfare measure for the overall nested model is based on a maximal expected utility. This expected utility can be cast in the notation of equation (2.15) as D if it is understood that the underlying choices include the don't go option. This D, which includes the participation decision, is then the maximal expected utility per choice occasion. Hence, the WTP measure defined above is WTP per choice occasion. The seasonal willingness to pay, SWTP is just WTP $\times$ T. If quality characteristics vary over the season, then the D's will vary by choice occasion. The seasonal measure is then the sum of the D's over all the choice occasions in the season.

2.4 The RUM Benefits Function

{*Still working on what level of detail to provide here ... **if any** ???*}

MNL Probabilities

Inclusive Value

Shape

Briefly present first and second derivatives

Discuss intuition (add graph)

Implications

Independent Valuations

How multi-site valuations should get done;

This is implicit in IV measures.

Has implications for GL management;

Chapter 3
The Michigan Random Utility Model

This chapter describes the specification and estimation of the repeated RUM that was developed for Michigan by a team of researchers that included the author. The model is used to derive estimates of the value of changes in lake trout catch rates. The sensitivity of these value estimates will be examined to explore the suitability of the value-per-fish approximation. Thus, the empirical model serves as a state-of-the-art tool for deriving the valuation results described and reported in Chapter 4.

The Michigan model or MSU model was developed at Michigan State University (MSU) under a grant from Michigan's Department of Natural Resources (MDNR) and Department of Environmental Quality. The principal investigators were John P. Hoehn of Michigan State University and Theodore Tomasi of University of Delaware and formerly of Michigan State University. The other members of the research team were Heng Z. Chen of Michigan State University and the Frank Lupi. The material in this chapter summarizes, and is drawn from, the project report for the MSU model (Hoehn, Tomasi, Lupi, and Chen).

The chapter begins with a discussion of the model structure and the variables used in the model. The exact specification of the site choice probabilities and the likelihood function is then given. The chapter then presents the actual welfare measure for the specific model that was estimated, and an overview of the methods for extrapolating results is provided. The chapter then reviews the survey that was developed to collect the behavioral data for the model. The next section presents the results of the model estimation. The chapter ends with model predictions for trips in Michigan for the baseline data on site characteristics.

3.1 Model Structure

The MSU model is a nested repeated random utility travel cost model that permits a wide variety of trip types. The presentation of the model structure begins with a section discussing the possible types of trips and sites that can be chosen in the model. The next section discusses the choice occasions which form the basis of the repeated model. The final section on the model structure describes the nesting of choices within the model.

3.1.1 Trip and Site Types

In the MSU model, trips are distinguished by trip duration, target species, water body, and destination. Single-day and multiple-day trips are treated as separate types of trips. Fishing trips targeting warm-water species such as walleye and bass are differentiated from trips targeting cold-water species such as trout and salmon. Fishing at Great Lakes, inland lakes, and inland rivers are treated as distinct types of trips. Finally, trips are distinguished by the destination county for the fishing trip. Thus, the MSU model distinguishes between several distinct fishing opportunities available in any given county in Michigan, as well as distinguishing among counties in Michigan.

Two categories of trip duration, single-day trips and multiple-day trips, were chosen to make the best use of the available data. Less than 20% of the trips reported by survey respondents were multiple-day trips (see Appendix 2, Hoehn et al.). The MSU team determined that it was important to allow the estimated site quality parameters to differ by trip lengths. The team also sought to keep the distinctions between fish species and water body types within each trip length (discussed below). As a result, there were not enough multiple-day trip observations to further subdivide them into additional trip length categories while maintaining the site, species, and water body distinctions mentioned above.

Table 3.1: **Product Line (PL) Descriptions.**

PL #	PL Code	Description of the Product Line
1	GL warm	Great Lakes warm-water species
2	GL cold	Great Lakes cold-water species
3	IL warm	Inland Lakes warm-water species
4	IL cold	Inland Lakes cold-water species
5	RS warm	River/Stream warm-water species
6	RS cold	River/Stream, non-anadromous, cold-water species
7	Anad	River/Stream anadromous run species.

Within either the single-day or multiple-day trip length, the different types of fishing trips are called "product lines." Each product line (PL) describes a generalized combination of water body type (Great Lakes, inland lakes, and river/streams) and fish species (cold and warm-water species), plus anadromous runs.[1] Two-story lakes, with warm water on top and cold water below (during the summer), are included in both warm and cold PLs. Cold-water species include salmon and trout, and warm-water species include bass, yellow perch, panfish, walleye, and pike. In addition, species on anadromous runs are separated from other cold-water river species; anadromous run species include salmon and steelhead. Each of the product lines is available as a single-day trip and as a multiple-day trip. As a result, there are seven fishing PLs within each trip length (Table 3.1).

The sites within each product line are the counties that offer fishing opportunities within that product line. For the Great Lakes product lines, the sites are the stretch of Great Lake shoreline in the county. Each of Michigan's 83 counties can appear several different

[1] This follows Jones and Sung who use a similar structure in their earlier RUM for Michigan fishing. Based on factor-analytic work by Kikuchi, they categorize fishing activities into seven product lines: Great Lakes, inland lakes, and rivers and streams, for both cold and warm species, plus anadromous runs.

places as a site in the model. For example, consider a Great Lake county with anadromous runs, warm and cold inland lakes, and with warm and cold inland streams. Such a county would support all seven product lines. Moreover, these seven types of fishing would be available for single and multiple-day trips. Thus, the county would appear in fourteen separate places in the model. Each of the 14 types of trips to this site (county) is treated as a distinct fishing opportunity in the model. In total, there are 854 distinct sites in the MSU model.[2]

In a RUM type model, the set of sites which can be chosen is called the feasible choice set. The feasible choice set in the MSU model varies across individuals and over time. The choice set varies over time because the anadromous run PL is not available during the summer months. The choice set varies for individuals because there is a constraint on how far an individual can travel for a particular trip length. The choice set for day trips is composed of feasible counties within 150 miles of an individual's permanent residence. From the survey data, only about two percent of the observed one-day trips exceed the 150 miles limit. Further, some of these extremely distant single-day trips are likely to be multiple-day trips that were mis-coded as several one-day trips. For example, an individual who drove 400 miles one way for a one-day trip, and then repeats the same one-day trip for the next 4 days is unlikely to have taken 4 single-day trips. The choice set for multiple-day trips consists of feasible counties within 600 miles of an individual's permanent residence; the maximum observed one-way driving distance in the sample was 600 miles. Due to the distance constraint, each individual has about 600 feasible fishing

[2] Michigan has 83 counties. The number of counties that are feasible for each PL are: 41 in GLcold, 40 in GLwarm, 83 in ILwarm, 67 in ILcold, 83 in RSwarm, 69 in RScold, and 44 in Anad. Combining these with the two trip durations yields 854 combinations of trip and site types that are in the model.

activity/site combinations to choose from on each choice occasion. There are about 60 fewer feasible alternatives in the summer months when anadromous runs are not available.

3.1.2 Choice Occasions

The MSU model is a *repeated* RUM, where the season is divided into a series of choice occasions. During each choice occasion, anglers decide whether or not to fish. The decision to fish or not is then made anew at each choice occasion. The length of the season and the length of a choice occasion jointly determine the number of choice occasions in a season. The MSU model considers only those trips made during the "open water" fishing season, defined as the period from April 1 to October 31.

While the determination of the season length is straightforward, many factors affect the selection of the length of the choice occasion. The more choice occasions there are and the larger the number of choices per occasion, the greater the computational burden of the model. On the other hand, if the model contains few choice occasions, there will be some individuals who have taken more trips than there are choice occasions, and some of their trips will need to be "trimmed" from the data.[3] When there is only one trip length, a researcher can err on the safe side by dividing the season length by the trip length to get the maximum number of choice occasions. For example, if the trip length is a single day, then using the number of days in the season as the number of choice occasions will ensure that no trips would need to be trimmed from the data.

However, defining the length of the choice occasions is somewhat more complex when each choice occasion must accommodate trips of differing lengths, as in the MSU

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[3] Morey, Rowe, and Watson choose 50 choice occasions for their study of fishing in Maine. They note that few individuals had more than 50 trips in the season.

model. Ideally, a choice occasion is long enough to accommodate all of trip lengths which are feasible within a choice occasion. However, when one considers only one trip per choice occasion, then the longer the length of the choice occasion, the greater the chance that there will be individuals with more trips than there are choice occasions, and hence, the more data that must be trimmed. This is due to the fact that longer choice occasions with fixed season length result in fewer total choice occasions. Therefore, the researcher's problem is to select a choice occasion that is long enough to accommodate the alternative trip lengths, but not so long that it will result in numerous anglers who have taken more trips than there are choice occasions.[4]

As mentioned, the MSU model permits two trip lengths, single-day trips and multiple-day trips. Also, the MSU model permits at most one trip per choice occasion. The decision to partition the trip length into two categories takes into consideration the limited number of multiple-day trip observations across the seven product lines. With more multiple-day trip observations, one could choose to partition the trip lengths into finer grids with a corresponding increase in computational burden -- for the MSU model, each additional trip length category adds 427 site/product line combinations to each choice occasion.

For the research reported here, the length of the choice occasion was set at 3.5 days, or two choice occasions per week. This period was selected because about 96% of all trips were for 4 days or less (3 nights away or less). Of the multiple-day trips, about 80% lasted three nights or less with the average nights away being just less than three. Thus, by setting

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[4] Alternatively, no data need be trimmed if all possible combinations of trips are modelled in each choice occasion. For example, if the choice occasion is every two days, four possible combinations of trips are (1) no trips, (2) a single-day trip and a day not fishing, (3) two single-day trips, and (4) a two-day trip. The longer the choice occasion, the more potential trip combinations there are. However, the data requirements and computational burdens of this approach are extreme.

the choice occasion length at 3.5 days, most of the multiple-day trips "fit" into the choice occasion period.

In the MSU model, catch rates vary by month so the month of a trip must be known in order to estimate the model. In this sense, the number of trips and choice occasions per month is what drives the data trimming decisions in the MSU model. If there are more trips in any month than there are choice occasions in that month, excess trips must be trimmed. For the MSU model, with the choice occasion length at 3.5 days there are 8 to 9 choice occasions in any month with a total of 61 occasions for the season. (The exact number of occasions in each month of the April to October fishing season are defined as {9, 8, 9, 9, 9, 8, 9}, respectively.) For any individual in the sample, if the sum of their reported single-day and multiple-day trips in any month exceeds the number of choice occasions in that month, a random selection of the trips are trimmed so that the month contains no more trips than the number of choice occasions in that month. In this study, less than 2% of the reported trips in any month exceeded the number of choice occasions in that month, and in most months less than 1% of the trips were trimmed.

3.1.3 Nesting Structure

The MSU model is specified statistically as a nested logit. This specification allows the analyst to group alternatives so that alternatives within groups are more correlated than alternative across groups. The grouping is referred to as "nesting" and allows the nested logit to avoid the IIA problem of the multinomial logit (see section 2.2.1). This section describes the nesting of alternatives in the MSU model.

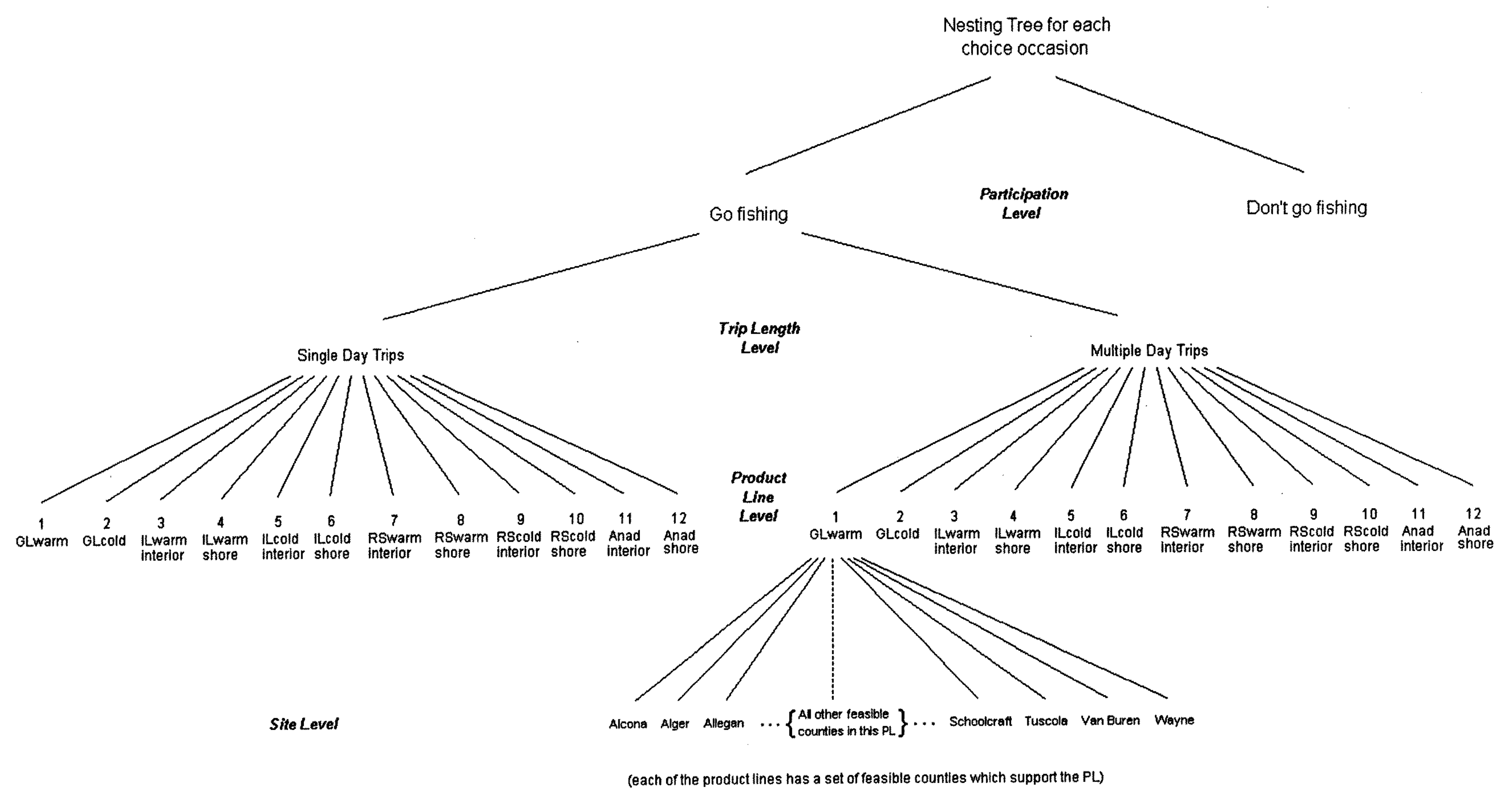

Figure 3.1: Four Level Nesting Structure for Each Choice Occasion: Participation, Trip, Product Line, and Site Levels.

Technically, a nesting structure takes account of possible correlations among the error terms. The nesting structure of the MSU model closely resembles the types of fishing activities in the model because nesting the different fishing activities allows choices to be structured to determine whether some activities are closer substitutes than others. For example, the model results will reveal whether single-day trips to sites within the same product line are closer substitutes than are single-day trips to sites in different product lines.

There are four levels of nesting in the model. The first involves the participation decision, the second is the choice of trip duration, the third is the choice of the product line, and the bottom level is the choice among specific sites (see Figure 3.1). This structure allows the distribution of the error terms for choosing not to take a trip to differ from the distribution of the error terms associated with choosing to take a trip. Likewise, the separate nesting of single and multiple-day trips allows the utility associated with a single-day trip to be more correlated with other single-day trips than with multiple-day trips. In addition, the nesting at the product line level allows utilities for sites within a product line to be more correlated with the utilities for sites in the same PL than for sites in different PL's.

One note on the nesting at the product line level is in order. Recall from the above discussion that there are seven basic product lines. In the nesting structure used in the MSU model, the inland lakes, rivers and streams, and anadromous run categories have been further subdivided to distinguish whether the site is in a county that has Great Lakes shoreline.[5] Unlike the product line designation, the shoreline distinction is mutually exclusive; a county is either in the group of counties that contain Great Lake shoreline or it is not. The

[5] Here the Jones and Sung nesting structure has been extended for non-Great Lakes product lines to distinguish between counties that do and do not have Great Lakes shoreline. The rationale is that such destinations allow of wider portfolio of fishing types on any given trip; e.g., one can fish on a Great Lake and also an inland lake. This is a particularly important effect for multiple-day trips.

Table 3.2: Description of Nesting Groups at the Product Line Level.

No.	Nesting Group	Description of the nesting group
1	GL warm	Great Lakes warm-water species
2	GL cold	Great Lakes cold-water species
3	IL warm, shore	Inland Lakes, warm-water species, county with GL shore
4	IL warm, interior	Inland Lakes, warm-water species, county without GL shore
5	IL cold, shore	Inland Lakes, cold-water species, county with GL shore
6	IL cold, interior	Inland Lakes, cold-water species, county without GL shore
7	RS warm, shore	River/Stream, warm-water species, county with GL shore
8	RS warm, interior	River/Stream, warm-water species, county without GL shore
9	RS cold, shore	River/Stream, non-anadromous, cold species, with GL shore
10	RS cold, interior	River/Stream, non-anadromous, cold species, without GL shore
11	Anad, shore	River/Stream, anadromous run species, county with GL shore
12	Anad, interior	River/Stream, anadromous run species, county without GL shore.
	"shore"	refers to counties with Great Lake shoreline
	"interior"	refers to counties without Great Lake shoreline

nesting at the PL level simply subdivides the existing PLs. As a result, within each trip length there are a total of twelve nested groups (*s*) corresponding to shoreline and product line combinations. The set of these combinations (*S*) is defined as

$$S \equiv \{\text{GLwarm, GLcold, ILwarm}^{\text{shore}}, \text{ILwarm}^{\text{interior}}, \text{ILcold}^{\text{shore}}, \text{ILcold}^{\text{interior}}, \text{RSwarm}^{\text{shore}}, \text{RSwarm}^{\text{interior}}, \text{RScold}^{\text{shore}}, \text{RScold}^{\text{interior}}, \text{Anad}^{\text{shore}}, \text{Anad}^{\text{interior}}\}.$$

where "interior" refers to counties without GL shoreline and "shore" refers to counties with GL shoreline. The twelve combinations are defined in Table 3.2 and are illustrated in Figure 3.1.

Bear in mind that the nesting structure is simply a way of grouping alternatives that are likely to be similar to one another. Whether the alternatives really are similar or not is revealed during the model estimation. The four levels of nesting add parameters to model estimation, the parameters on the inclusive value indices which were introduced in Chapter 2. If the inclusive value parameters are significantly less than one, then the nesting structure does capture some underlying similarities among sites within a nest. If the parameters on the inclusive value indices are not significantly different from one, then the model collapses to an *un*nested logit or a multinomial logit.

3.2 Variables

At each level of the nested model, there are variables that serve to "explain" fishing choices. In this section, the variables and their measurement are briefly described. A more detailed explanation of how each variable is constructed is contained in Appendix 1, Sections 4 and 6 of Hoehn et al. They include a trip price variable and various site quality variables. The construction of the trip price variable (travel cost) is discussed first.

3.2.1 Travel Cost

The trip price in the MSU model is the travel cost variable. Following the model formulation presented in section 2.2.2 of Chapter 2, travel costs are specified as the sum of driving, lodging, and time costs where time costs are measured by the total time required by the trip valued at the individual's wage rate. To the extent possible, the travel costs were tailored to the individual sample members.

Driving Cost Regression and Prediction: Driving costs per mile were calculated using a regression-based prediction of per mile fuel costs plus a per mile depreciation charge. Predicted fuel costs vary across individuals in the model. The dependent variable in the fuel

Table 3.3: Driving Cost Tobit Regression with Multiplicative Heteroskedasticity.

Variable	Variable description	Coefficient	Std. Error	t-ratio
Distance	Round trip distance	0.0759	0.005	14.11
Tow_D	Tow a boat dummy * distance	0.0304	0.011	2.72
Truck_D	Truck/camper dummy * distance	0.0378	0.012	3.08
Share_D	Share expenses dummy * distance	0.0055	0.011	0.45
Hetero terms				
Distance	Round trip distance	-0.0002	0.001	-0.28
Tow_D	Tow a boat dummy * distance	-0.0005	0.001	-0.73
Truck_D	Truck/camper dummy * distance	0.0062	0.001	9.77
Share_D	Share expenses dummy * distance	0.0024	0.001	3.96
σ	Estimated standard error	5.5523	0.105	52.72
Log-L = -2755.267				

cost regression was the reported fuel cost for the fishing trip. The equation itself was specified as a tobit model with multiplicative heteroskedasticity (see Greene 1993, p. 598; and Greene 1992, p. 698). The tobit form was used because the fuel cost responses were censored at zero.

The explanatory variables were the round trip distance and three dummies interacted with distance: *share*, *tow*, and *truck* which represented whether or not expenses were shared with other households, whether a boat was towed, and whether the vehicle was a truck or camper. After dividing through by distance, the coefficient for distance is the per mile driving cost, and the coefficients for share, tow, and truck can be interpreted as the individual effects of these variables on the per mile driving cost.

The fuel cost data was collected in the panel for the first trip any individual took in each wave of the panel survey (discussed in detail in section 3.4 of this chapter). The regression was estimated using the subset of these data that met several conditions aimed at minimizing any possible errors in the measurement of the travel distance. The conditions were: the trip was one day; the trip was to one site; the trip's primary purpose was fishing; the vehicle was a car, truck, or camper; and the measured distance for the trip was less than 150 miles one-way. In addition, we excluded any trips which were in a wave where the respondent indicated some trips were not taken to and from their permanent residence. Finally, because of a coding error in the survey instrument, the data did not include any of the travel and fuel information for the trips from the final interview of the panel survey. After screening for the above conditions, there were 828 observations for the regression. The regression results for the fuel cost model are reported in Table 3.3.

The complete per mile vehicle cost was calculated by adding to each individual's predicted fuel cost a 14.1 cent per mile depreciation charge, based on the AAA depreciation charge of $141 for each 1000 miles in excess of 15,000 miles driven annually for a full size passenger vehicle (AAA 1993). This figure does not take into account annual depreciation based on normal driving. Nor does it include any of the fixed costs of vehicle ownership such as insurance. The charge is aimed at capturing the marginal cost of depreciation.

In using the fuel cost regression to predict driving costs, the explanatory variables were based on the individual's response to the "usual" travel questions. In wave six of the panel, we asked individuals about their usual vehicle type, whether or not they usually towed a boat, and whether they usually shared expenses with other households. Of the 2135 individuals who were asked the "usual" travel questions, 129 did not have a usual vehicle type of car, truck, or camper. Most of these (101 cases) said they usually walked to their fishing site. For purposes of predicting their costs of accessing other sites, it was assumed that these individuals would have to drive to get to other fishing sites, and these 129 individuals were assigned the sample average predicted driving cost per mile. The sample average predicted driving cost per mile is $0.247 and includes the per mile depreciation charge. Table 3.5 presents the summary statistics for the predicted per mile driving cost for the individuals who completed the panel.

Lodging Cost: The lodging costs used in the MSU model was specified as the average lodging cost for each individual's "usual" lodging type. For each overnight trip, respondents were asked about actual lodging types and lodging costs. The predicted costs are based on the sample average per night cost of lodging for four types of lodging: camping, hotel, cabin, and other. The "hotel" category includes hotels, motels, cabin rentals, and lodge stays and had an average cost of $47.22 per night. The "camping" category includes tent, truck and RV camping and had an average cost of $14.55 per night. The "cabin" category includes stays at one's own cabin, condominium, or cottage as well as stays at a friend or relatives place. The cabin category had an average cost of $13.26 per night. The "other" category includes activities such as staying on a boat, fishing all night long, and staying in the car with an associated average cost of $13.05 per night. Individuals were assigned the per night cost that corresponded to the type of lodging that they indicated they usually use when they take overnight trips. Some individuals were not asked their usual lodging type because they indicated that they never take overnight trips. These individuals were assigned the sample average (over trips that were taken) per night lodging cost across all types which was $16.53 per night. The per night costs are then multiplied by 3 to reflect the cost of lodging for a multi-day trip. Lodging costs are zero for single-day trips. Table 3.5, which follows the next section, provides summary statistics for the predicted lodging cost for individuals who completed the panel.

Time Cost/Wage Estimation: Time costs are the predicted value of an individual's time multiplied by the time for the trip length. It was assumed that one-day trips require 8 hours of time and multi-day trips use 3.5 eight hour days or 28 total hours of time. These are based on an assumed 12 hours of available work time per day deflated by 2/3 for an after-tax rate (or 8 hours a day with no tax rate). The predicted value of an individual's time came from a regression of wages on demographic variables. The wage regression was

Table 3.4: Results of ln(wage) Regression with Multiplicative Heteroskedasticity.

Variable	Variable description	Coefficient	Std. Error	t-ratio
X_1 = Constant	Constant	0.6965	0.144	4.83
X_2 = Education/20	Years of education/20	2.1507	0.181	11.88
X_3 = Experience/30	(Age - Education - 6)/30	0.4367	0.051	8.55
X_4 = Sex	Sex of respondent (male=1)	0.3036	0.040	7.55
X_5 = Adults/3	Number of adults in hhd/3	-0.1153	0.076	-1.52
X_6 = Kids in hhd.	# of children (<18) in hhd	0.0173	0.014	1.27
X_7 = DTC county	Detroit tri-county dummy	0.1058	0.041	2.56
Hetero. var's.				
Z_1 = Education/20	Years of education/20	1.0559	0.384	2.75
Z_2 = Age/60	Age of respondent/30	0.7754	0.217	3.58
Z_3 = Sex	Sex of respondent (male=1)	-0.1996	0.085	-2.34
Z_4 = Adults/3	Number of adults in hhd/3	0.2357	0.160	1.48
Z_5 = Kids in hhd.	# of children (<18) in hhd	-0.0579	0.032	-1.82
Z_6 = DTC county	Detroit tri-county dummy	-0.2290	0.098	-2.35
σ	Estimated standard error	0.1390	0.045	3.13

N = 1342; Log-L = -1325.97.; $\chi^2_{6\ df}$ = 232.5 for (H_0:β_2,...β_7=0); sign. level 0.0000.
Homoskedasticity tests: LR $\chi^2_{6\ df}$ =60; Wald stat. (6 df) = 623; LM stat. (6 df) = 36.

specified as a semi-log model with multiplicative heteroskedasticity. The semi-log form was based on the work of Phagan and follows a long tradition in labor economics.

The wage variable was derived from the employment information collected in wave 6 of the panel survey (see section 3.4 and section 6.2 in appendix 2 of Hoehn et al.). For individuals who worked on an hourly basis, wage was specified as their reported wage rate. For those who are on a salary, wage was derived by dividing their annual salary by their annual hours worked. Annual hours worked was calculated using information on the months and hours per week that respondents worked. Specifically,

Annual hours = { (*weeks work typical amount*) × (*hours per week typically worked*) +
(*weeks work more than usual*) × (*hours per week when working more*) +
(*weeks work less than usual*) × (*hours per week when working less*) }

where

Weeks work typical amount = { (*months worked per year*) × (52/12) – (*weeks work less than usual*) – (*weeks work more than usual*) }.

The questions about hours worked were asked in this way to try to increase the accuracy of the derivation of hours worked per year and were based on experience with the pilot survey.

The underlying wage regression model was specified as

$$\ln(W_i) = \boldsymbol{\beta} X_i + \epsilon_i \quad \text{and} \quad \epsilon_i \sim N(0, \sigma^2 \exp(\boldsymbol{\gamma} Z_i)) \qquad (3.1)$$

where X is the vector of explanatory variables for the regression, Z is the vector of explanatory variables for the multiplicative heteroskedasticity, and $\boldsymbol{\beta}$, $\boldsymbol{\sigma}$, and $\boldsymbol{\gamma}$ are to be estimated (Greene 1993, page 405). The results for the estimated wage equation are given in Table 3.4. The independent variables used in the regression were years of education, age, gender, experience, the number of kids in the household, the number of adults in the household, and a dummy variable for those who live in the Detroit metro counties of Monroe, Oakland, and Wayne. Experience was defined as age minus years of education minus six. In the estimated model, several of the variables were rescaled to facilitate convergence because, as Greene notes, the multiplicative heteroskadastic models are very sensitive to the scaling of the data (Greene 1992, page 266). The rescaled variables are indicated in Table 3.4.

The wage model was estimated with the software package, *LIMDEP*, which reports statistics for three tests of homoskedasticity: a likelihood ratio test that all the $\boldsymbol{\gamma}$ terms are zero, a Wald test based on an OLS version of the model, and Breusch and Pagan's lagrange multiplier test. The statistics are presented in the bottom of Table 3.4. The hypotheses of homoskedasticity are rejected by all three tests. The model was also estimated with a constant and the full set of variables for the heteroskedastic term but without any of the other slope variables (X_2 to X_7). This was done to test the joint significance of the estimated slope variables, $\beta_2,\ldots,\beta_7$. The log likelihood value for this model was -1442.22, so the null hypothesis that slope variables were jointly zero was rejected.

The wage equation used to predict the time value of survey respondents was calculated using the following formula for semi-log models:

$$E(W_i|X_i) = \exp(\beta X_i + \sigma^2 \exp(\gamma Z_i)) \quad (3.2)$$

where β, σ, and γ are replaced by their estimated coefficients (see Kmenta, page 511). The regression was applied to all individuals with valid data for the independent variables. Table 3.5 presents the summary statistics for the predicted wage variable for the individuals who completed the panel.

Table 3.5: Summary of Predicted Values for Individual Specific Cost Variables.

			Percentiles						
Predicted values	**Mean**	**Std. dev.**	**Min.**	**10%**	**25%**	**50%**	**75%**	**90%**	**Max**
Hourly wage rate	15.22	5.20	5.5	9.6	11.6	14.2	17.9	22.0	42.9
Per mile driving cost	0.25	0.03	0.216	0.216	0.216	0.247	0.259	0.285	0.29
Per night lodging cost	19.24	11.14	13.1	13.3	14.6	14.6	16.5	47.2	47.2

3.2.2 Site Level Variables

This section briefly describes the variables which are used to describe the quality of elementary site alternatives.

Catch Rates (CR): Catch rates for various species in the GL warm, GL cold, and Anad product lines are included in the model. In the GL warm product line, catch rates were computed for yellow perch, walleye, northern pike, bass (which includes smallmouth bass, largemouth bass, bluegill, and pumpkinseed), and carp (which includes carp, freshwater drum, catfish, and suckers). In the GL cold line, catch rates are included for chinook salmon, coho salmon, lake trout, and rainbow trout. For the Anad product line, catch rates are included for chinook salmon, coho salmon, and rainbow trout. These catch rates were computed from MDNR Creel Survey data from the late 1980s and were employed by Jones and Sung. Specifically, catch rate equations were estimated by species for sites with creel data, and this equation was used to predict catch rates at all sites.[6] Predicted catch rates vary monthly throughout the open-water season. Section 3.1.1 of appendix 1 of Hoehn et al. provides additional information as well a summary statistics for the catch rates by species and by month.

Inland lakes: In the IL warm product line, the total surface area (in acres) of warm-water inland lakes within the county is included in the model. Similarly, for the IL cold product line, the total surface area (in acres) of cold-water lakes within the county is included. Two-story lakes are contained in the total lake acreages for both product lines.

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[6] These were Poisson regressions for count data, implemented by Douglas Jester, Michigan Department of Natural Resources.

Quality of streams: In both the RS cold and RS warm product lines, the miles of stream in various quality categories in the county are included. The categories are top quality main stem, second quality main stem, top quality tributary, second quality tributary. These categories were determined by the MDNR (Merna et al.), which has measured the miles of warm stream and cold stream in each category for each county in Michigan. In the MSU model, the main stem and tributary miles were combined. These stream quality variables reflect the overall ability of the stream to produce a high-quality fishery; they do not reflect any special aesthetic or other feature. The inland lake and stream variables are discussed in more detail in Appendix 1, Section 3.1.2 of Hoehn et al. -- see also the tables accompanying that section.

Cabin: This dummy variable was used to identify whether an individual had a cabin, cottage, or vacation home in a particular county. The cabin information was collected in the survey. The effect of this variable was allowed to differ by trip duration but it does not differ across product lines within a given trip length.

3.2.3 Other Levels of Nesting

Constants: When possible, choices (or branches of the nesting structure) were distinguished by including constants. Recall from the discussion of the nesting structure that there are 24 distinct groups at the product line level of the nesting structure -- 12 combinations of product lines and Great Lake/non-Great Lake counties, and 2 trip lengths. There are 22 dummy variables distinguishing the various combinations of product lines and Great Lake/non-Great Lake counties -- eleven each in the single and multiple-day branches of the model. There is also a constant at the trip duration level and another constant at the participation level. In a logit type model, the use of constants ensures that the estimated

model fits the observed sample data at the level of the constant, the baseline model predictions at the level of that constant will match the sample predictions. For example, since the MSU model contains a constant at the participation level, the model's baseline predicted trips will match the number of trips in the sample data. The baseline model predictions are the predictions that result from evaluating the model at the same data values that were used during estimation.

Demographics: At the participation level of the model, demographic variables are included to distinguish among different types of anglers. The demographic variables include sex, age, and years of education. At the trip duration level, the model includes a variable that allows individuals who were employed to have a different value of time than those who did not have a paying job. The variable serves as a shifter for the predicted value of time for individuals without a paying job. The variable was created by interacting an employment dummy with each individual's predicted wage. Specifically, the dummy variable took the value 1 if the person *did not* have a paying job and zero otherwise, and this dummy was multiplied by the person's predicted wage. The parameter on the shifter variable is only identified at the trip duration level of the model.

Inclusive values: As described earlier, at each level of the decision tree, an inclusive value index is included from the next lower level of the nesting structure. Since the MSU model has four levels, there are three inclusive value indices -- at the participation level, at the trip duration level, and at the product line level (see Figure 3.1). The inclusive value index is not a separate variable. Rather, it is used to identify parameters of the statistical distribution of nested logit models. If the parameter on the inclusive value is significantly less than 1, then the nested logit is preferred to a simple multinomial logit. In order for the model to be consistent with the economic theory outlined above, the estimated coefficients on the inclusive value indices need to lie between zero and one.[7]

3.3 A Repeated Logit Model of Recreational Fishing

The MSU model of the demand for recreational fishing in Michigan is a repeated random utility model (RUM) which was estimated as a four-level nested logit. The general structure of the repeated nested logit model (trip types, choice sets, nesting structure, and choice occasions) was presented above. Here, the model is cast in the general notation of Chapter 2. Elemental alternatives in the model are combinations of trip length, water body type, species type, and fishing destination. Fishing destinations are counties in Michigan which support trips for a particular water body type and a particular species type. The three water body types are Great Lakes (GL), inland lakes (IL), and river/streams (RS). The two broad species types are warm-water species (e.g., bass, yellow perch, and walleye) and cold-water species (e.g., trout and salmon). Combinations of water body type and species type (as well as anadromous runs) are referred to as product lines (PLs). The trip lengths are single-day trips and multiple-day trips. Because the MSU model is also a model of participation, there is another elemental alternative which represents "not fishing" or "staying home" during a choice occasion.

On a given occasion, let U_{kstp} be the indirect utility function of taking a trip to county k, product line/shoreline s, and trip length t, given a trip is taken (participation) p. Also let U_h be the utility of staying home, where h indicates not participating in the fishing activities on the occasion. As a result, under the hypothesis of random utility maximization, the

[7] This is a necessary condition for global consistency (McFadden, 1978 and 1981). A local condition can be derived which allows the coefficient on the inclusive value to be larger than one, but it does not give much leeway beyond the global condition (Herriges and Kling, 1996b).

decisions of whether or not to participate in fishing on an occasion, and if so, taking the trip to a particular county k^d, shore line and product line s^d, at length t^d imply the utility inequality:

$$U_{k^d s^d t^d p} > U_{kstp} \quad and \quad U_{k^d s^d t^d p} > U_h \tag{3.3}$$

for all feasible $\{k,s,t\} \neq \{k^d,s^d,t^d\}$, i.e., the utility of the chosen site and trip type is greater than the utility of any other type of trip to any other site in the choice set. Similarly, if the staying home option is observed on the occasion, we have the inequality

$$U_h > U_{kstp} \tag{3.4}$$

for all feasible $\{k,s,t\}$.

Since the researcher cannot observe all the factors that influence the choice decisions made by individuals, the utility function U_{kstp} is treated as stochastic and specified as the sum of a deterministic term, V_{kstp}, and a stochastic term, ϵ_{kstp}. V_{kstp} is the deterministic indirect utility of taking a trip of type kst, which in our case is specified as a linear function of the explanatory variables and parameters to be estimated. The ϵ's represent the stochastic utility portion that are not measurable by the researcher and are assumed to follow a generalized extreme value (GEV) distribution. The utility of "staying home" is also specified as the sum of deterministic and stochastic terms, $U_h = V_h + \epsilon_h$. V_h is specified as a linear function of demographic characteristics. The ϵ_h have the GEV distribution. Repeating the utility maximization behavior over the occasions in a season results in a repeated logit model.

3.3.1 The Sample Likelihood Function and Choice Probabilities

On an occasion in month m, let Pr^{im}_{kstp} be the joint choice probability of taking a trip to county k in product line/shoreline combination s of trip length t for individual i during month m. Let Pr^{im}_{h} be the probability of not taking a trip on the occasion in month m. For a particular individual i in the sample, the likelihood function during month m is the product of the joint choice probabilities Pr^{im}_{kstp} for the occasions in which the trips are observed and the probabilities Pr^{im}_{h} for the occasions when there is no trip. That is

$$L^{im} = N_{OC}{}^{im} \times Pr^{im}_{h} \times \{ \prod_{kst \in I^m} Pr^{im}_{kstp} \} \tag{3.5}$$

where $N_{OC}{}^{im}$ is the number of choice occasions in month m where no trip is observed, and I^m is the set of sites/trip types (kst) for individual i during month m. As a result, the product of the L^{im} over all individuals and months yields the sample likelihood function, $L = \prod_{im} L^{im}$.

To estimate the nested logit model by maximizing the likelihood function L, the choice probability of taking a trip on an occasion in month m for individual i (Pr^{im}_{kstp}) can be re-expressed as the product of the conditional probabilities as follows (the superscript i is suppressed when there is no confusion):

$$Pr^{m}_{kstp} = Pr^{m}_{k|stp} \, Pr^{m}_{s|tp} \, Pr^{m}_{t|p} \, Pr^{m}_{p} \tag{3.6}$$

where the conditional probabilities in the right hand side of the equation are defined as follows:

- $Pr^{m}_{k|stp}$ the probability of a trip to county k in month m, conditional on product line/shoreline combination s, trip length t, and participation p.
- $Pr^{m}_{s|tp}$ the probability of a trip to product line/shoreline combination s in month m, conditional on a trip of length t, and participation p.
- $Pr^{m}_{t|p}$ the probability of a trip of length t in month m, conditional on participation p.
- Pr^{m}_{p} the probability of taking a trip on a choice occasion in month m.

To estimate the model, the random terms ϵ's are assumed to follow a generalized extreme value (GEV) distribution

$$F(\epsilon) = \exp(-e^{-\epsilon_h}) \exp\left(-\left[\sum_t \left\{\sum_s \left(\sum_k e^{-\frac{1}{\rho_t}\epsilon_{kstp}}\right)^{\frac{\rho_t}{\omega}}\right\}^{\frac{\omega}{\eta}}\right]^{\eta}\right) \tag{3.7}$$

where the subscripts *k, s, t, p* index the feasible counties, product line/shoreline combinations, trip lengths, and the participation, respectively. The *k, s, t, p* subscripts index groups of alternatives within four-level hierarchy of the GEV nesting structure (see McFadden 1981 for more on the GEV distribution). To increase the model's flexibility, there are separate scale parameters at the level of the product line/shoreline combinations (ρ_t) for the single-day trip branch and the multiple-day trip branch. The other scale parameters ω and η remain the same within their respective levels.

As a result of using the GEV distribution function, there exist analytic solutions for the conditional choice probabilities making estimation of the nested logit model tractable even though the feasible choice set is very large. The conditional choice probabilities are expressed in what follows.

Conditional Site Choice Probabilities: At the bottom or fourth level of the nested logit, the conditional probability of taking a trip to county *k* in the product line/shoreline combination *s* of length *t* in month *m* is

$$Pr_{k|stp} = \frac{\exp(\alpha_1^t p_{kt} + \alpha_2^t q_{ks}^m + \alpha_3^t Cbn_{kt})}{\sum_{k|stp} \exp(\alpha_1^t p_{kt} + \alpha_2^t q_{ks}^m + \alpha_3^t Cbn_{kt})} \tag{3.8}$$

where $\sum_{k|stp}$ means that the summation is over the feasible counties within the product line/shoreline combination s, trip length t, and participation p in month m. $\boldsymbol{\alpha}$ represents parameters to be estimated. There are three types of explanatory variables at this level:

i. p_{kt} the individual specific trip price. The trip price is the sum of the predicted driving cost, predicted lodging cost, and predicted time cost. Trip price varies over individuals because the driving distances differ, and because the predicted costs of driving, lodging, and time value differ.

ii. q^m_{ks} the site quality variables. Some of the q are time varying since the catch rates change on a monthly basis.

iii. Cbn_{kt} is a dummy variable indicating if the individual has a cabin or vacation home in county k that is feasible for the trip length t.

The t superscript on $\boldsymbol{\alpha}$ reflects the fact that separate parameter vectors were used to index single and multiple-day trips ($\boldsymbol{\alpha}^1$ and $\boldsymbol{\alpha}^2$, respectively), allowing the variables to have different effects on the utility of trips of different length. The inclusive value of taking a trip to product line/shoreline s of length t in month m is $iv^m_{stp} = \log[\sum_{k|stp} \exp(\boldsymbol{\alpha}^t_1 q^m_{ks} + \boldsymbol{\alpha}^t_2 p_{kt} + \boldsymbol{\alpha}^t_3 Cbn_{kt})]$.

Conditional Product Line/Shoreline Probabilities: On the third level, the conditional probability of taking a trip to the product line/shoreline s of length t in month m is:

$$Pr_{s|tp} = \frac{\exp(\boldsymbol{\beta}^t_1 iv^{im}_{stp} + \boldsymbol{\beta}^t_2 D_s)}{\sum_{s|tp} \exp(\boldsymbol{\beta}^t_1 iv^{im}_{stp} + \boldsymbol{\beta}^t_2 D_s)} \qquad (3.9)$$

where $\sum_{s|tp}$ means that the summation is over all the feasible product line/shoreline combinations $s \in S$. There are two types of explanatory variables at this level:

i. Eleven dummy variables (D_s) for the combinations of product lines and counties with/without GL shoreline, s. GLwarm is normalized at 0 for identification during the model estimation.

ii. The inclusive values iv^m_{stp} of taking a trip to s, calculated from the bottom level.

$\boldsymbol{\beta}^t$ is the vector of parameters to be estimated. The t superscript reflects the fact that the parameter vectors differ by the trip lengths: $\boldsymbol{\beta}^1$ is for single-day trips and $\boldsymbol{\beta}^2$ is for multiple-day trips ($\boldsymbol{\beta}^2$). Then, the inclusive value of taking a trip of length t in month m is:

$iv^m_{tp} = \log\left[\sum_{s|tp}\exp(\boldsymbol{\beta}^t_1\, iv^m_{stp} + \boldsymbol{\beta}^t_2 D_s)\right]$.

Conditional Trip Length Probability: At the second level, the conditional probability of taking a trip of length t in month m is:

$$Pr_{t|p} = \frac{\exp(\boldsymbol{\gamma}_1 iv^m_{tp} + \boldsymbol{\gamma}_2 D_t + \boldsymbol{\gamma}_3 Tc_t Jb)}{\sum_{t|p}\exp(\boldsymbol{\gamma}_1 iv^m_{tp} + \boldsymbol{\gamma}_2 D_t + \boldsymbol{\gamma}_3 Tc_t Jb)} \tag{3.10}$$

where $\sum_{t|p}$ means that the summation is over the single-day and multiple-day trip types, given participation. The conditional trip length probability consists of three kinds of variables:

i. A dummy variable with D_t=1, if it is a multiple-day trip, 0 otherwise.

ii. The trip's time cost interacted with a dummy for individuals without a job ($Tc_t \times Jb$). The variable is intended allow individuals without a job to have a time cost that differs from the predicted time cost.

iii. The inclusive values iv^m_{tp} calculated from the shoreline/product line choice level.

The inclusive value for taking a trip in month m is $iv^m_p = \log\left[\sum_t \exp(\boldsymbol{\gamma}_1 iv^m_{tp} + \boldsymbol{\gamma}_2 D_t + \boldsymbol{\gamma}_3 Tc_t Jb)\right]$.

Participation Probability: At the top level, the probability of taking a trip in month m is

$$Pr_p = \frac{\exp(\boldsymbol{\delta}_1 iv_p^m + \boldsymbol{\delta}_3 D_m)}{\exp(\boldsymbol{\delta}_2 sd) + \exp(\boldsymbol{\delta}_1 iv_p^m + \boldsymbol{\delta}_3 D_m)} \tag{3.11}$$

where $\boldsymbol{\delta}$ are the parameters to be estimated. In any month *m*, there are two types of variables at the participation level: (*i*) seven dummy variables; D_m=1 if the trip was observed in month *m* for April through October, and (*ii*) the inclusive values iv_p^m calculated from the trip length choice level.

Similarly, the probability of staying home on an occasion in month *m* is

$$Pr_h = \frac{\exp(\boldsymbol{\delta}_2 sd)}{\exp(\boldsymbol{\delta}_2 sd) + \exp(\boldsymbol{\delta}_1 iv_p^m + \boldsymbol{\delta}_3 D_m)} \tag{3.12}$$

Again, $\boldsymbol{\delta}$ are the parameters to be estimated. The relative utility of staying home is indexed by three demographic variables *sd*: (1) the natural logarithm of age, (2) the natural logarithm of years of education, and (3) gender with 1 for male, 0 for female.

The inclusive value of an occasion in month *m* is $iv^m = \log[\exp(V_h) + \exp(\boldsymbol{\delta}_1 iv_p^m + \boldsymbol{\delta}_3 D_m)]$. Note that $iv^m + \boldsymbol{\kappa}$ (where $\boldsymbol{\kappa}$ is Euler's constant) is the expected maximum utility of taking a trip on an occasion in month *m*. This will be used for the welfare estimation later on.

<u>Joint Probability</u>: Using the explanatory variables presented above, on a given occasion the choice probability of taking a trip to *k, s, t, p,* in month *m* is given by:

$$Pr(kstp) = Pr(k|stp) \times Pr(s|tp) \times Pr(t|p) \times Pr(p)$$

$$= \frac{\exp(\boldsymbol{\alpha}_1^t p_{kt} + \boldsymbol{\alpha}_2^t q_{ks}^m + \boldsymbol{\alpha}_3^t Cbn_{kt})}{\sum_{k|stp} \exp(\boldsymbol{\alpha}_1^t p_{kt} + \boldsymbol{\alpha}_2^t q_{ks}^m + \boldsymbol{\alpha}_3^t Cbn_{kt})} \times \frac{\exp(\boldsymbol{\beta}_1^t iv_{stp}^{im} + \boldsymbol{\beta}_2^t D_s)}{\sum_{s|tp} \exp(\boldsymbol{\beta}_1^t iv_{stp}^{im} + \boldsymbol{\beta}_2^t D_s)}$$
$$\times \frac{\exp(\boldsymbol{\gamma}_1 iv_{tp}^m + \boldsymbol{\gamma}_2 D_t + \boldsymbol{\gamma}_3 Tc_t Jb)}{\sum_{t|p} \exp(\boldsymbol{\gamma}_1 iv_{tp}^m + \boldsymbol{\gamma}_2 D_t + \boldsymbol{\gamma}_3 Tc_t Jb)} \times \frac{\exp(\boldsymbol{\delta}_1 iv_p^m + \boldsymbol{\delta}_3 D_m)}{\exp(\boldsymbol{\delta}_1 iv_p^m + \boldsymbol{\delta}_3 D_m) + \exp(\boldsymbol{\delta}_2 sd)} . \qquad (3.13)$$

The probability of staying home on an occasion in month m was given in equation (3.12).

<u>Likelihood function</u>: By substituting (3.12) and (3.13) into (3.5) and incorporating the survey sampling weight w^i for individual i, the sample log-likelihood function is given by:

$$\log(L) = \sum_i w^i \left\{ \sum_m \left[\sum_{kst \in I^m} \log(L_{kst}^{im}) + No^{im} \log(L_h^{im}) \right] \right\} \qquad (3.14)$$

where I^m is the set of sites visited by individual i during month m, and No^{im} is the number of times individual i does not go fishing during month m. In addition,

$$\log(L_h^{im}) = \boldsymbol{\delta}_2 sd^i - \log\left(\exp(\boldsymbol{\delta}_2 sd^i) + \exp(\boldsymbol{\delta}_1 iv_p^{im} + \boldsymbol{\delta}_3 D_m)\right) \qquad (3.15)$$

and

$$\begin{aligned} \log(L_{kst}^{im}) &= \boldsymbol{\alpha}_1^t p_{kt}^i + \boldsymbol{\alpha}_2^t q_{ks}^m + \boldsymbol{\alpha}_3^t Cbn_{kt}^i - \log\left(\sum_{k|stp} \exp(\boldsymbol{\alpha}_1^t p_{kt}^i + \boldsymbol{\alpha}_2^t q_{ks}^m + \boldsymbol{\alpha}_3^t Cbn_{kt}^i)\right) \\ &+ (\boldsymbol{\beta}_1^t iv_{stp}^{im} + \boldsymbol{\beta}_2^t D_s) - \log\left(\sum_{s|tp} \exp(\boldsymbol{\beta}_1^t iv_{stp}^{im} + \boldsymbol{\beta}_2^t D_s)\right) \\ &+ (\boldsymbol{\gamma}_1 iv_{tp}^{im} + \boldsymbol{\gamma}_2 D_t + \boldsymbol{\gamma}_3 Tc_t^i Jb^i) - \log\left(\sum_{t|p} \exp(\boldsymbol{\gamma}_1 iv_{tp}^{im} + \boldsymbol{\gamma}_2 D_t + \boldsymbol{\gamma}_3 Tc_t^i Jb^i)\right) \\ &+ (\boldsymbol{\delta}_1 iv_p^{im} + \boldsymbol{\delta}_3 D_m) - \log\left(\exp(\boldsymbol{\delta}_1 iv_p^{im} + \boldsymbol{\delta}_3 D_m) + \exp(\boldsymbol{\delta}_2 sd^i)\right) \end{aligned} \qquad (3.16)$$

3.3.2 Estimation

The overall parameter vector ($\boldsymbol{\alpha},\boldsymbol{\beta},\boldsymbol{\gamma},\boldsymbol{\delta}$) in equations (3.15) and (3.16) consists of 78 parameters to be estimated. Given the size of the problem, the model was estimated in two stages. The lower three levels of nesting (trip length, product line, and site) were estimated at one time, using full information maximum likelihood methods (FIML). In the second stage, the participation model was estimated. The second stage employs a sequential estimation method for nested logits, using the inclusive value estimate from the lower three levels as one of the explanatory variables.[8] A FIML routine that would have permitted the model to be estimated in one stage was explored, but the sequential strategy allowed more cases to be included in the analysis. A case that did not have complete details of the location of a fishing trip could be used at the participation level of the model even though the information would not be suitable for use at the site choice levels of the model. In the four-level FIML such a case would need to be dropped because the joint probability of the event could not be computed. Moreover, FIML estimation of only the first stage of the model, the lower three levels, took almost a month to complete on a Pentium personal computer. Thus, due to the size of the estimation problem and the less stringent data requirements, the above two-stage approach was adopted. The parameter estimates will be presented in Tables 3.6 and 3.7.

3.3.3 The Welfare Measure

The MSU model can be used to estimate the benefits attributable to site quality changes and to the addition or elimination of a site. Before presenting the formula for

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[8] The sequential estimates are consistent, but not efficient (Amemiya). The sequential standard errors do not account for the fact that the inclusive value is itself a random variable.

welfare evaluations, the estimated parameters are mapped to the desired parameters of the underlying indirect utility functions.

In general notation, we can write the deterministic portion of the utility of a trip to site/type *kstp* as:

$$V^{m}_{kstp} = \boldsymbol{\lambda}(Y\text{-}p'_{kt}) + \boldsymbol{\theta} X \tag{3.17}$$

where Y is income per choice occasion (unobserved), p'_{kt} is the price of a trip of length t to county k, and X represents all of the variables which describe the different sites and trip types. The parameters to be estimated are $\boldsymbol{\lambda}$ and $\boldsymbol{\theta}$, where $\boldsymbol{\lambda}$ is the marginal utility of income and $\boldsymbol{\theta}$ represents the marginal utility of the elements of X.

By estimating the nested logit model using the joint density in specification (3.13), the generalized extreme value distribution parameters in (3.7) can be expressed as $\boldsymbol{\rho}_t/\boldsymbol{\omega}=\boldsymbol{\beta}^t_1$, $\boldsymbol{\omega}/\boldsymbol{\eta}=\boldsymbol{\gamma}_1$ and $\boldsymbol{\eta}=\boldsymbol{\delta}_1$. That is, $\boldsymbol{\eta}=\boldsymbol{\delta}_1$, $\boldsymbol{\omega}=\boldsymbol{\gamma}_1\times\boldsymbol{\delta}_1$, and $\boldsymbol{\rho}_t=\boldsymbol{\beta}^t_1\times\boldsymbol{\gamma}_1\times\boldsymbol{\delta}_1$. Therefore, in terms of the specific variables and parameters used in the above discussion of the probabilities, the deterministic portion of the utility of a trip to site/type *kstp* is given by

$$\begin{aligned} V^{m}_{kstp} &= \boldsymbol{\rho}_t\left(\boldsymbol{\alpha}^t_1 p_{kt} + \boldsymbol{\alpha}^t_2 q^m_{ks} + \boldsymbol{\alpha}^t_3 Cbn_{kt}\right) + \frac{\boldsymbol{\omega}}{\boldsymbol{\rho}_t}\boldsymbol{\beta}^t_2 D_s + \frac{\boldsymbol{\eta}}{\boldsymbol{\omega}}\boldsymbol{\gamma}_2 D_t + \frac{\boldsymbol{\eta}}{\boldsymbol{\omega}}\boldsymbol{\gamma}_3 Tc_t Jb + \boldsymbol{\delta}_3 D_m \\ &= \boldsymbol{\beta}^t_1\boldsymbol{\gamma}_1\boldsymbol{\delta}_1\left(\boldsymbol{\alpha}^t_1 p_{kt} + \boldsymbol{\alpha}^t_2 q^m_{ks} + \boldsymbol{\alpha}^t_3 Cbn_{kt}\right) + \frac{\boldsymbol{\beta}^t_2}{\boldsymbol{\beta}^t_1} D_s + \frac{\boldsymbol{\gamma}_2}{\boldsymbol{\gamma}_1} D_t + \frac{\boldsymbol{\gamma}_3}{\boldsymbol{\gamma}_1} Tc_t Jb + \boldsymbol{\delta}_3 D_m \end{aligned} \tag{3.18}$$

Notice that recovering the parameters of the underlying indirect utility function, requires the transformation of the estimated parameters $(\boldsymbol{\alpha},\boldsymbol{\beta},\boldsymbol{\gamma},\boldsymbol{\delta})$ by the appropriate parameters from the GEV distribution $(\boldsymbol{\gamma}_t,\boldsymbol{\omega},\boldsymbol{\eta})$.

The welfare measures are calculated as the areas under the site demand curves conditional on the number of single and multiple day trips. The overall welfare measure is then the sum of the trip weighted welfare measures. Specifically, for each individual, we calculate a monthly welfare measure and then sum these across individuals and across months. The individual and month specific welfare measure for individual *i* is defined by

$$\Delta W = \sum_m (T_m^{SD} \times CV_m^{SD} + T_m^{MD} \times CV_m^{MD}) \tag{3.19}$$

where T_m^t is the predicted single day (multiple day) trips in month *m* for this individual and CV_m^t is the welfare measure conditional on a trip of length *t* in month *m*. T^t is given by $Oc_m \times Pr_{t|p}^m \times Pr_p^m$ where *t*=sd,md; Oc_m is the feasible number of occasions in month *m*; and $Pr_{t|p}^m \times Pr_p^m$ is the probability of taking a trip of length *t* in month *m* and uses the probabilities as defined in equations 3.10 and 3.11. CV_m^t is givin by $\{iv_{tp}^m(1) - iv_{tp}^m(0)\}/\boldsymbol{\lambda}_t$ where 0,1 refer to the "with" and "without" levels of quality; iv_{tp}^m is the inclusive value of taking a trip of length *t* in month *m* as defined within and prior to equation 3.10; and $\boldsymbol{\lambda}_t$ equals $-\boldsymbol{\alpha}_1^t \times \boldsymbol{\beta}_1^t$ for *t*=sd,md.

The welfare measure in 3.19 differs from the welfare measure defined in the Hoehn *et al.* report and subsequently utilized in the valuations reported in Lupi. The measure in 3.19 accounts for the differing travel price parameters for the single and multiple day trip length. Alternatively, the Hoehn *et al.* report used the single day trip price parameter in the denomenator of the welfare measure, regardless of trip length. The *Hoehn et al.* report notes that using the single-day price parameter to value all trips results in a smaller welfare measure since it places less weight on multiple-day trips. The above measure mirrors the measure that would be obtained from *separate* demand models for single and multiple day trips. The decision to use the measure in 3.19 is based in part on the work of Lupi and represents our best judgement to date.

3.3.4 Extrapolating Model Results Statewide

This section describes the method used to extrapolate predicted trips and welfare measures from the model estimation sample to the state population. Intuitively, the extrapolation involves five steps: a) use the screening sample to determine the fraction of Michigan adults that are potential anglers; b) multiply this fraction by the population of Michigan adults to derive an estimate of the population of potential anglers in Michigan; c) make desired calculations from the model such as welfare measures and trip predictions; d) take the weighted average of these for the individuals used to estimate the model; and e) multiply the average by the population of potential anglers. The end result is a statewide estimate.

Define the following variables:

N = Population of adults in state (6,836,500).

S = Number of completed screening calls (6,342).

R_w = The weighted number of cases recruited using *wght_c* as the weight, i.e., the weighted number of potential anglers in the screening sample. The sum of *wght_c* is equal to S by construction. $R_w = 3393$. The weights are discussed in Section 5 of Appendix 1 of Hoehn et al.

$\frac{R_w}{S}$ = The estimated fraction of Michigan adults that are potential anglers (0.535).

$N \times \frac{R_w}{S}$ = The estimate of Michigan adults that are potential anglers (3,657,528).

F = Number of cases with complete panel data (1,902), discussed in Section 4 of Appendix 1 of Hoehn et al.

w_{fi} = Weight assigned to full panel member *i* which corrects for differences in screening sample of potential anglers and the sample meeting the conditions for complete panel data; defined as *wght_f* in Section 5, Appendix 1 of Hoehn et al.

ΔW_i = Welfare measure for full panel member *i*, as defined in (3.19).

The weighted average welfare measure over full panel members is denoted by ΔW ^{bar} which is defined as follows:

$$\Delta W \quad = \quad \frac{\sum_i w_{fi} \times \Delta W_i}{F} \qquad (3.20)$$

To extrapolate the welfare change to the statewide population of potential anglers, we need only multiply ΔW by our estimate of the population of potential anglers. If we let ΔW_{mich} denote the aggregate welfare measure for the state, then ΔW_{mich} is defined as

$$\Delta W_{mich} \quad = \quad N \times \frac{R_w}{S} \times \Delta W. \qquad (3.21)$$

The same approach was used to extrapolate other predictions from the model. In particular, predicted trips to site *j* during month *m* were extrapolated in the same two steps: first, the weighted average over the full panel of the predicted trips to site *j* in month *m* was derived, and second, the average was multiplied by the estimated population of potential anglers. Predicted trips associated with the baseline data are presented at the end of this chapter. Predicted trips and welfare measures for various scenarios involving changes in lake trout catch rates are presented in Chapter 4.

3.4 The Survey Data

In order to estimate the parameters of the MSU model, the data describing the sites and types of trips was combined with behavioral data from a survey of Michigan residents who were identified as potential anglers. These data included demographic information about individuals, where they went fishing, how often they went fishing, along with details of their fishing trips. This section provides an overview and summary of the survey. A more complete discussion is provided in Appendix 2 of Hoehn et al.

3.4.1 Survey Overview

An important goal of the survey was to obtain accurate data on the number and types of trips individual anglers take in Michigan over the course of a fishing season. Since it is difficult to remember the details of what one does over the course of a season, especially if there are many events to recall, the survey developed for this project followed a sample of anglers throughout the 1994 fishing season. This type of study is called a panel survey. Recall difficulties have been shown to increase with the length of the recall period and the number of intervening fishing events (WESTAT).[9] A panel study where individuals are followed over time can mitigate recall problems. In the MSU panel survey, the length of time between individuals' panel interviews was varied depending on the anticipated frequency of an individual's fishing activities. In this way, recall periods were shorter for anglers who fished often.

There are three main types of interview methods for conducting survey research: in-person interviews, telephone interviews, and mail surveys. Given the goals of the study, a telephone format was selected as the best mode of survey administration. Telephone surveys allow for both flexibility and control over how data is collected. In particular, the telephone method facilitates control over who answers questions, how questions are presented, and the order in which information is presented. In a telephone interview, questions can be used to screen and categorize respondents so that are only asked relevant

[9] The MDNR has experimented with alternative mail survey formats. A comparison of three month and annual recall periods demonstrated that frequent anglers' recall of trips is substantially biased upward with the longer recall period (Jester, personal correspondence).

questions. For example, one question can be used to determine whether or not a panel member has fished since the last contact. In-person interviews are impractical in this regard, and response rates in a mail survey might suffer from the necessity for repeated mail-backs.

The telephone survey was implemented using a Computer Assisted Telephone Interviewing (CATI) system. One advantage of CATI surveys is that the survey instrument can be programmed to utilize complex skip patterns without having to depend on the interviewer or the respondent to follow the appropriate skip patterns. A CATI instrument can also be programmed so that questions automatically utilize information that was provided in response to previous questions and earlier interviews. For example, when asking panel members whether they fished since the last interview, the CATI system provided the date of their last interview along with the date and location of their last trip. Tailoring the survey instrument to each individual can improve the accuracy of respondents' answers, reduce the length of the interview, and reduce the cognitive burden of the interview on respondents. The CATI system also made it easy to track the status of each case. For example, the system tracks the time and disposition of all call attempts on a particular case.

Before any survey instruments were developed, qualitative research was conducted through four focus groups composed of Lansing-area anglers. A great deal of use was made of a subsequent pilot survey, including feedback from interviewers, reading of case notes, and analysis of the pilot data. Researchers also listened to mock interviews, conducted pretest calls, monitored interviews, and debriefed interviewers. In addition, comments were sought and received from a team of external peer reviewers.

The survey research contained two stages: a pilot survey and the full survey. The pilot survey was a small-scale version of the full survey. The pilot survey was conducted during the fishing season of 1993, and the full survey was conducted in 1994. The pilot survey allowed the MSU team to thoroughly pretest and develop the survey questions. The pilot also provided an opportunity to determine some of the parameters of the population. The knowledge acquired from the pilot survey enabled the design of the full survey to be optimized.

Both the pilot and the full surveys consisted of two phases: a screening interview to recruit potential anglers into the panel and the subsequent panel interviews. The samples were based on stratified, randomly selected telephone numbers of Michigan residents. Each time panel participants were called, they were asked about their fishing activities since the previous interview.

3.4.2 The Survey Sample

The telephone sample was drawn from the phone numbers for the general population of Michigan residents. A list of randomly generated numbers was purchased from Survey Sampling, Inc. (SSI). To improve the efficiency of the screening interviews, the sample of telephone numbers was stratified. The stratification was done by county, so that the proportion of numbers from each county matched the proportion of licensed anglers in that county. There were 13,561 telephone numbers from which an attempt was made to obtain an interview.

All of the project's telephone interviewing was conducted by the Survey Research Division (SRD) of the Institute for Public Policy and Social Research (IPPSR) at Michigan State University. The initial telephone contact was a screening interview to identify potential anglers and recruit them into the panel. An adult (age 18 or older) respondent was selected from the household. Because males are more likely to fish than females[10], males were over-sampled in the screening interviews. In households with both male and female adults, a male was chosen two-thirds of the time while a female was chosen one-third of the time. In households with multiple male or female adults, a random adult member of the household was recruited by asking for the individual that most recently celebrated a birthday.

The screening interview was a short interview that asked a few questions about fishing and a few demographic questions (see Appendix 2, Section 6 of Hoehn et al. for the text of this instrument). The screening interviews for the full survey were conducted from late March through early May, 1994. Anyone who indicated that they fished in the previous year and/or that they were "likely" to fish during the upcoming year was asked to participate in the panel study. Thus, the population of interest was Michigan residents who are "potential anglers," where potential is measured by either having fished in the previous year or having stated an intention to fish in the upcoming season. All others are considered to be non-anglers. The project did not consider the impact that changes in fishing quality might have on movements between the potential and non-angler groups. For example, cleaning up a contaminated site may benefit anglers, and may entice some individuals who do not now fish to take up the sport. This latter effect was not included in the analyses, and, to the extent that it occurs, the MSU approach leads to an underestimate of the benefits of the clean-up.

6,342 individuals completed the screening interview. The response rate for completing the screening interviews was between 62% and 75%, depending upon the method of calculating response rates. Section 4 of Appendix 2 of Hoehn et al. presents the disposition codes for the survey so that any desired method of calculating response rate can

[10] That fact that males in Michigan fish more than females is based on the pilot information, license sales data, and previous surveys (Mahoney et al.).

GENERAL OUTLINE OF A PANEL WAVE INTERVIEW

1. Ask if R fished, and if so how many times R fished

2. **Trip Loop** (for each time R fished)

    Month and Date of trip
    Was it an overnight trip?
    Number of sites fished at

    Site Loop (for each site on this trip)
        Name and location of site
        Time spent fishing at site
        Species tried to catch at site
        Was a boat used?
    Repeat Site Loop for each site on this trip

    Main site (if multiple site trip)
    Purpose of trip
    Lodging question (if overnight trip)
    Transportation questions (first trip only)

    Repeat Trip Loop for each trip for this wave

3. Some Final Closing Questions

Figure 3.2: Structure of Panel Interview.

be applied to the data. Of the 6,342 individuals who completed the screening, 3,415 respondents were identified as potential anglers and asked to join the panel. Of these, 2,668, or 78%, agreed to participate. Of those that agreed to participate in the panel, 2,135, or 80%, completed the entire panel. In the analysis reported here, only data for individuals who completed the panel was used.

Weights were created to appropriately adjust for the stratification based on county population of licensed anglers, the male-female ratio, the number of adults in the household, and the number of telephone lines. After correcting for the sample stratification scheme used in the screening, there was evidence that persons responding to the screening interview were slightly different than the Michigan population as a whole. To correct for these differences, case weights were created for each sampled person. These case weights were calculated so that the screening sample matched regional census data regarding the age distribution, distribution of educational attainment, and ratio of males to females. This was done for each of three regions of the state defined for this study: the three-county Detroit metropolitan area, lower Michigan (the lower portion of the lower peninsula), and upper Michigan (the northern lower peninsula and the upper peninsula). For complete details of the weighting, see Section 5 of Appendix 1 of Hoehn et al.

3.4.3 The Design of the Survey

Each set of panel interviews was referred to as a wave. Basically, the panel wave interviews consisted of asking whether respondents fished or not, and if they fished they were asked a set of questions about each trip. A general outline of the survey instrument is found in Figure 3.2.

The CATI instrument employed a rostered structure that could accommodate complex trip types. The roster system consists of a programming loop and flexible data storage method for questions that are repeated a different number of times for different respondents. The MSU instrument had two levels of rostering. First, there was a loop through a set of questions about each trip. Second, within each trip there was a loop through a set of questions about each site.

The final panel wave also included a number of general questions about the respondents' fishing preferences, usual practices, boat and cabin ownership, and job characteristics. Respondents were also asked about their chances of fishing during the winter. Those respondents who indicated they were likely to fish during the winter were contacted once more in a wave of interviews that asked about any winter and/or ice fishing they may have done.

The timing of panel waves was designed so that the more frequent anglers were called more often than were infrequent anglers. Using the responses to screening questions, panel members were partitioned into three groups based on their anticipated frequency of fishing. The group of frequent anglers was called six times in the period from April through November. The middle range group was called four times while the group of infrequent anglers was called twice. The grouping of respondents and the number of waves for each group was based on an analysis of the pilot data. The goal was to obtain the highest quality data on as many trips as possible, keeping research budget constraints in mind. The scheduling of the panel waves balances the cost of the panel against the desire to reduce the recall period since the last interview. Another factor that was taken into account was feedback from the pilot survey indicating that infrequent anglers did not want to be called frequently, even if the interview was short. The number of panel interviews ranged from eight for the most frequent anglers to three for the least frequent anglers. Some detailed information such as the trip length or date was obtained on about 85% of all trips taken by the survey respondents.

Each time panel members were called they were asked how many times, if any, they had fished since their last interview. To avoid double counting of trips and to help respondents answer the question, interviewers would remind respondents of the date of their last interview along with the date and location of the last trip they took. This technique is referred to as bounded recall.

The survey instrument was structured to loop through a set of questions for each time an individual said they fished since their last interview. Inevitably, there were some individuals who could not or would not provide the details of some of the trips that they reported they had taken. In these cases, the survey process permitted an interviewer to leave the loop of trip questions prior to completing all of the questions within the loop for each trip. If this option was exercised, the respondent was given an opportunity to revise the total number of trips that they previously said they had taken. This was done by reminding the respondent of how many times they said they fished and how many of these times they reported on. They were then asked if they wanted to change their answer about the number of times they fished since their last interview. These revisions were included to minimize any recall bias in the trip count information.

Because there are thousands of places to go fishing in Michigan, it was not possible to have closed response categories for the locations where anglers went fishing. That meant that each time an angler was asked about trip destinations, the interviewers had to enter the name and location of each site. As it turned out, however, most anglers reported fishing at only a handful of sites. In the pilot, 91% of the people who fished did so at three or fewer different sites. Because of this, in the first wave interviews, some of the panel members were asked about up to three sites where they usually fish. These sites were then saved for each individual and subsequently used as individual-specific closed response categories in the site location portions of the first interview and all ensuing interviews. For trips to one of the usual sites, the interview was shorter because interviewers were able to avoid asking and typing text for the full set of questions about a site's name and location. Panel members in the infrequent angler group were not asked about their usual sites since they don't fish much.

To further streamline interviews, interviewers did not ask the full set of site and trip questions for repeat visits to the same site. Within any interview, if an angler took more than two single-day trips to one of their usual sites, the angler was asked if it was a typical trip to that site. If so, the interviewer would move on to the questions about the next trip.

In the screening process, some of the respondents who agreed to be in the panel were asked if they would like to receive a fishing log. The logs provided a place to record most of the information interviewers asked about in the panel interviews. The logs served as memory aids with the potential for speeding up the interviews. Again, since infrequent anglers do not fish much, they were not asked if they wanted a log. During the panel interviews, respondents with logs were asked if they wanted to use their log while completing an interview. If they used the log, their interview was more direct. If they did not want to read all the information from the log over the phone, interviewers offered to send them a replacement log along with a postage paid return envelope for the original log.

3.4.4 *The Analysis Sample*

The analysis sample, upon which the RUM model was estimated, consisted of a subset of the survey respondents and the trips they reported. An eligible case satisfied the following five conditions:

(1) the respondents completed the panel, *and*

(2) the month of every trip the respondent took is known, *and*

(3) there are valid observations for the respondent's demographic variables, *and*

(4) there are valid observations for the cabin questions, *and*

(5) the case was not flagged for errors.[11]

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[11] "Errors" included a respondent who was later identified as under 18 years of age, a respondent who, always traveled via airplane, and trips where the dates and sites matched some other trip for the same respondent (see Appendix 1, Hoehn et al. for details).

If a case did not satisfy the conditions for complete panel data, then that respondent (case) was not included in the analysis. There were 1,902 respondents (of the 2135 who completed the panel) that met the above criteria. All of these cases were used in the participation level of the model, and all of their valid trips were used in the trip levels of the model (see conditions below).

It is possible that implementing these exclusions might result in a sample that is not representative of the overall population of potential anglers. Therefore, a set of weights was created for the analysis sample of 1,902 cases that matched it to the (weighted) sample that was originally recruited to the panel, the "potential" anglers identified in the screening interview. This weighting process ensured that the distribution of characteristics of anglers in the analytical sample matched the distribution of angler characteristics in the original sample of recruited anglers. The characteristics matched include the angler's avidity group, the region of the state the angler lived in, the anglers age, and some additional demographic variables.

Recall that the model is estimated in two stages: first, the trip stage jointly estimates the trip, product line, and site levels of the model; second, the participation stage estimates the participation level. Additional data was needed for a trip to be used in the trip stage of the estimation. Valid observations for the trip stage estimation are those trips by valid individuals that satisfy the following criteria:

(1) the destination county is known, *and*

(2) the product line is known, *and*

(3) the trip duration (single or multiple day) is known, *and*

(4) the trip occurred between April 1, 1994 and October 31, 1994, *and*

(5) the purpose of the trip was fishing, *and*

(6) the product line is feasible for the county visited, *and*

(7) the trip has not been flagged for errors, *and*

(8) the trip distance is less than 150 miles for day trips.

Recall that the choice occasions are 3.5 days in length, and that only one trip was permitted per choice occasion. A small number (2%) of respondents had more trips in some month than there were choice occasions for that month. In such cases, a random integer was assigned to each of the individual's valid trips for the month, and an the following additional selection criterion was imposed:

(9) the trip's random integer is not greater than the number of choice occasions in that month.

Before these conditions are imposed there were 5,425 trips taken by the 1,902 cases. Of these, 4,269 trips meet all of the conditions for use at the trip level of the model.

3.5 Estimation Results

This section reports the results of the model estimation. Recall the structure of nesting in the MSU model: at the topmost level is a decision about participation on a choice occasion, at the next level is choice of day or multiple-day trip, then there is the choice of product line, and finally there is the choice of site. Recall too that the model was estimated in two steps. First, the site choice, product line choice, and duration choice components were estimated jointly in a single "trip choice" model. The trip choice portion of the model seeks to explain the nature of a trip if one was taken, and this part of the model was estimated using full information maximum likelihood techniques. Then, the participation model was estimated, using the inclusive value index from the trip choice model as a variable explaining whether people go fishing at all on a given choice occasions. The parameter estimates are presented in two tables corresponding to the two stages of model estimation.

Table 3.6 presents the estimated parameters associated with variables in the trip duration, product line, and site choice portions of the model. These parameters were estimated simultaneously in the first stage of the model estimation. Whenever possible, parameters were allowed to differ for single and multiple-day trips. Thus, in Table 3.6 there are two sets of columns representing the estimated coefficient and t-statistic for single-day and multiple-day trips.[12] The rows represent the variables which are grouped according to their role in the model.

The first set of rows in Table 3.6 reports the values of parameters from the trip duration level of the model, the choice between single-day and multiple-day trips. The three trip duration variables are the inclusive value parameter, a constant, and a time value shifter. For convenience, these three variables are presented in the single day column of Table 3.6, even though there is no distinction between parameters for single and multiple-day trips at this level of the model. The parameter on the trip level inclusive value index determines the importance of the nesting structure at this level. The coefficient is in a range that is consistent with theory (see section 2.2.1). Since the coefficient is significantly less than one, separating the two trip lengths into different nests was an improvement over not making the distinction. That is, the unmeasured characteristics of a trip of a particular duration are more correlated with those of a trip of the same duration than with a trip of a different duration.

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[12] The "true" β coefficient is not identified in this model. However, the coefficients are identified up to a scale parameter. This does not matter for welfare measurement, where the scale parameters cancel out. At the product line level, the relative scale parameters differ for single and multiple-day trips. Thus, to compare the site level coefficients across day and multiple-day trips, the coefficients should be multiplied by the corresponding coefficient on the inclusive value in the PL choice parameter estimates.

In addition to the inclusive value parameter, there is a trip duration constant that equals zero for single-day trips and equals one for multiple-day trips. The estimated parameter for the trip duration constant shows that people are less likely to take multiple-day trips. Finally, at the trip duration level there is a variable that alters the value of time for individuals with jobs relative to those without jobs. That the estimated coefficient is negative suggests that those without jobs have a higher cost of using their time to go fishing than those who have a job. In effect, individuals without jobs are less likely to take multiple-day trips.

After the trip duration choice, the next set of variables in Table 3.6 represent variables at the product line level and site level. The first of these are the inclusive value indexes for the product line level nesting. The coefficients on the product line inclusive values are positive and between zero and one for both trip lengths. Using a one-tailed test, the single-day coefficient is significantly less than one at the 5% level but not at the 1% level -- a point that bears on the results in Chapter 4. Each of the combinations of product lines and Great Lake/non-Great Lake counties has a nest-specific constant term. While these are identified at the product line level of the model, in Table 3.6 they are grouped within each of the PLs. Along with the explanatory variables within each PL, these constants serve to fit the model with the sample shares corresponding to each PL.

The next two rows of Table 3.6 present two site-level variables which share the same parameter across all product lines: trip cost and cabin. Having a cabin at a site makes a person more likely to visit the site where the cabin is, with the influence greater for multiple-day trips. Both the single and multiple-day cabin variables are highly significant. For both day and multiple-day trips, the travel cost variable is negative (as expected) and significantly different than zero. This shows that the farther away a site is (all else constant), the less likely it is that it will be visited. This effect is larger in the day trip branch than the multi-day branch, indicating that for single-day trips, the cost of travel is (relatively) more important. These variables were initially constrained to be the same across trip durations, but that specification was rejected by a likelihood ratio test. The implication is that the marginal utility of income differs by trip length, an issue which will be discussed further in Chapter 4.

Table 3.6: Estimated Parameters From the Trip Stage of the Model.

	Variable	Single Day Coefficient	Single Day t-stat.	Multiple Day Coefficient	Multiple Day t-stat.
Trip Duration Level*	Trip Duration Inclusive Value	0.043	3.28		
	Duration constant (single day=0)	-2.145	-11.82		
	Time value shifter for no job	-0.003	-7.50		
Product Line & Site Level	Product Line Inclusive Value	0.937	28.67	0.617	4.44
	Trip Cost	-0.143	-58.8	-0.015	-13.3
	Cabin at site (1=yes, 0=no)	1.892	7.86	4.424	19.2
Great Lakes Warm	Walleye CR	2.531	6.63	1.782	1.52
	Bass CR	5.912	1.45	1.652	0.14
	Pike CR	1.620	0.36	6.609	0.75
	Perch CR	-0.160	-2.75	0.041	0.32
	Carp CR	0.972	0.87	0.231	0.09
Great Lakes Cold	Constant, GL cold	-2.177	-14.75	-0.773	-2.97
	Chinook CR	9.170	5.14	15.28	6.05
	Coho CR	12.69	5.45	13.62	5.27
	Lake trout CR	4.570	3.23	3.036	1.05
	Rainbow CR	10.91	2.19	10.25	1.34
Inland lakes Warm	Constant, IL warm, shore	-1.398	-14.06	0.128	0.63
	Constant, IL warm, interior	-0.777	-7.80	0.054	0.24
	Warm lake acres/1000	0.067	21.58	0.055	11.71
Inland lakes Cold	Constant, IL cold, shore	-3.185	-11.43	-2.79	-4.92
	Constant, IL cold, interior	-3.368	-18.48	-2.933	-6.26
	Cold lake acres/1000	0.076	3.73	0.065	1.68
Rivers/streams Warm	Constant, RS warm, shore	-1.448	-10.09	-0.908	-3.41
	Constant, RS warm, interior	-1.771	-11.21	-1.519	-4.92
	Top quality miles/100	0.761	5.35	1.149	3.15
	Second quality miles/100	-0.221	-3.58	-0.413	-2.29
Rivers/streams Cold	Constant, RS cold, shore	-2.927	-15.23	-1.763	-5.42
	Constant, RS cold, interior	-3.146	-19.24	-1.562	-5.36
	Top quality miles/100	1.552	5.09	1.520	3.40
	Second quality miles/100	0.005	0.05	-0.035	-0.24
Anadromous Runs	Constant, Anad, shore	-1.480	-10.57	-0.475	-1.63
	Constant, Anad, interior	-1.582	-7.78	-0.913	-2.42
	Chinook CR	2.795	3.37	4.756	6.37
	Coho CR	-0.878	-0.30	6.876	4.28
	Rainbow CR	6.997	8.04	6.498	4.58

* For convenience, parameters at the trip duration level are listed in the single day column, though they apply to all trips. Only variables that enter the model "below" the trip duration can differ by trip length (see Figure 3.1).

In the Great Lakes warm product line, the estimated parameters are for catch rates for the individual species. Taken as a group, these catch rates are statistically significant contributors to the model for day trips. That is, if all of these catch rates are removed from the model, the model does a significantly poorer job of explaining fishing behavior. Catch rates are not significant at typically-employed significance levels for multiple-day trips for warm-water Great Lakes trips. The coefficients on the catch rates for the single-day part of the model tell us that higher bass and walleye catch rates are highly sought after (all else constant), while northern pike, carp and yellow perch catch rates are less sought after. The negative sign on yellow perch catch rates is unexpected; one might guess *a priori* that yellow perch would have a positive influence, larger than carp. This kind of result might arise because catch rates for perch are correlated with other factors that influence choice. For example, sites with high yellow perch catch rates might be composed primarily of smaller fish, whereas sites with lower catch rates might have a greater share of larger, more desirable fish.

In the Great Lakes cold product line, the estimated parameters are for catch rates for the individual species. The catch rates for each species have a positive influence on both single and multiple-day trips. Within the single-day trips, all of the species significantly contribute to the model's explanatory power. For multiple-day trips, the salmon catch rates are significant, yet the trout catch rates are not. Taken as a group, the multiple-day trip parameters on catch rates are significant. For both the single and multiple-day trips, chinook salmon, coho salmon, and rainbow trout are relatively more desirable than lake trout.

For the inland lakes warm-water product line, the inland lake acres is a highly significant variable. The estimates indicate that all else equal, a county with more acres of warm-water inland lakes is more likely to be the destination of single and multiple-day trips.

Similarly, in the inland lakes cold product line, acres of cold-water lakes has a positive effect on the chance of a county being selected for either trip length. The parameter on cold lake acres in the IL cold PL is significant at any standard significance level for single-day trips. However, for multiple-day trips in the inland lakes cold-water product line, the parameter on lake acres is only significant at the 10% level.

For the river and streams warm product line, the variables for the miles of top quality and the miles of second quality stream are both significant for single and for multiple-day trips. Top quality stream miles positively influence site choice, while second quality stream miles negatively influence site choice. For the RS cold product line, top quality stream miles again have a significant and positive influence on site choice for both the single and multiple-day trips. Second quality stream miles are not significant for either the single or multiple-day trips portions of the RS cold product line. For the anadromous run product line most of the catch rate variables are significant and positive for single and multiple-day trips. However, the coho catch rate for single-day trips is negative, although it is not a significant variable.

The final level of the model is the participation choice, whether to go fishing or not on a choice occasion. The estimated parameters for the participation model are given in Table 3.7. This model has several variables, in addition to a set of month-specific constants. First, there is the inclusive value index. This summarizes information from the trip choice model. Any changes in the trip choice model that improves (or degrades) the well-being of taking a trip will increase (or decrease) the inclusive value index. For example, an increase in the chinook salmon catch rate in the GL cold product line will increase the utility of taking a trip and increase the inclusive value. The positive coefficient for IV in the participation model shows that increases (decreases) in the inclusive value increase (decrease) the probability of taking a trip. Since the predicted number of trips in any month is the number

Table 3.7: Participation Choice Level Parameters

Variable	Coefficient	t-statistic
Inclusive value	0.087	1.28
ln (Age)	-0.444	-7.03
ln (Education)	-0.844	-9.29
Sex (male=0)	-0.880	-22.35
Month-specific constants		
April	-7.620	-20.16
May	-7.077	-18.76
June	-7.165	-19.00
July	-7.474	-19.79
August	-7.654	-20.24
September	-8.068	-21.25
October	-8.679	-22.72

of choice occasions times the probability of taking a trip, increases (decreases) in the inclusive value lead to a prediction that more (fewer) trips will be taken. While the participation-level IV is not significantly different from zero, it is significantly less than one indicating the nesting structure is significant.

The demographic variables show that, all else equal, older individuals, more educated individuals, and females have a lower probability of taking a trip than do younger, less educated, males. Finally, there is a set of month specific constants. For any individual, the only variables that vary over time are the inclusive value index and the monthly constants. Thus, these constants explain monthly variation in fishing trips that is not accounted for by the changes in the inclusive value index. They indicate that, all else equal, fishing trips are more likely to occur in May than in October.

3.6 Model Predictions Using the Baseline Data

In this section, the estimated model is used to predict total statewide fishing trips. Before using the model to produce statewide estimates of fishing in Michigan, it is important to bear in mind that the estimates apply only to the fishing activities included in the model. For example, the estimates do not include fishing by non-residents, as only Michigan residents are included in the sample. Likewise, the estimates do not include fishing trips with primary purposes other than fishing, since these trips were not included in the model.

The exact procedure for extrapolating model results was outlined in section 3.3.4. Here, a brief explanation of how the estimated model is used to predict statewide trips is provided. First, for each individual in the estimation sample, individual data and the site data are combined with the estimated parameters to compute each individual's probability of visiting each site on each choice occasion. Summing these site probabilities up across the choice occasions in the season gives that individual's predicted demand for trips to each site; i.e., the predicted share of their predicted trips associated with each site within each product line. Next, the weighted average of these seasonal shares is calculated across individuals. The weights used at this stage are the weights that were constructed so that the estimation sample is representative of the state population of potential anglers. The result of this stage gives the site demands for a representative potential angler in Michigan.

It remains to extrapolate these to the state by multiplying by the estimated population of potential anglers in Michigan. The population of potential anglers was estimated from the screening sample, and it too was weighted so that it would be representative of the state population of potential anglers. The results are statewide predictions of trips to each site within each product line. These can be added up within a product line and a trip length to produce aggregate estimates of trips within each product line. Likewise, the aggregate

Table 3.8: Statewide Estimates of Fishing Trips and User Days in Michigan During the April to October Season.

Product Line	Single Day Trips by PL		Multiple Day Trips by PL		Total User Days by PL†	
GL warm	2,082,100	29%	180,200	14%	2,776,100	23%
GL cold	299,900	4%	161,700	12%	922,400	8%
IL warm	3,091,500	44%	628,900	48%	5,512,900	46%
IL cold	113,000	2%	22,000	2%	197,600	2%
RS warm	971,600	14%	124,600	10%	1,451,500	12%
RS cold	225,000	3%	94,200	7%	587,900	5%
Anad	278,500	4%	99,800	8%	662,600	5%
Totals*	7,061,600		1,311,500		12,110,800	

† User days are defined by multiplying multiple-day trips by 3.85 and adding single-day trips.
* All numbers rounded to nearest one hundred. Totals may not add up due to rounding.

number of single and multiple-day trips is derived by summing across the single and multiple-day product lines.

The above method of estimating trips in the baseline is different than simply extrapolating from the sample, a process often referred to as calculating the sample shares. The difference stems from the use of the model to predict each individual's actions. In the sample, a person either does or does not visit a site during a choice occasion. In contrast, the model predictions are probabilities of visiting a site. For this reason, the trip predictions based on actual visited sites (sample shares) can differ from the model predictions. These differences will depend on the extent to which the model fits the underlying data. In the MSU model, the trip predictions will match the corresponding sample shares at the participation, trip length, and product line levels because of the constant terms at each of these levels. This property does not hold for the individual sites in the model since the model does not contain site-specific constants at the site level. Site level constants would add about 850 additional parameters to the model estimation (one for each site within each PL and trip duration).

The model predicts that during the open water season there were about seven million single-day trips and 1.3 million multiple-day trips in Michigan made by Michigan residents for the primary purpose of fishing. The predicted distribution of these trips across product lines is presented in Table 3.8.

The final columns of Table 3.8 provide an estimate of total recreational fishing user days by product line. A rough calculation of user days was made by multiplying the multiple-day trips times 3.85 (the average nights away plus one), and adding them to the single-day trips. This yields an estimate of 12 million user days for fishing in Michigan by state residents. Of the 12 million estimated user days, 58% are due to single-day trips.

In the next chapter, the estimated recreational angling model is used to examine policies involving changes in the catch rates of lake trout at Great Lakes sites. Lake trout are one of the species in the Great Lake cold product line (GL cold). As can be seen from Table 3.8, the GL cold product line accounts for only 4% of single-day trips, 12% of multiple-day trips, and 8% of user days. This will be important to keep in mind when interpreting the valuation results of the next chapter. Another factor to point out here is that within the GL cold product line, lake trout catch rate has the smallest parameter of all the GL cold fish (see Table 3.6). Thus, among the GL cold catch rates, the model estimation results indicate that lake trout catch rates are the least valuable.

Chapter 4
Valuation Results for Hypothetical Lake Trout Scenarios

The sea lamprey control issue was introduced in the opening chapter. In this chapter, empirical results are presented which shed light on the benefits of sea lamprey control. Recall that the lamprey negatively affect lake trout populations, so the value of lake trout can be used to help establish sea lamprey control targets. This chapter presents the empirical results of the application of the current MSU model to the valuation of lake trout in Michigan's waters of the Great Lakes. The lake trout valuation scenarios are used to examine the empirical validity of the value-per-fish approach. This chapter begins with a complete descriptions of the each of methods and scenarios used to arrive at the value estimates for lake trout. The chapter ends with some valuation results for broader changes in Great Lakes trout and salmon that are intended to add perspective to the lake trout results.

4.1 Methods for Using the Repeated RUM to Value Lake Trout

This section begins with an explanation of the approach used to estimate average values per fish. Next, the method for getting the marginal values for changes in lake trout catch rates (MVCR) is described. While not marginal values per fish, the MVCRs are the first step in that direction. The third sub-section discusses the policies that will be directly evaluated using the MSU model (rather than being translated into values per fish). The section ends with a discussion of the policies that will be run to examine the sensitivity of the various components of the value per fish (VPF) calculations. The sensitivity analysis is aimed at testing the two assumptions underlying the validity of using the VPF approach as a benefits function -- *VPF Question 1* regarding the linearity of benefits with respect to *own* site quality changes and *VPF Question 2* concerning the separability of the benefits function, i.e., independence of benefits at site i from the quality at *other* sites j. As in earlier chapters, the terms "site quality" and "lake quality" will be used interchangeably to refer to alternative levels of lake trout catch rates.

4.1.1 Deriving Average Values Per Fish.

The MSU model described in Chapter 3 was adapted to determine average values per fish (AVPF) for lake trout. Specific values are derived for each of Michigan's Great Lakes. The primary goal was to produce lake-specific "value per fish" estimates that could be used directly in the Koonce *et al.* sea lamprey control framework. The basic approach for calculating AVPF is to divide an estimate of the total recreational value of lake trout by an estimate of total recreational harvest of lake trout for each of Michigan's Great Lakes. One strength of such an approach is that it does not depend on knowledge of the relationship between lake trout catch rates and lake trout populations. On the other hand, average values are not generally the appropriate entity to compare with incremental costs when making a benefit-cost decision about a change in lamprey populations. However, if the VPF approach is valid, then the average values will be appropriate since they will be equivalent to the marginal values. Here, the proposed method of calculating total catch and total value in order to derive basin-specific AVPF is described.

As mentioned, the approach for estimating AVPF utilizes estimates of total value and estimates of total catch. The MSU model is directly used to derive an estimate of total recreational surplus value of lake trout for each Great Lake; call this TV_i. TV_i is calculated using equations (3.19) and (3.21) by reducing the lake trout catch rates to zero for each site within Great Lake *i*. Specifically, for TV_i the pre-policy quality at lake *i* is treated as the baseline catch rate variables and the post-policy quality is the result of replacing all the lake trout catch rate variables at lake *i* with zeros. Catch rates for other species and for lake trout at other Great Lakes are held constant at their baseline levels when calculating TV_i. Here *it is assumed that driving lake trout catch rates to zero at all sites at lake i would be the same as eliminating lake trout from lake i.*

To estimate total catch, the MSU model, the MSU survey data, and the Michigan creel survey data are all utilized. The MSU model is used to predict total GLcold trips to each county during each month. The panel survey data is used to calculate average hours fished for lake trout for single and multiple day trips in GLcold. The average hours per trip are used to turn the estimates of trips into estimates of total hours of effort. Effort estimates are then multiplied by the creel survey catch per hour to derive estimates of the total number of lake trout caught. Specifically, the following steps were used to derive estimates of total catch:

1. Use the MSU model to predict T^l_{ijm} which is aggregate GLcold trips per month, m, to each GL county, j, within each GL, i, for each trip length, l. The procedure for using the MSU model to predict trips was described in sections 3.3.3 and 3.6 of Chapter 3.

2. Use the MSU survey data to estimate hours fished for lake trout per GLcold trip by trip lengths, l. Denote these by e^l where l = sd for single-day trips, and md for multiple-day trips.[1]

3. Combine steps 1 and 2 to derive an estimate of aggregate fishing effort per site per month, $E_{ijm} = e^{sd} \times T^{sd}_{ijm} + e^{md} \times T^{md}_{ijm}$.

4. Translate the above effort estimates into total catch (harvest) estimates by multiplying by the month and county specific lake trout catch rates from the Creel Survey (r_{ijm}) as follows: $C_{ijm} = E_{ijm} \times r_{ijm}$.

5. Sum the above site specific, monthly total catch estimates over months and over sites within each lake to get an estimate of total recreational catch (harvest) per season for each lake: $C_i = \boldsymbol{\Sigma}_{j \in i} \boldsymbol{\Sigma}_m C_{ijm}$.

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[1] Naturally, the AVPFs will be very sensitive to the estimates of e^{sd} and e^{md}. This dependence is explored and discussed in more detail in coming sections.

Finally, the estimated TV_i and C_i are used to derive the average value per fish for each Great Lake by dividing total value by total catch, i.e., $AVPF_i = TV_i / C_i$.

4.1.2 Marginal Values Per Fish

If the VPF approach is appropriate, average values per fish will be approximately the same as marginal values per fish. However, if the VPF approach is not valid, then a marginal value per fish would be more appropriate to use than average values -- even though a marginal value would only apply for small changes in lake trout populations.

One method for calculating marginal value of a lake trout in a specific Great Lake would be to use the MSU model to estimate the marginal value of a change in lake trout catch rates for that Great Lake ($MVCR_i$). The marginal values for catch rates could then be translated into marginal values for lake trout by multiplying them by the marginal effect of fish populations levels on catch rates. Doing so would require a method of translating changes in lake trout populations into changes in lake trout catch rates. For example, in a common fisheries model, harvest is assumed to be proportional to fishing effort and stocks as follows:

$$H = aES, \tag{4.1}$$

where H is harvest, E is effort, and S is the stock of fish.[2] The proportionality term, a, is often referred to as a catchability coefficient. In this model, the catch-per-unit-effort or the catch rate is $H/E = aS$ so that $\partial(H/E)/\partial S = a$. Estimates of lake-specific catchability coefficients, or more general methods of translations have not been located at this time. Given such information, one can always translate the MVCR into value-per-fish estimates.

[2] The use of H to denote harvest follows Chapter 1. Elsewhere in this chapter the term "catch" is used interchangeably with harvest. Catch will be denoted by "C."

In the context of this research, if the MVCRs are sensitive to changes in *own* and *other* site quality levels, then the marginal values per fish will be too. In this case, the VPF approach would not be appropriate. Since this sensitivity analysis does not require that the MVCRs be translated into marginal values per fish, only the estimated MVCRs are presented.

The MVCRs are the probabilities of visiting the sites times the marginal implicit price of the quality variable. The marginal implicit price of any variable is given by its estimated parameter divided by the travel cost parameter (these were denoted by $\boldsymbol{\beta}/\boldsymbol{\mu}$ in Chapter 2). The marginal implicit prices translate the marginal value of a quality change from utility units to dollar valued units. At the aggregate level, the sum of individuals' site probabilities corresponds to the predicted trips, as discussed in section 3.3 of Chapter 3.

To get the MVCRs, the marginal implicit prices also need to be calculated. In the MSU model, the coefficients on lake trout catch rates and prices differed by single-day and multiple-day trips. To get the marginal implicit price for single day trips, $\boldsymbol{\alpha}^{sd}{}_{LT}$ was divided by $\boldsymbol{\alpha}^{sd}{}_{1}$ (using the notation of section 3.3 of Chapter 3). All the nesting and dissimilarity parameters cancel in the marginal implicit price calculation. From Table 3.6, these numbers are seen to be $\boldsymbol{\alpha}^{sd}{}_{LT} = 4.57$ and $\boldsymbol{\alpha}^{sd}{}_{1} = 0.143$ for single-day trips and $\boldsymbol{\alpha}^{md}{}_{LT} = 3.036$ and $\boldsymbol{\alpha}^{md}{}_{1} = 0.015$ for multiple-day trips. These parameters yield a marginal implicit price of $31.96 per fish per hour per single day trip. For multiple-day trips, the marginal implicit price of lake trout catch rates is $202.40 per fish per hour per multiple day trip.[3]

The marginal implicit prices can be interpreted as the value of catching one more fish per hour, conditional on taking a Great Lakes trout and salmon fishing trip of length *t*. Equivalently, the marginal implicit prices convey the value "per-GLcold trip of length *t*" of

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[3] Had the price parameter for single day trips been used for both trip lengths (as in the Hoehn *et al.* report), the estimated marginal implicit price for multiple day trip lake trout catch rates would be $13.98 -- the implications of and issues surrounding this issue are discussed in detail in Lupi, 1997.

increasing catch rates by one fish per hour at <u>all</u> GLcold sites. Recognize that a one-fish-per-hour increase in catch rates is a *huge* increase in catch. For comparison, the marginal implicit prices for the other species in the GLcold product line are, for single and multiple day trips respectively, as follows: for Chinook, $64 and $1,019; for Coho, $89 and $908; and for Rainbow, $76 and $683. Clearly, these are substantially higher than the marginal implicit prices for Lake Trout.

To get the single day portion of that lake's MVCR, the single day marginal implicit price was multiplied by predicted total single day trips to a lake to get the single day portion of that lake's MVCR; call this $MVCR_i^{sd}$. Likewise, to get the multiple day portion of that lake's MVCR, the marginal implicit price was multiplied by predicted total multiple day trips to that lake; call this $MVCR_i^{md}$. The overall MVCR for each lake was found by summing the single and multiple day portions of the MVCRs described in the above two paragraphs; that is, $MVCR_i = MVCR_i^{sd} + MVCR_i^{md}$. The marginal values are presented in subsequent sections. Before any empirical results are given, the methods for deriving the direct value estimates are discussed as are the methods for examining the sensitivity of the results.

4.1.3 Direct Valuations

Rather than estimate basin-specific values per fish, the MSU model can be used to directly value alternative sea lamprey control targets. In this approach, various GLFC targets are articulated. These targets are then translated into changes in lake trout catch rates for each of the Great Lakes. The policies are then directly valued by the MSU model. This method is a more sophisticated use of the MSU demand model because the recreational fishing benefits are directly evaluated using the repeated RUM welfare measure rather than being translated into "values per fish". Using equation (3.21), the MSU model directly evaluates multidimensional, non-marginal changes in quality in a theoretically valid manner. Therefore, with the direct evaluation approach, the complete array of catch rate changes across Great Lakes are evaluated simultaneously for each possible scenario. *If the VPF approach is rejected, the direct valuations should be used to value changes in lamprey populations.*

As mentioned in section 2.4 of Chapter 2, such direct evaluations avoid any bias associated with failure to jointly measure the multidimensional impacts of the scenarios. Recall that the bias was associated with failing to follow an appropriate path of integration as in the independent valuation and summation (IVS) procedure. Therefore, the direct measures permit a comparison of the correct measures and the IVS measures to examine the extent of bias resulting from IVS. The exact methods for the IVS assessment are discussed in section 4.4.

For the direct evaluations, the hypothetical lamprey policies are composed of three possible catch rate regimes at each of the three lakes: Lake Michigan, Lake Huron, and Lake Superior. The three catch rate regimes are: eliminating lake trout catch rates (CR0); doubling lake trout catch rates (CR2); and the status quo lake trout catch rates at each of the lakes (CR1). Applying the three regimes at each of the three lakes results in 27 combinations of catch rate changes to directly evaluate with the model. These various combinations are the same ranges of quality that will be used to test the sensitivity of each lake's TV, AVPF, and MVCR estimates. The direct valuations apply equation (3.21) and extrapolate the results to the state as described in section 3.3.3 of Chapter 3.

Throughout the chapter, a three-element vector (x,y,z) will refer to a policy. In this notation, x refers to the multiple of Lake Michigan lake trout catch rates, y refers to the multiple of Lake Huron lake trout catch rates, and z refers to the multiple of Lake Superior lake trout catch rates. The multiples are either 0, 1, or 2 which correspond to driving the lakewide lake trout catch rates to zero (CR0), leaving the lakewide lake trout catch rates at their original baseline level (CR1), and a doubling of lakewide lake trout catch rates (CR2). In the notation of this chapter, the *direct* valuations are movements in lakewide catch rates from (1,1,1) to (x,y,z). This process results in 26 direct policies that need to be evaluated since movement to (1,1,1) is "no policy." For example, direct policy (2,0,1) refers to a doubling of Lake Michigan lake trout catch rates, elimination of Lake Huron lake trout catch rates, and no change in Lake Superior lake trout catch rates. Note that these policies are not intended to reflect any exact restoration policy. CR0 was chosen to calculate the total value of lake trout, and CR2 is an equivalent incremental change from the status quo which can be used to examine the convexity of the benefits function.

4.1.4 Sensitivity of the Estimates.

Chapter 2 demonstrated that value estimates from a RUM model such as the MSU model are not independent of one another. The values are relative to the quality of substitute fishing opportunities included in the model. The fact that theoretically appropriate values depend on substitute fishing opportunities is the rationale for including all relevant substitute fishing sites in travel cost models. In this application, the values of recreational catch for any one basin will depend on the catch rates at other basins. Accounting for the interdependence of these values is an important step in performing theoretically valid valuation of multidimensional policies (Hoehn). For example, suppose a value of fish estimate generated above is used to set new target levels of sea lamprey control at one of the Great Lakes. If the new target results in a substantially different catch rate for that Great Lake, then the value of fish estimates for the other Great Lakes will no longer be theoretically correct. The practical significance of such an indirect effect is an empirical question addressed in the later part of this chapter.

The degree to which value-per-fish estimates might be treated as constants is explored by examining the sensitivity of the value per fish estimates to various assumptions about the relative quality at each of the Great Lakes. The sensitivity of each lake's TV, AVPF, and MVCR for lake trout is examined. The relative qualities used in the sensitivity analysis are the combinations of CR0, CR1, and CR2 lake trout catch rate levels at each of the other Great Lakes. For each estimate (TV, AVPF and MVCR), sensitivity is examined with respect to "*own*" lake quality and with respect to "*other*" lake quality. The *own* lake quality sensitivity is explored by estimating lake i values under alternative assumptions about the baseline quality level at lake i. The *own* lake quality sensitivity results inform *VPF question 1* (linearity of *own* site quality). The *other* lake quality sensitivity is explored by deriving the lake i estimates under various assumptions about the quality levels at lakes other than i. The results of the sensitivity to *other* quality will *VPF question 2* (separability).

The procedure for testing the empirical validity of the VPF approach can be expressed as an examination of the sensitivity of $F_i(q_i,q_j)$ to alternative levels of q_i and q_j for each of the functions $F_i = TV_i(q_i,q_j)$; $AVPF_i(q_i,q_j)$; and $MVCR_i(q_i,q_j)$. Specifically, to examine each of the two VPF assumptions, the following will be done:

For *VPF Question 1*: Calculate $F_i(q_i,q_j)$ for various q_i for $F_i = TV_i$; $AVPF_i$; and $MVCR_i$.

For *VPF Question 2*: Calculate $F_i(q_i,q_j)$ for various q_j for $F_i = TV_i$; $AVPF_i$; and $MVCR_i$.

For the VPF approach to be valid, the various F_i need to be insensitive to changes in both q_i and q_j (*own* site quality and *other* site quality).

In examining *VPF Question 1*, obviously the total value function, TV, will depend on the level of *own* site quality, but if VPF holds, then the increments in TV should all be the same for equal increments in quality. For example, if one compares the $TV_i(q_i)$ to $TV_i(2q_i)$, then if VPF holds, $2TV_i(q_i) = TV_i(2q_i)$. Since the benefits function is strictly convex (see Lupi), $2TV_i(q_i) < TV_i(2q_i)$. Thus, the TV comparisons will not only provide information on *VPF Question 1*, they will also convey information about the empirical importance of the convexity of the benefits function.

For the TV and AVPF calculations that are made from the original lake trout catch rates for a particular lake, there are nine combinations of *other* site quality that represent the combinations of CR0, CR1, and CR2 applied to the two other lakes. The TV and AVPF estimates are also calculated as if the baseline site quality at *own* lake was double its status quo level. That is, TV and AVPF are all calculated from CR1 and from CR2 at *own* lake. Thus, for examining the sensitivity of the TV and AVPF estimates, a total of 54 different policies were run (nine for each of the three lakes from the original baseline and from double the original baseline catch rates; 9×3×2=54).

A similar plan is followed to examine the sensitivity of the MVCR estimates for each lake. To test the sensitivity of each lake's MVCR estimate to the level of quality at *other* lakes, each lake's estimated MVCR is estimated for the nine combinations of quality level at the other lakes (CR0, CR1, and CR2). In addition, to test the sensitivity of the MVCRs to *own* lake quality, each lake's MVCR was derived at three reference points for the quality at the lake in question (CR0, CR1, and CR2).[4] Therefore, for examining the sensitivity of the

[4] The TV and AVPF calculations required a change in own lake quality from some baseline level to zero. Thus, with the three policies (CR0, CR1, and CR2), there were only two relevant combinations of *own* site quality for each lake. However, with the MVCR calculations, one only needs select a point at which to evaluate the expression for MVCR. Thus, each lake can be evaluated from all three of the chosen reference levels (CR0, CR1, and CR2).

MVCR estimates, a total of 81 different policies were run (nine for each of the three lakes from each of the three *own* lake reference levels; $9 \times 3 \times 3 = 81$).

4.2 Value Per Fish Estimates for Each Basin

This section presents the basic value per fish estimates for each of the Great Lakes. Before doing so, several relevant tables are presented. First, descriptive statistics for the lake trout catch rates are given. Next, the predicted trips by product line and by trip lengths are presented for changes in own lake catch rates. The product line predictions are followed by the predicted single and multiple day GLcold trips for each of the Great Lakes under the baseline catch rates as well as under some of the policies. Then, the predicted GLcold trips by site are presented for the same policies. After the trip predictions, the estimated catch by lake is given. Next, the value estimates are presented and discussed. Finally, the section ends with some qualifications associated with the derivations of the value estimates.

4.2.1 Descriptive Statistics for the Lake Trout Catch Rates

To provide some context for the changes in lake trout catch rates that will be examined in this chapter, Table 4.1 presents descriptive statistics for the lake trout catch rates. Recall the lake trout catch rates were provided by the Michigan Department of Natural Resources (MDNR). Douglas Jester of the MDNR used data from the Michigan creel survey to derive Poisson estimates of the catch rates that are specific to sites and months. The catch rate summary statistics are presented for the sites within each of the Great Lakes (columns in Table 4.1). The statistics are also presented by months (rows in Table 4.1). The second to last row presents the totals across sites and months for each lake. For reference, the last row gives the number of Michigan counties bordering each Great Lake.[5] The statistics in Table 4.1 include the mean catch rate, the maximum catch rate, and the number of observations equal to zero. The later is simply a count of the number of sites that have zero predicted catch rates in some month.

From Table 4.1, it is clear that the catch rates are very low at sites on Lake Michigan and Lake Huron and substantially higher at Lake Superior sites. For the season, the catch rates at Lake Michigan and Lake Huron average about one fish per 48 and 59 hours while at Lake Superior the seasonal average is better than one fish per 9 hours.

Also evident from Table 4.1 is the seasonality of the catch rates. For Lake Michigan and Lake Huron the catch rates are highest in May and June, tail off in July, and are almost zero otherwise. For Lake Superior, the catch rates remain high for a longer period, but they do tail off in the fall. Lakes Michigan and Huron also have high percentages of their sites with zero catch rates.[6] Thus, simply based on the lake trout catch rates, Lake Superior is best by several orders of magnitude. Also, Lake Michigan catch rates are about 20% higher than Lake Huron, and Lake Michigan has a somewhat lower share of sites/months with zero catch.

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[5] Two counties border multiple lakes: Mackinac County in the Upper Peninsula borders both Lake Michigan and Lake Huron while Chippewa County, also in the Upper Peninsula, borders both Lake Huron and Lake Superior. The lake trout catch rates are zero for these counties for all months. Therefore, the overlap does not affect the estimates of catch that are used in this chapter because changing catch rates by a scaler will not affect the zeros. However, for more general policies, these overlaps would need to be dealt with to derive more accurate estimates of items such as catch by lake.

[6] For the hypothetical changes in lake trout catch rates examined in this chapter, sites with a zero catch rate in the baseline data will always have a zero catch rate since a doubling of zero yields zero.

Table 4.1: Descriptive Statistics for Lake Trout Catch Rates by Great Lake by Month.

Month	Stat.*	Lake Michigan	Lake Huron	Lake Superior
April	mean	0.001	0.000	0.111
	max.	0.02	0.00	0.41
	# = 0	17	13	5
May	mean	0.041	0.044	0.149
	max.	0.17	0.25	0.41
	# = 0	4	8	4
June	mean	0.062	0.046	0.143
	max.	0.22	0.25	0.27
	# = 0	3	8	2
July	mean	0.027	0.026	0.166
	max.	0.07	0.13	0.39
	# = 0	4	7	2
August	mean	0.010	0.005	0.164
	max.	0.04	0.03	0.50
	# = 0	8	9	2
September	mean	0.001	0.000	0.062
	max.	0.01	0.00	0.17
	# = 0	16	13	4
October	mean	0.002	0.000	0.007
	max.	0.01	0.00	0.05
	# = 0	15	13	7
Totals	mean	0.021	0.017	0.115
	max.	0.22	0.25	0.50
	# = 0	67	71	26
# counties		18	13	9

* "# = 0" is a count of the counties with lake trout catch rates equal to zero.

4.2.1 Changes in Trips by PL and Trip Length

Table 4.2 presents the MSU model predictions for changes in single and multiple day trips at the product line level. The table is provided to illustrate the amount of substitution that occurs at the product line, trip length and participation levels of the MSU model. The six policies in Table 4.2 consist of changing each lake's level of lake trout catch rates from CR1 to CR0 or CR2 while the catch rates at other lakes are held at their CR1 levels. CR1 is the baseline lake trout catch rate, as described in Table 4.1 and as used to estimate the demand model; CR2 represents a doubling of lake trout catch rates and CR0 represents eliminating catch rates for lake trout. Thus, in Table 4.2, there are two columns for each of the three lakes. The first set of rows represents the changes in single day trips for the seven product lines, while the second set of rows presents the same for multiple day trips. In the last row for single day trips and the last row for multiple day trips there is a row labeled "total Δ T" which presents the total changes in single and multiple day trips respectively.

From Table 4.2 it is clear that while there is some substitution among trips at the product line levels of the model, there are virtually no changes in single and multiple day trips. Comparing the changes in trips with the baseline model predictions presented in Table 3.8 in Chapter 3 reveals that the percentage changes in total single day and total multiple day trips are all less than 0.01%. Moreover, even the product line changes are not overwhelmingly large relative to the baseline number of trips presented in Table 3.8. Since the only site quality changes are occurring within the GLcold product line, the largest changes are in the GLcold product line with increases in single day trips ranging from a low of 0.8% for the Lake Huron CR0 policy to a high of 6% for the Lake Superior CR2 policy. For multiple day trips, the changes in GLcold range from a low of 0.7% for the Lake Superior CR0 policy to a high of 3% for the Lake Michigan CR2 policy. Again, these percentage increases are relative to the baseline trips presented in Table 3.8. The results in Table 4.2 highlight the relative *inelasticity* of single and multiple-day trips for changes in site quality as estimated by the MSU model.

Table 4.2: **Predicted Product Line Changes in Single and Multiple Day Trips Under the CR0 and CR2 Policies for Each Great Lake.**

	Lake Michigan: change LM lake trout catch rates from CR1 to ...		Lake Huron: change LH lake trout catch rates from CR1 to ...		Lake Superior: change LS lake trout catch rates from CR1 to ...	
	CR0	**CR2**	**CR0**	**CR2**	**CR0**	**CR2**
Single-Day PLs						
GL warm	3484	-4235	1207	-2068	3085	-7139
GL cold	-10408	12863	-2432	4290	-8004	18874
IL warm	4189	-5272	748	-1335	2345	-5539
IL cold	318	-410	42	-77	125	-293
RS warm	1345	-1642	288	-510	671	-1595
RS cold	511	-628	69	-125	1241	-2883
Anad	591	-702	99	-194	496	-1268
Total Δ T^{sd}	30	-26	21	-19	-41	157
Multi-Day PLs						
GL warm	603	-708	203	-305	191	-386
GL cold	-3749	4398	-1204	1823	-1129	2269
IL warm	2087	-2454	671	-1019	604	-1234
IL cold	74	-87	23	-35	21	-42
RS warm	412	-484	135	-204	120	-247
RS cold	312	-367	97	-147	125	-250
Anad	176	-203	41	-67	72	-165
Total Δ T^{md}	-85	95	-34	46	4	-55

From Table 4.2, one can also see that the trip changes under the CR2 policies are larger than the changes under the CR0 policies. This result is consistent with the discussion in Chapter 2 about the shape of the site choice probabilities (see section 2.4). The largest divergence between the trip changes for CR0 and CR2 are exhibited at Lake Superior, though Lake Huron single day trips also show a large divergence. For single-day trips, Lake

Superior is most responsive to the policies (in absolute changes). For multiple-day trips, Lake Michigan is most responsive to the policies.

4.2.3 Changes in Trips to Each of the Great Lakes

The GLcold product line of the MSU demand model contains the sites where characteristics are changing as a result of the lake trout policy scenarios. Table 4.3 presents the trips in the GLcold product line under three lake trout scenarios as predicted by the MSU model. The predicted trips are broken out by the each of the Great Lakes and in total (the columns) and by single and multiple-day trip lengths (rows). The first set of rows is for the baseline lake trout catch rates at all lakes. The second set is for the predicted GLcold trips when all lake trout catch rates are driven to zero -- all lakes go to CR0 jointly. The final set of rows is for the predicted GLcold trips when all lake trout catch rates are doubled -- all lakes go to CR2 jointly. The rows present the share of trips by lakes, as well as the percent change in trips relative to the baseline.

The column for "other GL cold" represents GLcold sites that are not at the three Great Lakes under discussion -- places such as Lake Erie, Lake St. Clair, the St. Clair River, and the Detroit River. The lake trout catch rates are zero at all of these "other GLcold" sites. The predicted share of trips to "other GLcold" is around one-third for single day trips and about 3% for multiple day trips. Thus, these other sites garner a large share of single day trips even though they have very poor catch rates. In fact, less than 3% of the GLcold single day trips in the survey data are actually to these "other GLcold sites." For single-day trips then, the model over-predicts trips to nearby sites because a lot of weight is placed on the travel distance for single day trips. For the large number of sample members in the Detroit metro area, their single day GLcold choice sets are composed of sites with very low lake trout catch rates, and these are far away. In predicting GLcold trips for these individuals, the closer metro-area sites with zero catch rates are estimated to have higher measured utility than the distant sites with low, but non-zero catch rates.

Table 4.3: GLcold Trips by Great Lake for the Three Lake Trout Catch Rate Scenarios.

Scenario		Lake Michigan	Lake Huron	Lake Superior	Other GL cold*	Total GL cold
Baseline lake trout catch rate (CR1)	Single day trips	128,145	54,200	22,949	94,230	299,863
	% by lake	43%	18%	8%	32%	
	Multi day trips	102,563	40,718	13,531	4,870	161,687
	% by lake	63%	25%	8%	3%	
Zero lake trout catch rate (CR0)	Single day trips	117,753	51,773	14,923	94,230	279,018
	% by lake	42%	19%	5%	34%	
	% change	-8%	-4%	-35%	0%	-7%
	Multi day trips	98,836	39,649	11,999	5,040	155,531
	% by lake	64%	26%	8%	3%	
	% change	-4%	-3%	-11%	4%	-4%
Double lake trout catch rate (CR2)	Single day trips	140,972	58,478	41,879	94,210	335,879
	% by lake	42%	17%	13%	28%	
	% change	10%	8%	82%	0%	12%
	Multi day trips	106,334	42,393	16,640	4,680	170,037
	% by lake	63%	25%	10%	3%	
	% change	4%	4%	23%	-4%	5%

* Other GLcold sites include Lake Erie, Lake St. Clair, the St. Clair River, and the Detroit River. Lake Trout catch rates are zero at all of these "Other GLcold" sites.

The actual baseline survey shares to Lakes Michigan, Huron, Superior and other, respectively are as follows: for single day trips, 67%, 19%, 10%, and 3% compared to the 43%, 18%, 8%, and 32% predicted by the model; and for multiple day trips, 65%, 27%, 6%, and 2% compared to the 63%, 25%, 8%, and 3% predicted by the model. Thus, the model does a much better job of fitting the shares by lake for the multiple day trips than it does for the single day trips. For single day trips, most of the over-prediction at "other sites" seems to be at the expense of a large under-prediction of single day trips to Lake Michigan. Thus, even if the estimated parameters are good estimates of the true parameters, the model will *under-value* changes at Lake Michigan because the baseline single day probabilities are too low. This issue is addressed further in the final chapter.

Note that, even when lake trout catch rates go to zero at all GLcold sites, there are still GLcold trips since the remain available in the choice sets of anglers and other species are held at their baseline levels of catch rate. Moreover, inspection of the relative parameter estimates for the GLcold species indicates that these other species are all more desirable than lake trout -- the salmonids have higher marginal implicit prices.

Inspection of the second set of rows for the joint elimination of lake trout catch rates reveals that the shares of trips across the lakes do not change much for either trip length, although the share at Lake Superior changes some. The relative percentage change in trips is largest for single day trips at Lake Superior where there is a 35% reduction. For the joint doubling of lake trout catch rates, Lake Superior single day trips almost double. Lake Superior multiple day trips also see the largest relative increase at 23%. Recall that Lake Superior had the highest lake trout catch rates (see Table 4.1). Even though the trips to Lake Superior are most sensitive to the policy scenarios, the overall shares of trips by lakes are roughly the same as in the baseline, though, as with the elimination policy, Lake Superior shares do change somewhat. For all the policies in the joint doubling of catch rates, the absolute value of the changes in trips is larger than the respective change for the joint decrease in catch rates (and substantially larger for Lake Superior). For both the joint increase and the joint decrease in lake trout catch rates, total GLcold single day trips are more responsive to the quality change than are GLcold multiple day trips.[7]

4.2.4 Changes in Seasonal GLcold Trips by Sites

Table 4.4 presents the MSU model predictions for GLcold single and multiple day trips for each of the Great Lake counties. Bear in mind that the discussion in the previous sections and the discussion that follows describes what happens *as predicted by the model.* The rows of Table 4.4 represent the counties with the last row giving the respective column totals. The first two columns give the county names and indicate the lake the county borders. The third column provides the average of the monthly lake trout catch rates for each county. The next three columns present trip predictions for single day trips, and the last three columns give the same for multiple day trips. For each trip length, the number of trips predicted under the baseline catch rate conditions, (1,1,1), is presented first. Next, for each trip length there are two columns giving the *change* in trips under the two joint policies which represent movements from (1,1,1) to (0,0,0) and to (2,2,2). Thus, Table 4.4 gives the predicted trips under the baseline and the predicted trips for the same two joint policies presented in Table 4.3, i.e., joint elimination of lake trout catch rates (0,0,0) and the joint doubling of lake trout catch rates (2,2,2) -- these are CR0 and CR2, respectively.

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[7] Also note that over one third of the GLcold trips are multiple day which is higher than the 18.6% for the overall data.

Table 4.4 GLcold Trips by Sites for Each of the Three Lake Trout Scenarios.

#	County	Great Lake	mean CR	Single day trips: trips at (1,1,1)	Single day trips: Δ in trips to (0,0,0)	Single day trips: Δ in trips at (2,2,2)	Multiple day trips: trips at (1,1,1)	Multiple day trips: Δ in trips at (0,0,0)	Multiple day trips: Δ in trips at (2,2,2)
1	Alcona	H	0.070	2132	-748	1456	2629	-640	1069
2	Alger	S	0.076	2280	-306	466	3091	-212	249
3	Allegan	M	0.023	24136	-3041	3671	13743	-1084	1091
4	Alpena	H	0.047	3171	-652	1359	3728	-266	431
5	Antrim	M	0.013	2750	-160	164	2008	-47	32
6	Arenac	H	0.000	1720	12	-19	1886	58	-69
7	Baraga	S	0.239	2919	-1413	3838	1644	-411	1004
9	Bay	H	0.000	8099	10	-16	2072	72	-85
10	Benzie	M	0.021	2029	-237	282	6643	-453	443
11	Berrien	M	0.010	19612	-709	742	10287	-42	-19
15	Charlevo	M	0.059	1530	-415	764	3004	-459	631
16	Cheboyga	H	0.000	537	8	-11	1425	51	-61
17	Chippewa	S,H	0.000	3531	2	-3	1502	45	-57
21	Delta	M	0.001	2520	13	-26	899	39	-52
24	Emmet	M	0.073	767	-218	442	2407	-400	605
27	Gogebic	S	0.074	1100	-174	276	824	-40	39
28	GrandTrv	M	0.041	3968	-767	1053	2374	-259	294
31	Houghton	S	0.223	5011	-3354	8115	497	-261	613
32	Huron	H	0.027	2128	-267	351	4571	-283	299
35	Iosco	H	0.039	1901	-381	530	2770	-351	427
42	Keweenaw	S	0.166	733	-485	1991	381	-195	601
45	Leelanau	M	0.044	3049	-453	781	4148	-231	305
48	Luce	S	0.000	1384	4	-6	2594	116	-159
49	Mackinac	M,H	0.000	541	3	-3	1862	53	-67
50	Macomb	O	0.000	29993	2	-3	2706	90	-107
51	Manistee	M	0.009	3050	-129	131	7094	-76	26
52	Marquett	S	0.106	5057	-1845	3535	2451	-379	543
53	Mason	M	0.010	8400	-335	359	16272	61	-180
55	Menomine	M	0.004	1625	-26	23	583	20	-30
58	Monroe	O	0.000	17735	1	-2	2565	85	-101
61	Muskegon	M	0.016	20492	-1622	1840	8863	-315	265
64	Oceana	M	0.016	5279	-433	530	7950	-250	222
66	Ontonago	S	0.149	938	-459	711	545	-193	282
70	Ottawa	M	0.017	16633	-1227	1393	7337	-233	196
71	PresqueIsl	H	0.041	2110	-400	627	2401	-203	268
74	St.Clair	H	0.000	18127	3	-3	8480	196	-239
76	Sanilac	H	0.001	3748	-21	19	5271	123	-156
77	Schoolcr	M	0.000	1313	7	-13	1619	72	-94
79	Tuscola	H	0.000	6454	9	-12	2121	73	-86
80	VanBuren	M	0.013	10451	-642	690	5472	-124	91
82	Wayne	O	0.000	50908	2	-4	2968	97	-114
	Col. Totals			299861	-20843	36018	161687	-6156	8350

The first thing to notice from Table 4.4 is that the sites with high catch rates have large changes in trips, and the sites with very low or zero catch rates have very low changes in trips -- especially for single day trips. There are 12 sites which have zero catch rates in every month of the season. For single day trips, under CR0 (CR2) trips go up (down) at 13 sites -- 12 of these are the sites without lake trout. These sites get relatively more (less) attractive under CR0 (CR2). Yet, for each of these 13 sites, the change in trips is small -- totaling just 76 (−121) single day trips. Thus, few trips are drawn away from sites within the GLcold product line.

For multiple day trips, under CR0 (CR2) trips go up (down) at 17 sites a total of 1,209 (-1,676) multiple day trips -- 12 of these are the sites with zero catch rates, and the others are all sites with very low lake trout catch rates, mostly southern Lake Michigan sites. This means that for multiple day trips where trips go down (up), they do so by -7,365 (10,026), i.e., 16% (17%) of the total increase in trips comes from decreases at other sites *within* the GLcold product line, unlike single day trips where virtually all the increases in trips come from other product lines. Multiple-day trips draw more sites from within the GLcold product line than do single day trips because the GLcold multiple-day choice set has more sites and the lower inclusive value coefficient for multiple day trips places more emphasis on *within* product line substitution.

The top five sites in terms of the seasonal average lake trout catch rates are all Lake Superior sites; Baraga, Houghton, Keweenaw, Ontonogon, and Marquette counties. These same five sites are also the top five in terms of % changes in single day trips. The three sites with the highest lake trout catch rates all more than double their single day trips under CR2 (Houghton at 270% change, Keweenaw at 160%, and Baraga at 130%). Alcona Co.

on Lake Huron is ranked sixth in terms of percentage changes in single day trips with a 68% increase under CR2, while Emmet Co. on Lake Michigan is ranked seventh at 50%.

The largest absolute changes in single day trips under CR0 are as follows: Houghton on Lake Superior, Allegan on Lake Michigan, Marquette on Lake Superior, Muskegon on Lake Michigan, and Baraga on Lake Superior. The top five change slightly under CR2. The sites gaining the most single day trips under CR2 are as follows: Houghton and Baraga on Lake Superior, Allegan on Lake Michigan, and Marquette and Keweenaw on Lake Superior. Under CR2, Muskegon on Lake Michigan falls out of the top five, and under CR0, Keweenaw had the 12th largest change in single day trips.

For multiple day trips, there are only four sites experiencing more than a 50% increase in trips under CR2; Houghton, Keweenaw, Baraga, and Ontonogon. All four are on Lake Superior and are in the top five in terms of lake trout catch rates. Predicted multiple day trips under CR2 more than double at Houghton and Keweenaw Counties.

The largest absolute changes in multiple day trips under CR0 are at the following counties: Allegan on Lake Michigan (by far), followed by Alcona on Lake Huron, Charlevoix and Benzie on Lake Michigan, and Baraga on Lake Superior. As with single day trips, the five sites with the largest changes in multiple day trips change slightly under CR2. The sites gaining the most single-day trips under CR2 are: Allegan on Lake Michigan, Alcona on Lake Huron, Baraga on Lake Superior (the top three are very close), Charlevoix on Lake Michigan, and Houghton on Lake Superior. Houghton was 12th under CR0; Charlevoix was 11th under CR0).

In terms of the rankings of sites by total trips, there are no drastic changes in the overall ranking when the ranks are compared across the lake trout catch rate policy scenarios (CR0, CR1, and CR2). Under CR1, the top ten sites in terms of total single day trips are: Wayne, Macomb, Allegan, Muskegon, Berrien, St. Clair, Monroe, Ottawa, Van Buren, and Mason. The top sites are basically the same across the three catch rate levels. Under CR2, Houghton County becomes number 9 having been ranked 28th under CR0 and 15th under CR1. Three other sites make double digit changes in their ranks when CR0 is compared to CR2 (Baraga moves from 31st to 14th; Keweenaw moves from last, 41st, to 27th; and Alcona moves from 33rd to 21st).

Comparing the scenarios reveals little change in the ranking of sites by total multiple day trips. The top 14 and bottom 10 sites always have same sets of sites. The top 14 sites are exactly the same under CR1 and CR2, and under CR0 the top 14 only differ because the ranks of a couple sites are transposed. The top ten multiple day sites under CR1 are Mason, Allegan, Berrien, Muskegon, St. Clair, Oceana, Ottawa, Manistee, Benzie, and Van Buren. Comparing CR0 and CR2 rankings of sites based on total multiple day trips, only two sites make double-digit changes in rank. Alcona goes from 28th to 15th, and Baraga goes from 35th to 24th.

Thus, there are many sites within the GLcold product line where predicted trips change quite substantially under the hypothetical lake trout catch rate scenarios. These tend to be sites where lake trout catch rates are highest, though there are sites with high attendance and only moderate catch rates that also have large changes. The results also showed that practically all single day trip increases come from product lines outside of GLcold, while relatively more (but still only about 16%) of the multiple day trips are drawn from *within* the product line. This result is due in part to the limited number of GLcold sites in the single day choice set and to the greater substitutability across product lines for single day trips (as indicated by the nesting parameters by trip lengths at the product line level). In addition, the ranking of sites by trips is not radically changed by the policies. The top sites are basically unchanged while middle level sites do switch around in their rankings. Only a few sites change ranks considerably, and these sites were primarily the Lake Superior sites under CR2. Finally, the results once again show that the model over-predicts fishing trips to metro-area sites.

Some of the themes and factors that help explain the site level results in Table 4.4 will later be revisited to help interpret the results on the sensitivity of the values to the changes in the reference level of quality at other sites.

4.2.5 Changes in Lake Trout Catch by Lakes

Section 4.1.1 presented the steps for estimating the average value per fish (AVPF) which requires an estimate of the number of fish caught per lake. The method for estimating total catch by lake combines the MSU model trip predictions, the lake trout creel survey catch rate data, and the MSU angler survey estimates of hours fished. Table 4.5 presents the estimated lakewide recreational catch of lake trout for each of the Great Lakes. The numbers represent the C_i as described in section 4.1.1. Under baseline catch rate conditions, just over half of the lake trout are estimated to be caught at Lake Michigan. Also presented in Table 4.5 are the estimated lakewide catch under the joint doubling of the lakewide catch rates (the same policies presented in Tables 4.3 and 4.4).

Comparing the estimated catch in Table 4.5 to the predicted trips in Table 4.3 reveals that while Lake Superior is predicted to receive the fewest GLcold trips, relatively more fish are caught there due to high catch rates. In fact, under the doubling of catch rates, Lake Superior becomes the lake where the most lake trout are predicted to be caught.

Table 4.5: Estimated Lake Trout Catch by Lake.

	Lake Michigan	Lake Huron	Lake Superior	Total
***Method 1:* Effort based on all GLcold fishing hours (e^{SD}=4.49 & e^{MD}=12.2)**				
Baseline (CR1)	43,700	14,500	27,000	85,200
% catch by lake	51%	17%	32%	
Double (CR2)	106,600	48,200	134,900	289,700
% catch by lake	37%	17%	47%	
Ratio: catch in CR2/catch in CR1	2.4	3.3	5	3.4
***Method 2:* Effort based only on hours for trips where lake trout was named as a species the anglers were fishing for (e^{SD}=1.26 & e^{MD}=4.35)**				
Baseline (CR1)	14,600	4,900	8,500	28,000
% catch by lake	52%	18%	30%	
***Method 3:* Effort based only on hours for trips were lake trout was named as the main specie anglers were fishing for (e^{SD}=0.86 & e^{MD}=0.93)**				
Baseline (CR1)	4,900	1,500	3,800	10,200
% catch by lake	48%	15%	37%	

Under the joint doubling of lake trout catch rates, the total estimated catch increases by a factor of 3.4. The reason that estimated catch more than doubles when catch doubles is partly due to the fact that estimated trips are not held constant. From Table 4.3, estimated trips do increase when catch doubles with some of the new trips being drawn from outside the GLcold product line (see Table 4.2). But the increase in trips at any lake does not appear to be enough to explain the three-fold increase in estimated catch of lake trout. The key to understanding the increase is to recognize that catch rates vary spatially and temporally within any lake. That variation in the baseline lake trout catch rates is not fundamentally changed by the doubling of catch rates. Following the doubling of catch rates, there are shifts in trips from outside the product line and from other sites lakes within the product line, but there are also shifts within each lake toward the "better" sites. This shift *within a lake* toward sites with higher catch rates helps explain why the estimated catch increases more than would be accounted for just by a doubling of catch rate and an increase in trips at a lake. In fact, the degree of the reallocation of trips within a lake can be judged by the ratio in the third row of Table 4.5. Since the ratio is lowest at Lake Michigan, there is relatively less reallocation of trips at Lake Michigan than there is at Lakes Huron and Superior (see also the discussion of Table 4.4).

Table 4.5 also presents estimated catch of lake trout under two alternative methods of estimating the fishing effort per-trip. Clearly, the average values per fish will be sensitive to the estimated total catch per lake. These alternative methods and their implications will be discussed in detail section 4.2.7.

4.2.6 TV, AVPF, and MVCR by Lakes

As described in section 4.1, Table 4.6 presents the estimated total economic values (TV) for lake trout, the average values per fish (AVPF) for lake trout, and the marginal values for changes in catch rates (MVCR) for lake trout.[8] These values are presented by each of

[8] The MVCRs are presented for changes in expected lake trout catch per 100 hours. The MVCRs are interpreted as the aggregate value to Michigan anglers of a 0.01 increment in lake trout catch rates for all sites at a lake in all months of the season.

the lakes (columns). The first set of rows in Table 4.6 corresponds to the TV, AVPF, and MVCRs under the baseline lake trout catch rate conditions at each lake. The second set of rows corresponds to the TV, AVPF, and MVCRs under the doubling of *own* lake trout catch rates. The final set of rows in Table 4.6 relates the values under the baseline conditions to the values under the doubling of lake trout catch rates. Throughout the tables in this chapter, all value estimates are given in dollar units.

From the results in Table 4.6 for the baseline catch rates, one can see that Lake Michigan has the most valuable lake trout fishery and Lake Huron the least valuable, as measured by the total value of lake trout. Lake Michigan has the highest AVPF at about $12 with Lake Huron's AVPF closer to $11 and Lake Superior's AVPF at about $7.50. Lake Michigan has much higher MVCR than the other lakes, over twice those of Lake Huron and seven times those of Lake Superior. Of course, the marginal values are directly related to trips so that these results are completely consistent with the trip predictions in Table 4.3. Notice that the TV for Lake Michigan is only 2.5 times larger than the TV for Lake Superior. The TV at Lake Superior is larger than at Lake Huron and reflects the much larger reduction in lake trout that is being valued -- the baseline lake trout catch rates are substantially larger at Lake Superior. While the reduction in lake trout catch rates is only somewhat larger at Lake Michigan than at Lake Huron, the TV at Lake Michigan is over three times that of Lake Huron. This divergence reflects the difference in participation at the two lakes. Thus, the TV estimates depend on both the *change in quality* at the lake <u>and</u> the *number of trips* to the lake. In contrast, the MVCRs reflect differences in trips to the lakes. The MVCRs are largest at Lakes Michigan and Huron because they are closest to populations -- about 90% of the state population lives in the lower peninsula with most living in the Detroit metro area.

Table 4.6: TV, AVPF and MVCR for each lake under the baseline conditions.

	Lake Michigan	Lake Huron	Lake Superior
Baseline lake trout catch rates (CR1)			
TV: total value of lake trout	$538,000	$163,000	$202,000
AVPF: average value per lake trout (effort estimated using all GLcold fishing hours)	$12.30	$11.21	$7.48
MVCR: marginal value of lakewide change in lake trout catch rates (fish per 100 hours)	$249,000	$100,000	$35,000
***Double* baseline lake trout catch rates (CR2)**			
TV: total value of lake trout	$1,180,000	$420,000	$677,000
AVPF: average value per lake trout	$11.07	$8.72	$5.02
MVCR: marginal value of lakewide change in lake trout catch rates (fish per 100 hours)	$264,000	$107,000	$48,000
Convexity of benefit function			
Change in total value (TV_{CR2} - TV_{CR1}); i.e., value of the second increment.	$642,000	$257,000	$475,000
Ratio (TV_{CR2}-TV_{CR1})/TV_{CR1}	1.19	1.58	2.35
Ratio of AVPF ($AVPF_{CR2}$ /$AVPF_{CR1}$)	0.90	0.78	0.67
Ratio of MVCR ($MVCR_{CR2}$ /$MVCR_{CR1}$)	1.06	1.07	1.37

The second set of rows presents the same results under a doubling of lake trout catch rates. These policies are calculated for a doubling of the catch rate at the lake in question while the catch rates at the other lakes are held at their baseline (CR1) levels, as in the policies presented in Table 4.2. The rankings of the lakes based on the values are similar to those of before. Note that all of the AVPFs decrease. This is due to the more than doubling of the catch, i.e., while total values are increasing in catch rates, the estimated catch increases more than total value increase. While the rankings of the MVCRs do not change, the MVCRs do increase since the estimated trips increase.

Below the rows containing the results for the doubling of catch rates is a row that presents the increment in value that corresponds to the change in catch rates from the baseline to double the baseline (CR1 to CR2). This differs from the TV from CR2 since the TV is a change to zero catch rates. Comparing these increments in total value to the TVs from CR1 reveals that the increase in catch rates is more valuable than a decrease in catch rates of the same increment. This result was anticipated due to the convexity of the benefits function characterized in Chapter 2. For Lake Michigan the relative increase in catch rates is 20% more valuable than the same decrease in catch rates. Whereas for Lake Superior the increase is over twice as valuable as the decrease -- a rather substantial degree of convexity in the benefits function.

The comparison of the results in Table 4.6 for the values at the baseline catch rates and at double the catch rates also sheds light on *VPF Question 1:* are benefits linear with respect to changes in *own* site quality? While the total value results for Lake Michigan are not "too convex," the results for Lake Huron and for Lake Superior would seem to refute the empirical validity of the VPF approach. Likewise, the sensitivity of the AVPFs and the MVCRs to changes in the assumed baseline level of *own* site quality does not bode well for the VPF approach. As with the TVs, the AVPF and MVCR *own* site sensitivity is most pronounced for the Lake Superior results. The complete sensitivity results are explored in more detail in the next section.

The valuation results also highlight the notion that value comes from improving good sites, (sites close to people or very high in quality). Good sites in the baseline are essentially those sites where anglers are fishing. As a consequence, marginal values are highest where the current trips are being taken. Bear in mind that the costs of "achieving" a marginal change may not be equal across lakes. For example, the marginal values at Lake Michigan are over twice those for Lake Huron. However, if the cost of achieving a marginal change in lake trout catch rates were three times as high at Lake Michigan than at Lake Huron, then the money would be better spent at Lake Huron.

Are these values high or low? The AVPF values are not too different from the $12 dollar value used by the Koonce et al. as the value of a lake trout. However, as discussed below, the AVPF estimates are extremely sensitive to the units used to estimate effort and catch. For additional perspective on the value estimates, recall from Table 3.8 that the GLcold fishery accounts for only 4% and 12% of the single and multiple day fishing trips in Michigan. Moreover, the lake trout fishery is not the only GLcold fishery, and based on the estimated preference parameters, the lake trout fishery is the least preferred GLcold fishery. In addition, compared to other fishing opportunities such as inland lakes or GLwarm, the three lakes under consideration are relatively far from Michigan's major population centers. For most of the sample members, the GLcold single day choice set only contains one of the Great Lakes in question. One should also bear in mind that the baseline creel survey catch rates for lake trout are quite low so that reducing these catch rates to zero does not result in a massive change in lake trout catch rates. Finally, recognize that the value estimates obtained from reducing lake trout catch rates to zero may not adequately capture all the relevant use-values associated with the fishery and cannot measure non-use values.

For another perspective on the value estimates, the total value estimates in Table 4.6 can be translated into values per user day by dividing them by the estimated changes in user days. These can be calculated from the trips presented in Table 4.3 and by assuming that single day trips are one user day and multiple day trips are 3.5 user days (see the discussion accompanying Table 3.8 in Chapter 3). The results yield user-day values of about $22. The user-day value accounting is commonly used to compare recreation valuation results, and these user-day values are at the lower half of the range of the values for cold-water fishing found in the literature (cf. Walsh et al.).

4.2.7 A Closer Look at the AVPF Derivations

Section 4.1.1 described the methods used to derive the AVPF estimates. In that section, five steps were outlined. The second step involved using the survey data to estimate the hours fished for lake trout for single and multiple day GLcold trips, e^{sd} and e^{md} respectively. The e^{i}s are key to translating predicted fishing trips into total hours of fishing effort. Effort is then combined with the creel survey estimated catch per unit effort to estimate total catch. The estimates of catch per lake depend directly on the e^{i}s, and hence, the AVPF will depend on the e^{i}s. The TV estimates are unaffected by the estimated e^{i}s. Ideally, the definition of the e^{i}s would closely mirror the definition of effort used in the catch rates. For example, the catch rates may have been estimated using the creel survey party interview data on catch and effort for parties that *targeted* lake trout or the rates may have been derived using the data for parties fishing *for any* cold water species such as trout or salmon. The effort-per-trip estimates derived from the MSU survey data could be matched to either of these approaches. At the present time, the exact definitions of effort used in the catch rates derived from the creel survey is unknown. To examine the effect of alternative definitions, the AVPFs are derived under alternative assumptions regarding the catch rate effort definitions.

While there are surely many alternatives ways to use the MSU survey data to estimate lake trout fishing effort per trip, three quite different methods for calculating the lake trout fishing effort come to mind. The first would use all the hours of fishing associated with GLcold trips; the second would use only those hours for trips where lake trout was mentioned as a species that was being sought; and the third would only use the hours for trips that targeted lake trout. These are referred to as methods 1, 2, and 3 in Table 4.5. The sensitivity of the AVPF results for Lake Michigan for these three treatments of lake trout fishing effort per trip are presented below:

1.) One approach would use all the effort from all the GLcold trips regardless of the species sought or targeted for the fishing trip. In this case, the average hours fished for a GL cold trip was 4.49 hours for single day trips and 12.2 hours for multiple day trips. For Lake Michigan, this method resulted in an estimated catch of 43,700 lake trout and AVPF of $12.30. This is the method used for the AVPF results reported in Table 4.6 and in the next section for the sensitivity analysis.

2.) A second approach would use all the hours fished on any GLcold trip where lake trout was among the species sought and use a share of the hours for trips where "unspecified trout" was one of the species. Here, the lake trout does not necessarily need to be the species that was targeted. Also, many of the GLcold trips mention trout as a species sought, but the respondents did not distinguish the specific species. Since some portion of the "unspecified trout" likely involved fishing for lake trout, this approach tries to take account of some share of the effort for trips including "unspecified trout." Since 34% of the named trout species were lake trout, a reasonable share of the "unspecified trout" hours of effort would be to take 34%. Thus, using all the hours for trips that included lake trout as a species sought and using 34% of hours for any trip that includes "unspecified trout," but not lake trout, in the species list, yielded an average of 1.26 hours per single day trip and 4.35 hours per multiple day trip. For Lake Michigan, this method resulted in an estimated catch of 14,600 lake trout and AVPF of $36.96.

3.) A third approach would use the hours for trips where lake trout was targeted and use some share of the hours where "unspecified trout" was targeted. In the survey, anglers mentioning multiple species of fish were asked what they were primarily trying to catch. For these individuals, targeted means the primary species, and for individuals who named only one species, that species is treated as the one targeted. Again, 34% of the hours for trips which targeted "unspecified trout" were added to the hours for trips targeting lake trout. This approach yields average effort estimates of 0.86 hours per single day trip and 0.93 hours per multiple day trip. For Lake Michigan, this method resulted in an estimated catch of 4,900 lake trout and AVPF of $109.61.

Thus, the three methods differ by a factor of 9 in their associated estimates of the AVPF for Lake Michigan. The implications of this assumption are discussed more fully in Chapter 5. For now, bear in mind that the AVPF estimates presented here are preliminary, and the estimates depend greatly on the assumptions regarding the underlying effort that was used to estimate the creel survey catch rates. The total valuations and the marginal valuations of catch rates are not subject to this difficulty, though they are not without their own caveats. Finally, while the AVPF estimates are sensitive to the definition of effort per trip, the ability to draw conclusions about the sensitivity of these estimates to *own* and *other* lake quality does not depend on this definition.

4.3 Sensitivity to "*Own*" and "*Other*" Lake Quality

This section presents the complete results of the examination of the sensitivity of the components of the VPF calculations to changes in reference level of quality at *own* and *other* lakes. The sensitivity analysis was introduced in section 4.1.4, and is intended to provide the information to assess the empirical validity of the VPF assumptions. As already seen in Table 4.6, the TV, AVPF, and MVCR estimates are all sensitive in varying degrees to the level of quality at *own* sites. For this reason, they do not support the linearity of *own* site benefits assumption that was raised in *VPF Question 1*. This section more fully develops these results as well as providing the results for the sensitivity of the valuations to *other* lake quality. As will be seen, for the policies considered here, all of the value estimates are remarkably insensitive to changes in the quality conditions at other lakes. Thus, there is empirical support for treating the value estimates at one lake as if they are independent of the quality conditions at other lakes. This result is quite surprising given the standard economic discussions on the importance of including substitutes.

The first set of results are presented in Table 4.7 which shows the sensitivity of the TVs at each lake to the baseline quality at that lake (the columns) and to the reference level of lake trout catch rates at other lakes (the rows). The next three tables all follow a similar format. The columns refer to the lakes and to the relative *own* lake quality used for the valuation. For each of the three lakes, there are two columns -- one for the valuation from the baseline level of *own* lake catch rates (CR1) and one for the valuation from double the baseline level of *own* lake catch rates (CR2). Thus, each row contains six policies, two for each lake. The rows represent the various conditions at *other* lakes. The rows are indexed by a two-element vector (x,y): for any given column, the quality levels at the other two lakes are x times the baseline and y times the baseline. For the Lake Michigan columns, x refers to Lake Huron and y refers to Lake Superior. Likewise, for the Lake Huron (Superior) columns, x is Lake Michigan and y is Lake Superior (Huron). The x and y are either 0, 1, or 2 corresponding to the CR0, CR1, and CR2 lakewide lake trout catch rate scenarios. Thus, looking at Table 4.7 through 4.9, the rows with (x,y) = (1,1) presents the same results as those previously given in Table 4.6.

Table 4.7: Sensitivity of each lake's total value of lake trout to changes in baseline conditions at the own lake and at other lakes.

Conditions at other lakes	Lake Michigan total lake trout value from *own* site level ...		Lake Huron total lake trout value from *own* site level ...		Lake Superior total lake trout value from *own* site level ...	
	CR1	**CR2**	**CR1**	**CR2**	**CR1**	**CR2**
1. (0, 0)	545,189	1,194,533	168,714	433,257	205,257	685,481
2. (0, 1)	542,903	1,189,588	167,892	431,185	204,436	683,155
3. (0, 2)	538,646	1,180,430	166,387	427,399	203,186	679,624
4. (1, 1)	540,677	1,184,938	164,200	421,934	202,972	678,940
5. (1, 1)	538,463	1,180,143	163,450	420,042	202,223	676,812
6. (1, 2)	534,330	1,171,245	162,071	416,568	201,080	673,576
7. (2, 0)	533,867	1,170,406	159,118	409,131	200,315	671,388
8. (2, 1)	531,760	1,165,833	158,446	407,431	199,643	669,471
9. (2, 2)	527,814	1,157,321	157,200	404,292	198,616	666,550
Max % change	3.3%	3.2%	7.3%	7.2%	3.3%	2.8%

From Table 4.7, one can see that there is relatively little change in each lake's TV across the combinations of quality conditions at *other* lakes (looking down the rows for any column). The last row presents the maximum percentage change for the column, which was calculated by using the smallest and largest valuation in the column. The maximum percentage changes are all fairly small by any practical criteria; the largest changes are at Lake Huron at about 7%. The sensitivity results are not affected by the relative *own* lake conditions, i.e., they are about the same for both columns for any lake.

Table 4.8: Average Values Per Lake Trout at Each Great Lake

Conditions at *other* lakes	Lake Michigan AVPF from ...		Lake Huron AVPF from ...		Lake Superior AVPF from ...	
	CR1	CR2	CR1	CR2	CR1	CR2
1. (0,0)	12.34	11.10	11.31	8.77	7.53	5.04
2. (0,1)	12.33	11.10	11.30	8.76	7.52	5.04
3. (0,2)	12.31	11.08	11.28	8.75	7.50	5.02
4. (1,0)	12.32	11.09	11.25	8.73	7.50	5.02
5. (1,1)	12.31	11.08	11.25	8.72	7.49	5.02
6. (1,2)	12.30	11.06	11.23	8.70	7.47	5.01
7. (2,0)	12.29	11.05	11.20	8.67	7.46	5.00
8. (2,1)	12.28	11.05	11.19	8.67	7.45	4.99
9. (2,2)	12.27	11.03	11.18	8.65	7.43	4.98
Max % change	0.6	0.7	1.2	1.4	1.3	1.3

Table 4.9: Marginal Values of Lakewide Changes in Lake Trout Catch Rates (fish/100 hours).

Conditions at *other* lakes	Lake Michigan MVCR from ...			Lake Huron MVCR from ...			Lake Superior MVCR from ...		
	CR0	CR1	CR2	CR0	CR1	CR2	CR0	CR1	CR2
1. (0,0)	237,678	250,632	265,902	96,796	101,500	108,779	29,055	35,171	48,351
2. (0,1)	236,796	249,728	264,996	96,456	101,152	108,395	28,960	35,058	48,205
3. (0,2)	236,796	249,728	264,996	95,796	100,447	107,660	28,804	34,866	47,972
4. (1,0)	236,502	249,422	264,684	95,450	100,067	107,221	28,759	34,822	47,903
5. (1,1)	235,635	248,543	263,784	95,136	99,736	106,868	28,670	34,721	47,765
6. (1,2)	233;902	246,797	262,013	94,514	99,086	106,165	28,524	34,551	47,554
7. (2,0)	234,756	247,634	262,874	93,963	98,481	105,487	28,425	34,421	47,386
8. (2,1)	233,910	246,787	262,001	93,661	98,171	105,153	28,337	34,324	47,264
9. (2,2)	232,220	245,088	260,275	93,082	97,554	104,493	28,222	34,172	47,064
Max % change	2.35	2.26	2.16	3.99	4.05	4.10	2.95	2.92	2.73

Table 4.8 presents the sensitivity of the AVPF calculations for each lake (columns) to the different reference levels of quality at other lakes (rows). The interpretation of Table 4.8 is similar to Table 4.7. Compared to the TV estimates, the AVPF are particularly insensitive to the differing reference levels of catch rates at *other* sites.

Table 4.9 presents the sensitivity of the MVCR calculations for each lake (columns) to the different reference levels of quality at other lakes (rows). The interpretation of Table 4.9 is similar to that of Tables 4.7 and 4.8 except Table 4.9 contains three columns for each lake. The three columns represent the three possible reference levels of *own* site quality for the MVCR calculations (see footnote 26). As with the other value estimates, the MVCR are not sensitive to the differing reference levels of catch rates at *other* sites. The MVCRs show slightly less sensitivity than do the respective TVs.

The row labeled (1,1) in Table 4.9 provides one more *own* site observation for the MVCRs than appears in Table 4.6. Consistent with previous results on *own* lake sensitivity of MVCRs, the MVCR at CR0 is less than the MVCRs at CR1 and CR2. In absolute value, the MVCRs are least sensitive to *own* site quality changes at Lakes Huron and Michigan, and most sensitive at Lake Superior. Again, this is consistent with the previous results in Table 4.6 and is due to the comparatively large change in quality at Lake Superior that occurs in moving from CR0 to CR2. The large quality change induces a large change in Lake Superior trips so the MVCRs were expected to differ substantially. Also notice that for all the lakes, the increase in the MVCRs is larger when comparing the MVCRs at CR2 to those at CR1 than when comparing the MVCRs at CR1 to those at CR0. This effect is least pronounced for Lake Michigan where the second increment in MVCRs is larger by a factor of about 1.18. For Lake Superior, the difference between the MVCR at CR2 and MVCR at CR1 is about 2.2

larger than the difference between the MVCR at CR1 and MVCR at CR0. For Lake Huron, the factor is about 1.55.

All the directions of movement in Tables 4.7 to 4.9 are consistent with the shape of the benefits function derived in Chapter 2 -- though the changes are small. Looking down the columns in Table 4.7, one can see that the estimated TVs for a site decrease as the reference level of quality at other sites increases. This result coincides with the shape of the benefits function established in equation (2.xx) in Chapter 2. Similarly, looking down the columns in Table 4.8, the estimated MVCRs also decrease as the reference level of quality at other sites increases. This result is consistent with the negative cross partial derivatives of the benefits function as seen equation (2.xx) in Chapter 2.

In contrast to the pattern for the TVs and MVCRs, the AVPFs all increase as the quality at other sites increases. While there was no theory developed to anticipate the reaction of the AVPFs, the reason for this result is that, in response to increases in the quality of other sites, the estimated catch decreases faster than the TV. The estimated catch decreases as a result of the responsiveness of effort (trips). Even so, the changes in trips were not significant enough to induce much variation in the AVPFs.

As just mentioned, the catch and effort estimates were also fairly insensitive to changes in *other* site quality. While the results are not presented here, the sensitivity to *other* site quality was examined for each of the following: for the predicted single day and multiple day trips by product line (as in Table 4.2); for the predicted single and multiple day trips by lakes (as in Table 4.3); and for the predicted catch by lake (as in Table 4.5). For the trip predictions, the estimates were made from the three *own* site quality levels corresponding to CR0, CR1, and CR2. For the catch estimates, the derivations were made from the *own* site quality levels of CR1 and CR2.

The single day trip estimates (by lakes as in Table 4.3 or by product lines as in Table 4.2) were almost completely insensitive to changes in quality at other sites. For the single day trips by lakes, the maximum percentage change in single day trips by lake across the nine *other* site quality combinations was never more than 0.08% (this calculation corresponds to the last rows of Tables 4.6 to 4.8). Accordingly, if one was interested in the predicted single day trips for any of the *other* site quality scenarios, the existing predictions in Table 4.3 could be used. The predicted multiple day trips by product lines and multiple day trips by lake were relatively more responsive to changes in the reference levels of quality at *other* lakes. Still, the maximum percentage changes in multiple day trips by lake across the nine *other* site quality combinations was never greater than 5%. While relatively small, this change is substantially larger than for the single day trips. The largest percentage changes at each of the lakes were 2.8% at Lake Michigan, 5% at Lake Huron, and 3.8% at Lake Superior. Because predicted catch is composed of the predicted single and multiple day trips by lake, predicted catch by lake is somewhat sensitive to the nine *other* site quality combinations.[9] For predicted catch, the maximum percentage changes across scenarios is 2.9% for Lake Michigan, 6.5% for Lake Huron, and 2.3% for Lake Superior. Decomposing the sensitivity results for catch confirmed that the sensitivity was solely due to the sensitivity of multiple day trip effort,as there was negligible changes across scenarios in the catch attributable to single day trips.

That the multiple-day trips are relatively more sensitive than single-day trips to the reference levels of *other* lake quality makes sense since the 150-mile definition of single day

[9] Recall that the hours of effort per trip were 1.26 and 4.35, so multiple-day trips carry about four times the weight that single-day trips do when estimating the catch. Catch may also be more responsive to changes in *other* site quality because of changes in the spatial and temporal distribution of trips *within* each lake.

choice sets means that most individuals do not have multiple Great Lakes in their GLcold choice set for single day trips. On the other hand, all three Great Lakes are in the multiple day trip choice set for each individual. Even though all three lakes are in the multiple day choice sets and the multiple day trips were more sensitive to other site quality, the multiple day trips were not *that* sensitive. The reason for this is that, while all the multiple day choice sets include the three lakes, few of the multiple day choice sets have two of the lakes close to any individual sample member. Thus, the distance between the lakes inhibits substitution of trips across lakes.

4.3.1 Why Are the Values Insensitive to "Other" Site Quality?

There are some basic reasons why the values and trip estimates are relatively insensitive to changes in the quality of other sites. These reasons include the broad scope and type of policies being considered, the limited number of GLcold substitutes within any individual's single day choice set, and the degrees of substitution embodied in the MSU model. In this section, these reasons are developed more fully. That the results can be understood within the context of the RUM does not mean they are not surprising, nor does it mean they are rigged -- actual Great Lakes policies can be expected to be as broad in scope as the polices examined here.

To begin, recall the structure and estimated parameters of the MSU model. The RUM is a four-level nested logit. As illustrated in Figure 3.1, the four levels of nesting are at the participation level (go, don't go), the trip length level (single day, multiple day), the product line level (product lines are the various fishing types within each trip length), and the site level (counties that support the various product lines). The nesting is a means of partially overcoming the independence of irrelevant alternatives (IIA) property of simple multinomial logit models. Recall that IIA means that the ratios of site probabilities remain constant for sites that are unaffected by a policy. IIA can lead to peculiar substitution patterns as illustrated by the red bus/blue bus problem (see Chapter 2, section 2.3.3). What IIA implies is that when quality changes at some set of sites, trips will change at sites where quality does not change in a manner that preserves the pre-existing ratios of site probability among those sites. Even in nested-logit models, IIA will still hold for the ratios of probabilities for sites within any nest, but it will not hold across nests if the nesting parameters are significantly less than one (the inclusive value parameters).

From the estimates presented in Tables 3.6 and 3.7, one sees that the parameters on the inclusive values at the participation level and at the trip length level of the MSU model are very low and are significantly less than one. Thus, a priori, one would expect little substitution across the don't-go, single-day and multiple-day nests. Empirically, this is confirmed by the trip predictions in Table 4.2. So for either trip length, all substitution is among trips of the same length. For single-day trips, the IV parameter is close to 1, so changes in single-day trips will "almost" exhibit IIA across sites in different single day product lines. For multiple day trips, the IV parameter is 0.617 and is significantly less than 1 at the 1% level. Thus, changes in multiple day trips are more prone to come from sites within the GLcold product line than for single day trips. However, the trip changes are unlikely to be drawn from single day trips or from the don't-go option.

As mentioned above, another explanation for the results has to do with the number of substitutes within the GLcold choice sets. It is worth repeating that very few individuals will have all three of the Great Lakes in their single-day choice sets, and most individuals do not live *close* to more than one (if any) of the lakes. In addition, although all of these lakes are in each persons multiple-day choice set, only a handful of individuals live *close* to multiple lakes.

In terms of the policies, all of the lake trout catch rate policies considered here were simplistic. Because they were based on eliminating or doubling catch rates, the policies only affect (or change the quality of) sites with positive lake trout catch rates. These policies have a "once bad always bad" nature since a site with zero catch rates will still have zero catch rates even under the doubling policy scenarios. Sometimes this makes sense. For example, Bay County on Saginaw Bay of Lake Huron will never support cold water lake trout because it is so shallow. Alternatively, Cheboygan Co. is near the "worst" lamprey area on Lake Huron because of the difficulty of controlling lamprey spawning on St. Marys River (the shipping route to Lake Superior). Under more stringent control of lamprey, Cheboygan County might someday have positive lake trout catch rates.

Because the policies considered doubling and eliminating lake trout catch rates at the various Great Lakes, the scale of the policies differs across the lakes. The changes in catch rates are fairly small at Lake Huron and are rather large at Lake Superior. In reality, it may not be possible to increase Lake Superior lake trout catch rates to double their baseline levels. In terms of valuation aimed at lake trout restoration, it might be more realistic to consider bringing Lake Huron and Lake Michigan "up to" the baseline levels at Lake Superior. The results might then be more sensitive to changes at these sites, though even if they are, the point would then be that to get much cross site sensitivity, very large changes are needed.

Putting these features together, consider what happens under the policies for residents of the Detroit metro area. For sample members living in Detroit, the only site in the single day GLcold choice set where quality changes is Huron County. For those in the northern metro area, there are only two sites in the single day choice set where lake trout catch rates change (Huron and Iosco). Thus, for all of the Metro area residents (most of Michigan's residents), the sites where quality changes are about 100 or more miles away -- a sizable distance for day trips. For multiple day trips, all the Great Lakes are included in any individual's GLcold choice set; however, the closest Lake Superior sites where quality changes are some 400 miles from the Detroit metro area.

So, why don't single day trips at Wayne go down when Lake Huron quality goes up? For the Metro residents there are only one or two sites where quality actually changes; these changes are relatively small, and the sites are far away. Therefore, there is not a large change in trips for Metro residents even though there are a lot of individuals living in the Metro area. Moreover, for what changes in GLcold single day trips there are for the Metro area residents, the trips are drawn from all other product lines according to the near IIA of single-day trips.

Similarly, why is there so little change in trips to the Lake Michigan sites of the Upper Peninsula in Lake Superior? These sites have zero catch rates, but they lose *very* few trips. In the Upper Peninsula, the single-day choice set includes counties that border Lake Michigan and Lake Superior. Thus, one might expect that, taken individually, the (2,1,1) policy would draw trips from Lake Superior, and the (1,1,2) policy would draw trips from Lake Michigan. Consider Delta county (on Lake Michigan in the Upper Peninsula) where lake trout catch rates are almost non-existent. One might expect the GLcold trips to go down at this site when the quality of other GLcold sites greatly increases. They barely do. Why? First, there are other GLcold species at these sites. Second, IIA is at play here. Under CR2, the single day trips in GLcold go down at Delta by about 26 trips while the single day trips for other product lines at Delta go down by over 300 trips. They go down in a manner that maintains the proportions across sites and product lines where quality doesn't change. Thus, that the single day trips are "almost" IIA means that most of the trips will come from other product lines since the other product lines constitute most of the trips. At Delta County, GLcold accounts for only 6% of the predicted single day trips to that county, and less than 1% of the 326,000 trips to all sites and product lines in the Upper Peninsula where quality does not change. Therefore, the "almost" IIA property of the single day trips helps explain such minimal amounts of trip changes.

For multiple day trips, the sensitivity is small, even though all three of the lakes are in the choice sets and the nest is not subject to IIA. As mentioned in the discussion of Table 4.4, when catch rates jointly double, about 16% of the increase in trips at sites where quality goes up is offset by decreases in trips at sites within the GLcold product line. This contrasts with less than 1% for single day trips. While larger than single day, it is not large due to the broad scope of the policies and the spatial separation of the Great Lakes. However, the percent of trips drawn from within the GLcold is much higher when the doubling of catch rates are examined for the individual lakes.[10] For the three lakes, the share of multiple day trip increases that are drawn from other sites within the GLcold product line are 21%, 40%, 36% for Lakes Michigan, Huron, and Superior, respectively. Thus, when the scope of policies is not as broad, there is a larger amount of substitution within and across the lakes. Even with this increased substitution, however, the value estimates are not that sensitive to changes in *other* site quality. This is because the multiple day trips account for a smaller share of the trips.

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[10] These policies are denoted by (2,1,1), (1,2,1) and (1,1,2) for doubling at Lake Michigan, at Lake Huron, and at Lake Superior, respectively.

4.4 Direct Valuation Results and Independent Valuations (IVS)

Table 4.10 presents the direct valuations introduced in Section 4.1.3 of this chapter. The direct valuations represent the economic value of movement *from* the status quo lake trout catch rates at each lake *to* the 26 combinations of CR0, CR1, and CR2. In the notation introduced above, the table presents the value of policies moving from (1,1,1) to (x,y,z). These policies are provided as examples of how benefits functions derived from a recreational demand model can be used to jointly value multidimensional policies. Such use would be one way to evaluate lamprey policies in lieu of the value-per-fish approach.

Some of the values reported in Table 4.10 correspond to total values (TVs) reported in earlier tables. The rows where the results are printed in bold text are rows where only one of the lakes changes quality. Some of these values are reported in Table 4.7 as the TV from CR1 at other sites. Since these are the values associated with a change at just one lake, these values can be used to compare the IVS values associated with each of the joint policies presented in Table 4.10. These IVS values for each policy are presented in the fifth column. For example, to derive an IVS value for the (0,0,0) scenario, simply add each of the individual lake values for eliminating catch; i.e., add the values for the (0,1,1), (1,0,1) and (1,1,0) scenarios to get −538,463 + −163,450 + −202,223 = −904,136, reported in the first row of the "IVS Value" column in Table 4.10.

Table 4.10: Direct and IVS Values for the 26 Policy Combinations.

CR Levels at the Three Great Lakes*					
Lake Michigan	Lake Huron	Lake Superior	True Value	IVS Value	% Bias
0	0	0	-911,611	-904,136	0.82
0	0	1	-706,354	-701,913	0.63
0	0	2	-226,127	-227,323	-0.53
0	1	0	-742,898	-740,686	0.30
0	**1**	**1**	**-538,463**		
0	1	2	-59,741	-63,873	-6.92
0	2	0	-478,354	-484,094	-1.20
0	2	1	-275,165	-281,871	-2.44
0	2	2	201,271	192,719	4.25
1	0	0	-366,422	-365,673	0.20
1	**0**	**1**	**-163,450**		
1	0	2	312,519	311,140	0.44
1	**1**	**0**	**-202,223**		
1	**1**	**2**	**474,590**		
1	2	0	55,512	54,369	2.06
1	**2**	**1**	**256,592**		
1	2	2	729,087	731,182	-0.29
2	0	0	282,920	276,007	2.44
2	0	1	483,234	478,230	1.04
2	0	2	954,305	952,820	0.16
2	1	0	442,038	439,457	0.58
2	**1**	**1**	**641,680**		
2	1	2	1,111,505	1,116,270	-0.43
2	2	0	692,050	696,049	-0.58
2	2	1	890,665	898,272	-0.85
2	2	2	1,358,595	1,372,862	-1.05

* 0 or CR0: means lakewide lake trout catch rates go to zero.
1 or CR1: means lakewide lake trout catch rates stay at their baseline levels.
2 or CR2: means lakewide lake trout catch rates double.
The six lake values used to calculate the IVS are in bold text.

As discussed in section 4.1.3 of this Chapter and section 2.4 of Chapter 2, the theoretical difficulty with the IVS procedure is that it does not follow an appropriate path for joint changes in site quality. If the valuations are measures from the status quo quality level (1,1,1), the IVS procedure will over-state the value of joint improvements in quality and under-state the value of joint decrements in quality (see section 2.4). The reason for these directions of bias was that the benefits function has negative cross partials for quality changes at different sites. Inspection of Table 4.10 reveals that the IVS results do conform with these theoretical expectations. For example, the IVS value of the joint decrease in quality to (0,0,0) under-states the exact welfare measure, and the IVS value of the joint increase in quality to (2,2,2) over-states the exact welfare measure. However, in all cases, the percent bias due to the IVS procedure is small for the policies considered here and only exceeds 1 percent for a few cases. Consequently, the policies studied here do not exhibit substantial sequencing (embedding) effects.

These results reinforce the above results on the sensitivity of the value estimates to the levels of *other* site quality. The minimal sequencing effects are driven by the same factors that resulted in the insensitivity to *other* site quality as outlined in section 4.3.1. The IVS results suggest that little is lost by treating the lakes *as if* the value of changes in quality at any given lake is independent of the levels of quality at other lakes. That the values can be treated as if they are independent of quality at other lakes opens up many interesting possibilities for future valuation efforts and for uses of the current valuation results. These issues and their implications are discussed more fully in Chapter 5.

4.5 Some Additional Trout and Salmon Valuations

In this section, several additional scenarios are considered and evaluated using the MSU model. The scenarios considered here are broader than the lake trout scenarios presented earlier. The results are intended to add perspective to the lake trout valuations.

More Huron and Michigan policies: The catch rates for lake trout at lakes Huron and Michigan were many times lower than those at lake Superior, as seen from Table 4.1. This in part accounts for the magnitude of the estimated values associated with for doubling and driving these catch rates to zero at Lake Michigan and Lake Huron. As mentioned in earlier sections of this chapter, one difficulty with policies involving percentage increases or decreases in catch rates is that they essentially condemn sites with zero (or very low) catch rates to be zero no matter what the percentage increase in catch rates. Therefore, one alternative type of scenario would be to consider what would happen if the catch rates at lakes Huron and Michigan were "brought up" to the level of Lake Superior. Below, the results of two different scenarios for doing so are presented.

One way to "bring up" the catch rates at Michigan and Huron is to raise the catch rates so that they match, on average, the catch rates at Lake Superior. However, this would require multiplying all Lake Michigan lake trout catch rates by a factor of 5.5 and multiplying all lake trout catch rates at Lake Huron by a factor of 6.8 (see Table 4.1). Raising catch rates by such a large factor would result in some sites with lake trout catch rates over 1.5 fish per hour (three times the best catch rate at any Lake Superior site). Another way to approach this would be to choose an increase in catch rates that would make the best month at Michigan or Huron match, on average, as good as the best month at Lake Superior, on average. This would require raising catch rates at Lake Michigan by a factor of 2.68 and raising lake trout catch rates at Lake Huron by a factor of 3.61. Under this type of policy, the overall average lake trout catch rates will still be much lower at lakes Huron and Michigan than they are at Lake Superior (though, by construction, the averages match during peak months). These are the policies that were run.

Increasing lake trout catch rates at Lake Huron by a factor of 3.61 yields an estimated value of $1,065,000, as seen in row 4 of Table 4.11. Increasing lake trout catch rates at Lake Michigan by a factor of 2.68 yields an estimated annual value of $1,157,000, as seen in row 5 of Table 4.11. For reference, rows 1 to 3 of Table 4.11 reproduce the results presented earlier for the doubling of lake trout catch rates at each of the lakes. Following the results of the previous section on the near independence of joint lake valuations, the value of a joint policy raising lake trout catch rates by 3.61 at Lake Huron and 2.68 at Lake Michigan would be about 2.2 million dollars.

An alternative approach for "bringing up" the lake trout catch rates at Michigan and Huron to the levels of Lake Superior would be to increase catch rates at all sites so they match the monthly average catch rates at Lake Superior. To do so, the catch rates at Lakes Huron and Michigan were increased so that they were at least as high as the average monthly catch rates at Lake Superior as reported in Table 4.1. Because the lake trout season at lakes Michigan and Huron is not open during the months of April and October, the catch rates for these months were unaltered. For the months of May through September, any site on Lake Michigan or Lake Huron with a lake trout catch rate less than the average monthly Lake Superior value in Table 4.1 was assigned the Lake Superior value for that month. To focus on what would happen at lakes Michigan and Huron, the catch rates at Lake Superior and the Metro counties are left unchanged. The estimated value of this change in catch rates is 958,500 dollars, as reported in the first row of Table 4.11. Again, this is the value to anglers who are Michigan residents, and the estimate applies to the open-water season. This scenario changes the spatial distribution of catch rates because sites with very low or zero lake trout catch rates are being "brought up", while sites with high catch rates are unaffected.

These policies illustrate some of the issues involved in directly valuing changes in lake trout catch rates with a model such as the MSU model. Doing so requires that one specify the spatial and temporal pattern of the lake trout catch rates "with" and "without" the some policy. Policies involving percentage changes in catch rates preserve (impose) the existing spatial and temporal pattern of catch rates. As a by-product, sites with zero catch rates in the baseline are condemned to have zero catch rates no matter what the percentage increase in catch. This may be a useful feature since some site may never support lake trout. However, it may be that restoration policies not only result in percentage increases in catch rates, but they may also lead to positive catch rates in areas where they were previously zero. The exact approach has implications for how one might link lamprey control policies to a economic model such as the MSU model.

Salmon: Since lamprey can affect population levels of other species besides lake trout, the second row of Table 4.11 presents the results of a policy scenario where catch rates are reduced for all cold species. Specifically, the catch rates for coho salmon, chinook salmon, lake trout, and rainbow trout were multiplied by 1/3 in each month at each Great Lake site. Here, none of the species is driven to zero catch rate, but each is substantially reduced. Decreasing the catch rates for all Great Lakes trout and salmon by a factor of 1/3 results in a predicted loss to Michigan resident anglers of 1,269,600 dollars per open-water season. This scenario results in a far greater loss in value than the reducing only the lake trout catch rates. Again, this is due to the combined effects of the larger estimated parameters on the other species and the relatively greater catch rates for these other species, particularly the salmon.

Total surplus: Another scenario of interest is the total surplus use-value of the Great Lakes trout and salmon fisheries. This is akin to the area behind the demand curve for recreational angling for trout and salmon at the Great Lakes (see figure 2.2 of Chapter 2). This can be calculated from the MSU model by eliminating the Great Lake cold product lines form the model (i.e., close all Great Lake trout and salmon fishing sites). From row 8 of Table 4.11, the estimated total recreational use-value to Michigan resident anglers of the Great Lakes trout and salmon fisheries is about 20 million dollars per year. The final row of Table 4.11 shows the loss associated with a closure of all anadromous run fishing in Michigan along with a closure of the Great Lakes trout and salmon fisheries. This policy is calculated by closing the anadromous run and Great Lake cold product lines of the MSU model. The estimated total recreational use-value to Michigan resident anglers of the Great Lakes and anadromous trout and salmon fisheries is about 36 million dollars per year. These two examples provide estimates of the total annual use-value of these fisheries to Michigan resident anglers.

The above valuations shed light on the differences between the total surplus value associated with eliminating fishing sites/activities and the *changes* in the surplus value associated with changes in quality. Reductions in surplus value for decreases in quality cannot be greater than the total surplus use-value associated with access to a site. Recall from the discussion in Chapter 2 that the benefits (losses) of a management action is given by the *change* in surplus value associated with the action.

As pointed out in section 4.2.3, the current version of the MSU model under-predicts Great Lake cold fishing trips to lakes Michigan, Huron and Superior. The reason for this was that the Metro counties of Monroe, Wayne and Macomb were included in the model and are predicted to receive almost a third of the single day trips. The inclusion of the Metro counties means that trips are under-predicted to the lakes supporting lake trout, especially single day trips to Lake Michigan. The catch rate policies reported here (rows 1 to 7) under-estimate the values for these policies since they under-predict trips to the lakes affected by the policies. In contrast, the site closure values should be fairly robust to the Metro effect since these policies close all Great Lake trout and salmon sites, and the MSU model fits the survey sample shares for Great Lake cold species at the product line level.

User-days: User-days are also listed in Table 4.11. The estimated user-days are calculated the same way as in Table 3.8 of Chapter 3. The estimated values can be translated into values per user-day based on the changes in user days in the Great Lake cold product line. The value per user-day is roughly 22 dollars per user day across all policies. This value is at the lower end of the range of values for trout and salmon fishing reported by Walsh *et al.* in their national review of outdoor recreational use values.

Table 4.11: Additional Great Lakes Trout and Salmon Valuation Results.

	Policy description	Estimated annual benefits (losses)	Change in GL cold user days
1.	Double Lake Huron lake trout catch rates	$257,000	10,700
2.	Double Lake Superior lake trout catch rates	$475,000	26,800
3.	Double Lake Michigan lake trout catch rates	$642,000	28,300
4.	Raise Lake Huron lake trout catch rates by 3.61 (so peak monthly averages match those at Lake Superior)	$1,065,000	42,300
5.	Raise Lake Michigan lake trout catch rates by 2.68 (so peak monthly averages match those at Lake Superior)	$1,157,000	51,000
6.	Raise lake trout catch rates at all Lake Michigan & Lake Huron sites *up to* Lake Superior monthly average*	$3,893,000	174,600
7.	Reduce Great Lakes trout & salmon catch rates at all sites by 1/3	−$8,319,000	−312,700
8.	Eliminate (close) all Great Lakes trout & salmon fishing	−$20,610,000	−922,400
9.	Eliminate (close) all Great Lakes trout & salmon *and* all anadromous fishing	−$36,285,000	−1,585,000†

* This policy raises all lake trout catch rates at Huron and Michigan so they are at least equal to the monthly averages of Superior for the months of May thru September (see Table 4.1).

† This number refers to combined changes in both anadromous and GLcold user days.

Chapter 5
Conclusions and Implications

very rough draft, ...

Here, the results are reviewed and implications of the research are drawn out. In addition, several limitations of the results are highlighted, and areas for future research are discussed.

VPF Question 1: Linearity

The *VPF Question 1* addressed the possibility that benefits of changes in quality at a particular site could be treated as if they were linear. The fact that the discrete-choice welfare measure is nonlinear implied that this would not hold in theory. Moreover, the estimated increments of total value (TV) exhibited a sizable sensitivity to changes in the reference level of quality at *own* sites. Similarly, the marginal values of changes in catch rates (MVCRs) were relatively sensitive to the levels of *own* site quality. For the VPF to be empirically reasonable, the total value increments ought to be the roughly the same for improvements and decrements in quality and the marginal values ought to be roughly the same no matter the level of quality at which they are evaluated. Thus, the empirical results for the TV increments and the MVCRs do not support the VPF approach.

In Chapter 4, the TV estimates were also used to estimate average values per fish (AVPF). This was done by estimating total catch and dividing the TVs by the respective estimates of total catch. Total catch was estimated by combining the creel survey estimated catch per unit of effort with predicted trips and survey estimates of effort per trip. The resulting AVPFs were presented in Chapter 4. The AVPF estimates did exhibit sensitivity to changes in the *own* site quality conditions from which they were estimated. However, the variation in the AVPF estimates was well within an order of magnitude -- even for the huge increase in catch rates at Lake Superior that were considered here. Unfortunately, as noted below, the AVPF's were quite sensitive to the assumptions regarding the units of the creel survey catch rates variables.

VPF Question 2: Separability

As demonstrated in Chapter 2, the random utility model (RUM) demand functions and welfare measures are not separable in theory. In fact, this is one of the principle strengths of the RUMs relative to traditional demand models. However, as an empirical matter, the results in Chapter 4 demonstrated that the Great Lake demand functions and values were very insensitive to the quality conditions at other Great Lakes. Thus, the Great Lakes can be treated as if they were independent with little loss of precision. This result implies that independent valuation and summation closely approximates the true measures, as was supported by the examples in Chapter 4. Moreover, the results imply that lakes can be analyzed independently of each other by Great Lakes Fishery Commission (GLFC) and other fishery agencies.

The Value Per Fish Approach

The above two conclusions give mixed messages for the empirical performance of a VPF approach. While the apparent separability supports VPF approaches, the degree of convexity was too large to support routine VPF approaches when alternatives are available. On the other hand, the AVPF were not extraordinarily sensitive to changes in *own* site quality. However, the relevance of the latter type of insensitivity is tempered by the fact that the strong degree of convexity of the benefits function implies that the AVPFs are inappropriate for valuing marginal changes. Using the AVPFs would overstate the losses of decrements and understate the benefits of increases in catch rates. Thus, if VPF measures are needed, then they should be based on the MVCRs. Moreover, since the MVCRs vary with the baseline conditions, they are only valid for evaluating the benefits of small changes. Appropriate valuation of non-marginal valuations would need to be based on the discrete choice welfare measure, though the independence result implies that the IVS measures are close approximations.

Generality of Independence (IVS and Sequencing)

While the support for the VPF approach is weak, the results support treating lakes independently. As mentioned in the caveats associated with the separability results, these results are predicated on the types of policies considered here. That lakes can be treated independently greatly simplifies subsequent analysis because one does not need to evaluate every combination of possible policies at separate lakes.

One possibility that is made feasible by the independence result is the estimation of a benefits frontier for each lake. If the GLFC researchers and biologists could propose a pathway between the site/month specific catch rates and lake trout population levels, then the associated pathway for catch rates could be valued for some finite number of lake trout population levels. Such a frontier of values would greatly facilitate the setting of target levels of lamprey control since the GLFC can currently trace out a similar frontier for the costs of lamprey control. The GLFC's "optimal" policy for each lake is then the policy where the difference between the cost and benefits is greatest. The independence result implies that the benefit frontiers would not need to be recalculated every time quality changes at a small subset of substitute sites.

Some additional advantages accompany the independence result. That the results support treating Great Lake valuations independently of one another facilitates research into a dynamic optimization model of the broader, more holistic lake trout management problem. Such a problem would balance the benefits of fishing against the costs of fish stocking and the costs of lamprey control (the Koonce et al. framework assumes that stocking is exogenous). While such a problem would be easier to address if the lake trout values could be cast on a per-fish basis (linear), treating the lakes separately is much simpler than having to model a dynamic interdependence in the values. The independence result also bodes well for any attempts to do Krinsky-Robb simulations of the standard errors associated with the estimated welfare measures.[1] Since simulations such as these require thousands of loops though the welfare calculations, they would not be feasible for every possible combination of lake policies at each of the Great Lakes. The results on the independence of the lakes implies that such simulations might be feasible for a few select policies, such as for the points on a lake valuation frontier.

The general applicability of the independence result is more qualified. For example, that the values for the individual Great Lakes were found to be largely independent of quality at *other* Great Lakes, does not imply that values for individual sites would be independent of other individual sites. As discussed in Chapter 4, some reasons for the separability results include the use of broad policy scenarios (quality changes were lakewide), the spatial separation of the lakes for the dominant single-day trip length, the distance of most of the

[1] This would also apply to the possibility of employing the Gibbs-sampler Markov simulations of welfare measures for models that are non-linear in income (as described in McFadden, 1997).

state population from sites that were affected by any of the policy scenarios, and the "once bad always bad" nature of the policies. These factors combine to make the lakes poor substitutes for one another. Thus, a different conclusion regarding IVS and embedding effects might emerge if the value of a specific location was examined for its sensitivity to the levels of quality at an adjacent site.

Also note that none of the results of this research imply that species *at a lake* can be treated as independent. In fact, since any change in quality at site j is equivalent (in ΔV_j) to some change in lake trout at site j, the present results on the sensitivity of the estimated values to *own* site quality mean that species at a site cannot be independent of one another (theoretically or empirically). Further, the convexity means that any improvement in lake trout makes all the other GLcold species that much more valuable. (In a more general nested RUM, these arguments would not hold if fishing for each species were to be treated as a separate activity, though this would not be consistent with the high degree of multiple-species trips in the data).

Implications of the Sensitivity Results for RUMs Versus Traditional Single-Site Models

Because the results here suggest that *own* site effects are more important than *other* site effects, one might conclude that traditional single-site travel cost models could be used. However, the results do not imply that substitutes do not matter when estimating and calculating demands. In fact, the discussion of the bounds highlights the importance of getting the *own* site elasticity correct. The only way to get this right is to incorporate the potential for shifting to and from alternative sites as quality changes. If one is using a single-site model, then it must have some process for attracting new users to that site and allowing them to switch out to other sites as the quality at the site changes. This is the essence of the corner-solution problem. The results of this research imply that this process is very important. The insensitivity results simply state that these changes in demand and value at a site are about the same regardless of the reference level of quality at a relatively small, and somewhat distant, set of substitute sites.

There is some irony in this result. If you have few substitutes, then the quality of the substitutes will have a relatively large effect on any site, but if there are a "ton" of substitutes then any one substitute (or group of them) will have little effect on the value of a site.[2] Yet such a small sensitivity effect can only be achieved by modelling a large number of substitutes.

Goal of Generating Policy Relevant VPF Estimates

It is not recommended that the VPF estimates established by the extant research be used in a policy setting without serious qualifications. Many of these were already mentioned or are summarized in the model recommendations section. A few are mentioned here.

First, the AVPF estimates were very dependent on the assumed hours of fishing effort per trip. The effort per trip should match the definition embodied in the catch rate estimates. Since that definition was unknown, the estimates presented here are based on one among many possible means of defining the effort per trip. Investigation of other seemingly reasonable definitions of effort per trip revealed that the AVPFs were too dependent on this definition to be used reliably until it is known or re-established -- see model recommendations below.

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[2] There is a lot of substitution in the MSU model. When site quality changes, predicted trips to that site change, and predicted trips at other sites change. The results of the policies considered here demonstrated that the changes at other sites were very spread out. Since there are so many sites and activities in the MSU model, the effect of a quality change at any one site (or small set of sites) is small.

Since it is strongly recommended that the MSU model be re-estimated (see below), all model parameters and values are likely to change. However, because the relative values of the lakes will track the participation at those lakes, the rankings of the marginal values from the baseline conditions will be the same as the rankings of participation in the baseline.

The marginal values for changes in lake trout catch rates (MVCRs) have not been translated into marginal values for changes in lake trout populations, but they could be if the fish population information were available. While these estimates will change if the model is re-estimated, the issues of how to translate catch rates into lake trout population levels remains. Without a link between catch rates and populations, the benefits of catch rate changes cannot be linked to lamprey control. This linkage is also needed for the use of marginal values per fish and for the use of the independent lake valuation functions. One of many possible linkages was given in Chapter 4 in equation (93). To complete that simple linkage, biological estimates of the lake-specific catchability coefficients would be needed. Thus, research establishing this linkage is highly recommended.

While the exact numbers produced here are not recommended for direct policy application, the general themes are robust. The results on the sensitivity of the policies to changes in *own* and *other* site quality do not depend on the exact marginal implicit prices used, nor do they depend on the units of effort used to derive the AVPFs. Even if the MSU model is re-estimated, any changes in the array of catch rates at the various sites will affect the baseline site probabilities, but are unlikely to greatly alter the sensitivity of site demand to the reference level of quality at other lakes.

It should also be noted that the use of the total value estimates (TVs in Chapter 4) to evaluate benefits of sea lamprey program would be naive. Eliminating sea lamprey control programs would affect other species besides lake trout. As sea lamprey predation on lake trout increased, lake trout populations would decline. As the lake trout populations decline, the lamprey would increase their predation on alternative sportfishing species such as coho and chinook salmon, as well as commercially harvested species. As evidenced by the estimated parameters for the MSU model, salmon are much more valuable to anglers than are lake trout. Thus, simply eliminating lake trout would not measure all of the relevant effects of discontinuing the lamprey control programs. In addition, the values reported here only apply to Michigan residents, yet the benefits of lamprey control spill over to other jurisdictions. Benefits to anglers fishing in other affected jurisdictions, as well as benefits to non-residents fishing in Michigan, have not been included in the analysis. Further, the valuation results presented here only measure use values. Thus, any non-use values related to the existence of native fish populations or negative non-use values relating to the existence of non-indigenous nuisance species are not measured. Moreover, the use values measured here only capture quantity effects (number of fish caught per hour), and do not capture qualitative effects such as the health of the fish (their fight) or the aesthetics of the fish (scarring or presence of attached lamprey).

Implications for Further Valuations of Great Lakes Fish

The analysis revealed several empirical issues that ought to be resolved in future re-estimation of the MSU model and others like it in any application to valuation of Great Lakes fish. First, comparing the model's predicted trips to the survey sample shares in the GLcold PL reveals a poor fit for single day trips. The major difficulty was a large share of single day GLcold trips getting predicted for Metro area counties that had zero estimated catch rates for all GLcold species. These predictions were due to the importance of the estimated travel cost. Future efforts should consider ways of improving the baseline fit of the model. The baseline fit will affect the welfare measures since, as evidenced by the discussion of the welfare bounds, the welfare measure for changes in the quality of a site are bounded by the baseline predicted trips to that site. Two options for improving the fit are to include Great Lake specific dummy variables, and to consider removing the Metro area sites from the Great Lake cold choice set since these sites do not appear to support any of the cold species.

Second, the magnitude of the AVPFs depend directly on the definitions of catch rate units. Plausible ways of handling the effort for anglers with differing degrees of species targeting resulted in widely varying fish values. This sensitivity reveals the importance of matching the model definitions with data definitions. While the definition of effort embodied in the catch rate units does not affect the estimated total and marginal values presented here, it would affect any attempt to link these values to changes in lake trout population levels as the exact definition of the catch rates would almost surely need to be known.

Third, the catch rate data is outdated. The data was provided by the Michigan Department of Natural Resources and was previously used in the Jones and Sung model. While the Jones and Sung report does not give the exact years of the creel survey data that was utilized, the most recent creel survey year in the catch data likely pre-dates the MSU survey data by several years.

A few other minor issues surfaced in the analysis. The definitions of Great Lake sites do not uniquely map to the individual Great Lakes since there are counties bordering multiple lakes. Also, since the lake trout catch rate parameter was not a significant determinant of the location of multiple day trips, standard errors for the value estimates are likely to be large. In addition, in estimating and applying the MSU model, if a site was missing catch rate data, the value from the next month was used. As it turns out, all the missing catch rate data was for the months of April and for sites on Lake Superior. Thus, the missing data procedure is likely to greatly overstate the April catch rates.

For the above reasons, it is recommended that the creel survey data be obtained and all the Great Lake catch rates be updated. The MSU demand model should then be re-estimated. The process of re-estimating the creel survey catch rates may resolve many of the problems identified above. Specifically,

- The effort definitions (treatment of alternative levels of species targeting) in the new catch rate estimates can be documented and matched to the RUM easing any subsequent efforts to link benefits to lake trout stocks.
- Great Lake sites can be defined to match the lakes and the creel survey sites.
- The resulting parameters will all change as will their significance.
- The model fit will change and can be examined with the updated catch rate data.

Research Underway ...

Catch rates analysis

Model re-estimation

{Other Implications?? }

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