WESTERN REGIONAL RESEARCH PUBLICATION

W-133
BENEFITS AND COSTS OF RESOURCES POLICIES AFFECTING
PUBLIC AND PRIVATE LAND

12[TH] INTERIM REPORT
JUNE 1999

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INTRODUCTION

This volume contains the proceedings of the 1999 W-133 Western Regional Project Technical Meeting on "Benefits and Costs of Resource Policies Affecting Public and Private Land." Some papers from W-133 members and friends who could not attend the meeting are also included. The meeting took place February 24th - 26th at the Starr Pass Lodge in Tucson, Arizona. Approximately 50 participants attended the 1999 meeting, are listed on the following page, and came from as far away as Oslo, Norway.

The W-133 regional research project was rechartered in October, 1997. The current project objectives encourage members to address problems associated with: 1.) Benefits and Costs of Agro-environmental Policies; 2.) Benefits Transfer for Groundwater Quality Programs; 3.) Valuing Ecosystem Managment of Forests and Watersheds; and 4.) Valuing Changes in Recreational Access.

Experiment station members at most national land-grant academic institutions constitute the official W-133 project participants. North Dakota State, North Carolina State, and the University of Kentucky proposed joining the group at this year's meeting. W-133's list of academic and other "Friends" has grown, and the Universities of New Mexico and Colorado were particularly well represented at the 1999 W-133 Technical Meeting. The meeting also benefitted from the expertise and participation of scientists from many state and federal agencies including California Fish and Game, the U.S. Department of Agriculture's Economic Research and Forest Services, the U.S. Department of Interior's Fish and Wildlife Service, and the Bureau of Reclamation. In addition, a number of representatives from the nation's top environmental and resource consulting firms attended, some presenting papers at this year's meeting.

This volume is organized around the goals and objectives of the project, but organizing the papers is difficult because of overlapping themes. The last section includes papers that are very important to the methodological work done by W-133 participants, but do not exactly fit one of the objectives. -- I apologize for the lack of consistent pagination in this volume.

On A Personal Note... Any meeting or conference is successful (and fun!) only because of its participants, so I would first like to thank all the people who came and participated in 1999 - listed below. I also want to thank Jerry Fletcher for all his help at this meeting and prior to it, and John Loomis who passed on his knowledge of how to get a meeting like this to work, and who continues to have the funniest little comments to lighten the meetings up. I especially thank Paul Jakus, who helped me to organize this conference and have a lot of fun during it and afterward. Finally, I want to thank Nicki Wieseke for all her help in preparing this volume, and Billye French for administrative support on conference matters.

W. Douglass Shaw, Dept. of Applied Economics & Statistics, University of Nevada, Reno.
June, 1999

P.S. P.F. and J.C. - As far as I can tell, that darn scorpion is still dead!

Valuing Non-indigenous Species Control and Native Species Restoration in Lake Huron

Frank Lupi,[1] John P. Hoehn,[2] and Gavin C. Christie[3]

Abstract: Sea Lamprey are a non-indigenous aquatic nuisance specie that prey on lake trout – a key native specie in the Great Lakes. Lamprey induced mortality is partially credited with the collapse of lake trout populations in the Great Lakes in the late 1940s. Ongoing lamprey control efforts have permitted the recovery of lake trout stocks in Lake Superior and parts of Lake Michigan. However, rehabilitation of lake trout in Lake Huron has been hampered by large populations of lamprey originating from the St. Marys River. This research estimates some of the economic benefits and costs associated with several new options for controlling sea lamprey in the St. Marys River. All treatment options are shown to have positive net present value, even though only part of the economic benefits have been measured. The paper also highlights areas where further research might reduce some of the uncertainties associated with the present analysis.

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Introduction[1]

Numerous non-indigenous aquatic species pose threats to the native species in the Great Lakes (Mills et al). One of the best know invaders is the sea lamprey. Sea lamprey prey on lake trout – a key native specie in the Great Lakes. Earlier research has shown the benefits of sea lamprey control in the Great Lakes outweighs the costs (Talhelm and Bishop). We use a model of the demand for recreational fishing in Michigan to estimate some of the economic benefits associated with lamprey control in Lake Huron. Specifically, we estimate 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 available for the St. Marys. 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. Finally, 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.

Sea Lamprey and Lake Trout. As mentioned, the sea lamprey is a non-indigenous aquatic nuisance specie in the Great Lakes.[2] The lamprey likely made its way into the Great Lakes following the 1829 construction of the Welland Canal around Niagara Falls. Sea lamprey prey on lake trout and other species of

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[1] We are grateful for research support provided by the Great Lakes Fishery Commission (GLFC). We thank Shawn Sitar and James Bence for providing information and population models for the policy scenarios. We have benefitted from discussions with Douglas B. Jester. Any errors or omissions are the responsibility of the authors.

[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."

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 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 lampricide 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).

Three St. Marys River Treatment Options. In this research, we examine three recently refined 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. 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). GB 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. Uncertainty associated with the long run effectiveness of SMRT is thought to be 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).

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

Recreation Demand Model for Michigan

A repeated-random utility travel cost 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 travel cost method is widely used to estimate the use-values associated with recreational activities (see Freeman or Bockstael et al, 1991 for reviews of the travel cost method). Travel cost methods that are based on random utility models (RUM)[3] are well suited to estimating recreation demand when there are numerous substitute sites and can be used to value of changes in the quality of recreational fishing sites. In a repeated

[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.*, Hausman *et al.*, and Shaw and Jakas. while Jones and Sung represents an earlier application of the RUM to fishing in Michigan.

RUM such as the Michigan model,[4] the season is divided into a series of choice occasions in which anglers decide whether to take a trip, and if so, where to fish. In the Michigan model, 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. Additional techniques to ensure response accuracy included the use of the following: 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. The model and data used here draws on the work of previous research documented 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, i.e., the go fishing/don't go fishing level. 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.

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[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.

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 multiplied by 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. Each site is also described by its catch rate for the following species: salmon, lake trout, and other trout (other trout includes rainbow and brown trout). These catch rates are specific to each county and vary on a monthly basis from 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.

Destination sites (fishing locations) are defined by the stretch of Great Lake shoreline within a Michigan county that offers opportunities to catch Great Lakes trout and salmon. While there are 41 Michigan counties that border the Great Lakes, not all of these provide access to trout and salmon fishing. For example, the Michigan 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] Single day trips and multiple day trips to any of these sites are treated as distinct alternatives in the RUM choice sets. Feasible sites that enter anglers' choice sets for single day trips include the Great Lake counties in Michigan within 150 miles of an individuals permanent residence. For multiple day trips, all 35 sites enter the choice set of each individual.

The repeated RUM that is estimated here is specified as a nested logit with the participation level nested above the site choice level (see McFadden or Morey for details on nested logit). In the nested logit, the

[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.

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 angler characteristics, γ is a vector of parameters to be estimated, IV stands for inclusive value and θ is the parameter on the inclusive value. The IV is a summary index that describes the utility of the recreation site choices, and it is given by $IV = \sum_j \exp(\beta X_j)$.

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 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 Lupi et al, 1998 or Lupi and Hoehn, 1998.

Catch Rate Modeling

Part of the research effort 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 rate 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, it is possible that those catch rates do not reflect the status for the Great Lakes fisheries in the year that anglers made their fishing site choices. Because of potentially important changes in these fisheries, we went back to the raw creel survey data and re-estimated the catch rates to include more recent years. The catch rate estimation is documented in Lupi, Hoehn, and Jester.

Negative binomial regression models were used to estimate species-specific 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. The nine catch rate models range in size and include from 35 to 110 explanatory variables and from 5,000 to 50,000 observations. 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 are given in Lupi et al.

Estimated RUM 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. As shown in Table 1, the estimated parameters on the travel cost variables are negative. The estimated parameters on the catch rate variables are positive. 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 1 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 the each Great Lake will match the shares in the survey data.

The third part of the table presents the participation level results. The estimated inclusive value 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 1 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 levels of significance). In addition, individuals who do not have a paying job are less likely to take Great Lakes trout and salmon fishing trips.

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 provide estimates for catch rates specific to three specie groups: lake trout, salmon, and other trout. The combined catch rate variable used in the model presented in Table 1 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

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

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. Some 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 species of Great Lakes trout and salmon had the same parameter. One difficulty that bears on this result is that the specie-specific catch rates are significantly correlated with one another which complicates attempts to identify their separate effects. A second difficulty relates to the correlation between species-specific catch rates and the lake specific constants. Another explanation may be that anglers who are targeting a specific species may not care about the catch rates of other species when they make their site choices.

Table 1: 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.

Figure 1: 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, SMRCS, & GLFC                                          model
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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.

Linking the Lamprey Treatments to Economic Values

In order to use the RUM to value changes in the fishery, we need to establish a link between the treatment options and variables that enter the RUM. While the obvious variable is catch rates, the diagram emphasizes that a complex chain of information is needed in order to evaluate the treatment options. First, the effect that treatments will have on lamprey populations needs to be established. Second, changes in lamprey populations must be linked to changes in the lake trout populations. Third, one needs to map the changes in lake trout populations into changes in lake trout catch rates. Finally, the RUM is used to estimate the use-value that accrue to anglers due to increased catch rates. Thus, the diagram illustrates one pathway in which changes in management actions result in changes in value. Anderson refers to this as marginal analysis to emphasize that we seek to identify how value changes 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 Sitar (the first two linkages in Figure 1). 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 Great Lakes Fishery Commission (SMRCS). Thus, for each treatment option as well as for the no treatment option, we have a time series of lake trout population levels for various regions of Lake Huron. The projected age 8+ lake trout population levels in the three regions are presented in Figure 2.

The third step in Figure 1 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. Such a relationship is often used in the fisheries literature and can be written as $C/E = \alpha S$ where C represents total catch, E represents angling effort, α represents a catchability coefficient, and S represents the population or stock size (this relationship is discussed further in Lupi, Hoehn, and Jester). 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%. Referring back to equation (4), 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 increase by less than X%.

To complete the linkage, 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 year of the behavioral survey. The absolute and proportional changes over time in the populations of mature lake trout for each region are presented in Figure 1. 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.

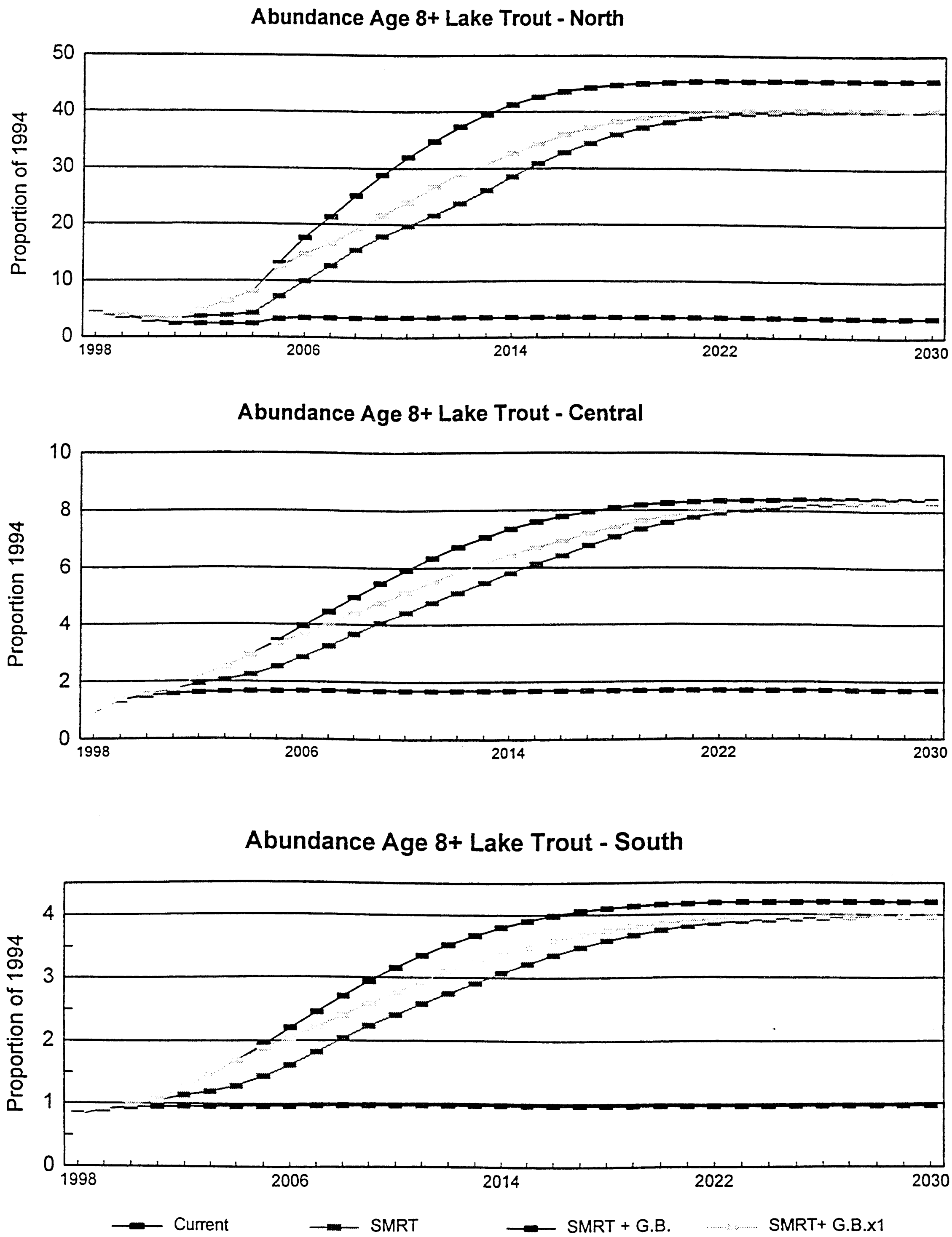

Figure 2: *Proportional Change* **in Estimated Annual Abundance of Mature Lake Trout by Regions of Lake Huron for each Treatment Option**

Valuation Results

The 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 2). 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 2: Estimated recreational angling benefits for the projected lake trout populations in 2015 for each St. Marys River treatment options.

	Option 1 SMRT only	**Option 2** SMRT + GB	**Option 3** 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

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

Table 2 shows the estimated annual use value that would accrue to Michigan's recreational anglers in the year 2015 if lake trout catch rates were to increase by the factors in the table. The table also shows that, as one would expect, the treatment options that yield the largest lake trout population increases have the largest benefits. 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 as seen in Table 2. The final row of Table 2 also presents the lakewide average proportional change in lake trout population. One might ask whether the spatial delineation of the changes in lake trout population affects the estimated economic values. It turns out that the spatial (regional) composition of the catch rate 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 estimated value based on the lakewide average population change is much larger because the southern portions of the lake that are closer to population centers get a larger catch rate change when the lakewide average lake trout population change for the lake is used than they do when the regional changes are used. The outcome 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.

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. 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 3 graphs the annual stream of net benefits (benefits to Michigan anglers minus costs). Figure 3 shows that 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 3 that the 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.

Figure 3: Annual Benefits to Michigan Anglers Minus Program Costs

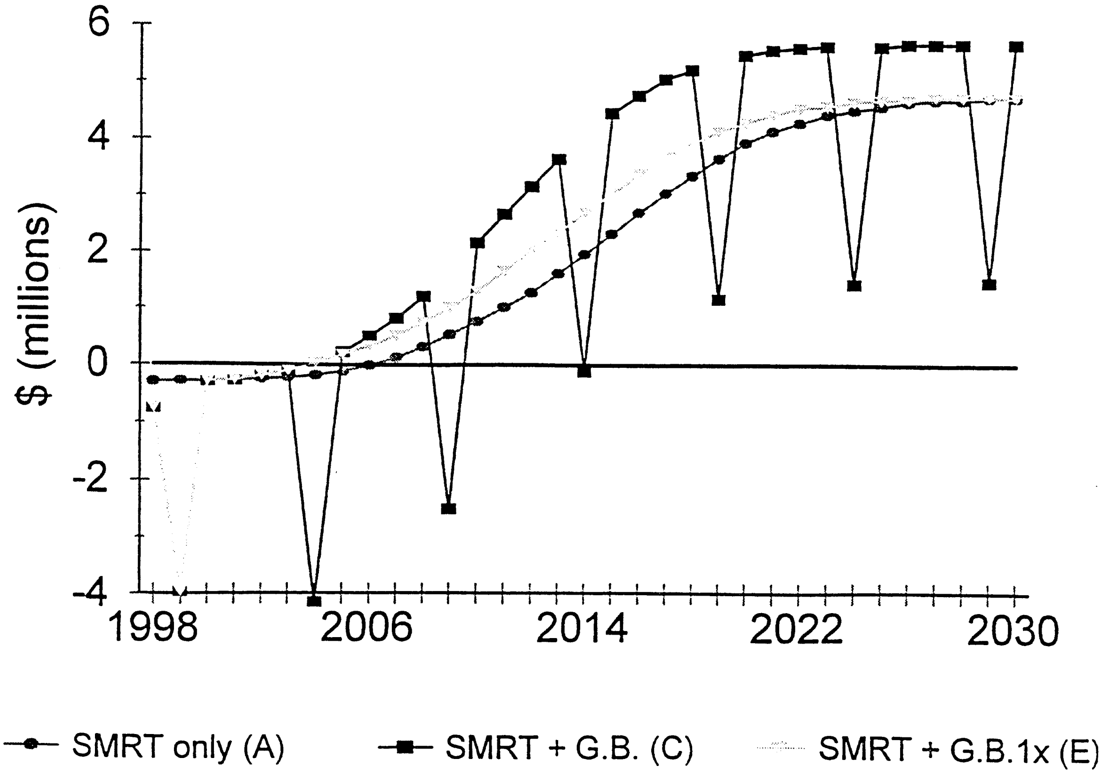

Table 3: **Net Present Value of the St. Marys River policies under alternative interest rates**
(The economic values in table are in $1,000 units)

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 costs).

The net present value of benefits minus cost was calculated for each option using a variety of discount rates (see Table 3). The results show that all three treatment options are estimated to have positive net present values at reasonable discount rates, even though not all of the benefits have been quantified here. 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). Referring back to Table 3, 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.

Limitations and Future Research

It is important to bear in mind some of the caveats associated with the numbers reported in table 3. 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+). Also, In addition, the analysis does not 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's no accounting for 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);
- the recreation model values travel time at the full opportunity cost;
- any possible increases in lake trout in northern Lake Michigan (due to reduced lamprey populations in northern Lake Michigan) have not been valued;
- 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.

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. The additional data might permit the modeling of anglers specie target decisions in addition to their site choices. Another possibility would be to directly question anglers about their species preferences and their preferences for alternative lake management plans. The information about anglers specie preferences could be used to augment the travel cost data, while the information on preferences for lake management plans would permit the estimation of some of the non-use values associated with native specie restoration. Finally, preferences for lake management plans could be collected the general public, as opposed to just anglers.

References

Anderson, Lee G., *An Introduction to Economic Valuation Principles for Fisheries Management*, Special Publication 94-2, Great Lakes Fishery Commission, Ann Arbor, Michigan, 1994.

Ben-Akiva, Moshe, and Steven R. Lerman, *Discrete Choice Analysis: Theory and Application to Travel Demand*, Cambridge: MIT Press, 1985.

Bockstael, Nancy E., Kenneth E. McConnell, and Ivar E. Strand, Jr., "Recreation," in: *Measuring the Demand for Environmental Quality*, (Braden, John B., and Charles D. Kolstad, eds.), New York: North-Holland Publishing, 227-355, 1991.

Bockstael, Nancy E., W. M. Hanemann, and I. E. Strand, "Measuring the Benefits of Water Quality Improvements Using Recreation Demand Models," Vol. II of *Benefit Analysis Using Indirect or Imputed Market Methods*, EPA Contract No. CR-811043-01-0, 1984.

Bockstael, Nancy E., W. Michael Hanemann, and Catherine L. Kling, "Estimating the Value of Water Quality Improvements in a Recreational Demand Framework," *Water Resources Research*, 23(5):951-960, May, 1987.

Chen, Heng Z., Frank Lupi, and John P. Hoehn, "An Empirical Assessment of Multinomial Probit and Logit Models for Recreation Demand," forthcoming in: *Valuing the Environment Using Recreation Demand Models* (C.L. Kling and J. Herriges, eds.) Edward Elgar Publishing.

DesJardine, R.L., T.K. Gorenflo, R.N. Payne, and J.D. Schrouder, *Fish-Community Objectives for Lake Huron*, Special Publication 95-1, Great Lakes Fishery Commission, Ann Arbor, Michigan, 1995.

Feather, Peter, Daniel Hellerstein, and Theodore Tomasi, "A Discrete-Count Model of Recreational Demand," *Journal of Environmental Economics and Management*, 29:214-227, 1995.

Freeman III, A. Myrick, *The Measurement of Environmental and Resource Values: Theory and Methods*, Washington, D.C.: Resources for the Future, 1993.

Hausman, Jerry A., Gregory K. Leonard, and Daniel McFadden, "A Utility-Consistent, Combined Discrete Choice and Count Data Model: Assessing Recreational Use Losses Due to Natural Resource Damage," *Journal of Public Economics*, 56:1-30, 1995.

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 Natural Resources and the Michigan Department Environmental Quality, December, 1996.

Jones, Carol Adair, and Yusen D. Sung, *Valuation of Environmental Quality at Michigan Recreational Sites: Methodological Issues and Policy Applications*, Final Report, EPA Contract No. CR-816247-01-2, September, 1993.

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.

Lupi, Frank, J. P. Hoehn, T. Tomasi, and H.Z. Chen, “The Michigan Recreational Demand Model,” Staff

Paper 97-58, Department of Agricultural Economics, Michigan State University, 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 1998a.

Lupi, Frank, and John P. Hoehn, "The Effect of Trip Lengths on Travel Cost Parameters in Recreation Demand," in *Benefits and Costs in Natural Resource Planning*, (P. Jakus, ed.), Western Regional Research Publication, 1998b.

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.

McFadden, Daniel, "Econometric Models of Probabilistic Choice Models," in: *Structural Analysis of Discrete Data with Applications*, (Manski, C., and D. McFadden, eds.), Cambridge: MIT Press, 1981.

Mills et al., "Exotic species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research,* 19:1-54, 1993.

Morey, Edward R., *TWO RUMs un CLOAKED: Nested-Logit Models of Site Choice and Nested-Logit Models of Participation and Site Choice*, forthcoming in: *Valuing the Environment Using Recreation Demand Models* (C.L. Kling and J. Herriges, eds.) Edward Elgar Publishing, 1998.

Morey, Edward R., W. Douglass Shaw, Robert D. Rowe, "A Discrete-Choice Model of Recreational Participation, Site Choice, and Activity Valuation When Complete Trip Data Are Not Available," *Journal of Environmental Economics and Management*, 20:181-201, 1991.

Morey, Edward R., Robert D. Rowe, Michael Watson, "A Repeated Nested Logit Model of Atlantic Salmon Fishing," *American Journal of Agricultural Economics*, 75(3):578-592, August, 1993.

Sitar, Shawn Paul, *Estimation of Lake Trout (Salvelinus namaycush) Abundance and Mortality Due to Sea Lampreys (Petromyzon marinus) and Fishing in the Main Basin of Lake Huron, 1984-1993*, Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report 2030, April 17, 1996.

Shaw, W. Douglass, and Paul Jakas, "Travel Cost Models of the Demand for Rock Climbing" *Agricultural and Resource Economics Review*, 25:133-42, 1996.

Small, Kenneth A., Harvey S. Rosen, "Applied Welfare Economics With Discrete Choice Models," *Econometrica*, 49(1):105-130, January, 1981.

SMRCS, St. Marys River Control Strategy, Report of the St. Marys River Control Task Force to the Great Lakes Fishery Commision Annual Meeting, June 10, 1997.

Talhelm, D., and R. Bishop, "Benefits and Costs of Sea Lamprey (Petromyzon marinus) Control in the Great Lakes: Some Preliminary Results," *Canadian Journal of Fisheries and Aquatic Sciences,* 37:2169-74, 1980.

Train, Kenneth, *Qualitative Choice Analysis*, London, England, 1986.