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Application of the Tracking and Analysis Framework (TAF) to Assess the Effects of Acidic Deposition on Recreational Fishing in Maine Lakes

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APPLICATION OF THE TRACKING AND ANALYSIS FRAMEWORK (TAF) TO ASSESS THE EFFECTS OF ACIDIC DEPOSITION ON RECREATIONAL FISHING IN MAINE LAKES

By

Petra Warlimont

B.A., Colorado State University, 1999

A THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science
(in Resource Utilization)

The Graduate School
The University of Maine
May, 2002

Advisory Committee:

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APPLICATION OF THE TRACKING AND ANALYSIS FRAMEWORK (TAF) TO ASSESS THE EFFECTS OF ACIDIC DEPOSITION ON RECREATIONAL FISHING IN MAINE LAKES

By
Petra Warlimont
Thesis Advisor: Dr. Jonathan Rubin

An Abstract of the Thesis Presented
In Partial Fulfillment of the Requirements for the
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Burning fossil fuels releases sulfur and nitrogen oxides (No_x) into the atmosphere where they convert to sulfuric and nitric acids. Deposition of these acids is now widely accepted as the major cause of environmental damage to forests, streams and lakes. The 19990 Clean Air Act Amendments (CAAA) require reduction in airborne sulfur and No_x, with an estimates cost of $2 billion. The purpose of this study is to place an economic value on the impact of acid rain on recreational fishing in Maine lakes.

This thesis builds on the work of Englin et al. (1991) who evaluate damages to recreational trout fishing in the upper Northeast due to acidic depositions. In this study water and soil data from the Maine are re- calibrated to model and examine the effects of acid deposition in Maine's lakes. Anglers' economic well being is evaluated by analyzing the changes in catch rates due to a reduction in fish populations from acid deposition. The toxicity model as used in the 1990 NAPAP assessment is used to analyze the effects of acid rain on fish biota. Baker et al. (NAPAP, 19990) describe effects, estimation procedures, and expected results of acidification on lakes. The measure of

acidification is the Acid Stress Index (ASI), which determines critical values of acidification in lakes. The ASI is used as a reference level for determining the survival of fish in a given lake. These in turn are used to related catch-per-unit-effort (CPUE) to biological fish abundance. Data from the 1994 Maine fishing Survey is used to determine catch rates of anglers in Maine lakes. CPUE is then regressed on angler characteristics, and the ASI. The regression results are used in a random utility model in order to place an economic value on fishing sites.

ACKNOWLEDGEMENTS

Earnest gratitude to my mother and father for supporting my education in the United States, and believing in my capabilities.

Supreme special thanks to my Grandmother, sending survival packets to the US, and supporting me in any way possible.

Dan, thanks for being there for me, pushing me on to follow through with my work.

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1. INTRODUCTION

Acid rain is a widely used term describing the deposition of acidic chemical materials from the atmosphere. The effects of acid deposition on the environment have long been studied, and effects of acidity on fish populations are widely known (Haines et al., 1985, van Winkle et al. 1985). Although acidic deposition cannot be linked conclusively to loss of fish, we assume in this paper that the result will be smaller populations of fish, which may in turn reduces angler catch rates.

Researchers identify the burning of fossil fuels as the major cause of acidic deposition. Burning fossil fuels releases sulfur and nitrogen oxides into the atmosphere where they convert to sulfuric and nitric acids. Several pollution prevention programs have been implemented in the United Stated to decrease acidic deposition by reducing the burning of fossil fuels. The 1990 Clean Air Act Amendments (CAA) require reductions in airborne pollutant chemicals, with an estimated cost of $2 billion (TAF).

The NAPAP (National Acidic Precipitation Assessment Program) was tasked by Congress to assess the status of implementation, effectiveness, and cost and benefits of the acid-deposition control program created by Title IV of the 1990 Clean Air Act, which created a major innovation in environmental regulation by introducing market-based incentives. A key objective was to determine whether additional reductions in deposition are necessary to prevent adverse ecological effects. The major tool used by NAPAP to fulfill this assessment was the Tracking and Analysis Framework (TAF), which integrates models of science and technology into an assessment framework that can address key policy issues.

In 1980, NAPAP launched an integrated assessment concerned with the effects of acid rain on the environment. Several programs were included to assess the current pollution levels of acidic deposition and the effects on aquatic environments. The analysis was organized using different scenarios to evaluate the future impact of the burning of fossil fuels.

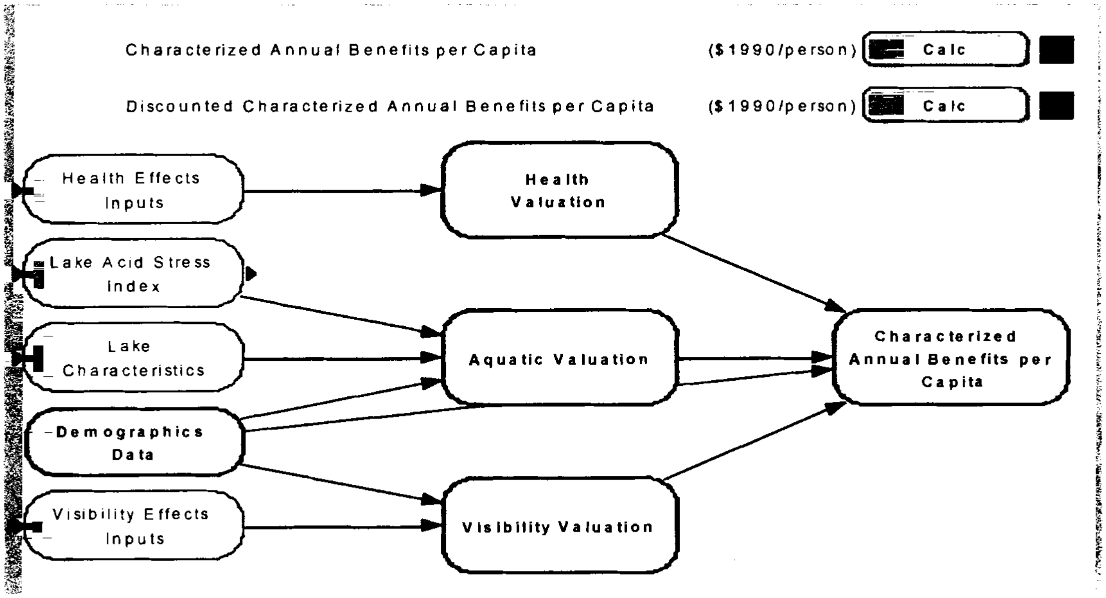
The scenarios are three sensitivity scenarios that examine the model performance; a current damages scenario comparing pre-industrial levels of pollution and two policy scenarios, scenario 1 and 4 (hereafter denoted as S1 and S4) of controlling SO_2 emissions regulation (Englin et al., 1991). S1 allows current pollution to continue at current or increased levels of pollution. S4 requires pollution reductions from the current levels of pollution to reach a 100% reduction in emissions by 2010.

Amongst other things, benefits from recreational fishing in the Adirondack mountain region were examined in these scenarios. This research contributes to the existing body of knowledge by examining the effects of acid deposition on the economic value of fishing in Maine. It builds on the work of Englin et al. (1991), who evaluate damages to recreational trout fishing in the upper Northeast due to acidic deposition (Englin et al., 1991). Englin et al. (1991) findings were used in the 1991 NAPAP study.

TAF – TRACKING AND ANALYSIS FRAMEWORK

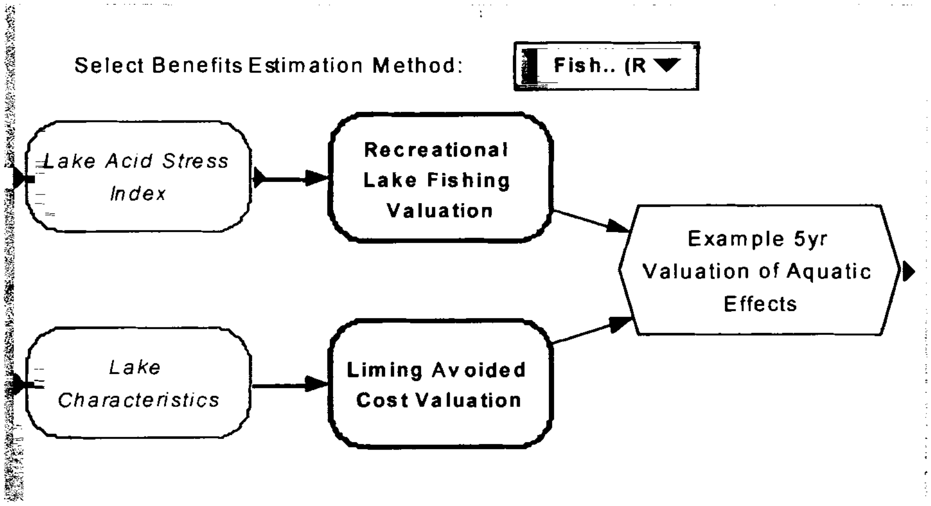
TAF provides an integrated assessment framework for estimating the impact of acid deposition. TAF evaluates environmental and economic damages in relation to future changes of deposition levels due to the Clean Air Act. The program consists of several reduced form models, which are combined to provide educated decision-making information on the subject of pollution prevention policies. Each model provides subsequent models in a hierarchical order with outputs for further investigation of effects or economic impact. TAF consist of 11 modules such as: emissions scenario selector, pathways and deposition, visibility effects, benefits, and so forth.

Figure 1.1.: Benefits Valuation Module



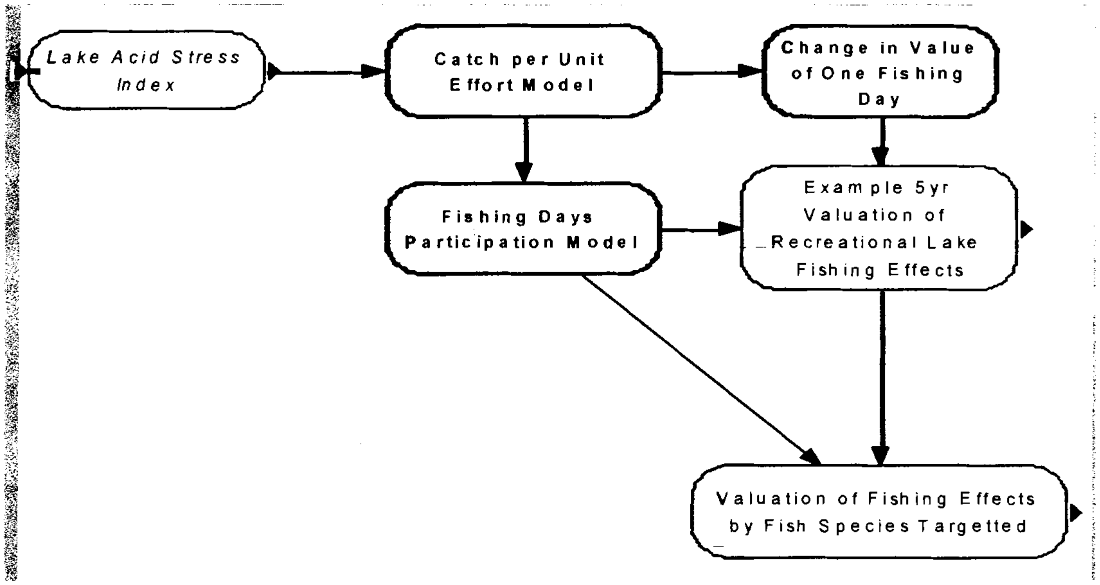
The Benefits Valuation Module (Figure 1) in TAF enables users to assess the value that society places on the effects of Title IV. The measures are given as the opportunity cost of preserving one asset or service over another. The Benefits Valuation Module has several sub modules, providing annual benefits data. Part of the Benefits Valuation Module is the Aquatics Effects Module (figure 2), which currently evaluates the effects of acidic deposition on lakes in the Adirondack Park region. The methodology of this study can be used to implement a module in TAF that describes the effects of acidic deposition on recreational fishing success. The Aquatics module of the Benefits Valuation Module has several sub-modules as described below.

Figure 1.2.: Aquatics Effects Module



The Recreational Fishing Sub Module (figure 3) estimates changes in anglers' success by measuring changes in catch per unit effort (CPUE) with changes in acid stress index (ASI). Changes in ASI are based exclusively on policy driven changes in acidic deposition on recreational fishing lakes.

Figure 1.3: Recreational Fishing Sub Module



The Catch per Unit Effort Model predicts changes in catch rates with changes in chemical and biological characteristics of recreational fishing sites. The chemical and biological changes are measured as Acid Stress Index (ASI), and give indices to determine fish fry survival in a controlled laboratory experiment. The indices are established for several fish species' fry (young fish), including sensitive (rainbow trout), intermediate (smallmouth bass), and tolerant species (brook trout). Acid sensitivity is determined by the ability of fish to resist acidic conditions in a lake. Changes in ASI are the major determinant of the valuation, given in the difference of baseline policy and policy scenarios.

The Change in Value of One Fishing Day Sub module estimates the value an angler places on catch rates by utilizing travel cost models. Lake site characteristics and catch rates are combined to estimate values placed on the visited site with values of other sites that could have been visited. Lake site characteristics include lake amenities (such as scenic qualities and accessibility). Travel costs to visited sites combined with lake amenities and catch rates make it possible to estimate the implicit value anglers place on those amenities.

The Participation Sub module estimates the effect of policy driven changes in fishing quality on angler participation. It only forecasts the participation of current anglers in future years, but does not include the recruiting of new anglers in the estimation.

This paper will predict the impact of acidic deposition on fishing in Maine's lakes. This study can be utilized to estimate future damages or benefits achieved by the different scenarios measured by the change of angler welfare as a function of catch rates.

METHODOLOGY

Englin et al. (1991) value anglers' economic well being by analyzing the changes in catch rates due to changing fish populations from acidic deposition. They utilize two travel cost models, a hedonic travel cost (TC) model and a random utility (RU) model to price recreational fishing at various sites in the Adirondack mountain region. The RU model includes lake specific variables or qualities of the site, and travel costs; whereas, the TC model evaluates marginal willingness to pay (WTP) for each marginal increase in attribute, such as water quality and angling specific attributes. Anglers are assumed to choose which lake to visit by weighing the costs (e.g. travel related costs) and benefits of each lake.

Englin et al. (1991) linked an ecological model of fish abundance to catch-per-unit effort (CPUE) to predict changes in acidic deposition to changes in angler catch rate. They examined policy scenarios of alternative future pollution prevention policies, and via a participation model, connecting the number of fishing days, CPUE, WTP, to changing population demographics. Future populations of anglers are estimated by utilizing cohort data. Welfare changes then were estimated by multiplying the average willingness to pay per trip times the average number of trips per individual, then multiplied by total number of individuals in the population of anglers.

After running the different pollution scenarios, Englin et al. (1991) found that there are moderate economic gains under the different scenarios, ranging from \$3.5 million to \$9.7 million annually (Englin et al., 1991).

Our work can be used as a guideline for future work. The base year for our study is 1994, including all trips by anglers to lakes in Maine.

DATA DESCRIPTION AND INTERSECTION DATA SET

In order to examine the effect of acid deposition on angler success in Maine we determine how many anglers visited Maine lakes and link this information with lake chemical response.

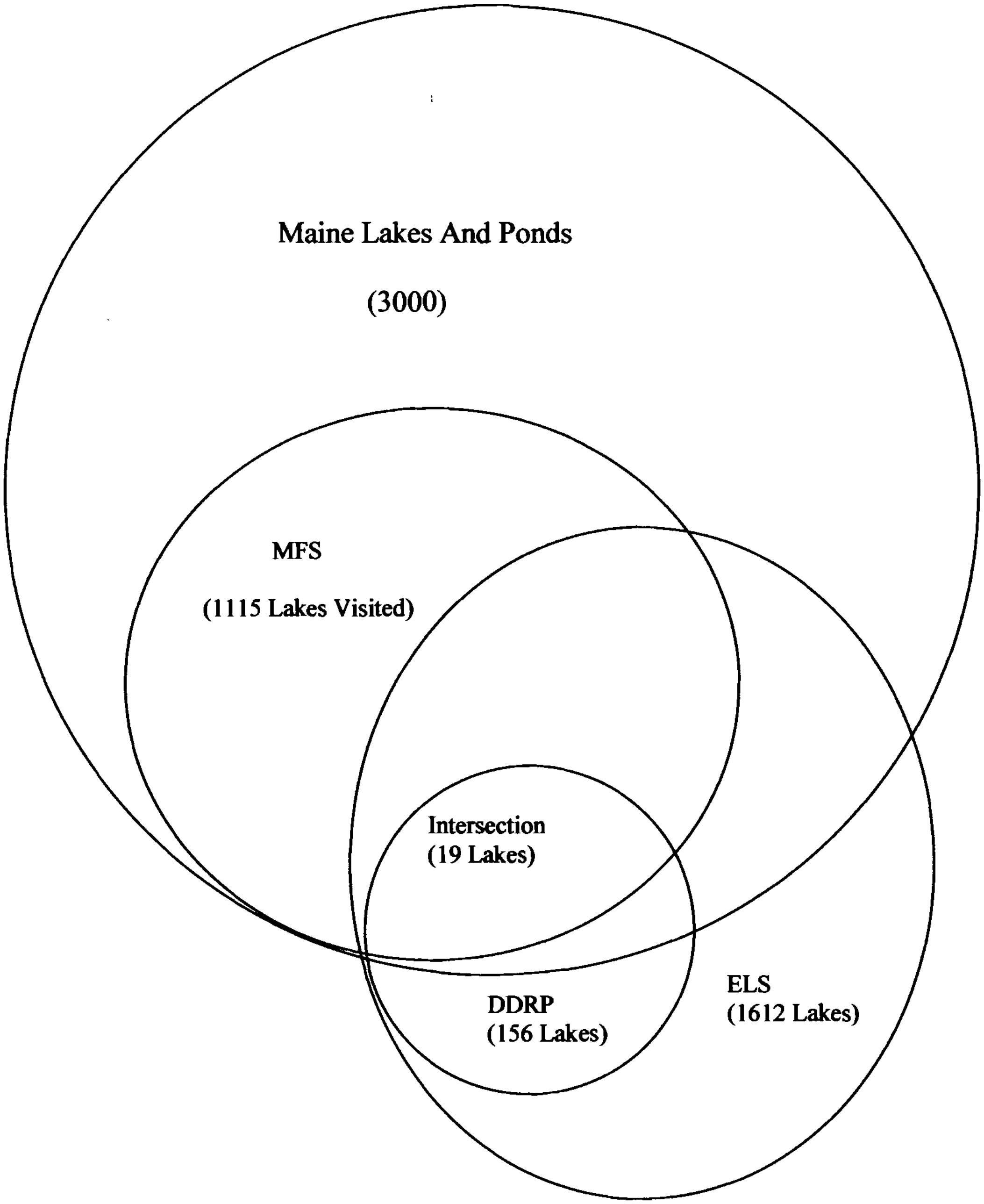
The Maine Fishing Survey (from hereon denoted as MFS) conducted in 1994 (MacDonald, Boyle, K., Fenderson, 1996) was sent in 1994 to a random sample of resident and nonresident anglers who had fishing licenses in 1994. From a total of 5504 surveys delivered, 3460 were usable and entered into the report. In this survey, 1114 Maine lakes were visited by at least one angler for one day.

The Eastern Lakes Survey (ELS) includes a random sample of lakes in the Northeast (EPA, 1985), supplying lake chemical and physical characteristics. From a total of 1612 lakes surveyed, 233 are Maine lakes (from here on denoted as ELSM). The Direct Delayed Response Project (DDRP) (EPA, 1989) is a random sub-sample of the ELS database, accounting for 156 lakes in the Northeast, and 19 in Maine (from here on denoted as DDRPM). The DDRP database contains specific lake chemical information (soil, bedrock), which allows scientists to forecast or backtrack acidity levels and investigate changes in water chemistry with changes in pollution prevention policies.

The MFS-ELSM intersection includes 105 lakes-- that is, anglers visited 105 lakes of the ELS dataset. The MFS-DDRPM intersection data set consists of 19 lakes (which are part of the MFS-ELSM overlay), and allows us to utilize deposition-forecasting models as discussed later. Since the DDRPM data set is a random sample of the ELSM data set we know angler participation for a random sample of lakes in Maine for which we have detailed water chemistry data. This intersection data set was used for this study.

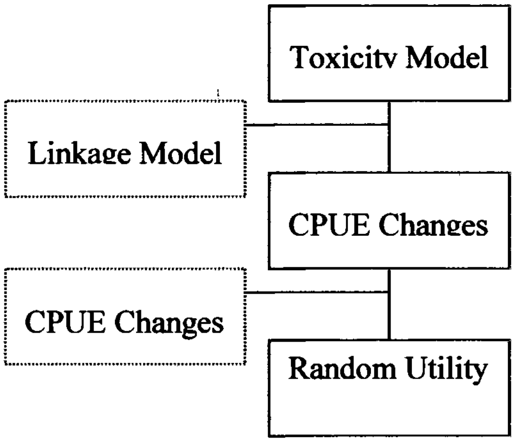
Figure 1.4: Description of the Data Sets and Intersection Data

(Number of lakes in parenthesis)



2. MODELS

Figure 2.1: Linkages between Changes in Toxicity and Changes in Social Welfare



The assumptions for the valuation of recreational fishing is that the site choice (lake, pond) and the number of trips a person takes are a function of 1. the catch rate measured as the catch per unit effort (CPUE) 2. the attractiveness of the site, and 3. the number of alternatives fishing sites available to an angler, and will result in the total economic welfare an individual can receive. CPUE then is a function of site characteristics, or the attractiveness of the visited lake. The Acid Stress Index (ASI) is part of this function and is influenced by the level of acidification of a lake. The welfare of recreational fishing during a fishing season can then be expressed as

$$\text{Welfare}_i = \text{Trips}_i\,(\text{CPUE}\,(\text{ASI})) * \text{TC}_i\,(\text{CPUE}\,(\text{ASI}))$$

where TC is the travel cost an individual incurs for each trip. The random utility model will be used to explain the choice an angler makes given a choice set of several alternative sites.

The ASI, which is assumed to influence the choice an angler makes, is determined by the pH, and concentration of Aluminum (Al) and Calcium (Ca) in the water body. ASI can be expressed as:

ASI = ASI (pH, Ca, Al)

ASIs can be calculated for lakes that have information on the concentration of the needed variables for the estimation. For this study, all lakes need to be assigned a measure of ASI. By using regression equations, ASIs can be related to lake characteristics as reported by the Maine Lakes Inventory data. The equations produced by this regression can then be used to estimate ASI levels for lakes that do not have chemical data available. The acidification estimation model goes into further detail.

Table 2.1: Description of Models

MODEL	PURPOSE VARIABLES	VARIABLES	UNIT	SAMPLE POPULATION	SAMPLE SIZE
DDRP Models	Creating Scenarios	pH, Ca, Al	Lake, Pond	DDRP lakes	19
Toxicity Model	Estimate ASIs	ASI	Lake, Pond	Intersection data set	91
ASI Regressions	Predict ASIs for lakes in the MFS that are not ELS lakes	ASI	Fishing trip	Visited lakes in the MFS – ELSM intersection	105
CPUE Model	Estimate the effect of ASI on catch rates	(Number of fish caught) / (day)	Trip	Trips in the MFS-ELSM overlay with expected catch	
RUM Model	Estimate the welfare effects of changes in catch rates per trip	Probability of selecting a fishing site	Trip	All MFS lakes that were visited	

TOXICITY MODEL

The Toxicity Model as used in the NAPAP 1990 assessment analyzes the effect of acid rain on lake biota. Baker et al. (NAPAP, 1990) describe effects, estimation procedures, and expected results of acidification of lakes as part of NAPAP's State of Science Report. Baker et al. (NAPAP, 1990) introduce three measures to relate fish viability to lake water acidification: acid stress index (ASI), Probability of Fish Presence, and Fish Species Richness.

For this paper, ASI is of importance, since it allows us to relate CPUE to lake acidification. There are three toxicity models with different specifications for ASI relating to tolerant, intermediate, and sensitive species. Tolerant species include brook trout fry survival, intermediate species is based on small mouth bass fry survival, and sensitive species is based on rainbow trout fry survival. The different calculations for ASI are shown below.

Figure 2.2: Calculations of ASI as developed by Baker et al. (1985)

$$\mathrm{ASI}_{\mathrm{sensitive}} = \frac{100}{1+e^{-8.90+1.56\cdot pH+0.00409\cdot Ca-0.0704\cdot Al}}$$

$$\mathrm{ASI}_{\mathrm{intermediate}} = \frac{100}{1+e^{-18.73+3.57\cdot pH+0.0146\cdot Ca-0.044\cdot Al}}$$

$$\mathrm{ASI}_{\mathrm{tolerant}} = \frac{100}{1+e^{-23.49+5.35\cdot pH+0.00297\cdot Ca-0.00193\cdot Al}}$$

Figure 2.2 defines the response of fish fry to the different measurement of the acid stress index.

Table 2.2: Reference Levels for the Acid Stress Index

Reference Acid Stress Index (Lakes)	Fish Response
Tolerant ASI > 30	Loss of all fish species
Tolerant ASI > 10	Loss of brook trout
Intermediate ASI > 80	Loss of other sport fish, such as smallmouth bass and lake trout
Sensitive ASI > 80	Loss of acid-sensitive species, such as minnows

(Baker et al., NAPAP 13-194)

The 1994 Maine Fishing Survey questioned anglers for catch rates of the following species; brook, lake, and brown trout, bass, pickerel, white fish, white perch, landlocked salmon, and smelt. After consulting with Dr. Terry A. Haines, who specializes in aquatic toxicology and environmental effects of pollutants at the University of Maine, we are able to classify lake, and brown trout, bass, pickerel, white fish, white perch, landlocked salmon, cusk, and smelt as intermediate sensitive species. This consultation helped us classifying the fish for which catch rates are known, but for which no laboratory experiments have been conducted.

Dr. Haines furthermore advised us of other species residing in Maine that are sensitive to raised levels of lake acidity; Blue Back, Artic Char, Blue Char, and several species of the Minnows family (the primary feed to sport fish). It may be possible that the population of Minnows is reduced due to acidic deposition and in turn influence the size and growth of sport fish population. The other species as listed above have not been reported in the Maine Fishing Survey, and their habitats are reduced to only a handful of lakes in Maine. Making statements about the influence of acid rain on those fish species in the state of Maine is therefore not relevant.

Table 2.3: Acid Stress Index Sensitivity of Fish in Maine

Acid Stress Index	Fish Species
Sensitive	Blue Char, Blue Back, Artic Char, Minnows
Intermediate	Lake and Brown Trout, Bass, Pickerel, White Fish, White Perch, Landlocked Salmon, Smelt
Tolerant	Brook Trout

(source: Haines, personal communication)

For our study, ASIs are calculated from the ELSM data set and then extrapolated to all Maine lakes that were visited by anglers from the 1994 survey under the assumption that the DDRPM data set represents a random sample of the ELSM and thereof all Maine lakes.

ACIDIFICATION ESTIMATION

To be able to predict ASI for 1994, ASIs for lakes that are missing the necessary chemical variables need to be estimated. Englin at al. (1991) regressed the different ASIs (sensitive, intermediate, tolerant) from lakes for which ASI data are available on watershed characteristics, water quality, and angling activity.

Englin et al. (1991) found that three lake characteristics correlate with ASI: vegetation in the lake, the size and the geographic location of the lake. Since precise measures of lake vegetation were not available to Englin et al. (1991), characteristics as they are observable by laypeople were used instead. The final regression for estimating the different ASI levels included the following variables: a measurement of weed density, type of watershed, geographic location, and types of recreational activities (see Englin et al. (1991) section A1.2. for regression results). With the regression results Englin et al. (1991) estimated ASI levels for all lakes that were visited by anglers.

The three chemical variables (Ca, Al, pH), necessary to calculate ASIs, are regressed on lake characteristics to estimate ASIs for all lakes in Maine that were visited by anglers in the 1994 MFS. Not all the variables as were used in Englin at al. (1991) are available for Maine lakes. To be specific, measurements of weeds in the lake, and lake vegetation are not available for all lakes visited by anglers in 1994. In order to estimate ASIs for all Maine lakes, lake specific variables available to both, the ELSM and MFS data set had to be identified. For the analysis to be credible, the characteristics that resulted in the largest intersection between MFS and ELSM were chosen from a dataset, which was made available from Pearl, the Maine lakes information network (www.pearl.spatial.maine.edu). Those variables are lake volume, area, elevation, and maximum and mean depth.

The Eastern Lakes Survey divides Maine into several strata, where each strata is given a weight in order to estimate chemical information on a sub-strata population level. Our regression analysis combines these strata, not implementing the weights used for population estimates, since dummy variables used to represent the different strata with the weights were not significant in preceding regression runs. We therefore assume that the weights of the different strata for our purposes do not have interactive effects on the relationship between Al, Ca, and pH and the independent variables[1].

The following tables show the regression results for lake pH, Ca, and Al concentrations. The regressions are conducted on the ELSM data that had 141 records that have the same variables available then the MFS lakes.

The different chemical variables necessary for calculating ASIs were estimated by multiple regressions. The final regression equations where estimated in a log-log relationship, to reduce the high variation of the data for lake physical characteristics.

Table 2.4: Multiple Regression Analysis of pH in ELS Lakes in Maine

Parameter	Estimate	T- Statistic
CONSTANT	0.67347	15.5753
Log_Area	-0.0035064	-0.30024
Log_Elevation	0.0245334	5.09936
Log_MaxDepth_	-0.0306793	-2.44195
Log_MeanDepth	-0.0143085	-1.25441
Log_Volume	0.0263286	2.28496
R^2=.3324		
Adj. R^2=0.3061		

Table 2.4 shows the regression results for pH. Carbon dioxide reacts with water to form carbonic acid. This in turn effects the pH (acidity) of water. The results of the above regression suggest that the deeper the lake, the lower the pH. It needs to be made clear that dissolved organic carbon also has a controlling effect on lake pH. The R^2 for

---

[1] The weights for the different Strata were also assumed to not have any effects on the relationships between the different chemical variables in the Englin et al. (1991) study.

this regression is 33%, that is 33% of the movement in pH is explained by the model. For data of this type the R^2 is acceptable. The t-statistics for the different variables, except for the log of area, are in satisfactory range.

Table 2.5 shows the regression results for Aluminum in the ELSM lakes. The amount of aluminum in lakes is related to the acidity of the water, and the dissolved organic carbon in the water, which Aluminum binds. While moderately low pH does not usually harm fish, metals such as aluminum become soluble in low pH water and therefore become detrimental to the fish's health.

Table 2.5: Multiple Regression Analysis of Al Concentration in ELS Lakes in Maine

Parameter	**Estimate**	**T- Statistic**
CONSTANT	2.46613	4.48369
Log_Area	0.328737	4.48369
Log_Elevation	0.194021	2.75095
Log_MaxDepth_	0.353935	2.52636
Log_MeanDepth	-0.264071	-1.71156
Log_Volume	-0.334836	-2.48028
R^2=.204135		
Adj. R^2=.172802		

The equation was estimated in the same way, transforming the variables to a log-log relationship. The R^2 for the Al estimation is 20%, again a satisfactory result for cross sectional data. While the pH regression coefficients are partially explainable through lake characteristics, the coefficients for the aluminum regressions are less obvious. Lake volume does negatively impact aluminum in lakes. That is, lakes with large volume have a higher ability to buffer the effects of acidity in the lake.

Calcium concentrations are related to the presence of calcium-bearing minerals in the watershed. Calcium creates a buffer to lake acidity, and has a positive effect on fish in lakes with low pH. Again, the regression results suggest that the levels of calcium concentration is related to soils and sedimentation information rather than lake characteristics.

Table 2.6 shows the regression results for Calcium. The R^2 is 26%.

Table 2.6: Multiple Regression Analysis of Ca Concentration in ELS Lakes in Maine

Parameter	**Estimate**	**T- Statistic**
CONSTANT	0.998278	2.27897
Log_Area	-0.0251057	-0.212873
Log_Elevation	0.224904	4.61915
Log_MaxDepth_	-0.287888	-2.26834
Log_MeanDepth	-0.198703	-1.72364
Log_Volume	0.190632	1.64783
R^2=.262393		
Adj. R^2=.233122		

One of the problems in this estimation procedure is that chemical data are estimated by lake characteristics. In order to better estimate pH, Al, and Ca, more detailed water chemical information is necessary. Because acidity of a lake is not only induced by acid rain, but also by DOC and leaching of aluminum and calcium from bedrock and lake sediments, trying to estimate the parameters from lake characteristics only results in an unspecific estimate. With future technology, collecting environmental information of this type will hopefully become easier, and allow studies such as this to be more precise.

The coefficients resulting from the regression analysis are then used to calculate the different sensitivity measures for all lakes in Maine that were visited by anglers in 1994. The data are organized so that each record reveals the catch rate an angler had at a specific lake. The total number of records in this data set is 4719. The following table gives the summary statistics on ASI for this data set.

Table 2.7: Summary Statistics of ASI Measurements for all Lakes in Maine that were Visited by Anglers in the 1994 MFS

	ASI Sensitive	ASI Intermediate	ASI Tolerant
Minimum	12.65	0.001	0
Maximum	100	96.88	0.0677
Average	56.68	0.66	0.0002

The following three graphs show the distribution of ASI sensitive, intermediate and tolerant. Lakes' identification codes are plotted on the y-axis, and the ASI measures is plotted on the y-axis. Figure 6 shows the distribution of ASI sensitive.

Figure 2.3: ASI Sensitive Distribution in all Maine Lakes visited in the 1994 MFS

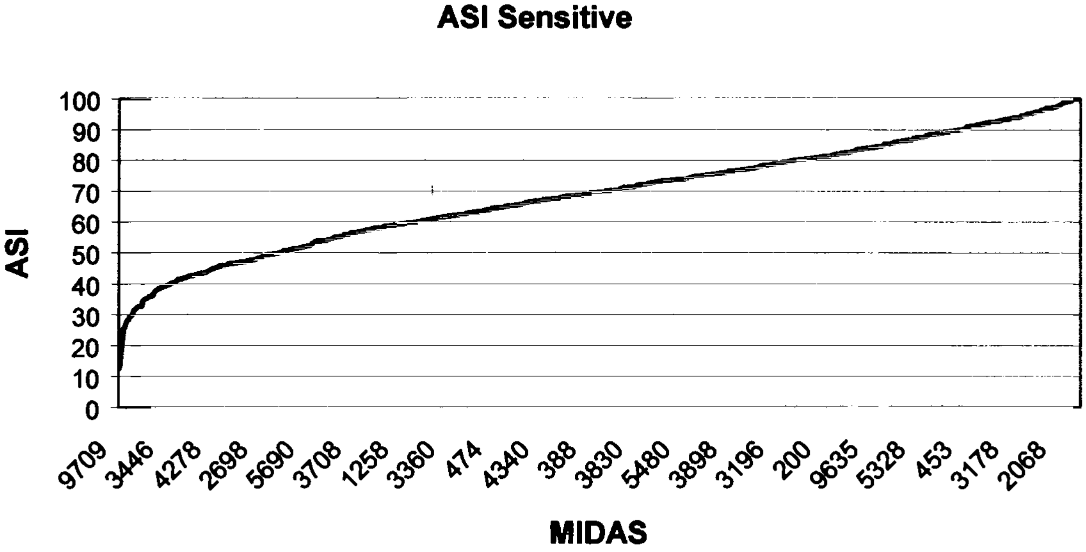


Figure 7 shows the distribution of intermediate ASI. The y-axis was scaled down to a max of 10, to emphasize those lakes that are above an ASI of 10 (the average of ASI intermediate is 0.66).

Figure 2.3: ASI Intermediate Distribution in all Maine Lakes visited in the 1994 MFS

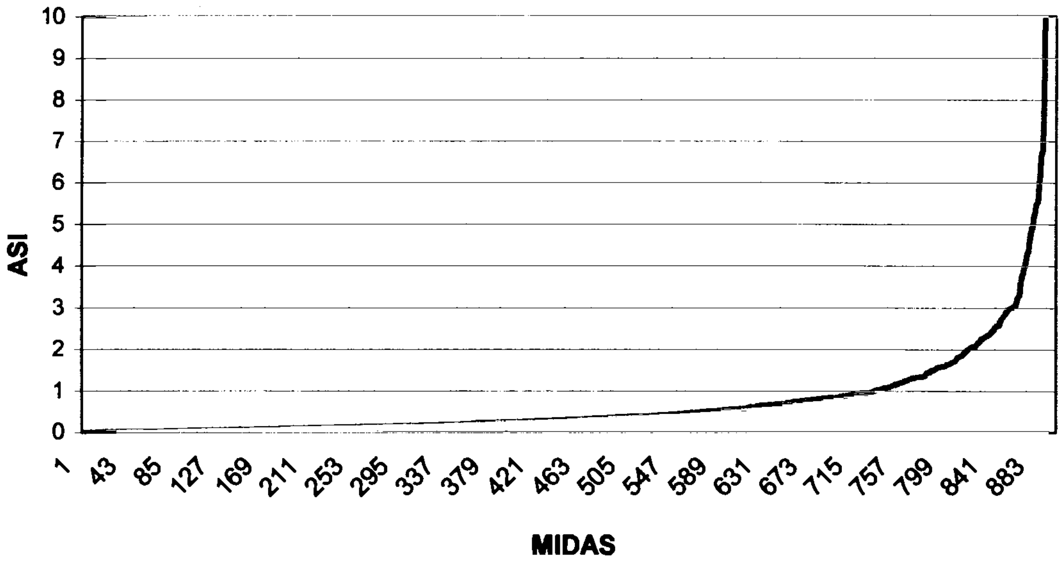


Figure 2.4: ASI Tolerant Distribution in all Maine Lakes visited in the 1994 MFS

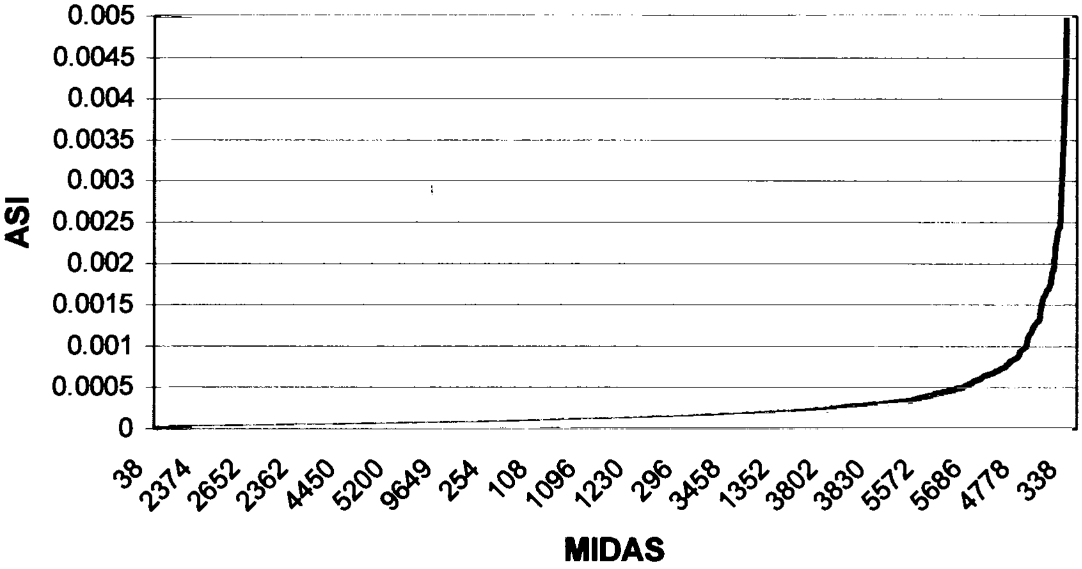


Figure 8 shows the distribution of ASI tolerant. Again, the y-axis had to be scaled to make the graph meaningful. The maximum on the y-axis is 0.005.

The data are then used to calculate estimated harvest rates of the different species, which will later be used as a deterministic variable for the Random Utility Model (RUM) model.

LINKAGE MODEL

Englin et al. (1991) estimated the relationship between fish abundance and catch per unit effort. Individual catch per hour is regressed on lake characteristics, angler characteristics and the different sensitivity measures (ASI) to establish the relationship.

$$\text{Individual catch/Hour} = \alpha_0 + \alpha_i z_i + \alpha_j z_j + \alpha_k ASI$$

Where z_i = individual characteristics

z_j = lake characterisitics

ASI = Acid Stress Index

The regression was estimated for different species (rainbow, brook, brown, and lake trout), since an angler will target different species, and catch per unit effort changes among the different species. The regression results can be found in Englin et al. (1991, A.2). By multiplying the coefficient of ASI by the predicted change in acidity from the different policy scenarios it is then possible to calculate changes in catch per unit effort.

We will predict changes in Catch per Unit Effort (CPUE) with measures of acidity in a similar manner, by regressing catch per unit effort per day on lake and angler characteristics, and ASI. The general equation can be stated as:

$$CPUE = \alpha_0 + \alpha_1 z_1 + \alpha_2 z_2 + \alpha_3 ASI + \varepsilon$$

where z_1 = vector of Angler characteristics (MFS data)

z_2 = vector of Lake characteristics (ELS)

ASI = estimated ASIs for all MFS lakes (acidification forecast)

Catch per unit effort is related to acid stress, fishing characteristics and socioeconomic variables as available from the MFS, lake characteristics as available from

ELSM and the Maine State Lake Inventory. In order to predict catch per unit effort, the data set with all the variables as mentioned above is analyzed using a bioeconomical model written for a statistical analysis program, STATA. STATA then predicts harvest rates by regressing catch per unit effort on the following variables: number of fishing days, whether the species was targeted, fishing specific characteristics such as whether the angler is an expert or beginner, bait used, and lake specific variables such as size, depth, elevation, volume, and the species specific ASI of the lake (ASI sensitive, intermediate, or tolerant), and whether the lake has a boat landing. Demographics variables such as age, gender, income, education, and employment are also included.

Table 2.8: Harvest Predictions (All Variables) (Species with positive ASI omitted)

	Landlocked Salmon	**Landlocked Salmon**	**Lake Trout**	**Lake Trout**
Constant	.87577 (.862)	1.802 (1.992)	.1973 (.303)	.1988 (.167)
Species Targeted	2.047 (4.293)	2.575 (6.187)	1.195 (3.74)	1.721 (5.688)
Stress Indices				
ASI Intermediate	-.0455 (-.597)	-.0243 (-.48)	-.0174 (-.363)	-.0125 (-.377)
Fishing Specific Variables				
Fly Fishing	-.04921 (-.704)	-.0414 (-.595)	-.0546 (-1.025)	-.028 (-.635)
Lures	-.08707 (-1.231)	-.112 (-1.617)	-.0601 (-1.33)	-.073 (-1.622)
Dead Bait	-.05525 (-.53)	-.06722 (-.648)	-.0568 (-.846)	-.54 (-.795)
Worms	-.22635 (-3.23)	-.2365 (-3.399)	-.12 (-2.68)	-1.277 (-2.821)
Lake Characteristics				
Acres	0.00003 (.294)		.00008 (1.32)	
Average Depth	0.0148 (1.021)		.00115 (.123)	
Elevation	0.000743 (1.62)		-.000034 (.9)	
Max Depth			.00056 (.191)	
Boat Launch	.12167 (.546)	.1863 (.378)	-.0778 (-.222)	.30567 (.328)
Angler Specific				
Male	-1.988 (-3.46)	-2.04 (-3.56)	.09812 (.266)	.0287 (.077)
Expert	.347 (.553)	.355 (.608)	.5688 (1.516)	.6619 (1.736)
Beginner	-2.052 (-.704)	-2.1466 (-1.968)	-.645 (-.924)	-.6514 (-.917)
R-Square	0.1581	0.1383	0.1317	0.0933
t-stats in parenthesis				

The fishing specific variables listed below are dummy variables, describing the importance of an angler to exercise his/ her fishing style. The fishing specific variables list fly fishing, lures, dead bait, worms and live bait. The fifth dummy variable, trolling, is left out of the regression equation so that the coefficients can be interpreted properly. The same principal accounts for the angler specific variables. The dummy variable for gender, and the dummy for fishing skills (novice, beginner, expert).

The following table shows the regression results with t-statistics in parenthesis. The R^2 for the predictions are shown at the bottom of each column.

Table 2.8 cont.: Harvest Predictions

	White Fish	White Fish	White Perch	White Perch
Constant	-.235 (-1.24)	-.1274 (-.759)	1.437 (.538)	-.0517 (-.022)
Species Targeted	6.362 (18.51)	6.385 (18.627)	15.026 (9.56)	15.75 (10.229)
Stress Indices				
ASI Intermediate	-.0155 (-1.1)	-.00061 (-.064)	-.06 (-.309)	.211 (1.58)
Fishing Specific Variables				
Fly Fishing	.000243 (.02)	.000384 (.029)	-.284 (-1.55)	-.3244 (-1.779)
Lures	.0103 (.78)	.00733 (.56)	-.4089 (-2.2)	-3.57 (-1.967)
Dead Bait	.0478 (2.42)	.0509 (2.603)	-.346 (-1.27)	-3.66 (-1.35)
Worms	.0123 (.919)	.00896 (.679)	-.244 (-1.313)	-.267 (-1.45)
Lake Characteristics				
Acres	.000001 (.03)		-.00004 (-.147)	
Average Depth	-.002 (-.07)		-.075 (-1.96)	
Elevation	.0001 (1.235)		-.0009 (-.757)	
Max Depth	.0012 (1.42)		.254 (2.121)	
Boat Launch	.0418 (.404)	.0377 (.413)	.0155 (.011)	.018 (.014)
Angler Specific				
Male	.00293 (.027)	.0069 (.064)	2.513 (1.662)	2.699 (1.786)
Expert	.0969 (.862)	.0916 (.818)	2.874 (1.868)	2.8 (1.822)
Beginner	-.0049 (-.02)	-.0097 (-.047)	-1.88 (-.685)	-1.61 (-.563)
R-Square	0.3083	.3053	0.1729	0.1642
t-stats in parenthesis				

RESULTS

There are two regression results listed in the above table. One includes all variables relevant to the harvest prediction, and the other one excludes lake specific variables. Comparing the two results shows that the coefficients of the variables related to the harvest rates are robust, that is, when removing variables from the equation the coefficients are not changing significantly, and the constant term does not pick up additional variation. One of the goals for this exercise is to see if the coefficient for ASI becomes more statistically significant. Since the coefficient for ASI in the above results does not improve significantly, it further shows that the relation between CPUE and acidity in Maine lakes is weak. The regression equation that excludes lake specific variables is being used for further analysis in this study.

The results of the regression that were omitted from the above table had a positive sign for ASI. The positive coefficient for ASI suggests that an increase in acid stress in a specific lake increases the catch rates. This result might be explained by the low effect of acidic deposition on fish species residing in Maine lakes, or the temporary availability of large fish in the lakes that were visited. As stated earlier, most fish in Maine are tolerant or intermediate sensitive species, which is expected due to the harsh environment in this area, so that the regression does not pick up on the relation between ASI and catch rates.

Furthermore, the relationship between ASI and fish mortality is assumed to be non-linear in nature. The change in mortality is smaller at lower levels of ASI, and increases significantly as the levels of ASI become toxic to fish. When relating the mortality rates of fish to harvest rates, marginal changes in catch rates are small at lower levels of ASI. This could be a reason for the weak coefficient of ASI in the above model, since most lakes in Maine have levels of ASI that do not affect sport fish. Also, the relationship between ASI and mortality might be skewed for the most popular fishing lakes in Maine, since the Fish and Wildlife Service heavily stocks them.

The species with the expected sign on the ASI coefficient are Landlocked Salmon, Lake Trout, White Fish and White Perch. The negative sign on the ASI coefficients suggests that an increase in acid stress reduces catch rates of the species at a specific lake.

Please note that the coefficients of the ASI are statistically not significant. This further suggests that the estimation procedure for ASIs in this study is relatively weak. The R^2 for the Landlocked Salmon equation is 13%, for Lake Trout 9%, for White Fish 30%, and for White Perch 16%. The low R^2 for these models can be explained by the predictive nature of the equation. Furthermore, the equation takes into account a predicted ASI from a sample of only 19 lakes. This might have also be the cause for the positive nature of the ASI coefficients for the other species. In order to have a better estimation of the harvest rate prediction, exact chemical measurement of all lakes should be gathered which is time consuming and expensive.

The four fish species that do have the expected negative sign on the ASI coefficients will be considered for the Random Utility model and further estimations.

RUM ANALYSIS/ SUBSTITUTION EFFECT

Our study will use a random utility model (RUM) to value the economic impact of acidic deposition on recreational anglers. The RUM model has been well developed in literature (see McFadden 1978, Bockstael et al. 1987, Parsons and Kealy 1992). The model was first applied to the valuation of recreational activities by Hanemann (1978). A detailed model of recreational valuation can be found in Bocksteal et al. (1991).

The RUM is especially useful for the valuation of recreational fishing when there are several alternative sites (recreational fishing lakes). In order to investigate correctly the value an angler places on a fishing site, the substitution effect has to be included in the analysis.

When using the RUM, the demand for a specific site will be a function of the prices and site-specific characteristics (qualities) of all sites considered in the model (Hoehn et al., 1996).

Anglers usually have several choices of fishing sites available to them. Each site bears a combination of characteristics, such as fishing site quality and costs (i.e. travel costs) of reaching that site. Information on where anglers fish reveals their preferences of trading income for site quality. One of the site qualities important to recreational angler will be the fishing success, i.e. catch rate.

Englin et al. (1991) estimate the random utility model on a subset of anglers that made at least one day trip to a lake in the study region. Since there are a large number of lakes an individual could visit, the opportunity set for each angler is randomly drawn. To build an opportunity set for each angler, a set of lakes that was within 3 driving hours from the angler's home is established. From this set 11 lakes were randomly drawn. For the estimation of the model each angler then has 12 lakes in his/ her opportunity set -- that is, 11 lakes that were randomly drawn plus the lake actually visited. Englin et al. (1991) then estimate the model by standard multinomial logit procedure.

The non-nested model as estimated by Englin et al. (1991) included explanatory variables for price, catch rate, and characteristics of importance to the angler. The specification and results of this model can be found in Englin et al. (1991) B.2.

The RUM model can account for substitution effects. If an angler visits a lake that is highly acidic and therefore has a low catch rate he/she might consider a different lake located within an acceptable distance. Even though anglers take many trips during the fishing season, we assume that each choice is independent of another. This choice is then being modeled as the probability that an angler chooses a specific site depending on site characteristics and costs of reaching that site.

If the relationship between harvest rates and ASI levels were stronger, we could assume that the different policy scenarios will have an effect on lake acidification (positive or negative), and will, in turn, effect the value an angler places on a fishing site. Unfortunately, the coefficients of the ASIs in the harvest rate predictions are very weak, so that changing the ASI by decreasing or increasing the levels of ASI will not have the expected effect of catch rates.

Individuals from the MFS who made at least one day-trip to Maine lakes are used to estimate the model. Since there are a large number of lakes in Maine, and the choices and angler can make, each angler will be assigned to a randomly drawn opportunity set of 4 lakes. So the choice set for each angler contains 4 lakes plus the site visited.

The reason for this small opportunity set is that the driving distance has been reduced to a maximum of 50 miles one way. If the allowed mileage driven to the fishing site were increased, the angler's opportunity set would include lakes that are very similar to the lake he/she initially visited. The opportunity set then contains a set of lakes that is within a 50 mile range from the angler's home, assuming that all trips in the database are one daytrips. With this restriction in driving distance we try to avoid that lakes with smaller harvest rates are not being chosen by an angler.

BASIC MODEL

Consider each angler making a trip decision, making a choice between several different available sites denoted as i=1,2,...,S. In a RUM, the probability of visiting site S depends on its own characteristics as well as characteristics of other sites. Specific to our case these characteristics will include expected harvest rate depended on the ASI in the lake, site characteristics such as ease of access, and travel costs to the site. The utility of site I then is

$$V_i = u(tc_i, \mathbf{q}_i) + e_i$$

Where tc_i is the cost of reaching the site, q_i is the vector of site characteristics, and e_i is a random error term. It is expected then that an increase in costs of reaching the site decreases utility, and an increase in site characteristics increases utility of visiting the site.

We can assume that the angler is visiting the site which gives the highest utility. Site j is chosen if

$$u(tc_j,q_j) + e_j \geq u(tc_i, \mathbf{q}_i) + e_i \quad \text{for all } i \in S$$

Since the e_i are random elements, the site choice can be viewed as the outcome of a probabilistic model. For different e_i's different site choices will be observed. The probability of an individual choosing site j can then be written as

$$pr(u(tc_j,q_j) + e_j) \geq pr(u(tc_i, \mathbf{q}_i) + e_i) \quad \text{for all } i \neq j.$$

The form on the probability depends on the distribution of the error terms e_i. The multinomial logit (MNL) assumes that the e_i across the S sites are independently and identically distributed Weibull. The following equation as developed by McFadden (1978) describes this form of probability

$$pr(k) = \frac{\exp(u(tc_j, q_j))}{\sum_{i=1}^{S} \exp(u(tc_i, q_i))}$$

The above equation shows that the probability of visiting site j depends not only on its own characteristics but also on the characteristics of all other sites (appearing in the denominator). The probabilities of all sites S sum to 1.

The site utilities v_i are assumed to have a linear form

$$v_i = \beta_{tc}tc_i + \beta_q q_i + e_i,$$

where β_{tc} is the coefficient of the travel cost variable which is expected to have a negative sign, and β_q is the coefficient of the site characteristics variable, assumed to have a positive sign. The probability to be estimated in the model can then be rewritten as

$$pr(j) = \frac{\exp(\beta_{tc}tc_j + \beta_q q_j)}{\sum_{i=1}^{S} \exp(\beta_{tc}tc_i + \beta_q q_i)}$$

The parameters can then be estimated using the logit probability model specified above. Accepting the basic site utility model and the distribution of its random error term, the likelihood of observing the pattern of visits actually made by N anglers can be written as

$$\prod_{n=1}^{N} \prod_{i=1}^{S} pr(i)^{r_{in}}$$

where $r_{in} = 1$ if individual n visits site i and = 0 otherwise. Pr(i) is the probability in logit form.

The different parameters are estimated by maximum likelihood, where the above equation describes the likelihood function.

Since anglers are taking multiple trips to one site in a fishing season, r_{in} will equal the number of trips taken to site i. This formulation will assume independence across trips to one specific site.

MODEL SPECIFICATION

The random utility model is estimated using the data set that includes anglers who made at least one-day trip to a lake in Maine. The data set is described in the Data section. The data set includes information on a total of 6955 trips to Maine lakes. The opportunity set for each angler includes 4 lakes plus the lake visited. The RUM is estimated by standard multinomial logit using STATA. The explanatory variables used in the model are explanatory variable for travel cost, size of the lake, whether the lake has a boat landing, and catch rates for different species. The table 2.9 describes the variables used.

Table 2.9: Variable Definitions for RUM

Variable Name	Definition
Travel Cost	Travel cost to the visited site: 0.56 * one-way travel distance (miles) * 2
Surface Area	Lake size in acres
Boat Landing	= 1 if lake has a boat ramp = 0 otherwise
LLSC_PRD	Predicted catch rate of Landlocked Salmon
LKTC_PRD	Predicted catch rate of Lake Trout
WHTC_PRD	Predicted catch rate of White Fish
CSKC_PRD	Predicted catch rate of Cusk

RESULTS

The multinomial logit procedure estimates each trip taken by an individual in the data set. The resulting coefficient estimates are then summed over all individuals, and then divided by the number of total trips taken by all individuals to produce an average value. This average value is associated with an individual trip, and represents the utility related to a stepwise increase in the value of a characteristic. The implicit value of a unit change in catch rate can be described as the marginal utility with respect to the cost of a trip divided by the marginal utility with respect to a change in CPUE. This can be calculated by dividing the coefficient of CPUE for a given species by the coefficient of the cost of reaching a specific site.

Equation:

$$\text{Implicit value of unit change in catch rate} = \frac{\frac{\text{MU}}{\text{TCost}}}{\frac{\text{MU}}{\Delta\text{CPUE}}} = \frac{\Delta\text{CPUE}}{\text{TCost}}$$

The following table shows the estimate results of the Random Utility Model.

Table 2.10: Random Utility Model Results for Baseline Model

Discrete choice (multinomial logit) model – Dependent Variable is the lake visited

Number of observations	3105
LR $chi^2(7)$	2830.46
Probability > chi^2	0.0000
Log likelihood	-3147.3284
Pseudo R^2	0.3102

Wghts	Coefficients	z-value
Travel Cost	-0.1092517	-28.376
Surface Area	0.0001029	21.969
Boat Landing	-1.038814	-14.446
Predicted Catch Landlocked Salmon	0.1973471	2.544
Predicted Catch Lake Trout	0.1322172	7.991
Predicted Catch White Fish	0.6063862	3.025
Predicted Catch White Perch	0.1939697	9.857

The coefficient for travel cost is negative, which is expected because the higher the costs of reaching the site, the smaller the probability of visiting the site. The coefficient of landing is negative, which means that the presence of a boat ramp negatively influences the probability of visiting a site. Furthermore, the coefficients for the catch rates of brook trout, lake trout, and white fish and white perch are positive. This means the higher the catch rates of these species, the higher the probability for an angler of visiting that site.

The implicit value for the species where the catch rate has the expected positive sign is $ 1.07 for Landlocked Salmon, $1.21 for Lake Tout, $1.46 for White Fish, and $1.59 for White Perch. These values describe the utility in dollars received by an angler with a stepwise increase in catch rates.

Coefficients other than the catch rates show that the probability of visiting a site is greater the larger the lake, and the availability of a boat launch. The pseudo R^2 for the multinomial logit model is 0.28.

PARTICIPATION MODEL

The participation model relates the number of fishing days to catch effort, travel costs and demographic characteristics of the population (Englin, 1991). This model is necessary to predict the number of fishing days after 2000, adjusting the average values of fishing trips with changes in deposition. It predicts the changes in fishing trips with changes in acid deposition with the implementation of the different policy scenarios. In order to address long-term trends in fishing participation Englin et al. (1991) utilize a cohort data set to account for shifts in population composition (i.e. Baby-Boomers).

In order to predict the changes in fishing participation cohort data will be used. As discussed in Englin et al. (1991), time-series data will best describe the participation of anglers. An ideal situation would be to follow a randomly selected group of people over several years. Data sets that would allow the ideal analysis are unfortunately not available. Englin et al. (1991) therefore use the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (NSFHWR), which is administered every 5 years by the

U.S. Fish and Wildlife Service, to follow cohorts, rather than individuals over time.

The data is then used to model participation under the different policy scenarios, which is depended on CPUE effort changes with changes in acidification, and demographic population changes.

Englin et al. (1991) use demographic data on age, income, ethnicity, social status (i.e. married, retired etc.), and average catch rates for bass and trout, and miles traveled to those fishing sites where fish were caught.

The participation model will be used in TAF in order to forecast future changes of angling participation and catch rates with different policy scenarios. It is listed here only for the purpose of utilizing it for future scenarios embedded in TAF.

3. RESULTS

The results of this study suggest that the measurements of acidic deposition, the ASI, do not give a valid indicator for the damage to recreational fishing in Maine lakes from acidic deposition. First, detailed water chemical information is only available for a small sample of lakes in Maine, considering that there over 3000 lakes in Maine that are fished by anglers each year. The estimation for the ASIs in Maine lakes is based on 19 lakes and extrapolated over all lakes appearing in the 1994 fishing survey. This estimation is very weak as the results of the toxicity model show. In order to have a more significant estimation of actual acidity levels in Maine lakes, in depth studies of lakes are necessary, taking into account the chemical composition of lake sedimentation and soil components of the specific area. Furthermore, influences such as stocking of sport fish in Maine is not accounted for, and might have a large impact of the study, since catch rates at lakes are influenced by how many and what species of fish are stocked. Another strong position is that the initial choice of anglers in Maine is determined by the expected catch rate, and through information on fishing in specific lakes, lakes the yield less might not be chosen. This means that lakes that might be acidic, and therefore might contain smaller populations of fish, are not even considered for sport fishing since there are a large number of lakes available, and word to mouth information might discourage anglers to visit such a lake.

Furthermore, historical catch rates and fish population counts are not available for most of Maine lakes, so that catch rates cannot be compared to previous data. The study would have a different approach of addressing this issue, because it might have been the case that there was a larger (or smaller) variety and population of fish present in Maine lakes. This could then be used to show the effect of the 1990 Clean Air Act.

Regardless of the results of this study, one could use these results as a baseline for future studies, comparing catch rates and deposition levels with 1994 rates. The study is also important with regards to TAF, because it allows other states to replicate this study and add recreational fishing valuations to the existing TAF model. Furthermore, as technology is advancing, reading chemical deposition and acidification of specific areas will become easier, and utilizing the new data and information that will become available in this model might make the outcomes satisfying in term of solid statistical results.

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APPENDIX: DATA DESCRIPTION

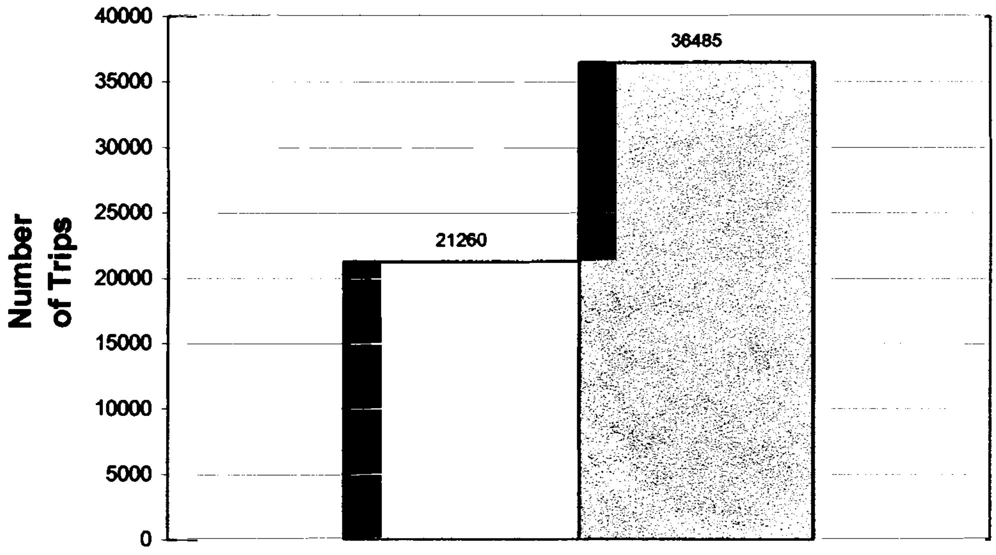
MAINE FISHING SURVEY (MFS)

The Maine Fishing Survey conducted in 1994 was sent to a random sample of five thousand Maine fishing license holders (MacDonald, Boyle, Fenderson, 1996). With a response rate of 62% the survey provides information on angler characteristics, lakes and streams fished, gear information, and demographic information.

SUMMARY STATISTICS OF THE 1994 MFS

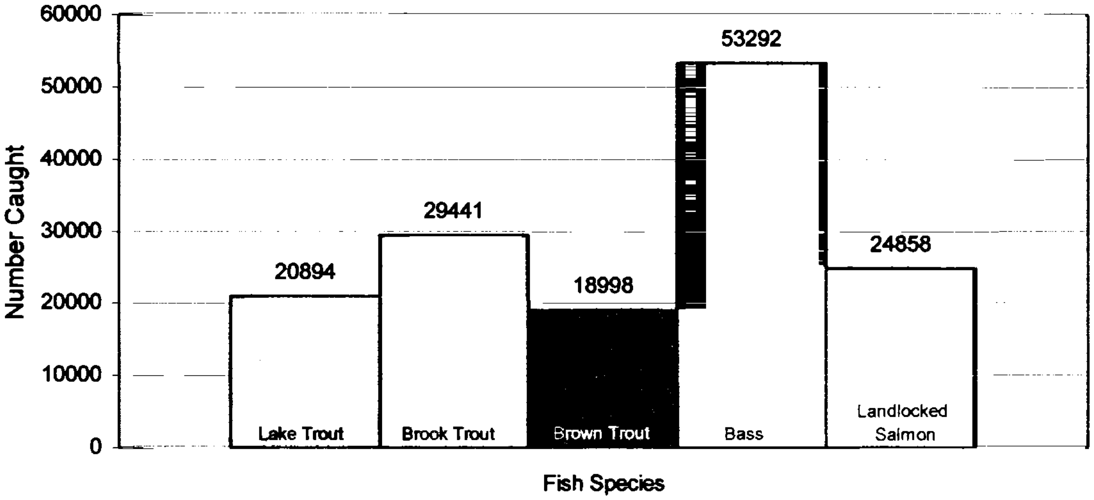
The 1994 MFS contains information on 21260 trips, totaling 36485 fishing days.

Figure A.1. 1994 Trip Information



The total catch is summarized in the following table. Anglers caught 20894 Lake Trout, 29441 Brook Trout, 18998 Lake trout, 53292 Bass, and 24858 Landlocked Salmon at 1141 lakes in Maine during the 1994 fishing season.

Figure A.2. 1994 Maine Fishing Survey



PREPARATION OF MFS

For the toxicity and forecasting models MFS data is organized by lake. That includes summing the trip and catch information per lake, so that total catch effort per day and per fish species can be calculated. For the RUM model, the MFS data set needs to be organized by angler ID, so that lakes visited, fish caught and targeted can be identified. Distances from the lake to the nearest town are calculated, and lakes that are within a 3 hour drive from an individual's home added to the set of lakes.

The final data set for the toxicity and linkage models contains lake characteristics and water chemical information organized by lake. The final data set for the RUM model is organized by angler ID and contains individual characteristics such as demographic and angling characteristics, and a set of lakes, the opportunity set for each angler. Following is the list of variables included in the Maine fishing survey:

Effort Related Questions:

- Identification number of the angler questions
- MIDAS
- Lake name
- Name of nearest town or township
- Trips from the angler home
- Days fished
- Single-day trips from the anglers home
- Landlocked salmon caught, kept and targeted
- Lake trout caught, kept and targeted
- Brook trout caught, kept and targeted
- Brown trout caught, kept and targeted
- Smelt caught, kept and targeted
- Cusk caught, kept and targeted
- Pickerel caught, kept and targeted
- Bass caught, kept and targeted
- White Perch caught, kept and targeted
- Whitefish caught, kept and targeted
- Other species caught, kept and targeted.

Other questions of importance:

- Angler ID
- Open water fish?
- Ice Fish?
- Marine Fish?
- Hunt?
- Trap?
- Observe wildlife?
- No Activities
- Ever open water fish?
- What season do you enjoy most?
- Fish in October?

- Fish in November?
- Did not fish in Nov or Oct
- Use public boat launch for access
- Use public road for access
- Use public land for access
- Use own land for access
- Use others land for access
- Use private road with permission for access
- Use private road without permission for access
- Use other access
- Listing of other access
- Select because of access?
- Open water fish during 1994 season?
- Any access problems?
- Able to resolve access problems?
- Was able to resolve problems
- Didn't fish because of access problems
- Went to other access point
- Went to different water
- Did something else because of access problems
- Listing of response to access problems
- Nearest town to water
- Problem in searching for access
- Problem in finding access
- Problem with no public access
- Problem in getting permission
- Problem with conflict
- Problem in not getting permission
- Problem in parking
- Problem with safety
- Problem with lost time
- Problem with not fishing
- Other access problem
- Listing of other access problem
- Willing to pay extra $1
- Willing to pay extra $5
- Willing to pay extra $10
- Willing to pay extra $25
- Willing to pay extra $50
- Willing to pay extra $75
- Willing to pay extra $100
- Willing to pay extra $200
- Willing to pay extra $300

- Willing to pay extra $400
- Willing to pay extra $500
- Willing to pay extra $1000
- Willing to pay extra $1500
- Willing to pay extra $2000
- Catch and release in 1994?
- How often catch and release
- Catch and release when not required by law?
- How often catch and release when not required?
- Catch and release because undesirable species
- Catch and release because not legal to keep
- Catch and release because small fish
- Catch and release because large fish
- Catch and release because concerned
- Catch and release because don't like to clean fish
- Catch and release because don't like to eat fish
- Catch and release because caught limit
- Catch and release because shared catch
- Catch and release because mercury
- Catch and release because contamination
- Catch and release because other reason
- Other reason for catch and release
- Approve of no kill trout reg on favorite water?
- Approve of no kill if it increases size?
- Approve of reduced keep?
- Number of licenses in 1993
- Purposely fish for bass
- Incidentally fish for Bass
- Do not fish for bass
- Purposely catch bass
- Incidentally catch bass
- Do not catch Bass
- Keep any Bass?
- Consider Bass important species
- Know of Mercury advisory?
- Read Mercury advisory?
- Catch any fish in 1994?
- Respondent age
- Respondent gender
- Respondent educational level
- Respondents work status
- Respondents living area
- Respondent income

EASTERN LAKES SURVEY (ELS)

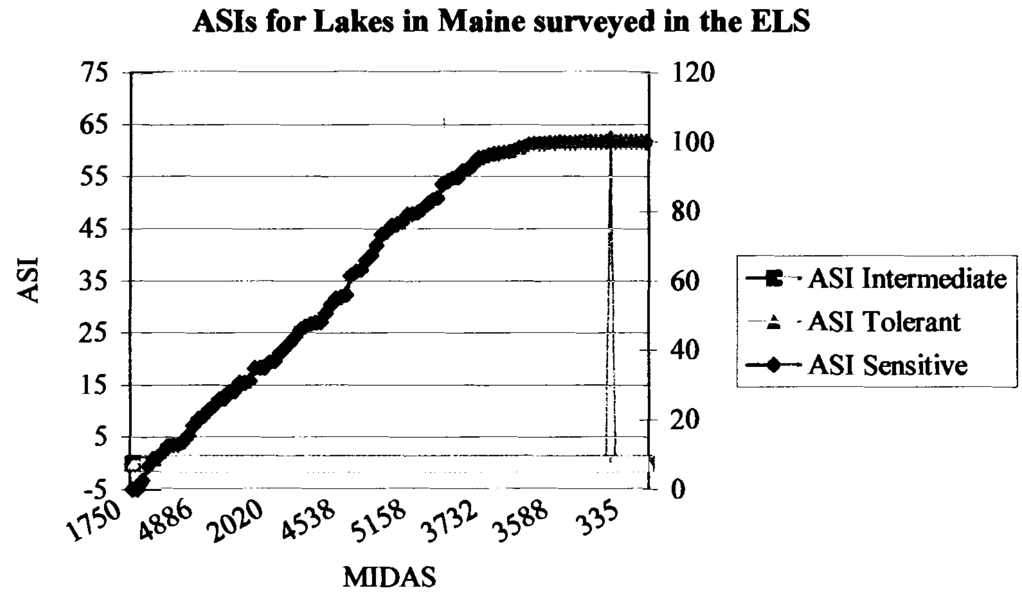
The Eastern Lake Survey -Phase II, conducted in the fall of 1984, was the first part of a long-term effort by the U.S. Environmental Protection Agency known as the National Surface Water Survey (Environmental Research Laboratory, 1989). This survey was designed to quantify the acid-base status of surface waters in the United States in areas expected to exhibit low buffering capacity. The effort was in support of the National Acid Precipitation Assessment Program. The survey involved a three-month field effort in which 1612 probability sample lakes and 186 special interest lakes in the northeast, southeast, and upper Midwest regions of the United States were sampled. Among other chemical information, the ELS data set contains following information:

- Lake name
- County
- Township
- MIDAS
- Date of measurement
- Elevation
- Sample type
- Secchi
- Area of lake
- Depth
- And the chemical components: Ca, Mg, K, Na, Si, NH_4, Al, Cl, NO_3, SO_4, I, closed cell pH, and equivalence pH.

SUMMARY STATISTICS OF THE ELS:

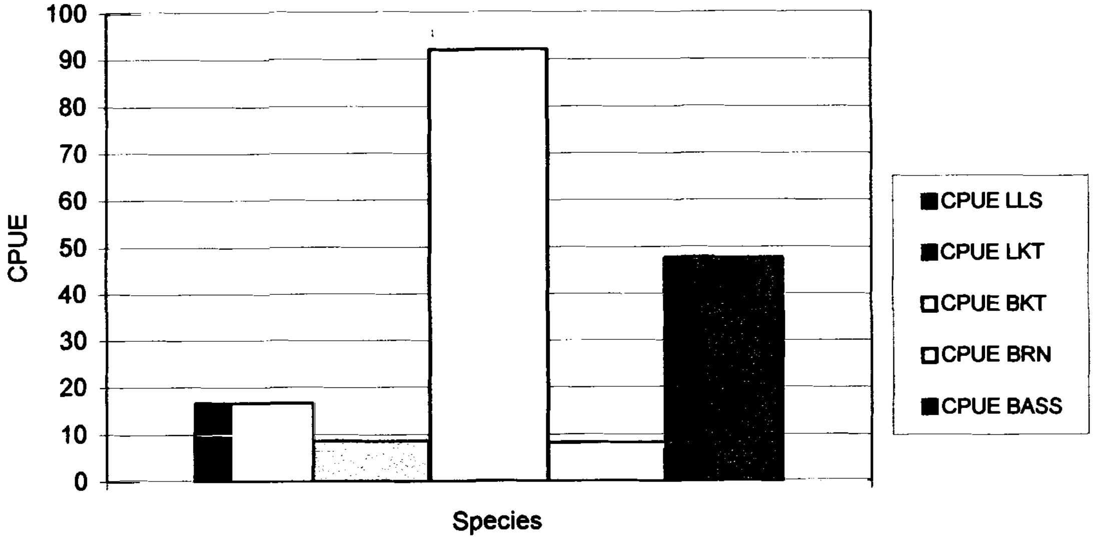
The MFS ELSM overlay allows us to calculate ASIs for the lakes that were visited by Maine anglers in 1994. The following graph depicts measurements of tolerant, intermediate, and sensitive ASIs for those lakes.

Figure A.3 ASIs for Lakes in Maine Surveyed in the ELS



The tolerant and intermediate ASIs in the ELSM do not reach critical levels. Several lakes reach critical levels for Rainbow Trout, the sensitive species. The following graph shows the catch per effort summary for ELSM lakes only. Catch per effort is calculated by dividing the sum of fish specific catch rates by the sum of angler days at a given lake.

Figure A.4. Catch per Unit Effort in ELSM Lakes



PREPARATION OF ELS

Every lake, which is visited by Anglers as recorded in the MFS dataset, is identified in the ELS by matching lake name and geographic location (longitude/ latitude). Resulting from this overlay are 105 lakes. The resulting data set consists of lake specific information as listed in the ELS. The ELS data set is used for toxicity (calculation of ASI) and linkage models.

DIRECT DELAYED RESPONSE PROJECT (DDRP)

The DDRP data were obtained from 145 lakes and 35 streams in the Upper Northeast. The lakes were chosen as a sub sample of the ELS data, excluding lakes with high ANC (ANC> 400 μeq L^{-1}), shallow lakes (<1.5m deep), and anthropologically disturbed lakes. The DDRP data set was further constraint by lake size since adequate soil mapping would not have been possible for lakes greater than 3000 ha.

There are a total of 19 lakes in the Maine intersection data set. This data set will be used for TAF, from which outcomes of lake chemical forecasts will be used to calculate ASI, which is the measure of lake acidity in this study.

Summary Statistics for DDRPM:

Figure A.5. ASIs for DDRPM

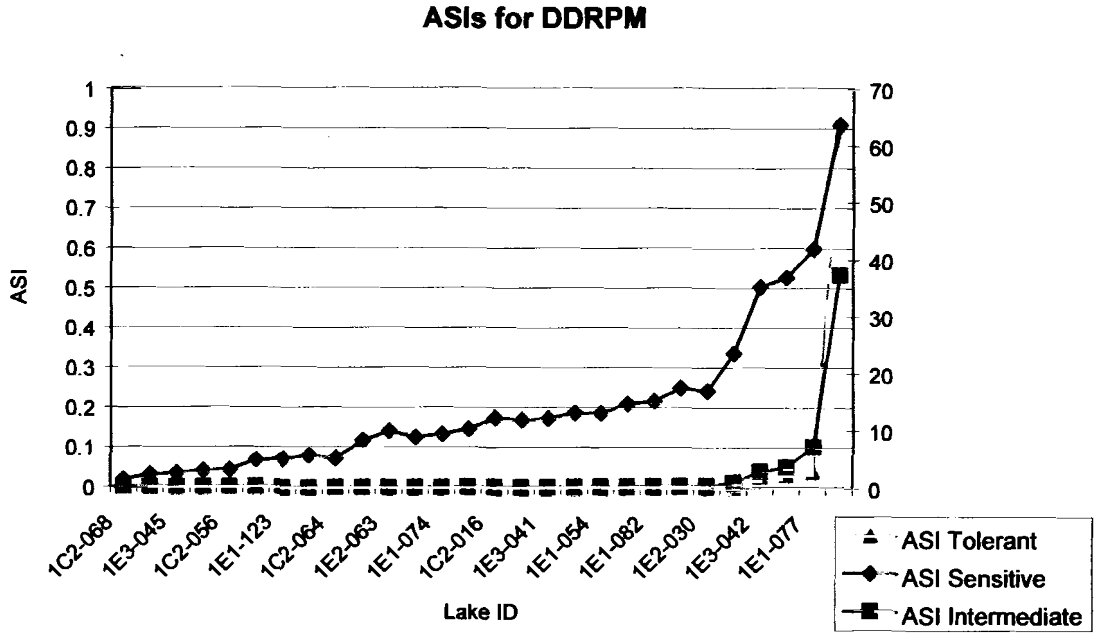
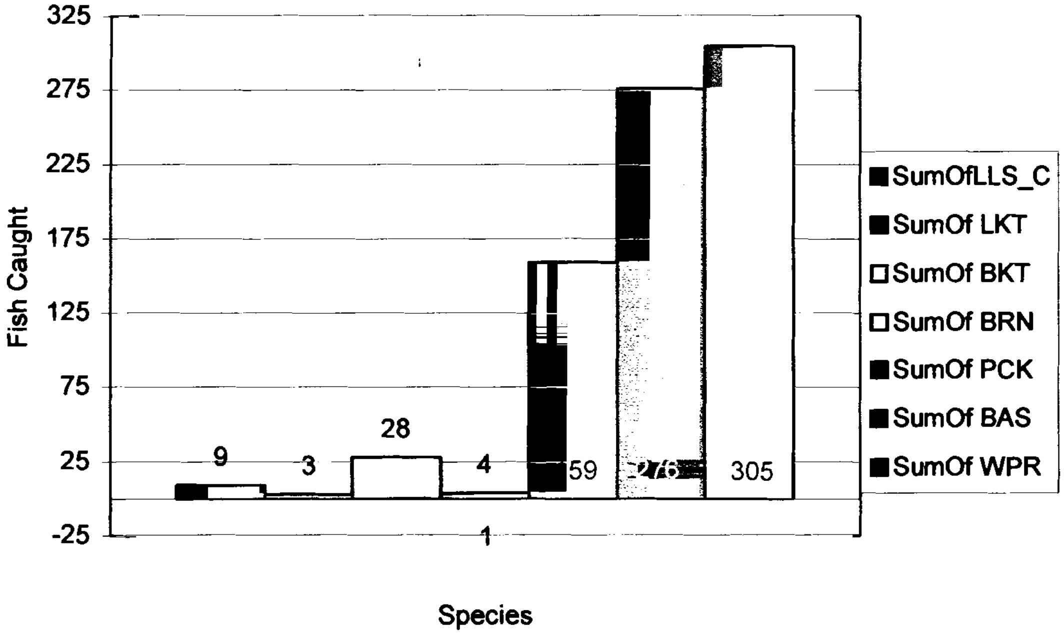


Figure A.6. Catch Rates at DDRPM



MAINE LAKES INVENTORY (MLI)

The Maine Lakes Inventory will be used to add missing lake specific information to the other data sets. The dataset contain 3695 lakes of which 86 are in the ELS MFS overlay.

The Maine Lakes Inventory data set contains information shown below:

- Area in acres
- Average depth in feet
- Presence of boat landing
- County name
- Catch and release
- Elevation in feet
- Fee access
- Ice fishing information

- Lake name
- Lake number (MIDAS: a four-digit code assigned to uniquely identify each lake in Maine.)
- Lake trophic type
- Maximum depth in feet
- Lake management type
- Motorboat restrictions
- Open water fishing information
- IF&W administrative region
- Presence of deeded right of way
- Shoreline feet
- Ice fishing county codes
- Landlocked salmon stocked
- Rainbow trout stocked
- Lake trout stocked
- Brown trout stocked
- Brook trout stocked
- Sunapee stocked
- Splake stocked
- Town name
- Vehicle access

Table A.1: Multiple Regression Analysis of pH in ELS Lakes in Maine

```
------------------------------------------------------------------------------
                                       Standard          T
Parameter               Estimate         Error       Statistic         P-Value
------------------------------------------------------------------------------
CONSTANT                  0.67347      0.0432395        15.5753          0.0000
Log Area               -0.0035064      0.0116787       -0.30024          0.7645
Log Elevation           0.0245334      0.00481107       5.09936          0.0000
Log Max Depth          -0.0306793      0.0125635       -2.44195          0.0160
Log Mean Depth         -0.0143085      0.0114066       -1.25441          0.2120
Log Volume              0.0263286      0.0115226        2.28496          0.0240
------------------------------------------------------------------------------
                           Analysis of Variance
------------------------------------------------------------------------------
Source             Sum of Squares     Df   Mean Square    F-Ratio       P-Value
------------------------------------------------------------------------------
Model                   0.0266766      5   0.00533533      12.65        0.0000
Residual                0.0535774    127   0.00042187
------------------------------------------------------------------------------
Total (Corr.)           0.0802541    132

R-squared = 33.2402 percent
R-squared (adjusted for d.f.) = 30.6119 percent
Standard Error of Est. = 0.0205395
```

Table A.2: Multiple Regression Analysis of Al Concentration in ELS Lakes in Maine

```
-----------------------------------------------------------------------------
                                       Standard          T
Parameter                Estimate        Error       Statistic        P-Value
-----------------------------------------------------------------------------
CONSTANT                  2.46613      0.550022        4.48369         0.0000
Log Area                 0.328737      0.146674        4.48369         0.0267
Log Elevation            0.194021      0.0705287       2.75095         0.0068
Log Max Depth            0.353935      0.140097        2.52636         0.0128
Log Mean Depth          -0.264071      0.154287       -1.71156         0.0894
Log Volume              -0.334836      0.134999       -2.48028         0.0144
-----------------------------------------------------------------------------


                          Analysis of Variance
-----------------------------------------------------------------------------
Source              Sum of Squares     Df    Mean Square     F-Ratio      P-Value
-----------------------------------------------------------------------------
Model                     2.51958       5     0.503917        6.51         0.0000
Residual                  9.82315     127     0.0773476
-----------------------------------------------------------------------------
Total (Corr.)             12.3427     132

R-squared = 20.4135 percent
R-squared (adjusted for d.f.) = 17.2802 percent
Standard Error of Est. = 0.278114
```

Table A.3: Multiple Regression Analysis of Ca Concentration in ELS Lakes in Maine

```
-----------------------------------------------------------------------------
                                       Standard          T
Parameter               Estimate         Error       Statistic        P-Value
-----------------------------------------------------------------------------
CONSTANT                0.998278       0.438038        2.27897         0.0244
Log Area               -0.0251057      0.117937      -0.212873         0.8318
Log Elevation           0.224904       0.0486894       4.61915         0.0000
Log Max Depth          -0.287888       0.126916       -2.26834         0.0250
Log Mean Depth         -0.198703       0.115281       -1.72364         0.0872
Log Volume              0.190632       0.115686        1.64783         0.1019
-----------------------------------------------------------------------------

                           Analysis of Variance
-----------------------------------------------------------------------------
Source             Sum of Squares     Df  Mean Square    F-Ratio      P-Value
-----------------------------------------------------------------------------
Model                     1.93287      5     0.386574       8.96       0.0000
Residual                  5.43346    126     0.0431227
-----------------------------------------------------------------------------
Total (Corr.)             7.36633    131

R-squared = 26.2393 percent
R-squared (adjusted for d.f.) = 23.3122 percent
Standard Error of Est. = 0.20766
```

BIOGRAPHY OF THE AUTHOR

Petra Warlimont was born in Stuttgart Bas-Cannstadt, Germany on December 3rd, 1972. She was raised in Freigericht-Neuses, Germany, and graduated from the Wirtshaftsgymnasium Gelnhausen in 1994. She moved to Seattle, Washington in 1994 and attended the English as a Second language Program at The University of Washington. She then attended North Seattle Community College in 1995 as a pre-Veterinary student, and moved to Fort Collins, Colorado in 1997, graduating from The Colorado State University with a Bachelor of Arts in Economics in 1999.

Petra moved to Maine in September of 1999 to enter the Resource Utilization program in the Resource Economics and Policy Department at The University of Maine. Petra is currently registered Assistant Trainer to Amy Woodruff-Sarto, who is competing at advanced level in eventing. She is teaching dressage and jumping at Sweetwater Equestrian in Fort Collins, Colorado.

After receiving her degree Petra is hoping to begin her career in environmental consulting in Colorado, and keep the equestrian sport as her hobby. Petra is a candidate for the Master of Science degree in Resource Utilization from The University of Maine in May 2002.