AN ECONOMIC MODEL TO ASSESS THE IMPACT OF ACID RAIN:

A CHARACTERISTICS APPROACH TO ESTIMATING THE DEMAND FOR AND BENEFITS FROM RECREATIONAL FISHING

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I. INTRODUCTION

This paper specifies and estimates a characteristics-based utility-theoretic model of site-specific recreational fishing demand. The estimated parameters are used to calculate the conditional compensating variations (CCVs) that different individuals would associate with the changes in the availability of fish that might result from changes in the level of acid deposition. The almost universally ignored, but policy relevant, standard deviations of these consumer's surplus measures are also reported. These results indicate that the benefits recreational fish-

Advances in Applied Micro-Economics, Volume 5, pages 195–216.

ISBN: 0-89232-797-9

ermen would receive from reduced acid deposition are significantly positive but possibly quite small.

The lakes and ponds considered are all in the Adirondacks State Park, an area where the general adverse impacts of acid rain are well documented.[1] The specifics of the linkage between acid deposition and stock sizes are not well known, but Brook and Lake Trout are the species most affected and acid rain has already caused their extinction in many of the area's high-altitude lakes.

Policymakers have been grappling with ways to estimate the consumer's surplus fishermen associated with the availability of these species. One method, supposedly suggested by a former U.S. Director of the Budget, is to value them at their retail price at the grocery store. The intent of this paper is to provide and implement a superior method of valuation. The CCVs for changes in the availability of trout at a site (or sites) are found to vary extensively across fishermen as a function of their species preference, ability level, location of residence, value of time, and fishing budget. For example, the individual CCVs for a simultaneous 25% increase in the catch rates for trout at all the sites considered average $3.56, but vary from zero to $159.46 as a function of the above factors. This illustrates the danger of just reporting average or aggregate benefit measures, though attempts to do so are common in the literature (see Vaughan and Russell (1982) and Mullen and Menz (1985) for examples).

A utility function for fishing activities is derived by assuming that fishing activities are weakly separable from all other activities in the individual's preference ordering. Weak separability is assumed because data do not exist to estimate the marginal rate of substitution (MRS) between fishing and nonfishing activities, i.e., the sample of individuals does not contain data on the prices or quantities consumed of the nonfishing activities.

The characteristics of the fishing sites, and the individual's fishing ability and species preference, are explicit arguments in the utility function for fishing. The three characteristics considered are acreage, and two average catch rates that vary across individuals for a given site as a function of their ability level and species preferences. The individual maximizes fishing utility subject to his fishing budget and the parametric costs of fishing at each of the sites (including travel costs, on-site costs, and the opportunity cost of his time) to obtain a system of "partial" share equations for the fishing sites. Each share (a site's share being the proportion of fishing days that the individual will spend at the site) is a function of the costs and characteristics of all the sites. The share equations are "partial" in that they are conditional on the total budget allocation to fishing so do not measure the marginal rate of substitution between fishing and nonfishing activities. This system of partial share equations is estimated and used to obtain an estimate of the expenditure function for fishing. This fishing expenditure function is then used to estimate the CCVs that different individuals would associate with different changes in catch rates at the different sites. Each CCV is a lower bound estimate of the CV an individual would associate with an improvement in one or more of the sites.

The correct management of acid rain and many other environmental issues that impact on recreators requires that policymakers have a way of estimating the consumer's surplus that different individuals would associate with changes in the number, locations, and characteristics of the sites where they recreate. Unfortunately, the data needed to estimate the exact CVs are usually not available; most recreational data sets contain no information on the costs or the amounts of the nonrecreational activities that individuals consume.[2] However, the available data are often sufficient to estimate a utility-theoretic lower bound on each CV. This paper provides one policy-relevant example.

The model is linked to acid deposition through the catch rates for the different species at the different sites. Acid rain impacts on the stocks of the different species at the different sites, which in turn affects the catch rates. Once these biological links are modeled, our model can be used to estimate lower bounds on the CVs that each fisherman would associate with different amounts of reduction in the level of acid deposition. For a given level of improvement, a lower bound estimate of total fishing benefits can then be obtained by summing the CCVs of the individual fishermen.

II. THE MODEL

Suppose there are M potential activities, the quantity of the mth activity consumed by the ith consumer being denoted by v^i_m. Let $V^i \equiv [v^i_m]$ denote individual i's consumption vector. Assume that activities are nonjointly produced subject to constant returns to scale. Associated with each activity is a vector of L effective physical characteristics, $z^i_{.m} \equiv (z^i_{1m}, \ldots, z^i_{\ell m}, \ldots, z^i_{Lm})^T$ where L is assumed to include all the characteristics of all the activities.[3] These characteristics vary across activities for a given individual because different activities are produced from goods with different physical characteristics and they vary across individuals for a given activity as a function of the characteristics of the individuals. The complete matrix of characteristics for individual i is $Z^i \equiv [z^i_{\ell m}]$. The individual ranks bundles of activities on the basis of the quantities of the different activities in each bundle and their characteristics, not on the basis of the activities names. Assume individual i's ranking can be represented with some direct utility function, $U^i = U(V^i, Z^i)$. Since all the characteristics of the activities are explicitly included as exogenous variables, the mathematical form of $U(V^i, Z^i)$ is invariant to which activity is associated with each of the m subscripts.[4] This preference ordering can also be represented with its indirect utility function, $\chi(Y^i, P^i, Z^i)$, or its expenditure function, $E(U^i, P^i, Z^i)$, where Y^i is individual i's total income and $P^i \equiv [p^i_m]$ such that p^i_m is the parametric cost to individual i of producing one unit of activity m.

This expenditure function, $E(U^i, P^i, Z^i)$, can be used to determine the dollar amount that must be given to, or taken from, individual i to make him indifferent between two alternative cost-characteristic configurations. Assume that individual i initially faces the constraints $Y^{i\prime}$, $P^{i\prime}$, and $Z^{i\prime}$. These constraints allow the consumer to achieve some maximum utility level $U^{i\prime}$. Costs and characteristics then exogenously change to $P^{i\prime\prime}$ and $Z^{i\prime\prime}$. The compensating variation, CV^i, that individual i associates with the change is

$$CV^i = E(U^{i\prime}, P^{i\prime}, Z^{i\prime}) - E(U^{i\prime}, P^{i\prime\prime}, Z^{i\prime\prime}). \qquad (1)$$

The CV^i is the amount of money that would make individual i indifferent between facing the set of exogenous parameters $(P^{i\prime}, Z^{i\prime}, Y^{i\prime})$ and the set $(P^{i\prime\prime}, Z^{i\prime\prime}, Y^i - CV^i)$. The CV^i is positive for improvements and negative for deteriorations.

Order the M activities so that the first J activities are site-specific fishing activities, i.e., partition V^i such that

$$V^i \equiv [X^i, W^i] \qquad (2)$$

where $X^i \equiv (x^i_1, x^i_2, \ldots, x^i_J)^T$, where x^i_j is the quantity of fishing activity j consumed by individual i. Fishing activity j is produced and consumed at site j and

$W^i \equiv (w^i_1, w^i_2, \ldots, w^i_{M-J})^T$, where w^i_m is the quantity of nonfishing activity m consumed by individual i.

The price vector, P^i, can therefore be partitioned

$$P^i \equiv [C^i, D^i] \tag{3}$$

where $C^i \equiv (c^i_1, c^i_2, \ldots, c^i_J)^T$, where c^i_j is the parametric cost to individual i of producing one unit of fishing activity j, and
$D^i \equiv (d^i_1, d^i_2, \ldots, d^i_{M-J})^T$, where d^i_m is the parametric cost to individual i of producing one unit of nonfishing activity m.

Order the L characteristics so that the first K characteristics are the characteristics of the fishing activities and the last L − K characteristics are the characteristics of the nonfishing activities; i.e., partition Z^i such that

$$Z^i \equiv \begin{bmatrix} A^i & 0 \\ 0 & B^i \end{bmatrix} \tag{4}$$

where $A^i \equiv [a^i_{kj}]$, where a^i_{kj} is the amount of characteristic k that individual i associates with fishing activity j, k = 1, 2, ..., K and j = 1, 2, ..., J, and
$B^i \equiv [b^i_{\ell m}]$, where $b^i_{\ell m}$ is the amount of characteristic ℓ that individual i associates with nonfishing activity m, ℓ = 1, 2, ..., L − K and m = 1, 2, ..., M − J.

The CV^i that individual i would associate with a change in the costs and characteristics of the fishing activities from $(C^{i\prime}, A^{i\prime})$ to $(C^{i\prime\prime}, A^{i\prime\prime})$ is therefore

$$\begin{aligned} CV^i = {} & E(U^{i\prime}, C^{i\prime}, D^{i\prime}, A^{i\prime}, B^{i\prime}) \\ & - E(U^{i\prime}, C^{i\prime\prime}, D^{i\prime\prime}, A^{i\prime\prime}, B^{i\prime}). \end{aligned} \tag{5}$$

Estimation of the CV^i for a general change in the cost-characteristic configuration of the fishing activities is not possible because samples of fishermen do not contain data on the costs, D^i, and quantities, W^i, of the nonfishing activities consumed by each fisherman sampled, but this information is needed to estimate the expenditure function, $E(U, P^i, Z^i)$.[5]

One, however, can proceed by assuming that fishing activities are weakly separable from all other activities, i.e.,

$$U^i = U[U_f(X^i, A^i), W^i, B^i] \tag{6}$$

where the function $U_f^i = U_f(X^i, A^i)$, is the direct utility function for fishing activities. Individual i's system of partial demand functions for the J fishing activities can be obtained as the solution to the constrained optimization problem

$$\max_{wrt\ X^i} U_f(X^i, A^i) \qquad s.t.\ Y_f^i = C^{i^T} X^i \tag{7}$$

where Y_f^i is individuals i's total expenditures on fishing activities.

The demand equations are partial in that they are conditional on the budget allocation to fishing. Substituting this system of partial demand functions into the direct utility function for fishing, one obtains the indirect utility function for fishing activities, $X_f(Y_f^i, C^i, A^i)$, which may be inverted to obtain the expenditure function for fishing activities, $E_f^i = E_f(U_f^i, C^i, A^i)$.

The conditional CV^i, CCV^i, that individual i would associate with a change in the costs and characteristics of the fishing activities from $(C^{i\prime}, A^{i\prime})$ to $(C^{i\prime\prime}, A^{i\prime\prime})$ is therefore

$$CCV^i = E_f(U_f^{i\prime}, C^{i\prime}, A^{i\prime}) - E_f(U_f^{i\prime}, C^{i\prime\prime}, A^{i\prime\prime}) \tag{8}$$

where $U_f^{i\prime}$ is the maximum fishing utility that individual i can achieve from the fishing activities given $(C^{i\prime}, A^{i\prime}, Y_f^{i\prime})$, where $Y_f^{i\prime}$ is the utility maximizing budget allocation to fishing given $(C^{i\prime}, D^{i\prime}, A^{i\prime}, B^{i\prime}, Y^i)$. The CCV^i is the amount of money that would make individual i indifferent between facing the set of exogenous parameters $(C^{i\prime}, A^{i\prime}, Y_f^{i\prime})$ and the set $(C^{i\prime\prime}, A^{i\prime\prime}, Y_f^{i\prime} - CCV^i)$.

Hanemann and Morey (1989) have proven that $CCV^i \leq CV^i$, so if $(C^{i\prime\prime}, A^{i\prime\prime})$ is preferred to $(C^{i\prime}, A^{i\prime})$, CCV^i provides a lower bound estimate of the CV^i associated with the improvement. Morey (1981, 1985) failed to recognize this relationship in previous work. The CV^i and CCV^i are equal if the costs and characteristics of only some of the fishing activities change and if the partial demand functions for that subset of fishing activities have zero income effects. This is unlikely. Intuitively, the CCV^i provides, in absolute terms, a lower bound estimate because improvements or deteriorations in the fishing activities will most likely cause the individual to change his fishing budget. The CV^i, but not the CCV^i, incorporates this adjustment that the individual makes to the change. An individual will pay less to bring about an improvement, $(C^{i\prime}, A^{i\prime})$ to $(C^{i\prime\prime}, A^{i\prime\prime})$, if they are constrained in their ability to take advantage of that improvement. Holding the fishing budget at $Y_f^{i\prime}$ is one such constraint.

III. EMPIRICAL IMPLEMENTATION

A. Characteristics

It is assumed that each of the J site-specific fishing activities can be completely described in terms of the magnitudes of three effective physical characteristics, a^i_{1j}, a^i_{2j}, and a_{3j}. Characteristic a^i_{1j} is the average catch rate at site j for individual i's most preferred species for everyone of individual i's fishing ability (novice, intermediate, or advanced). The characteristic a^i_{1j} is a function of site j's stock size for each species, and individual i's most preferred species and ability level. It varies across sites for a given individual because stock sizes vary across the sites, and it vary across individuals for a given site because species preference and ability vary across individuals. Characteristics a^i_{2j} is the average catch rate at site j for individual i's second most preferred species for everyone of individual i's ability level. Characteristic a_{3j} is the total amount of fishable acreage at site j. Total acreage, a_{3j}, captures some elements of the fishing experience that the catch rates may not, such as scenery and open space. Anglers may enjoy aspects of the fishing experience other than the act of catching a fish. Previous literature shows that the demand for fishing sites can be explained fairly well with these few principal characteristics (see Mullen and Menz (1985) or Vaughan and Russell (1982)).

B. The Utility Function for the J Site-Specific Fishing Activities

The CES functional form is used to approximate the direct utility function for the fishing activities, $U_f(X^i, A^i)$. This choice is motivated by the fact that it is well-known, relatively simple, and easily allows for the incorporation of characteristics.[6]

$$U_f(X^i, A^i) = \sum_{j=1}^{J} (x_j^i)^{\beta}\, h(a^i_{1j}, a^i_{2j}, a_{3j}) \qquad (9)$$

where

$$h(a^i_{1j}, a^i_{2j}, a_{3j}) = [\alpha_0 + \alpha_1 a^i_{1j} + \alpha_2(a^i_{1j})^{1/2} + \alpha_3(a^i_{1j}a^i_{2j})^{1/2} + \alpha_4 a^i_{2j} + \alpha_5(a^i_{2j})^{1/2} + \alpha_6(a^i_{2j}a_{3j})^{1/2} + \alpha_7 a_{3j} + \alpha_8(a_{3j})^{1/2} + \alpha_9(a^i_{1j}a_{3j})^{1/2}]^2. \quad (10)$$

The CES form constrains all the Hicks–Allen elasticities of substitution to equal $1/(1 - \beta)$. The function $h(a^i_{1j}, a^i_{2j}, a_{3j})$ can be viewed as a second-order approximation to any nonnegative function of the three characteristics. The CES function is a well-behaved direct utility function if $1 > \beta \neq 0$.

Assuming a CES utility function for fishing activities, the solutions to maximization problem (7) can best be derived in share form

$$s^{i*}_j = \frac{x^{i*}_j}{x^*} = [h(\tfrac{i}{j})/c^i_j]^\sigma / \sum_{m=1}^{J} [h(\tfrac{i}{m})/c^i_m]^\sigma \quad j = 1, 2, \cdots, J \quad (11)$$

where

$$x^* = \sum_j x^{i*}_j, \sigma = 1/(1 - \beta), \text{and } h(\tfrac{i}{j}) = h(a^i_{1j}, a^i_{2j}, a_{3j}).$$

Site j's share, s^{i*}_j, is the proportion of fishing days that we expect individual i desires to spend at site j. Note that all the share equations are identical. The only thing that varies from one site's shares equation to another is the value of the exogenous variables (c^i_j, a^i_{1j}, a^i_{2j}, a_{3j}). Demand equations are ordinarily allowed to differ between goods, in this case between site-specific fishing activities. However, when all the characteristics that explain variations in demand are included in the analysis, there is no reason to have different demand equations for different goods.[7]

The characteristics approach that we propose is attractive for a number of reasons. First, there is only one equation to estimate, yet the model is compatible with a system-wide approach and with an underlying preference ordering for fishing activities. The number of parameters that must be estimated depends only on the number of characteristics. Hence, our approach is particularly useful if the number of activities exceeds the number of characteristics as it does in the Adirondacks where there are hundreds of lakes from which to choose.

A second advantage is that it is possible to estimate how the demand for the different sites will change as the costs and characteristics of the fishing activities change. For example, the estimated model can be used to predict how the conditional demand (conditional on the initial budget allocation to fishing) for the different sites will change if a decrease in acid deposition increases the catch rates for trout at some of the high-altitude lakes.

Third, it should be emphasized that when estimating Eq. (11), it is not necessary to include data on every one of the J site-specific fishing activities. Estimation of all the unknown parameters can be done with data from a subset of the J sites.[8] This follows from the assumption of weak separability in the fishing utility function, i.e., the MRS between site 1 and site 2 does not depend upon attributes of any $J + 1^{th}$ site. This is very important when there are hundreds of sites. The parameter estimates can nevertheless be used to estimate an individual's share for a site, including those omitted from the sample, as a function of its cost and characteristics.

Finally, the approach allows us to estimate the CCV^i for any change in the costs or characteristics of the fishing sites. The incorporation of characteristics that depend on the stock sizes of the different species at the different lakes provides the link to acid rain and makes the model capable of estimating, through its effect on the catch rates, the CCV^is that different individuals would associate with a change in the level of acid deposition. An expenditure function for fishing that is dual to our CES direct utility function for fishing is

$$E_f(U_f^i, C^i, A^i) = -e(C^i, A^i)/U_f^i \tag{12}$$

where

$$e(C^i, A^i) = [\sum_{j=1}^{J} h(\frac{i}{j})^{-1/(\beta-1)} c_j^{i\,\beta/(\beta-1)}]^{(\beta-1)/\beta}. \tag{13}$$

The CCV^i that individual i would associate with a change in the costs and characteristics of the fishing activities from $(C^{i\prime}, A^{i\prime})$ to $(C^{i\prime\prime}, A^{i\prime\prime})$ is, by substitution of Eq. (12) into Eq. (8),

$$CCV^i = [e(C^{i\prime\prime}, A^{i\prime\prime}) - e(C^{i\prime}, A^{i\prime})]/U_f^{i\prime}. \tag{14}$$

The estimated CCV^is are easily calculated using the data and the estimated parameters of the share equation.[9]

C. Stochastic Specification

We assume that utility is deterministic from the individual's perspective but random from our perspective because we do not observe everything that the individual observes. We further assume that $U_f(x^i, A^i)$ represents the expected value of individual i's utility. Therefore, from our perspective, the observed share for individual i at site j is a random variable with the expected value s_j^{i*}. Rather than explicitly introduce the distributional properties of the random component at the level of the utility function, it is easier to append a random term to the expected shares. This is due to the fact that many of the distributional properties of the observed shares are well known. For each observation, the J stochastic shares must sum to one and each must be in the zero–one range. One would also expect the distribution of the shares to be skewed, especially for shares with expected values near zero or one.

It is therefore assumed that individual i's density function for the observed shares; s_j^i, j = 1, 2, . . . , J, is

$$f(s_1^i, s_2^i, \ldots, s_J^i; x^i; \theta) = \left(x^i! \Big/ \prod_{j=1}^{J} x_j^i!\right)\left(\prod_{j=1}^{J} (s_j^{i*})^{(x_j^i)}\right) \quad (15)$$

where $\theta \equiv (\beta, \alpha_1, \alpha_2, \ldots, \alpha_9)$ is the parameter vector and x^i is the total number of fishing trips that individual i took during the year. This density function has the mathematical form of the multinomial distribution; however, it is not assumed that s_j^{i*} is the probability that individual i will choose site j on a given trip, and it is not assumed that the site choice for each trip is independent. This qualified multinomial was chosen as the appropriate density function because it is simple and because it maintains the inherent properties of the shares. The standard normality assumption is inappropriate because many of the observed shares in the sample are zero.[10]

If it is assumed that the choice of sites by one individual is independent of any other individual's choice of sites, the likelihood function for a sample of N individuals is

$$L = \prod_{i=1}^{N} f(s_1^i, s_2^i, \ldots, s_J^i; x^i; \theta). \quad (16)$$

The maximum likelihood parameter estimates for a particular sample is the $\hat{\theta}$ which globally maximizes the likelihood function (16).

D. Data

Estimation of the share equation, (11), requires a cross-sectional survey of fishermen which details where each individual fished during an entire season and the costs they incurred to visit each of the sites. Data on the surface acres and catch rates (by species and ability level) at each site are also required.

Data on New York anglers have been collected by the New York State Department of Environmental Conservation (1977). For most of the individuals sampled, there is a complete record of where they fished during the 1976/77 season, the number of fish of each species they caught on each trip, their species preferences, their site expenditures, their years of fishing experience, their income, and the location of their residence.

These individuals visited many sites in the Adirondacks State Park but to ease the problem of estimation we restricted the analysis to seven fishing sites. Remember that the parameters can be estimated using data on only a subset of the J sites. The sites chosen were popular with many of the fishermen and exhibit a lot of cross-sectional variation in the costs and characteristics. The sites vary in terms of location, size and species caught. The seven sites are listed in Table 1. Lake Placid and Lake Saratoga are single lakes but each of the other sites is an aggregate of a number of adjacent lakes. Lakes were aggregated into a single site if the lakes were located in a small cluster such that they could all be easily fished in a single day and if they were all at approximately the same altitude. Lakes were aggregated so as to increase the number of visits to each site.

Fishermen with incomplete records and fishermen whose distance to the farthest site was greater than 200 miles were eliminated from the sample.[11] This left 607 fishermen. Our results therefore apply only to fishermen who are capable of making day trips to any of the sites. Sixty-three of the 607 anglers are classified as beginners (those with 0–10 years of fishing experience), 152 are classified as intermediates (11–20 years of experience), and the remaining 392 are classified as advanced anglers.

The acreage data are reported in Table 1 and are from the Gazetteer

Table 1. Average Daily Catch Rate (Number of Fish Caught per Day)

Site	Panfish	Walleye	Pike	Smelt	Trout 1[a]	Bass	Trout 2	Salmon	Total acreage
A. Beginner[b] catch rates for the eight species									
Saranac[c]	1.482	.0	.029	.0	.224	.093	.10	.405	9,856
Raquette	.864	.0	.0	.0	.004	.175	.053	.0	11,214
Lake George and Brandt Lake	1.353	.0	.028	.555	.040	.205	.016	.0	29,517
Lake Placid	.027	.500	.0	1.111	.427	.0	.026	.0	2,803
Piseco	.363	.0	.0	.0	.093	.128	.0	.0	4,909
Great Sacandaga	2.972	.087	.137	.0	.0	.534	.0	.0	4,096
Lake Saratoga	.52	.261	.050	.002	.0	.258	.192	.0	26,656
B. Intermediate catch rates									
Saranac	1.134	.0	.160	.0	.060	.097	.42	.529	
Raquette	.950	.0	.009	3.93	.310	.35	.35	.0	
Lake George and Brandt Lake	1.367	.0	.186	.174	.031	.565	.052	.011	
Lake Placid	.086	8.960	.088	.0	.835	.817	.087	.0	
Piseco	1.380	.094	.481	.0	.037	.502	.386	.0	
Great Sacandaga	2.306	.145	.399	.0	.051	.619	.0	.0	
Lake Saratoga	.498	.234	.324	.0	.015	.292	.0	.0	
C. Advanced catch rates									
Saranac	2.141	.0	.315	.017	.304	.19	.394	.153	
Raquette	1.012	.0	.014	2.323	.154	.49	.742	.001	
Lake George and Brandt Lake	4.200	.001	.764	.704	.074	.524	.183	.012	
Lake Placid	.006	.0	.0	.0	1.534	.439	.624	.0	
Piseco	.920	.136	.344	.0	.309	.226	.413	.0	
Great Sacandaga	3.166	.157	.282	.0	.0	.696	.0	.0	
Lake Saratoga	.813	.596	.144	.0	.058	.447	.011	.0	

[a]Trout 1 consists of Rainbow and Brown Trout. Trout 2 consists of Lake, Brook Trout, Splake, and Whitefish. Trout 2 is the species most impacted by acid rain.
[b]A beginner has 0–10 years of fishing experience. An intermediate has 11–20 years experience. An advanced has over 20 years experience.
[c]Saranac consists of Colby Lake, St. Regis Lake, and all of the Saranac Lakes. Raquette consists of Blue Mt. Lake, Raquette Lake, Indian Lake, and the Eighth Lake in the Fulton Chain. Piseco consists of Sacadandage Lake, Piseco Lake, and Lake Pleasant. Great Sacandaga consists of Great Sacandaga Lake, Ballston Lake, and Round Lake.

of Lakes, Ponds and Reservoirs prepared by the New York State Department of Environmental Conservation and the U.S. Department of the Interior (1970). The average catch rates for eight species groups and the three ability levels were calculated for each site using the catch data of the over 2000 individuals in the overall sample that visited at least one of the seven sites. These average catch rates are reported in Table 1 and can be interpreted as the expected catch rates for someone of that ability level. Ability level causes catch rates to vary because of ability per sec but also because more experienced fishermen often target harder to catch species and because they often "handicap" themselves with difficult to use equipments such as fly rods.

We assume that individual i's expected cost of producing one unit of site-specific fishing activity j is

$$c_j^i = \delta_{ij}\begin{pmatrix}\text{per mile}\\ \text{transportation}\\ \text{costs}\end{pmatrix} + \begin{pmatrix}\text{opportunity}\\ \text{value of}\\ \text{time}\end{pmatrix}\begin{bmatrix}\text{travel} \\ \text{time}\end{bmatrix} + \begin{bmatrix}\text{on-site}\\ \text{time}\end{bmatrix} + \begin{bmatrix}\text{on-site}\\ \text{expenditures}\end{bmatrix} \tag{17}$$

where δ_{ij} is twice the distance from individual i's residence to site j. Transportation costs in 1977 were \$.15 per mile (Department of Transportation, 1977). Travel time is calculated assuming an average speed of 40 mph. On-site expenditures were assumed to be \$7.29; the per trip average over all 607 fishermen. The average expenditure is used because prices must be exogenous and we estimate demand for the "representative" fisherman. On-site time is assumed to be 4 hours because no data are available. The opportunity value of each fisherman's time is assumed to be their yearly income divided by the number of hours an average individual is expected to work. Hourly wage data were not available.

IV. ESTIMATION

Given the sample of 607 fishermen, maximum likelihood estimates of the parameter vector, θ, were obtained by finding those values of θ which maximize

$$\ell^* = \sum_{i=1}^{607}\sum_{j=1}^{7} x_j^i \log(s_j^{i*}) \tag{18}$$

where x_j^i is the actual number of trips that individual took to site j and s_j^{i*} is individual i's predicted share for site j. The shares equations are homogeneous of degree zero with respect to the α parameters so α_0 was set equal to one without loss of generality. The log of the likelihood function was maximized using a quasi-Newton search algorithm developed by Schnabel and Dennis (1985).

The parameter estimates for three models are reported in Table 2. The regularity condition, $1 > \beta \neq 0$ is satisfied in each case. Model 1 assumes that the individual randomly allocates his time among the seven sites. It involves no estimation and assumes that $\sigma = \alpha_1 = \alpha_2 = \ldots = \alpha_9 = 0$. Model 2 allows the costs, but not the characteristics ($\alpha_1 = \alpha_2 = \ldots = \alpha_9 = 0$), to explain the allocation of fishing days. Model 3 is the full model and allows both costs and characteristics to explain each individual's allocation of fishing days. The asymptotic t values for model 3 are shown in parentheses. Likelihood ratio tests show that Model 2 explains the allocation significantly better than Model 1 and that Model 3 explains the allocation significantly better than Model 2. We can therefore reject the null hypothesis that costs and characteristics are not important determinants of where the individual will fish. The psuedo R^2 proposed by Baxter and Cragg (1970) is 0.728 for Model 3 indicating that the Model 3 is explaining a significant proportion of each fisherman's behavior. This is also indicated by examining the actual and the predicted aggregate shares (not reported here) for the seven sites.[12] The parameter estimates from Model 3 are used to estimate the elasticity and consumer surplus measures reported in the rest of the paper.

The expected conditional share elasticities with respect to both costs and characteristics, along with their standard deviations, were calculated for each individual in the sample. These elasticities are conditional in that they do not consider substitution in and out of fishing.[13] These own share elasticities with respect to cost are all significantly negative, varying from −1.75 to −4.47.[14] These cost elasticities vary across individuals for a given site as a function of species preference, ability level, and cost, and vary across sites for a given individual as a function of relative travel costs and the availability of each species at each site. The vast majority of the expected share elasticities with respect to characteristics one and two, a_{1j}^i; and a_{2j}^i, are significantly positive, indicating that, for most fishermen at most sites, a site's share increases as the site's catch rates for the individual's preferred species increase. Most, but not all, of the negative elasticities with respect to the catch rates are significantly negative. This indicates that, at least

Table 2. Maximum Likelihood Estimates for Three Models

Model	ℓ^*	σ	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9
1	−17,009.2										
2	−13,322.8	3.59	—								
3	−11,550.0	4.24	−.200	.386	.0231	−.0652	.2149	.0003	.5E−05	−.3E−09	.0006
		(74.9)[a]	(17.6)	(23.1)	(1.91)	(8.64)	(12.2)	(25.8)	(4,341.0)	(6.8)	(3.6)

[a] Values in parentheses are asymptotic t statistics calculated for Model 3.

for some fishermen, increasing their catch rates for their preferred species at particular sites can make them worse off. A characteristic that is normally an attribute at one site can be bad at another site because of the way it interacts with the site's other characteristics. Like the cost elasticities, the catch rate elasticities vary extensively across sites and individuals. The expected share elasticities with respect to acreage, a_{3j}, are all significantly positive, varying from 0.06 to 1.20.

V. EXPECTED CONSUMER'S SURPLUS

Equation (14) and the estimated parameters, along with individual i's fishing expenditures and initial vectors of fishing costs and characteristics ($C^{i\prime}$, $A^{i\prime}$), can be used to estimate the expected CCV that individual i would associate with any change from ($C^{i\prime}$, $A^{i\prime}$) to ($C^{i\prime\prime}$, $A^{i\prime\prime}$).[15] Our intent is to use these CCV^i measures to assess the impact of acid deposition on recreational fishermen. We have no a priori reason to suspect that the CCV are significantly different than zero. The species most harmed by acid deposition in the Adirondacks are the Brook and Lake Trout (Trout 2), which live in the cold, high-altitude lakes.[16]

Acid rain is a major issue and numerous policies are being considered that could decrease the level of acid deposition in many of the Adirondacks high-altitude lakes. While the exact impact of acid deposition on stock sizes and catch rates is outside the domain of this study, it is clear that different policies have the potential to increase the catch rates for Trout 2 by different amounts at many sites in the Adirondacks.

We concentrate on Brook and Lake Trout (Trout 2) at sites near or above 1500 feet. Four of our seven sites (Saranac, Raquette, Lake Placid, and Piseco) are in this category. Examination of Table 1 shows that most of the trout are caught at these sites. Three policy scenarios are considered, policies that increase the catch rates for Trout 2 at these four sites by 5%, 25%, and 50%. Table 3 contains the expected CCV^is that 10 representative fishermen would associate with these three policies. The asymptotic standard deviations are in parentheses. This is the first empirical demand study that we are aware of that calculates the estimated standard deviations on the estimated consumer's surplus measures when the prices (and characteristics) of more than one activity are simultaneously changing.

The average CCV^is, along with their ranges and aggregate values, are also reported for each of the three scenarios. The CCV^is reported

Table 3. Selected Individual Annual Expected CCV^{i}s for an Increase in the Catch Rates for Brook and Lake Trout (Trout 2) by 5%, 25%, and 50% at Saranac, Raquette, Lake Placid, and Piseco[a]

Origin	*Ability*	*Fishing budget*	*Most preferred species*	*Second most preferred species*	*Increase 5% CCV^i*	*Increase 25% CCV^i*	*Increase 50% CCV^i*
Albany	(A)	$212.76	Trout 2	North. Pike	$0.29	$1.29	$2.21
					(0.06)	(0.26)	(0.49)
	(B)	507.70	Trout 2	Yellow Perch	0.25	1.20	2.30
					(0.04)	(0.27)	(0.34)
	(I)	244.44	Trout 2	Trout 2	0.46	2.16	4.06
					(0.07)	(0.35)	(0.66)
Plattsburg	(I)	179.88	Trout 2	Trout 2	0.89	4.04	7.23
					(0.13)	(0.59)	(1.06)
	(A)	117.90	Trout 2	North. Pike	0.45	1.95	3.37
					(0.07)	(0.30)	(0.56)
	(A)	36.69	Trout 2	Panfish	0.17	0.75	1.30
					(0.03)	(0.11)	(0.21)
Utica	(I)	419.50	Trout 2	Trout 2	2.03	9.12	16.16
					(0.34)	(1.53)	(2.75)
	(I)	422.94	N. Pike	Trout 2	1.17	5.51	10.27
					(0.16)	(0.73)	(1.36)
	(A)	38.07	Bass	Trout 2	0.08	0.37	0.68
					(0.01)	(0.05)	(0.09)
Oneonta	(A)	632.90	Trout 2	Bass	1.59	6.90	11.59
					(0.30)	(1.39)	(2.52)
Range across all individuals with positive CCV^{i}s					$0.01–$35.60	$0.02–$159.46	$0.04–$280.93
Mean across all individuals with positive CCV^{i}s					$1.91	$8.68	$15.51
					(0.05)	(0.21)	(0.36)
The aggregate CCV for the 607 individuals					$475.87	$2162.04	$3862.94
					(11.22)	(51.47)	(89.23)

[a] The asymptotic standard deviations are in parentheses. The CCV^{i}s are zero for all those individuals who did not specify Trout 2 as either their most or second most preferred species. There are 358 (59% of the sample) individuals in this category.

are quite representative, even though they do not represent the entire range of the estimates. For example, the CCV^is for a 5% improvement range from zero to \$35.60 but 77% of the positive CCV^i are less than \$2.00. The CCV^is at the high end are definite outliers.

The first thing to note is that $CCV^i = CV^i = 0$ if Trout 2 is neither individual i's most or second most preferred species. Acid deposition therefore affects only 41% of the fishermen in our sample. The homotheticity of the CES preference ordering implies that the expected CCV^i that a given type of individual (all those with the same ability, species preference, origin zone, and value of time) associates with a specific change is a constant proportion of their fishing budget. For example, for the 25% increase in the Trout 2 catch rates it is 0.006 for all fishermen who have the same characteristics as the first individual reported in Table 3.

The expected CCV^i are all significantly positive (some in theory could be negative) and vary extensively across individuals as a function of their ability, species preference, origin zone, and value of time. The estimates, however, are in general quite small in magnitude. The estimated standard deviations indicate the degree of error that can be attributed to the different CCV^i estimates. For example, for the 25% increase and the first individual in Table 3, Prob (\$0.78 $\leq CCV^i \leq$ \$1.79) = 95%. Without the estimated standard deviations, it would be easy to forget that these CCV^is are stochastic variables. On the basis of the expected CCV^is and their estimated standard deviations, one can reject the null hypothesis that $CV^i \leq 0$ for each individual who specified Trout 2 as a preferred species.

Assuming independence and summing across the 607 individuals in the sample, the aggregate expected CCV for the 50% scenario is \$3,862.92 with an estimated standard deviation of \$89.23. One should bear in mind that his aggregate is the sum of many different CCVs. The aggregate CCV can be interpreted as a lower bound estimate of the total amount of money that would have to be paid by the 607 fishermen to make them each indifferent between the payout with the 50% increase in the Trout 2 catch rates and the original situation. If, for example, there were 10,000 fishermen in the population from which our sample was randomly drawn, the aggregate expected CCV for the population would be \$63,639.54 with an estimated standard deviation of \$1,470.02. Adopting conventional benefit–cost analysis, one would, for example, be at least 95% certain that it is worthwhile to clean up the lakes by an amount that would induce a 50% increase in the Trout 2 catch rates if the total cost of that cleanup is less than

\$61,213.98. We would be at least 50% certain if the total cleanup cost is less than \$63,639.54. While not telling us everything we would like to know, this is valuable information given that our sample did not contain the information that is required to estimate the marginal rate of substitution between fishing and nonfishing activities. Since the CCV is all that may be calculated when analyzing the impact of a wide spread reduction in acid rain, lower bound measures are what must be used for policy decisions. Our results also point out the importance of how aggregate benefits are distributed.

VI. CONCLUSIONS

This paper has presented lower bound estimates of a benefit measure for individuals that fish at a small group of sites in the Adirondacks. Our measure incorporates use values for the sites only. No attempt was made to estimate option or existence values in this paper. The first implication for policies that might affect acid rain levels is that we present identifiable, statistically significant, positive benefit measures for reductions in acid rain. This, in itself, is significant because there was no a priori reason to suspect that the expected CCVs would be significantly different from zero.

The second implication of this paper for policy is that the CCVs vary greatly across individuals with different recreational abilities. Policy managers may want to take this point into consideration by "targeting" specific sites for cleanup according to the expected willingness to pay of those individuals who frequent the site. The technique used in this paper is ideal for identifying willingness to pay as a function of the individual's characteristics.

The magnitude of the aggregate benefit measure presented here is small, and reflects the fact that only those fishermen who target trout have a positive willingness to pay for trout, the species most likely to be affected by acid rain. Should more results from other studies become available, it will be interesting to see how they compare to the results from our model of constrained individual utility maximization.

ACKNOWLEDGMENTS

This paper stems from the second author's Ph.D dissertation. An earlier version of the paper was presented at the First National Symposium on Social

Science in Resource Management, Corvalis, Oregon. We would like to thank Peter Caulkins, Phil Graves, Chuck Howe, Gary Johnson, Kerry Smith, and Don Waldman for their helpful suggestions and insights, and would like to thank RCG/Hagler Bailly of Boulder, Colorado for providing the raw data.

NOTES

1. For more details on the impact of acid deposition on fish stocks in the Adirondacks and in general, see Cowling (1982), Dahl (1921), Henriksen (1980), Hultberg and Stenson (1970), and LaBastille (1981).

2. Hausman's (1981) methodology can be modified to show that even with such limited data the exact CV may be calculated if one assumes that the quality level changes at only one site, with quality and prices remaining constant for all other commodities (fishing and nonfishing). However, acid rain does not impact on only one site so the Hausman technique cannot, in general, be applied to our problem. Hausman's method could possibly be used to calculate the CV associated with the chemical treatment of a single site. More is known about the chemical treatment of a single site than the general impact of acid rain (see Dutkowsky and Menz (1985).

3. Note that T denotes transpose.

4. For more details see Morey (1985).

5. To our knowledge, no sample of recreators contains data on their nonrecreational activities.

6. The CES with characteristics, Eq. (9), was first specified and estimated by Morey (1981).

7. The assumption that all the characteristics are included in the model is not tested. Its plausibility obviously depends on the analyst's ability to identify and measure the important characteristics. For an application of this characteristics approach to skiing, see Morey (1981, 1984, 1985). For applications to the estimation of import demand functions, see Kohli and Morey (1988 and 1990).

8. Naturally, statistical efficiency increases with the number of sites included.

9. Morey (1985) estimated the CCV^i for the introduction of a new ski area but did not recognize the important distinction between the CCV^i and the CV^i. Morey (1985, p. 228) incorrectly states that "the magnitude of the (estimated) compensating variation does not depend on the fact that skiing activities were assumed weakly separable from all other activities."

10. For more details on this qualified multinomial specification as compared to a normality specification see Morey (1984). Woodland (1979), Wales and Woodland (1983), and Morey (1984) indicate that the distribution of a system of share equations can be approximated with a joint normal distribution if, for each observation, none of the observed shares is near zero, but if many of the observed shares are zero, the normality assumption will lead to nonsensical results. Kohli and Morey (1988 and 1990) estimated import share equations assuming normality but their two samples contained no observed shares of, or near, zero.

11. Observations were not used when data on income were missing. Using only complete observations introduces the possibility of sample selectivity bias. We do not feel that sample selectivity bias is an important issue in this case because we have no reason to expect a systematic correlation between the nonreporting of income and the

site-selection process. See Smith and Kopp (1980) for a discussion of a distance limit for feasible 1 day trips.

12. For example, the correlation coefficient between the predicted share and actual share for average anglers from the cities of Albany, Utica, Saranac, and Blue Mountain Lake is 0.827.

13. Like the CV, the full elasticities cannot be estimated if the data set does not include the prices, characteristics, and consumption levels of the nonfishing activities.

14. The asymptotic variances of the elasticity estimates and the variances of the CCV^i estimates are obtained by noting that for any function $q = q(\Gamma)$, where $\Gamma \equiv [\delta_i]$ is a vector of random variables, the variance of 9 is

$$[\partial q/\partial \delta_1, \partial q/\delta_2, \ldots, \partial q/\partial \delta_N] \ \Omega \begin{bmatrix} \partial q/\partial \delta_1 \\ \partial q/\partial \delta_2 \\ \vdots \\ \partial q/\partial \delta_N \end{bmatrix}$$

where Ω is the variance–covariance matrix of Γ. For details see Theil (1971).

15. Bockstael and Strand (1987) point out that the source of the randomness can affect the size of consumer surplus estimates. However, their discussion relates to an expected Marshallian measure, which is a function of endogenous variables. Our (expected CCV) measure depends only on exogenous variables so the issue that Bockstael and Strand raise is not relevant here. [Note that the equation for the expected CCV can be replaced with an equation that substitutes the indirect utility function for U_f, so our expected CCV depends only upon prices, income, and characteristic levels.]

16. For more details see Schofield (1976).

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where fl is the variance-covariance matrix of I'. For details see Theil (1971).

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