Theoretical and Empirical Specifications Issues in Travel Cost Demand Studies

Mary Jo Kealy and Richard C. Bishop

A travel cost demand model is derived from a utility function which postulates that individuals choose the optimal total number of site recreation days given by the product of the number and length of their recreation trips. By relaxing the assumption that on-site time is constant across recreationists, the applicability of the travel cost method is extended. The model is estimated using a maximum likelihood procedure appropriate for the truncated sample data which is characteristic of most user-specific recreation data. Failure to do so would result in overestimating the value of Great Lakes fishing by 3.5 times.

Key words: limited dependent variable, on-site time, travel cost demand.

The ultimate objective of empirical travel cost demand studies is to obtain an estimate of the welfare derived from utilizing outdoor recreational resources. Thus it is apparent that travel cost demand equations must be linked to utility maximization (Deyak and Smith; Freeman; Bockstael and McConnell; Hanemann; Bockstael, Hanemann, and Strand). We specify a model of utility-maximizing recreation demand behavior which postulates that individuals choose the total number of days that they wish to spend at the recreation site. This total number of recreation days is the product of the number of trips to the site and the average number of days per trip. It is assumed that the recreationist first determines the optimal length of time to recreate at a particular site and, second, decides upon the number of trips of that optimal length to take.[1] The length-of-stay decision is predetermined in our model, and yet different consumers are nonetheless permitted to take their recreation days in trip packages which most ideally suit their needs. The traditional travel cost model, on the other hand, is only applicable for cases where it is reasonable to assume that all visits to the site by all consumers are of the same duration. While many have recognized this as a severe limitation, until now this specification issue had defied resolution (McConnell; Cesario; Wilman; Smith, Desvousges, and McGivney; Johnson; Ward; Bockstael, Hanemann, and Strand).

An additional distinguishing feature of this work is that it utilizes a maximum likelihood (ML) estimation procedure for truncated samples to estimate the parameters of the demand equation. While recreation demand behavior is only defined for non-negative values, ordinary regression methods require that dependent variables take on values over the full real line. Thus, the estimation of site visitation behavior using ordinary regression procedures leads to biased coefficient estimates (Judge et al.; Bockstael, Hanemann, and Strand; Mad-

Mary Jo Kealy is an assistant professor of economics at Colgate University; Richard C. Bishop is a professor of agricultural economics at the University of Wisconsin.

This research was supported by Colgate University, the College of Agriculture and Life Sciences of the University of Wisconsin, and the University of Wisconsin Sea Grant Institute under grants from the National Sea Grant College Program, the National Oceanographic and Atmospheric Institute, and the U.S. Department of Commerce from the State of Wisconsin Federal Grant NA84AA-D-00065, Project R/PS32.

The authors are grateful for the comments of the anonymous reviewers and the editor. Interchanges with Nancy E. Bockstael, Thomas A. Heberlein, Kenneth E. McConnell, Mark Montgomery, Irene Powell, V. Kerry Smith, and Robert W. Turner also were appreciated. Special thanks are owed to Karl C. Samples and the Wisconsin Department of Natural Resources for the survey data. Finally, the authors are indebted to Mark L. Rockel for his substantive contributions to numerous drafts of the manuscript. All remaining errors are due to the authors.

Review was coordinated by Alan Randall, associate editor.

[1] This assumption implies that the optimal duration of a visit to a recreation site is independent of the total number of trips. It is our view that this assumption is reasonable for many forms of outdoor recreation activities including recreational fishing, the activity we analyze here. However, should this assumption be violated, the estimation of our empirical model would result in simultaneous equations bias.

dala; Smith and Desvousges). The fact that almost all recreation data is characterized by limited dependent variables raises serious questions concerning the validity of all past empirical work that failed to account for the truncated nature of the data used in the analyses. Indeed, we compare welfare measures calculated using parameter estimates from ML and ordinary least squares (OLS) procedures, and find that the difference between the estimates is quite large for our sample of Lake Michigan anglers.

Organization of the Paper

The next section describes the general form of a utility function which is linear in income and the value of time. Then, a quadratic form for the average individual's utility function is postulated. From the theoretical model, the linear demand equation for the number of recreation days is derived and estimated for a sample of Lake Michigan anglers. To avoid biases from omitted variables, care is taken to control for the tastes and preferences of the anglers (Bishop and Heberlein; Allen, Stevens, and Barrett). In addition, the empirical model controls for the multiple destination trips, which can also cause a bias (Clawson and Knetsch, Haspel and Johnson). Substitute activities are not included because it is assumed that the commodity being valued has no close substitutes. The data are described in the fifth section, and then willingness-to-pay measures are reported. Finally, the conclusions of the paper are summarized.

The Theoretical Model

Travel cost recreation demand equations can be derived from utility functions which are linear in income and time. The underlying assumption is that utility is additively separable in the recreation activity, all other income, and all other leisure time. The linearity assumption, a maintained hypothesis for many empirical demand studies, is reasonable for goods which require only a small proportion of the individual's income and time for consumption.

The general form for the linear-in-income utility function can be found in Samuelson and Blackorby et al. We extend the model to include time. This problem is formalized as follows:

$$(1)\quad \max_{Z} U = U(Z; s) + P_y Y + \gamma(\cdot)\tau$$

$$\text{s.t. } Z\left(\frac{P_n}{D} + P_S - \frac{P_s}{D} + P_c\right) + P_y Y = I$$

$$Z(d/D + h) + \tau = T.$$

Substituting the constraints into the objective function simplifies the expression to

$$(2)\quad \max_{Z} U = U(Z; s) + I - Z\left(\frac{P_n}{D} + P_S - \frac{P_s}{D} + P_c\right) + \gamma(\cdot)[T - Z(d/D + h)],$$

where

Z is the total number of recreation days devoted to the site;

s, vector of individual characteristics;

Y, a composite good or income spent on all other goods;

$\gamma(\cdot)$, the function which converts the individual's time into money and as such is the dollar equivalent of a unit of time;

τ, residual time, or time not spent working, traveling to, or recreating at the site;

D, the average number of days per recreation trip, taking D as exogenous;

P_n, the monetary cost associated with traveling to and from the recreation site;

P_c, daily variable on-site costs;

P_s, daily overnight expenditures (It is assumed that the number of nights per trip is equal to the number of days per trip, D, minus 1.);

P_y, price of the composite good Y (All prices are normalized with respect to Py which is set equal to one.);

I, income;

d, round-trip traveling time to the site, measured in hours;

h, the number of hours in a typical recreation day (a constant set equal to eight hours); and

T, total discretionary time.

The Demand for Recreation Days

In order to derive the equation for recreation days, the functional form of (2) must be specified. Although we understand that our choice of functional form is somewhat arbitrary, it is nonetheless true that theory offers little guidance in this area. We postulate a quadratic form for the individual's utility function. Subsequently, (2) can be rewritten as follows:

$$(3)\quad \underset{Z}{\text{Max}}\ U = A0Z + \frac{A1}{2}Z^2 + I - Z\left(\frac{P_n}{D} + P_s - \frac{P_s}{D} + P_c\right) + \gamma(\cdot)[T - Z(d/D + h)],$$

where A0 and A1 are parameters of the utility function.

To incorporate the individual's characteristics into the utility specification, we follow the convention of expressing one of the parameters, $A0$, as a function of the individual's characteristics, s (Pollak and Wales). Specifically, we let $A0$ be a linear function so that equation (3) now takes the form:

$$(4)\quad \underset{Z}{\text{Max}}\ U = \left(a_o + \sum_{k=1}^{K} a_k s_k\right)Z + \frac{A1}{2}Z^2 + I - Z\left(\frac{P_n}{D} + P_s - \frac{P_s}{D} + P_c\right) + \gamma(\cdot)[T - Z(d/D + h)] + \epsilon Z,$$

where the error term, ϵ, is normally distributed with mean zero and variance σ_ϵ^2. Solving the maximization problem for the optimal level of Z gives the demand equation for Z equal to

$$(5)\quad \frac{-1}{A1}\left(a_o + \sum_{k=1}^{K} a_k s_k\right) + \frac{1}{A1}\left(\frac{P_n}{D} + P_s - \frac{P_s}{D} + P_c\right) + \frac{\gamma(\cdot)}{A1}(d/D + h) + \omega.$$

The error term ω is normally distributed with mean zero and variance σ_ω^2.

Prior to obtaining estimates of the parameters in equation (5), it is necessary to specify the functional form of $\gamma(\cdot)$. For this we refer back to the utility function, (2). It is obvious that the linear-in-income utility function implies that the marginal utility of income is a constant equal to one. Furthermore, since (2) is also linear in leisure time, it is assumed that the marginal utility of an additional unit of leisure time is also a constant but equal to $\gamma(\cdot)$. At issue is how best to specify $\gamma(\cdot)$. Since $\gamma(\cdot)$ is the conversion factor of time into dollars (utils), a likely candidate is that it is some function of the individual's wage rate (e.g., a constant proportion of the wage rate, McConnell and Strand). We prefer this specification to the alternative of assuming that $\gamma(\cdot)$ is equal to a constant because the former allows the value of time to vary across individuals while the latter does not. Thus we let $\gamma(\cdot) = Ak$ times wage rate, where Ak is a parameter of the utility function to be estimated. The altered demand equation has the form:

$$(6)\quad Z = \frac{-1}{A1}\left(a_o + \sum_{k=1}^{K} a_k s_k\right) + \frac{1}{A1}P + \frac{Ak}{A1}VT + \omega,$$

where

$$P = \left(\frac{P_n}{D} + P_s - \frac{P_s}{D} + P_c\right), \text{ and}$$

$$VT = \text{wage rate} \cdot (d/D + h).$$

Before describing the empirical model to be estimated, the variables used in the analysis are described in the data section below.[2]

The Data

Primary data on individual anglers were obtained from a 1978 mail survey of Lake Michigan sports persons (Samples). The dependent variable in the model is the individual's total number of days spent fishing in the Wisconsin portion of Lake Michigan.[3] The opportunity cost of a recreation day includes both a monetary cost component and a time cost component. Included in the monetary cost is the cost of travel after adjusting for the number of people sharing expenses and for the proportion of

[2] A copy of the survey and a detailed description of the variable construction methods are available upon request from the authors.

[3] It has been argued that the appropriate unit of measurement is the fishing trip and not the fishing day because "the relationship between travel costs and user-days cannot truly be called a demand curve" (McConnell, p. 332). This criticism does not apply to our specification, however, as the number of recreation days is related to the opportunity cost of a recreation day and not simply to the individual's travel cost.

the trip intended solely for the purpose of fishing in Lake Michigan. Also included are daily on-site expenditures on bait, fishing line, hooks and lures, rental equipment, boat charters, and recreation-related food and beverages. Finally, to obtain a proxy for the opportunity cost of spending the night, we used the fitted value from a regression of reported per night lodging costs on the independent variables of the model.[4] The time cost associated with each recreation day includes travel time plus time spent at the recreation site.

The remaining independent variables include the angler's reported daily catch rate,[5] a boat ownership dummy, and four indexes of angler attitudes toward fishing for recreation in Lake Michigan. In table 1 we include descriptions of these indexes, which were constructed from the data using principal components analysis. Estimates of their reliability coefficients and their minimum, maximum, and mean values are also reported.[6]

Two additional independent variables, income and leisure time, are relevant, although the theoretical model (2) implies that the demand for recreation days is independent of these two factors. For the income variable we use the mean values of thirteen response categories with means ranging from $2,000 to $50,000 in 1978 dollars. As our proxy for available leisure time, we use a variable which differentiates between individuals who are fully retired, semiretired, or not retired. Tests of the restrictions implied by the theoretical model are reported in table 2. The null hypothesis that income should not be included in the demand equation is accepted at levels of significance greater than .025, and the null hypothesis that our leisure time variable is not significantly different than zero is accepted at levels of significance greater than .25. Throughout our analysis we maintain the zero restrictions on the coefficients of both variables.

The Empirical Model and Results

Since our sample of individuals is restricted to those with positive observed recreation days, the estimation of equation (6) by OLS would lead to biased parameter estimates. The appropriate log likelihood function for the truncated sample is

$$(7)\quad \log L = -N \log [(\pi)^{1/2}\sigma] - \frac{1}{2} \sum \left(\frac{Z - h(\cdot)}{\sigma}\right)^2 - \sum \log \Phi \left(\frac{-h(\cdot)}{\sigma}\right),$$

where $h(\cdot)$ is given by equation (6), and $\Phi(\cdot)$ is the cumulative normal density function (Maddala). We use an ML procedure to estimate (7). The results are reported in table 3, where for reasons of comparison we also include the results from the OLS regression model. All of the parameter estimates of the ML model are significant at the .01 level with one exception, namely, the estimate corresponding to the fishing success rate variable.

To interpret the effect of a change in P on desired days, refer to equation (6). The derivative of recreation days with respect to this variable is $1/A1$ or -1.79. Thus a one dollar increase in monetary cost will decrease predicted desired recreation days by 1.79. The *ML* point estimate of Ak is $.51(A1)$ or .287 (McConnell and Strand). Thus, the estimate of the dollar equivalent of an hour of time is .287 times the individual's wage rate. The estimate of the parameter, Ak, has a standard error of .095 giving the estimate brackets of .192 and .382.[7]

The first and fourth attitude indexes, *GOODWILL* and *CONGESTION*, respectively, have negative signs suggesting that the anglers least hampered by the activities of commercial fishermen and other anglers are those who are also least likely to go fishing. The positive sign on the *PCB* attitude scale implies that the anglers who are the most concerned with PCB contamination tend to fish less frequently than other anglers. Finally, the positive relationship between recreation days

[4] This procedure was followed in order to avoid any possible simultaneous equations bias which could result if the exogeneity assumption of our theoretical model was violated. Specifically, we assumed that the type of accommodations that individuals chose was independent of their chosen total number of recreation days.

[5] We assumed that this variable was exogenous; but even if anglers do view their catch rates as decision variables, no simultaneous equations bias is introduced into our estimations unless it can be argued that the number of fish caught per day depends upon the number of days fishing.

[6] A reliability coefficient is a measure of the degree to which responses to separate questions relate to the same underlying attitude (Guttman, Magnusson, Novick and Lewis).

[7] Since $AK/A1 = .51$ is a maximum likelihood estimate, $AK = .51/(1/A1)$ is also a maximum likelihood estimate. To obtain the standard error of AK, we retrieved the appropriate element from the JVJ' matrix, where J is the matrix of first derivatives of the coefficients of the demand equation, e.g., $(AK/A1)$ with respect to the parameter of interest, e.g., AK, and V is the variance/covariance matrix of the estimated coefficients.

Table 1. Variable Scales

Scale Name	Description	Description of Variables That Comprise the Scale	Minimum	Maximum	Mean	Reliability Coefficient[a]
1. *GOODWILL*	Positive attitude toward the activities of commercial fishermen	The six variables that comprise this scale are all related to the angler's perceptions of the effects of the activities of the commercial fishermen on the angler. A high score on this scale reflects a relatively favorable perception.	5.8	24.2	14.5	.65
2. *PCB*	Lack of concern toward PCB contamination	Anglers responded to six questions regarding the extent to which they have altered or will alter their angling and related activities as a result of publicity about the harmful effects of PCB contamination. A high score on this scale represents a low level of responsiveness to the negative publicity.	9.7	33.3	25.8	.52
3. *SNAG*	Negative attitude toward snagging practices	Snagging is the practice of catching fish by rapid retrieval of large, unbaited hooks. It is quite controversial because some anglers consider it unethical and because, while mature salmon that are near death are the target, fish other than mature salmon are sometimes caught. Three questions related to the angler's perception of the legitimacy of snagging were combined to form the scale, *SNAG*. A high score on this scale is indicative of a negative attitude toward snagging practices.	3.0	12.0	6.8	.53
4. *CONGESTION*	Positive attitude toward the number of anglers fishing in Lake Michigan	The seven variables that comprise this scale all pertain to the angler's perception of the effects of the number of other anglers on their fishing enjoyment. A high score on this scale reflects a relatively favorable perception.	3.2	16.0	9.9	.70

[a] The reliability coefficient, Chronbach's Alpha, is given by

$$\text{Alpha} = \frac{K}{K+1} \cdot \frac{1 - \sum_{i=1}^{K} S_i^2}{S_T^2},$$

where S_i^2 is the variance of variable i and S_T^2 is the variance of the sum over the K items.

and the third scale index, *SNAG*, suggests that the infrequent angler is more likely to be tolerant of the activities of other anglers than is the serious fisherman. Based upon the significance of these attitude indexes, we conclude that it is important to include them in the estimated equation. The last variable, the boat ownership dummy, has a positive and significant coefficient estimate indicating that people who own boats tend to fish in Lake Michigan more frequently than those who do not own boats.

Table 2. Empirical Tests of the Assumptions Implied by the Theoretical Model

Test for the Independence of Income	
Loglikelihood excluding income	2,426.0
Loglikelihood including income	−2,420.9
	5.1
Test for the Independence of Time	
Loglikelihood excluding retire	2,427.3
Loglikelihood including retire	2,426.0
	1.3

The predicted desired number of site recreation days, Z_p, is given by

$$(8)\quad Z_p = \left(\frac{\widehat{a_o}}{A1}\right) + \sum_{k=1}^{K}\left(\frac{\widehat{a_k}}{A1}\right)s_k + \left(\frac{\widehat{1}}{A1}\right)\cdot P + \left(\frac{\widehat{Ak}}{A1}\right)VT.$$

While equation (8) gives the underlying relationship between visitor days and the independent variables of the model, the desired number of site recreation days only coincides with the observed number of site recreation days when both are positive. Clearly, for the purposes of demand and welfare estimation only positive observed days matter since people who fail to visit the site do not derive utility from visiting the site. Therefore, the utility maximization model (2) applies only to individuals with positive desired and observed visitor days.

The expression for the predicted positive observed number of site recreation days, Z^*_p, can be found by adding an adjustment factor to equation (8). Hence,

$$(9)\quad Z^*_p = Z_p + \hat{\sigma}\,\frac{\phi(-Z_p/\hat{\sigma})}{\Phi(-Z_p/\hat{\sigma})},$$

where $\hat{\sigma}$ is the estimated standard error of the regression, ϕ is the standard normal density function, and Φ is the cumulative normal density function (Maddala). Individuals with positive observed days tend to have positive error terms in their underlying desired number of days equation. Therefore, the underlying desired visitor days equation has to be incremented by this positive error term for individuals known to have visited the site in order to give an accurate prediction of the individual's desired (and observed) visitor days. For example, the mean value of Z_p, the predicted desired number of Lake Michigan fishing days for the general population, is −76 while the mean value for Z^*_p, the predicted number of Lake Michigan fishing days for the user population, is 32.

In the next section we calculate the average individual angler's total compensating variation from fishing in the Wisconsin portion of Lake Michigan. The welfare estimates calculated using the ML parameter estimates are compared to those computed from OLS estimates.

Welfare Estimates

A convenient attribute of the utility specification, (2), is that the resultant demand equation is a Hicksian compensated demand equation. Thus, the compensating variation and equivalent variation welfare measures are

Table 3. Recreation Days Results

Variable Description	Variable Name	Coefficient	OLS Coefficient Estimate	Standard Error	ML Coefficient Estimate	Standard Error
Monetary cost	*P*	1/*A*1	−.51**[a]	(.08)	−1.79**	(.36)
Monetary equivalent of time cost	*VT*	*Ak*/*A*1	−.05**	(.03)	−.51**	(.11)
Attitude scale 1	*GOODWILL*	−a1/*A*1	−1.11**	(.42)	−8.94**	(1.78)
Attitude scale 2	*PCB*	−a2/*A*1	2.64**	(.44)	5.68**	(1.68)
Attitude scale 3	*SNAG*	−a3/*A*1	2.46**	(.54)	8.73**	(2.35)
Attitude scale 4	*CONGESTION*	−a4/*A*1	−.36**	(.33)	−3.46**	(1.08)
Fishing success rate	*SR*	−a5/*A*1	−.01	(.03)	.03	(.14)
Boat ownership dummy	*OWNBT*	−a6/*A*1	9.19**	(2.85)	20.2**	(10.23)
Intercept	*INTERCEPT*	−a0/*A*1	−23.65**	(15.66)	−26.39	(60.58)

Notes: The number of observations = 560; chi-squared with 8 degrees of freedom = 138.85.
[a] Double asterisk indicates significance at the .01 level.

equivalent to ordinary consumer surplus. Given the implied source of error in our regression model (either omitted variables or human indeterminacy), the formula for the ordinary surplus is

$$(10)\quad CS = \int_{Po}^{P^{max}} Z(p)dp = \frac{-Z^2}{2\left(\frac{1}{A1}\right)}$$

(Bockstael, Hanemann, and Strand). Here, Z is defined as the individual's actual number of site recreation days and P^{max} is the price that drives the number of recreation days to zero. Actual, rather than predicted, recreation days are used to compute welfare except in cases where the predominant source of error is believed to be due to measurement error in the dependent variable (Bockstael and Strand).

The estimates of (10) obtained from substituting the ML likelihood and OLS estimates for $1/A1$ into (10) will differ in proportion to the difference in the size of the two price coefficients.

The OLS estimate for $1/A1$ leads to consumer surplus values which exceed the ML calculations by a factor of 3.6. The mean consumer surplus per recreation day is only \$20.35 for the ML model but is \$73.52 for the OLS model. Aggregating the consumer surplus estimates to the full current user population gives estimates of approximately \$55 million and \$200 million, respectively.

Unfortunately, since we have the ML estimator of $1/A1$ rather than the true parameter, the estimate of ordinary consumer surplus obtained from substituting $1/A1$ into (10) is biased (Bockstael, Hanemann, and Strand). That is,

$$(11)\quad CS \cong \frac{-Z^2}{2(\widehat{1/A1})},$$

which has an expected value approximated by[8]

$$(12)\quad E(\widehat{CS}) \cong \left[\frac{Z^2}{-2\left(\frac{1}{A1}\right)}\right] \cdot \left[1 + \frac{\mathrm{var}\left(\frac{\hat{1}}{A1}\right)}{\left(\frac{1}{A1}\right)^2}\right].$$

[8] The expected value is approximated by

$E[x/y] \cong E(x)/E(y) - \mathrm{cov}(x,y)/[E(y)]^2 + E(x)\{\mathrm{var}(y)/[E(y)]^3\}$.

Thus, the estimate of ordinary consumer surplus obtained from substituting $(\widehat{1/A1})$ for $(1/A1)$ is biased by the factor var $(\widehat{1/A1})/(1/A1)^2$. Lacking knowledge concerning the value of the true parameter, it is impossible to calculate the bias precisely. However, it can be approximated by $[\hat{\sigma}^2(\widehat{1/A1})/(1/A1)^2$ or $1/(t\text{-ratio})^2$ (Bockstael, Hanemann, and Strand).

The estimate of the bias in our welfare calculations is 4% of the total. Thus, our corrected estimate of the mean consumer surplus per recreation day is \$19.54.

Summary and Conclusions

In order to obtain an estimate of the welfare that anglers derive from recreational fishing in Lake Michigan, we estimate a travel-cost-based demand equation, which is derived from a model of utility-maximizing behavior. The utility function we specify postulates that individuals derive utility from time-intensive goods as well as from goods with a monetary price tag, but that both types of goods are separable from the total number of days spent fishing for recreation in Lake Michigan.

This total number of recreation days is the product of the number of trips to the site and the average number of days per trip, which is predetermined in our model. Our theoretical model is appealing because it allows for the fact that different consumers will choose to take their recreation days in trip packages most ideally suited to them.

Although we assume that the individual's length of stay is predetermined, it is not constrained to be the same for all recreators. The econometric implication of our model is that on-site time must be included on the right-hand side of our travel-cost-based recreation demand equation. This is an improvement over past travel-cost-based demand equations which omitted on-site time altogether and thereby assumed implicitly that all individuals consumed trips of equal length.

Our best estimate for the value of Great Lakes fishing is \$19.54 per day. A comparison of this amount computed using estimates from an ML estimation procedure for truncated samples with consumer surplus calculations based upon OLS estimates confirms the expectation by some that severe biases from using the latter procedure are likely. Ordinary least squares produced consumer surplus estimates that were approximately three and onehalf times the size of the maximum likelihood estimates. For this reason we recommend that estimation procedures appropriate for data with limits on the dependent variable be employed for travel cost demand analysis.

[*Received January 1984; final revision received June 1985.*]

References

Allen, P. G., T. H. Stevens, and S. A. Barrett. "The Effects of Variable Omission in the Travel Cost Technique." *Land Econ.* 57(1981):173–80.

Bishop, R. C., and T. A. Heberlein. "Measuring Values of Extramarket Goods: Are Indirect Measures Biased?" *Amer. J. Agr. Econ.* 61(1979):926–30.

Blackorby, C., D. Donaldson, D. Priomont, and R. R. Russell. *Duality, Separability and Functional Structure.* New York: American Elsevier, 1978.

Bockstael, N. E., W. M. Hanemann, and I. E. Strand. "Benefit Analysis Using Indirect or Imputed Market Methods." *Measuring the Benefits of Water Quality Improvements Using Recreation Demand Models,* vol. 2. Washington DC: Environmental Protection Agency, Office of Policy Analysis draft manuscript CR-811043-01-0, no date.

Bockstael, N. E., and K. E. McConnell. "Theory and Estimation of the Household Production Function for Wildlife Recreation." *J. Environ. Econ. and Manage.* 8(1981):199–214.

Bockstael, N. E., and I. E. Strand. "The Nature of Error in Recreation Demand Analysis and its Effect on Benefit Estimates." Paper presented at the American Fisheries Society Meetings, Cornell University, Aug. 1984.

Cesario, F. J. "Value of Time in Recreation Benefit Studies." *Land Econ.* 52(1976):32–41.

Clawson, M., and J. L. Knetsch. "Economics of Outdoor Recreation." Washington DC: Resources for the Future, 1966.

Desvousges, W. H., V. K. Smith, and M. P. McGivney. "A Comparison of Alternative Approaches for Estimation of Recreation and Related Benefits of Water Quality Improvements." Washington DC: Environmental Protection Agency, Office of Policy Analysis, 1983.

Deyak, T. A., and V. K. Smith. "Congestion and Participation in Outdoor Recreation: A Household Production Approach." *J. Environ. Econ. and Manage.* 5(1978):63–80.

Freeman, A. M., III. *The Benefits of Environmental Improvement: Theory and Practice.* Baltimore MD: Johns Hopkins University Press for Resources for the Future, 1979.

Guttman, L. "A Basics for Analyzing Test-Retest Reliability." *Psychometrika* 10(1945):255–82.

Hanemann, W. M. "Discrete-Continuous Models of Consumer Demand." *Econometrica* 52(1984):541–61.

Haspel, A. E., and F. R. Johnson. "Multiple Destination Trip Bias in Recreation Benefit Estimation." *Land Econ.* 58(1982):364–72.

Johnson, G. "Measuring the Cost of Time in Recreation Demand Analysis: Comment." *Amer. J. Agr. Econ.* 65(1983):169–71.

Judge, G. G., W. E. Griffiths, R. C. Hill, and T. C. Lee. *The Theory and Practice of Econometrics.* New York: John Wiley & Sons, 1980.

Maddala, G. S. *Limited-Dependent and Qualitative Variables in Econometrics.* Cambridge: Cambridge University Press, 1983.

Magnusson, D. *Test Theory.* Reading MA: Addison-Wesley Publishing Co., 1966.

McConnell, K. E. "Some Problems in Estimating the Demand for Outdoor Recreation." *Amer. J. Agr. Econ.* 57(1975):330–34.

McConnell, K. E., and I. Strand. "Measuring the Cost of Time in Recreation Demand Analysis: An Application to Sportfishing." *Amer. J. Agr. Econ.* 63 (1981):153–56.

Novick, M. P., and C. Lewis. "Coefficient Alphas and the Reliability of Composite Measurements." *Psychometrika* 32(1967):1–13.

Pollak, R. A., and T. J. Wales. "Estimation of the Linear Expenditure System." *Econometrica* 37(1969):611–28.

Samples, K. C. "An Economic Analysis of Integrated Fisheries Management: The Case of the Lake Michigan Alewife/Salmonid Fisheries." Ph.D. thesis, University of Wisconsin, 1980.

Samuelson, P. A. "Constancy of the Marginal Utility of Income." *Studies in Mathematical Economics and Econometrics,* ed. O. Lange, F. McIntyre, and T. O. Yntema, pp. 75–90. Chicago: University of Chicago Press, 1942.

Smith, V. Kerry, and W. H. Desvousges. "The Generalized Travel Cost Model and Water Quality Benefits: A Reconsideration." *S. Econ. J.* 52(1985):371–81.

Smith, V. K., W. H. Desvousges, and M. P. McGivney. "The Opportunity Cost of Travel Time in Recreation Demand Models." *Land Econ.* 59(1983):259–78.

Ward, F. A. "Measuring the Cost of Time in Recreation Demand Analysis: Comment." *Amer. J. Agr. Econ.* 65(1983)167–68.

Wilman, E. A. "The Value of Time in Recreation Benefit Studies." *J. Environ. Econ. and Manage.* 7(1980):272–86.