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Comparison of Environmental Quality-Induced Demand Shifts Using Time-Series and Cross-Section Data

John Loomis and Joseph Cooper

Almost all applications of the Travel-Cost-Method demand function which include site quality variable(s) are multisite models. The results of this study serve as a note of warning that using the demand equation derived from multisite cross-sectional data to perform a benefit-cost analysis of changes in quality at a single site may not accurately predict the resulting change in the number of trips to that site. In this situation, estimates of the benefits of quality improvements may be unreliable.

Key words: benefits, cross section, demand, fishing, quality, recreation, time series, travel cost model.

To perform Benefit-Cost-Analysis (BCA) of changes in recreational site quality, such as improving water quality or facilities, it is necessary to know how the demand function shifts with changes in site quality. Since many exogenously determined site quality variables change only by season or year, estimation of a coefficient on site quality usually must be performed using multisite cross-sectional data, i.e., observing how recreationists respond to differences in site quality across sites (Vaughan and Russell). However, the application of BCA to value changes in site quality often involves changes in quality at just one site. This application requires information on the recreationist's response to changes in quality at that particular site. Since time-series data frequently are not available, it is not possible to estimate visitors' responses to quality over time at the study site. For a single site, the coefficients for many quality variables whose values are exogenously determined cannot be estimated using only that site's cross-sectional data. The critical issue becomes whether the estimated response of visitors to differences in quality across sites is an accurate measure of the way they would respond to changes in quality at a given site. Specifically, is the multisite equation estimated from cross-sectional data equal to, and hence a proxy for, the single-site demand equation that would be estimated for a given site if time-series data on how recreationists responded to changes in quality at that site were available? This issue is methodologically important since time-series data are rare and future studies will continue to rely on cross-section data.

The relationship of habit formation in visitation patterns to the time-series model is another issue empirically tested in this study. Because the recreationist frequently has little information on the current level of quality at a site, he or she may rely on knowledge and/or experience of past levels of quality as a factor in deciding whether or not to visit that site. Even if the recreationist knows of a drop in quality at a site the individual has visited often in the past, he or she may still choose to visit the site. Either case could be suggested by significant coefficients on lagged quality variables, especially those that are larger than the current period's coefficient.

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Travel Cost Model Structure

To be more explicit about the hypothesis to be tested, consider below equation (1), the multisite regional (cross-section) Travel Cost Model (TCM), and equation (2), the single-site pooled time-series, cross-section TCM, which will be called the single-site time-series model in this article. These models will be used to estimate the demand for trout fishing along the North Fork of the Feather River in northern California. Because individual observation data were not available, zonal TCM models are specified.

For each of the T years spanning the study, the following multisite regional TCM equation is estimated:

$$(1)\quad TRIPS_{ij}/POP_i = f(TRVCOST_{ij}, INCH_i, QUALITY_j, PS_{ik}) + u_{ij},$$

where: $i = 1, \ldots, n$ is the number of visitor origins; $j = 1, \ldots, m$ sites, where $n > m$; $TRIPS_{ij}$ is the number of trips from origin i to site j; POP_i is the population of origin i; $TRVCOST_{ij}$ is the cost of traveling from origin i to site j; $INCH_i$ is average household income in origin i; $QUALITY_j$ is a site quality variable for site j; PS_{ik} is the price to origin i of visiting substitute site k; and u_{ij} is a random disturbance term.

For each of the m sites, we have the following time-series equation:

$$(2)\quad TRIPS_{it}/POP_{it} = f(TRVCOST_{it}, INCH_{it}, QUALITY_t, PS_{ikt}) + u_{it},$$

where: $i = 1, \ldots, n$ is the number of visitor origins; $t = 1, \ldots, T$ years; $TRIPS_{it}$ is the number of trips from origin i to the site in year t; POP_{it} is the population of origin i in year t; $TRVCOST_{it}$ is the cost of traveling from origin i to the specified site in year t; $INCH_{it}$ is average household income in origin i in year t; $QUALITY_t$ is a site quality variable at time t; PS_{ikt} is the price to origin i of visiting substitute site k in period t; and u_{it} is a random disturbance term.

To answer the question of whether the equation estimated from multisite cross-sectional data (equation [1]) in any given year equals the equation estimated for time-series data on a given site (equation [2]), the regression results for the m recreational sites are compared to each other.[1] If the site-specific regression results are statistically different from each other, then the multisite cross-section equation is not a reliable proxy for the single-site equations. It is assumed that because travel costs vary little between the m study sites used in this paper, and hence site selection is not a function of price, most of the potential differences between the single-site regressions can be attributed to site quality differences.

Habit Formation and the Role of Lagged Catch Variables

Before proceeding to the empirical test of equality of single-site time-series and multisite cross-section demand curves, it is worthwhile to explain whether the two should be equivalent from an a priori standpoint. The concept of habit formation (Johnson, Hassan, and Green) may serve as a plausible basis for why time-series and multisite cross-section demand equations yield different parameter estimates. Habit formation tries to explain why consumers may not modify, or be slow in modifying, their market basket decisions in the face of nonstatic market characteristics. A person's consumption decisions this year may be based on some habit formation related to factors formed over the course of time.

For example, a site quality variable such as the fish catch variable, in this case *CREEL*, is a likely candidate for one whose past levels may influence current demand decisions. One would expect the catch history at a fishing site to be an important site characteristic in determining the current decision to visit the site. But even if more fish were stocked in the current year on a river section that traditionally had low levels of fish catch, the angler might not respond to the change by significantly increasing his or her trips to the site. The angler may readjust attitudes to a particular site only after several years of higher fish catch.

[1] A slightly more direct test would be to compare the single-site coefficients on the quality variable across the m sites. However, implementing this two-way ANOVA by regression adds five interaction variables to the regression equation. Attempting to estimate this within the framework of nonlinear least squares resulted in a singularity of the inversion matrix in the nonlinear regression. However, the nonlinear least squares approach was retained because it allowed estimation of a nonlinear functional form on the complete untruncated data, which included several zero observations from one or more counties in one or more years.

This theory regarding why fish catch may be statistically insignificant in the time-series regressions does not necessarily preclude fish catch from being statistically significant in a cross-section regression. Although the levels of *CREEL* do vary among years at each site, examination of the data indicates that the ranking of the sites in terms of the level of catch remains relatively constant over time. Assuming that anglers are rational, if the level of catch is one of the key differentiations between two sites and this difference has persisted for some length of time, one would expect more anglers to choose the site with the higher fishing quality. Consistency of the data with habit formation can be checked by examining the lag structure in the time-series data.

Because this dichotomy may exist between the single-site time-series case and the multisite cross-section case, if the researcher or planner uses the coefficient on fish catch from the multisite cross-section regressions to forecast the changes in demand with respect to changes in fish catch for a particular site and if habit formation is present, he or she may overstate the impact on trips to that site from the change in fish catch at that site.

Case Study

The study river was the North Fork of the Feather River, north of the Oroville Dam. Visitation data were collected by the California Department of Fish and Game using a short on-site survey for the years 1981–85. (Funding was provided by Pacific Gas and Electric Company.) The on-site survey of anglers recorded such information as angler's county of origin, composition of fish catch, hours fished, and fishing equipment used. The raw data were compiled by the Department of Fish and Game in an aggregate form by county of origin, i.e., the individual anglers were not asked to state their seasonal number of visits. Hence, zonal TCM models were used for this study.

The amount of angler's *CREEL,* i.e., the number of fish kept by the angler, was incorporated into the model as the fishing quality variable. The level of *CREEL* was available for each of the six separate sections of the river, thereby opening up the possibility of performing individual time-series regressions on the river sections instead of over the whole river. Hence, the quality coefficients from the time-series regressions could be estimated separately for each of the six sites. For the cross-section analysis, site quality data were constant for any given site in any given year. To estimate the cross-section quality coefficients, the regressions must be run across all the sites in a given year. As some sections are influenced by impoundments, and therefore have slow-moving water whereas other sections are true riverine environments, the six river sections correspond to unique recreational sites along the river.

The TCM model specified here presents trips per capita as a function of the travel expenses from a particular county of origin to the recreational site plus other monetary parameters, such as the average household income for the area of origin, and a quality variable, such as fish catch. The price of substitutes was not included since these data were not collected in the survey. While omission of substitutes could lead to omitted variable bias in parameter estimates, since price of substitutes was omitted in both the single-site time-series models as well as the multisite cross-section models, the comparisons between the models are still valid. Furthermore, the availability of substitutes did not change over the five-year period studied. The model can be specified, in cross-sectional form (the time-series form would be subscripted as in [2]), as:

$$(3) \quad TRIPS_{ij}/POP_i = B0 * TRVCOST_{ij}^{B1} * INCH_i^{B2} * CREEL_{ij}^{B3} + u_{ij},$$

where: $i = 1, \ldots, 57$ is the number of counties in California, excluding Imperial County, from which no visitations originated over the five-year period of the study; $j = 1, \ldots, 6$ is the specified number of recreation sites along the North Fork of the Feather River; $TRVCOST_{ij}$ is the cost of traveling from county i to site j on the North Fork of the Feather River (*TRVCOST* is a function of round-trip distance (rtdist) to the site, variable vehicle expenses such as fuel and repair costs per mile, the average number of passengers per automobile, and the opportunity cost of travel in terms of a fraction of the wage rate. *TRVCOST* is specified as follows: $TRVCOST_{ij}$ = (rtdist * fuel and repair costs per mile)/2.5 passengers + (rtdist/40 mph) * (½ * wage rate)); $CREEL_j$ is the aggregate number of fish kept by anglers at site j for the year of the cross-sectional regression.

Nonlinear equation (3) is mathematically equivalent to the nonlinear in the variables double-log form.[2] Adamowicz, Fletcher, and Graham-Tomasi validate the double-log model as a variance-minimizing functional form for TCM. Due to this specification, the coefficients of the double-log model are interpreted as elasticities. Model (3) is also a constant elasticity model with a homoskedastic dependent variable.

A nonlinear form is desirable for several reasons. In general, taking the log of trips per capita has been found to reduce heteroskedasticity (Strong; Vaughan, Russell, and Hazilla). Also, the problem of a negative prediction of trips that can occur with a linear model is avoided with certain specifications that are nonlinear in the variables or coefficients. Furthermore, if the coefficient on *CREEL* is less than one, then the property of diminishing marginal values per fish caught will be realized.

Since the dependent variable contains some zero observations, (3) must be estimated in lieu of the semi- or double-log forms. To exclude counties with zero trips at time t to river section j from the sample is equivalent to excluding relevant information from the sample and would add a truncation bias to the coefficients (Smith and Desvousges). To apply the double-log functional form to this data would require the dependent variable to be scaled up by some arbitrary constant. Since no theoretical basis exists to justify this latter approach, the nonlinear-in-the-coefficients functional form was chosen over the linear-in-the-coefficients double-log form.

The approach for valuing travel time utilizes the "fraction of wage rate" approach suggested by Cesario rather than more recent approaches suggested by Bockstael, Strand, and Hanemann. Without primary data on each angler's time budget, i.e., was he or she fishing on weekends, paid vacation, etc., it is not possible to implement a more sophisticated approach. For the purposes of comparing the coefficients on fish catch from the time-series versus the cross-section regressions, the chosen approach to valuing travel time should have little effect as the same procedure was used for all years.

Data on fuel and repair costs for each of the five years were obtained from Hertz Corporation surveys (*Hertz News*). County-specific wage rates were also obtained for each of the five years (*California Statistical Abstract*). To develop relative prices over the period of the study, the nominal dollar figures were converted to real 1985 dollars.

Statistical Results

The results for the five cross-sectional regressions across all the sites are presented in table 1. For the time-series regressions (table 2), yearly data on the number of visits from the California counties to an individual river section were collected for the years 1981 through 1985. The results were obtained through TSP's Version 5.1 nonlinear least squares regression program. This program uses a quasi-Newton algorithm.

To test for the presence of heteroskedasticity, separate Goldfeld-Quandt tests were performed on *POP, TRVCOST, CREEL,* and *INCH* with the population variable generally considered to be the most likely cause of heteroskedasticity in this type of model. In the tests, one-third of the data, or 114 observations, corresponding to the central data were omitted. The null hypothesis of homoskedasticity was not rejected at the 5% level of significance for all the variables except population, where the null hypothesis was not rejected at the 1% level. With the levels of heteroskedasticity found to be insignificant, generalized least squares techniques were deemed unnecessary for this data set.

In table 1, the cross-section coefficients on *CREEL* are significant at the 1% level in all years. While all the coefficients on *CREEL* occupy the inelastic range, their values do vary, from a high of .83 to a low of .4. Since all the *CREEL* coefficients are less than one, they indicate that the demand equations have the property of diminishing marginal values of additional fish catch. The coefficient on income (*INCH*) is not significant in any of the regressions in table 1 but is left in the regressions to be consistent with demand theory.

For the single-site time-series regressions, if

[2] If one assumes an additive error term in the double-log model, then by transformation, the nonlinear in the variables model (3) should have a multiplicative error term. Of course, the specification of an additive error term in the double-log model is usually made for ease of estimation and not necessarily on the basis of theory. Like other programs of its type, the nonlinear estimation program used operates on the assumption of an additive error term. Hence, model (3) is specified with an additive error term. The choice between a multiplicative and an additive error is essentially a choice between assuming the dependent variable is heteroskedastic or homoskedastic (Judge et al.).

Table 1. Multisite Cross-Sectional Regressions (Dependent Variable = *TRIPS/POP*)[a]

Year	Intercept	*TRVCOST*	*INCH*	*CREEL*	Adj. R^2	Log Likelihood
1981	0.001	−2.194	0.424	0.559	.28	2,598
	(0.13)	(−9.13)	(0.53)	(4.67)		
1982	6.111	−3.271	−0.592	0.833	.76	2,823
	(0.13)	(−20.88)	(−0.76)	(19.85)		
1983	0.411	−2.251	−0.384	0.408	.36	2,813
	(0.086)	(−10.72)	(−0.34)	(4.25)		
1984	0.001	−2.694	0.550	0.773	.68	2,982
	(0.12)	(−19.80)	(0.67)	(9.84)		
1985	0.001	−2.545	0.296	0.651	.18	2,521
	(0.04)	(−6.92)	(0.14)	(3.87)		

Note: The number of observations is 342 (6 sections • 57 counties). *TRIPS/POP* = trips per capita; *TRVCOST* = travel cost; *INCH* = average household income; *CREEL* = fish catch.
[a] The *t*-statistics are in parentheses.

the *CREEL* variable is to be included, a test for heteroskedasticity across the years cannot be conducted: the *CREEL* variable is constant within any given year so regressions cannot be run on the individual years. Within any year, though, since the levels of heteroskedasticity were found to be low in the multisite cross-sectional regressions, one would expect that these levels would be the upper bound for the single-site cases. Note that with only five years of data, a test for autocorrelation is difficult to conduct.

The results for the time-series regressions on the individual river sections with respect to *CREEL* were generally mixed: the coefficients on *CREEL* are both significant and of the correct sign only for river sections 3 and 4. A comparison of the coefficient on *CREEL* between these two river sections suggests that the two coefficients are fairly similar with both being inelastic, thus exhibiting the property of diminishing marginal value per fish. The coefficients on *CREEL* for the other river sections are either insignificant or of the wrong sign.[3]

[3] In the demand equations specified in the paper, *TRIPS/POP* and *CREEL* conceivably can be jointly dependent variables, i.e., not only does *CREEL* determine the level of *TRIPS/POP*, but *TRIPS/POP* might also influence the level of *CREEL*. It could be possible that the low *t*-statistics on *CREEL* for the time-series case are attributable, at least in part, to a simultaneity problem. Comparison of the single-equation and two-stage least squares regression results for several of the river sections reveals little difference in the log-likelihood values, with the simultaneous regressions having slightly, but not statistically, lower log-likelihood values. Hence, simultaneity does not appear to be a serious problem for this data set.

Table 2. Time-Series, Cross-Sectional Regressions by River Section (Dependent Variable = *TRIPS/POP*)[a]

River Section	Intercept	*TRVCOST*	*INCH*	*CREEL*	Adj. R^2	Log Likelihood
1	0.659	−3.542	1.196	−1.469	.77	2,509
	(−0.16)	(−18.93)	(1.85)	(−7.80)		
2	0.001	−2.893	0.786	0.151	.22	2,196
	(0.06)	(−6.84)	(0.47)	(0.57)		
3	0.001	−3.004	0.391	0.732	.77	2,265
	(0.15)	(−21.86)	(0.64)	(4.92)		
4	461.389	−1.507	−1.417	0.790	.16	2,193
	(0.08)	(−6.04)	(−1.11)	(2.94)		
5	269.579	−1.276	−1.194	0.222	.04	2,179
	(0.05)	(−3.19)	(−0.58)	(1.20)		
6	6.483	−1.638	−0.643	0.091	.13	2,268
	(0.07)	(−5.47)	(−0.45)	(0.22)		

Note: The number of observations is 285 (5 years • 57 counties). *TRIPS/POP* = trips per capita; *TRVCOST* = travel cost; *INCH* = average household income; *CREEL* = fish catch.
[a] The *t*-statistics are in parentheses.

Table 3. Pooled Time-Series, Cross-Sectional Regression—Over All River Sections and Years (Dependent Variable = *TRIPS/POP*)[a]

Intercept	*TRVCOST*	*INCH*	*CREEL*	Adj. R^2	Log Likelihood
0.001	−2.669	0.349	0.707	.34	13,311
(0.20)	(−22.18)	(0.70)	(14.23)		

Note: The number of observations is 1,710. *TRIPS/POP* = trips per capita; *TRVCOST* = travel cost; *INCH* = average household income; *CREEL* = fish catch.
[a] The t-statistics are in parentheses.

The coefficient on *INCH* is significant at the 10% level for river section 1.

Table 3 presents the pooled time-series, cross-sectional regression across all the river sections and time periods. Both *TRVCOST* and *CREEL* coefficients are significant at the 5% level, while the other two variables are not. The coefficient on *CREEL* is also of the expected magnitude.

With the nonlinear functional form chosen, two of the common data transformations for pooled data, the fixed- and random-effects models, could not be used. The fixed-effects model transforms the data into deviations from group means, and the random-effects model transforms the data into quasi-deviations from group means. The transformation for the former model will produce some data points with values less than one as will the latter model, except in the case where the quasi-deviations are small enough which was not the case for this data. Obviously, negative data values are incompatible with coefficient values less than one in equation (3).

Discussion of the Hypothesis

In order to check for the equality of the single-site demand equations across the six sites, the following F-test was constructed. This test is asymptotically valid in large samples for nonlinear models (Judge et al.). This F-test took the form

$$(4) \qquad F = ((RSS_1 - RSS_2)/q)/(RSS_2/(n-k)) \sim F(q, n-k),$$

where RSS_1 is the residual sum of squares of the restricted model, RSS_2 is the residual sum of squares of the unrestricted model, q is the difference between the degrees of freedom of RSS_1 and RSS_2, which also equals the number of restrictions, and $n - k$ is the degrees of freedom of RSS_2, where n is the number of observations per site times six and k is the number of regressors for each equation times six. The residual sum of squares for the restricted model, RSS_1, is derived from the regression results for the equation over all the data (table 3). The residual sum of squares for the unrestricted model is the sum of the error sum of squares of each of the six single-site regressions from table 2. The calculated value of 11.09 for the F-test in (4) was greater than the critical value $F_{.05}(20,1686) = 1.57$. Hence, the hypothesis that the single-site demand equations are equal across the six sites is rejected. As an alternative or adjunct to the F-test, a likelihood ratio test could be used to test the hypothesis. This test was constructed, and it also rejected the null hypothesis.

Lagged TCM Models as Applied to the North Fork of the Feather River

As mentioned earlier, habit formation (Johnson, Hassan, and Green) may serve as a plausible basis for an explanation for why the coefficient on the quality variable is significant and less than one for all the multisite cross-section demand functions but performs poorly in the single-site time-series case. To empirically examine the nature of the habit formation, lagged values of the quality variable are added to the regressions. Analysis of the coefficients on the lagged values will indicate how the current demand for trips is a function of the fishing quality in previous years and, hence, test the power of habit formation. That is, if current visitation is strongly affected by past site quality levels, then habit formation is supported and provides a reasonable explanation of the divergence between cross-section and time-series demand equations.

For this test, the level of trout stocking per year on the North Fork was used as a proxy for fishing quality. While *CREEL* data were

Table 4. Regressions with Lagged Stock Variable (Dependent Variable is *TRIPS/POP*)[a]

Variable	Regression (A)	(B)	(C)
Constant	0.558	0.001	0.0002
	(0.17)	(0.17)	(0.19)
TRVCOST	−2.422	−2.456	−2.473
	(−17.57)	(−18.59)	(−18.89)
INCH	−0.084	0.299	0.474
	(−0.14)	(0.53)	(0.92)
$STOCK_t$	0.193	0.036	—
	(2.51)	(0.47)	
$STOCK_{t-1}$	—	0.457	0.421
		(5.27)	(5.84)
$STOCK_{t-2}$	—	−0.100	—
		(−1.13)	
Log Likelihood	1,931	1,946	1,946
Adjusted R^2	.64	.68	.68

Note: The number of observations is 285. *TRIPS/POP* = trips per capita; *TRVCOST* = travel cost; *INCH* = average household income; $STOCK_t$ = fish stocked in current year; $STOCK_{t-1}$ = fish stocked in the previous year; $STOCK_{t-2}$ = fish stocked two years earlier.
[a] The t-statistics are in parentheses.

available only over the period 1981–85, data for fishing stock (*STOCK*) were available from as far back as 1976. Hence, observations were not lost when lagged values of *STOCK* were included in the regressions. *STOCK* was not used in equation (3) as it was not available for all six individual river sections.

In order to allow the data to determine their own lag structure—as opposed to having it imposed on the data through, for example, a polynomial lag model—the regressions incorporate the lagged variables without restrictions. An autoregressive model was not estimated as it is difficult to find a theoretical justification with aggregate zonal data for the existence of a nonzero correlation between error terms in the current period with those of past periods. However, with individual observation data, one may want to consider this application. Furthermore, with only five years of data, the existence of autocorrelation cannot be reliably tested.

As a reference, a time-series regression was performed on the following unlagged model:

$$(5)\quad TRIPS_{it}/POP_{it} = B0 * TRVCOST_{it}^{B1} * INCH_{it}^{B2} * STOCK_t^{B3} + u_{it},$$

where $i = 1, \ldots, 57$ is the number of California counties and $t = 1, \ldots, 5$ covers the five years of data from 1981 to 1985. Hence, the number of observations is 285. The results of this regression (A) and the regressions with the lagged *STOCK* variables (regressions (B) and (C)) are presented in table 4.

Now if one assumes that the previous year's level of stocking is better known to the angler—his or her information set on the current year's level of stocking may not be complete until the end of the current year—or that some level of habit formation is present, then the previous year's level of stocking may have a greater bearing on his or her current year's demand for recreation than the current year's stock level. To test this hypothesis, $STOCK_{t-1}$ and $STOCK_{t-2}$ were added to the model specified in equation (5). These results are presented as regression (B) in table 4. Regression (C), which includes only $STOCK_{t-1}$ and drops the insignificant $STOCK_{t-2}$, is based on the assumption that the current year's level of *CREEL* has no effect on current demand.

In both regressions (B) and (C), the coefficients and t-statistics on $STOCK_{t-1}$ are twice the magnitude as those on $STOCK_t$, which becomes insignificant when regressed together with $STOCK_{t-1}$. Hence, last year's level of fish stock appears to be a more important factor in site demand than the current level.

While this result may not be surprising, in general one would expect that earlier levels of stock, such as $STOCK_{t-2}$, $STOCK_{t-3}$, etc., would have progressively less effect on the current level of demand. In fact, the $STOCK_{t-2}$ coefficient is insignificant. Little correlation exists among the *STOCK* variables.

That the coefficient on $STOCK_{t-1}$ is not only greater but more statistically significant than the coefficient on $STOCK_t$, assuming the angler's level of information on both is similar, suggests that some degree of habit formation is present. But the insignificance of the coefficients on all the lagged variables except the first lag seems to suggest that the degree of habit formation is low, i.e., just the past year's level of fish influences current demand. These results are consistent with those appearing on table 2: the current level of *STOCK* in the time-series regressions, like *CREEL*, is not strongly significant. Since $STOCK_{t-1}$ is more significant, it is possible that habit formation in this case is largely confined to the recent past.

Conclusion

The results of this study should serve as a note of caution that using a multisite cross-sectionally derived demand equation to perform a benefit-cost analysis on a single site with respect to variations in the quality at that one site may not accurately predict the corresponding change in trips to the site. An inaccurate estimation of the change in trips due to a change in site quality would result in unreliable estimates of the benefits of site quality improvements. However, more rigorous testing of this conclusion awaits consistently collected microlevel data over a number of years. Additionally, as the results of the time-series estimation with the lagged quality variables indicate, single-site demand models should incorporate lags. The inclusion of these lags would be especially important in cases where the consumer exhibits long-term learning behavior. Part of the reason why anglers do not react as quickly to quality changes as a multisite travel cost model might indicate is that angler behavior appears to exhibit some habit formation.

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