# Economic Benefits of Instream Flow to Fisheries: A Case Study of California's Feather River

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*ABSTRACT:* Performing a benefit cost analysis of changes in instream flow requires knowledge of how the demand function shifts with changes in flow or flow related variables, such as fish catch. This paper presents a simultaneous system of demand and production equations that explicitly incorporates an instream flow variable. With this simultaneous system, the effect on recreationists' benefits of a change in instream flow can be directly measured. The Travel Cost Model demand equation includes the level of fish catch as the quality variable, that is, in turn, a function of river flow. The case study modeled this relationship between river flow and fishing trips to the North Fork of California's Feather River.

*KEY WORDS:* Recreation, demand curves, travel cost method, consumer surplus, regression, fishing quality.

## INTRODUCTION

Ensuring adequate river flows for recreational fisheries on Northern California's Feather River is a major challenge for state and federal water managers. The challenge lies in providing equal consideration for fisheries and developmental uses of water. For example, federal water resource agencies governed by the U.S. Water Resources Council Principles and Guidelines (WRC 1983) and the Federal Energy Regulatory Commission under the Electric Consumers Protection Act of 1986 (16 U.S.C. 791a–825r as amended), require a comparison of benefits and costs for proposed water projects. One way to provide equal consideration to fisheries resources is to answer the question: How much is water worth to society when left in a particular stretch of the river?

To answer this question, one first has to define the affected members of society, and, second, measure the impact. Past studies have shown that visitors to rivers such as anglers, boaters and swimmers are affected by changes in instream flow (Walsh et al. 1980; Daubert and Young 1981; Ward 1987). If flow levels are substantially reduced, shoreline users, such as picnickers, can also be affected. When the decision is made to dam a river, even the nonvisiting general public is affected (Walsh et al. 1985).

Knowing that a broad segment of the public suffers when streamflows are reduced begs the question of how this impact can be measured. In general, there are three theoretically correct and widely recommended techniques for measuring the value of environmental goods: (1) contingent valuation method (CVM); (2) travel cost method (TCM); and (3) hedonic property value approach (McConnell 1985). The CVM and TCM are commonly used in instream flow studies. The first study to quantify the economic value of alternative levels of instream flow was performed by Daubert and Young (1981) using the CVM. Since then, the majority of instream flow studies have largely relied on the CVM or contingent behavior data (Loomis 1987). The CVM is a market simulation approach that asks people their net willingness to pay for alternative river flows. The method can be used to value visitors' as well as the general public's willingness to pay for river protection.

The TCM is a demand estimating technique that quantifies visitors net willingness to pay for recreation. Unlike the contingent valuation method, TCM relies on visitors' actual behavior to infer net willingness to pay. To perform a benefit cost analysis (BCA) of changes in recreation benefits with *different* instream flows, it is necessary to know how the TCM demand function shifts with changes in instream flow. However, it is often difficult to collect the needed data indicating how visitation rates actually change with flow levels. Past applications of TCM to valuing instream flow shifted the demand curves by the change in visitation rates recreationists stated they would make in response to alternative river levels (Narayanan et al. 1983; Ward 1987). While combining actual behavior to estimate the underlying demand curve with intended behavior to estimate the shift in the demand curve is clever, it would be desirable to rely entirely on actual behavior in estimating both the underlying demand curve as well as the shift in the demand curve.

The contribution of this paper is in providing an approach for using actual data to estimate both the underlying demand equation as well as estimating how the demand equation is indirectly shifted with changes in flow. This is done by noting that instream flow is often an input to producing fishing quality; that is, river flow influences both the amount (e.g., wetted perimeter, depth of pools) and quality of habitat (e.g., water temperature). Thus, an angler might partially judge the adequacy of river flows in terms of fishing quality. Of course, the river flow itself may be of additional value to the anglers in terms of the aesthetics of the river and vigor of riparian vegetation.

Nonetheless, fishing quality is certainly one instream flow related variable of interest to the angler. While the relationship between instream flow and angler benefits has been measured using the CVM for steelhead trout (Johnson and Adams 1988), it has not been measured relying only on actual behavior within the TCM framework.

Incorporating fishing quality into a TCM to be built using secondary data is difficult. If fishing quality is measured as the total fish catch over some period of time it may be a function of both streamflow and the number of fishing trips taken to a site. Because of this simultaneity between fish catch and trips, proper econometric procedure requires that a two equation system be estimated. One equation is the demand for trips and the other is a quasi-supply or production equation for fish catch. In the presence of simultaneity a single demand equation that includes total fish catch may result in biased and inefficient coefficient estimates. Even if the relationship between trips and catch is minimal, the estimation of these two equations simultaneously allow the level of river flow in cubic feet per second (cfs) to be explicitly incorporated as the river quality control variable. Hence, the effect of a change in river flow on recreationists' benefits can be directly measured. No TCM studies allowing this direct interaction between observed visitation data and instream flow have ever been performed (Douglas 1987).

## THE MODEL

The economic benefit of maintaining instream flow is measured as the visitor's consumer surplus or net willingness to pay. Consumer surplus, or maximum net willingness to pay, is the maximum increase in dollars above current costs a person would be willing to pay for the purchase of a good or service. Examples of a "good" are a fishing trip or the viewing of a wild bird. Total or gross willingness to pay is the sum of net willingness to pay and the amount actually spent on the good. Since the amount actually spent is part of the cost of participation, the benefits (i.e., the net willingness to pay) are that amount in excess of what people actually spent.

To estimate the changes in consumer surplus resulting from changes in streamflow in the single-site format, the following single-site pooled time-series cross-section travel cost model (equation [1]) needs to be estimated. This model will be used to estimate the demand for trout fishing along the North Fork of the Feather River. Because individual observation data were not available, a zonal TCM model is used. The zonal form of the TCM utilizes counties of visitor residence as the "zones" of visitor origin. All visits from a given county are aggregated together as one observation. Thus, there are as many observations as there are counties visiting the site. This compares with the individual observation TCM model in which the number of observations equals the number of individuals visiting the site.

Since many site quality variables, such as total fish catch, are available only on a seasonal or yearly basis, estimation of a coefficient on site quality must usually be performed using multi-site cross-sectional data; that is, observing how recreationists respond to differences in site quality across sites (Vaughan and Russell 1982). However, the application of BCA to value changes in site quality often involves changes in quality at just one site. Performing this analysis requires knowledge of the visitors' response to changes in quality at just that site. Since time-series data are rarely available, the possibility of estimating the visitors' response to quality over time at the study site is eliminated. However, for this project, five years of data for individual sections of the North Fork of the Feather River were available. Therefore, it was possible to estimate a single-site demand equation incorporating a site quality variable.

For the recreational site, the following simultaneous system is specified:

$$TRIPS_{it}/POP_{it} = f(TRVCOST_{it}, INC_{it}, FISHCATCH_t, SUBS_i) + u_{it}, \qquad (1)$$

$$FISHCATCH_t = f(FLOW_t, TRIPS_{it}/POP_{it}) + v_{it}, \qquad (2)$$

where:

$i = 1, \ldots, n$ are the number of visitor origins.

$t = 1, \ldots, T$ years.

$TRVCOST_{it}$ is the transportation and time cost of traveling from origin $i$ to the specified site in year $t$.

$INC_{it}$ is average household income in origin $i$ in year $t$.

$FISHCATCH_t$ is a river quality variable at time $t$.

$SUBS_i$ is the price of substitute fishing site available to origin $i$.

$u_{it}$ and $v_{it}$ are random disturbance terms.

$FLOW_t$ is a cubic feet per second of flow in year$_t$.

## CASE STUDY

The study river is the North Fork of the Feather River in Northern California, upstream of the Oroville Dam. The visitation data were collected by the California Department of Fish and Game with funding provided by Pacific Gas and Electric Company. The data were collected using a short on-site survey for the years 1981–1985. The survey recorded such things as county of angler 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). As a result, the zonal TCM model must be used for this study.

The anglers' creel, the number of fish kept by the angler, is incorporated into the model as the fishing quality variable. The level of creel is available for each of the six separate sections of the river for each of the five years of the study. Therefore, river section specific pooled time-series cross-section regressions, that include the creel variable for each of the river sections, can be estimated. Unlike the purely cross-sectional case, where a quality coefficient can usually only be estimated with multi-site data, the quality coefficients can be estimated separately for each river section.

As some sections are influenced by impoundments, and therefore have slow moving water, other sections are true riverine environments. Each of the six river sections is considered a separate recreational site.

Since flow data are available only for section 3, empirical results are derived only for this section. River section 3 spans the North Fork of the Feather River between Rock Creek Dam and Rock Creek power house.

The TCM model specified in this study 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 model can be specified, in time series form, as:

$$TRIPS_{it}/POP_{it} = Bo \cdot TRVCOST_{it}^{B1} \cdot INC_{it}^{B2} \cdot CREEL_{t}^{B3} + u_{it}, \qquad (3)$$

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.
$t$ = years from 1981 to 1985.
$TRVCOST_{it}$ is the cost of traveling from county $i$ to river section 3 in time $t$.
$INC_{it}$ is average household income in county $i$ in time $t$.
$CREEL_t$ is the aggregate number of fish kept by anglers at river section 3 in year $t$.

We chose to model fishing quality as total number of fish kept rather than catch per angler day primarily because we believe, and other fishing research has shown (Sorg et al. 1985:5), that aggregate catch may be a better approximation of how anglers form their perception of a river's fishing quality. That is, anglers form their perceptions, concerning total fish catch, by word of mouth rather than catch per unit.

The variable labeled TRVCOST is a function of round trip distance 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:

$$TRVCOST_{it} = ((rtdist \cdot \text{fuel and repair costs per mile})/2.5 \text{ passengers}) + (rtdist_{it}/40 \text{ mph}) \cdot (\tfrac{1}{2} \cdot \text{wage rate}).$$

Data on fuel and repair costs for each of the five years were obtained from Hertz Corporation surveys (Hertz News 1981–1986). To develop relative prices over the period of the study, the nominal dollar figures were converted to real 1985 dollars. The cost per mile in 1985 was 17 cents.

The secondary data require valuing travel time by the "fraction of wage rate" approach suggested by Cesario (1976) rather than more recent primary data approaches suggested by Bockstael et al. (1987). The value of time was calculated as one-half the County specific wage rates in each of the five years (California Department of Finance 1986).

The nonlinear equation (3) is mathematically equivalent to the nonlinear in the variables double-log form. Model (3) is a constant elasticity model with a homoscedastic dependent variable. With a homoscedastic dependent variable the additive error term in equation (3) is acceptable (Judge et al. 1985).

A nonlinear form is desirable for several reasons. In general, taking the log of trips per capita has been found to reduce heteroscedasticity (Vaughan et al. 1982; Strong 1983). 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.

Since the dependent variable contains some zero observations, equation (3) must be estimated in lieu of the semi- or double-log forms. To exclude counties with zero trips at some time $t$ from the sample is equivalent to excluding relevant information from the sample and would add a truncation bias to the coefficients (Smith and Desvousges 1985).

Ideally, equation (3) should have a variable for price of substitute sites as there are a few substitute stream fishing areas on the west side of the Sierra Nevada Mountains; however, a substitute variable is not included in this analysis. As Caulkins et al.



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| INTERCEPT | TRVCO |
|---|---|
| 0.001 | −2.77 |
| (0.12)[b] | (−19.58 |

(2) Nonlinear Least Squares r

| INTERCEPT | FLOW |
|---|---|
| 2,282.291 | 0.067 |
| (12.35) | (6.34) |

[a] The number of observatio
[b] The $t$-statistics are in paren

(1985) have noted, one cannot a priori determine the direction of bias in consumer surplus estimates from omitting a variable for substitutes. In addition, if other factors influencing fishing demand on the North Fork of the Feather River were changing over the period studied, they should be reflected by a specific independent variable. We are not aware of any significant changes in factors affecting fishing demand other than those included in equation (3); therefore, no additional variables have been included.

The equation for CREEL is:

$$CREEL_t = Bo \cdot FLOW_t^{B1} \cdot (TRIPS_{it}/POP_{it})^{B2} + v_{it}, \quad (4)$$

where $FLOW_t$ is the average discharge downstream of Rock Creek Dam, in cfs, from May to August for the years $t = 1981\text{–}1985$.

A positive correlation is expected between the level of river flow and the level of creel. In some respects, equation (4) is a simple production function which quantifies the productivity of water in producing harvestable fish. While it may be desirable to focus on weekly or monthly flow rather than seasonal average over the five years, we feel the fishery population during a given season is more influenced by these seasonal flows rather than weekly flows as long as critical flow and temperature thresholds are not exceeded.

Since $CREEL_t$ is a measure of total creel in time $t$, it is expected that $CREEL_t$ is an increasing function of $TRIPS_{it}/POP_{it}$. Hence, there is the possibility of simultaneity between equations (3) and (4). Estimated jointly, equations (3) and (4) form a simple, yet powerful, bioeconomic system. The nonlinear format in equation (4) provided a better fit of the data than a simple linear model, which performed quite poorly.

## STATISTICAL RESULTS

The regression results are presented in Table 1. The results were obtained through the TSP's Version 5.1's nonlinear least squares regression program. At each iteration, this quasi-Newton algorithm computes the approximate derivatives with respect to each of the coefficients. The dependent variable is then regressed on these derivatives. The disturbance term is assumed to be distributed normally.

The Two Stage Least Squares (TSLS) estimation procedure is used to estimate equations (3) and (4) as a system. The TSLS regression results for equation (3) are presented in Table 1. Since the regression estimates for equation (4) are mainly of interest for estimating $CREEL_t$ for the TCM demand equation (3), a TSLS regression is not performed for equation (4). However, for informational purposes, Table 1 also presents the nonlinear least squares results for regression (4). Both regressions are

**TABLE 1**

*Pooled time-series cross-section regressions for river section 3 of the North Fork of the Feather River.*

(1) Nonlinear Two Stage Least Squares regression for TRIPS/POP[a]

| INTERCEPT | TRVCOST | INCOME | CREEL | Adj. $r^2$ | Log likelihood |
|---|---|---|---|---|---|
| 0.001 | −2.772 | 0.223 | 1.110 | 0.76 | 2,257 |
| (0.12)[b] | (−19.58) | (0.38) | (2.52) | | |

(2) Nonlinear Least Squares results for CREEL

| INTERCEPT | FLOW | TRIP/POP | Adj. $r^2$ | Log likelihood |
|---|---|---|---|---|
| 2,282.291 | 0.067 | 0.030 | 0.232 | −21,600 |
| (12.35) | (6.34) | (7.06) | | |

[a] The number of observations is 285, or 5 years × 57 counties.
[b] The $t$-statistics are in parentheses.

TABLE 2

*Consumer surplus estimates for increases in flow for section 3 of the North Fork Feather River in 1981.*

| | Consumer surplus | | |
|---|---|---|---|
| Average flow | Total | Net change | Marginal change per cfs |
| (initial): | $108,465 | — | — |
| 20 cfs increase: | $109,923 | $1,458 | $72.90 |
| 100 cfs increase: | $114,137 | $5,672 | $56.72 |
| 200 cfs increase: | $117,605 | $9,140 | $45.70 |

strongly significant and all coefficients are of the expected sign. The CREEL and TRAVCOST variables are significant at the 5 percent level, while INCOME and INTERCEPT are not significant in the TSLS regression. All coefficients estimated for equation (4) are significant at the 5 percent level.

## BENEFITS OF ADDED INSTREAM FLOW

Net economic benefits, or consumer surplus, to the anglers are calculated using the TSLS estimate of equation (3). The area under this demand curve between the TRAVCOST at the initial level of trips and the maximum observed TRAVCOST (taken as the vertical intercept of the demand equation), is the net willingness to pay, or consumer surplus. This integral is approximated through a numerical technique programmed into LOTUS 123.

Since the creel census summary for the Rock Creek section (section 3) of the North Fork Feather River estimates that 4,721 total angler trips were taken to that section in 1981, a sample blowup factor of 15 (total angler trips/estimated angler trips) is used to adjust estimated sample trips and estimated sample consumer surplus up to the level of total actual visits and consumer surplus of the site. Table 2 shows the total consumer surplus under existing flow conditions is $108,465. This translates into a consumer surplus per trip of $23.00.

Table 2 also shows the new consumer surplus when the seasonal average observed rate of flow in 1981 (101 cfs) is increased by 20 cfs, 100 cfs and 200 cfs. These new benefits are calculated by increasing the FLOW variable in the CREEL equation in Table 1 to predict the new level of CREEL. This new level of CREEL is then inserted into the TCM demand equation to predict the new higher level of trips per capita. The area under this shifted TCM demand equation for a 20 cfs increase is $109,923. Thus, the 20 cfs increase during the season adds $1,458 to angler benefits. This translates into a value of $72.90 per additional cfs. As can be seen in Table 2, the bigger the increase in flow, the larger the total benefits. However, also notice that the value of an additional cfs diminishes as flow is increased more and more. Anglers are willing to pay a great deal for the first increases in flow but less for each increment as flow increases. Some functional forms of the demand or value function might result in extremely high flows having a negative value to anglers.

## CONCLUSION AND QUALIFICATIONS

Our analysis demonstrated that a simple bio-economic system could be estimated using angler origin data. The results indicated a statistically significant relationship between flow and catch. Given that the angler's demand function is partially a function of fish catch, we derived benefit estimates for changes in streamflow. We think this is an important result because it is based on relating actual visitation data to an actual fish catch-flow relationship.

The economic value of instream flow reported in this paper is the value to current anglers from the effect of increased flow on improving the number of fish caught on the North Fork Feather River. Lower flows can result in greater angler access to fish and may temporarily result in an increase in catch until reduced water quantity and quality kills the remaining fish. This is not a sustainable change in fishing quality, however, and has been excluded in our analysis. Increases in flow may also increase the size of fish caught, but this benefit has not been measured in this study. The flow in the river may have additional value to anglers in terms of the river's aesthetics. Barring site congestion increases in flow and fishing quality may induce additional anglers to visit the North Fork Feather River thereby increasing recreational benefits. Increased streamflow is much like a public good in that it is also available to other river users such as boaters, swimmers and picnickers. These benefits need to be added to the $73.00 per cfs previously estimated.

To the extent that anglers represent most of the river's users and fishing quality is their dominant concern regarding streamflow, fish stocking might be a viable mitigation option to offset below natural flows. Our simple bioeconomic model provides the information on the productivity of instream flow in producing fish (equation [4]) and how anglers value additional fish caught. This information can be compared with how much society values additional electricity production and the productivity of the river for some other out-of-stream purposes. A comparison between these two values would indicate whether fish production is more inexpensively carried out using flow in the river or at a hatchery.

The estimation procedure outlined in this paper can be generalized to many possible TCM demand functions that include a variable(s) which measures site quality. If the site quality measure is a function of some variable that can be manipulated by a decision maker, then the analyst can directly estimate the changes in visitors' net economic benefits resulting from changes in the level of this variable.

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