ON THE USE OF HEDONIC PRICES TO MEASURE SPORT FISHING DEMAND

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INTRODUCTION

Information requirements of public policy makers have placed a heavy responsibility on economists involved in applied research in the area of sport fishing. Increased fishing pressure and, in some cases, decreasing stocks have generated considerable competition between sport and commercial fishermen over scarce fish. Regional Fisheries Management Councils have sought advice as to how they can "best" allocate the scarce stocks between these two competing interests. Federal and state agencies, too, have sought guidance on estimation of benefits from replenishment and other programs for increasing sport fish catch.

The value of benefits derived from sport fishing is required for determination of net social gains from an optimal economic allocation of fish resources. These gains are difficult to measure (McConnell and Norton). The problem of estimation of the values is the composite nature of the experience. That is, the sport fish is only one element in an array of composite products consumed during a recreational outing.

Boating, comradery, and isolation are among other inputs identified to be consumed by sport fishermen (Spaulding). Fortunately, advances in economics (e.g., Lancaster) have offered new avenues of pursuit in estimating the value of the sport fish. The purpose of this paper is to illustrate how developments in the understanding of composite products are being applied to the measurement of sport fish value, some of the inherent problems that arise, and a direction that might be useful to explore.

At the core of the paper is the hedonic price equation that relates the cost of an activity (such as a sport fishing trip) with various outputs (such as sport fish) produced during the activity. In this paper, we present a summary of how hedonic equations have been applied in sport fish research and two conflicting interpretations of the hedonic price equation. We offer a resolution of the conflict by presenting an interpretation based on a problem conceptualization presented in the second section. Practical difficulties and potential uses of the approach are contained in the third section. A potentially useful modification is discussed in the fourth section.

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CURRENT APPLICATIONS AND INTERPRETATIONS

The sport fishermen acts both as a producer and consumer of a vector of products or outputs (z) associated with the recreation activity. Among these outputs could be fish, boating and isolation. The vector of the amount of inputs (X) used to generate the activity could include equipment, bait, boat fuel and the individual's time. With a vector of input costs (P), the total cost of the sport fishing outing (C) is the sum of input costs (PX'). For simplicity, conformity in the matrices and vectors is assumed throughout the paper.

The current practice is to estimate a function from which hedonic prices are derived:

$$c = c(z,p) \qquad (1)$$

where c(...) is a vector of functions relating per unit activity costs to outputs and input prices. A typical specification is linear (King) and for the two output case is:

$$C = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2. \qquad (2)$$

The coefficients α_1 and α_2 show, in certain instances, how much the consumer is willing to expend to obtain an additional unit of output (Z_1 or Z_2). The equation has been specified non-linearly (Harrison and Rubenfeld) and has been termed the hedonic price equation with the hedonic prices being α_1 and α_2. It has also been referred to as an expenditure function (Brown, Hay and Charbonneau).

There is substantial variation on this general theme. Usually, however, equation (1) is differentiated with respect to output, yielding a function:

$$\pi(Z,P) = \partial C/\partial Z. \qquad (3)$$

The function (π) showing hedonic prices has been referred to both as a marginal cost function (Bockstael and McConnell) and a marginal willingness to pay function (Harrison and Rubenfeld). Brown avoids the issue by referring to it as a set of equilibrium prices.

Those who consider equation (3) a marginal cost function, generally proceed to estimate what they refer to as a demand curve for the outputs. This requires estimation of:

$$Z = D(\pi, k_1) \qquad (4)$$

where D(...) is the demand function and k_1 are exogenous shifters of demand. Income and marital status are examples of possible shifters. On the other hand, those that consider equation (3) to be a marginal willingness to pay function obtain the necessary supply function S(...) by using equation (3) and estimating:

$$Z = S\ (\pi,\ k_2) \qquad (5)$$

where k_2 are exogenous shifters such as fish population or method of catch.

The set of assumptions with which each author is working must be made explicit if a clear understanding of the general method is to be made. The remainder of the paper attempts to make explicit some of the assumptions and resolve some of the apparent conflict.

CONCEPTUAL PROBLEM

It is useful to return to the original conceptualization of the problem for clarification. The theoretical basis for the current practice is found in the demand for characteristics (Lancaster) and the household production (Muth) literature. The former focuses on consumers deriving satisfaction from characteristics (outputs) embodied in goods (inputs), whereas the latter emphasizes consumers producing desired outputs with purchased goods and their time. Because the fishing experience requires much production by the consumer, the household production terminology is more appropriate than the "hedonic" terms. However, the original Lancaster framework is a useful point of departure to understand the technique.

Lancaster's article on product characteristics serves as a cornerstone of the hedonic price approach. He asserted that the individual does not desire goods consumed but rather the characteristics or attributes that the goods possess. Milk, for example, is both a thirst quencher and a source of calicum. In this manner, a sport fishing trip is like milk in that it provides attributes such as the excitement of landing fish, protein from consuming fish, and boating enjoyment. The interest is in developing the demand and supply relationships for the individual attributes rather than for the composite good.

THE LINEAR SYSTEM

Because most hedonic price equations have been estimated in a linear form, our illustration uses assumed linearity in production processes, an assumption which is later dropped. The individual is assumed to maximize utility derived from attributes (outputs, Z) that goods (inputs, X) help produce. Activities (Y) or processes (i.e., sport fishing) transform the inputs into outputs. With an assumption of linearity, inputs are transformed into an activity via a matrix, A, whereas the activity is transformed into outputs via a matrix B. This is represented as:

Maximize $U(Z)$

Subject to:

$$Z = BY$$
$$Y = AX$$
$$PX' = I$$
$$Z,\ X \geq 0$$

where I (a scalar) is the individual's income. The optimal allocation of income requires a relationship between input prices (P) and outputs (Z) such that (for interior solutions) the per unit activity cost vector is:

$$C = P \cdot A^{-1} = B(\partial U/\partial Z \cdot \partial I/\partial U) = B\ f(Z) \qquad (6)$$

where the elements of A^{-1} show the amount of input per unit activity and C shows the expenses of all activities used to produce Z. Equation (6) gives the marginal value that an activity produces via its production of outputs.

A two-activity, two-output case is illustrated in Figure (1) where points 1 and 2 represent outputs of z_1 and z_2 attainable with income solely allocated to activities y_1 and y_2, respectively. Points along the line $\overline{12}$ are possible with combinations of activities $(y_1,\ y_2)$. The linearity of these combinations is due to the presumed linearity in A and B. Maximum utility is achieved with the tangency (A) of the indifference surface (U) and the consumption possibility frontier 012.

The linearity assumption simplifies the procedure for estimation of a representative consumer's marginal valuation of an output. Consider expenses of an outing as a cost (c_1) associated with producing sport fish (z_1) and boating (z_2). Also, allow that these expenses are taken from a sub-allocated budget (I_1) that the consumer has allocated to the entire trip (Strotz). In this case, one equation in system (6) can be expressed as:

$$c_1 = (\partial U/\partial z_1 \cdot \partial I/\partial U)\ B_{11} + (\partial U/\partial z_2 \cdot \partial I/\partial U)\ B_{12} \qquad (7)$$

If one knows the amount of fish (B_{11}) that a sport fishing activity will yield and the amount of boating (B_{12}) a sport fishing activity will yield, then using the relation $Z = BY$ one can substitute for B_{11} and B_{12} in equation (7) and estimate the representative consumer's marginal valuation as:

$$c_1 = \alpha_0 + \alpha_1\ (z_1) + \alpha_2\ (z_2) + \alpha_3\ I_1 \qquad (8)$$

where z_1 is the amount of sport fish per activity, z_2 is the amount of boating per activity, and I_1 is added to adjust for different subbudgets. The interpretation of α_1 follows from equation (7) as the marginal value of sport fish per fishing outing (z_1).

The specification of equation (8) resulting from equations (6) and (7) suffers from a major limitation - the consumer's marginal valuation (α_1) is independent of the amount of the output produced per outing. Theory suggests that the marginal valuation of output should decline with increases in output level. This implies that

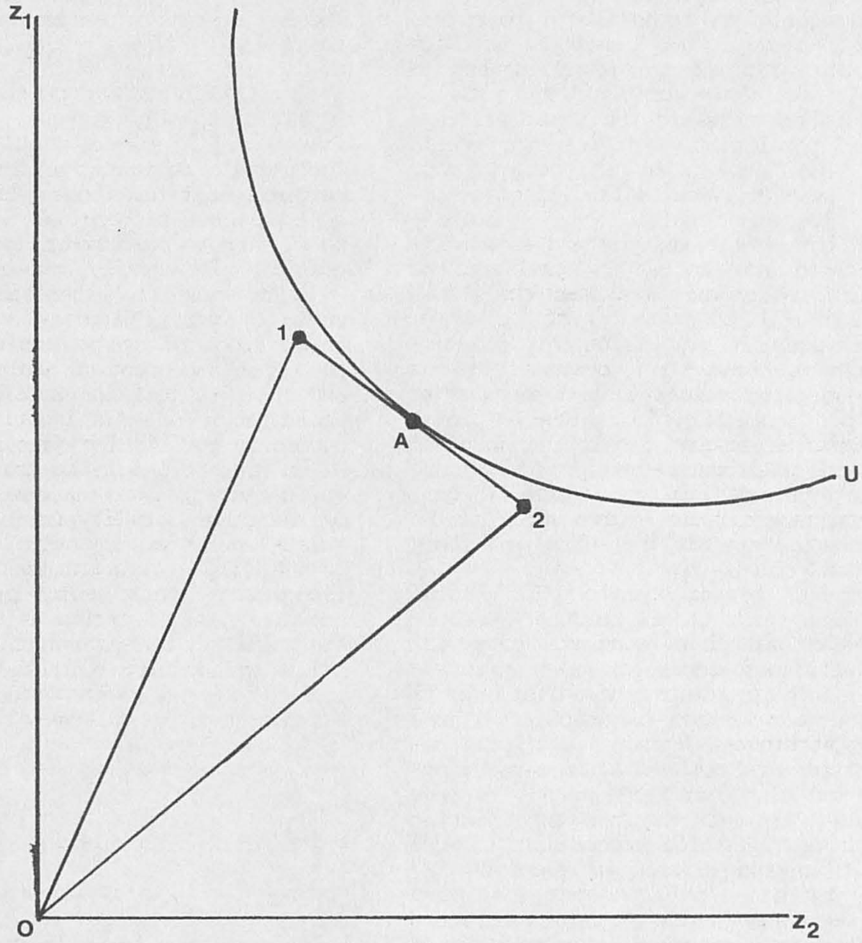

FIGURE 1. Equilibrium with linear technology, two outputs (z_1, z_2), two activities (y_1, y_2). and an indifference surface (U).

either consumers do not have declining marginal utilities associated with outputs or equation (8) only reveals one equilibrium point for a representative consumer.

This limitation was addressed by Bockstael and McConnell, and their development provides an insight into possible improved techniques. To explore these techniques, it is useful to introduce graphics in terms of total cost per activity of an output (z_1) and the total willingness to pay per activity for that output. (Figure 2).

On the vertical axis are the total willingness-to-pay and total cost. For interior equilibria (e.g., z_1^*), the marginal output cost (slope at a) equals the marginal willingness-to-pay (slope at b). This results because the individual accrues both the producer's and consumer's surplus associated with an output level and the sum of the surpluses is maximized when the slopes are equal.

The reason equation (8) yields only one marginal valuation is easier to understand if one considers the marginal values that correspond to total values of Figure 2. For the given total cost and willingness-to-pay curve, the marginal cost (supply) and willingness-to-pay (demand) are illustrated in Figure 3. The derivative of equation (8) is the marginal cost curve which has no variables which would permit the shifts necessary to trace a demand curve.

The logic for terming equation (8) a total cost curve relates to rational producer-consumer behavior. Individuals have no reason to reveal their total willingness-to-pay in their trip expenses and should only reveal minimum total costs of a particular combination of outputs. There might be cases, like real estate, where the nature of the sales transactions might cause individuals to reveal the total willingness to pay. This, of course, implies that the input market has perfectly discriminating monopolists. More importantly, the specification of equation (8) suggests that there is only one marginal cost curve (i.e., the derivation of equation (8)) and that the marginal cost function is independent of output and other factors. Thus, it is obvious that the problem specification results in estimation of only one marginal valuation and that interaction terms between output and other factors must be included in the total cost function if the demand curve relationship is to be estimated. Thus, it is necessary to respecify our problem so that the demand can be estimated.

THE NON-LINEAR SYSTEM

Rather than going back to equations (6) - (8) and respecifying another technology matrix which would make marginal costs dependent on other factors, we use the duality theorem and consider cost curves directly. The original problem specification was to illustrate the roots of the most commonly used hedonic price equation and, since the limitations of that formulation have been developed, it is useful to go to the more general form of the problem.

Following Pollack and Wachter, the hedonic price equations can be written as:

$$C = f(Z, P, k_2) \qquad (9)$$

The key element in estimating the demand curve is that:

$$[\partial(\partial f/\partial z_i)\partial z_j] \cdot [\partial(\partial f/\partial z_i)/\partial P] \cdot [\partial(\partial f/\partial z_i)/\partial k_2] \neq 0 \qquad (10)$$

for all i such that $i \neq j$. In other words, the marginal cost function ($\partial f/\partial z_i$) must be dependent on other factors, whether they be other outputs, input prices or exogenous shifters of costs.

The case of $\partial(\partial f/\partial z_i)/\partial z_j \neq 0$ is relevant to sport fishing and it is necessary for joint products. When the marginal cost of an output is dependent on another output, the inputs and activity must be yielding two outputs. This could occur on a fishing trip if boating were as necessary for fishing, yet was an output itself. Fixed proportions in the output mix must not occur because costs then cannot be related to one or the other output. Perfect collinearity would exist between the z_i.

A simple illustration of a cost specification which allows demand to be estimated may be useful. Let k_2 be a variable which explains the skill of a fisherman. One might expect that skills would shift the marginal cost of producing a fish so that total cost function for sport fishing could be written:

$$c_1 = \alpha_0 + \alpha_1 z_1 k_2 + \alpha_2 z_2 + \alpha_3 I_1 \qquad (11)$$

The marginal cost curve or supply curve is:

$$\pi_1 = \partial c_1/\partial z_1 = \alpha_1 k_2 \qquad (12)$$

which does vary across individuals so that a demand curve can be estimated. The demand curve then can be estimated as:

$$z_1 = D(\pi_1, k_1) \qquad (13)$$

where k_1 might be a cultural variable.

IMPLEMENTING THE TECHNIQUE

To this point, the discussion has been largely abstract and mathematical so that the system could be succinctly presented. The actual implementation of the technique, however, entails a number of practical problems and choices. Attention is now directed to practical implementation of the technique.

DATA DEFINITION

An inherent problem in econometric analyses is the selection of an appropriate measurement

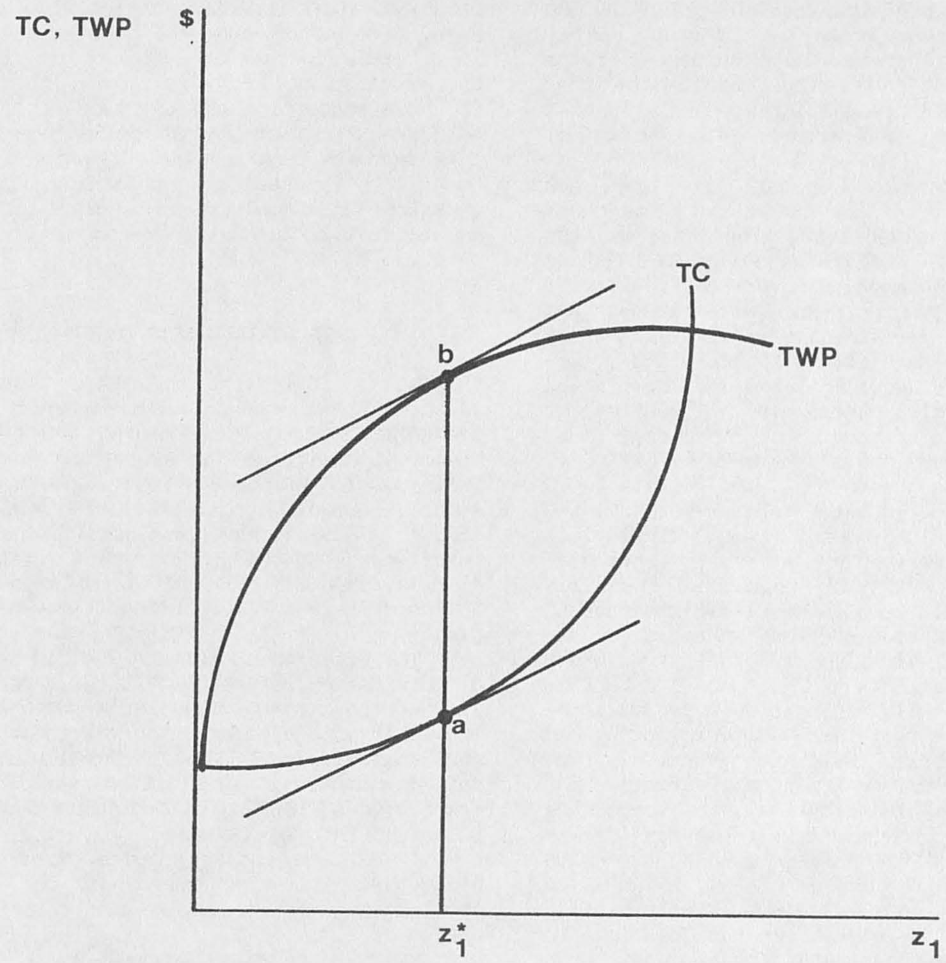

FIGURE 2. Total cost (TC) and willingness to pay (TWP) as related to output per activity.

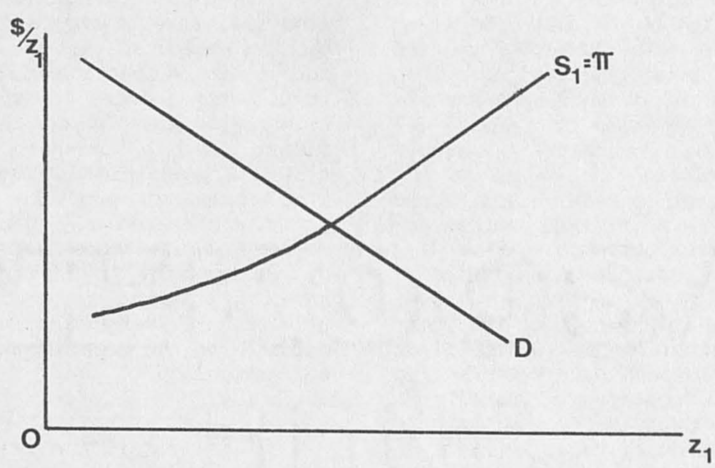

FIGURE 3. The marginal cost (S) and willingness to pay (D) for output per activity as related to output per activity.

long enough to recognize long-run plans concerning sport fishing trips but short enough to allow for estimating output substitution during any one trip. To accomodate both, an intercept survey can be designed to record both number of trips per year information and daily trip cost information. One can then use the intercepted trip as a representative trip and aggregate to get annual information.

There are several aspects to consider when determining how to measure the outputs (or characteristics) of a given trip. The first relates defining just what the individual values during the trip. Most researchers have a difficult time measuring ethereal outputs such as excitement and will most likely resort to some combination of number of fish, length of the longest fish or total pounds to act as surrogates for the "true" outputs. Secondly, there is a question of whether actual or expected catch is the more meaningful determinant of expenditures. Some preliminary work suggests that, for certain types of fishermen, expected catch is much more related to expenditures. This result would be logical for those fishermen who are not reliable predicters of what they are going to catch. There remains the difficult problem of eliciting accurate responses to a question such as "What did you expect to catch?" Finally, one must define the other outputs of the sport fish trip. The problem is not necessarily naming them but rather determining how to measure such esoteric outputs as boating, isloation or comradery. There has been some initial success in using boat length as a proxy for boating pleasure, but this represents only the beginning of an extensive search for appropriate proxies. A problem even arises with defining "isolation" because of the presence of other vessels in the vicinity fished since fish often run in schools so that one must be close to others if the best fishing is desired. A large sample may be necessary to help reduce the collinearity problem.

Another issue arises in the treatment of sport fishing costs. When one observes persons during a sport fishing trip, certain decisions have to be made concerning how to allocate fixed costs associated with the trip. A $1,500 rod and reel, for example, will normally last longer than one trip. Does one use the depreciation associated with using the rod and reel or a fixed depreciation period for the equipment? Variable costs are usually considered to begin at the pier, including such things as bait, gasoline and refreshments. These are not unique problems associated with the hedonic approach and equally apply to more traditional methods of analysis.

Questions also arise as to whether travel costs should be included in the cost of the sport fish trip. The resolution of that question is not easy. One would expect that total trip costs, including travel costs, would influence the number of trips taken per year (a la Clawson), however, they may not be influential in determining whether someone fishes once on the trip. Having sampled in Ocean City, Maryland and around Williamsburg, Virginia, the authors are well acquainted with the casual fisherman whose principal purpose is a vacation, not necessarily fish. One could view the vacationer's decision in a two-stage process. Money is allocated to the vacation or trip first, and then decisions are made concerning how to allocate the sub-budget between fishing and nonfishing activities. This approach requires including a sub-budget for total trip expenses and nonfishing activities in equation (12). Which nonfishing activities or substitutes should be included is open for debate.

DATA AVAILABILITY CONSTRAINTS

It is clear that the theory portrays each fisherman as a market, with internal supply and demand motivations determining the observed behavior. Each creel intercept or interview, is analogous to an observation of one market, presumably in equilibrium. Variations in the equilibrium can be observed by considering different interviewees at one point in time (cross-sectional analysis) or by observing the same individual during different time periods (time-series analysis).

The researcher ultimately decides which form of observation to use, but there is one consideration worth noting. Currently, there is considerable advantage to applying the theory to cross-sectional samples. The time delay in obtaining sufficient number of time series observations makes time series analysis disadvantageous if results are to be obtained within a reasonable time. Cross-sectional samples offer the possibility of estimating the supply and demand for sport fish with one sample in a relatively short period of time.

STATISTICAL

The estimating equations (11) and (13) do not have the usual statistical properties. Equation (11) reveals that activity cost is a function of outputs, yet equation (13) states that outputs are a function of the hedonic price which is directly related to activity costs via equation (12). Also, we are using an estimated coefficient (α_1) to create a variable for equation (13). All of this suggests that normal estimating procedures probably are not sufficient to estimate the system. There is undoubtedly some degree of simultaneous equation bias compounded by nonlinearity in the system. These problems have not, however, been adequately addressed. Readers are referred to Kelejian (1971) for guidance on the general problem of nonlinear system estimation.

OBJECTIVES OF POLICY

Another issue is determining what information is needed to improve resource management decisions. Sometimes information is developed for the researcher's benefit, but the more usual circumstance has the researcher providing information that will be useful in a policy context. Policy decisions may range from actions to improve catch per sport fish outing to those allocating fish between recreational and commercial harvest. Economic considerations generally play a major role in these decisions.

Economic analysis of government expenditures--whether it be for sport fishing sanctuaries, hatchery programs, or information pamphlets--requires estimation of net benefits. The net benefit function (e.g., willingness-to- pay function) normally will have as an argument a factor that the manager can influence. (The question, then, is what are the factors that managers can control?)

The usual practice of resource managers is to change only factors in the supply equation. The population of sport fish and the amount of sport fish landed per day are factors that have been influenced by policy makers. The former is affected by habitat or hatchery programs, whereas the latter arises when creel limits (catch limits) are set. To provide necessary policy information, the researcher must determine not only the relationship between the willingness-to-pay for the fish and the amount of fish already caught, but also the relationship between number of trips and species abundance. The joint determination of sport fish trips and fish caught per trip is addressed explicitly in Bockstael and McConnell.

A NEW DIRECTION

Suppose there is reason to believe that the marginal cost of output is independent of other factors. What should the researcher do to assure that both supply and demand equations can be estimated.

There is a method that can potentially remove many of the previous complications in an interview. The question would attempt to elicit the sport fisherman's total willingness-to-pay for an output. Given that the individual has already incurred the fishing activity expenses, one might be able to find out the minimum catch required to make the trip acceptable. In eliciting the acceptable catch response, the individual would be shifted from the total cost curve (pt. a in Figure 4) horizontally to the total willingness-to-pay curve (pt. b). The substitution of minimum catch for actual catch in the hedonic price equation would transform it from a total cost curve to a total willingness-to-pay function. The derivative of the total willingness-to-pay function with respect to an output yields the demand curve directly. Thus, one may be able to estimate both supply and demand from one cross-sectional data base by estimating two forms of price equation (1).

It is worthwhile to show the normal benefit measure, consumers surplus, in figure 4. Assume the individual has landed z_1^*, pounds of fish with expenses TC_1. The individual, however, would be willing to pay TWP_1 for z_1^* amount of fish and consumers surplus whould then be $TWP_1 - TC_1$. Thus, one can determine the net benefits from estimates of total cost and total willingness-to-pay.

If the respondents can give well-reasoned estimates of a minimally acceptable catch, then the complicated process developed earlier may be avoided. With both actual (or expected) catch and minimally acceptable catch, the researcher estimates equation (1) twice. The first equation would include minimally acceptable catch and variables associated with total willingness to pay function. The derivative of the first equation then is a demand curve for sport fish. The second estimated equation would include actual (or expected) catch and variables associated with a total cost curve function. Its derivative would be a supply curve for sport fish.

CONCLUSION

This paper provided a review of various lines of current thinking on the use of hedonic prices to measure demand for unpriced natural resources in general, sport fish in particular. It was not intended to offer a complete answer as to "the proper" manner to estimate the demand for sport fish. Rather, it was intended to give the reader an understanding of the complexity of the problems arising in applications of this technique. At the same time, we have an insight into the potential of the technique was revealed.

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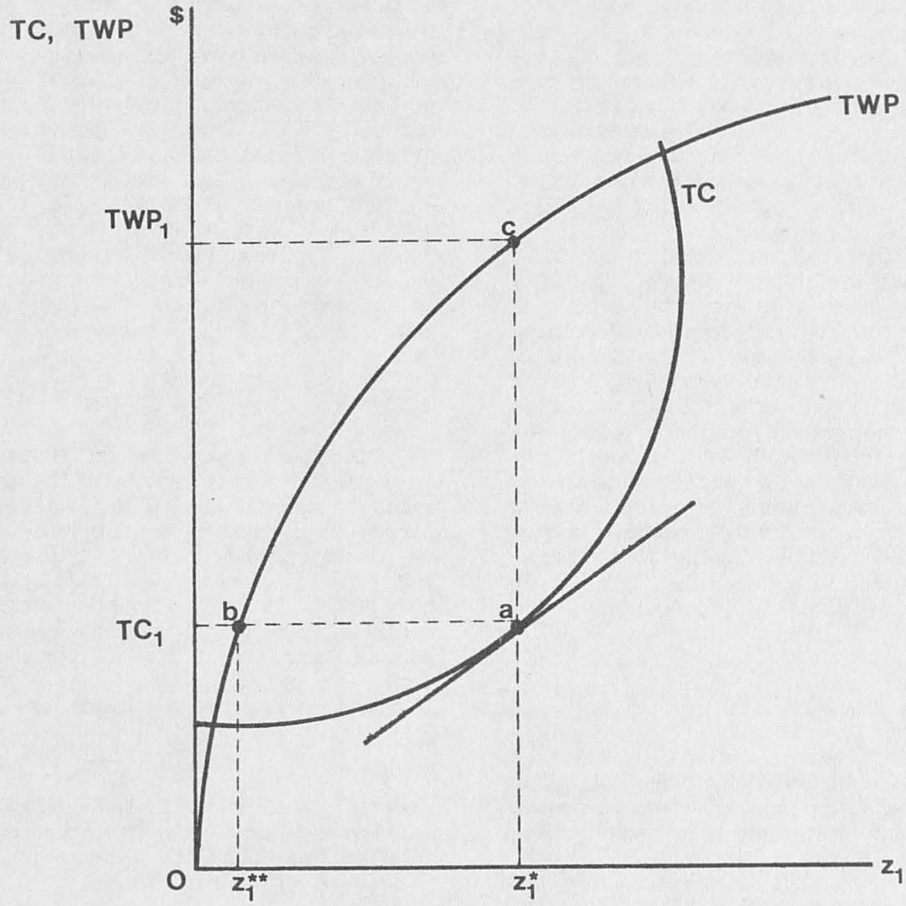

FIGURE 4. Total cost (TC) and willingness to pay (TWP) for output per activity as related to output per activity - Response to actual catch (a) and acceptable catch (b).

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