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EXACT WELFARE VALUES OF NATURAL RESOURCE QUALITY: A REGIONAL APPROACH[1]

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I. INTRODUCTION

Public resource managing agencies are viewed as wishing to maximize the economic value of products from their land and water base. If that is true, then a public agency which has a given set of productive resources and is producing products for sale in a market economy, the efficient solution to the multiple product question is obvious: The agency should produce that combination of outputs so that the marginal rate of transformation along its production possibilities curve is equal to the inverse ratio of the competitive market prices for each pair of products taken two at a time. However, when one or more of the land and water products is not sold in the market economy, for example recreational trips or environmental quality improvement on the public lands, the efficient solution is more difficult to obtain, because the competitive price does not exist. It is precisely this lack of price information which has motivated theory and methods to estimate recreation and related non-market goods' demand schedules (Cory and Martin, 1985).

Two widely used procedures for estimating such non-market values include the "travel cost method" and the "contingent valuation method". While valuation information generated by traditional travel cost and contingent valuation methods is useful in choosing among mutually exclusive production alternatives on a given large scale land base (e.g., Martin, Tiney and Gum, 1979), most land and water management decisions for obtaining objective measures of resource quality, particularly as such measures relate to individual's subjective resource quality perceptions. Third is incorporation of measured resource quality, once defined, into multisite demand functions in a manner consistent with underlying utility functions. Fourth is measuring exact welfare changes associated with price and/or quality changes at one or more sites.

Regarding the first major area, specification and estimation of multi-site ordinary demand systems (ODS) two approaches have been followed: (1) specifying one (or more) utility functions directly, then deriving the algebraic form for each resulting ODS, and (2) specifying the ODS directly in such a way that they satisfy the integrability conditions, i.e., are consistent with some underlying utility function.

Given that direct utility function specification is chosen, the question arises as to what one should do about demand functions for goods not of interest (all other goods than the sites in question). One way is to assume that prices of other goods move in proportion to each other. By assuming this, we can specify all other goods as a Hicksian composite commodity in the utility function (Hanemann, 1984b).

A major unresolved difficulty relates to how one should specify a multisite utility function if we choose not to take the Hicksian composite commodity approach. For example, even if we assume separability in the utility function between recreation sites and all other goods (Hanemann, 1984b and 1984c) this raises as yet unresolved difficulties in the specification and estimation of multi-site demands.

The second major area discussed above, i.e., objective versus perceived site quality linkages, has long been recognized as a problem. For example, Kneese (1968) observed that evaluating recreational benefits associated with improved (water) quality was a major barrier to rational (water) quality management. Before economists can meaningfully establish welfare measures of site quality improvement, two prior barriers must be overcome: (1) forecasting the effects of management policies on objective (water) quality parameters, and (2) establishing the linkage between objective water quality parameters and sources of perceived site attractiveness. An excellent review of some of the research issues relating to perceived versus objective measures of environmental quality is developed by Craik and Zube (1976). For the remainder of this paper, it is assumed that objective measures of site quality can be meaningfully defined.

The third major area is that of incorporating measured resource quality into multisite demand functions in a manner consistent with underlying utility functions. Here, it is generally recognized that in order to estimate exact welfare measures associated with quality change at one or more sites using fitted demand equations, these demand functions should be consistent with an underlying quality-dependent utility function. Without this consistency, it is not clear how welfare evaluation could be made.

In this vein, Maler (1974) demonstrated that if the utility function possesses "weak complementarity" between a single site's consumption and that site's "quality" (loosely speaking, marginal utility of quality improvements at a site is zero when price is sufficiently high to reduce quantity consumed to zero), then the resulting demand functions posses some desirable attributes. Specifically, the area beneath the individual's compensated site demand schedule resulting from a quality change exactly measures the desired compensating variation equivalent/variation (CV/EV) welfare change indicator. However, he did not generalize to multiple sites.

As to multiple site systems, with the exception of some recent work by Hanemann (1984a, 1984b, 1984c), little has been done on the specification of quality in multisite utility functions. Hanemann however, has shown that the functional form for the utility function which should be chosen for a particular analysis would depend on how quality was viewed as entering the utility function. For example, many recreation site systems are such that a quality change at each site affects the demand at all sites in the system.

Hanemann develops several classes of associated ODS, each consistent with an underlying utility function in which quality enters in a specialized manner.

Clearly, more work is needed in classifying functional forms for utility functions in which site quality enters that function in ways which are meaningfully related to environmental quality policy decisions. In particular, we need to know more about which kinds of resource quality affects the utility function in what way, and the resultant ODS which results from each utility function specified.

The fourth major issue above, measuring exact welfare changes associated with one or more sites' price and/or measured quality changes, is where much more work needs to be done. Willig (1976) has demonstrated how such exact welfare change measures can be approximated for the ODS in which quality is not a factor. Hanemann (1982) has shown how to recover exact CV/EV welfare change measures from quality change for some of the utility functions mentioned above. However, most of this work has yet to see much empirical application among practitioners.

Thus, there has been significant progress in each of these four major areas, but there are several gaps remaining, and even where the gaps have been closed, little in the published literature has presented an integrated treatment for practitioners.

The objective of this paper is to demonstrate to practitioners how some of the theoretical developments discussed above can be applied to empirical problems related to valuing multiple site quality changes. This objective is met by presenting a numerical example which demonstrates an empirical method for recovering exact welfare change measures associated with price and/or quality changes in systems of multiple recreation sites.

This paper is organized into four remaining sections. First, we briefly review theory of welfare measurement associated with quality change for systems of recreation site demand equations. Next, we propose a four-step procedure for empirically recovering a multi-site quality-dependent welfare change measure. Third, we present a simple numerical example which demonstrates how to employ the four-step procedure. Finally, the conclusions are presented.

II. WELFARE MEASURES FOR MULTI-SITE QUALITY CHANGES

Following Hanemann (1982), suppose that b_{ik} represents the amount of the kth (objectively measurable) quality characteristic associated with a visit to site i, where k = 1,...,K and 1 = 1,...,N and let b_i be an index of the ith site's overall quality, some function of $(b_{i1},\ldots,b_{ik})$.

Assuming then that the representative visitor's utility function varies with visits and the quality index b_i at each of the N sites, that quality-dependent utility function would be:

(1) $$U(x_1,\ldots,x_N,b_1\ldots,b_N z)$$

where x_i is the visit rate to the ith site, and z measures the consumption level of the Hicksian composite "all other goods". In general, then we can write each ith site's resulting ordinary demand function derived from that underlying utility function as:

(2) $$x_i = h_i(p_1,\ldots,p_N,b_1,\ldots,b_N,q,y)$$

where p, is the ith site price (possibly including travel time), q is the price of z and y is money income.

Alternatively, viewing the visitor as an expenditure minimizer rather than a utility maximizer, the solution to the expenditure minimization problem gives rise to the N compensated demand functions:

(3) $$x_i^* = g_i(p_1,\ldots p_N,b_1,\ldots,b_N, q,u^o)$$

where u^o is the utility level reached under initial price, quality, and money income levels. Thus (3) is the Hicksian compensated demand system (HCDS).

The expenditure function defines the minimum value of expenditure (E) required by the recreationist under any price or quality regime to reached u_o, and is defined as:

(4) $$E = E\ (p_1,\ldots p_N;b_1,\ldots,b_N;u^o)$$

The expenditure function E, in practice can be computed as the sum of compensated demands in (3) multiplied by the respective site prices. Assuming that each site's quality index b_i contributes positively to utility, E will be lower as each b_i increases.

Exact welfare measures are defined as the finite change in E due to changes in price/quality. Suppose superscripts "o" refer to initial conditions and "1" refer to terminal conditions. For a constant money income, y, the CV and EV from multi-site price/quality changes are respectively measured as:

(5a) $$CV = E(p_1^1,\ldots p_N^1;\ b_1^1,\ldots b_N^1;\ u^o) - E(p_1^o,\ldots p_N^o;\ b_1^o,\ldots b_N^1;\ u^o)$$

(5b) $$EV = E(p_1^o,\ldots p_N^o;\ b_1^o,\ldots b_N^o;\ u^1) - E(p_1^1,\ldots p_N^1;\ b_1^1,\ldots b_N^1;\ u^1)$$

The CV (EV) measures the money income change necessary to offset (take the place of) the utility change due to price/quality changes at one or more sites, (Hanemann, 1980). This paper proposes and presents a numerical example of a method for estimating the exact welfare measures in (5).

III. A PROPOSAL

Morey (1984) demonstrated that it is not always necessary to use the Marshallian measure (consumer surplus) approximations to recover exact welfare change measures for estimated ODS. Specifically when one begins by specifying the utility function directly and then deriving the corresponding ODS (rather than the traditional way of specifying the demand equations directly) then the

Marshallian approximations are unnecessary. That is, given a known utility function the expenditure function can be derived and hence the exact CV/EV can be determined with no Marshallian approximation required. Hanemann (1982) demonstrates that Morey's conclusions can be carried over to the case where quality enters the utility function, as long as quality enters the utility function exogenously and is not a choice variable to the consumer.

In this section, we propose that the developments of Morey and Hanemann be used to advantage by offering the following four steps to obtain exact welfare measures from quality change in recreation site systems: (1) specify one or more alternative algebraic forms for the quality-dependent utility function, each function which is defined by both an algebraic structure and general parameters to later be estimated; (2) analytically derive the corresponding ODS, HCDS, and the expenditure function (EF) for each utility functional form considered; (3) use data on observable consumption choices to estimate the coefficients for each ODS, thence choose that ODS which best fits the observed data; and (4) based on the estimated coefficients and known relationship between the ODS, HCDS and EF from (2), recover the exact welfare change measures for any price/quality policy desired. Each step is further discussed.

Step I. First, the researcher specifies one or more candidates for a multi-site utility function for the representative recreationist. Each candidate function would include a family of unknown parameters, which would be later estimated. Depending on a prior knowledge of the recreation site system in question, each candidate utility function would include quantities and qualities of all relevant sites as arguments, as in the general function (1). Knowledge of the relationship between the utility function and the ODS is needed because it allows us to later recover the exact utility function. That is each quality-dependent utility function is initially defined by both an algebraic structure and general parameters. Once numerical values of those parameters are later recovered by estimating the associated ODS from market data, we insert those values back into the utility function where only general parameters were previously available. Thus, we first go forward from the utility function to the ODS, which later allows us to go backward from the estimated ODS coefficients to the fully specified utility function. This proposed approach is a logical out-growth of utility function specification in which qualities are not arguments.

Thus, suppose that we define

(6) $$H_i[p_i,\ldots,p_N,q,y]$$

as the known formula for the ordinary demand function for the ith site, when quality does <u>not</u> enter the utility function, i.e., when utility is defined as

(7) $$U\ (x,z) = U(x_1,\ldots,x_N,z)$$

In this light, given the general quality-dependent utility function in (1) and associated ODS, Hanemann develops three methods for introducing quality into multisite utility functions, and provides examples of how the quality-dependent ODS (2) can be derived for each method.

The first method for incorporating quality is to add to the utility function in (7) a particular function $f_i(x_i,b)$. One example includes the well-known "pure repackaging" case, discussed below: (Fisher and Shell, 1967). This results in the translation of (7) to

(8) $$U(x,b,z) = U(f_1(b_1)x_1,\ldots,f_n(b_n)x_n,z)$$

where $f_i(b_i)$ is interpreted as a function of site i's quality index. The resulting quality dependent ordinary demand functions translations of H[·] in (6) are:

(9) $$x_i = \frac{1}{f_i(b_i)\ H_i[p_1/f_1\ (b_1),\ldots,p_N/f_N(b_N),q,y]}$$

for each ith site.

A third method is to take a standard neoclassical utility function and write its coefficients as functions of b. For example, one might translate the utility function underlying the linear expenditure system (LES) into quality space. Given the LES

(10) $$U(x,z) = \Sigma R_i \log x_i \text{ where } \Sigma R_i = 1$$

where the last element of i refers to the Hicksian composite good, z.

The resulting quality independent ordinary demands (6) for each ith site is:

(11) $$H_i[p,y] = \Sigma R_i \; y \;/\; p_i$$

One way of translating U(•) for the LES in (10) into quality space such as required by (1) is:

(12) $$U(x,b,z) = \Sigma R_i \log (x_i - T_i)$$

where T_i is some specified $-f_i(b_i)$.

That particular quality translation of (7) results in the quality dependent ODS, where for each ith site:

(13) $$h_i(p,b,y) = \Sigma R_i/p_i \; [y + p_j \; f_j(b_j)] - f_i(b_i)]$$

The reader is referred to more details in Hanemann (1984b). In any case, these three methods of systematically incorporating site quality into the hitherto quality-independent utility function provide ready means of translating the quality-independent demands of (6) into the quality-dependent demands required by (2). One only needs to know how to derive the demands in (6) from the utility function in (7) and apply the translations of the utility functions into quality space to recover the quality-dependent ODS.

Step II. Next, for each candidate utility function specified in step I which is under tentative consideration, the researcher would analytically derive two important families of functions. No data would be used at this step. The two families of functions to be derived are (1) the ODS and (2) the EF, where the EF is found by computing the HCDS.

Knowing the link between the utility function and the HCDS/EF is also important, because it is the fully specified EF which allows us to compute the exact welfare measures from the relevant price/quality policy changes.

Step III. The third step brings in the real data. Assuming that a methodology such as the travel cost method is used, one would assemble multi-site, multi-zone-of-origin data on site prices, incomes, quantities (visitation levels), and qualities. These data would be empolyed to completely estimate the parameters of all the candidate ODS's specified in general form from Step I. Each estimated ODS would be known to be consistent with an underlying utility function. Standard statistical goodness-of-fit measures would be employed to choose that demand system (and implied underlying utility function) which best fit the market data.

Step IV. Last, after finding the ODS which best fit the market data, one would use the estimated parameters from the demand system to fully specify the utility function, expenditure function, and exact welfare measures, as allowed for by completion of Step II.

Note that under this four step proposal, at no point are we asked to integrate beneath systems of demand functions to evaluate quality-dependent welfare change measures. In fact, in following this proposal, there is no direct use for the ODS other than that of using their parameter estimates to recover the expenditure function. For welfare evaluations one can ignore the ODS after inserting its parameter estimates into the general EF from Step II.

Furthermore, since areas beneath demand functions are not used to calculate welfare measures, we are relieved of having to specify the utility function as possessing Maler's "weak complementarity" conditions. Thus, we can specify utility functions for which no finite site price reduces (compensated) site demand to zero, yet still be able to empirically recover an exact welfare change measure from observable consumption data.

III. NUMERICAL EXAMPLE

This section illustrates how the proposed four-step procedure can be employed to recover the exact CV/EV. In it, we follow step I by choosing a specific functional form for the utility function in which both site qualities and quantities are included as arguments. We then complete step II by analytically deriving the ODS, HCDS and the EF.

In following step three, we simulate the gathering of field data by employing a Monte Carlo approach to generate observable consumption data facing the recreation researcher. This is accomplished by assuming prior knowledge of exact values for parameters in the utility function specified in step I, i.e., a fully specified, utility function. Then, based on that fully specified utility function, we compute numerical values for ordinary demand quantities for several price, quality, and income combinations. Then, to simulate randomness and data errors facing the field researcher, random normal deviates are added to each generated ordinary demand quantity above. Based on those stochastic error terms added to the exact ordinary demand quantities, a nonlinear regression procedure is used to "estimate" the quality-dependent ODS parameters, as if the exact parameter values were in fact unknown.

To complete step four, after estimating the ODS in this manner, the estimated coefficients are used to find the EF and the HCDS, as uncovered in step II. From the fully specified expenditure function, the exact welfare change measures (CV and EV) associated with various exogenous site price quality changes are presented.

Step I. Suppose that one candidate utility function for the representative recreationist/site visitor is the Cobb-Douglas, modified to account for quality parameters unique to each site,

$$U = A_0 x_1^{f_1(b_1)} x_2^{f_2(b_2)} z^{f_3} \tag{14}$$

where A_0 is a constant, x_1 and x_2 are participation rates at sites 1 and 2 respectively, 2 is the Hicksian composite commodity "all other goods", and the $f_i(b_i)$ indicate that each of the exponents includes the respective site "quality" as an argument.

For this example, we explicitly specify the effects of each site's quality (b_i) into the respective f_i function in (14) as follows:

(15) $$f_1 = C_1\, b_1; \qquad f_2 = C_2\, b_2; \qquad f_3 = (1-C_1-C_2)$$

where C_1 and C_2 are constants (parameters) to be estimated from the data. Note that for this example, we are using Hanemann's third method of incorporating quality into the utility function (Hanemann 1982). Also, observe that for each ith site, this candidate utility function displays a rising marginal utility as either site's quantity or quality increases.

Step II. Applying standard constrained utility maximizing techniques, (14) is maximized subject to the budget constraint, $y = \Sigma\, x_i p_i$, one can derive the ordinary demand schedule for each of the two site demands of interest.

(16) $$x_i = \frac{M_i y}{p_i} \qquad \text{for } i = 1,2$$

where $M_i = [1 + (\sum_{j \neq i} f_j/f_i)]^{-1}$

given the quality-dependent f_i defined in (15).

The empirical task in estimating (16) is to use observable data to estimate C_1 and C_2. Given estimated values for the two coefficients C_1 and C_2 in (15) the ordinary demand functions in (16) are completely determined, and the utility function (14) is completely known (up to a monotonic transformation).

Next the HCDS and the associated EF are derived. Given the functional form assumed for the quality-dependent utility function in (14), the compensated demands are:

$$(17) \qquad x_i^* = (u^0/A_0)^{1/(f_1+f_2+f_3)} \prod_{j \neq i} [(f_j/f_i)/(p_j/p_i)]^{-f_j/(f_1+f_2+f_3)}$$

where u^0 is conditioned as the prepolicy utility level, assuming that the CV is the welfare measure desired. The HCDS in (17) <u>are</u> independent of the utility index, i.e., consistent with any monotonic transformation of (14). For example, if the utility index in (14) were doubled through a doubling of A_0, then u^0 would double, but u^0/A_0 in (17) would remain invariant.[2]

Finally, the expenditure function associated with (14) and (15) is simply the sum of all three compensated demands in (17) multiplied by respective prices, and is

$$(18) \qquad E = \sum_i p_i x_i^*$$

where the x_i^* are defined in (17). The expenditure function, which is needed for welfare comparisons, is of course also independent of the choice of the utility index.

<u>Step III</u>. Table I shows thirteen simulated random observations for the two sites and Hicksian composite commodity under thirteen price, quality, income combinations. Each jth observation on the three x's was derived from the exact ODS in (16) fully specified by the prior known, parameters in (15) with $C_1 = 0.05$ and $C_2 = 10$. XR_i (Table 1) refers to the ordinary demand quantities x_i, to which a random normal error term of mean 0 and standard deviation of 1 is added, to simulate data facing the recreation researcher.

TABLE 1

Simulated observations generated from three known ordinary demands functions under various prices, qualities, and incomes. Demand quantities XR_i are derived from utility function in (14) and (15), with $C_1 = 0.05$ and $C_2 = 0.10$, augmented by a standard normal error with mean 0 and variance 1.

XR_1	XR_2	XR_3	p_1	p_2	p_3	b_1	b_2	Income
5.15	9.56	85.05	1	1	1	1	1	100
3.21	10.88	85.59	2	1	1	1	1	100
2.07	10.13	84.53	3	1	1	1	1	100
4.14	4.99	84.34	1	2	1	1	1	100
5.43	3.78	84.35	1	3	1	1	1	100
7.39	11.13	5.69	1	1	20	1	1	100
3.03	10.35	3.01	1	1	30	1	1	100
8.96	9.09	81.79	1	1	1	2	1	100
12.74	9.66	5.86	1	1	1	3	1	100
4.67	17.65	75.73	1	1	1	1	2	100
2.61	25.04	71.66	1	1	1	1	3	100
8.15	20.67	169.17	1	1	1	1	1	200
14.42	31.45	256.25	1	1	1	1	1	300

In order to simulate the estimation of the three ordinary demands from the Table 1 data, it is necessary to estimate C_1 and C_2 as if neither were known. From (16), we know that the general functional form for the ordinary demands can be written as:

(19a) $$x_1 = \frac{1}{[p_1/y + \delta_0 (p_1 b_3/y b_1) + \delta_1 (p_1 b_2/y b_1)]}$$

(19b) $$x_2 = \frac{1}{[p_2/y + (1/\delta_1) (p_2 b_1/y b_2) + (\delta_0/\delta_1) (p_2 b_3/y b_2)]}$$

(19c) $$x_3 = \frac{1}{[p_3/y + (1/\delta_0) (p_3 b_1/y b_3) + (\delta_1/\delta_0) (p_3 b_2/y p_3)]}$$

where (20a) $C_1 = 1/[1 + \delta_0 + \delta_1]$

(20b) $C_2 = \delta_1 [1 + \delta_0 + \delta_1]$

Because (19) are nonlinear in the parameters, a nonlinear SAS regression procedure, SYSNLIN, (SAS 1982) was applied to the Table 1 data to estimate the parameters δ_0 and δ_1 in (19) and thence to recover C_1 and C_2 from (20).

Applying the SYSNLIN regression procedure to the data in Table 1 to estimate the model in (19), we found that $\hat{\delta}_0 = 17.09$ with an approximate standard error of 0.288 and $\hat{\delta}_1 = 2.04$ with an approximate standard error of 0.036.

Employing (20) to recover $\hat{C}_1$ and $\hat{C}_2$ from $\hat{\delta}_0$ and $\hat{\delta}_1$, the calculated values for $\hat{C}_1$ and $\hat{C}_2$ were found to be 0.0497 and 0.1011 respectively, both "close to" the prior known values of 0.05 and 0.10 respectively. Thus, we have demonstrated an example of recovering the relevant utility function parameters C_1 and C_2 by estimating the ODS from observable consumption data.

Step IV. Next, the HCDS and EF are fully specified. Recognizing that Hicksian and ordinary demand quantities are identical under initial (terminal) conditions, we can solve for the value of u^0/A_0 in (17) which forces the initial (terminal) Hicksian and ordinary demand quantities to be equal, thus allowing complete recovery of the HCDS. Only initial condition (u_0) Hicksian demands are discussed here.

Suppose that "initial conditions" are those in which all three prices and qualities facing the recreationist equal to one, and income is 100, i.e., conditions shown in first line of Table 1. Initial conditions in a real recreation valuation study would be charaterized by status quo prices and qualities.

Given those initial conditions, the initial values of Hicksian quantities consumed (the x_i^*) must equal those of the ordinary demand quantities, and are respectively, 5.15, 9.56 and 85.05 for the three goods. Employing the general formula for recovering the Hicksian schedules in (17), we can solve for u^0/A_0, since all terms are known except u^0/A_0. Using (17) we find that u^0/A_0 equals 59.56.

Having computed all three compensated demand quantities at initial condition utility levels, all are now completely specified. Therefore, as seen in (17) we can determine the remainder of the values of each x_i^* for any combination of values of prices, incomes, and qualities desired. With the compensated demands completely specified, computation of both the EF and associated welfare measure is possible[3] by inserting the estimated values of the f_i's into (17) and (18).

Table 2 shows computed expenditure function values for several combinations of site price and qualities. Ordinary and Hicksian demand quantities are not shown. Expenditure function values were calculated for both initial (5a) and terminal (5b) conditions which permit computation of the CV and EV respectively.

TABLE 2

Expenditure function-based estimates of CV and EV associated with various prices, qualities, and incomes.*

Policy #	p_1	p_2	p_3	b_1	b_2	y	E_1 +	CV	E_2 ++	EV
1	1	1	1	1	1	100	100	0	100	0
2	10	1	1	1	1	100	112	12	113	-13
3	1	1	1	10	1	100	40	-60	381	281
4	10	1	1	6.7	1	100	100	0	100	0
5	20	20	1	1	1	100	157	57	64	-36

*An expenditure function, CV, and EV can only be defined relative to a given level of utility. The level of utility used in this table is assumed to be that prevailing under prices, qualities, and incomes shown as policy #1.

+E_1 is the expenditure function value described in (5a), used to find the C.V., i.e., valued at $E\ (p_1^1, \ldots p_n^1;\ b_1^1, \ldots b_n^1;\ u^o)$

++E_2 is the expenditure function value described in (5b), used to find the E.V., i.e., valued at $E(p_1^o, \ldots p_n^o;\ b_1^o, \ldots b_n^o;\ u^1)$

EV values are presented for several interesting combinations of pricing and quality policies. Relative to no policy change (#1) and the associated initial utility level, Table 2 shows that a <u>price</u> increase at site 1 from $1 to $10 (policy #2) requires minimum expenditures to increase from $100 to $112 (CV = +$12). However, if site 1's <u>quality</u> increases from 1 to 10 (policy #3), minimum expenditures to sustain initial utility falls to $40 (CV = -$60). If the managing agency decides to raise entry fees at site 1 from $1 to $10 (policy #4), they would have to increase site 1's quality to 6.7 in order to maintain initial utility (EF value at 100). Alternatively viewed, an exogenous quality increase at site 1 to 6.7 could be financed by a price increase to $10 at site 1 without sustaining a utility loss. A simultaneous increase of both site prices to $20 (policy #5) could be offset by an income increase from $100 to 157 (CV = $57). Similar results are presented for the EF and associated EV conditioned on "terminal" policy combinations, for which results are shown in the last two columns.

V. CONCLUSIONS

The purpose of this paper has been to propose a practical method for evaluating the effects of a change in the quality of recreation sites on welfare of site users using data on observed consumption choices. The approach proposed in this paper consists of four steps.

First specify several alternative candidate utility functions dependent on site quantities and qualities. Viewing each site as having a single measurable index of quality, each candidate utility function specified could in principle depend on the parameters, qualities, and quantities of all sites in the system.

Second, for each candidate utility function, one would analytically derive (1) the ordinary demand system (ODS) and (2) the compensated demand system (HCDS)/expenditure function (EF). Because of these computations, the researcher would then know the relationship of the ODS to the EF. No data are used at this step.

Third, assemble data on observed recreation consumption choices at the relevant system of sites. Observations would be made on prices, qualities, and incomes. Those data would then be used to estimate the parameters for the representative recreationist's ODS. Among all the potential ODS's (each system associated with a known utility function) the one system would be chosen which best fit the data.

Fourth, one would use those estimated parameters from the chosen ordinary demand system in combination with the known relationship between each ODS and its EF to recover that EF. After recovering the EF, one can find the exact welfare change measures (CV and/or EV) associated with any price/quality change desired.

An example of the proposed method was presented using a modified "Cobb-Douglas" utility function, in which utility was specified to depend on both quantity and quality of two sites and quantity of a third good representing "all other consumption." It was then shown how one could obtain estimates of the EF and the exact CV/EV welfare change measures for several combinations of multi-site price and quality change.

The methodology proposed may be preferred to ones which attempt to measure welfare change by integrating over price and quality changes beneath one or more site demand schedules. When using the proposed method, one is not required to choose ad hoc specifications of demand systems and later hope they are consistent with some utility function. Rather, it is proposed that we assure utility consistency by specifying several alternative utility functions in the first step. That way, we are assured that the demand system ultimately chosen will be consistent with a known utility function. Furthermore, where multiple sites are involved, the proposed method is more theoretically credible and may require less computational effort than empirical welfare evaluation methods for quality change which are in common practice.

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FOOTNOTES

1. This study was funded in part by the USDA Regional Project W-133, "Benefits and Costs in Natural Resource Planning," New Mexico State University Agricultural Experiment Station; the New Mexico Game and Fish Department; and the New Mexico Water Resources Research Institute.
2. Empirically, the ratio U_0/A_0 can be determined by observing that the Hicksian and Ordinary demands are equal under initial prices, qualities and income. This will be illustrated subsequently. Of course, at any other prices, qualities and incomes, the Hicksian and ordinary schedules will diverge.
3. The discussion here demonstrates how to find the Hicksian demands associated with "initial" prices, qualities, and incomes. A similar initialization process allows the calculation of compensated demands associated with "terminal conditions". By computing terminal condition compensated demands, one can also find the expenditure function needed to identify the EV welfare change measure.