WESTERN REGIONAL RESEARCH PUBLICATION W-133

BENEFITS & COSTS IN NATURAL RESOURCES PLANNING

INTERIM REPORT

COMPILED BY

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Under the procedure of cooperative publication, this regional report becomes, in effect, an identical publication of each of the participating experiment stations and agencies and is mailed under the indicia of each.

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<u>PROJECT</u>: BENEFITS AND COSTS IN NATURAL RESOURCES PLANNING (PROJECT W-133)

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"BENEFITS AND COSTS IN NATURAL RESOURCES PLANNING"

TABLE OF CONTENTS

SECTION III: APPLICATIONS OF MARKET AND NONMARKET BASED VALUATION METHODS TO SPECIFIC RESOURCE BASE OUTPUTS

*Not a participating University or cooperating agency.

DEDICATION

This volume is dedicated to Clyde Fasick, our former administrative advisor, for his support of our research project over the years.

ACKNOWLEDGMENTS

I would like to thank all the W-133 members that contributed their papers, disks and graphics to this publication. I appreciate our current administrative advisor, Enoch Bell's support in preparing this report.

Lastly, Sharon Lynch at Division of Environmental Studies, University of California, Davis did an incredible job with foreign disks, page scanners and laser printers in producing this report. The appearance of this report is related to her persistent efforts and eye for detail.

ACCOMPLISHMENTS AND CHALLENGES IN VALUING NONMARKETED NATURAL RESOURCES: A PROGRESS REPORT

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OBJECTIVES OF THE W-133 REGIONAL RESEARCH PROJECT

There are three objectives of the W-133 regional research project. These are:

1. Conceptually integrate market and nonmarket based valuation methods for application to land and water resource base services.
2. To develop theoretically correct methodology for considering resource quality in economic models and for assessing the marginal value of competing resource base products.
3. To apply market and nonmarket based valuation methods to specific resource base outputs.

All three objectives contribute to the regional research project's goal of improving the methodologies used in evaluating the economic efficiency of natural resource allocations. The purpose of improved methodologies is to provide more accurate information on the benefits and costs of alternative uses of natural resources to both private and public decision makers. Armed with more complete information about the values of natural resources in alternative uses, optimal allocations of these resources are more probable.

One implicit objective of all regional research projects is to facilitate development of methodology with broad multi-state applicability and to assemble a critical mass of experts working in a highly specialized field of research. As the table of contents of this report indicates, both of these goals are being attained by this W-133 project. Extension and refinement of economic theory to valuation of resource quality is as applicable to environmental quality problems in Arizona as in Washington. Laboratory experiments conducted jointly by University of Georgia and Texas A & M University add to the foundation of our understanding of the Contingent Valuation Method. Insights gained from such research is truly a public good equally applicable to all states planning to undertake Contingent Valuation

OVERVIEW OF PAPERS AND PROJECT RELATED RESEARCH

PAPERS RELATING TO OBJECTIVE #1:

CONCEPTUAL INTEGRATION OF MARKET AND NONMARKET BASED VALUATION METHODS

Functional Form and the Statistical Properties of Welfare Estimates

by Wiktor Adamowicz (MN), Jerald Fletcher (IN) and T. Graham-Tomasi (MI).

Understanding the variance around the estimated mean value of benefits is an important component for performing sensitivity analysis in benefit cost analyses. However, little research has been preformed on the effect of functional form on the variance of welfare estimates such as consumer surplus or compensating variation. Information on the variance of the benefit estimates is needed for both marketed and nonmarketed natural resources to determine if the social values of these resource uses are statistically different.

The authors show that linear and semi-log functional forms will result in greater instability of consumer surplus estimates than will the double log functional form. Rather than pre-specifying one of these functional forms the authors develop a restricted Box-Cox form and relate it to the formula for consumer surplus.

The authors provide an empirical comparison of mean benefits and measures of dispersion around the mean benefits for bighorn sheep hunting in Alberta, Canada. A simple Travel Cost demand model is estimated in linear, semi-log, double log and linear-log functional form. The linear and semi-log models did not have statistically significant coefficients on travel cost. As is not surprising when the price coefficient is insignificant, the standard deviation of benefits around the mean is quite large. However, the double log demand equation had a t-statistic of 4.27 on the travel cost coefficient. The resulting standard deviation of benefits for this functional form is plus or minus $200 around the sample mean value of $1608. The linear-log model's travel cost coefficient was only significant at the 10% level and had a standard deviation of benefits of $300 around a mean of $1873.

This paper provides an important broadening of the criteria by which functional form of demand equations is chosen. Besides arguing for the consistency of demand specification with utility theory, statistical criteria should be broadened from a narrow view of "best fit" to a concern for the variance as well as the mean as a performance indicator. For many economic evaluations of trade-offs between marketed and nonmarketed resources, a comparison of benefit distributions might be a more "fail safe" applied welfare criterion than simply comparing means.

<u>Empirical Estimation of Supply in a Multicohort Fishery: Implications for Managing the Alaska King Crab Industry</u> by Scott Matulich (WA)

Efficient resource management of a marketed natural resource is important to many different groups in society. For example, in the management of the Alaska King Crab fishery, a boom-bust cycle takes a serious toll on commercial anglers and processors. This boom-bust cycle can be significantly reduced if fishery managers set harvest regulations that account for the long (8 or more years) and complicated lags that are typical of king crab populations.

Matulich develops a "trajectory adjusted intrinsic recruitment" model for the king crab fishery in Bristol Bay. A series of biological models predicting number of legal and nonlegal crabs (by age class) are linked to a series of market models that predict harvest as a function of effort and fleet size. Abundance of legal crab effects both effort and fleet size. The exvessal price for crab is used to reflect processors' derived demand for raw crab. This exvessal price is translated into a wholesale crab price, that along with the price of substitute and disposable per capita income determines consumer demand for crab.

The failure to use these types of integrative bio-economic models in setting fishing regulations may be a contributor to the boom-bust cycle on this billion dollar crab fishery. Matulich demonstrates that recognition of the long lag structure and the feedback effects in the market for crab is necessary for efficient management of the biological stocks of crab.

Using Volunteer Time as a Payment Vehicle in Contingent Valuation Studies of Endangered Species by Karl Samples (HI) and James Hollyer (HI)

Consistency in comparison of marketed and nonmarketed natural resources hinges, in part, on consistency in the way consumers pay for the goods. Money or the sacrifice of income is the common numeraire in welfare economics and represents the price of most marketed commodities. In dealing with natural resources that are public goods and hence indivisible, establishing a means of payment that is consistent with marketed goods and yet reflective of the way such public goods are paid for has been a challenge. For many of these public good resources such as endangered species, no formal markets or market prices exist. Therefore surrogate means of paying dollars or income in the form of a payment vehicle is often employed when developing hypothetical markets using the Contingent Valuation Method. Examples of common payment vehicles include payment into a trust fund, a higher utility bill, and a "wildlife stamp", just to name a few. However, for many public goods, implicit markets have developed where consumers desiring more of these goods can attempt to purchase additional units for society by paying with their time. By donating time to educational, lobbying or habitat restoration efforts, consumers are implicitly engaging in a transaction that trades their scarce time for a higher probability of increased supply of the public good. Can we use this sacrifice of volunteer time as an alternative payment vehicle in place of dollars in Contingent Valuation? If we use volunteer time as the means of payment how does one convert this time to dollars in a manner commensurate with the dollar value of other goods or income?

These issues are addressed by Samples and Hollyer in their paper. These authors build upon earlier suggestions made in two papers by W-133 participants (Bocksteal and Strand, 1985; Cory, 1985) that willingness to pay in time be evaluated in addition to willingness to pay in dollars. The trade-off between these two welfare measures is developed in the form of an equivalent surplus locus reflecting different combinations of money and time a person would pay to avoid a decrement in environmental services.

The feasibility of using volunteer time as a payment vehicle in Contingent Valuation was empirically tested using a valuation experiment for two marine mammals. Respondents were asked to pay for preservation of Monk Seals and Humpback Whales. They could choose not to pay in any form, or to pay in either money or time. When given the choice nearly an equal proportion choose to pay in money as in time. One of the most difficult issue in using time as a payment vehicle revolves around how to empirically convert willingness to pay in hours to dollars. This problem is similar to the problem of converting travel time to travel cost in the Travel Cost Method (McConnell and Strand, 1981). Not surprisingly, the final values for preservation of the species depends on the rate at which time is converted to dollars. Additional research on this issue may be necessary to take full advantage of Samples and Hollyer's innovative payment vehicle in Contingent Valuation studies.

PAPERS RELATING TO OBJECTIVE #2: DEVELOPMENT OF THEORETICALLY CORRECT METHODOLOGIES FOR CONSIDERING RESOURCE QUALITY AND ASSESSING MARGINAL VALUATION

Contingent Valuation as an Experimental Science by John Bergstrom (GA) and John Stoll (TX)

Traditionally, the Contingent Valuation Method has been one of the primary techniques for valuing changes in resource quality and the marginal value of increments and decrements in resource availability. CVM has been used to value changes in water quality (Greenley, et al., 1981; Smith and Desvousges, 1986) and air quality (Randall, et al., 1974; Schulze, et al., 1983) as well as to estimate the marginal value of increases in the number of elk (Brookshire, Randall and Stoll, 1980).

One long standing concern that some economists and public decision makers have with CVM is the method's reliance on hypothetical responses to survey questions rather than actual behavior. Technically speaking CVM provides respondent's intended behavior contingent on the characteristics of the market described in the survey.

The validity of this intended behavior as a guide to respondent's actual behavior has been tested in a variety of ways by many W-133 researchers. The paper by Bergstrom and Stoll takes an experimental economics approach to testing the validity of CVM. The authors argue the framework of experimental economics, provides a description of the controlled environment necessary for systematic investigation of the validity of CVM. Bergstrom and Stoll review the experimental economics literature on microeconomic markets to establish the properties that are necessary for a properly structured market. These include nonsatiation of rewards given to the respondent, saliency of responses to real outcomes, privacy of one's own reward schedule and those of others, parallelism of the contingent market with real markets that might be implemented to provide the good and incentive compatibility for revelation of the respondent's true values.

The authors argue that if the properties of nonsatiation, saliency and privacy are met, this will satisfy the necessary conditions for internal-validity of CVM benefit estimates. This means that benefit estimates could be replicated over similar experiments. If, in addition, the property of parallelism is met, then CVM estimates may have external-validity, i.e. the CVM values can be generalized to real world scenarios.

Bergstrom and Stoll's paper provides a useful guide for conducting laboratory experiments designed to test a particular CVM issue (e.g., information bias, payment vehicle bias, etc.). More importantly, their paper provides a mental checklist for designing a credible CVM survey in a real application. That is, to insure the respondent is valuing what you intend them to value, many of the properties of microeconomic markets described by Bergstrom and Stoll must be met. To insure that values provided by the respondent can be generalized to the actual change in resource quality or resource availability postulated in the survey, such a survey must employ the property of parallelism (i.e., realism). While many of our informal guidelines (e.g., Reference Operating Conditions, etc.) discuss these issues, natural resource economists can improve future applications of CVM by incorporating the guidelines suggested by experimental economics.

Analyzing the Effects of Glen Canyon Dam Releases on Colorado River Recreation: Using Scenarios of Unexperienced Flow Conditions by Kevin Boyle (ME), Michael Welsh (OK), Richard Bishop (WI) and Robert Baumgartner (WI)

This paper by Boyle, et al., evaluates the effect of realism in survey descriptions of unexperienced changes in resource quality versus inference of values from actual experience of the different levels of resource quality. The issue of unexperienced quality levels versus experienced quality levels is a significant empirical issue in valuing resource quality. Ideally, the economist would prefer the consumer to experience each alternative levels of resource quality and then provide their valuations of each. However, in many situations it is not practical to modify the resource quality to value changes (e.g., killing off half of the fish to assess the value of fishing quality). In other cases it may be quite costly to modify resource quality to alternatives levels so as to perform a realistic CVM. For example, operating a large hydropower project for several weeks at alternative release patterns might involve millions of dollars in foregone power benefits. All is not lost if there is some natural fluctuation in resource quality. The economist can survey at different times during the year when site quality is high, medium and low. The values respondents report under these conditions can be related to the resource quality at the time of the survey to quantify the relationship between resource quality and value. In this situation it may even be possible to rely on actual trip behavior and calculate benefits from a Travel Cost demand equation.

This latter approach has two minor drawbacks, however. First, since no one person experiences all of the alternative levels of resource quality, unbiased values can be inferred only if the analyst adequately accounts for differences in respondent characteristics (e.g., tastes, income, skill, etc.) sampled at different times of the season. If during high water times only skilled boaters visit the site, inference of the value of high water to all boaters will likely be erroneous. In addition, this intra-seasonal approach will not work when resource quality does not vary over the recreation use season.

As a result of these limitations, the intra-seasonal approach has seen limited application. The typical CVM survey often proposes alternative levels of resource quality to the same respondent. This controls for differences in respondent characteristics, the concern involved in the intra-seasonal approach discussed above. However, for some visitors one or more of these alternative levels of resource quality may be outside the range of what they may have experienced. How valid are the benefit estimates for unexperienced changes in resource quality?

The paper by Boyle, Welsh, Bishop and Baumgartner begins to address this later issue regarding the validity of benefit estimates for unexperienced changes in resource quality. The authors use respondents valuation of rafting and fishing under different river flows. Since the sample was taken over the course of a season, different people had actually experienced a high, medium or low flow level, although few people had experienced more than one flow level. Each person was asked a dichotomous choice question to value the trip they had actually taken. These values would reflect the resource quality actually consumed on that trip.

In addition, each respondent was asked a series of dichotomous choice CVM questions for the value of their trip if everything had been the same except the flow was 3,000 cfs, 10,000 cfs, 25,000 cfs and 40,000 cfs. The changes in river characteristics under the four flow scenarios were described in a series of narratives.

The comparison of recreation trip values under the actual trip conditions versus the unexperienced flow scenarios indicates a fairly close ordinal ranking of the preferred flows. In terms of absolute magnitude of the dollar amounts, the value of the unexperienced scenarios is slightly higher at low flows than the actual trip value but slightly lower than the actual trip values at high flows. In general, the differences between the two approaches is about 25%. Some of this difference is attributed by Boyle et al., to the distinction that actual trip values may reflect "ex post values" while the unexperienced scenarios may reflect "ex ante values".

Research addressing experienced versus unexperienced quality changes is also addressed from a slightly different perspective by Walsh, et al., in the next section. This perspective relates to valuations of experienced quality levels based on actual behavior (using the Travel Cost Method) versus valuations of unexperienced quality levels based on intended behavior (using the Contingent Valuation Method). For a description of this paper see Section III.

<u>Valuing Recreational Services With Quality Adjusted Prices</u> by John Hoehn (MI) and Gideon Fishelson

The authors develop a new method for valuing changes in a single site's environmental quality when there is insufficient variation in the site's price or lack of time-series data on quality over time to allow traditional demand estimation. The lack of variation in a site's price or lack of time-series or cross-section data to estimate a coefficient on quality has limited the application of market-based approaches to estimating the value of environmental quality. However, this new approach calculates a "quality adjusted price" by combining price and quality data. The resulting variable provides the necessary variation to allow estimation of the demand function for a environmental quality at a single site.

The paper demonstrates the usefulness of this new approach with an application to estimating the demand for visibility at the Hancock Tower in Chicago. Demand functions are estimated for two air quality characteristics: visual range and visibility. The net willingness to pay or surplus per visit ranges from $18.50 to $30.40. The annual change in total consumer surplus for a 10% increase in visual range is between $56,000 and $69,000.

This new methodology maybe a promising approach to demand estimation for changes in site quality at a single site. The data requirements a greatly simplified over more traditional "varying parameter models", which require collection of data on multiple recreation sites in order to estimate a coefficient on site quality. One additional assumption possibly required to use either of these revealed-preference market-based approaches is that consumers know, ex ante, what site quality will be when making their decision to visit the site. This assumption was easily met in the case of visitors to the Hancock Tower, since the degree of visibility from the Hancock Tower would be readily observable prior to a decision to pay the admission fee.

However, in the case of a more remote site such as a river, ski area or reservoir, prior knowledge of river flow, snow conditions, or reservoir level may be difficult to acquire prior to travel decisions if these site characteristics do no vary in a predictable manner. If site quality is predictable ahead of time, then this quality adjusted price method appears be a potentially useful new tool in valuation of changes in resource quality.

Some Thoughts on the Multiple Destination Trip Problem in Travel Cost Models

by John Hof (U.S.F.S.)

The Travel Cost Method (TCM) is a widely used and in its basic form a relatively straightforward approach to estimate the demand for outdoor recreation. TCM relies on visitor's travel costs as a proxy for site price. This is legitimate only if the travel costs were incurred exclusively to visit that particular site and not to visit several other destinations (e.g., business, other recreation sites, etc.). For many outdoor recreation activities such as hunting, fishing and backpacking this assumption is often met by 80-90% of visitors. However, when valuing recreation sites such as National Parks or those close to major highways, a high percentage of the visitors do visit more than one destination. There are several ways of dealing with this situation. One is to attempt to estimate the model on just the visitors that meet the assumptions of the strict TCM. However, this is not desirable if only 30-50% of the visitors meet the assumption. Alternatively, one might abandon the TCM in this case and apply the Contingent Valuation Method.

The paper by Hof explores a third solution: use a cost function approach to split out the separable costs of visiting any particular site on the overall trip and then logically allocate the remaining joint costs of the trip between sites. The approach specifies a cost function and then demonstrates the multi-destination problem is one of recreation sites having interdependent marginal travel cost functions. One solution is to develop a logical path of integration that allows the costs to be allocated to each site in a manner that exactly allocates total cost. To illustrate the principles involved, a geometric plane is displayed for a recreator having four destinations on his or her trip. The general approach that emerges is that each site receives its full separable costs and its share of any costs required to visit more than one site. For example, if driving up a particular canyon moves the visitor closer to three of the four sites, then the costs of this leg of the trip would be split equally among the three sites. By examining visitor's trip itineraries, the travel costs necessary for visiting each site can be identified and the cost allocation scheme presented can be applied. While Hof discusses the weaknesses in this approach, it represents a generalization of past approaches used by others. In this way the implicit assumptions of less general methods of cost allocation are made clearer using Hof's framework.

Estimation of Marginal Values of Wildlife and Forage Using the Travel Cost Method by John Loomis (CA), Dennis Donnelly (U.S.F.S) and Cindy Sorg (U.S.F.S)

In some resource settings there is sufficient variation in environmental quality to allow a revealed preference approach to valuation of changes in resource quality. In this paper, the authors demonstrate how marginal valuation of changes in hunting quality (e.g., wildlife availability) can be empirically measured using one type of revealed preference approach, the Travel Cost Method. A pooled multi-site demand function for elk hunting and deer hunting in Idaho is estimated that contains elk harvest and deer harvest, respectively, as demand shifters. Inclusion of these variables allows for calculation of the incremental consumer surplus associated with increasing elk and deer harvests. To account for the possibility of simultaneity of the elk or deer harvest variable in the demand function, two stage least squares is used to estimate the demand functions for each species. The marginal value of an additional elk harvested in two hunting areas in Challis, Idaho ranged from \$502 to \$647. The marginal value per deer harvested ranged from \$155 to \$310.

A simple production function was then developed that related elk and deer populations to forage availability, age structure and sex ratio's of the herds. From these simple production functions, the marginal product of forage could be calculated. Using the marginal value per animal harvested, the value marginal product of the forage to elk and deer was calculated. The marginal values for elk ranged from $6.65 to $8.25 per Animal Unit Month (AUM) of forage. For deer the values ranged from $6.33 to $15.33 per AUM. Comparison with livestock forage values from appraisal surveys and ranch budgets indicates the value of forage to wildlife is competitive with that of livestock. '

Exact Welfare Values of Natural Resource Quality: A Regional Approach
by Frank Ward (NM)

Early work on the theoretical foundation of measuring quality changes dealt with just one site at a time and no interrelationships between sites. That is, a change in site quality at one site had no influence on visitation to the other sites. Hanemann (1982) began to investigate utility theoretic demand specifications that accounted for quality changes at one site which was one of a number of recreation sites in a region. Hanemann also addressed the issue of calculating exact welfare measures (i.e., the four Hicksian measures) rather than Marshallian consumer surplus. Ward's paper builds upon and extends the research of Hanemann for quantifying the benefits of a change in quality in one site in a multiple site demand system. In addition, Ward proposes a four step procedure to implement a utility theoretic approach to demand estimation when performing applied studies. The four steps involve specification of a utility function, derivation of the associated ordinary and compensated demand functions as well as the expenditure function, estimation of the ordinary demand function and then use of the estimated coefficients of the demand function with the formula for the expenditure function to derived the Hicksian welfare measures.

Ward provides a numerical example of his four step procedure using simulation techniques. Data are generated, demand models estimated and then compensating and equivalent variations calculated. The model is then exercised to evaluate four policy options that include raising the entrance fee, increasing site quality and then a combination of these approaches. Welfare estimates with each of these policies are provided.

Ward's approach appears to make possible tying theory and practice more closely together in demand estimation of quality changes. As Ward points out, this is particularly desirable when the analyst wishes to use welfare economics to justify the use of the benefit measures as indicators of potential Pareto improvements.

PAPERS RELATING TO OBJECTIVE #3: APPLICATIONS OF MARKET AND NONMARKET BASED VALUATION METHODS TO SPECIFIC RESOURCE BASE OUTPUTS

Travel Cost Demand Models With Linkages to Fishing Quality: Computerized Models for the Pacific Northwest by John Loomis (CA)

Large area watershed planning often involves comparisons of benefits and costs over a multi-state area. For example, evaluation of hydropower and fisheries trade-offs in the Columbia basin involves salmon fisheries in Idaho, Oregon and Washington. Consistent valuation of the fishery impacts from alternative water release patterns for hydropower or irrigated agriculture is enhanced if the same modelling approach is used for all states.

Evaluation of allocation of water between hydropower, irrigated agriculture and andadromous fisheries also involves marginal analysis of shifting water releases in terms of quantity and timing. Performing such marginal analysis of alternative water releases requires the ability to simulate the shifts in the demand for recreational fishing associated with changes in fishing quality. Unfortunately, Federal agencies such as the Bureau of Reclamation, U.S. Army Corps of Engineers, etc., have historically relied on Unit Day Values from the U.S. Water Resources Council (1979) to estimate the value of an angler day and then used the average number of angler days required to catch a fish to arrive at the change in value of fishing. More recently, these agencies have substituted estimates of the average consumer surplus per angler day from existing site specific studies in place of the Unit Day Values but continue to rely on the average number of angler days per fish caught for a measure of quantity.

The computerized models of anadromous fishing developed by Loomis puts site-specific quality-augmented demand equations and data into the hands of Federal agency economists in a menu driven model. The models allow the agency economist to input the change in fish production at a specific river and the program then shifts the site demand curve and takes the area between the old and new demand curve. The resulting benefit estimate reflects the marginal or incremental gain in recreational fishing benefits associated with the change in fish production. These models thus allow agency economists to generate both the value and use estimates from the same site specific data set.

The demand equations used in the models are estimated using a multi-site regional Travel Cost Method. The TCM demand equations contain fish catch as a shift variable. The fish catch variable provides the link from project effect on fishery habitat (e.g., different river flows, water temperature, dissolved oxygen, sediment, etc.) or fish populations to economic benefits. These multi-site demand equations have been estimated for the major salmon and steelhead rivers in Idaho, Oregon and Washington. The value of ocean sport fishing of salmon in Oregon and Washington is also estimated.

The demand equations and data are provided to the user as a LOTUS 123 spreadsheet file along with a LOTUS MACRO program file. The entire process, from selecting the river or port, entering the annual change in fish catch and calculation of benefits, is menu driven. The program also provides the option to perform discounting of annual benefits.

The programs have recently been used by USDA Soil Conservation Service for evaluation of the benefits of sediment reduction in the Columbia Basin and by the U.S. Army Corps of Engineers for evaluation of river flow augmentation for fish migration and spawning.

Recreational Demand for Trees in National Forests by Richard Walsh (CO), Frank Ward (NM) and John Olienyk (CO)

When assessing the benefits of different levels of environmental quality economist often faces a trade-off between relying on actual behavior and the use of hypothetical behavior implied in the Contingent Valuation Method. While reliance on how recreationists actually adjust their visitation rates to different levels of environmental quality may be preferred by some economists, there are many situations where this approach is not feasible. As discussed earlier in the Boyle, et al. paper on Grand Canyon river flows, if the change in environmental quality is irreversible or difficult to vary in an experimental setting then the analyst is required to rely on hypothetical responses. Closer examination of the nature of these hypothetical responses indicates they reflect what is called "behavioral intentions". Specifically, what does the respondent intends to do if the set of conditions described in the survey took place. Of course economists and decision makers wish to know how well do these behavioral intentions predict actual behavior.

In the Boyle, et al., paper discussed above, the authors addressed this issue by comparing Contingent Valuations of river trips under river flow levels actually experienced by the visitor versus valuations of river trips under flow levels they had not experienced but rather were described to them. In the Walsh, et al. paper, visitors not only experienced the level of environmental quality but their valuations were based on actual behavior using the Travel Cost Method. Valuation of the unexperienced environmental quality used the same basic approach as Boyle, et al., except that pictures supplemented the narrative descriptions and iterative bidding was used rather than the dichotomous choice approach.

The particular resource quality addressed by Walsh, et al., relates to forest quality, specifically, the number of ponderosa and lodgepole pine trees per acre in the Front Range of the Colorado Rockies. On-site interviews were conducted of visitors during the summer of 1980 to assess how visitation and value per visit to six specific recreation areas would change with different number of trees per acre. Six different photos displaying no trees, 20-40 trees per acre, 60-80 trees per acre, 100-120 trees per acre, 140-160 trees per acre and 200-300 trees per acre were shown to respondents. They were asked the number of days they would visit the site per season and the maximum willingness to pay per day under each of the different scenarios. In addition information was collected on their travel costs and actual number of times they had visited the particular site where they were interviewed.

Using the intended number of trips a "willingness to participate" equation was estimated as a function of trees per acres and a host of other variables. A willingness to pay equation was also estimated as a function of trees per acre and other shifter variables. Trees per acre and trees per acre squared were highly significant. Multi-site Travel Cost demand functions are estimated which contain a variable for trees per acre. Both OLS and two stage least squares are used to test the sensitivity of benefits to demand specifications.

Walsh, et al., make several comparisons between CVM and TCM results. Benefit estimates for the two approaches compare quite closely for existing site conditions. The authors then compare the predicted change in number of trips and benefits per trip for a 10%, 20% and 30% reduction in number of trees per acre. The TCM appears to be more sensitive in relating the change in tree quality to trips per season than CVM. For a 10% and 20% change, TCM predicts almost twice the reduction in trips than CVM. That is, the actual number of trips falls off twice as fast as what visitors stated they would react. However, the reverse is true when evaluating the responsiveness of benefits per day to trees per acre. Here, CVM values showed nearly twice the sensitivity of values per trip than did the TCM. When the effects of changes in value per trip are combined with the changes in number of trips to provide an estimate of the annual value of the change in forest quality, the two effects offset one another for each method. As a result, estimates of the annual change in benefits from a 10% or 20% reduction in the number of trees per acre is nearly identical under both TCM and CVM. There is some disparity for a 30% reduction in trees, with CVM estimates being about 20% larger.

In general, the authors feel that intended behavior for unexperienced levels of environmental quality matches reasonably well with actual behavior. However, more research is needed to explain why CVM derived values per trip are more sensitive to site quality changes than are TCM derived values.

<u>Total and Existence Value of a Herd of Desert Bighorn Sheep</u> by David King (AZ), Deborah Flynn (AZ) and William Shaw (AZ)

The preservation of certain relatively unique natural resources provide benefits beyond simply recreation. The presence of environmental groups specializing in saving relatively remote ecosystems such as the Mono Lake

Committee or isolated species indicates that people often derive satisfaction from knowing a species exists or a certain unique natural environment is protected. While these values have often been discussed, they have seen relatively limited use in Federal benefit cost analysis. This is due, in part, to the paucity of studies that measure such values and in part due to the belief that for many of these areas or species, perhaps recreation benefits captures a bulk of the total social value.

The paper by King et al., adds to our understanding of the empirical importance of existence value by quantifying and explaining the variation in this value for a herd of desert bighorn sheep in Arizona. The authors used a mail survey to perform an open ended Contingent Valuation question regarding the total economic value (e.g., viewing, option for future viewing, existence value) of preserving 70 desert bighorn sheep. This was followed by an open ended willingness to pay question for preserving the bighorn sheep except that to minimize stress to the bighorn sheep, no viewing or other human activity would be allowed in the area. This particular bid is intended to reflect just the pure existence value.

The total annual benefits (i.e., willingness to pay) for preservation of the 70 bighorn sheep was $17 per household. The existence value was $15 or 80% of the mean of total value. Clearly, existence value represents a major component of total value for this bighorn sheep herd. This conclusion is supported by respondents' ranking of altruistic motivations for preserving the bighorn sheep herd ahead of on-site recreational use.

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FUNCTIONAL FORM AND THE STATISTICAL PROPERTIES OF WELFARE MEASURES: A PRELIMINARY ANALYSIS[1]

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INTRODUCTION

A large literature exists on the problem of specifying economic relationships for purposes of statistical estimation and testing. Regarding demand relationships, economic theory provides some restrictions on admissible specifications, but still allows considerable leeway concerning variables to be included and the appropriate choice of functional form. In the absence of specific guidance in these respects, a variety of statistical criteria for model selection have been suggested, but the problem essentially remains unresolved.

In an influential article, Ziemer, Musser, and Hill note the importance of functional form specification for the magnitude of welfare measures. They report results for demand for a recreation site based on the travel cost model [see McConnell (1985) for an overview of this model] which exhibit nearly a four-fold difference between consumer's surplus based on a linear demand curve and surplus computed from a semi- log demand. Ziemer, et al., go on to show that for their data, the semi-log demand statistically out-performs (in terms of t and F statistics) the then popular linear form. Moreover, they estimated a restricted Box-Cox transform (discussed below) and found the estimated Box-Cox parameter to be relatively close to zero, which also indicates a semi-log form. A number of subsequent investigators in the area of recreation demand modeling have followed the lead of Ziemer, et al., and employed the semi-log form.

Smith and Desvousges rationalize the use of the semi-log on the basis of the work by Ziemer, Musser, and Hill and that of Vaughan, Russell, and Hazilla (Smith and Desvousges, page 254). Several studies use the semi-log and/or linear form without consideration of any other forms (e.g. Kealy and Bishop; Wilman and Pauls; Bockstael and Strand; Smith, Desvousges, and Fisher). McConnell summarizes the past efforts in functional form choice by stating that, "...a researcher who was forced to choose from the literature...would find that the bulk of the evidence supports a semi-log form" (page 701). These conclusions may lead researchers to employ the semi-log form without full consideration of its effects on the welfare measure.

The research of Ziemer, et al., emphasizes that in many circumstances estimation of the demand curve is only an intermediate step in the overall research process. Often, consumer surplus computed from the estimated demand curve is used to make resource allocation decisions. While considerable attention has been devoted to obtaining good estimates of demand, what one really wants is a good estimate of the welfare measure. However, the former does not necessarily lead to the latter; the estimate of consumer's surplus is a random variable and alternative functional form specifications affect not only its mean, but also its variability.

That estimates of consumer's surplus are random variables is, of course, well-recognized. For example, Bockstael and Strand discuss the impact that alternative interpretations of the error term in the demand equation have on methods of computing expected consumer's surplus. In one interpretation, the error term is due to individual-specific excluded variables and the analyst should compute consumer's surplus for each observation and then take the expected value. In another interpretation, sources of error are not individual-specific and it is appropriate to base surplus estimates on the expected demand, i.e., the estimated demand. In general, these two will differ due to nonlinearity in the surplus function and Jensen's Inequality. As well, the issue of stochastic welfare measures has received attention in the context of discrete-choice, random utility models by Hanemann (1982a).

While these analyses have addressed some of the stochastic properties of welfare estimates, to our knowledge the influence of model specification on properties other than the mean or some other measure of central tendency has not been assessed. In this paper we simply note that different functional forms imply different transformations from demand parameters to welfare measures and that these transformations map instability in parameter estimates into instability of welfare estimates in different ways.

We show below that this insight can alter assessments of fits of alternative specifications to the sample data. The key results are driven by the fact that the coefficient on the price variable appears in the denominator of the consumer's surplus equation. In some instances (linear and semi-log) this parameter appears alone or multiplied by a constant. Hence, if the parameter is not significantly different from zero, it often will be the case (in a repeated sampling sense) that near-zero coefficients will be realized and the welfare measure will exhibit marked instability. These effects may be quite large. Below we present Monte Carlo estimates for recreation data which show that, although the semi-log form is superior to the double-log form in terms of overall fit (as judged by t and F statistics), the coefficient of variation ($\sigma/|\mu|$) of consumer's surplus for the semi-log form is 24 times that for the double-log form.

Similar results can hold for decisions regarding whether to include a variable. Exclusion of an important variable is known to bias parameter estimates, but if the excluded and included variables have an appropriate correlation structure, the ratio of the estimated price coefficient to its standard error might rise by excluding a variable. Thus, excluding a variable could greatly decrease the variance of the welfare measure, a fact that may at first glance appear counter intuitive.

Why should one care about the variability of the welfare measure and not just its mean? Presumably, in many instances the welfare measure is to be used in making a resource allocation decision in a benefit-cost framework.

The decision-maker can then be viewed as a statistician who is testing the hypothesis that the true population welfare measure exceeds the cost of the project or policy under consideration. Exactly how this statistical decision problem should be formulated raises complex questions regarding the treatment of uncertainty in benefit cost analysis which are beyond the scope of this paper. But in many formulations of this problem, there will be curvature in the associated statistical loss function and the variance of the estimates will matter.

This discussion reveals that a trade-off may exist between a bias in consumer's surplus estimates from choosing an incorrect specification and the variance of these estimates induced by the welfare transformation. This would suggest that a minimum mean square error criterion is appropriate. Unfortunately, economic theory cannot be used to deduce a true form and therefore bias cannot be assessed. We offer our analysis to provoke consideration of this issue in assessing alternative demand specifications. No exact guidance concerning the best solution to this problem is offered here.

The remainder of this paper is organized as follows. In the next section the consumer surplus functions for linear, semi-log, double-log, linear-log, and restricted Box-cox forms are presented and discussed in terms of the implication for the variance of surplus and statistical assessment of "best fits." In addition, the issue of variable inclusion is analyzed briefly. Then, Monte Carlo estimates of the importance of functional form choice on welfare variance are presented. The data used concerns the demand for hunting of big game in Canada. A final section presents the conclusions reached.

WELFARE MEASURES AND DEMAND FUNCTIONAL FORM

The most commonly used functional forms for demand functions are the linear and the semi-log. As discussed above, these forms have been advocated both for how they fit the data (Ziemer, Musser, and Hill) and for their theoretical properties (see Bockstael, Hanemann, and Strand). In this section we consider the properties of the consumer's surplus functions from these two functional forms as well as the double-log and the linear-log forms.

The linear, semi-log, double-log and linear-log functional forms for a simple demand equation are:

(1) Linear $Q = \alpha_1 + \beta_1 P$

(2) Semi-log $\ln Q = \alpha_2 + \beta_2 P$

(3) Double-log $\ln Q = \alpha_3 + \beta_3 \ln P$

(4) Linear-log $Q = \alpha_4 + \beta_4 \ln P$

The derivation of the consumer's surplus functions for each of these forms requires an assumption regarding the source of error in the equation. Bockstael and Strand show that the estimated consumer's surplus function depends on whether the predicted quantity for an individual or their actual quantity is used. We present the consumer's surplus functions based on the assumption of "omitted variables", using the actual value of quantity in the surplus function. An alternative is to use the predicted quantity consumed which Bockstael and Strand argue is appropriate if the equation error is due to errors in measurement.[2] As is common in applied work, the demand functions which are asymptotic to the price axis are evaluated at the maximum and the average price.

The consumer's surplus functions for each of these forms are evaluated using:

(1-a) Linear $CS1 = Q^2/(-\beta_1*2)$

(2-a) Semi-log $CS2 = Q/(-\beta_2)$

(3-a) Double-log $CS3 = e^{\alpha_3}*P^{(1+\beta_3)}/(1+\beta_3)$ {eval at MAX(P),AVG(P)}

(4-a) Linear-log $CS4 = \alpha_4 P + \beta_4*P*(\ln P - 1)$ {eval at MAX(P),AVG(P)}

where Q is the actual quantity. These consumer's surplus functions are functions of the estimated slope and intercept of the demand functions; thus, they themselves are random variables. The distributions of these random variables are unknown. The linear form, for example, is a constant over a random variable. The expected value of this new random variable can be approximated but we know little of the other parameters of its distribution.

In typical demand studies the estimated parameters are of primary concern and hence the statistical fit has been used to discriminate between models. However, in cases where the consumer's surplus is of interest, both the expected value and the variance of the surplus measure are of importance. A significant t-statistic on a price parameter in a demand equation may not ensure low variance in the consumer's surplus. In particular, when discriminating between functional forms the most common tactic has been to examine t-values and measures of overall fit of the demand parameters. Some studies have used Box-Cox estimation to choose functional form (Ziemer, Musser, and Hill). This method of choosing functional form may be inappropriate when higher moments of consumer's surplus variables are of interest.

In both the linear and semi-log functional forms the β parameter cannot become zero, since as β approaches zero the estimate of consumer's surplus becomes infinite. This indicates the potential for a large variance of the consumer's surplus when the demand parameter β has a low t-statistic.

In addition to the requirements on the β parameters, one should consider the effect of other included variables on the price variable if consumer's surplus is the final interest of the estimation. Specification bias will occur by excluding important variables, but including variables that lower the significance levels of the price parameters can inflate the variance of the consumer's surplus. For example, if the researcher is interested in a confident measure of surplus, the addition of socioeconomic factors to a demand function must be approached carefully.

An alternative to estimating several functional forms is the Box-Cox estimation procedure applied in many tests of functional form. The restricted Box-Cox form[3] is:

(5) $$\frac{Q^{\lambda} - 1}{\lambda} = \alpha + \beta P$$

The consumer's surplus for this general form (again using actual quantity) is:

(5-a) $$CS5 = -\frac{1}{(1 + \lambda)\beta} * Q^{(1 + \lambda)}$$

For the case of $\lambda=0$ this becomes the semi-log form and for $\lambda=1$ this is the linear form. Once again the consumer's surplus is highly sensitive to the value of β. If β approaches zero, the consumer's surplus measure is unbounded. Thus for any transformation within this simple Box-Cox form, caution must be taken regarding the choice of the demand form.

Bockstael and Strand have shown that the expected value of the linear and semi-log consumer's surpluses can be approximated using the form for the expectation of the ratio of two random variables (derived by taking the expectation of a second order Taylor expansion of xy^{-1} around $(\bar{x},\bar{y})$

(6) $$E(x/y) \approx E(x)/E(y) - cov(x,y)/E(y)^2 + E(x)\ var(y)/E(y)^3.$$

This approximation can be used to derive the following approximation to the variance of (x/y).[4]

$$(7)\quad Var(\frac{x}{y}) = E(\frac{x^2}{y^2}) - [E(\frac{x}{y})]^2$$

$$\approx \frac{E(x^2)}{E(y^2)} - \frac{cov(x,y)^2}{E(y^2)^2} + \frac{E(x^2)var(y^2)}{E(y^2)^3} - \frac{E(x)^2}{E(y)^2} - \frac{cov\ (x,y)}{E(y)^4}$$

$$- \frac{E(x)^2 var(y)^2}{E(y)^6} + 2\frac{E(x)}{E(y)^3}\left[cov(x,y) + \frac{var(y)\ cov(x,y)}{E(y)^2} - \frac{E(x)\ var(y)}{E(y)}\right]$$

In a model with measurement error, the numerators for the consumer's surplus estimates in (1a) to (4a) are random variables. In the interpretation used here, we may assume x to be constant and terms involving covariances drop out of (7), but terms involving the mean and variance of the square of the coefficient β on the price variable remain. Therefore we shall proceed to perform Monte Carlo analysis on these distributions for a given data set to observe the distributions of the welfare measures.

EMPIRICAL ANALYSIS

In order to illustrate the effects of functional form on the statistical properties of welfare measures, we estimate several functional forms of demand functions for recreation. These functions correspond to the travel cost demand model popular in the recreational demand literature. The data, collected by mail survey, are the number of visits in a season and travel costs to a bighorn or Rocky Mountain sheep hunting site in Alberta, Canada.[5] The travel costs are expressed in 1981 dollars. The travel cost model is a simple one estimated with visits the measure of quantity and travel cost the measure of price. The consumer's surplus is the value of the site for recreational use.

The results of estimations of the linear, semi-log, double-log, and linear-log models are reported in Table 1. Inspection of the results indicates that the linear and semi-log models perform well in terms of t-statistics on the price variable and F-tests. The double-log and linear-log models do not perform as well under these criteria. Typically, a researcher would choose the semi-log model in this case as it has the highest F-value and the highest t-statistic on the travel cost variable.

TABLE 1

Regression Results of Alternate Functional Forms

Dependent variable: VISITS
Independent variable: TRAVEL COST

Model	Constant*	Slope*	R^2	Adj R^2	F	Standard Error
Linear	2.869 (0.1809)	-.0025 (.00103)	.043	.036	5.84	1.658
Semi-log	0.864 (0.0677)	-.0010 (.00038)	.050	.042	6.79	0.621
Double-log	1.126 (0.2380)	-.0885 (.05573)	.019	.011	2.52	0.631
Linear-log	3.652 (0.6326)	-.2516 (.14810)	.022	.014	2.89	1.677

* Standard errors in parentheses

The point estimates of consumer's surplus are provided in Table 2. As found in other studies, the (expected) consumer's surplus measure is quite sensitive to the choice of functional form. We also estimated the Box-Cox form described above and provide Figure 1 which shows the consumer's surplus

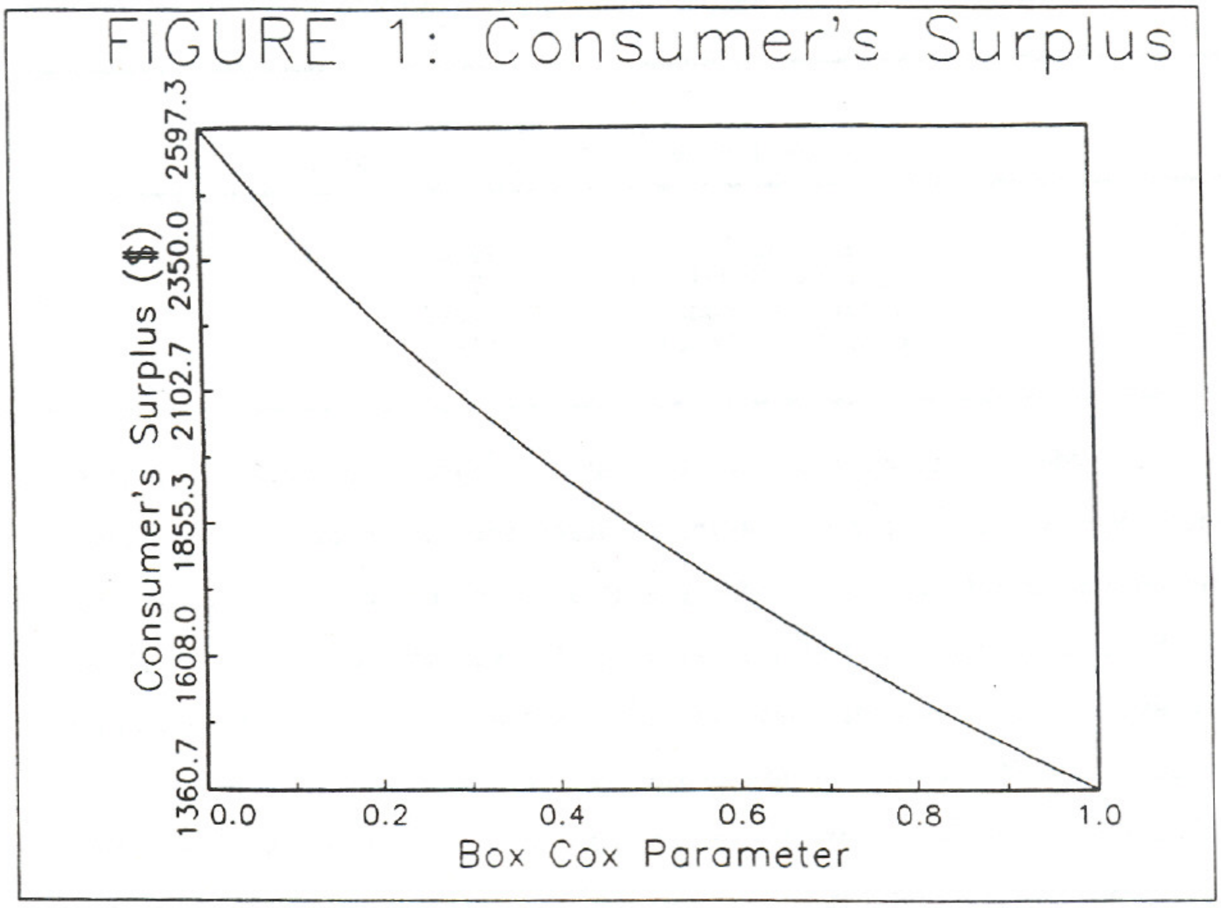
FIGURE 1: Consumer's Surplus
Consumer's Surplus ($)
1360.7
1608.0
1855.3
2102.7
2350.0
2597.3
0.0
0.2
0.4
0.6
0.8
1.0
Box Cox Parameter

measure as a function of the Box-Cox parameter. As the Box-Cox parameter increases the measure of consumer's surplus declines.[6] We are interested in describing the variance around selected points on the curve drawn in Figure 1, as well as the variance of consumer's surplus for other forms not nested within the Box-Cox framework.

TABLE 2

Point Estimates of Consumer's Surplus

Functional Form	Consumer's Surplus
Linear Model	$1367
Semi-log Model	$2593
Double-log Model	$1598
Linear-log Model	$1876

In order to estimate the variance of the consumer's surplus measures, for each model we generate a new series of dependent variables using the non-random design matrix and a randomly generated error from a normal distribution which has mean zero and variance equal to the variance of the error of the regression. This new dependent variable is then used to determine a new set of demand coefficients; the new demand parameters are in turn used to calculate new estimates of the consumer's surplus for each functional form. This procedure is replicated 5000 times. The result is a distribution of welfare measures for each functional form.[7]

The results of the Monte Carlo analysis are presented in Table 3. The mean, standard deviation, minimum, maximum and coefficient of variation are presented for each functional form. The size of the standard deviation of the welfare measure for the linear and semi-log model is most apparent. The large variances occur because the travel cost parameter is only significantly different from zero at a 1 percent level. Therefore, many replications of the model result in travel cost parameters near zero. The semi-log and linear-log models do not suffer from this inflation.

TABLE 3

Measures of Welfare*

Model	Mean	Standard Deviation	Minimum	Maximum	Coefficient of Variation
Linear	1,974	12,090	-184,766	624,327	6.12
Semi-log	3,282	10,379	-320,804	365,844	3.16
Double-log	1,608	203	1,021	2,540	0.13
Linear-log	1,873	300	963	2,990	0.16

* From a Monte Carlo experiment designed to calculate estimates of consumer's surplus from 5,000 sets of randomly generated observations.

In the case of the double-log and linear-log models, the means of the Monte Carlo analyses and the point estimates of the means provided by equations (3-a) and (4-a) are not very different. For the linear and semi-log models, the means of the Monte Carlo analyses are somewhat larger than the point estimates. This is due to the fact that the Monte Carlo results provide a direct estimate of, rather than an approximation for, the expected consumer's surplus. While equations (1-a) to (4-a) provide the point estimates usually used in welfare analysis, the expected value of consumer's surplus can be approximated for the linear and semi-log functional forms using relation (6) above. However, this approximation may not be appropriate for cases in which the price parameter approaches zero.[8] The Monte Carlo analysis will choose some values of the price coefficient which are very close to zero and this will have a severe effect on the estimate of the mean and variance of the consumer's surplus. For this reason, the expected value of consumer's surplus calculated in the Monte Carlo analysis for the linear and semi-log models is somewhat higher than the value provided by the approximation. The approximated expected values for the semi-log and linear models are $2971.14 and $1601.12, respectively. Comparing these to the mean values of consumer's surplus estimates reported in Table 3 shows that the difference between using the approximation and the Monte Carlo analysis is as large as the difference in consumer's surplus between two different functional forms.

The analysis of the distribution of the welfare measures has shown that even though the parameters of the demand equation may appear preferable, the distribution of the consumer's surplus measure may not be appealing. The investigator must realize that the curve drawn in Figure 1 also has a distribution around each point and that altering the choice of functional form will affect the distribution of the estimate of the welfare measure. For the data analyzed above, the demand equations for the double-log and linear-log appear more appealing on the grounds of confidence in the welfare measure.[9]

DISCUSSION

Most analyses of different functional forms for demand equations have labeled the form that "best fits" the data as the "true" form and the welfare measure computed from it as the "true" measure. This is not strictly true, since the true forms are unknown. The use of statistical demand analyses results in a probability distribution for the welfare measure. In many situations, the variance of this distribution, as well as its mean, will matter to the analyst. In this paper we point out that different function forms imply different dispersion of this distribution in addition to the different means noted previously in the literature (Ziemer, Musser, and Hill). Our results indicate that this effect may be substantial. Of course these specific Monte Carlo results may not generalize to all data sets.

One method of choosing functional form is to use the Generalized Box-Cox. Unfortunately, integrating the generalized Box-Cox form to find the consumer's surplus measure requires integration by reduction which implies that the Box-Cox parameters must be known before integration. Thus, the general form of the consumer's surplus for the Generalized Box-Cox cannot be defined. Once the welfare measure is determined for each specific combination of Box-Cox parameters, however, the variance can be estimated using the procedures outlined above -- a very cumbersome recommendation. A simple approach is to estimate a few functional forms and follow some rules to determine how sensitive the welfare measure is, namely, the price coefficient must be different from zero for the linear or semi-log. A more complete analysis must address the question of how different these should be.

This analysis does not preclude the results of Hanemann (1982b) and others who have investigated the restrictions that demand parameters must satisfy in order to be consistent with an underlying utility function. Our analysis only addresses the question of functional form and the statistical properties of the welfare measure within the class of integrable demands. However, not all forms are consistent with utility theory and some investigators may be willing to sacrifice theoretical consistency for good fits and small variance. Also, some forms, such as the double-log form, imply that the resource is "essential" (Bockstael, Hanemann and Strand). These theoretical considerations may influence the choice of functional form. The results from our experiments imply that if one chooses a functional form on the basis of the variance of consumer's surplus, for our data the double-log appears to be the appropriate choice among the functional forms considered.

Our results imply that there is a tradeoff between the utility-theoretic models and models which provide appealing statistical results. While we do not provide any final recommendations on this problem, we have noted that the problem exists, may be important, and is worthy of further attention via both basic and applied research.

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FOOTNOTES

1. The authors would like to thank Jim Binkley, Jay Coggins, Marie Livingston, and Ted McConnell for helpful discussions.

2. For each sample of consumers we use the actual quantity of visits to estimate the consumer's surplus. This hypothesis does not preclude repeated sampling experiments to investigate the distribution of the welfare measure. This may not be the case for the "errors in measurement" hypothesis which uses predicted quantities. That is, in the absence of measurement error, the latter approach implies the absence of an inference problem; all individuals are identical and sampling variability is not an issue. This seems extreme. In the absence of a measurement model to identify the different sources of error, we believe that the omitted variable approach is more reasonable.

3. This is distinguished from the Generalized Box-Cox form in which both the dependent and independent variables have Box-Cox parameters attached to them.

4. We thank Kenneth McConnell for pointing out this possibility to us.

5. Further details on the data are available from the authors upon request.

6. Implicit in this figure are the changing parameters in the demand function.

7. The data are provided in the Appendix. This procedure can be replicated except for the random number generation procedure chosen. The algorithm and any further information desired on the Monte Carlo procedures used are available from the authors upon request.

8. The approximation presented in (6) is a second order Taylor series approximation of the ratio of random variables evaluated around the expected values. Extension of this Taylor series to the third order yields additional terms which involve the variance of y, the covariance of y and y2, and the expected value of x in the numerator with E(y)3 and E(y)4 in the denominator. Larger variances increase the size of this term. Division by E(y)3 and E(y)4 when E(y) is small may also lead to large values for this term. The significance of the higher order terms is illustrated by the fact that the first order term for the semi-log model is $2,593 and the second order term adds $378; the Monte Carlo mean is $3,282 indicating terms higher than 2nd order add $311 to the expected value. For the double-log model, the Monte Carlo estimate and the point estimate differ by only $10 or 0.6%.

9. We have also estimated these models using Bockstael and Strand's measurement error form with predicted quantity (number of trips taken) in the welfare measure. The results obtained do not differ qualitatively from the results presented here.

APPENDIX

Data on Visits and Trip Costs

VISITS	TRAVEL COST	VISITS	TRAVEL COST	VISITS	TRAVEL COST	VISITS	TRAVEL COST
6.00	66.67	1.00	133.33	3.00	37.50	2.00	44.12
7.00	40.00	7.00	25.00	6.00	23.33	2.00	141.67
3.00	100.00	1.00	37.50	2.00	37.50	4.00	75.00
2.00	250.00	6.00	30.70	4.00	46.15	1.00	27.27
1.00	71.43	1.00	11.94	1.00	51.72	2.00	90.00
6.00	91.67	1.00	25.00	2.00	83.33	3.00	232.56
1.00	61.97	2.00	50.00	1.00	350.00	5.00	52.17
7.00	21.43	1.00	93.75	2.00	76.92	2.00	12.68
1.00	71.94	2.00	70.00	1.00	50.00	2.00	120.00
5.00	157.45	7.00	71.43	1.00	108.02	1.00	291.97
2.00	28.26	1.00	123.76	2.00	30.00	3.00	18.01
2.00	123.08	1.00	462.96	6.00	140.00	2.00	150.00
1.00	71.43	2.00	72.29	2.00	42.55	2.00	20.00
4.00	23.08	3.00	78.36	1.00	62.23	6.00	66.67
4.00	347.22	2.00	113.33	2.00	180.49	2.00	100.52
3.00	119.57	3.00	58.33	4.00	62.50	4.00	60.87
1.00	50.00	5.00	13.20	1.00	764.71	2.00	55.93
1.00	95.24	2.00	560.75	1.00	26.67	2.00	40.12
2.00	321.10	4.00	49.85	3.00	25.40	2.00	27.48
2.00	20.66	3.00	52.17	5.00	59.49	1.00	6.86
1.00	1000.00	2.00	50.00	3.00	66.67	5.00	34.87
4.00	100.00	1.00	121.21	3.00	100.00	2.00	24.19
4.00	49.87	2.00	40.00	4.00	52.82	2.00	50.00
4.00	145.45	1.00	50.00	1.00	350.88	1.00	30.61
3.00	81.70	2.00	65.43	3.00	18.50	2.00	4.03
2.00	250.00	5.00	32.00	3.00	104.13	2.00	23.16
5.00	9.00	1.00	63.06	1.00	200.00	5.00	30.00
1.00	79.11	1.00	121.62	1.00	600.00	7.00	85.71
2.00	48.95	1.00	40.85	4.00	125.00	1.00	22.73
3.00	198.11	5.00	40.95	3.00	259.26	1.00	37.97
1.00	35.71	1.00	196.51	1.00	27.27	4.00	17.21
1.00	264.08	3.00	116.67	1.00	30.38	2.00	180.00
4.00	85.71	1.00	45.00	1.00	2.94	4.00	30.41

Descriptive Statistics (Number of observations = 132)

Variable	Mean	Standard Deviation	Minimum	Maximum
VISITS	2.61	1.69	1.00	7.00
TRAVEL COST	106.05	140.91	2.94	1000.00

EMPIRICAL ESTIMATION OF SUPPLY IN A MULTICOHORT FISHERY: IMPLICATIONS FOR MANAGING THE ALASKAN KING CRAB INDUSTRY

BY

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INTRODUCTION

The Alaskan king crab industry is in a transition period, recovering from a dramatic boom-bust cycle.[1] Statewide harvests began an unprecedented period of growth in 1969 that continued through 1980. Harvests more than tripled, culminating in record catches of 185.7 million pounds. Growth in the Bristol Bay fishery management area was largely responsible for the boom; Bristol Bay harvests rose from 8.6 million pounds in 1970 to the record catch of 130 million pounds in 1980. Within 3 years, however, the industry collapsed. King crab stocks were so scarce that the Alaska Department of Fish and Game (ADFG) ordered complete closure of the Bristol Bay fishery. Statewide harvests plummeted to 26.9 million pounds. An additional 10 million pounds were lost by 1985 (U.S. Department of Interior 1947-1975; Alaska Department of Fish and Game 1969-1983, 1970-1983).

The economic wake of this collapse has been extensive, involving virtually every participant in the fishery. Between 1980 and 1983, exvessel revenues to fishermen fell by more than 50 percent, dropping by 93.2 million dollars. Processor sales dropped 178.0 million dollars (a 60 percent reduction), while sales from wholesalers declined by 304.2 million dollars (a 66 percent reduction). Multimillion dollar fishing vessels were idled, others shifted into different fisheries, processing plants closed and an industry-wide restructuring commenced.

The significance of the collapse may be placed in perspective by considering the fact that the king crab fishery was the second most valuable Alaska seafood industry between 1968 and 1983. Only the combined value of all six salmonid species harvested in Alaska exceeded that of king crab (ADFG 1969-1983). Yet, the statewide king crab catch rarely exceeded one-third the total catch of salmon, by weight.

The impact of the collapse extends well beyond the Alaskan economy. Butcher et al., (1981) identified direct linkages between the shellfish sector and the economy of the Puget Sound area in western Washington. Only 32 percent of total shellfish revenues were returned to the Alaskan economy in direct purchases of goods and services. Much of the remaining 68 percent were spent in the Seattle area for vessel maintenance/construction, gear and supplies, and general consumer goods. Moreover, most of the processing and cold storage firms are based in the Seattle area. The diminished flow of processed king crab products to domestic and foreign markets also caused a tripling of nominal wholesale and retail prices between 1980 and 1986 (National Marine Fisheries Service 1969-1984).

Short of blaming the open access milieu of this common property fishery, specific causes or contributing factors to the collapse must be identified if policymakers are to contribute to a recovery. Resolution of the underlying bioeconomics is essential in this regard. Such a bioeconomic analysis of the Alaskan king crab industry is reported by Hanson (1987) and Matulich, Hanson and Mittelhammer (1987a, b, c).[2] This paper presents one aspect of that research -- the framework developed to estimate a facet of the biological response, and ultimately supply, in this multicohort fishery. The specific framework addressed in this paper is a trajectory adjusted intrinsic recruitment (TAIR) model which offers considerable promise in modeling this and other fishery stocks that are characterized by multiple age class spawning (hereafter referred to as multicohort species).

Initially, an overview of the composite bioeconomic model is presented as backdrop to the particular biological modeling framework of concern here. The composite model describes how the Alaskan king crab industry has operated for nearly 2 decades.

OVERVIEW OF THE BIOECONOMIC MODEL

The king crab industry can be viewed in a market equilibrium context involving supply and demand at two levels of the market: an input or raw crab market model and a final processed product market model. See Figure 1. The explicit interaction between management, biology, harvest and the market for king crab shown in this figure accounts for the feedback inherent in the overall bioeconomic system for a single year (July 1-June 30). A brief summary of each component is presented below as an overview of this complex fishery model. Details pertaining to theoretical underpinnings and empirical estimation of all submodels are discussed in Matulich, Hanson and Mittelhammer (1987a, b, c).

Management provides an external control on industry behavior. A variety of regulations are employed in the management of this fishery, including gear restrictions and exclusive registration in selected fishing areas. However, sex, size and season length are the principal regulations that are actively used to manage the Bristol Bay fishery. Annual decisions regarding these regulatory controls historically have been based on a combination of one-period-ahead stock forecasts and intraseasonal industry performance. Fishery policy has never explicitly recognized the dynamic market feedback effects among annual harvest policy, future harvestable stocks, current prices and future prices. In fact, economics has never played a prominent policy role in this once lucrative fishery.[3]

The importance of formulating policies that explicitly recognize the extremely long and complicated lags that characterize king crab population dynamics, and thus, the long range economic health of this industry, is illustrated in Figure 2. The beginning stock of legal (harvestable) crab in 1987 is shown to consist of three age classes of male crab: 8 year old legals

FIGURE 1

Components of Market Equilibrium in the Alaskan King Crab Industry

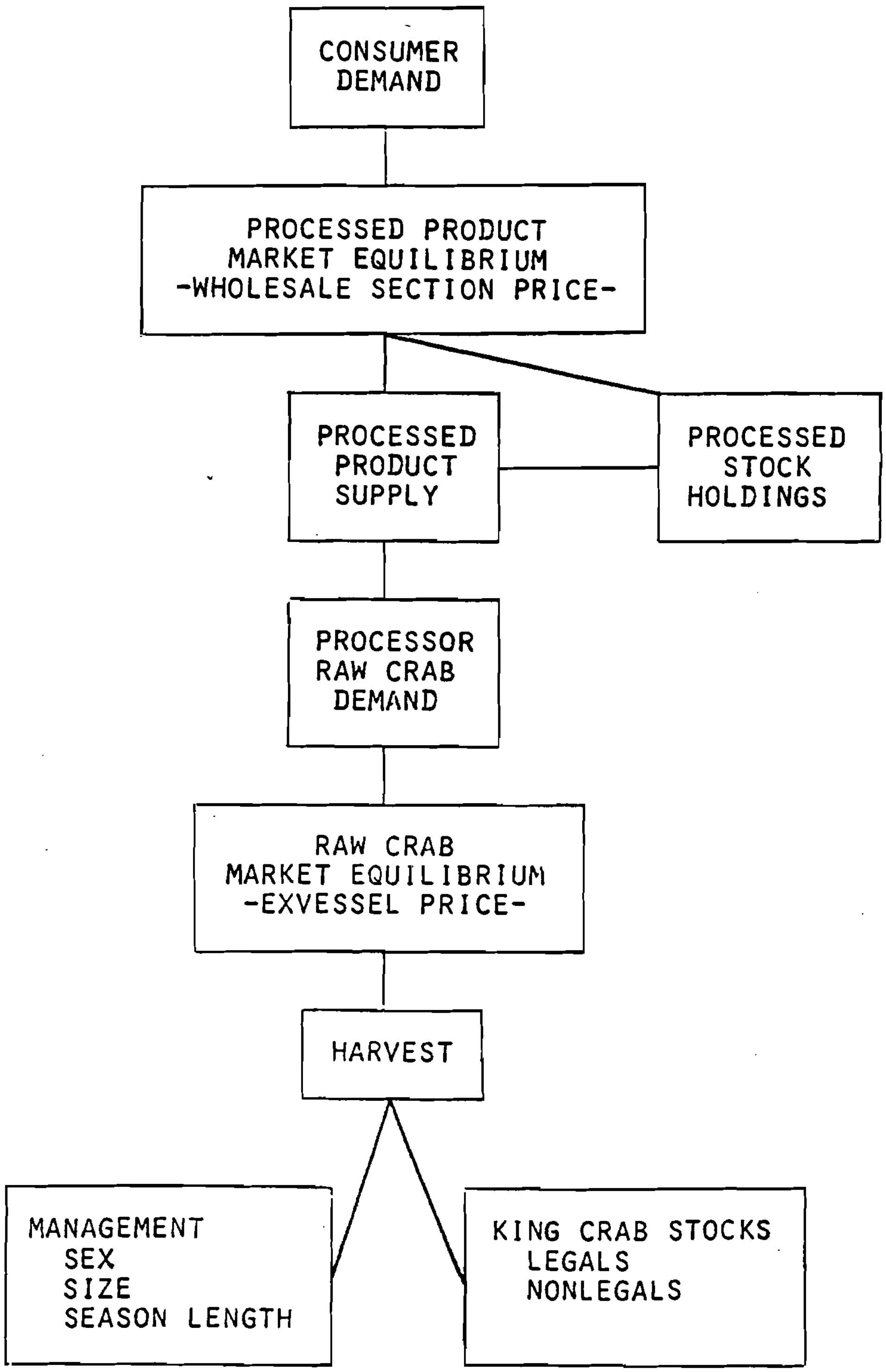
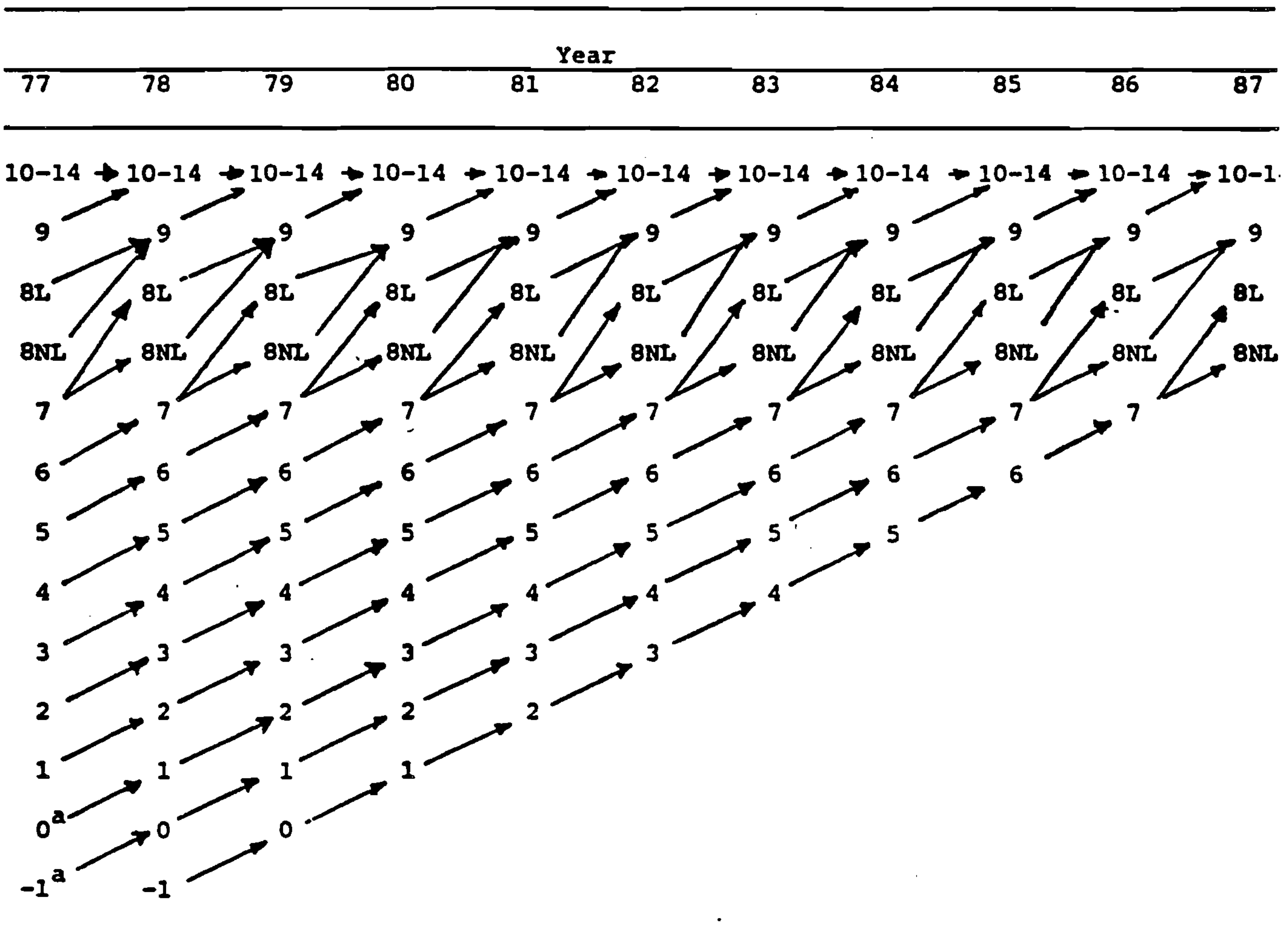


FIGURE 2

Recursive Age Structured Character of Red King Crab



[a]The terms 0 and -1 refer to newly hatched larvae and breeding, respectively.

(8L), 9 year olds (9) and 10 to 14 year olds (10-14). The recursion illustrated in this figure shows the pass-through or pipeline of unharvested legal (L) and nonlegal (NL) crab in the previous year that comprise the beginning stock of current year age class. For example, both the current stock of $8L_t$ and of $8NL_t$ were formed from surviving 7_{t-1} the previous period. Likewise, 9_t was formed from $8L_{t-1}$ and $8NL_{t-1}$; $10\text{-}14_t$ was formed from 9_{t-1} and $10\text{-}14_{t-1}$. Carrying this recursion back to parental stocks, 8 year old recruits in 1987 were created by sexually mature parent stock 9 years earlier (1978). Nine year old recruits in 1987 are the progeny of adult crab stocks in 1977 (10 years earlier). The abundance of 10 year olds in 1987 are a function of parental stock 11 years earlier, and so on.

This figure clearly illustrates there are three dimensions to current period decisions concerning size limit policy that should determine the magnitude of 8L versus 8NL. Eight year old potential recruit class crab can have value as: 1) currently harvestable stocks, 2) future harvestable stocks (up to 6 years into the future), and 3) parent stocks of crab that can be harvested 9 to 15 or 16 years into the future. Evaluation of the implied biological and economic tradeoffs is precisely what is required by the Magnuson Act and is the general objective of the composite bioeconomic analysis.

The biological response submodel for red king crab in Bristol Bay consists of seven estimated recruitment/growth functions and several definitional identities. The seven behavioral relationships combine to form a recursive, age-structured growth model for sexually mature male and female king crab biomass. The sexes are modeled separately to reflect the impact of males-only harvest regulations on population abundance. Primary research emphasis is given to the male equations because of this regulation.

Three classes of recruitment/growth relationships are formulated: Ricker (1954) spawner-recruit models, trajectory adjusted intrinsic recruitment (TAIR) models, and growth/mortality models similar to Deriso (1980). Individual single age-class equations are derived for beginning stocks of 5, 6, 7 and 8 year old males, and for 5 year old females. Aggregate cohort equations are estimated for 9 to 14 year old males and for 6 to 14 year old females. Statistical significance, overall goodness of fit and ability of these behavioral equations to predict history are good. The beginning stock of legal king crab is defined as the sum of all 9 to 14 year old male crab and that portion of the 8 year old males allowed to be harvested by the ADFG size limit. Nonlegal crab are defined as all sublegal males and all females.

The biological submodel is linked to the market submodel through a lagged harvest relationship. Fishermen provide the primary supply of king crab by applying harvest effort to the beginning crab stock. Their behavior is captured by three behavioral relationships: total quantity harvested, effort, and fleet size. Total quantity harvested is formulated as a production function that depends upon total fishing effort and the beginning stocks of both legal and nonlegal crab. The abundance of legal crab at the start of the next season, in turn, is affected by current total harvest. Total effort, as measured by the number of potlifts during the season, is a function of fleet size, abundance of legal males, and the current price received, i.e., exvessel price. Season length and the harvest guideline control total harvest through the effort relationship. Fleet size depends on existing capital stock, abundance of legal crab, and seasonal revenue expectations based on the previous season's total harvest revenue.

An exvessel price offer function is used to incorporate processors' derived demand for raw crab into the market equilibrium model. Fishing commences when an initial exvessel price is negotiated; subsequent price changes reflect cumulative harvest and overall crab quality as the season progresses. The processors' bid or offer takes into account expected wholesale prices, processing costs and the costs of fishing. Accordingly, the seasonal average exvessel price offer relation is modeled as a bilateral monopoly price.

The wholesale market for king crab translates the processors' derived demand for raw crab into a supply of processed crab that confronts final demand for processed crab products. The supply of processed king crab is modeled as an inverse supply relationship linking total processed production to changes in inventory holdings. A minor quantity of imports are included as an exogenous injection to total supply. Production indirectly depends on holdover inventories, input prices, processing capacity, and market price expectations through the wholesale price relationship. Inventory holdings are modeled as a combination of transactional and speculative motives. Consequently, current production, future wholesale price expectations and the opportunity cost of holding inventories enter the holdings equation.

Domestic consumption behavior is a function of the wholesale crab price, the price of a substitute good, and disposable per capita income; exports are treated as exogenous. Domestic consumption and export demand equilibrate with supply through the wholesale price.

TRAJECTORY ADJUSTED INTRINSIC RECRUITMENT

The most difficult, and certainly, crucial component of the analysis was the development of a suitable/accurate biological response submodel. National Marine Fisheries Service biologists recommended the use of an age specific, lagged Ricker (1954) spawner-recruit model. Recruitment into the n_{th} age class in period t ($R_{n,\ t}$) is shown in equation (1) to be a function of properly lagged parental spawning stock that reflects the time required for progeny to reach the given cohort group, i.e.,

$$(1) \qquad R_{n,\ t} = a_n P_{t-(n+1)} e^{-b_n P_{t-(n+1)}}$$

This generic framework provided excellent predictions for 5 and 6 year old male king crab, but erred substantially for older crab. In fact, the older the age class, the greater the predictive error. The problem appeared to be inherent to the Ricker framework which predicts age class recruitment based on an underlying expected natural propensity to recruit. However, age class growth may fluctuate up or down from intrinsic tendencies. A Ricker approach ignores a variety of potential sources of predictive error including the effects of cyclic variations, environmental perturbations, structural changes in survival, and even measurement errors of previous age class stocks that are used to predict the abundance of some subsequent age class.

An adjustment framework was developed to incorporate the cumulative effect of such factors on intrinsic recruitment tendencies. Specifically, an intermediate observation of age class abundance is used to adjust the intrinsic recruitment trajectory and improve the estimate of actual age class development. The TAIR specification is given in equation (2) for 7 year old male recruits

$$(2) \qquad MALE7_t = (MALE7_t^*)^{w_1} (c_7 MALE6_{t-1})^{w_2}$$

Recruitment of 7 year old male king crab is hypothesized as the product of two geometrically weighted expectations. The initial expectation ($MALE7_t^*$) is formed as a Ricker spawner-recruit model

$$(3) \qquad MALE7_t^* = a_7 F_{t-8}\, e^{-b_1 F_{t-8} + b_2 FM_{t-8} - b_3 M}$$

where F and M are adult/sexually mature king crab and FM is the product of these two biomass observations.

This intrinsic recruitment trajectory is formed 8 years earlier based solely upon spawning stock biomass. The adjustment to this trajectory involves two components: (a) the second expectation ($c_7 MALE6_{t-1}$), formed as the growth/survival of an intermediate observation of prerecruit biomass, and (b) geometric weights (w_1 and w_2) that measure the relative importance of each expectation. These components adjust the intrinsic recruitment trajectory to more accurately reflect actual spawning, growth and survival. Accordingly, this weighted adjustment process reflects the cumulative effect of environmental perturbations or other sources of predictive error that cannot be modeled at the time of spawning.[4] The parameter c_7 is an age specific growth/survival rate.

The TAIR specification is empirically flexible, permitting the data to determine the tendency toward intrinsic recruitment. If $w_2 = 0$ and $w_1 = 1.0$, then the Ricker specification given in (3) predicts observed recruitment. If $w_2 = 1.0$ and $w_1 = 0$, growth/survival of observed prerecruit biomass is sufficient to explain age class recruitment. When neither of these parameters are zero, then the TAIR specification reflects adjustment away from the intrinsic recruitment rate.

Two parameters (a_7 and c_7) in equation (2) are not statistically identifiable. An equivalent but more aggregate form of (2) that combines the influence of these unidentifiable parameters was estimated.

(4) $$MALE7_t = \alpha_7 F_{t-8}^{w_1} e^{-\beta_1 F_{t-8} + \beta_2 FM_{t-8} - \beta_3 M_{t-8}} MALE6_{t-1}^{w_2}$$

where $\alpha_7 = a_7^{w_1} c_7^{w_2}$

$\beta_i = b_i w_1$, i = 1, 2, 3 .

King crab population estimates for the southeastern Bering Sea developed by the National Marine Fisheries Service were used to estimate the parameters of the biological response submodel. Observations were available for the period from 1968 to 1985. The weighted nonlinear least squares estimate of the male 7 year old TAIR model is given in (5).[5]

(5) $$MALE7_7 = \underset{(18.32)}{0.058} \left[F_{t-8}^{\underset{(5.76)}{2.424}} e^{(\underset{(-5.07)}{-0.054} F_{t-8} + \underset{(4.77)}{0.00008} FM_{t-8} - \underset{(-5.62)}{0.011} M_{t-8} - \underset{(-2.40)}{0.708} DUM83)} \right] MALE6_{t-1}^{\underset{(1.70)}{0.334}}$$

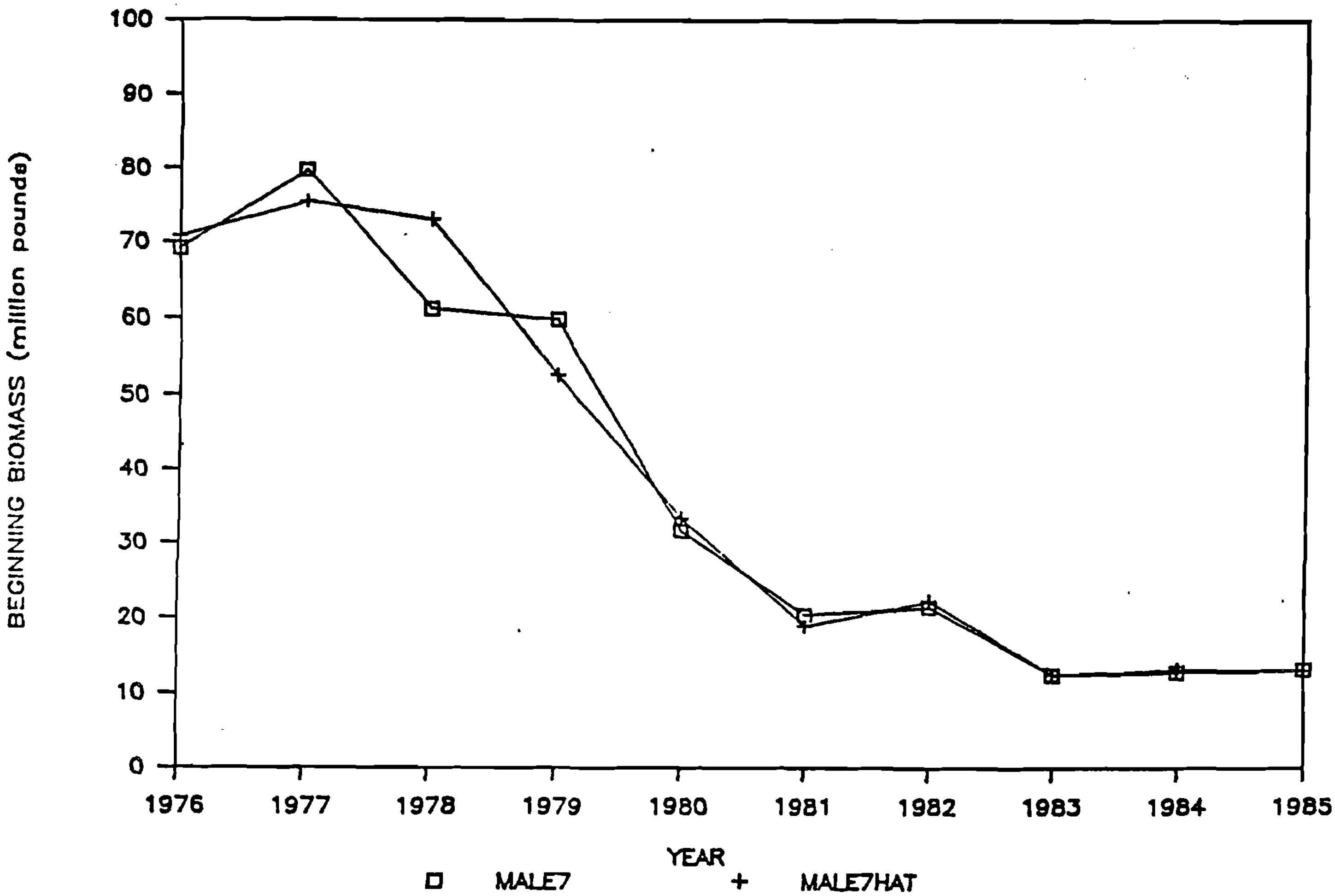
$^2R = 0.986$ df = 3

The statistical goodness of fit measures in combination with Figure 3 illustrate the predictive accuracy of (5) over the period 1976 to 1985.[6] DUM83 marks the 1983 MALE7 observation as an apparent structural increase in natural mortality, occurring sometime between 1982 and 1983. This one time structural break is believed to depress recruitment of $MALE6_{82}$ into the $MALE7_{83}$ cohort.

Equation (5) reveals modest adjustment to the expected 7 year old recruitment trajectory. The w_2 parameter was estimated to be 0.334. The value of w_1 in (5) is 2.424.

FIGURE 3

Actual Versus Predicted Population Levels of 7 Year Old Male King Crab (MALE7 and MALE7HAT, Respectively), 1976-1985.



Comparing the TAIR estimate given in (5) with that of a pure Ricker model given in (6) confirms the importance of adjustment.

$$(6) \qquad MALE7_t = 6.771\ F_{t-8}\ e^{-0.022\ F\ +\ 0.039\ FM\ -\ 0.009\ M\ -\ 0.629\ DUM83}$$

$$(3.13) \qquad (-4.58) \qquad (2.28) \qquad (-2.75) \qquad (-0.78)$$

$R = 0.833 \qquad df = 5$

The Ricker specification yields 2 turning point errors and 5 of 9 predictions that err by more than 10 percent -- three of which err by more than 37 percent.

CONCLUSIONS

Two levels of conclusions may be drawn from this research. One narrowly focuses on the potential of trajectory adjusted intrinsic recruitment models, the other addresses the critical nature of modeling supply in natural resource management.

1. An adjustment framework like TAIR is a promising approach to modeling multicohort fisheries, possibly even non-fish species.

2. The research underlying this paper demonstrates the essential role of supply in bioeconomic analysis. Failure to understand (model) the nexus between the resource stocks and the economic markets is in part responsible for the collapse of this $1 billion king crab fishery. In a more generic context, such failure has perpetuated a broad spectrum of national fishery policies that artificially separate resource conservation from allocation, and focus on the former. Stated differently, failure to adequately model this complex supply problem as an inseparable part of the economic problem ensures that policymakers will never recognize the complex dynamic feedback effects between the underlying biological stocks and various aspects of the market.

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FOOTNOTES

1. "King crab" is the common name given to three crustaceans in the family of stone crabs, Lithodidae. The three species are the red king crab (Paralithodes camtschatica), the blue king crab (Paralithodes platypus), and the brown or golden king crab (Lithodes aequispina). All three species inhabit waters of the north Pacific Ocean. They are similar in appearance though noticeably varied in shell color. The red king crab, which is addressed in this report, has been the cornerstone of the Alaskan king crab industry because of its large size; shallow, inshore distribution; and historically greater abundance. The other two king crab species, though harvested commercially, have been much less abundant and restricted to more localized and remote habitats. Harvest pressure and commercial importance of these two species has increased during the past 6 years principally because red king crab stocks have declined; only limited (primarily incidental) catches were made prior to 1981.

2. The first report by Matulich, Hanson and Mittelhammer (1987a) presents a recursive age-structured biological model of Alaskan king crab. The second report (1987b) details the economic/market submodels, from initial harvest to final consumption. The biological and economic submodels are then integrated in the third report (1987c) to simulate industry responses/behavior under a variety of historical and potential future policy scenarios.

3. The general management objectives of the Alaska Board of Fisheries have been almost exclusively biological in nature, emphasizing conservation. The twofold objectives are: "(1) to establish a stable fishery, insofar as possible, eliminating the extreme fluctuations in catch that have characterized this fishery, and (2) to develop and maintain a broad based age structure of legal size male king crab, insuring both breeding success and the availability of a wide spectrum of year classes to the fishery" (ADFG 1985).

4. The adjustment factor is incorporated multiplicatively because Ricker (1954, p. 573) argued that inclusion of ". . . environmentally caused deviations from the reproductive norm must be multiplicative rather than additive."

5. A weighted estimation procedure was used to treat the presence of heteroskedasticity. The weight used, $(MALE6_{t-1})^{-2}$, was proportional to the inverse of the $MALE7_t$ sample variance.

6. The t-statistic for the parameter premultiplying the bracketed function tests the null hypothesis around 1.0. All other t-statistics refer to tests around zero.

VOLUNTEER TIME AS A COMPENSATION VEHICLE IN CONTINGENT VALUATION STUDIES OF ENDANGERED SPECIES[1]

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INTRODUCTION

Transfer of money income is the typical compensation mechanism used in Valuing public goods with the contingent valuation method (CVM). However, recent theoretical work by Bockstael and Strand, and Cory suggests that alternative welfare measures, other than those based solely on money transactions, deserve more consideration in non-market valuation research. Compensation in the form of discretionary time payments is discussed as one such alternative. Their work demonstrates that reliance on money transfers alone may have clear distributional implications favoring individuals with relatively higher income endowments. Such reliance may also lead to understatements of underlying social values of individuals who, because of their relative endowments of income and discretionary time, prefer that at least a portion of their compensation be in the form of a time commitment.

The inclusion of time as a CVM payment option raises two fundamental issues. First, can time payments be feasibly implemented in a manner that is both acceptable to respondents and conducive to unbiased valuation estimates? Second, what monetary cost should be ascribed to time compensation made or received? The CVM literature provides almost no insight into the first question, except perhaps to warn that use of an unpopular payment vehicle can lead to downward-biased value estimates, along with refusals to cooperate in valuation exercises (Cummings et al.). Practical experience, however, suggests that donation of discretionary time without pay is a relatively popular contribution mechanism, at least in the United States. By Hodgkinson and Weitzman's estimates, 52 percent of all adult Americans contributed volunteer time in 1981 to secure provision of public goods. Over half of these volunteers contributed more than two hours per week.

With respect to the second question, there are no studies to our knowledge that estimate the monetary value of individuals' time contributions. Somewhat parallel studies, however, exist in the outdoor recreation demand analysis literature where several attempts have been made to convert travel and on-site time into a money metric. For example, Mcconnell and Strand proposed estimating the value of travel time as a constant fraction of participants' wage rates. Smith et al., estimated hedonic prices for travel and on-site time on an individual observation basis. Time values were derived using data on each respondent's personal, job and residential site characteristics. Notwithstanding these developments, no clear consensus has yet been reached about appropriate methods to value time spent in recreational pursuits. This is troublesome because as Bishop and Heberlein have shown, final benefit estimates appear to be extremely sensitive to time cost assumptions. Similar difficulties could likely arise if time payment options are adopted in CVM applications.

In this paper we propose a simple welfare model that illustrates the theoretical basis for including time payments to estimate economic surpluses. This general framework is then applied to value the preservation of two endangered marine mammals. A dichotomous choice valuation technique is used that incorporates both time and money payment options. Implicit values of time contributions are estimated from sample data. We show that the contribution of discretionary time is a popular payment option in this specific valuation context. Due to this popularity, however, time contributions have low estimated implicit values which are far below opportunity wage rates. This outcome is significant because preservation values estimated using our approach are acutely sensitive, and directly related, to the value placed on time donations.

WILLINGNESS TO PAY AND WILLINGNESS TO VOLUNTEER TIME

Consider a representative individual with a utility function,

(1) $$U = U(s,x)$$

where s represents the exogenously determined population size of a particular endangered species; and x is a vector of all other private goods and services weakly separable from s.

Faced with limitations on available income from all wage and non-wage sources (Y), and on available discretionary time after income-producing activities (T), the individual's constrained choice problem is to

(2) $$\max_{x} L = U(s,x) + \lambda(Y-px) + \Psi(T-tx)$$

where p and t are the price and time input requirement vectors associated with x, respectively. Both income and time have separate utility shadow values given by λ and Ψ, respectively.[2] The ratio of shadow values (Ψ/λ) can be interpreted as the marginal rate of substitution between time and income. The solution to the problem in the two-constraint case yields the indirect utility function,

(3) $$U = V(p,t,Y,T,s).$$

Consider now an exogenous decrease in the population level of the endangered species from s' to s'', holding p, and t constant, and assuming $U(s') > U(s'')$. Presumably the individual would be willing to forgo income, leisure time, or both, to avoid having this population decrement occur.[3] The maximum time and income amounts that the individual would forgo, and still maintain utility at the subsequent level (given by V'') is

(4) $$V''(p,t,Y,T,s'') = V''(p,t,Y-WTP,T-WTVT,s')$$

where WTP is maximum willingness to pay in terms of dollars, and WTVT is maximum willingness to contribute volunteer time towards preservation efforts.

As pointed out by Cory, various combinations of WTP and WTVT exist that solve equation (4). Let the entire set of feasible combinations be written as

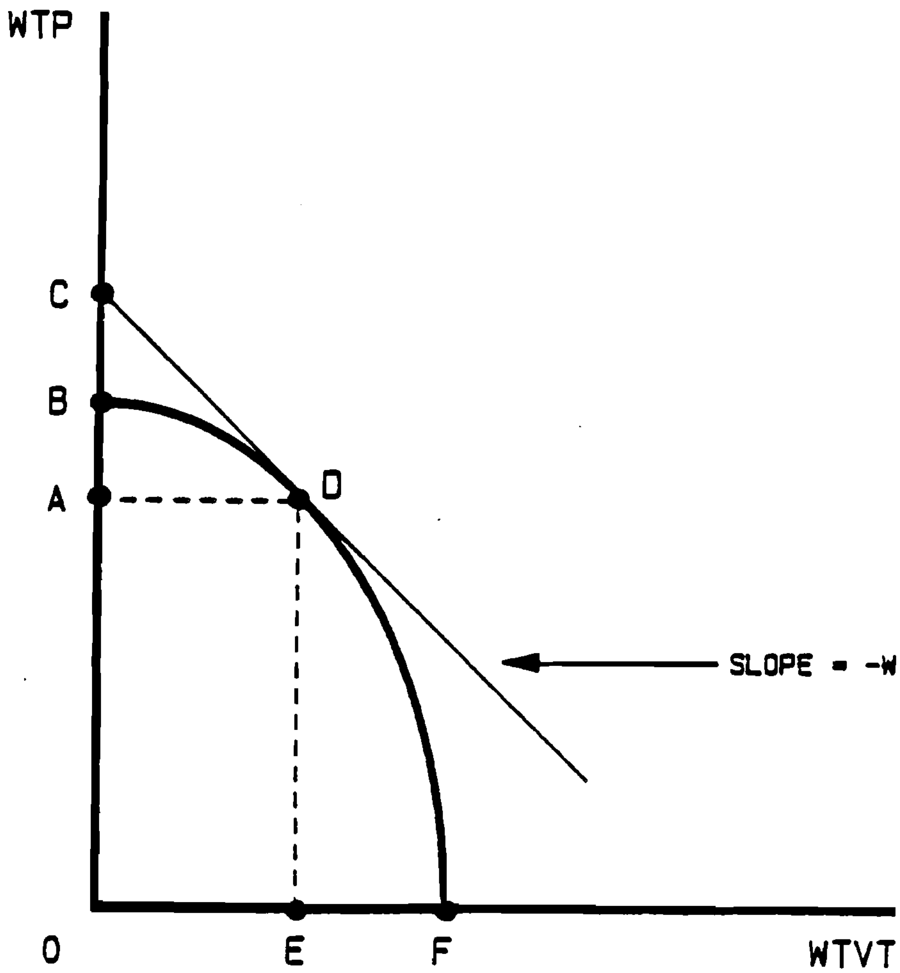
(5) ES = (WTP,WTVT)

where ES signifies that this is an equivalent surplus measure of a welfare loss arising from an exogenous decrement in the quantity of s available.[4] The locus of points in WTP, WTVT space that map out the ES function is illustrated in Figure 1. By definition, the individual is indifferent between any two points along the curve. Combinations northeast of the locus are too costly in terms of forgone income and time relative to the reduction in s. Conversely, combinations inside the frontier do not represent maximum possible time and money payments that the individual will pay to avoid the decrement in s. The corner solutions, points B and F, are relevant in situations where payment options are limited to be in the form of either money or time, but not both. For example, if only money payments are permitted, then ES equals OB. This vertical distance represents the maximum WTP for the individual.

The shape of the ES locus is found by totally differentiating equation (4). The slope, given by $dWTP/dWTVT = -(\partial U/\partial WTVT)/(\partial U/\partial WTP)$, is downward. The locus is concave to the origin as long as there is diminishing marginal utility associated with increases in income and leisure time. Its steepness is determined by the relative marginal <u>disutility</u> of time versus cash payments. For example, the locus will tend to be steep for an individual with scarce discretionary time relative to income such that the disultility of time payments far outweighs monetary outlays. Conversely, it will tend to be more flat for a person who has a generous leisure time endowment relative to income.

FIGURE 1

TRADEOFFS BETWEEN WILLINGNESS TO PAY (WTP) AND WILLINGNESS TO CONTRIBUTE VOLUNTEER TIME (WTVT)



A more shallow sloped ES locus would also characterize a person who, by contributing volunteer time, realizes some utility gain which to some extent offsets the disutility of a reduction in leisure time. Cesario, Wilman and others have interpreted this utility gain as arising from the "commodity value of time," or the utilitarian value of time spent in a particular manner. If volunteering to save an endangered species yields satisfaction to an individual, then the commodity value of time is positive. A utility maximizing individual will tend to adjust the scarcity value of time downward to account for this positive commodity value of time. A reduced perceived opportunity cost of discretionary time translates into a more shallow sloped ES curve.

Cory has noted that although the individual is indifferent concerning the various payment combinations given by the ES locus, a public agency seeking to maximize the total value of preservation contributions has clear preferences in this matter. For example, suppose that the change from s′ to s" can only be forestalled using purchased inputs of materials and labor. Money payments (WTP) obtained from individuals can be used to acquire materials. Similarly, contributions of volunteer time (WTVT) can be used to substitute for labor inputs that would have to otherwise be hired at some market-determined wage rate. From the perspective of the public agency, therefore, the maximum market value of preservation contributions (PC) that can be extracted from an individual is found by

$$(6) \qquad \max_{WTP,WTVT} PC = WTP + w * WTVT$$

subject to U = V′′ as defined in equation (4). The term w is a constant market wage rate for hired labor used in the preservation effort. The solution to equation (6) implies that the optimal combination of time and money contributions to extract from an individual is defined where dWTP/dWTVC = - w, or where the slope of the individual's ES locus equals the negative market wage rate for hired preservation labor inputs. In Figure 1, this equality occurs at point D, where OE units of volunteer time are obtained, along with OA dollars in monetary contributions.

PC in this instance equals OC, if time contributions are valued at w per unit. Notice that PC exceeds the individual's maximum WTP (equal to OB) by the amount BC. This means that if only money compensation was permitted, then the maximum dollar contributions forthcoming from the individual would be less than monetary value of the individual's maximum combined time and money contributions.

The divergence between PC and maximum WTP serves to illustrate the importance of appraising discretionary time payments. The difference is attributable entirely to how the individual's time compensation is valued. From the perspective of a public agency engaged in preservation projects, time contributions are appropriately valued at the market wage rate paid for hired labor. This is because each unit of volunteer time generates an average labor cost savings equal to W. From the volunteer's perspective, however, the relative scarcity value of forgone discretionary time is governed by the shape of the ES locus. If the locus is concave, this value declines as money payments are substituted for time payments. Consequently, although the marginal value of time contributions indeed equals w at point D in Figure 1, the marginal value is less than w for all inframarginal units of donated time. The monetary equivalent of all inframarginal units (OE) is given by the vertical distance AB. This amount, except perhaps by chance, has little correlation with some external wage rate paid by the public agency for hired labor. Moreover, as Wilman points out in the case of valuing discretionary recreation travel time, this amount is not always directly proportional to the individual's average wage rate. The link between time value-and average wage rates is weakest when the individual cannot readily transform discretionary time into wages, and when time donations yield direct utilitarian benefits to the volunteer.

AN EMPIRICAL EVALUATION

The feasibility of including time payment options in CVM was explored in the context of a recent study of endangered species preservation in Hawaii. Two marine mammals were targeted for valuation: the Hawaiian monk seal (Monachus schauinslandi) and the humpback whale (Megaptera novaeangliea). The empirical analysis centered on measuring Hawaii residents' willingness to sacrifice time and income to ensure the continued existence of these seals and whales at their existing population levels. Several different versions of a standard survey instrument were developed to value monk seals and humpback whales individually and jointly. The order in which the mammals were valued varied across survey versions. The effects of sequencing has been discussed elsewhere by Samples and Hollyer and will not be treated here.

The following fabricated contingent market situation provided the basis for valuation. Depending on the questionnaire version, respondents were asked to imagine themselves learning the next morning that a rare disease had killed either two seals or two whales. Respondents were further informed that the disease would rapidly destroy the entire remaining population unless expensive medical attention was provided. They were told that medical care, if provided in sufficient quantities, would absolutely guarantee the short-run survival of the remainder of the affected population from this particular disease. However, no guarantees were made about long-term survival in the face of other maladies. In short, respondents were presented with a dramatic and urgent situation requiring a discrete input of resources to ensure preservation over the short-run.

After describing this hypothetical scenario, valuation assessment was conducted in two stages. During the first stage, respondents were asked if they would contribute to preserving the threatened resource at hand. It was explained that contributions could be made in the form of money (payable over the next 12 months), or in the form of volunteer time (to be delivered over the next 12 months at home or a central location preparing medical supplies), or both. Respondents were further given the option of not making a contribution at all. The percentage of selecting the zero donation alternative ranged from 18 to 31 percent depending on survey version. Individuals in this group were automatically assigned a zero valuation for preserving the resource at hand. Motives of non-contributors were not further probed, although less than 1 percent of respondents refused to participate in the valuation exercise altogether.

Selected payment methods did not vary significantly (at the 95 percent level of significance) across survey versions and across species (Table 1). The most commonly selected contribution option was payment of "money only," which was selected by 34 to 45 percent of respondents, depending on survey version. Nearly an equal proportion of individuals, however, expressed willingness to contribute "time only," or some combination of time and money. Therefore, of those respondents willing to make some form of contribution, nearly half expressed a desire to make a time contribution.

Hypothesized relationships between preferred payment option and respondent total annual household income (a categorical variable) were explored using contingency table tests. Modes of payments differed across all survey versions (at the 95 percent significance level) depending on whether household income was greater than or less than $20,000 (approximately the Hawaii 1985 median household income). Respondents in the higher household

TABLE 1

RESPONDENT CHOICE OF PAYMENT OPTION FOR

PRESERVING MONK SEALS AND HUMPBACK WHALES

PAYMENT OPTION	PERCENTAGE OF RESPONDENTS: Survey Version I (a) (N=88) Seals	Whales	Survey Version II(b) (N=77) Seals	Whales
Time Only	23%	24%	16%	19%
Money Only	36	34	43	45
Time & Money	16	16	10	17
Neither Time Nor Money	24	25	31	18
Refusal	1	1	0	0
Total	100%	100%	100%	99% (c)

Notes: (a) Seals valued first, then whales

(b) Whales valued first, then seals

(c) Deviation from 100% due to rounding error

income bracket generally preferred making money rather than time payments. Presumably, this reflects their high scarcity value of discretionary time relative to income.

In the second stage of the valuation exercise, respondents who expressed a willingness to make some form of contribution were then asked if they would contribute at least X dollars or Y hours, or both, depending on the contribution method they selected. This presented a relatively simple dichotomous choice situation with the acceptable responses being either "Yes" or "No." Fixed amounts for X and Y were independently and randomly assigned. Requested time contributions ranged from 1 to 136 hours. Money payments were on the average three times larger, and ranged from $3 to $213.

Assigned time amounts translated into assigned money amounts using a $3.00 "wage" conversion factor. This meant that for respondents who valued their discretionary time at a rate greater than $3.00 per hour, assigned time payments were more costly on the average compared with assigned money payments. Nevertheless, payments of time were generally more acceptable to respondents compared with money payments. Out of 179 persons presented with fixed requested money contribution amounts, 57 percent said "yes" to contributing the amount specified. By comparison, 85 percent of 117 respondents responded affirmatively that they would contribute specified time amounts.

For each survey version and particular resource, data on the binary response ("Yes" or "No") and fixed contribution amounts were used to fit a logistic probability function (see Bishop and Heberlein, Hanemann and Sellar et al., for discussion of this procedure). The basic estimation model used to accommodate inclusion of volunteer time payments was specified as

(7) $P(Yi) = 1/[1 + \exp-(B_0 + B_1{*}Ci)]$.

where P(Yi) is the probability that the ith respondent will answer affirmatively to a given total time and money contribution amount Ci. B_0 and B_1 are parameters to be estimated. A linear specification of the exponential term was adopted following Hanemann who showed that this form is consistent with utility theory.[5]

The contribution amount (Ci) was formulated as a linear combination of the fixed money (Mi) and time (Ti) amounts proposed to the ith respondent, $Ci = (Mi + w{*}Ti)$.[6] The time variable was expressed in monetary terms using a constant hourly "wage" rate (w). Two approaches were followed to define w. The first was to set w arbitrarily at the 1986 U.S. minimum wage rate ($3.35). This approach is admittedly problematic because of the ambiguous relationship between an individual's marginal valuation of volunteer time contributions and an exogenous wage rate. Given this uncertainty, a wage rate of $1.00 was also used to test for the sensitivity of preservation value estimates to changes in assigned volunteer time "wages."

A second approach was to let sample data determine w as a prior step to estimating equation (7). By first estimating the logistic probability function as:

(8) $P(Yi) = 1/ [1 + \exp-(B_2 + B_3{*}Mi + B_4{*}Ti)]$

an estimate of w was obtained as B_4/B_3.[7] This ratio reveals respondents' overall average willingness to trade money for time contributions. Specifically it gives the dollar value of one unit of volunteer time and is constant for all sample observations regardless of occupation and income. McConnell and Strand used an analogous approach to estimate the implicit value of the opportunity cost of time spent in recreational travel.

Maximum likelihood estimates of equation (8) coefficients for seals and whales, based on data from two different survey versions, are given in Table 2. Statistical tests indicate that the estimated models have relatively high predictive power as measured by the percentage of correct forecasts which ranged between 73 and 82 percent. The money donation variables were consistently significant with negative signs as expected. The time variables were consistently insignificant and took on positive signs in both whale models.

TABLE 2

MAXIMUM LIKELIHOOD ESTIMATES FOR LOGIT MODELS

TO ESTIMATE IMPLICIT VALUES OF VOLUNTEER TIME CONTRIBUTIONS

SURVEY VERSION	RESOURCE	INTERCEPT	MONEY	TIME	PERCENT OF CORRECT FORECASTS(a)	IMPLICIT TIME VALUES
I (b)	Seal	1.832 (0.457)	-0.018 (0.005)	-0.001 (0.009)	82	$0.05
	Whale	1.264 (0.438)	-0.011 (0.004)	0.007 (0.009)	75	-0.60
II(c)	Seal	0.830 (0.477)	-0.016 (0.006)	-0.006 (0.008)	73	0.38
	Whale	2 .246 (0.552)	-0.018 (0.005)	0.003 (0.013)	79	-0.16

Notes: Estimated standard errors of coefficients in parentheses.

(a) Fraction of observations where predicted response is the same as observed response

(b) Seals valued first, then whales

(c) Whales valued first, then seals

Implicit time values which were calculated from the estimated time and money coefficients are given in Table 2. The implicit values were consistently low, and were negative in the case of whales. We interpret these results to mean that individuals perceived essentially zero opportunity costs associated with contributing volunteer time, at least within the range of time commitments we set forth. At least two factors may have contributed to this outcome, the first of which is the fact that volunteer time contributions could be made at home preparing supplies, thereby eliminating conflict with many other at-home leisure pursuits. Given this payment alternative, respondents may have percieved little opportunity cost associated with donating large quanitities of time. The second factor is that individuals may have expected to receive some private <u>benefit</u> by volunteering that would offset the opportunity costs of forgone discretionary time. Stated in terms of the model given above, the typical respondent's perceived commodity value of time spent in preservation activities apparently equals (for seals) or exceeds (for whales) his or her scarcity value of time.

Estimated imputed wage values, along with the two arbitrarily selected exogenous wage values ($1.00 and $3.35) were used to fit final logistic models [equation (7)] via maximum likelihood estimation. Not surprisingly, best fits were obtained in those models where estimated implicit values of volunteer time were used instead of arbitrary wage rates. Statistical tests indicate that the estimated models have relatively high predictive power as measured by the percentage of correct forecasts between 65 and 90 percent. Estimated coefficients on the Ci variables were significantly different from zero at the 90 percent significance level across all equations.

Willingness to provide time and money (hereinafter called total willingness to pay, or TWTP) for seal or whale preservation was computed in two steps. First, expected willingness to pay was derived by integrating each estimated logistic probability equation from zero to infinity using the formula $E(WTP)=(-B_0/B_1)+ln[1/\{1+exp-(B_0)\}]/B_1$. Evaluating this definite integral is analogous to integrating the area above the cumulative distribution function (CDF) for willingness to pay. By definition the area above a CDF of a random variable equals its expected value. The second step was to weight the resulting integral to reflect the proportion of respondents who were unwilling to commit time or money to the particular preservation effort. For example, if 20 percent of respondents would contribute neither time nor money, the value of the integral was multiplied by 0.8 to arrive at a final weighted expected value.

Resulting weighted expected TWTP estimates to preserve seals or whales for two survey versions and three alternative values assigned to time are given in Table 3. Calculated expected TWTP ranged between $52 and $266 for seals and between $101 and $1,050 for whales. These amounts may seem inordinately high compared with typical values in the range of $5 to $15 reported elsewhere in the other wildlife valuation studies (see for example Brookshire et al.; Boyle and Bishop). However, it is important to bear in mind that the values reported in Table 3 represent lump- sum TWTP amounts rather than annual WTP annuities as are more commonly reported. These disparities are greatly reduced by either capitalizing the annual values reported elsewhere to arrive at a lump-sum amount, or by amortizing the lump-sum values given in Table 3 to estimate annual values; in both cases using a discount rate in the range of 7 percent. For example, the annuity equivalent of a $266 lump-sum payment is approximately $19.

TABLE 3

ESTIMATED TOTAL WILLINGNESS TO PAY FOR MONK SEAL AND HUMPBACK WHALE PRESERVATION UNDER ALTERNATIVF- ASSUMPTIONS ABOUT VALUE ASSIGNED TO CONTRIBUTIONS OF VOLUNTEER TIME

	ESTIMATED TOTAL WILLINGNESS TO PAY			
VALUE ASSIGNED PER UNIT HOUR OF TIME DONATED	Survey Version I(a) (N=88)		Survey Version II(b) (N=77)	
	Seals	Whales	Seals	Whales
$1.00	$103	$ 142	$ 62	$125
3.35	266	1050	178	244
Imputed	82	101	52	109

Notes: (a) Seals valued first, then whales

(b) Whales valued first, then seals

Estimated TWTP was significantly affected by the value assigned to volunteer time. The lowest estimates were consistently associated with the imputed wage models. These estimates differed by as much as an order of magnitude from TWTP estimates based on a $3.35 wage rate. On the average, estimates based on a $3.35 hourly time value were 220 percent higher compared with those based on a $1.00 assigned wage.

The relatively low TWTP values derived using imputed wages presents an apparent paradox: a high willingness to sacrifice discretionary time to save the resource leads to low estimated preservation values. According to the received knowledge about time valuation, this outcome, albeit curious, makes perfect sense and is explained as follows. Imputed values of volunteer time are low because sampled individuals are overwhelmingly willing to provide volunteer effort to preserve seals and whales. Low imputed wage values in turn imply that the opportunity cost of time, as perceived by respondents, is also low relative to average wage rates. When time payments are converted to monetary flows using low time opportunity costs, TWTP is therefore accordingly lower than what would otherwise be the case if opportunity wage rates were used to value time payments. Clearly whether one accepts this argument or not depends on the premise that it is acceptable to deduct the commodity value of volunteer time from its scarcity value. If this premise is rejected, then the method used here is problematic. This is because our procedure entails measuring the combined commodity and scarcity components of the opportunity cost of time as a single imputed value. Identification of individual time value components is therefore not possible.

CONCLUSIONS

Welfare theory suggests that individuals may be willing to forgo income, discretionary time, or both in order to secure provision of a public good such as endangered species preservation. However, valuation research using CVM has largely ignored compensation options that take the form of time payments or receipts. Results of this study show that many individuals are willing to make donations of volunteer time, and some individuals prefer this option exclusively. The preference for time payments appears to be inversely related to household income.

We interpret the generous response to requested time payments as a clear indication of a high degree of respondent acceptance of a time payment vehicle. However, the popularity of time payments in this study also gives cause to question respondent's motives and perceived payoffs underlying their willingness to make significant donations of volunteer time. This concern comes directly into play when trying to estimate the value of time contributions in a simple manner, as we have done here.

It appears unavoidable that the inclusion of time payments in CVM requires that a value be placed on this time, assuming that CVM estimates are to be expressed in monetary terms. Selection of an appropriate value for time appears to be critical, as evidenced by the sensitivity of estimated seal and whale preservation values to time value assumptions.

Assigning an arbitrary constant "wage" value to volunteer time for the sample is certainly convenient but it does not satisfactorily address the relationship between discretionary time value and average wage rates. Alternatively, time values can be imputed using cross-sectional data on time-money tradeoffs. In this study, calculated shadow values for contributions of volunteer time were found to be low relative to U.S. minimum wage levels. This in turn results in lower preservation value estimates that would be the case if only the scarcity value of discretionary time is used to monetize time contributions. We hypothesize that this outcome reflects positive personal benefits associated with volunteer action that tend to balance reductions in wage-earning potential. Nevertheless, the same result could conceivably arise due to respondents' lack of familiarity with making volunteer time contributions and a consequent overstatement of actual willingness to contribute. Further research is needed to better understand motives for making time payments, and how these should be appropriately valued on an individual observation as well as a sample-wide basis.

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FOOTNOTES

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2. This two-constraint formulation assumes that discretionary time cannot be readily converted into income. If, however, leisure time and income are perfectly substitutable, then the two constraints on time and income collapse to a single constraint on "full income" which is normally defined as actual and potential income from all sources.

3. The choice of income and time payments rather than receipts is purely expositional. The model presented here (except for minor changes in signs) applies equally when compensation is received rather than given. Similarly, it is straightforward to consider quantity increments, along with changes in the reference utility level from a posteriori to a priori.

4. ES is formulated here as a multi-dimensional welfare measure indicator that includes both time and money compensation components without any explict conversion between the two. However, for purposes of interpersonal comparisons and aggregation it is useful to express ES in dollar terms by appropriately converting the WTVT term.

5. Respondent household income was included as an explanatory variable in preliminary model testing phases. Income was expressed as a series of four dummy variables because that income data were collected in a categorical format. The income dummy variables were jointly insignificant at the 90 percent significance level on a consistent basis and occasionally had incorrect signs. This result, as Hanemann points out, follows directly from our specification of the logit model which essentially eliminates income effects. The income variable was dropped in all final estimation models.

6. Mi was set to zero for respondents who chose the "time only" payment option. Similarly, Ti was set to zero for those who chose the "money only" option.

7. This can be seen by first rewriting the exponential term in Equation (7) to reflect the definition of Ci (that is, $B_0 + B_1(Mi + w*Ti)$). Next, expand it to form $B_0 + B_1*Mi + B_1*w*Ti$. Now, by allowing B_0 to equal B_2 in Equation (8), and similarly $B_1=B_3$ and $B_1*w=B_4$, then w is recovered by the ratio $B_4/B_3=(B_1*w)/B_1$.

CONTINGENT VALUATION AS AN EXPERIMENTAL SCIENCE

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INTRODUCTION

Although widely accepted as a viable nonmarket valuation technique, concerns over the accuracy and reliability of contingent valuation results persist (Cummings, Brookshire, and Shulze). Many of these concerns focus on contingent valuation methodology; that is, the empirical process by which willingness-to-pay (WTP) and willingness-to-accept compensation (WTA) measures are elicited. The credibility of the contingent valuation method (CVM), it is argued here, is threatened by the fact that the method is relatively easy to use, but difficult to use well. Many authors have emphasized the importance of careful design and conduct of CVM surveys (Arthur D. Little, Inc.; Cummings, Brookshire, and Shulze; Randall, Ives, and Eastman). As a result, recommendations and guidelines for application of CVM have been proposed. An example of these recommendations and guidelines are the "Reference Operating Conditions (ROC's)" (Cummings, Brookshire, and Shulze.)

The ROC's, in general, are based on observations of "what has worked well in the past". Although providing a useful compilation and summary of past research, the ROC's do not provide an overall analytical framework for CVM methodology. Such an analytical framework, in addition to the ROC's, is needed in order to judge the validity of individual CVM applications.

In this paper, an experimental economics approach is taken to CVM methodology. Experimental economics terms and concepts are introduced first. The relationships between experimental economics objectives and contingent valuation research are then considered. After this discussion, contingent markets are argued to be microeconomic systems and properties of contingent valuation experiments are presented. The contingent market microeconomic system and properties of contingent valuation experiments provide an analytical framework for CVM methodology. It is argued in the last section that this framework may enhance the validity and credibility of the contingent valuation method.

EXPERIMENTAL ECONOMICS CONCEPTS

Experimental economics methodology attempts to examine economic phenomena and behavior in controlled settings. These controlled settings fall into two general categories, field experiments and laboratory experiments. Field experiments involve some perturbation and monitoring of a naturally occuring economic system (Plott 1981). For example, a field experiment was conducted to test for the effects of changes in relative prices on residential electricity demand. In the experiment, electricity prices faced by actual residential electricity customers were perturbed, and the resulting changes in electricity demand were observed and analyzed (Battalio, Kagel, Winkler and Winette).

Laboratory experiments are standard research techniques in the physical sciences. In resource and environmental economics, however, laboratory experimental methods are seldom employed. Unlike field experiments, laboratory experiments do not involve the use of a naturally occuring economic system. Rather, economic systems are constructed by the researcher in a controlled, laboratory setting. A sample of respondents are then invited to participate in the researcher-constructed economic system. As with field experiments, the researcher can perturb the system and analyze the resulting effects on economic behavior and phenomena.

As a research technique, experimental economics has several noteworthy advantages. First, economic behavior can be observed and tested directly. Thus, the need for abstract inferences concerning the influence of certain variables on economic behavior, which often hinders econometric analysis of field data, is minimized (Smith 1985). Economic experiments also provide a relatively inexpensive means of gaining knowledge and insight into complex economic systems and processes. Economic experiments are also very flexible in the types of economic systems and processes which can be examined. For example, an economic experiment can be designed to analyze the impacts of alternative policy proposals on an economic system, before these policies are actually implemented. The results of such experiments may provide policy makers with valuable insight regarding the performance of alternative policies (Plott 1979).

One of the major advantages of experimental economics methodology is control. That is, because the researcher constructs an economic system in which economic agents operate, control can be exercised over the amount and type of variables (e.g., institutions) which impact economic behavior. The independent effect of individual treatment variables is often very difficult to observe in naturally-occuring economic systems where a multitude of uncontrolled variables may impact economic behavior. Thus, the control which is needed to adequately address many economic questions of interest may only be possible in an economic experiment.

Establishing control in an economic experiment requires that the experiment be carefully designed and conducted. This careful formulation of procedures facilitates replication of experimental results. The possibility of replication is a further advantage of economic experiments because replication is a convenient and widely accepted means of validation. As stated by Smith (1985), replication and control are the two primary means by which the error in researchers' shared knowledge of economic systems is reduced.

MICROECONOMIC SYSTEMS

Experimental economics methodology has been applied primarily in the area of applied microeconomics. A fundamental component of the methodology as it relates to applied microeconomics is the use of microeconomic systems. First, it is necessary to define what is meant by a microeconomic system. Microeconomic systems are defined in two recent articles (Smith 1982, 1985). The conceptual model presented in these articles is summarized in this section.

Microeconomic systems are defined as having two general components; an environment and an institution. The environment consists of K economic agents {1,...,K}, a set of commodities and resources {1,...,L}, and certain features of each agent k, such as preferences, U^k, technological endowment, H^k, and initial endowments, Z^k. An economic agent is therefore described by the set, $R^k = \{U^k, H^k, Z^k\}$. The features of R^k are assumed to be defined over the L dimensional commodity space. The collection of agent features, $R = \{R^1,\ldots,R^k\}$ is defined as a microeconomic environment. The microeconomic environment defines "a set of initial circumstances that cannot be altered by the agents or the institutions within which they interact" (Smith 1982). A distinguishing element of these initial circumstances is that they are essentially private and agent-specific.

It has been recognized in many fields of economics that institutions are an integral part of economic systems. Institutions are defined as ordered relationships between agents which define rights, privileges, and responsibilities (Schmid). In a microeconomic system, institutions include the rules which govern the communication, exchange, and transformation of commodities subject to the initial economic environment given by R. An important point concerning institutions is that they govern the messages which agents can communicate in an economic system, as well as the physical exchange and transformation of goods and commodities. In other words, institutions determine a language, $G = \{G^1,\ldots,G^k\}$. This language specifies the messages that agents are permitted to communicate in an economic system. For example, G^1 represents the set of messages that can be sent by agent 1. The final set of messages which are actually sent by all agents in an economic system is defined by $m = (m^1,\ldots,m^k)$. For example, m^1 represents the messages that agent 1 sends. Final messages may include bids, offers and acceptances.

Institutions also specify allocation and cost assignment rules. The allocation rule for a particular agent is given by $h^k(m)$. Because it is a function of m, the allocation rule indicates that the final commodity allocation to a particular agent is determined by the messages of all agents. Since each agent faces an allocation rule, the total set of allocation rules is given by $H = \{h^1(m).,\ldots,h^k(m)\}$. Agents in microeconomic systems also face cost assignment rules. The cost assignment rule for a particular agent is given by $c^k(m)$. The argument m implies that the final costs imposed on a particular agent is also determined by the messages of all agents. Since each agent faces a cost assignment rule, the total set of cost assignment rules is given by $C = \{c^1(m),\ldots,c^K(m)\}$.

Finally, institutions specify adjustment process rules faced by each agent. These rules include a starting rule, a transition rule, and a stopping rule. The starting rule, denoted by $b(t^o, . , .)$, specifies the time or conditions under which the exchange of messages can begin. The transition rule, denoted by b(., t, .), regulates the sequence and exchange of messages. The stopping rule, denoted by b(., ., T), specifies the time or conditions under which the exchange of messages must end. Thus, the institutions which govern a particular agent's message communication and commodity exchange are defined by $W^k = \{G^k, h^k(m), C^k(m), b(t^o, t, T)\}$. The set of institutions faced by all agents, denoted by $W = \{W^1,\ldots,W^K\}$, defines a <u>microeconomic institution</u>. Having defined both a microeconomic environment and a microeconomic institution, microeconomic system can be formally defined. A <u>microeconomic system</u> is defined by S = {R, W}, where R is the microeconomic environment, and W is the microeconomic institution.

The performance of the microeconomic system, $S = \{R, W\}$, depends upon the conduct or choice behavior of economic agents. Observable choice behavior, or final agent messages, are determined by the function $m^k = f(R^k, W)$. This function indicates that agent's messages are determined by an agent's features (e.g., preferences) and the set of institutions inherent in the microeconomic system. Given the messages sent by each agent, the final outcomes of the microeconomic system are determined by W. That is, commodity allocations and cost assignments are not directly determined by agents. Rather, the choice behavior of agents leads to messages. These messages are incorporated into the institutional structure of the microeconomic system. The institutional structure then determines final commodity allocations and cost assignments. In notational form, final commodity allocations are determined by the function, $h^k(m) = h^k[f(R^1,W),\ldots,f(R^K,W)]$, and final cost assignment rules are determined by the function, $c^k(m) = c^k[f(R^1,W),\ldots, f(R^k,W)]$. Thus, final-outcomes of the microeconomic system are dependent upon institutions, endowments, and features of individual agent's which impact their choice behavior.

MICROECONOMIC EXPERIMENTS

In this section, the basic features of a microeconomic experiment are summarized. Microeconomic experiments examine economic behavior and phenomena in microeconomic systems. The microeconomic system of interest is almost always some sort of economic market. Smith defines economic markets as "...,institutions of exchange that use price to guide resource allocation and human economic action" (Smith 1985). As Smith argues, markets operate because of a basic human desire to improve initial circumstances through exchange.

Markets provide an ideal medium for examining economic behavior and phenomena experimentally. Whether naturally-occuring or researcher-constructed, markets used in microeconomic experiments are "real" microeconomic systems. That is, a fundamental proposition supporting microeconomic experiments is that economic principles which apply to "real-world" markets, also apply to experimental markets (Plott 1982). Thus, all of the theoretical and empirical tools at an economist's disposal are readily applicable to properly designed experimental markets. Within the context of experimental settings, the research results are just as valid as any other market-oriented research. For a more detailed defense of the validity of microeconomic experiments, see Plott 1982.

Once the microeconomic system (e.g., market) is in place, it can be utilized for conducting specific experiments. The design and conduct of any type of experiment, including economic experiments, requires strict attention to proper experimental procedures. Over the years, a number of procedural guidelines for economic experiments have been proposed. First, there is a need to word and present <u>instructions</u> given in an economic experiment in a clear, unambiguous, and defensible manner. The extreme care given to instructions is dictated by two concerns. First, other researchers must be able to follow the same procedures in order to replicate results. Second, the researcher must be capable of defending the instructions against the charge that they somehow bias the results of the experiment. For example, one must be able to argue that agents interpret instructions in a uniform manner. Also, one must be able to argue that the instructions do not tell agents how they "should" behave or how the researcher expects them to behave unless such instructions are included as deliberate treatment variables (Plott, 1982).

Several sufficient conditions for a valid, controlled microeconoic experiment have been proposed (Smith 1982). The first condition is _nonsatiation_, or monotonicity of reward. Nonsatiation implies that subject agents strictly prefer any increase in the reward medium (e.g., more is preferred to less). The second condition is _saliency_. Saliency means that the institutions of an experimental market give agents the unqualified right to outcomes (e.g., rewards, costs) resulting from their message choices. The conditions of nonsatiation and saliency are sufficient for establishing an experimental microeconomic system, S = {R, W}. If two further conditions are met, the system is said to be a _controlled_ microeconomic system. The first of these additional conditions is _dominance_. Dominance means that own rewards dominate any subjective costs of participating in the experimental market. Subjective costs include, for example, the cognitive effort required to negotiate and complete transactions. The second additional condition for a controlled system is _privacy_. Privacy means that agents receive information only on their own individual reward schedules. The privacy condition provides control over interpersonal utilities.

The conditions of nonsatiation, saliency, dominance, and privacy are sufficient for testing hypotheses from theory. Economic experiments, however, are sometimes used to provide insight into the structure and performance of "real-world" markets. In these cases, the condition of _parallelism_ must also be met. Parallelism means that "propositions about behavior and/or the performance of institutions that have been tested in one microeconomy (laboratory of field) apply also to other microeconomies (laboratory or field) where similar _ceteris paribus_ conditions hold" (Smith 1982). The parallelism condition is consistent with the standard economic belief that where the environment and institutions are the same, economic behavior should be the same. Thus, if an experimental market and a "real-world" market have similar _ceteris paribus_ conditions, the outcomes of these systems should be comparable.

In summary, microeconomic experiments involve the study of economic behavior and phenomena in microeconomic systems. Economic agents operate in these microeconomic systems (e.g., experimental markets) by following a set of well defined instructions. The behavior of agents is influenced by their economic environment (e.g., preferences, household technology, endowments) and the institutions of the microeconomic system. Experiments generally involve some perturbation of the system and subsequent observation and analysis of the resulting impact on the conduct and performance of the system. Sufficient conditions for a microeconomic experiment are nonsatiation and saliency. A controlled microeconomic system requires two further conditions; dominance and privacy. Control in a microeconomic experiment is important for internal-validity (e.g., the experiment and its results can be replicated). If an objective of an experiment is to draw inferences concerning the performance of some microeconomic system besides the one used in the experiment, the condition of parallelism must hold. Parallelism is important for external-validity (e.g., experimental results can be extended to "real-world" settings).

CONTINGENT VALUATION EXPERIMENTS

Contingent valuation is part of the broader field of applied welfare economics. Welfare economics is concerned with determining the relative desirability of alternative economic states. A natural application of welfare economics is cost-benefit analysis of public policies because these policies alter the allocation of resources to groups and individuals. Cost-benefit analysis, by and large, is an a priori method for evaluating the impacts of public policies. That is, cost-benefit analyses are conducted before a public policy is actually carried out.

Perhaps the greatest difficulty encountered in the application of cost-benefit analysis is the measurement of all relevant benefits and costs. A persistent problem is the lack of historical data upon which to base quantification of policy impacts. This problem is particularily acute with regard to public policies which impact natural resource service flows. Many types of natural resource service flows are classified as nonmarket goods, i.e., goods or commodities for which no markets exist. Hence, the value of these goods cannot be estimated directly from market data. Changes in nonmarket goods (quantity or quality) often account for a major portion of public policy costs and benefits. However, without market prices the valuation of such costs and benefits is hindered.

Sometimes it is possible to estimate the economic value of changes in nonmarket goods indirectly from market data. Such indirect techniques include the travel cost method and various hedonic price methods. Indirect nonmarket valuation techniques, however, have limited applicability. One major limitation of these techniques is that they rely upon the availability of related, market-generated data which is applicable to the valuation problem at hand. Many times such data is simply not available. One particular reason why these data may be unavailable is that the state or scenario which will result from a public policy has never existed before. Thus, in this case, history does not provide a set or data for comparing "with" policy states to "without" policy states. Sometimes it is possible to find an historical situation which closely approximates the impacts of a proposed public policy. For example, the U.S. Army Corps of Engineers sometimes values new water projects by estimating the value of similar, existing water projects. Most public policies, however, have unique impacts determined by features of affected resources and parties, institutional settings, and the particular objectives of the policy. In many cases these policy impacts are sufficiently unique that "similar policy or project" cost-benefit analysis is not valid.

When market-generated data are unavailable or inadequate for valuing policy impacts, what options are left open for conducting a priori cost-benefit analysis? It is argued here that one of the most viable options is the use of experimental economics methodology, which includes contingent valuation experiments as a special case.

MEASUREMENT OBJECTIVES

One of the main uses of experimental economics methodology is measurement. Economic experiments are used to accomplish two specific types of measurement objectives (Plott 1981). The first objective is to measure the sensitivity of economic system outcomes to changes in the system's institutions. For example, a number of studies have been conducted on the sensitivity of auction market results to the particular type of auction mechanism employed (Coppinger, Smith, and Titus; Cox, Roberson, and Smith; Vickrey). The second measurement objective is to provide data on the parameters of economic models (e.g., values).

The measurement objectives for economic experiments are quite consistent with the measurement objectives of applied cost-benefit analysis. That is, a major objective of applied cost-benefit analysis is to measure public policy impacts. Economic experiments can help meet this objective by providing data on the parameters of value estimation models. Persons involved in the policy process are also often interested in the sensitivity of values to changes in institutions. For example, the question may be asked. "Are policy impacts greater or lower under institutional arrangement B vs. institutional arrangement A?" Because control can be exerted over institutional structures, experimental economics seems particularly relevant for addressing such questions. For collaborating arguments, see Coursey and Schulze; Plott 1979; and Plott 1981.

SIMULATION OBJECTIVES

A second objective of experimental economics methodology which is relevant to applied cost-benefit analysis is simulation (Plott 1981). Simulation, for example, involves constructing an experimental market which mimics the operation of some actual market. Economic behavior and outcomes observed in the experimental market are then used to draw inferences concerning economic behavior and outcomes in the actual market. That is, an experimental market is constructed to capture the essential features of an actual market and experience with the impacts of proposed public policies can then be gained. For example, the experimental market might be used to simulate changes in consumer's surplus as a result of different resource allocations in the actual, or potentially actual, market. Notice that this example of the use of experimental economics actually combines the objectives of measurement and simulation.

APPLICATION OF CONTINGENT VALUATION EXPERIMENTS

In applied cost-benefit analysis, measurement and simulation objectives are often accomplished using contingent valuation method (CVM). CVM is defined here as any valuation technique which elicits individual values for commodity allocations in experimental markets, where allocations, costs, and adjustments are contingent upon actual operation of the microeconomic system described by the experimental market. Because of the use of contingent allocations and payments, these experimental markets are referred to as contingent markets. Contingent markets, if properly designed, are microeconomics systems as described by Smith, 1982. The distinguishing feature of contingent markets is the use of contingent payments, rather than actual cash payments.

The classification of contingent markets as microeconomic systems is illustrated in the following example. A common usage of contingent markets is to elicit individual valuations of changes in the quantity or quality of some public good. The contingent market would present {1,...,K} respondents with a scenario describing the public good's initial quantity, quality, location, and time dimension (Coursey and Schulze). Information concerning the services which the public good supports may be given to subjects as well. Preferences (U^k), household technology (H^k), individual information sets (I^k), attitudes and values (A^k), and initial endowments of private goods, public goods, and income (Z^k) describe each respondent, e.g., $R^k = \{U^k, H^k, I^k, Z^k\}$. The contingent market environment is therefore defined as $R = \{R^1,...,R^K\}$. The contingent market would also have a detailed description of allowable messages and how these messages would impact public good allocation, cost assignment, and adjustments, should the market actually be implemented. The set of allowable messages, allocation rules, cost rules, and adjustment rules make up the institutions of the contingent market. These institutions, for example, could specify initial rights to the public good, and the method of compensation or payment for increments or decrements in the public good. This combination of institutions and environment defines the complete contingent market microeconomic system (Coursey and Shulze; Cummings, Brookshire, and Shulze).

Operation of the contingent market is initiated by messages sent from the researcher to respondents. Respondents then respond to these messages with messages of their own. For example, the researcher may send a message to respondents asking them to submit a bid for a given increment in the public good. Such bids would be contingent upon the increment in the public good and all other conditions described in the contingent market. Thus, the messages that participants send back to the researcher represent their assessment of how they would react to the circumstances posited in the contingent market. In the experiment itself, commodities and money do not actually change hands. Bids for the public good are interpreted as contingent payments. That is, the bids are an approximation of how much participants would pay for the public good should the microeconomic system described by the contingent market actually be implemented.

Establishment of the general microeconomic properties of nonsatiation, saliency, dominance, privacy, and parallelism, and incentive-capability in contingent valuation experiments is discussed next. Three types of rewards in contingent markets are participation rewards, altruistic rewards, and expected commodity allocation rewards. The property of <u>nonsatiation</u>, it is argued here, applies to all three of these reward types. Participation rewards are the subjective value participants attach to the process of evaluating and making a decision (Smith 1979). Altruistic rewards refer to the satisfaction that a participant receives from providing requested information and (or) from participation in the public policy process (e.g., feelings of "civic duty"). Finally, subjective rewards take the form of expected allocations of real commodities. That is, in a well designed contingent market, participants are told that their responses may be used to determine the future allocations of real commodities. Thus, if participants value the commodities addressed in the contingent market, they have a vested interest in completing the exercise. Moreover, it is argued that subject agents have the unqualified right to claim the rewards generated by the contingent market. This unqualified right is inherent in the participation and altruistic rewards (e.g., feelings of altruism or benefits from being altruistic). Thus, it is argued that these rewards meet the <u>saliency</u> property. The saliency of expected commodity rewards is not so straightforward. Expected commodity rewards are salient only if CVM participants actually feel that their messages may result in some expected future allocation of commodities to themselves. For instance, suppose the contingent market is highly unrealistic and outside the range of participants, actual experiences. In this case, participants may perceive very little or no connection at all between their responses and the future allocation of commodities. The saliency of the expected commodity allocation reward may therefore be lost. Consequently, the value that participants place on their messages would be reduced, perhaps to the point where they refuse to send valuation messages, or they send valuation messages which are frivolous and unreliable (Coursey and Schulze).

The magnitude of own participation rewards relative to subjective participation costs determines whether dominance has been established in contingent valuation experiments. In a contingent market, as in other microeconomic systems, subjective costs are composed primarily of the time and cognitive effort required to process information, evaluate alternatives, and make final decisions. If own rewards do not exceed these subjective costs (e.g., it the net benefits of participating in the contingent market are not greater than zero), control in the experiment will be lost. This loss of control may manifest itself in a refusal to send messages, or the sending of messages which could be unreliable (Coursey and Schulze).

A symptom of the loss of dominance in a contingent valuation exercise may be information overload. Information overload refers to the emergence of confused or dysfunctional consumer choice behavior resulting from an increase in information quantity or complexity (Grether and Wilde). As the quantity and complexity of information presented in the contingent market increases, the subjective costs of information processing increase as well. At some point, increases in subjective information processing costs may cause total subjective costs in the experiment to rise above own rewards. Consequently, dominance and control would be lost. As a result, participants' decision-making behavior may become "confused and dysfunctional".

Several steps can be taken to establish dominance in contingent markets. First, perceptions of the own rewards of participating in a CVM exercise may be increased by providing participants with information related to reward recognition, realism and credibility, and focus and attention. Also, even though it is rarely used, participants could be paid a monetary inducement to help cover subjective (and real) costs of participating in the contingent valuation exercise. Second, instructions, information, and calculations should be presented as clearly and simply as possible in order to reduce subjective costs associated with information processing. Another way of reducing subjective costs is to provide participants with information designed to facilitate analytical calculations. Still another way of reducing subjective costs is the use of computerized contingent markets. Computerized markets, for example, may substantially reduce the time costs associated with iterative bidding methods (Bergstrom and Stoll).

In order for a contingent valuation experiment to satisfy privacy, an individual participant cannot receive information on other participants' reward schedules. That is, each participants' preferences should be private, and nonobservable to others. If this condition is not met, control can quickly be lost. If participants somehow communicate their preferences to each other, the probability that messages reflect individual preferences (e.g., valuation of a commodity) is greatly reduced. Thus, steps should be taken to ensure that contingent markets satisfy the privacy condition. Such steps may include the use of moral suasion, and ensuring that the CVM study and its objectives are not highly publicized before and during survey implementation. For example, newspaper articles covering a CVM survey may induce a participant to incorporate someone else's preferences (e.g., the article's author) into his or her answers to survey questions. It may be particularly difficult to establish privacy when employing a mail survey. A personal interview survey may also pose privacy problems if participants react strongly to perceived preferences of the interviewer. The use of computerized contingent markets may provide one of the most viable means for facilitating privacy.

The overall credibility of the contingent valuation method rests upon the argument that if the microeconomic system described by the contingent market were actually implemented, behavior and outcomes would approximate behavior and outcomes observed in the experimental, contingent market. Thus it is important that contingent markets satisfy parallelism. It is argued here that parallelism between contingent markets and actual markets holds provided the contingent market is properly designed.

An illustration may help make the point clear. Consumers often make contingent decisions. For example, suppose Mr. A is considering purchasing a yearly membership to a health club. Suppose that without yet visiting the club, he sends away for a package of information which describes the facilities and services offered by the club and the annual membership fee. Now, suppose on the basis of this information, Mr. A decides he would like to join the club. Note that this is a contingent decision. Mr. A has decided that he is willing to pay the stated membership fee, contingent upon the actual allocation of the club's facilities and services to himself during the open membership period. Thus, when it comes time to actually join the club, even if it is six-months later, Mr. A should be willing-to-pay the stated membership fee, provided that the facilities and services described in the package of information and everything else (e.g., his preferences, income) have remained the same as when he originally decided it was worthwhile to join.

This example captures the essence of the type of parallelism which is argued to exist with respect to well designed contingent markets. That is, participants are presented with a package of information describing some nonmarket good of interest. Participants are then asked to reveal how much they would be willing-to-pay (or accept) for changes in the level of nonmarket good provision. Payments are contingent upon the actual provision of the stated changes. Thus, if all conditions posited in the contingent market remain unchanged, participants should be observed to pay approximately the same amount for actual changes in the commodity, as observed for hypothetical changes in the contingent market.

Strictly speaking, there will always be one major institutional difference between contingent markets and actual markets which may impact parallelism. The difference is that in contingent markets consumers do not actually pay their stated bids, while in actual markets consumers do have to pay their stated bids. Thus, in contingent markets and actual markets consumers face different cost assignment rules which may influence valuation messages. For example, when participants actually have to pay stated bids there is incentive for consumers to state bids lower than their maximum willingness-to-pay in an attempt to capture a surplus equal to the difference between their true maximum WTP and their stated WTP. This understatement of WTP represent the "free-rider" problem (Samuelson). The possibility of free-riding implies that when participants actually have to pay stated bids, there is a real cost imposed on revealing one's maximum WTP for a good. This cost is the surplus foregone by not stating a bid lower than the maximum WTP.

In a contingent market, there is no real cost associated with stating one's maximum WTP for a nonmarket good if it is known that payments will not actually be collected. What an individual states he will pay is not actually what he has to pay. Thus, in this situation participants cannot earn a real surplus by stating a bid lower than their maximum WTP. Moreover, participants may assign subjective benefits to revealing their maximum WTP when asked to do so (e.g., "telling the truth" being viewed as desirable social behavior). Similarly, participants may assign subjective costs to misrevealing preferences.

In addition, since participants know that the results of the contingent market may influence future resource allocations and relative costs of other commodities (e.g., taxes, product prices, and wealth), they may perceive additional benefits associated with revealing their true preferences. If participants understate their bids for a nonmarket good in a contingent market, they run the risk that the good will be underprovided. Also, if participants overstate their bid for a good in a contingent market, they run the risk that it will be overprovided and may end up costing them more than they are willing to pay. Thus, the risk-adverse strategy may simply be to state one's true valuation of the nonmarket good. In addition, as argued by Rowe, d'Arge, and Brookshire, strategic misrevelation of preferences by CVM participants requires certain information in order to be effective. The typical CVM respondent, they argue, probably does not have access to such information.

Given that there are benefits from revealing one's true preferences, and often few directly controllable costs, contingent markets may give proper incentives for true demand revelation. Thus, suppose a contingent market and an actual market with a similar environment and similar institutions produce different results. One explanation for this divergence could be that in the contingent market participants have incentives to reveal their actual preferences, while in the actual market there may be strong economic incentives to misreveal, or at least hide true preferences. Other conjectures about the incentives and disincentives for misrevelation of preferences in contingent markets can be formulated, or possibly parallelism was not as strong as initially believed. The point to be made, however, is that a case can be made that with proper attention to design and administration, contingent markets are capable of generating data which are demand revealing (for collaborating arguments and a specific example, see Hoehn and Randall). Indeed, a number of recent studies designed to test for the demand revelation properties of contingent markets have supported the use of these markets for directly eliciting valuations for nonmarket goods (Brookshire and Coursey; Brookshire, Thayer, Schulze, and d'Arge; Coursey and Schulze; Cummings, Brookshire, and Schulze; Hovis, Coursey, and Schulze; Sellar, Stoll, and Chavas).

A final property of relevance to contingent markets is incentive compatibility. A microeconomic system is incentive compatible if the information and incentive conditions that it provides are compatible with (i.e., support) the attainment of socially preferred outcomes such as "Pareto optimality" (Smith 1982). In order to examine the incentive compatibility of microeconomic systems, including contingent markets, it is necessary to define exactly what is meant by a "socially preferred outcome". For example, suppose the value judgement is made that a move from State A to State B is a social improvement if the gainers from the move could compensate the losers, and still be better off. That is, the move from State A to State B must pass the Potential Pareto Improvement criterion (PPI).

For simplicity, suppose that the move from State A to State B represents a transfer of some nonmarket good, Q, from Party A to Party B. Following the PPI criterion, the value of Q in its current use is equal to Person A's willingness-to-accept compensation for losing Q. Willingness-to-accept compensation for a decrement in a good or service represents a Hicksian compensating measure of welfare change, denoted by WTA^c. The value of Q in its alternative (or state B) use is equal to Person B's willingness-to-pay for gaining Q. This willingness-to-pay, is also a Hicksian compensated measure of welfare change, denoted by WTP^c. If $WTP^c > WTA^c$, then the gainers (e.g., Party B) of the move from State A to State B could compensate the losers of such a move (e.g., Party A), and still be better off. Hence, if $WTP^c > WTA^c$, the move from State A to State B satisfies the PPI criterion (Randall and Stoll 1980).

WTP^c and WTA^c can both be collected in contingent markets. In order to collect these values, the informational structure (e.g., wording of valuation questions) of the contingent market must be consistent with collection of WTP^c or WTA^c. In addition, the structure of the contingent market, in conjunction with individual behavior, must provide incentives for revelation of "true" WTP^c and WTA^c. If these conditions are met, the contingent market would provide valuation data (e.g., outcomes) which indicate the existence of the Potential Pareto Improvement. Thus, in this case, the contingent market is incentive compatible, at least in terms of the PPI criterion.

The previous example illustrates that incentive compatibility is attainable in contingent markets. Incentive compatibility, however, is not an inherent property of contingent markets. Rather, it must be established through proper attention to the conceptual basis of valuation questions, and incentives provided for "true" demand revelation. The incentive compatibility of contingent markets, in terms of the PPI criterion, is discussed in more detail by Hoehn and Randall.

DISCUSSION AND IMPLICATIONS

In the past two decades, application of the contingent valuation method has exploded. Design and implementation procedures, however, vary widely across individual applications. As a result, replication of results is difficult if not impossible.

In applications of the contingent valuation method, control and replication would be facilitiated by regarding CVM as a branch of experimental economics methodology as implied by Plott. Control is established in an economic experiment if the properties of non-satiation, saliency, dominance, and privacy are met. Thus, in order to have a controlled contingent valuation experiment, it must satisfy these properties. For example, Randall, Ives, and Eastman recommend that a contingent market be designed to be as realistic and credible as possible. Such realism and credibility is important for establishing the properties of saliency and dominance. If respondents are faced with a highly unrealistic contingent valuation scenario, they are not likely to take the valuation exercise seriously and perceived rewards from participation will decrease. If perceived participation rewards decrease below perceived participation costs, the dominance property will not be satisfied. As a result, control would be lost and respondents may react by sending unreliable responses or no responses at all.

Researchers can take a variety of steps to facilitate control in contingent valuation experiments. Several of these steps have been mentioned previously in various places, but not in the analytical framework of experimental economics methodology. Nonsatiation and saliency require that the increment or decrement in the nonmarket commodity of interest be presented to respondents in a clear and unambiguous manner with well-defined property rights and other institutional arrangements (e.g., commodity and cost allocation mechanisms). Dominance can be facilitated by providing respondents with information which helps them to recognize own participation rewards. In addition, any steps taken to reduce subjective participation costs (e.g., provision of calculation information) will facilitate dominance. In order to establish privacy, the contingent market structure should be consistent with elicitation of private, confidential values. For example, communication between resondents should be discouraged and an individual respondent should not be provided with information on other respondents' valuations (which could occur, for example, through news media coverage of a CVM survey).

Establishing control in a contingent valuation experiment by satisfying the properties of nonsatiation, saliency, dominance, and privacy is a necessary, but not sufficient, condition for <u>internal-validity</u>. Internal validity implies that the results of a contingent valuation experiment can be replicated. For replicability, it is also necessary that treatment variables such as instructions, information, and bid elicitation procedures be held constant across CVM applications. Several recent studies, for instance, suggest that CVM results are quite sensitive to the type, quantity and complexity of information presented in contingent markets (Bergstrom and Stoll; Rowe and Chestnut; Samples, Dixon, and Gowen; Shulze, d'Arge, and Brookshire). These results suggest that in order to replicate or compare CVM results, the informational structure of contingent markets would have to be held constant across applications. In general, it is recommended that much closer attention be paid to instructions, information, and bid elicitation protocol with an overall objective of standardizing procedures across CVM applications.

In most CVM applications, <u>external validity</u> is an important consideration as well as internal-validity. External-validity implies that CVM results can be extended to actual "real-world" scenarios. A necessary condition for external-validity is that the property of parallelism be satisfied. In the case of CVM, parallelism requires that the environment (e.g., respondent characteristics) and institutions (e.g., commodity allocation mechanisms) of the contingent market be similar to an actual, or potentially actual, market. Parallelism implies that consumer behavior in a contingent market would in fact be observed should the market actually be implemented. Thus, if parallelism is satisfied, it is legitimate to extend CVM results to 'real world' scenarios.

If the purpose of a CVM application is to provide input into public policy decisions the property of incentive compatibility, as well as all other properties, should hold. For example, suppose a public policy decision will be based on application of the potential Pareto improvement (PPI) criterion. In this case, a contingent market is incentive compatible if it provides values which are consistent with the PPI criterion. Establishing this consistency requires that the contingent market structure (e.g., wording of questions) be consistent with Hicksian compensated measures of welfare change. A further requirement is that the bidding method be demand-revealing. That is, the bidding method must provide incentives for calculation and statement of "true" values. The iterative bidding method and dichotomous choice questions, for example, are argued to be demand-revealing (Brookshire and Coursey; Hoehn and Randall).

In conclusion, experimental economics methodology is argued to provide a useful analytical framework for the design and administration of contingent markets. A distinct advantage of using this framework is an increased potential for control and replication. Control and replication are the primary means by which researchers' shared misunderstanding of economic systems is reduced (Smith, 1985). Lack of control and replication contribute to persistent fundamental questions concerning the validity of the contingent valuation method. As the scope and complexity of a valuation problem increase, such questions are likely to intensify. CVM methodology is being subjected to closer scrutiny from expanded sources including agencies, public interest groups, lawyers, judges, and Congress. Thus, reduction of "shared misunderstandings" of the contingent valuation method through sound, scientific methodology is not only desirable from an academic standpoint, but is perhaps essential for firmly establishing and maintaining the credibility of the method among clientele groups.

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ANALYZING THE EFFECTS OF GLEN CANYON DAM RELEASES ON COLORADO RIVER RECREATION USING SCENARIOS OF UNEXPERIENCED FLOW CONDITIONS[1]

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INTRODUCTION

The validity of the contingent-valuation method has been evaluated from a number of different perspectives. Comparisons have been made across contingent-valuation (CV) questioning formats, with estimates of value derived from hedonic-price and travel-cost models, and with values estimated in experiments employing actual cash transactions (Bishop, Heberlein and Kealy, 1983; Boyle and Bishop, 1988; Brookshire et al., 1982; Dickie, Gerking and Fisher, 1987; Heberlein and Bishop, 1986; Sellar, Stoll and Chavas, 1985; Smith, Desvousges and Fisher, 1986; and Welsh, 1986). A question that has not been addressed by these comparison studies is whether scenarios of unexperienced environmental conditions are useful in eliciting statements of Hicksian surplus for either an enhancement or a degredation of a natural environment. The comparison studies only tell us that two valuation procedures either do or do not, as the case may be, provide comparable estimates of value in a movement from an experienced existing condition to an unexperienced future condition. For example, Boyle and Bishop (1988) estimated the loss in Hicksian surplus that would occur if an existing level of scenic beauty was degraded, and Smith, Desvousges and Fisher (1986) valued an enhancement in water quality. In both of these cases, respondents had experienced the status quo but would not have experienced the proposed degraded or enhanced levels for the resources in question.

The research reported here asks whether CV estimates derived using scenarios of unexperienced environmental conditions are comparable to CV estimates based on actual experience with these conditions. The application is an evaluation of the effects of varying Glen Canyon Dam releases on downstream recreation on the Colorado River. In the paper we summarize the procedures used to evaluate recreationists preferences for a variety of Colorado River flows. After discussing procedures, important relationships between river flows and Hicksian surplus per trip will be highlighted. We will close with conclusions regarding the use of scenarios in CV studies to evaluate unexperienced environmental conditions.

RESEARCH SETTING

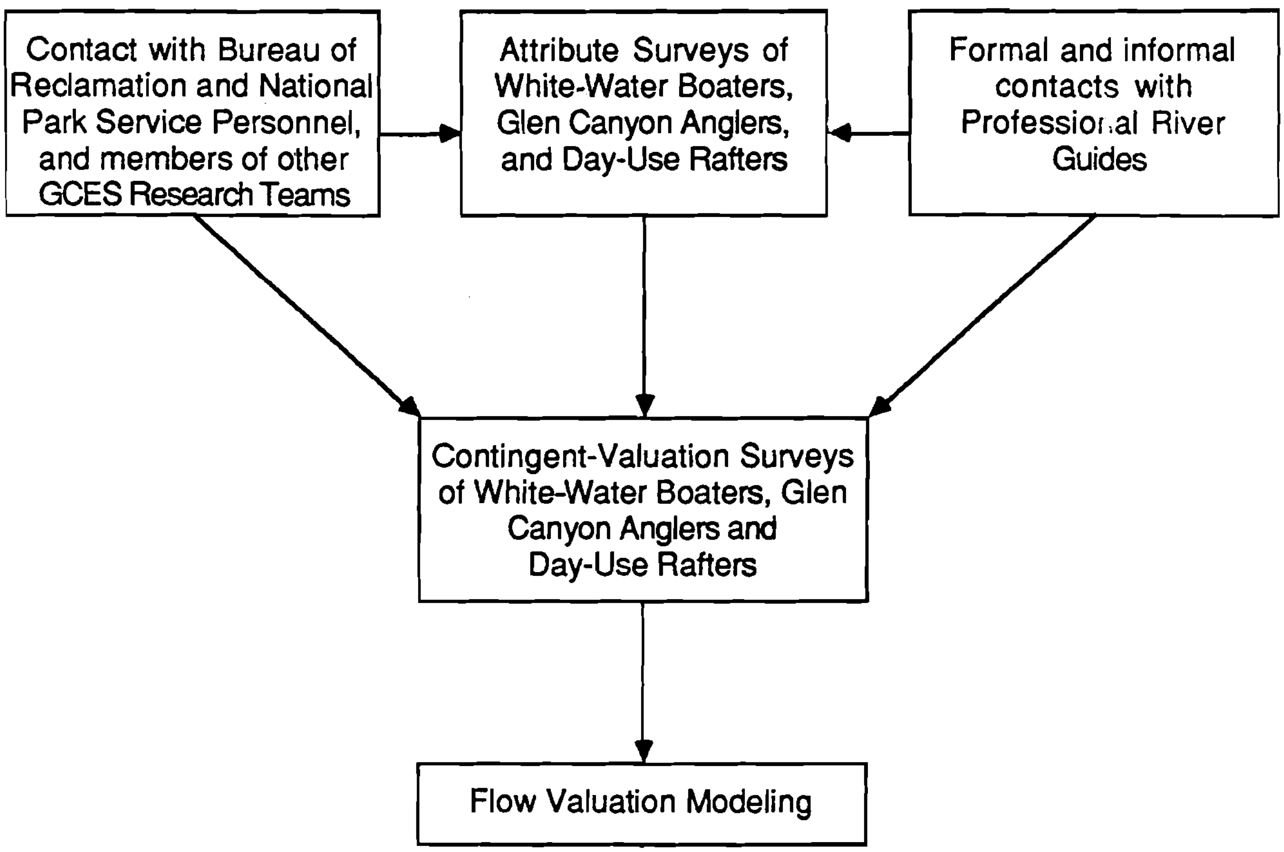
The research focused on the relationships between stream flows and river based recreation along the nearly 300 miles of the Colorado River below Glen Canyon Dam and above Lake Mead. Although the casual visitor viewing the Grand Canyon from the South Rim may enjoy seeing the river, the quality of this experience is not likely to be dependent on how much water is released from the dam. There are three groups of recreationists, however, that may be directly affected by stream flows. The first group will be referred to as "white-water boaters." These are people using a variety of rafts and boats to take a white-water trip on the Colorado River between Lees Ferry and the Lake Mead. The second group is composed of "Glen Canyon anglers" who typically fish the Colorado River between the dam and Lees Ferry. The third group of recreationists are "day-use rafters" in Glen Canyon. These people take half-day trips on flat water between the dam and Lees Ferry.

RESEARCH PROCEDURES

The effect of various Glen Canyon Dam releases on downstream recreation was ultimately evaluated for each user group by examining the relationships between estimated Hicksian surplus and a variety of flow levels. A novel aspect of the study is the considerable research conducted prior to implementing the CV surveys which was designed to identify important attributes of the recreational experiences and to learn about user preferences and qualitative terms. The results of this step were subsequently used in the design of the CV surveys and to interpret value estimates. The interrelationships of the study components are shown in Figure 1 (for a more complete discussion see Bishop et al., 1987).

FIGURE 1

DIAGRAM OF THE RELATIONSHIPS AMONG STUDY COMPONENTS



The first stage of the research incorporated the knowledge of resource managers concerned with the recreational use of this section of the Colorado River and input of other researchers who were studying the physical and biological effects of varying Glen Canyon Dam releases on the natural environment. Second, river guide's practical knowledge of the recreational experiences was incorporated in the research design. The people who serve as guides for white-water trips, for anglers, and for day-use raft trips constitute an important group of experts on the relationship between flows and recreation. River guides have first-hand knowledge of the recreationists, the recreational experience, and the river itself. A formal mail survey of white-water guides was conducted and, because of the small number of people involved, fishing and day-use rafting guides were contacted informally.

The third stage involved "attribute surveys" of recreationists. The effects of varying flow release patterns are transmitted to recreationists largely through changes in the quality of the experiences. The attribute surveys were designed to learn more about the characteristics or attributes of the recreational experience that influence recreational quality.

The fourth, and final, step in the research involved the CV surveys of recreationists to estimate their Hicksian surplus for a variety of flow release patterns.[3] As shown in Figure 1, the design of the CV surveys drew heavily on the findings from each of the three previous steps in the research process. In the remainder of this paper, however, we will focus only on the results of the CV exercises.

CONTINGENT-VALUATION SURVEY DESIGN

The dichotomous-choice technique was used to ask the valuation questions. This technique involves asking respondents if they would pay a prespecified amount, an amount over and above their actual trip expenses, to take a white-water trip, a fishing trip or a day-use raft trip.[4] The yes/no responses, along with the corresponding offers and other explanatory variables were analyzed by estimating logit models which are used to calculate expected consumer surplus for fixed flow levels. For a complete discussion of the procedures used to implement this questionning format and to analyze responses see Bishop et al., (1987), Boyle and Bishop (1988), and Hanemann (1984). Other applications of the dichotomous-choice questionning technique have been conducted by Cameron and James (1987), and Sellar, Stoll and Chavas (1985).

Two types of dichotomous-choice questions were used to estimate values. First, all three groups valued an actual trip (see Figure 2). Trip expenditures were chosen as a payment vehicle to meet the key criteria of being both realistic and neutral (Mitchell and Carson, 1987). Since day-use rafters and white-water boaters would not, in all probability, have taken more than one trip in any given year, they were simply asked to value the trip taken in 1985. Many Glen-Canyon anglers, however, take more than one trip per year. This problem was solved by implementing an on-site sample selection procedure so that anglers could be asked to value the trip taken on that date of the on-site interview. To help anglers recall this trip when they later received the CV survey in the mail, information from the on-site interview was incorporated in the introduction to the survey and in the CV section of this survey.

A wide variety of flow levels are generally experienced by recreationists throughout the year. A random sample of individuals from an entire year would hopefully select a group of individuals who would have collectively

FIGURE 2

GLEN CANYON ANGLER EXPENDITURE AND ACTUAL TRIP CV QUESTION

As near as you can recall for the trip when you filled out our short survey, about how much was your share of total trip expenses for the following items? (Include only money you personally spent. If you didn't spend money on a certain item, please put $0). [PLEASE CALCULATE AND FILL IN THE TOTAL ON THE LAST LINE].

Gas and Oil for vehicle	$________
Food and Beverages	$________
Lodging, Camping	$________
Fishing equipment/bait/license	$________
Guide fees	$________
Boat/equipment rental	$________
Airfare	$________
Car rental	$________
Other ____________________	$________
__________________________	
TOTAL YOU SPENT ON THIS TRIP	$________

Would you still have gone on that particular trip to Lee's Ferry if your expenses had been $_____ more than the total you just calculated? (CIRCLE ONE NUMBER)

1 YES, the trip would still be worthwhile

2 NO, it would not be worthwhile

experienced all, or at least most, of the flow levels during the year under consideration. Thus, respondents from each group would collectively experience a wide variety of river flows and responses to this first valuation question (actual trip) could be used to develop relationships between river flows and estimated Hicksian surplus per trip, a flow-value function.

We were concerned that individuals in each group may not have collectively experienced a wide range of river flows since 1985, the year from which the samples were drawn, was a year of unusually, high flows. Thus, after white-water boaters and Glen Canyon anglers had answered a CV question for their actual trips, they were asked to value trips at several alternative flow levels as described by flow scenarios.[5] The flow scenarios described trips under different flow conditions, primarily in terms of the changes that would occur in important, flow-sensitive attributes identified in the attribute surveys. Descriptions were supplemented with the information gained from contacts with guides and resource managers. A great deal of effort was exerted to insure that the scenario descriptions were based on documented facts and that they were worded in matter-of-fact language (see Figure 3). Scenario values could be used as an alternative source of data to develop flow-value functions in the absence of collective experience with a variety of flows.

These two types of valuation questions, actual trip and scenarios, provide the basis for determining whether scenarios of unexperienced environmental conditions are appropriate to use in CV surveys. The unexperienced conditions here are the flow levels described in the scenarios and their resulting impact on the recreational environments. If the scenarios work well, then the resulting value estimates should correspond with the appropriate value from the flow-value functions based on actual experiences.

FIGURE 3

WHITE-WATER BOATER CONSTANT FLOW SCENARIO (5,000 cfs)

AND ASSOCIATED VALUATION QUESTION

At a constant flow of 5,000 cfs, the speed of the river is relatively slow, reducing time for side canyon visits and other attractions. Boaters must break camp early to stay on schedule. Although rapids are present at this low water level, the waves are smaller and do not produce the big "roller coaster" ride created by higher flows. Due to exposed rocks, some rapids may be so difficult that it is likely passengers would have to walk around them. However, camping opportunities are abundant with many large sandy beaches exposed.

We would now like you to imagine that you are presently deciding whether or not to go on a Grand Canyon white-water trip. Imagine that the trip would be the same as your last trip (e.g., the same people, same food, etc.) with <u>two exceptions</u>:

The water level would be constant at 5,000 cfs

AND

<u>Your individual</u> costs for the trip increased by $______ (over the total cost you calculated on page 8, question A26)

Would you go on this trip? (CIRCLE ONE NUMBER)

1 YES, I WOULD PAY THIS AMOUNT TO TAKE THE TRIP

2 NO, I WOULD NOT PAY THIS AMOUNT TO TAKE THE TRIP

SUMMARY OF CONTINGENT-VALUATION RESULTS

White-Water Boaters

Subsamples of individuals taking commercial white-water trips and privately sponsored trips, each collectively experienced a wide range of river flows. Hicksian surplus per trip varies with the average flow experienced as well as the type of trip, commercial or private. For commercial passengers, values rise from $47 per trip at a flow of 1,000 cubic feet per second (cfs) to a maximum of $898 at 33,000 cfs, and then declines to $732 at 45,000 cfs (see Figure 4). Private boaters' surplus follows a similar pattern, rising from $21 per trip at a flow of 1,000 cfs to a maximum of $688 at 29,000 cfs, and then declining to $376 at 45,000 cfs (see Figure 5). Respondents experienced flows ranging from 10,000 to 44,000 cfs and flow-value functions are extrapolated down to 1,000 cfs to cover a somewhat wider range of flows for policy analyses. The scenarios evaluated generate point estimates of Hicksian surplus for flows of 5,000, 13,000, 22,000 and 40,000 cfs (see Figures 4 and 5).

Glen-Canyon Anglers

Sampled Glen Canyon anglers did not collectively experience a wide variety of flows and it was impossible to develop a flow-value function. This condition occurred because nearly all of the respondents experienced relatively high flow levels in 1985. The valuation question for their actual trip only generated a point estimate of $130 per trip. This being the case, the scenario values become very important in determining the relationship between flows and Hicksian surplus per trip for anglers.

Scenarios anchored at 3,000, 10,000, 25,000 and 40,000 cfs were evaluated. The flow-value function developed from the resulting value estimates, using linear interpolation between the point estimates, reveals that values rise from $60 at 3,000 cfs to a maximum of $126 at 10,000 cfs and then decline to $94 at

FIGURE 4

COMMERCIAL BOATER HICKSIAN SURPLUS FOR CONSTANT FLOW SCENARIOS AND ACTUAL TRIP

($ PER TRIP)

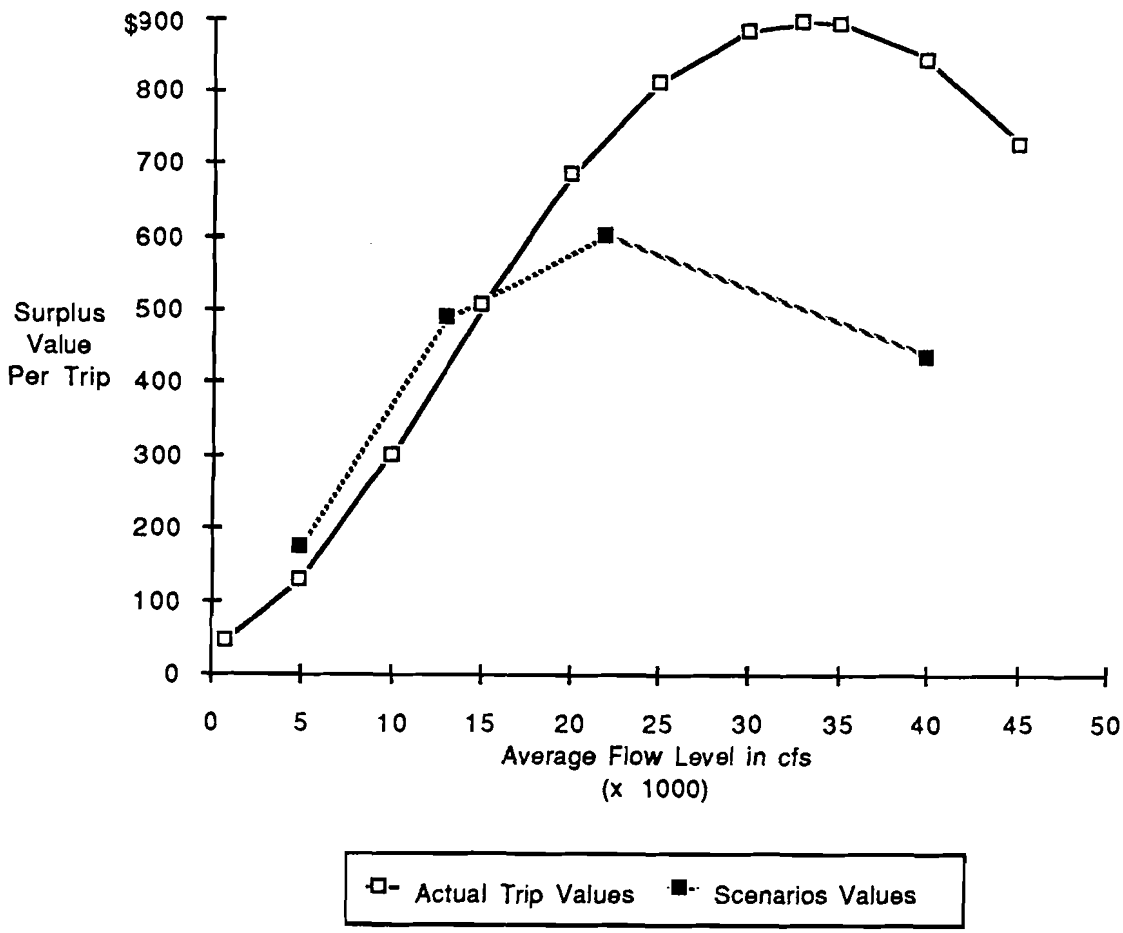
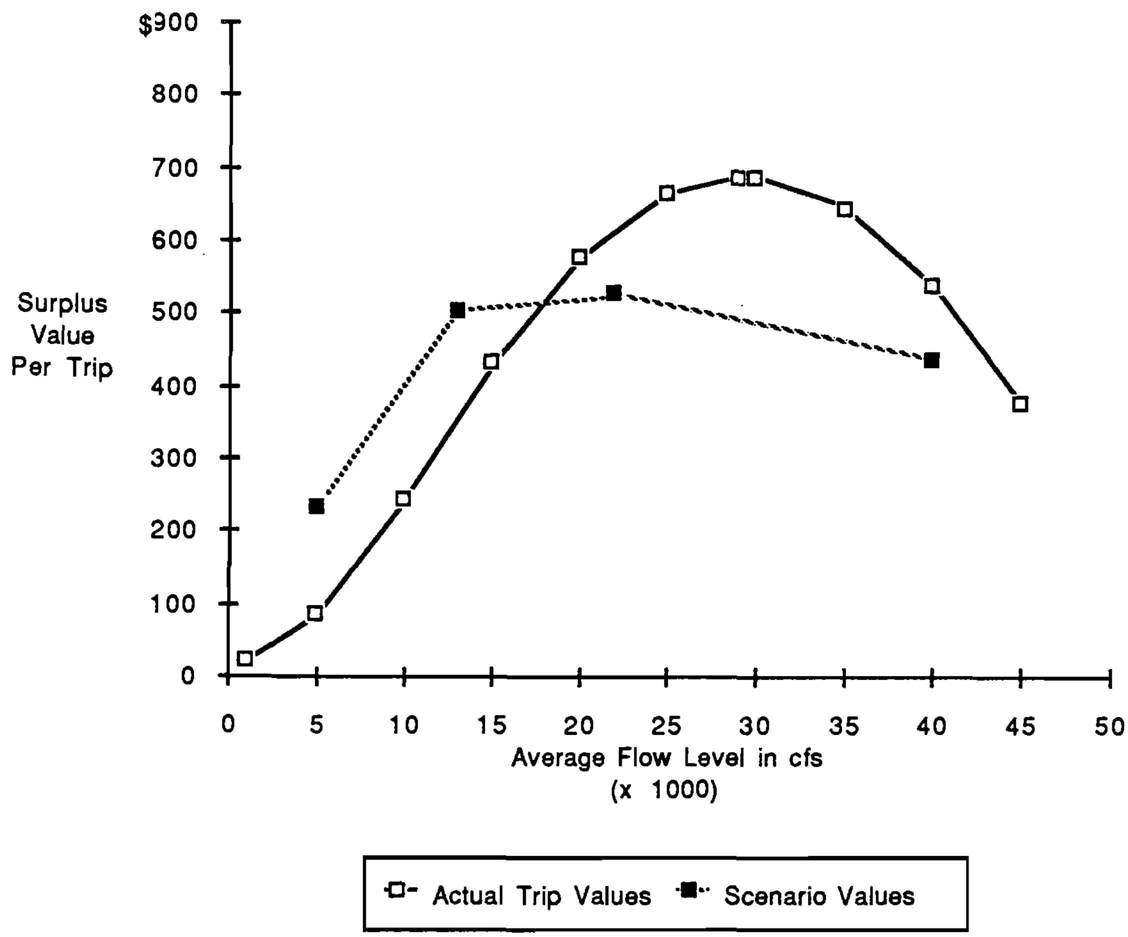


FIGURE 5

PRIVATE BOATER HICKSIAN SURPLUS FOR CONSTANT FLOW SCENARIOS AND ACTUAL TRIP

($ PER TRIP)



25,000 cfs and $52 at 40,000 cfs (see Figure 6). While the scenario estimates can not be used to define a unique optimum flow due to their discrete nature, the optimum would almost certainly fall in the 8,000 to 15,000 cfs range.

Day-Use Rafters

Estimated consumer surplus for this group was found to be constant at $26 per trip across all relevant flows. This finding is not surprising given that these are flat-water trips, and the only effect of higher or lower flows is to change the point of origin of the raft trip. The trip experience is quite similar regardless of the point of origin.

Summing Up

Examining Figure 6 reveals that while anglers attain a maximum value per trip at 10,000 cfs, white-water boaters attain their maximums at 29,000 and 33,000 cfs. In addition, white-water boater values are substantially higher than those for anglers and the flow-value functions for commercial passengers and private boaters are quite similar. Given equal numbers of white-water boaters and anglers, an overall unconstrained, optimum flow will correspond closely to the preferences of white-water boaters. However, if the number of anglers greatly exceeds the number of white-water boaters, then, the optimum would occur at a lower flow and would approach 10,000 cfs at the limit.

The flow-value functions were used to evaluate 1984 and 1985 monthly Glen Canyon releases and to calculate an unconstrained, optimum flow regime across all three groups of recreationists. These analyses were conducted using 1985 use rates as a common denominator and summaries of the annual benefits are presented in Table 1. The results show that the high flow years of 1984 and 1985 approach the benefits of an unconstrained optimum. The total water released in 1984 and 1985, respectively, was 20.8 and 16.6 MAF, and the total annual release for the optimum regime would be 18.2 MAF.

FIGURE 6

FLOW VALUE FUNCTIONS FOR CONSTANT FLOWS

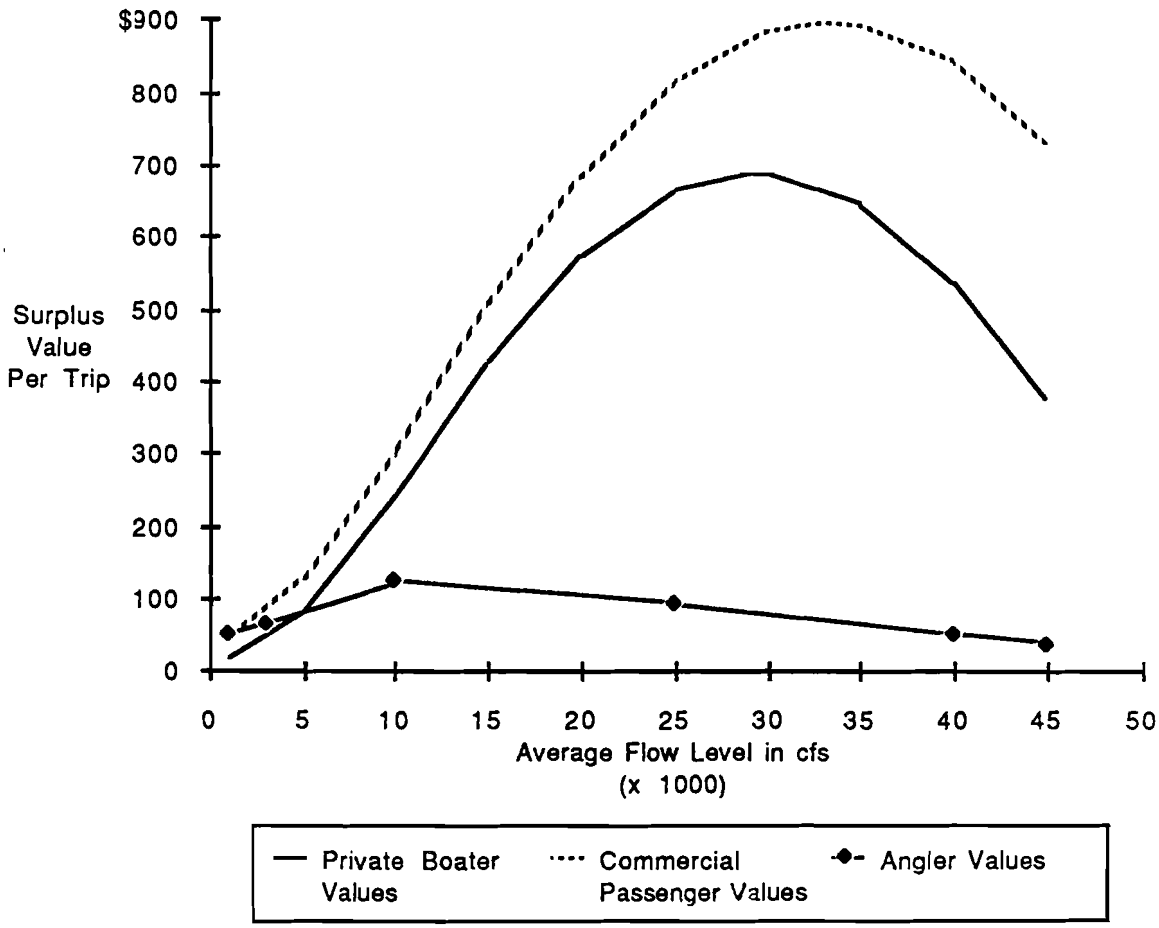


TABLE 1

Evaluation of 1984 and 1985 Flow Regimes and an Unconstrained, Optimum Flow

	White-Water Boaters			
Flow Regime	Commercial	Private	Anglers	All Groups
1984	9,578,038	$1,471,946	$525,591	$11,575,575
1985	9,436,994	$1,359,037	$524,699	$11,320,730
Unconstrained optimum	$10,197,556	$1,590,312	$571,264	$12,359,132

An operational flow regime, however, would need to reflect considerations for fish spawning habitat, beach erosion and other environmental considerations. In effect, managing releases from Glen Canyon Dam involves a complex balancing of many environmental, operational and legal considerations. Recreational use of these flows forms a small, yet still important component of this process.

COMPARISON OF ACTUAL TRIP AND SCENARIO VALUE ESTIMATES

The scenario and actual trip value estimates are only comparable for white-water boaters. A visual inspection of Figures 4 and 5 reveals that the scenario estimates appear to correspond closely to the actual trip estimates at flow levels below 20,000 cfs, but diverge at moderate flows from 25,000 to 35,000 cfs. The scenario and actual trip flow-value functions appear to converge once again at high flow levels above 40,000 cfs. The divergence that occurs at moderate flow levels, approximately the optimum for both commercial passengers and private boaters, may be due to the fact that a scenario was not evaluated for a specific flow within this range. The scenario flow-value functions only present linear interpolations between the point estimates at 22,000 and 40,000 cfs.

This visual comparison indicates that the scenario estimates do maintain ordinal rankings that are consistent with the actual trip flow-value functions. However, if only scenarios were employed, it would be difficult to state that the highest scenario values correspond to an optimum flow due to the discontinuities in the resulting flow-value functions.

A second issue of concern deals with the use of the scenario estimates as cardinal measures. This is due to the absolute differences between the scenario estimates and the corresponding actual trip estimates (Table 2).[6] The largest absolute differences for commercial passengers and private boaters, respectively, are $404 at 40,000 cfs and $149 at 5,000 cfs. These discrepencies may be explainable, in part, by the inate difference in the two types of evaluations. The actual trip question yielded ex ante estimates which are based on actual experience. In contrast, the scenarios generate ex ante evaluations that can be influenced by the information presented to respondents about the proposed environmental conditions.

For example, the difference between the scenario and actual trip estimates at 40,000 cfs for commercial passengers may be due to the safety information presented in the scenario. That is, the safety information may have acted to reduce the scenario estimate. On the other hand, safety considerations may not have entered the actual trip evaluation as strongly since respondents may only recall the large "roller-coaster rides" through the rapids at high flow levels. If nothing bad happened, respondents may only remember the high flow as a very exciting experience.

The divergence between the actual trip and scenario values may not be as dramatic for private boaters at a flow of 40,000 cfs because these respondents were relatively more experienced with the river and with white-water rafting in general. They averaged two trips down the section of the Colorado River

TABLE 2. Comparable Actual Trip and Scenario Estimates of Hicksian Surplus for White-Water Boaters

	Commercial Passengers				Private Boaters			
Flow (cfs)	Actual Trip	Scenario	Absolute Difference*	Absolute Difference As a Percent of Actual Trip Value	Actual Trip	Scenario	Absolute Difference*	Absolute Difference As a Percent of Actual Trip Value
5,000	$130	$176	$ 46	35%	$ 84	$233	$149	177%
13,000	427	488	61	14	358	504	146	41
22,000	744	602	142	19	620	525	95	15
40,000	843	439	404	48	539	434	105	19
Average	---	---	163	29	---	---	124	63

*The absolute differences were calculated by taking the absolute value of the differences between the corresponding actual trip and scenario values at each flow level.

under study. For commercial passengers, a Grand Canyon white-water raft trip is a once in a lifetime experience.

Finally, an additional insight is revealed by examining the differences between the scenario estimates and the corresponding actual trip estimates as percentages of the actual trip estimates. Four of the differences, when expressed as percentages, are less than 20 percent and only one exceeds 50 percent. When this one extreme difference (177 percent) is removed from consideration, the overall average of the differences divided by the corresponding actual trip estimates is 27 percent. A cursory review of previous CV studies reporting standard errors of estimated mean values reveals that it is not unusual for 95 percent confidence intervals to include values within plus or minus 30 percent of the estimated mean (Boyle and Bishop, 1988; Edwards and Anderson, 1987; Samples, Dixon and Gowen, 1986; and Sellar, Stoll and Chavas, 1985). In some instances the confidence intervals include values up to plus or minus 50 percent of the estimated mean.

CONCLUSION

The discussion in the preceding section indicates that the scenario estimates are plausible, but they should not be interpreted as perfect substitutes for values based on actual experience. This is especially true when estimates will be used as cardinal measures of welfare gain or loss in benefit-cost analyses. It is nearly impossible to identify an optimum condition and those who have the most to gain or lose, as the case may be, can be short changed by under or over estimates of Hicksian surplus. On the other hand, scenario values may be the best available estimates. The results presented here indicate that estimates of value based on scenarios would be acceptable to use in this case. However, careful consideration needs to be given to the types of information and level of detail presented in tbe scenarios, and how the resulting estimates will be interpreted and used in policy analyses.

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FOOTNOTES

1. Selected paper, annual meetings of the American Agricultural Economics Association, Michigan State University, August 2-5, 1987. This research was funded by a contract from the U.S. Bureau of Reclamation to HBRS, Madison, WI.
2. Boyle, Welsh and Bishop are also associated with HBRS. We would like to thank Steve Reiling for his helpful comments. Of course, all errors are the responsibility of the authors.
3. Glen Canyon Dam is used for peak power generation, and at such times, downstream flows can vary dramatically during a 24-hour period. Thus, two types of flows were evaluated. The first, constant flows, occur when daily fluctuations are 10,000 cfs or less. Fluctuating flows occur when daily fluctuations exceed 10,000 cfs. We only report the valuation results for constant flows since values for these flows were found to dominate those for fluctuating flows.
4. The prespecified amounts were selected based on the results of pretests of the CV surveys and these dollar amounts were randamly assigned to the final CV surveys.
5. Scenarios were not evaluated by day-use rafters since the attribute and CV-pretest surveys of day-use rafters yielded strong evidence that a relationship did not exist between river flows and consumer surplus for this group. The experts (guides and resource managers) concurred with this finding.
6. No statistical tests for differences were conducted because the actual trip and scenario value estimates are not derived from independent samples.

VALUING RECREATIONAL SERVICES WITH QUALITY ADJUSTED PRICES

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INTRODUCTION

The prospect of valuing environmental services through the demand for market goods is well established. Mäler identifies "weak complementarity" [(1974), p. 183] as the basic sufficient condition. Weak complementarity implies that (1) the environmental service of interest is enjoyed jointly with a market good and (2) the individual is indifferent to changes in the environmental service when the quantity demanded of the market good is zero. Independently, Bradford and Hildebrandt (1977) develop the weak complementarity concept for the case of multiple market goods.

A drawback of the weak complementarity approach is that it often requires a substantial data base. For example, given J prices and K environmental services, the weak complementarity approach requires variation across at least J + K parameters in order to estimate an appropriate demand function.[1] These data requirements make application difficult. Appropriate serial data appear to be virtually nonexistent; there are no widely recognized studies that have been able to use serial price and environmental variation to estimate the weak complementarity relation. Travel cost applications using spatial price and environmental variation are somewhat more common. Smith, Desvousges, and Fisher (1986) and Vaughn and Russell (1982) exemplify the use of the travel cost technique for valuing environmental quality.

In this paper, we suggest a new method for estimating the weak complementarity relationship. Using an argument first introduced by Fisher and Shell (1971), we reduce the dimensionality of the estimation problem by introducing the idea of quality adjusted prices. With quality adjusted prices, variation in environmental quality alone is sufficient for demand estimation.

The quality adjusted price method is applied to the valuation of site-specific viewing services at a major urban observation point, the Hancock Tower Observatory (HT) in Chicago, IL. The HT case is interesting for three reasons. First, admission prices are typically changed only once a year and visitation records are kept for only a few years at a time. Ordinary demand estimation procedures are therefore not feasible. Second, the ability to see the Chicago landscape varies with day to day changes in visual air quality. This variation in viewing services makes it possible to define a quality adjusted price with sufficent variation to estimate demand. Third, against a background of continuing regulatory interest in visual air quality [Bachman (1985)], the HT case provides an opportunity to estimate the value of visual air quality through the use of realized, rather than contingent, behavior.

The HT case demonstrates the feasibility of the quality adjusted price method. Price elasticities estimated on quality adjusted prices range from -1.055 to -1.090. Statistical tests find no significant difference between these estimates and the HT price elasticity of -1.146 estimated by a previous study using an ordinary demand approach and a different serial data set.

The quality adjusted price method indicates that a ten percent increase in visual air quality results in an site-specific increase of $56,000 to $69,000 per year in aggregate surplus. Elasticity estimates from the ordinary demand approach indicate an aggregate surplus of $71,000 for the same increase in quality.

WEAK COMPLEMENTARITY AND THE QUALITY ADJUSTED PRICE METHOD

The weak complementarity approach (WCA) values a change in environmental quality through the demand for a market good. An algebraic statement of the WCA clarifies both its conceptual and empirical requirements.

We begin with an individual that derives utility, u, from both market goods, $\mathbf{x} \in \mathbf{R}^J$, and environmental services, $s \in \mathbf{R}^K$. The service indexes, s, are defined in an entirely general fashion and may include attributes of both market and nonmarket services. Given market prices, $\mathbf{p}$, we can define an expenditure function, $e(\mathbf{p},u;s)$ that is concave and increasing in $\mathbf{p}$, and convex and decreasing in s.[2] At an initial set of prices, utility, and environmental services, the expenditure function is equal to an individual's initial income, m. The vector of income compensated or Hicksian demands is derived by differentiating $e(\cdot)$ with respect to $\mathbf{p}$, $\mathbf{Dp\_e}(\mathbf{p},u;s) = \mathbf{x}(\mathbf{p},u;s)$.[3]

Suppose that the ith market good, x_i, is weakly complementary to the ith quality index, s_i. Let $\mathbf{p}_{-i}$ and $\mathbf{s}_{-i}$ denote, respectively, the price and environmental service vectors with their ith elements, p_i and s_i, deleted. Let p_i^* be a price such that $x_i(p_i^*,\mathbf{p}_{-i},u;s) = 0$ for all s_i. The WCA requires that $e(p_i^*,\mathbf{p}_{-i},u;s_i,s_{-i})$ is a constant for all s_i [Small and Rosen (1981)].

If the requirements of the WCA are met, the Hicksian welfare measure for a change from an initial s_i^0 to a subsequent s_i^1 is

$$(1) \qquad hm(s_i^0,\ s_i^1) = \int_{p_i^0}^{p_i^*} [x_i(p_i,\mathbf{p}_{-i},u;s_i^1,s_{-i}) - x_i(p_i,\mathbf{p}_{-i},u;s_i^0,s_{-i})]dp_i$$

where p_i^0 is the initial price [Small and Rosen (1981)]. Equation (1) computes hm as the difference between the area under the demand for x_i evaluated at s_i^1 and the area under the demand for x_i evaluated at s_i^0. The quantity hm is a Hicksian compensating measure if u is the initial level of utility.

Because the Hicksian demands are not directly observable, an approximation of hm begins with an estimate of the Marshallian demand, $x_i(\mathbf{p},m;s)$.[4] A general estimate of $x_i(\mathbf{p},m;s)$ requires variation across x_i, $\mathbf{p}$, m, and s -- across J + K + 2 dimensions. However, these data requirements can be reduced. For instance, if we assume that changes in p_i, m, and s_i are uncorrelated with changes in $\mathbf{p}_{-i}$ and $\mathbf{s}_{-i}$, unbiased least squares estimates of the coefficients of p_i, m, and s_i in $x_i(\mathbf{p},m;\mathbf{s})$ can sometimes be obtained with variation in only three dimensions -- those involving p_i, s_i, and m. Data requirements can be reduced to variation in p_i and s_i alone if we assume that p_i and s_i are uncorrelated with changes in m. Unfortunately, there are many cases where even these last, rather limited data requirements may not be met. For instance, in the case of HT, p_i is virtually constant over long periods of time.

The quality adjusted price method (QAPM) is useful where existing variation in p_i or s_i is insufficient to estimate $x_i(\mathbf{p},m;\mathbf{s})$. The basic approach is to substitute a quality adjlisted price $\tilde{p}_i$ for p_i where $\tilde{p}_i$ is a function of both p_i and s_i.

The idea of a quality adjusted price is a general concept [Fisher and Shell (1971); Deaton and Muellbauer (1980)]. For instance, given a fixed s_i^0, it is always possible to find a price index $\hat{p}_i$ such that

(2) $$e(p_i,\mathbf{p}_{-i},u;s_i,\mathbf{s}_{-i}) = \hat{e}(\hat{p}_i,\mathbf{p},u;s_i^0,\mathbf{s}_{-i})$$

for any s_i [Deaton and Muellbauer (1980)]. In its most general form, $\hat{p}_i$ is a function of $\mathbf{p}$, $\mathbf{s}$, and u. Thus, in this general form, $\hat{p}_i$ does not help with the dimensionality problem.

Fisher and Shell show that the general form of $\hat{p}_i$ can be simplified if one assumes that $D_{s_i}\hat{p}_i$ is independent of the of $\mathbf{p}_{-i}$, $\mathbf{s}_{-i}$, and u. In this case, the quality adjusted price can be written as a simple function of p_i and s_i alone; specifically, $\tilde{p}_i = p_i/s_i$. Using $\tilde{p}_i$, the expenditure function is

(3) $$e(p_i,\mathbf{p}_{-i},u;s_i,\mathbf{s}_{-i}) = \tilde{e}(\tilde{p}_i,\mathbf{p}_{-i},u;\mathbf{s}_{-i})$$

and the ith compensated demand is

(4) $$x_i = x_i(p_i,\mathbf{p}_{-i},u;s_i,\mathbf{s}_{-i}) = g_i(\tilde{p}_i,\mathbf{p}_{-i},u;\mathbf{s}_{-i})/s_i$$

where $g_i = D_{\tilde{p}_i}\tilde{e}(\cdot)$ is the demand for total services, x_i times s_i, available through the purchase of x_i. In order to specify the demand for x_i, one focuses on specifying appropriate s_i and g_i.

Given an estimate of $g(\cdot)$, one can approximate equation using the Marshallian demand, $x_i(\cdot) = g(\cdot)/s_i$, in place of the Hicksian compensated demand, $x_i(p,u;s)$. This approximation is very close to the underlying hm if the income elasticity of demand or the budget share of $x_i(\cdot)$ is small [Willig (1976)].

Overall, the QAPM reduces two barriers to the estimation of x_i and hm. First, it reduces the overall dimensionality of the estimation problem by the number of environmental services that can be respecified in terms of quality adjusted prices. Second, where price variation is absent, the QAPM can be used to introduce quality adjusted price variation that may be sufficient for the estimation of a demand function.

THE DEMAND FOR VIEWING SERVICES AT HANCOCK TOWER

Hancock Tower (HT) provides an average of 350,000 visitors a year with an opportunity to view the Chicago landscape. Because the quality of the HT view varies with visual air quality, daily visitation at HT is positively correlated with changes in visual range -- the maximum distance at which objects can be seen against the horizon [Horvath (1981)]. The objective of our empirical research was to value changes in visual range at HT through the demand for HT admissions. Since HT admission prices were virtually constant during the year and a half for which we had data, aggregate demand was specified using the QAPM.

The HT demand relation may be viewed as a function of admission price, p_h, the prices of substitutes and complements, p_o, and an index of view quality, s_h.[5] Climactic and weather variables, z, such as rain and snow may also affect HT demand due to their impact on the nonmonetary costs of a trip to downtown Chicago. Times series variables, t, such as the season of the year and day of the week effects, may shift the demand function due to long term leisure plans and conventional labor contracts [Hoehn (1986)]. In log-linear form, the demand relation is

(5) $$x = A(p_h/s_h)^{-a}(p_{0i})^b \exp(zc + \mathbf{td} + e)/s_h$$

where A is a constant, e is a lognormally distributed error term, and each element of $\mathbf{p_0}$ would be entered in the same fashion as the price p_{0i}.[6] Because p_h is a constant, (5) reduces to

(6) $$x = B(s_h)^{a-1}(p_{0i})^b \exp(zc + \mathbf{td} + e)$$

where $B = A(p_h)^{-a}$ is a constant. Equation (6) contains no explicit HT admission price information -- yet it does contain information on the price elasticity of demand. Specifically, the exponent on the viewing services index, s_h, is the absolute value of the price elasticity, a, minus one.

Two different indexes of viewing quality, s_h, were used in empirically implementing equation (6). First, s_h was assumed to be equal to visual range, v. This first index was intended to account for the depth of the HT view. The second index was intended to account for depth, the breadth of a view, and the fact that similar objects at different distances from an observer may yield different viewing services. The second index measures overall viewing services,

(7) $$vs = \int_0^v 2\pi r \exp(-\tau r)dr = 2\pi[1 - (1 + \tau v)\exp(-\tau v)]/(\tau^2).$$

In (7), the term $2\pi r$ represents the potential to view objects in a circle of radius r about the tower. This circular effect takes into account the breadth of the HT view. The view along each circle is discounted at a rate τ using the term $\exp(-\tau r)$. To account for depth, the potential view at radius r is summed from 0 to the maximum distance at which objects can be seen, v.

Assuming that income effects are negligible for HT visitation, surplus estimates can be computed directly from an estimate of (6). Following equation (1), hm for a change from s_h^0 to s_h^1 is

$$hm(s_h^0, s_h^1) = [p_h^0/(a-1)][(x^1/x^0) - 1]x^0 \quad (8)$$

where p_h^0 is the price of admission to HT, x^1 is HT visitation at s_h^1, and x^0 is HT visitation at s_h^0. For the log-linear form, the calculation of surplus reduces to a simple formula: the average surplus obtained per visit -- p_h^0 divided by (a-1) -- times the percentage change in visitation brought about by the change in viewing quality times the initial level of visitation, x^0. Importantly, even if p_h is constant, (a-1), x^0, and x^1 can be obtained from an estimate of equation (8).

THE VALUE OF AN IMPROVEMENT IN VISUAL RANGE AT HANCOCK TOWER

The HT demand relation given in (6) was estimated using ordinary least squares and daily visitation data beginning on January 1, 1979 and ending on June 30, 1980. Ordinary least squares was appropriate since the supply of admissions could be viewed as perfectly elastic within the range of visitation. The estimated equations explained approximately 60 percent of the variation in visitation and coefficient estimates were consistent with intuition. Iterated least squares was used to select values of τ in the viewing services index. Values of τ between 0.10 and 0.12 maximized the explained variation in daily visitation and were selected as the best estimates of τ [Granger and Newbold (1976)].

Table 1 presents the estimates of (a-1) and the HT valuation results.[7] Results are given for both the QAPM analysis carried out in this paper and, in the fourth column, for a previous analysis [Hoehn (1986)] that used an ordinary demand approach and a different serial data set. We first review the QAPM results and then use the previous analysis as a point of comparison.

TABLE 1
HT Surplus Estimates Obtained from the Quality Adjusted Price Method and an Ordinary Demand Analysis[a]

Estimate	Quality Adjusted Price Method			Ordinary Demand Analysis[b]
	Visual Range	Visibility Services, τ = to 0.10	Visibility Services, τ = to 0.12	
1. Estimate of (a-1)	0.0904	0.0550	0.0565	0.1460[c]
2. Standard error	0.0189	0.0113	0.0117	0.415
3. t-statistic for the difference from the QAPM visual range estimate	-	1.50	1.47	0.41
4. t-statistic for the difference from the ordinary demand analysis estimate	0.41	0.67	0.66	-
5. Surplus per additional visit ($)[d]	18.5	30.4	29.6	15.0[e]
6. Change HT daily visitation for a for a 10% change in V	8.3	6.2	5.7	13.0
7. Total surplus induced by a 10% change in V ($ per day)	154	188	169	195[e]

a. Dollar values given at the 1980 price level.
b. Estimates are computed fron the results given in Hoehn (1986).
c. The estimate of (a-1) and its standard error are computed from results given in Hoehn (1986). Since the Hoehn regression estimated a demand equation that was exponential in admission price, an estimate of "a" was computed by taking the product of the Hoehn coefficient estimate, 0.533, and the average price of admission, 2.15, for the time period analyzed. The standard error estimate was computed by multiplying the standard error of the Hoehn coefficient by the average price of admission.
d. These estimates are corrected for the fact that the price elasticity is a random variable. The correction followed Mood, Graybill, and Boes [(1974), p. 180].
e. Computed using ordinary demand estimates and equation (8).

The first two rows of Table 1 report the QAPM estimates of (a-1) and the corresponding standard errors. Each coefficient estimate is significantly different from zero. The estimate of (a-1) for the visual range and extinction coefficient indexes is about 60 percent larger than the estimates obtained with the visibility services index. Since this variation has an impact on value estimates, the statistical significance of the difference between these estimates is of interest. As shown in the third row, these differences are statistically insignificant.

The fifth and sixth rows of Table 1 report value estimates and visitation changes for a ten percent change in visual range. The visual range index gives an average surplus of $18.5 per visit and a change in visitation of 8.3 persons per day. Taking the product of these terms as in equation (8), the total surplus estimate is $154 for a ten percent change in visual range.

For the viewing services index, the average surplus obtained from HT visitation is $30.4 per visit for τ equal to 0.10 and $29.4 per visit for τ equal to 0.12. Through equations (7) and (6), a ten percent change in visual range induces a change in visibility services and a concomitant change in visitation ranging from 6.2 persons for τ equal to 0.10 and 5.7 persons for τ equal to 0.12. The total surplus estimate for the visibility services equations ranges from $169 for τ equal to 0.10 to $188 for τ equal to 0.12.

The QAPM total surplus estimates range from $154 to $188 for a ten percent change in visual range. However, the visibility service indexes did provide a marginally better fit to the data. Thus, one would suspect that the true surplus measure lies in the upper portion of the estimated range.

Additional perspective on the QAPM estimates comes from comparing them with results of an ordinary demand analysis. Hoehn (1986) used admission price variation during the Spring of 1981 to estimate an ordinary demand function that was exponential in admission price. Column 4 of the first row of Table 1 gives the estimate of (a-1) computed from the demand parameters reported by Hoehn. The fourth row of Table 1 shows that the differences between the QAPM estimates and the ordinary demand estimate are not statistically significant. Thus, in terms of parameter estimation, the QAPM appears to perform at least as well as an ordinary demand analysis.

Surplus estimates computed using the QAPM compare very favorably with those obtained using the ordinary demand estimates. The fourth column of the fifth and seventh rows in Table 1 give surplus estimates that were computed using equation (8) and the demand parameters estimated by Hoehn. The ordinary demand estimate of average surplus of $15.0 is slightly less than the smallest QAPM estimate of $18.5. In terms of total surplus, however, the ordinary demand estimate of $195 is slightly larger than the largest QAPM estimate of $188. Given the order of magnitude criterion that is often used to compare the surplus estimates of different estimation methods [Cummings, et al., (1986)], the difference between the QAPM and ordinary demand estimates is negligible.

CONCLUSIONS

This paper presents a new method for estimating the weak complementarity relationship between market goods and environmental services. Derived from the work of Fisher and Shell, this quality adjusted price method (QAPM) permits the estimation of demand relations even where "nominal" price variation is nonexistent. The basic idea is to reduce both the price and environmental service dimensions into a single quality adjusted price index. Variation in either prices or environmental services alone is enough to introduce variation into this price index.

In the application to data from Hancock Tower, the QAPM performed at least as well as a previously reported ordinary demand analysis. Statistical tests showed no significant difference between the QAPM estimates and the ordinary demand estimates. The QAPM estimates indicate that a ten percent increase in visual range results in an annual increase of surplus at Hancock Tower ranging from $56,000 to $69,000. This range of surpluses compares favorably with the surplus estimate of $71,000 obtained using an ordinary demand analysis.

The QAPM provides an additional approach to estimating the value of environmental services. The QAPM relies on realized rather than intended behavior and may therefore provide past-choice corroboration for the values obtained from methods such as contingent valuation. As shown by the HT case, the QAPM yields demand estimates that are entirely comparable to those obtained with an ordinary demand approach.

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FOOTNOTES

1. Procedures for identifying demand may require additional data beyond that required for estimating the relation between quantities demanded, prices, and environmental services.
2. For a discussion of the derivation of the expenditure function, see Diamond and McFadden (1974) and Small and Rosen (1981).
3. The notation **Dy**_f(**y**) indicates the derivative of the function f(**y**) with respect to **y**.
4. A variety of procedures could be used to approximate equation (1). For instance, an approximation based on the results of Willig (1976) would involve three steps: (1) estimate the Marshallian demand, $x_i(\mathbf{p},m;s)$; (2) compute the Marshallian surpluses conditioned on s_i^0 and s_i^1, and (3) use the Willig procedures to transform the Marshallian measures to Hicksian measures. Bergland (1985) suggests an alternative exact procedure.
5. Income would ordinarily enter the demand specification. However, data on income is not available for HT visitors and aggregate income is relatively constant over the year and a half for which we have data. We therefore exclude income from the analysis and assume that income effects are negligible.
6. The model was actually developed and estimated with three functional forms: a log-linear form, a linear model, and an semi-log form. Using the R^2 criterion of Granger and Newbold (1976), the log-linear model provided the best fit. To meet the page requirements of a selected paper, we discuss only the best-fitting, log-linear form.
7. The estimated demand equations are available upon request.

SOME THOUGHTS ON THE MULTIPLE DESTINATION TRIP PROBLEM IN TRAVEL COST MODELS

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INTRODUCTION

This note discusses a logically appealing approach to handling the problem of multiple destination trips in travel cost models. This problem is discussed by Haspel and Johnson (1982), who show the potential biases from ignoring the problem to be quite large. The basic problem is simply that a travel cost for a given site is difficult to determine if the given traveler visits more than one destination. The problem is one of allocating a joint cost to more than one output (destination). Though such problems are generally intractable, this particular case may have a solution that is not completely arbitrary. A general theoretical framework for analyzing multiple destination trips is provided here, followed by a logically appealing means of allocating travel costs to more than one destination.

THE TRAVEL COST ALLOCATION PROBLEM

Define a travel cost function:

$$C^* (W_1, \ldots, W_m, Y_1, \ldots, Y_n) \qquad [1]$$

where the W_i are factor prices and the Y_i are quantities of travel (zero or one) to i = 1, n different destinations. Equation [1] is derived from first order conditions in a cost minimization formulation (Silberberg 1978).

Holding factor prices constant, define:

$$\frac{\partial C^*}{\partial Y_i} = S_i (Y_1, \ldots, Y_n), \; i = 1, n \qquad [2]$$

where the S_i are marginal cost functions. Since the concern is with allocating costs of <u>one</u> trip, total trip costs are:

$$C^* (W_1, \ldots, W_m, 1, \ldots, 1) - C^* (W_1, \ldots, W_m, 0, \ldots, 0) \qquad [3]$$

Using equation [2], an alternative expression for [3] would be:

$$\int_c \sum_i S_i \, d \, Y_i \qquad [4]$$

where $\int_c$ is a line integral evaluated between $\tilde{Y}° = (0, \ldots, 0)$ and $\tilde{Y}' = (1, \ldots, 1)$.

Equation [4] is analogous to the generalized consumer surplus measure for multiple price changes in interrelated demand-functions (see, for example, Hotelling 1938; Silberberg 1978; Just et al., 1982).

By expressing the cost function (1) as a line integral [4], the problem of cost allocation is mathematically captured as a problem of choosing a path of integration. Since cross partial derivatives are symmetrical,[2] the value of C^* is independent of the path of integration. The allocation of C^* to the Y_i, however, is not independent of the integration path.

A common theorem on line integrals (see, for example, Danese 1965, p. 103) indicates that with symmetrical cross derivatives, this line integral [4] is equivalent to a sum of ordinary definite integrals as follows (see Just et al., 1982).

Define a quantity vector for each j = 1, m as:

$$\tilde{Y}_j\ (Y_j) = (Y_1^*,\ Y_2^*, \ldots,\ Y_j,\ Y_{j+1}^\circ, \ldots,\ Y_n^\circ)$$

where all $Y_{j+1}^\circ, \ldots, Y_n^\circ = 0$ and all $Y_1^*, \ldots, Y_{j-1}^* = 1$. All $Y_{i,i \neq j}$ are parametrically represented as functions of Y_j. Then [4] is equivalent to:

$$\sum_{j=1}^{n} \int_0^{Y_j^*} S_j\ [\tilde{Y_j}\ (Y_j)]\ dY_j \qquad [5]$$

To simplify the exposition, assume only two destinations (Y_1 and Y_2).[3] Equation [5] would then indicate that trip costs could be <u>either</u>:

$$\int_0^1 S_1\ (Y_1,\ 0)\ dY_1 + \int_0^1 S_2\ (1,\ Y_2)\ dY_2 \qquad [6]$$

<u>or</u>

$$\int_0^1 S_2\ (0,\ Y_2)\ dY_2 + \int_0^1 S_1\ (Y_1,\ 1)\ dY_1 \qquad [7]$$

The first [6] implies a path of integration from (0,0) to $(Y_1^*,0)$ to (Y_1^*,Y_2^*). The second [7] implies a path of integration from (0,0) to $(0,Y_2^*)$ to (Y_1^*,Y_2^*).

The trip cost allocation problem now becomes obvious. If one chooses the integration path in [6], then one is implicitly assuming no travel to Y_2 when integrating S_1, but is assuming travel to Y_1, when integrating S_2. The converse is true for the integration path implied in [7]. In viewing equations [6] and [7], one is tempted to use the order of visitation on the recreator's itinerary to define the integration path. That this is incorrect, clarifies the nature of the problem. That is, when a recreator travels to his first destination, he is also moving closer (or farther away) to (from) his other destinations. It is thus not appropriate to use an integration path such as in equations [6] and [7]. Each of the (n+1) "legs" of the trip occurs in sequence, but each leg constitutes simultaneous movement towards or away from potentially all of the destinations. What is needed is a means of accounting for this "secondary" effect on travel distances to other destinations that occurs with any movement towards a given destination.

The theory above also suggests that the relative "importance" of different destinations is generally not relevant to the travel cost allocation problem. In equation [6], site 1 is treated as a dominant site. The only costs allocated to site 2 are the additional costs necessary to reach site 2, given previous travel to site 1. The converse is true for equation [7]. The travel cost allocation problem arises simply because of interdependent marginal travel cost functions -- the act of traveling to one destination influences the travel cost at other destinations. Whenever this occurs, then travel towards any destination actually involves travel towards (or away from) more than one destination simultaneously. Thus an integration path such as that implied by [6] or [7] is not appropriate. Thus, in general, allocation of costs to a "dominant" site is not tenable.

There is one exception that can best be addressed by example. Suppose an individual travels first to destination 1, then to destination 2, then back to 1, and then returns home. If it can be established that destination 1 was "dominant" such that the trip to destination 2 was a purely marginal decision, then [6] would imply an appropriate integration path and cost allocation. The cost of destination 1 would be the round trip cost from home to destination 1 and back, and the cost of destination 2 would be the round trip cost from destination 1 to destination 2 and back. If, however, the individual returned home directly from destination 2, then a discrete, independent, round trip cost for neither destination would be defined, even though destination 1 is identified as "dominant." The path of integration implied by [6] would not be tenable.

Basically, what is being sought is a representation of the travel cost function in parameters that account for the fact that any travel movement affects the marginal travel costs to other destinations. The next section discusses a travel cost function whose parameters are geometric vectors of the sequential trip legs. These vectors serve this purpose and provide a logical means of allocating travel costs to different destinations.

A GEOMETRIC TRAVEL COST FUNCTION

In order to pursue this logic, the cost function [1] will be defined in much the same manner as in Burt and Brewer (1971, p. 815):

> "The relevant geographic region is denoted by R and is approximated by an area on a geometric plane. . . .We define c_1 (z_i) as the cost (price) associated with consumption of one unit of the ith-commodity, which makes the coordinates x and y implicitly arguments of the cost function c_i."

Without loss of generality, locate the "geometric plane" such that the origin is the given recreator's residence. Figure 1 portrays a simple example where the recreator goes on a trip with three destinations (A, B, and C).

Naturally, this trip has four legs, the costs of which are: T_1, T_2, T_3, and T_4. The problem is to allocate the travel cost of these four legs to the three destinations (one of which might be a recreation site which is to be evaluated, using the travel cost method). Notice that the four legs of the trip do occur in sequence (as in the integration path in equations [6] and [7]), even though each leg involves, potentially, movement to all destinations simultaneously.

Looking at the first leg of the trip depicted in Figure 1 (which costs T_1), the movement from the origin to destination A can be defined by x and y vectors: $x_1 + x_2 + x_3$ and y_1. It is clear that the x_3 vector only occurs because of destination A. Vector x_2, however, is equally necessary for both destinations A and B. This reflects the fact that the marginal travel cost functions for destinations A and B are interrelated. Similarly, the horizontal vector x_1 is equally necessary for all three destinations, and the vertical vector y_1 is equally necessary for all three destinations. This, then, suggests a way to determine the "contribution" of the first leg of the trip to travel to the three destinations. Weighting all horizontal and vertical vectors equally[4], T_1, would be allocated to the three destinations as follows:

$$\frac{1/3\ x_1 + 1/2\ x_2 + x_3 + 1/3\ y_1}{x_1 + x_2 + x_3 + y_1} \cdot T_1$$

should be allocated to destination A.

$$\frac{1/3\ x_1 + 1/2\ x_2 + 1/3\ y_1}{x_1 + x_2 + x_3 + y_1} \cdot T_1$$

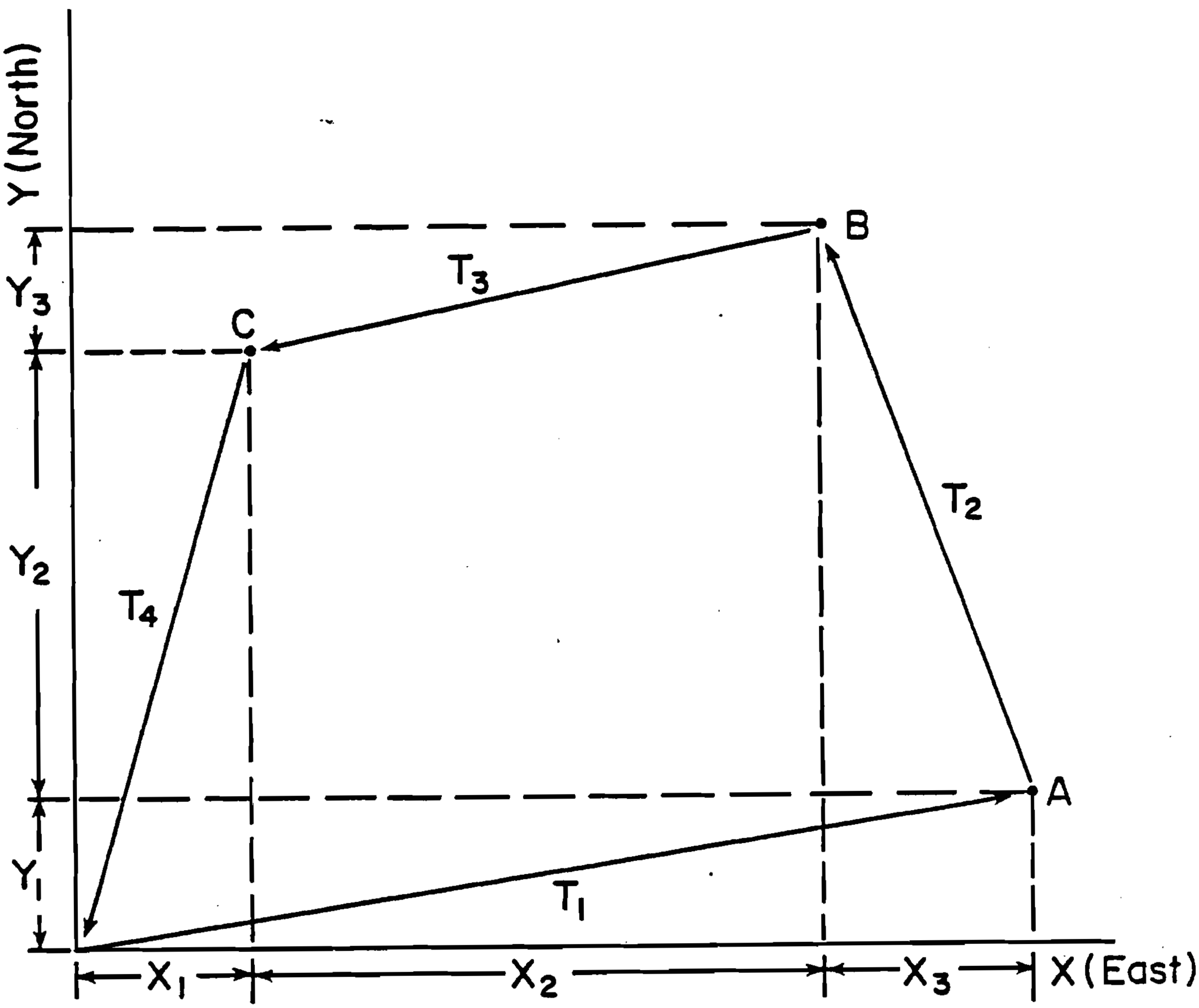
should be allocated to destination B. And,

$$\frac{1/3\ x_1 + 1/3\ y_1}{x_1 + x_2 + x_3 + y_1} \cdot T_1$$

should be allocated to destination C.

FIGURE 1

An Example Trip Itinerary Mapped Onto a Geometric Plane



Following this logic for all four legs, the costs to be allocated to the three destinations, C(A), C(B), and C(C), would be as follows:

$$C(A) = \frac{1/3\ x_1 + 1/2\ x_2 + x_3 + 1/3\ y_1}{x_1 + x_2 + x_3 + y_1} \cdot T_1 + \frac{x_3}{x_3 + y_2 + y_3} \cdot T_2 + \frac{1/2\ x_2}{x_2 + y_3} \cdot T_3 + \frac{1/3\ x_1 + 1/3\ y_1}{x_1 + y_2 + y_1} \cdot T_4$$

$$C(B) = \frac{1/3\ x_1 + 1/2\ x_2 + 1/3\ y_1}{x_1 + x_2 + x_3 + y_1} \cdot T_1 + \frac{1/2\ y_2 + y_3}{x_3 + y_2 + y_3} \cdot T_2 + \frac{1/2\ x_2 + y_3}{x_2 + y_3} \cdot T_3 + \frac{1/3\ x_1 + 1/2\ y_2 + 1/3\ y_1}{x_1 + y_2 + y_1} \cdot T_4$$

$$C(C) = \frac{1/3\ x_1 + 1/3\ y_1}{x_1 + x_2 + x_3 + y_1} \cdot T_1 + \frac{1/2\ y_2}{x_3 + y_2 + y_3} \cdot T_2 + \frac{0}{x_2 + y_3} \cdot T_3 + \frac{1/3\ x_1 + 1/2\ y_2 + 1/3\ y_1}{x_1 + y_2 + y_1} \cdot T_4$$

Extension of this example to any multidestination trip itinerary is straightforward. It should be noted that:

$$C(A) + C(B) + C(C) = T_1 + T_2 + T_3 + T_4,$$

always. It should also be noted that the logic for "allocating" a vector is whether or not it is necessary for the destination in question. Thus, for example, all of X_3 is allocated to destination A in both legs 1 and 2. And, it should be noted that the vectors are only used to apportion T_1, T_2, T_3, and T_4 among destinations. The vectors themselves are never actually costed.

If the legs in a given trip are not straight, then this "circuity" can be handled by adjusting the estimates of T_1, T_2, T_3, and T_4. The basic geometric logic just presented should still provide a tenable means of allocating the travel costs. The simple example in Figure 1 did not involve any destinations in the second, third, or fourth quadrants (West and/or South of the origin). This presents no problem. The only additional complication is to assure that movements in one quadrant are never allocated to destinations in any other quadrant.

It should be clear that this approach assumes that all destinations are of equal importance, except as indicated by the different prices (cost allocations). Since the purpose of the valuation analysis is, in a sense, to measure the relative importance of the site, it would be circular to use some (a priori) relative importance scales to adjust prices and then interpret the prices as values. One possible alternative would be to adjust quantities rather than prices to account for multidestination trips.

It is also important to note that the cost allocation that is generated with the approach discussed above is somewhat sensitive to the orientation of the axes. Since this orientation (for example, orienting the vertical axis to point north) is arbitrary, the cost allocation for any given recreator is not thoroughly tenable. However, if recreator origins are located somewhat randomly around the recreation site, and a consistent orientation is used for all recreators, then the effect of the axis orientation will more-or-less be averaged out. This would be most tenable when valuing high-valued sites that draw recreators from many origins. It is most likely that a relatively complicated approach such as the one discussed above would only be undertaken when analyzing such a high-valued site.

In the case that all destinations are equidistant, the scheme just presented (with a "neutral" axis orientation) reduces to the simple averaging of travel costs across destinations, as discussed in Haspel and Johnson (1982). And, in a situation where a number of destinations are very close together, this scheme does not preclude the possibility of grouping them into one destination as Haspel and Johnson also discuss.

CONCLUSION

Clearly, application of this cost allocation scheme requires rather complete itinerary information on each individual trip. It is likely that zip codes would be adequate to identify locations, if they can be ascertained. Programs are available that can convert zip codes into latitude-longitude and other location identifiers. It is also obvious that in a study with many observations, the allocation scheme would have to be automated. This may be difficult, given the large number of itinerary types that are possible (for example, with crossing legs, coincident legs, etc.). This should not be impossible, however. The extra effort of using this cost allocation scheme would be most defensible when the recreation resource being analyzed is of high value, when multiple destination trips are ubiquitous in the visitation data, and when the multiple destinations are typically not close to being equidistant.

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FOOTNOTES

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2. $\frac{\partial^2 C^*}{\partial Y_i \partial Y_j} = \frac{\partial^2 C^*}{\partial Y_j \partial Y_i}$, by Young's Theorem.

   Thus, $\frac{\partial S_i}{\partial Y_j} = \frac{\partial S_j}{\partial Y_i}$, $i \neq j$.

3. The basic logic, of course, applies to m destinations, by equation [5].

4. Because per unit costs of vertical and horizontal movement should be equal, this seems tenable.

ESTIMATION OF MARGINAL VALUES OF WILDLIFE AND FORAGE USING THE TRAVEL COST METHOD[1]

BY

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NEED FOR MARGINAL VALUATION

On many tracts of public land there is some degree of competition between domestic livestock grazing and big game wildlife. There is also competition among various wildlife species for the same piece of land. As in many economic evaluations the relevant allocation issue is marginal adjustments toward some optimum mix of animals rather than all or nothing choices (Cory and Martin, 1985:282-283; Keith and Lyon, 1985:216). This is particularly true in the wildlife-cattle and wildlife-wildlife trade-offs since the competition occurs primarily at certain times of the year or at high stocking levels. Information on commensurate values of forage for cattle and wildlife would improve application of existing analytical tools used by Federal Agencies (e.g., U.S. Forest Service, FORPLAN and Bureau of Land Management's SAGERAM) and could identify an efficient forage allocation in Grazing Environmental Impact Statements (EIS's) prepared by Bureau of Land Management as well as U.S. Fish and Wildlife Service, (e.g., Charles M. Russell Refuge controversy).

In terms of economic theory, determining the optimum mix of cattle and wildlife species is relatively straight forward and can be derived in terms of the factor market for forage. Economic efficiency in forage allocation would require equating the value of marginal product of forage between cattle and each wildlife species. Economists, (Godfrey, 1982; Bartlett, 1982; 1984; Dyer, 1984; Cory and Martin, 1985.) have noted the difficulties of actually making such a determination for wildlife due to several factors: 1. hunting on public lands is not priced in a competitive market, 2. while economists have developed the Travel Cost Method (TCM) as one technique for valuing public hunting, simple TCM demand models have historically estimated "all or nothing" benefits of recreation at a site under current conditions, 3. attempts to link these recreation benefits to wildife production have produced estimates of "average" rather than marginal benefits. These average values often reflected the entire value of the trip rather than the incremental contribution to trip value made by increases in wildlife populations.

The only published estimates of marginal values of elk and deer specifically associated with public lands are Cory and Martin (1985) and Keith and Lyon (1985), respectively. One study of marginal values of deer is also available for private land in Texas (Livengood,1983). The Cory and Martin study use the Contingent Value Method for determining the marginal value per elk. The Keith and Lyon paper use a household production function (hedonic) approach within an optimal control framework to estimate a marginal value per deer. Their approach develops a dynamic bioeconomic model.

This paper differs from Cory-Martin and Keith-Lyon in that we use the Travel Cost Method to estimate marginal values of two big game species (elk and deer) and calculate the marginal value product of an Animal Unit Month (AUM) of forage to these species. In this way, not only can marginal value of forage between wildlife and cattle be compared but inferences can be made about relative values of forage between different big game species. These tasks are carried out by applying two stage least squares to estimate a multi-site Travel Cost Method demand equation where big game harvest is endogenously determined in a bio-economic system. Like Cory-Martin, our model is not dynamic but does capture simple bioeconomic production relationships between harvest, big game populations and habitat. Of course all of these approaches to derive shadow prices to simulate an efficient outcome fall into the domain of "second-best" (Lipsey and Lancaster, 1958). In an ideal world, both grazing rights and hunting licenses would be sold in a competitive market.

MARGINAL VALUATION WITH TCM

The potential for applying TCM to measuring the benefits of improved environmental quality was first investigated by Stevens (1966), with work on the necessary theoretical conditions by Maler (1974) and Freeman (1979). Drawing on Maler's (1974) concept of "weak complementarity" between a private good (travel) and a public good (environmental quality), Freeman (1979:196-214) discusses alternative ways in which the Travel Cost Method can be used to estimate the benefits of improved conditions at a recreation site. Assume an ordinary demand curve for a recreation site of the following form:

(1) $V = h(P,Q,Y)$

where: V = visits, P = price, Q = site quality and Y = income.

Weak complementarity allows us to state the benefits of improving site quality from Q_0 to Q_1 as:

$$(2) \qquad CS(Q_1 - Q_0) = \int_{P_0}^{P_2} h(P,Q_1,Y)dP - \int_{P_0}^{P_1} h(P,Q_0,Y)dP$$

where P_1 and P_2 drive visits to zero for demand curves associated with the current and improved level of quality, respectively and P_0 is the current price. The conditions under which this consumer surplus measure is equal to the compensating variation for the improvement in site quality is given in Hanemann (1980). The marginal (incremental) value of a harvested animal is the ratio of the increase in surplus (Eq. 2) to the increment in number of animals harvested associated with moving from Q_0 to Q_1.

Empirical estimation of a demand function with a variable for quality is not possbile when a demand curve is estimated for just one site however, since there is no variation in site quality across observations (origins). Freeman (1979:212) suggested a two step process, which Vaughan and Russell (1982:453) demonstrate can be combined into one equation of the following form:

$$(3)\ V_{ij} = B_0 - B_1TC_{ij} + B_2Q_j + B_3(TC_{ij} * Q_j) + \ldots B_{n-1}Z_{ij} + B_n(Z_{ij} * Q_j)$$

Where: V_{ij} = visits by individual i to site j, i = 1,..t and j = 1,..s

TC_{ij} = transportation and time costs of individual i to site j

Q_j = a measure or index of site j's quality

Z_{ij} = other variables including price of substitutes, demographics of recreationists, etc.

Equation 3 presents the full interaction model where site quality is assumed to affect all of the other variables (Vaughan and Russell, 1982:453). Whether all variables are affected by quality is a hypothesis, that can be tested. A similar approach was developed earlier by Knetsch, et al., (1976). The varying parameter model allows for pooling of visitation data across many sites. If these sites have sufficient variation in site quality, then the analyst will be able to estimate coeficients that predict how visitation will change with changes in site quality. As such, a new second stage site demand curve can be estimated for each site under improved site conditions. As discussed above, the area between these curves is the incremental (marginal) benefits attributable to that improvement.

While there are other market based approaches to measuring site quality and characteristics (see Mendelshon and Brown, 1983; Feenberg and Mills, 1980) and of course, Contingent Valuation Methods (Brookshire, et al., 1980; Cory and Martin, 1985) this paper adopted the multi-site TCM approach of Vaughan and Russell (1982), and Knestch, et al., (1976) for the reasons stated below.

DATA SOURCES

Data was derived from a survey of persons hunting in Idaho in 1982. The sampling frame was any resident or nonresident having a valid Idaho hunting license. However, only hunters indicating that hunting was the primary trip purpose and that hunt unit was the primary destination were included in the analysis to insure the assumptions of TCM were met. The elk hunting survey contacted, via telephone, 2.1% or 1,629 elk hunters during January-February 1983 regarding the 1982 hunting season. For more details see Sorg and Nelson (1985). The deer hunting survey contacted 0.917% or 1445 deer hunters during January-February 1983 regarding their 1982 hunting season. See Donnelly and Nelson (1985) for more details. Data was collected on hunter expenditures, travel distances, success, days afield, etc. Unfortunately, interviewers were not allowed to collect data on individual hunter income, tastes and preferences, etc.

DEMAND MODEL

Since the survey did not include individual specific data on explanatory variables such as income and to minimize the effect of recall of trip distances, etc. on estimated coeficients (Brown, et al., 1983) the zonal TCM model was estimated for deer and elk.

It was desirable to estimate both elk and deer demand equations using the double log demand model. This functional form produces a diminishing marginal value per animal when the coefficient on harvest is less than one. However, we could not estimate this functional form with the full interaction model. As specified in equation 3, this model had very high multicolinearity due to presence of the interaction terms. This resulted in a near singular matrix. The simplified model proposed in this study for elk and deer is thus closer to a pooled multi-site demand equation. This model is given below as:

(4) $$\ln(V_{ij}/POP_i) = B_0 - B_1(\ln DIST_{ij}) + B_2(\ln INC_i) + B_3(\ln THVST_j)$$

Where: V_{ij} = hunter trips from origin i to site j

POP_i = county i's population, i = 1,...n

$DIST_{ij}$ = round trip distance from origin i to site j.

INC_i = county i's per capita income

$THVST_j$ = total hunt unit harvest of respective species at site j = 1,..63 for elk and j = 1,..78 for deer.

Since the quality variable is total site harvest, the possibility exists this variable is endogenous in a time dependent bio-economic system. That is, even though the dependent variable is trips per capita from each origin to site j rather than total trips to site j, simultaneity may be present. In particular, the demand equation in equation (4) may be part of a two equation bio-economic system. One such system is presented in equations 5-6:

(5) $\ln(V_{ij}/POP_i) = B_0 - B_1(\ln DIST_{ij}) + B_2(\ln INC_i) + B_3(\ln THVST_j)$

(6) $\ln(THVST_j) = A_0 + A_1(\ln APOP_{jt-1}) + A_2(\ln V_{ij}/POP_i) + A_3(\ln HA_j) + A_4(\ln THAB_j)$

where: $APOP_{jt-1}$ = Elk or deer populations at site j in time t-1

HA_j = Hunt ability of site j in terms of terrain, denseness of vegetations, etc.

$THAB_j$ = Total amount of habitat in site j measured in square miles

All other variables are as defined earlier.

However, data is not available for all of the variables in this system and therefore equation 5 may be estimated using two stage least squares. Since data is available on the exogenous variable $THAB_j$ and $APOP_{jt-1}$ as well as $DIST_{ij}$ and INC_i the order condition for equation 5 is met for both deer and elk.

STATISTICAL RESULTS

The elk TCM demand equation estimated using two stage least squares is presented in equation 7:

(7) $\ln(V_{ij}/POP_i) = 24.173 - 1.629(\ln DIST_{ij}) - 3.126(\ln INC_i) + 0.4311(\ln THVST_j)$

T values (20.85) (-30.28) (-24.09) (5.51)

The R^2 was 0.74 and the F value was 526. All of the individual coefficients and the F value are significant at the 99% level. The negative sign on income may at first appear somewhat counterintuitive. It may be a result of using county per capita income instead of individual hunters income (which was not available) coupled with the fact the further one lives from these rural outdoor recreation sites, the higher their incomes are likely to be (Duffield, 1984:77). However, even when using primary data on deer hunter income, Mendelsohn (1984:98) found a statistically significant negative relationship between number of trips and income. Perhaps, when dealing with time intensive activities such as hunting, higher income measures the higher opportunity cost of time. Thus the negative sign on income reflects a price coefficient with respect to onsite time costs rather than ability to pay in the traditional use of money income. As evidenced by the F values and t statistics, the double log functional form offered a good explanation of the relationships between the variables.

The deer demand equation estimated using two stage least squares is:

$$(8)\ \ln(V_{ij}/POP_i) = 47.19 - 0.649(\ln DIST_{ij}) - 6.381(\ln INC_i) + 0.327(\ln THVST_j)$$

T values (11.33) (-11.88) (-13.14) (2.21)

The R^2 was 0.47 and the F value was 160. The distance and income coefficents and the F value are signficant at the 99% level. The harvest variable is significant at the 95% level. It was not possible to incorporate a statistically significant variable to reflect the price or quality of subsitutes in either the elk or deer equations. As such the empirical values that follow are very likely overestimates.

It must be acknowledged there are several other site characteristic variables that should be included in all of the above species demand curves. Variables reflecting a proxy for congestion (hunters per acre) and other site quality varibles such as number of animals seen (trip total and per day) were tried for deer and elk but were consistently insignificant.

CALCULATION OF MARGINAL VALUES

From the overall per capita demand equations it is possible to derive the second stage or hunt unit specific demand curves in terms of added distance. Once the second stage demand curves have been derived in this way, it is necesary to convert the distance increments to dollars. This translation requires estimates of the transportation cost per mile plus the value of travel time per mile. Incorporation of travel time in this fashion assumes the hunter can trade-off work time for hunting. While this may or may not be realistic, given the survey data avaiable it was necessary to make this assumption. Transportation costs were converted to dollars using the average transportation cost of $0.31 per mile reported by elk hunters and $0.183 per mile of deer hunters, each divided by the average number of hunters per vehicle. Travel time was valued at one-third of the wage rate, which was the mid point in Cesario's (1976) survey of transportation planning literature. While more recent analysis questions the use of a fraction of the wage rate rather than the entire wage rate (Smith, et al., 1983) other analyses of recreation travel behavior provide support for use of a fraction rather than the entire wage rate (McConnell and Strand, 1981).

To illustrate calculation of marginal values of elk and deer hunt areas 36 and 36B in the Challis, Idaho area have been selected. The Challis area was designated by the Natural Resources Defense Council vs Morton court decision to be the area for Bureau of Land Management's first Grazing Environmental Impact Statement. The Challis area has been the scene of substantial controversy over grazing versus wildlife prior to, during and after the preperation of the EIS (Nelson, 1980). BLM's Final EIS (1977:Chap 3:21) states that during May and June there is spatial and dietary competition for grasses between cattle and antelope, deer, elk and bighorn sheep in the area. Elk and cattle have strong dietary similarities (particularly in the spring) in terms of their preferences for consuming grasses, so the potential competition from increasing elk or cattle populations may be the greatest. There also exists substantial evidence of social avoidance of cattle by elk, with presence of cattle (and associated humans tending the livestock) causing elk to leave an area of otherwise desirable habitat (Lyon, 1985:17; Nelson, 1984).

Since there is still some debate about the exact form and extent of competition between cattle and elk in general and specifically in the Challis area, no attempt will be made to establish an explicit production possibilities curve for cattle and elk in this paper (see Nelson, 1985; Cory and Martin, 1985 for attempts in other areas). Rather we will analyze the incremental values of wildlife and forage for likely attainable increases in wildlife numbers. This increase in wildlife numbers involves costs in terms of either reduced cattle numbers or capital investment to increase range productivity. BLM's Final EIS indicates that at least a 30% increase in deer numbers could be sustained with additional forage and that this is consistent with Idaho State Department of Fish and Game's ojectives for deer herds in those units (Bureau of Land Management, 1977, Chap 3:27). The potential for increased carrying capacity of elk habitat is about 20% (1977, Chap 3:29). The purpose of these estimates is to provide a benchmark of what the potential improved condition might be. For the purposes of the remaining analysis we will calculate marginal values of wildlife and forage using a 25% increase.

In unit 36, a 25% increase in the number of bull elk harvested (28 more), generates a rightward shift in the elk hunting demand curve. The area between the new and old curves for Unit 36 represents an increase in net economic benefits of $14,075, annually. The marginal value of a harvested bull elk is $502. To calculate the marginal value product of the forage in producing elk requires knowledge of the production relationships. According to information provided by the Idaho Fish and Game (Parker, 1985) production of 28 more elk available for harvest (surplus production) annually would generally require the elk herd in unit 36 increase by 378 elk in total, with the composition being 19% bulls, 54% cows and 27% calves. The available literature (Bureau of Land Management, 1977:1-2; Thomas, 1984) indicates that each adult elk consumes between 0.4 and 0.67 AUM's of forage each month. For illustration purposes use the average of these two estimates or 0.54 AUM's per adult elk and half this amount per calf. This latter information when combined with the herd structure above allows derivation of a simple production function for unit 36 relating the number of elk available for harvest to quantity of forage:

(9) $EH = 0.01322AUM$

Where: EH = bull elk available for harvest

AUM = Animal Unit Month of forage consumed by elk.

Combining the marginal product calculated from equation 9 with the marginal value of an elk ($502) yields a value marginal product of $6.65 per AUM. The $6.65 represents the maximum amount hunters would bid for the increased forage to produce 25% more elk in hunt unit 36. Deer marginal value products were calculated in Unit 36 using the same procedure outlined above. The simple deer production function is:

(10) $DH = 0.04083AUM$

Where: DH = deer harvested

AUM = Animal Unit Month of forage consumed by deer

Table 1 presents marginal values per animal and per AUM for big game units 36, and 36B[2]. While marginal values per animal are higher for elk than deer, comparison of equations 9 and 10 reveal that a standardized AUM produces about four times as many deer as it does elk. This is reflected in the MVP

TABLE 1

MARGINAL VALUES OF WILDLIFE, CHALLIS IDAHO

	MV PER ANIMAL	MVP PER AUM
<u>UNIT 36</u>		
ELK	$502	$ 6.65
DEER	$155	$ 6.33
<u>UNIT 36B</u>		
ELK	$647	$ 8.25
DEER	$310	$15.83

figures. The large difference in forage value for deer in the two units relates to differences in marginal value per deer and to the higher marginal productivity of Unit 36B in producing deer. Specifically, it takes only an increase of 7.6 deer to produce 1 more available for harvest in unit 36B as compared to 9.5 deer to produce 1 more for harvest in unit 36 (Parker, 1985). The higher marginal value per deer in Unit 36B appears to reflect the higher harvest and greater opportunities to select the particular deer harvested as evidence by much higher median deer sighted by hunters in Unit 36B.

COMPARISON OF WILDLIFE AND CATTLE VALUES

The value of public land forage to cattle ranchers can be estimated by a variety of methods including comparison with market priced forages, capitalization of permit values and production function techniques such as linear programming (Bartlett, 1984). The joint US Forest Service and Bureau of Land Management Appraisal Report (Tittman and Brownell, 1984) indicates that fair market value of public land grazing in the Region were Challis is located would be $7.60 per AUM. While the representativeness of the values in this report are under question (Obermiller, 1985), it provides one estimate of forage value. Wilson, et al., (1985) used a linear programming approach with ranch budget data to estimate forage per AUM on BLM land in the area studied here. Inclusion of an opportunity cost for family labor results in a value of $9.59 per AUM (inclusion of opportunity costs for investments other than land reduces the value to about $5). The values derived from the linear programming approach may be more reflective of maximum willingness to pay than the appraisal values.

Comparison of the widlife values in Table 1 with these forage values shows that deer and elk are economically competitive with cattle in Unit 36B. Since the functional form of the estimated demand curves conform to diminishing marginal utility, the marginal value of elk and deer do rise as the herds are made smaller. For example, a 10% decrease in the deer harvest in Unit 36 results in the marginal value of a deer rising from $155 to $173 and the forage value rising to $7.08 an AUM. Thus it is just a question of what size deer and elk herds would be economically competitive with cattle in Unit 36.

If public land managers had efficiency as their only objective then wildlife and cattle populations could be modified until the marginal value of forage to all species was equalized. For the time being these values per AUM at least provide information on which direction livestock and wildlife populations should be moving from an efficiency view point. For example, perhaps more forage should be allocated to deer (from cattle and elk) in Unit 36B until MVP are equalized across all species. In Unit 36, either existing forage could be allocated from deer and elk to cattle or the feasibility of investments to increase forage production evaluated by comparing these incremental wildlife values to costs of producing additional AUMs.

CONCLUSION

This paper demonstrated that marginal values of wildlife and marginal value product of forage to wildlife can be developed utilizing the Travel Cost Method. The resulting values are commensurate with the values of forage to livestock and hence allow use of efficiency analysis in suggesting forage allocations on public lands. Such values can be incorporated into Federal agency analytical models as well as used in determining allocations of forage in Grazing Environmental Impact Statements. In the Challis, Idaho area the marginal value product of forage to wildlife ranges from a low of $6.33 an AUM to a high of $15.83 per AUM. These marginal value products for wildlife are in the same range as the $7.60 to $9.59 MVP of forage to cattle. As this paper, Cory and Martin (1985) and Keith and Lyon (1985) demonstrate methodologies that if widely applied could greatly increase the use of economic efficiency analysis in the forage allocations on public lands.

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FOOTNOTES

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2. The elk and deer production functions for Unit 36B are EH = 0.0127485 AUMS and DH = 0.05103 AUM, respectively.

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 <u>offset</u> (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 not 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.

<u>Step III</u>. 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.

<u>Step IV</u>. 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,

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

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 <u>quantity</u> or <u>quality</u> increases.

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

where u^0 is conditioned as the prepolicy utility level, assuming that the CV is the welfare measure desired. The HCDS in (17) are 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) $$E = \sum_i p_i x_i^*$$

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.

Step III. 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 price 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 quality 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.

TRAVEL COST DEMAND MODELS WITH LINKAGES TO FISHING QUALITY: COMPUTERIZED MODELS FOR THE PACIFIC NORTHWEST

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INTRODUCTION

The primary off-site benefits of soil conservation practices which improve water quality include recreation, especially, recreational fisheries. Clark, et al., (1985) indicated recreational fisheries would be the largest component of social benefits (ranging from $490 million to $2.670 billion) and represent about 20% of the total social benefits. However, this estimate is necessarily based on extraplolation from other studies as there has been little empirical estimation of how the values of fishing change with site quality. Two empirical studies that are available use different modelling approaches to incorporate water quality associated with erosion control and arrive at quite different conclusions: Ribaudo (1986) found almost no recreation benefits and Patrick, et al., 1987 found $1.1 to $5.8 million dollars of annual benefits for a 2% reduction in suspended solids and associated pollutants in Indiana. Patrick et al., use a hedonic travel cost method.

This paper reports on a series of bio-economic demand models for recreational fishing built using the Travel Cost Method, which run on IBM-PC. The models link changes in catchable fish populations to net economic benefits. These GAMEFISH programs and data provide a user friendly (menu driven) bio-economic model for measuring the economic benefits of recreational salmon and steelhead fishing in the Pacific Northwest. The basic modeling and programming structure described here can be applied (with the addition of the appropriate data) to estimating the benefits of improved water quality for warmwater fisheries and other coldwater fisheries in all regions of the country.

Estimates of change in net willingness to pay are needed for performing a wide variety of applied welfare analysis. These include calculation of a change in angler benefits from a change in fish production stemming from: (1) Agricultural practices affecting soil erosion rates and hence water quality

(2) application of insecticides and herbicides (3) land use conversions and timber harvesting practicies affecting sedminentation and stream temperature (4) reduction of nonpoint source pollution from feedlots and (5) investment in municipal waste treatment plants.

The GAMEFISH program discussed here is a series of LOTUS 123 (release 2) files constructed with the limited programming capability provided by the LOTUS feature called "macros". The menu driven program is designed to run on an IBM-PC type machine that will operate LOTUS 123. Only 256K of RAM and one floppy disk are required.

METHODOLOGY AND CALCULATION OF NET WILLINGNESS TO PAY

The GAMEFISH programs use measures of net willingness to pay (consumer surplus) to represent the net economic values of recreational fishing at selected sites. Use of net willingness to pay in Benefit Cost Analysis is required by U.S. Water Resources Council Principles and Guidelines (1983), and recommended in textbooks on Benefit Cost Analysis (Sassone and Schaffer, 1978; Just, et al., 1982).

The methodology employed estimates the incremental (marginal) net willingness to pay of additional recreational fish catch by calculating the area between a fishing site's demand curve at the current and changed levels of catch. The site's demand curves were estimated using a multi-site Travel Cost Model (TCM) which is discussed in more detail below. Specifically, if equation 1 is the demand equation with site quality as a shift variable:

(1) $Tij = f(Pij, Qj, Yi)$

Where: Tij = trips by individual i to site j

Pij = Price (travel costs) of individual i to site j

Qj = quality characteristics of site j such as fish catch

Yi = income of individual i

then equation 2 specifies the incremental benefits of a change in fish catch from Qj′ to Qj" as:

$$(2)\ \Delta CSi = \int_{Po}^{P''} (Pij,\ Qj'',\ Yi)\ dPij - \int_{Po}^{P'} (Pij,\ Qj',\ Yi)\ dPij$$

Equation 2 represents the conceptually correct measure of the additional net willingness to pay of changes in site quality (Freeman, 1979:74-75; Feenberg and Mills, 1980:63-69). The site quality variable, total recreational fish catch, is directly affected by water quality and thus the recreational fisheries component of improved water quality is captured in equation 2.

When successfully employed, this approach to measuring the benefits of improved recreational fish harvest overcomes most of the drawbacks associated with currently used average value per day of fishing (regardless of the level of catch per day) or average value per fish derived by assigning the entire value of the fishing experience to the fish (Grobey, 1985). This method also results in each river drainage having its own unique marginal value per fish caught. This marginal value varies from river to river drainage based on the river's location (price or travel distance) and on demand shift variables such as angler population and availability of substitute rivers. The models can be utilized for evaluating both positive and negative impacts to fisheries and water quality.

SPECIFICS OF RECREATION DEMAND AND BENEFIT ESTIMATING METHODOLOGY

The method employed in this study is a regional Travel Cost Method (TCM). This approach is recommended by the U.S. Water Resources Council (1979, 1983) as one of the two preferred techniques for estimating recreation benefits. The method is one of the most widely applied demand estimating techniques and has been applied in every region in the country. (See Stoll; 1983 and Stoll et al., 1984). TCM uses observations of travel distance as a measure of price and trips taken as a measure of quantity to statistically trace out a demand equation. The resulting first stage or per capita demand equation allows the analyst to calculate the additional amount the recreationists would pay over and above their travel costs to have access to the site for recreational fishing. See Ward and Loomis (1986) for a discussion of the basic TCM approach.

Estimating First Stage or Per Capita Demand Equation

The specification of the per capita or first stage TCM demand equation estimated for Oregon, Washington and Idaho is given in equation 3 as:

(3) $\ln(TRIPSij/POPi) = Bo - B1(\ln DISTij) + B2(\ln TFISHj) + B3(\ln SUBSij) + B4(\ln INCi)$

where: TRIPSij = angler trips from county i to river or port j

POPi = population of county i

DISTij = round trip distance from anlger's county of residence i to river or port j

TFISHj = total recreational fish catch at river or port

SUBSij = substitute index of county i for river or port j

INCi = household income of anglers living in county i

One equation was estimated in each of the three states for steelhead rivers, one equation was estimated for each of the two states with freshwater salmon streams and one equation was estimated for each of the two states with recreational ocean salmon fishing. A total of seven equations were estimated. Each equation represents a pooling of origin-destination trip data across rivers or ports within a given state. Such pooling is the primary way in which variation in site quality can be observed (Ward and Loomis, 1986). Of course variation in site quality is needed to allow estimation of a coefficient on site quality.

Assumptions

For travel distance or travel cost to be considered the price paid to visit the site, such travel costs must be incurred exclusively to gain access to the recreation site. If the trip has many destinations, one cannot correctly interpret all of the travel cost as a price paid for fishing at any one particular river. To satisfy this assumption using the secondary data which was available to estimate these models, visitation data was used only for the respective state residents.

Calculation of Benefits from the Per Capita Demand Equation:
The Second Stage Demand Curve

Once the per capita demand equation of the form in equation 3 is estimated using ordinary least squares regression, benefits can be calculated in several ways. Following equation (2) the per capita curve could be integrated for each zone of origin between the current distance and the maximum distance that would drive visits to zero to calculate net willingness to pay for each zone. Site benefits would be the population weighted sum of each county's net willingness to pay.

Alternatively, a "second stage" or site demand curve can be calculated from equation 3. This site demand curve relates total site visitation to added distance or travel costs (i.e., price) over and above the existing distance (or cost). The area under this site demand curve is net willingness to pay. This site demand curve approach is used in this program since it is more amenable to programming with LOTUS 123 commands and LOTUS macros. The equivalence of these two approaches has been demonstrated in the literature (Burt and Brewer, 1971; Menz and Wilton, 1983).

To convert added distance or net willingness to pay calculated in miles to net willingness to pay (consumer surplus) in dollars, miles must be converted to dollars. The issue of converting travel distances to a monetary price involves accounting for two costs of travel: transportation cost and opportunity cost of travel time. To convert distance to 1984 dollars, we used the variable costs of vehicle operation from the U.S. Department of Transportation's "Cost of Owning and Operating a Vehicle-1984". This is not only a widely used source for operating costs, but is recommended by the U.S. Water Resources Council (1979, 1983) for use in performing Travel Cost Method studies. The variable cost per mile is $0.15 for an intermediate size automobile.

Since time is scarce, time spent traveling has an opportunity cost in terms of either foregone time fishing at the recreation site or foregone time spent in other activities which may be other recreation or leisure. There is empirical evidence that travel time is viewed as costly both in the transportation planning literature (Cesario, 1976) and in sportfishing (McConnell and Strand, 1981). In the case of Rhode Island saltwater sport anglers, comparison of the deterrent effects of travel time and travel cost, indicated that anglers valued the time spent travelling at about 60% of their wage rate. The U.S. Water Resources Council (1979, 1983) relies on Ceasrio's (1976) work and suggests using a value between one-fourth and one-half the wage rate as a proxy for the opportunity cost of time. In this study we used one-third of the state wage rate for the value of travel time which for Oregon and Washington averaged approximately $2.90 per hour. Assuming an average speed of 40 mph, time cost per mile is $.0728. The combination of this value of travel time with the $.15 per mile variable travel costs results in a cost per mile of $.22. In the program conversion of the willingness to pay in terms of added distance into dollars is made using this $.22 per mile figure.

DATA SOURCES AND DEMAND EQUATIONS

The models contain demand equations for recreational fishing of freshwater salmon in Oregon and Washington, steelhead fishing in Idaho, Oregon and Washington and Ocean salmon fishing in Oregon and Washington. Due to space limitations, only the Oregon data for freshwater steelhead will be presented. Complete presentation of all of the demand equations can be found in in the program documentation and user manual by Loomis and Provencher (1986).

While the current data, demand equation and program are limited to three states, a user familiar with LOTUS 123 can easily adapt the program to any demand function of the form in equation 3. Since the demand coefficients and data are in a file separate from the program, a new equation and accompanying data can be used in place of the existing data as long as certain conventions are followed. Using the WASALPGM program file and WASFWSA data file as templates, these conventions include: (1) placement of equation and variables in the same cells in the spreadsheet as the original equations and data and (2) the number of observations per recreation site or river not exceed 24 zones of origin for any given site. That is, while the number of rivers or sites cannot exceed 15, the number of observations for any one site cannot exceed 24. Thus the maximum number or origin, destination, site combinations is 360.

A user familiar with LOTUS 123 Macro's can of course update the menu's and screen displays to be specific to the new sites or rivers added. A detail description of the Macro's and their locations within the spreadsheet can be found in Loomis and Provencher, 1986.

<u>Specific Data and Equations Used in Program</u>

The file ORSTLPGM concerns the estimation of benefits of steelhead fishing in selected rivers of Oregon. The estimated demand equation and data for the program are stored in a file called ORSTELHD. The source of the data is a 1977 survey of Oregon anglers. This survey is described in Sorhus et al., (1981). Briefly, a sample of 9000 anglers was drawn from the population of Oregon angling licensees. A mail questionnaire queried each angler about his fishing activity and expenditures. This questionnaire was sent out each quarter to minimize recall problems. A total of 55.6% of the sampled anglers responded to the questionnaire.

The estimated demand equation is also stored in ORSTELHD. The double log functional form was chosen so that each additional fish caught would have a diminishing marginal value. The following equation was determined to be the best regional travel cost model of steelhead fishing in Oregon, and consequently it is the one used for benefit estimation in ORSTLPGM:

(4) ln(TRIPSij/POPi) = -3.9008 - 0.8281ln(DISTij) + 0.5243ln(FISHj) - 0.0775ln(SUBij)

(T Values) (-2.21) (-5.78) (2.46) (-2.09)

R2 = 0.482 n = 81 F = 23.89

where, all variables are defined as in equation (3) except:

FISHj = total steelhead caught at site j in 1977

SUBij = an index of the availability of substitutes for site j

The index is SUBij = Σ $(FISH_k/DIST_{ik})$

for all $(FISH_k/DIST_{ik}) > (FISH_j/DIST_{ij})$

This equation performs relatively well in predicting actual trips. The equation predicts within 10% of the sample estimate of actual trips (predicted was 657,600 versus actual of 683,117).

OPERATION OF THE PROGRAM AND DATA INPUT REQUIREMENTS

To execute the GAMEFISH program the user must first load LOTUS 123 into RAM and select the spreadsheet mode. The user then performs a File Retrieve command in LOTUS to bring up the GAMEFISH files. The file with the last six letters being ___PGM.WKS is the program file to be selected. The program will execute automatically once the file is retrieved. In the complete GAMEFISH series, there is one PGM.WKS file for each species (salmon or steelhead) in each state for a total of seven files split between three disks.

The program begins by providing a menu of different rivers or ports in the particular state from which the user can choose. The user specifies the particular river to be analyzed in the project under study. Given a specific river, the program retrieves from the data file the relevant observations and previously estimated demand equation (e.g., equation 3 if the state where Oregon and the species was steelhead) applicable to the site chosen by the user and places it in the spreadsheet. At the same time, the program then calculates the consumer surplus for the current fish population at the chosen site and stores the result in the spreadsheet.

The user is then prompted to indicate whether the change in catchable fish populations or surplus production of fish due to the project will be expressed numerically or as a percentage of current catch. Depending on the response, the user is prompted to enter the change in catchable fish in the units selected. This change in catchable fish due to changes in water quality, water quantity, stream temperature, etc., must be calculated "outside" of the GAMEFISH model. Consultation with fisheries biologists or use of fish habitat models such as Theurer, (1985), Bjornn (1986), Heller et al., (1983) is recommended.

Given the water quality induced change in catchable fish, the program then calculates the incremental consumer surplus estimate at the chosen site. The program displays results of consumer surplus calculations on the monitor. The program then prompts the user to indicate whether results are to be printed. After printing the user is given three choices in a menu. They can terminate the program (QUIT), try another change in fish catch at the same river (REPEAT), or initiate the discounting feature (DISCOUNT).

If the user chooses DISCOUNT then the program retrieves the file DISCOUNT.WKS and places it in the spreadsheet. The user is then prompted to enter the appropriate interest rate as well as the first and last years of the project (not to exceed 50 years) to which the specified change in fish catch applies. The program then calculates the net present value of the change in fish catch, displays it and allows printing of output. If different years of the project involve different levels of fish catch, successive benefit calculations for each sub-period can be made and the software will accumulate the net present values. The user may select another river for analysis by reactivating the MACRO's by holding down the ALT key and pressing A. This will bring up the menu providing the alternative rivers which may be selected. The specific instructions for all program options are contained in a user manual by Loomis and Provencher (1986).

Field Tests and Applications

The software has been field tested by economists in the U.S. Army Corps of Engineers and the Soil Conservation Service (both in Portland, Oregon). The Soil Conservation Service test involved estimation of fishing benefits due to soil conservation practices on the Tucannon River in southwest Washington. The software has been applied by the author to valuation of timber harvesting induced sedimentation of recreational fisheries in Oregon.

Sample Session

To illustrate the use of this software package, a sample analysis for steelhead fishing at the Umpqua river in Oregon will be presented. After entering LOTUS 123 spreadsheet program and making the default directory the one that contains the GAMEFISH program and data files, the user performs a /File Retrieve within LOTUS. Select the ORSTLPGM.WKS file which contains the program. Once this file is retrieved the program automatically starts and provides a Menu with the choice of rivers to be analyzed. (However, you must leave the disk in the drive as the program calls data or additional program code from the disk). Due to screen length limitations, the 21 rivers are listed on four separate lines, but only one line is visible at a time. Thus the first line of rivers starts with Alsea, Chetco, Clackamas, Coquille, Coos and Deschutes but provides the choice called NEXT. Highlighting NEXT with the cursor yields a message to select this choice to get to additional rivers. Since the Umpqua is the fourth set of rivers down the list, continue to select the "NEXT" option until the menu with UMPQUA is displayed. Then select this Umpqua. Once this river is selected, the program will automatically call in the appropriate data file and equation for the Umpqua river.

Once the data is read into the computer's memory, the user is prompted to indicate whether the change in fish catch will be expressed as a percentage change from current catch or as number change to be added or subtracted from current catch. For this example select number. The screen display will change to prompt the user to enter the change in number of fish. Indicate the change is 30 fish. The program will add this to current catch. If a reduction in fish catch was desired, simply enter -30.

Upon entering the change in number of fish, the program will then change the value of the fish catch variable in the equation and calculate the new second stage TCM demand curve under the new condition. Then it will substract the benefits under the new condition (the area under the new second stage TCM demand equation) from the benefits under the existing condition. The result will be displayed on the screen as shown here in Figure 1. At this point the user can choose to print the results or not. If either option is selected, the next menu asks the user to choose between (1) REPEAT the analysis for the same river but a different change in fish catch; (2) DISCOUNT which is to perform present value calculations using the annual benefits just calculated or (3) QUIT to terminate the program. For this example select DISCOUNT. The user will then be prompted for the discount rate. Enter 8.8125 for this example. The screen display will change and the user then prompted for the first and last years of a consecutive series of years that the annual benefits calculated above would apply to. For the purpose of this example, enter 1 for the first year and 30 for the last year.

The program will then calculate the present value of the existing catch, new catch and the difference in value. Figure 2 presents this screen display. The user is given choices as to whether to print the results, display the results, to do both or neither. If you wish to print the results choose both, otherwise choose display. The user is then prompted to choose whether the analysis is: (1) COMPLETE; (2) SAME CATCH-discount the same annual benefits for a different series of years or (3) NEW CATCH-calculate annual benefits associated with a different fish catch level and allows the user to calculate the present value of a specified annual series of these benefits. The COMPLETE option sums up the present values of previous runs to calculate the total present value over the series of years specified in each of the separate present value periods. That is, if there are two different levels of fish catch occuring over the project period with level A occuring the first 20

FIGURE 1

ANNUAL BENEFITS OF A CHANGE IN FISH CATCH

(PROGRAM DISPLAY)

SUMMARY OF RESULTS

	11-Aug-87
OREGON..........STEELHEAD.......... UMPQUA	
Enter the change in the number of fish:	31
Consumer surplus under the new condition:	$1,720,294
Consumer surplus under the existing conditions:	$1,717,267
Net change in consumer surplus:	$3,027
Marginal value of fish:	$98

FIGURE 2

PRESENT VALUE OF A CHANGE IN FISH CATCH

(PROGRAM DISPLAY)

SUMMARY OF DISCOUNTED VALUES

OREGON..........STEELHEAD.......... UMPQUA	
BASELINE CATCH:	9,213
NEW CATCH:	9,244
CHANGE IN CATCH (#):	31
CHANGE IN CATCH (%):	0.34%
INTEREST RATE (%):	8.813%
YEARS:	
BEGIN	1
END	30
NPV NEW:	$17,971,752
NPV BASELINE:	$17,940,131
NPV CHANGE:	$31,621

years and level B occuring in years 21 through 50 then two present values runs could be performed for the respective periods. The COMPLETE option simply sums the present values for each of the sub periods and presents the total present value, the length of the period over which the total present value is calculated and the interest rate used for discounting. See the user manual for a detailed example.

CONCLUSIONS

The bio-economic model and software presented in this paper represent an improvement over current approaches to valuation of recreational fisheries by Federal Agencies: (1) Marginal rather than average values are derived for recreational fisheries and (2) river or port specific rather than State average values are derived. These advances are made accessible to the user via a menu driven software program called GAMEFISH. The program is applicable to estimating both losses and gains at sport fishing sites due to hydropower, timber production, agricultural practices and other production activities affecting recreational fish populations. The current program structure can be used as a template by experienced spreadsheet users to customize this program for use at other recreation sites or rivers for which zonal Travel Cost Method demand equations and data are available.

Anyone interested in having copies of the software should send one 360K double-sided, double density floppy disk for each State's models they desire. The models will be copied to the user's disk and a copy of the user manual along with the program documentation will be provided. There is no charge for copying the program but the user manual and program documentation cost $5.00 to cover photocopying, labor and mailing costs.

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FOOTNOTES

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RECREATIONAL DEMAND FOR TREES IN NATIONAL FORESTS[1]

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INTRODUCTION

In the past decade, an extensive body of literature has developed assessing the accuracy of the contingent valuation method (CVM) of estimating individual willingness to pay for the recreational use of environmental resources. Initial results were challenged on the grounds that what people say they are willing to pay contingent on the availability of an environmental resource represent behavioral intentions rather than a directly observable action or historical fact. More recently, the relationship between intentions and actual behavior has been submitted to systematic empirical investigation. Despite some continuing controversies and unsettled points, CVM studies of the recreational benefits of familiar environmental resources have performed reasonably well when compared to the available empirical evidence from travel behavior, actual cash transactions, and controlled laboratory experiments (Cummings, et al., 1986).[2] Levels of accuracy have been reasonable and consistent with levels obtained in other areas of economics and in other disciplines.

The task remains to discover how far these results can be generalized. The importance of continued research is illustrated by the conceptual and empirical difficulties associated with their estimation and the potential importance of recreation benefits in the economic assessment of environmental protection programs, such as forest management (Calish, et al., 1978). Foresters face important problems of evaluating recreation opportunities in a way that will allow comparisons with their economic costs. The problem is especially acute at many forest recreation sites where it would be useful to determine how much recreation users value specific levels of forest quality in order to improve managerial decisions relating benefits to costs of alternative forest management practices.

The CVM is by far the most important tool that we have to decide these questions. The approach has been recommended as providing an acceptable measure of the economic value of recreation opportunities and resources. The interagency committee, the U.S. Water Resources Council (1979 and 1983), specifically authorized use of the CVM for application to environmental quality problems. Since the method represents the most likely path of new empirical research, efforts to clarify several potential problems with the approach and to assess its accuracy will be of continuing interest.

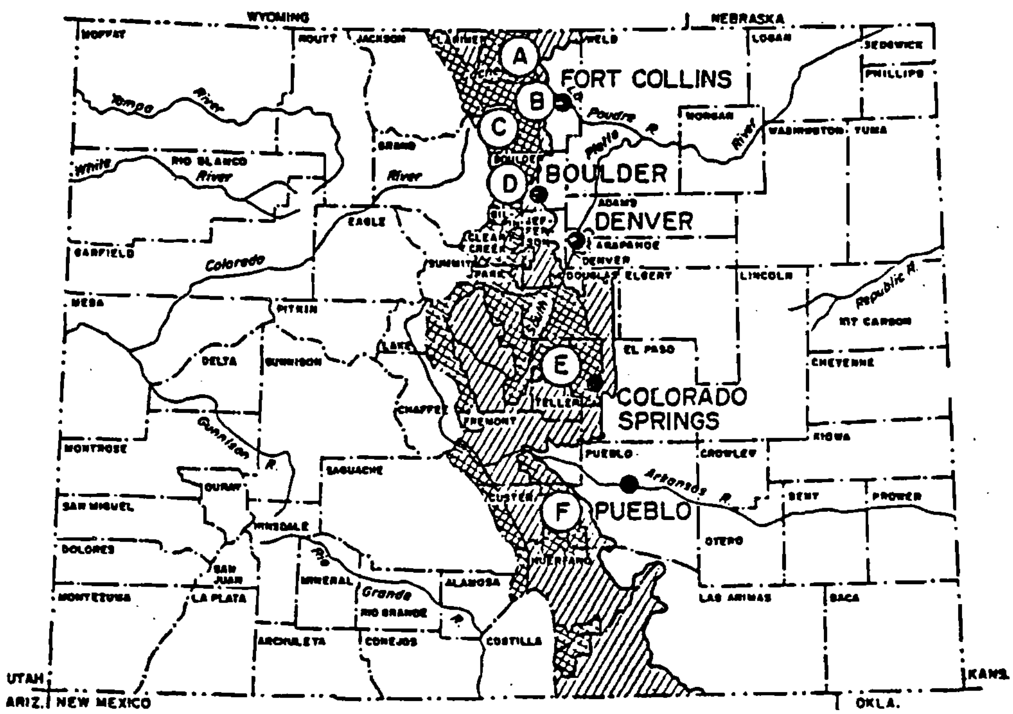
The purpose of this paper is to compare the consistency of the CVM and travel cost method (TCM) when applied to the problem of estimating the value of existing forest recreation sites and the effects of changes in forest quality on demand and benefits of recreational use. The objective is to contribute to the development of the best practicable methodology for application of economics to the valuation of publicly administered recreation resources. It will be shown that the two procedures provide reasonably consistent values which should prove of practical use in the decision-making process.

PROBLEM AND STUDY AREA

The problem considered here is a major outbreak of mountain pine beetles on two million acres of mixed age ponderosa pine in the front range of the Colorado Rocky Mountains (Figure 1). As a result, approximately 15 percent of the trees have been killed at forest recreation sites. Moreover, it has been projected that in the next 10 years, 30 percent of the lodgepole pine at recreation sites on the west slope of the state will be lost to insect infestation. Similar estimates have been made of douglas fir loss to spruce budworm. This problem is not limited to the Rocky Mountains. The pine beetle, spruce budworm, gypsy moth, and other insects have caused extensive damage to forests throughout the United States, particularly in the northwest,

FIGURE 1

Front Range Study Areas, Rocky Mountains, Colorado[a]



a. The front range is shown as the shaded area. The Roosevelt National Forest, part of Arapaho National Forest, Pike National Forest, and Isabel National Forest are shown as the cross-hatched areas. Study sites are identified A-F.

northeast, and south. Nations around the world face similar problems of how much they can afford to pay for the protection of forests from insect pests and other hazards such as acid rain (Crocker, 1985) and wildfire (Vaux, et al., 1984). In addition to the loss of merchantable timber, forest management decisions require knowledge of the loss of aesthetic benefits from trees to visitors at forest recreation sites.

When mountain pine beetles attack and kill ponderosa pine trees, discoloration of needles and dead and down trees detract from the aesthetic beauty of the forest in the short-run. As the dead and down trees are removed or decay, the long-run effect is to reduce the density of the stand of live trees and thus change the quality of the forest. Once the dead trees are removed, it is likely that most first-time visitors to a recreation site will be unaware that a beetle attack ever occurred in the area. The possibility remains, however, that in a forest with fewer trees, persons who would use the site for recreation without the damage may use it less or not at all after the beetle attack. The recreation value and thus the demand for recreation use of the site may be a function of tree density.

The case considered here is the recreation use of the Arapaho, Roosevelt, Pike, and San Isabel National Forests located along the front range of the Rocky Mountains of Colorado. The forests represent an area of nearly 3.2 million acres extending along the east side of the Rocky Mountains the length of the state from approximately 6,000 feet in elevation to the continental divide with peaks over 14,000 feet. Ponderosa pine is common in mixed stands from 6,000 to 8,000 feet elevation.

These forests were selected because they are among the most intensively used and are subject to deteriorating forest quality. In 1980, the agency recorded a total of 8.8 million recreation visitor days (RVD) at front range forests, equal to nearly 1,800 RVDs per square mile, 2.3 times the recreation use of forests nationwide. This reflects the fact that front range forests provide the two million residents of the state's metropolitan areas an opportunity to obtain a forest recreation experience within 1-3 hours drive from their homes. From 1970 to 1980, compound annual growth in recreation use of front range forests averaged 7.4 percent, 1.5 times the 4 to 5 percent rate elsewhere in the system. The rapid growth in demand for recreational services has encouraged public policies to maintain forest quality.

RESEARCH PROCEDURE

Six study sites were selected by the funding agency to represent the range of insect infestation of ponderosa pine forest at recreation sites in the front range. Study sites were designated to encompass the types of recreation within a 10 mile radius of: (A) Lory State Park, 70 miles north of Denver; (B) Red Feather Lakes, 120 miles northwest; (C) Estes Park, 70 miles northwest; (D) Nederland, 45 miles west; (E) Woodland Park, 70 miles southwest, and (F) Lake Isabelle, 150 miles southwest, as shown in Figure 1.

CONTINGENT VALUATION METHOD

The basic economic data were obtained from on-site interviews with a sample of 435 recreation users. Interviews were conducted on random days in the summer of 1980. Since most of the recreation uses affected by forest quality occur during the summer season, the stratified random sample was selected to represent the range of summer recreation uses of the study area including: developed camping, semi-developed camping, backpacking, hiking, fishing, picnicking, driving off-road vehicles, and staying at resorts. Summer activities account for two-thirds of total annual use. The most important activity omitted was hunting in the fall, representing about 5 to 10 percent of total annual use.

The questionnaire was pretested and designed to be completed in less than 30 minutes to minimize inconvenience and respondent fatigue. The survey was administered by four trained interviewers who were graduates of the University program in natural resource economics with previous experience interviewing recreation users of front range forests. Name tags identified them as employees of the University to establish the legitimate scientific purpose of the study. Less than 5 percent of those approached refused to participate in the survey.

The assessment of the CVM by Cummings, et al., (1986) concluded that several reference operation conditions should be met if the approach is to provide reasonably accurate measures of the recreation use value of changes in environmental resources. Respondents who are asked willingness to pay questions should understand the resource to be valued, have had prior experience valuing it and choosing levels of quality to consume under conditions of little uncertainty. There is reason to believe that these conditions are present in this study.

The survey was introduced as a scientific experiment administered to a representative sample of users whose answers may affect forest quality programs. Individuals were assured their answers would be confidential. They were provided information about the deterioration of forest quality at recreation sites and informed that this is likely to continue in the future without an effective forest quality program. They were shown color photos of trees with discolored needles from insect infestation, and of recreation sites with varying numbers of surviving trees.

The interviews began with questions about individual preferences for trees on recreation sites and their importance relative to other resources such as rock outcroppings, nearness to rivers and lakes, topography, and the rocky mountain view. Fully 95 percent reported that forest quality is important to the recreation experience. When preference variables were ranked on a 5-point scale of importance, 85 percent reported that trees are very important on recreation sites compared to 76 percent on adjacent property in the near view, and 68 percent in the far view. Fifty-one percent rated trees more important than view of the mountains, 48 percent more important than rock outcroppings, 44 percent more important than topography, and 35 percent more important than nearness to rivers and lakes. Trees were rated of equal importance to these site quality variables by about 30 to 45 percent of the sample. The replies indicate that they had experience valuing choices with respect to levels of forest quality at the study sites. They took an average of 3.2 trips per year to the study sites averaging 2.7 days each. They generally were knowledgeable of forest quality related to their recreation trip destinations. Uncertainty clearly played a negligible role in this study.

The payment vehicle was selected because it corresponds with how people actually pay for forest quality when they select a recreation site with a previously known or observable tree density. They may take more trips, travel greater distance, and increase their stay at sites with the preferred number of trees. They have had considerable prior experience in paying additional travel cost to obtain access to recreation sites with preferred forest quality. They were asked to assume that payment of trip expenses would be the only way to assure themselves of a desired recreation experience, as affected by forest quality. About 4 percent of the respondents rejected the payment vehicle, and were removed from the analysis.

Respondents were asked to report annual participation and total direct trip costs for transportation (gas, oil, and maintenance), added food, lodging, entrance fees, etc. for the current trip to the site. Then, they were asked to estimate the maximum amount they would be willing to pay rather than forego the recreation experience. The question was: What is the maximum you would pay per trip? Would you pay (an average of) $__ per trip to continue coming to this area __ times per year (the number of trips you usually make to this site?). Direct costs actually paid were subtracted from willingness to pay resulting in an approximation of net benefits, e.g. the area below the demand curve and above direct cost or price.

An iterative technique recommended by the federal guidelines was utilized to encourage respondents to report maximum values, representing the point of indifference between having the amount of income stated or the level of environmental quality. They answered "yes" or "no" to increases in direct trip costs and days until maximum willingness to pay and to participate were identified. Distribution of the values appeared to be consistent with the expectation of little or no strategic bias of the study results.

The anchor or reference point with respect to change in forest quality was the level experienced on the day of the interview. Respondents reported their perceptions of forest quality at the study sites by identifying which of 6 photos most closely approximated the number of trees per acre 6 inches diameter breast height (dbh) or more. The photos showed: no trees, 20-40, 60-80, 100-120, 140-160, and 200-300 trees per acre. Information was provided as to density, including the number of trees per acre and average distance between trees shown in each photo. This base case was recorded as one of four observations of willingness to pay, to participate, and number of trees per acre. From this starting point, respondents estimated changes in willingness to pay and to participate contingent on 3 hypothetical changes in the number of trees per acre. Values were obtained from each respondent for low, medium, and high tree density as depicted in the color photos.

The answers to these questions represent four points on total bid functions for each individual where willingness to participate and to pay are functions of forest density, income, and other socioeconomic variables as in the Seller, et al., (1984) study of boating in Texas. The functions are estimated using the quadratic functional form with linear and squared terms for forest density. The reduced equations are shown below.

Willingness to Participate

$$DAYS = 10.78 + \underset{(2.77)}{0.0826T} - \underset{(-2.35)}{0.0002T^2} \qquad R^2 = 0.76$$

Willingness to Pay

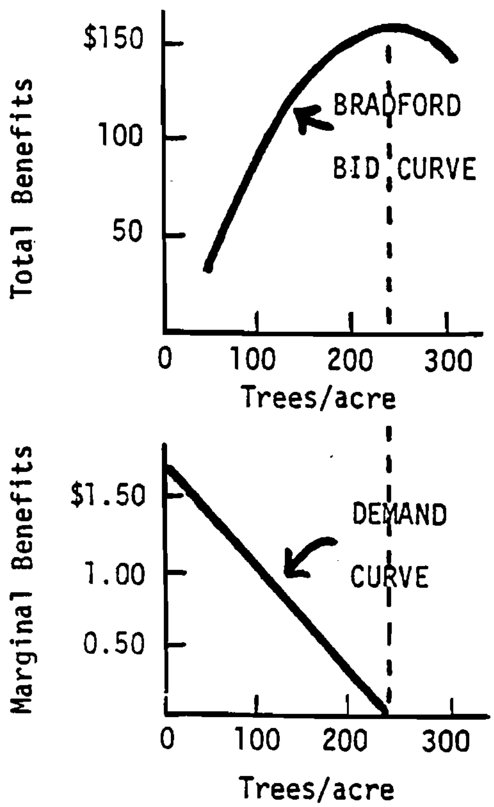
$$WTP = -1.32 + \underset{(4.02)}{0.0767T} - \underset{(-2.39)}{0.00015T^2} \qquad R^2 = 0.51$$

Where WTP = net willingness to pay or benefits per day (dollars); DAYS = annual participation at the study site; and T = number of trees per acre (6 inches dbh or greater). The t-ratios are shown in parentheses below the coefficients.

The regression coefficients for tree density indicate the effect on demand and benefits, with other variables held constant. Tree density is highly significant at the 0.01 level, as indicated by the t-statistics. The complete equations (in Walsh and Olienyk, 1981) include several social and economic variables (income, substitution, site attributes, preferences, etc. which are held constant). The overall equations are significant at the 0.01 level and explain 51 to 76 percent of the variation in willingness to pay and to participate. This is considered a satisfactory level of explanation with data from a cross-sectional survey of individual consumers.

FIGURE 2

TOTAL AND MARGINAL BENEFITS OF FOREST QUALITY PER USER



The upper panel of Figure 2 illustrates the Bradford-type (1970) total benefit function when the willingness to participate and to pay functions are combined. The lower panel shows the changes in total benefits resulting from changes in the amount of forest quality protected. The first derivative of the total benefit function represents the demand curve for forest quality. The demand curve shows that individuals are willing to pay a great deal for a program which protects a minimum level of forest quality due to the scarcity value of trees. However, as forest density increases, the willingness to pay for each additional tree becomes smaller, indicating diminishing marginal benefits. As individual demands for forest quality are fully satisfied, benefits eventually become negative with more and more trees. Clearly, changes in forest density can be a benefit or a cost depending on whether the current stock is lesser or greater than the economic optimum.

TRAVEL COST METHOD

A subsample of 220 respondents were selected for application of the travel cost method. Nonresident tourists and off-road vehicle users were removed to meet the single-destination trip criteria of the method. One study site was excluded because it is virtually an urban park with insufficient variation in travel costs. The procedure conforms with recommendations of the federal guidelines that single-destination trips and sites with sufficient variation in travel costs are necessary for applications of the travel cost method.[3]

Application of the regional travel cost method is based on interviews at a cross-section of 5 recreation sites with varying forest quality. Interview locations were randomly selected within study sites where there are many possible locations to engage in each activity.[4] Respondents were asked to identify the tree density clearly observable at the interview locations.

Since there is sufficient range in tree density experienced by individuals, its effect can be estimated statistically in the demand function. The regression coefficient for tree density indicates the effect on demand and benefits, with other variables held constant. In multiple regressions, it is possible to hold the effects of other site attributes constant so they are not mixed in with the tree density variable (Loomis, et al., 1986a).

The travel cost variable is defined as the sum of direct trip costs reported by respondents and the opportunity costs of travel time, as suggested by Cesario and Knetsch (1970). Individual perception of travel costs actually paid is considered the most appropriate basis for predicting travel behavior. The value of travel time is estimated as the marginal rate of substitution between travel time and travel costs in the production of recreation trips, as in McConnell and Strand (1981) and Ward (1983). In an individual trip equation (not shown), the coefficient for an independent variable specified as round-trip travel time (at 40 MPH on mountain roads) multiplied by hourly income is divided by the coefficient for direct travel costs per trip. On this basis, the opportunity cost of travel time is calculated as $6.57 per hour which divided by 40 MPH equals 16.43 cents per mile. Following the federal guidelines, the sum of direct travel cost per mile (averaging 26 cents) and estimated time cost (16.43 cents) is multiplied by the round-trip miles traveled to the study sites, and then divided by 2.7 persons per vehicle.

The dependent variable, trips, is defined as individual trips per capita from distance zones defined as cities.[5] Essentially, the individual's own demand for trips to study sites is weighted by per capita participation in their zones of origin. The number of trips by each individual is divided by a proportion of population. For example, where 10 individuals come from a particular city, the number of trips by each individual is divided by onetenth of population in 1,000s. This specification, suggested by Brown, et al., (1983), has the advantage of combining both the number of trips per individual and the probability of participation into a single measure while avoiding a problem of the standard zonal approach which averages the socioeconomic characteristics of individuals from origin zones, resulting in a loss of sensitivity to important determinants of demand (Ward and Loomis, 1986). When the individual per capita variable is averaged across all visitors from an origin zone, the result is the standard zonal average visits per capita.

The TCM model is specified in two ways to test the sensitivity of the approach to alternative assumptions as to consumer choice. Ordinary least-squares (OLS) statistical demand functions recommended by the federal guidelines assume that individuals choose the number of trips to a recreation site in response to out-of-pocket and time cost of travel, which is not subject to individual choice. On the other hand, the two-stage least-squares (2SLS) procedure introduced here allows three things -- number of trips, length of stay, and travel cost -- to be choice variables.

The 2SLS procedure is based on recent theoretical work suggesting that quality of the recreation experience can be produced by individuals varying their travel cost and length of stay as well as number of trips to a forest recreation site (Bockstael and McConnell, 1981; Ward, 1984). The 2SLS approach is preferred over OLS because it facilitates estimation of the consumer surplus associated with all three variables when the stock of trees at a recreation site changes. In the first stage, three equations are estimated separately for number of trips, length of stay, and travel cost. In the second stage travel cost equation the independent variables, number of trips and length of stay, are predicted values from the first stage equations. Likewise, in the second stage equations for number of trips and length of stay the independent variable, travel cost, is a predicted value from the first stage. Table 1 shows these three second stage equations, and the OLS equations for purpose of comparison.

Data for the sample of 220 individuals visiting the 5 sites are pooled for efficiency of analysis. Categorical variables for each site (S) and recreation activity (A) are included in the demand functions to account for heterogeneity across sites and to allow their unique characteristics to shift the demand functions. The forest quality variable, square root of trees per acre (T 1/2), is consistent with the expectation of diminishing marginal effects of increased tree density on willingness to pay and visitation to the study sites. The substitution variable (E2) indicates that annual days of recreation at other sites is positively related with travel costs and site time at study sites.[6] Income (Y) is significant and positively related to travel cost as expected, however, it is negatively related to individual trips per capita. Apparently, residents with lower income realize some economies of scale in the use of forest recreation sites. The positive relationship between travel cost and site time indicates that higher travel costs tend to be spread over more days on site. Taste and preference variables are included to account for the psychological importance of trees on site (P1) to shift the demand function for trips.

The 2SLS estimates a demand system to overcome the well-known statistical problem of biased and inconsistent parameter estimates of OLS. The second stage uses predicted values to purge visit rates, travel cost, and onsite time of the component correlated with each disturbance term. Although the procedure yields estimates which are also biased, they are consistent. The regression coefficients generate asymptotic standard errors which are used to construct t-tests of statistical significance, shown in parentheses. While

TABLE 1

Regression Results for the 2SLS and OLS Models of TCM[a]

Two-Stage Least-Squares

(1) Travel Cost

$$TC = 2.47 - \underset{(-2.16)}{15.29V} + \underset{(4.39)}{7.33D} + \underset{(1.81)}{6.01Y} + \underset{(2.28)}{2.80E2} + \underset{(1.60)}{0.65T^{1/2}} + \underset{(2.96)}{10.32A2}$$

$$- \underset{(-2.25)}{7.87A5} + \underset{(3.20)}{12.78S6}$$

(2) Onsite Time

$$D = 1.39 + \underset{(3.63)}{0.04TC} + \underset{(2.06)}{0.02P2} - \underset{(-3.86)}{0.92A5} - \underset{(-4.62)}{1.19A6} + \underset{(2.64)}{0.82S1}$$

(3) Trips

$$V = 0.0743 - \underset{(-2.70)}{0.0076TC} + \underset{(2.23)}{0.0186T^{1/2}} + \underset{(2.10)}{0.0719P1} - \underset{(-2.64)}{0.002E1} - \underset{(-2.14)}{0.0028Y}$$

$$+ \underset{(4.07)}{0.0084P2} - \underset{(-1.43)}{0.1023A2} + \underset{(1.35)}{0.1040A5} - \underset{(-2.04)}{0.1508S5}$$

Ordinary Least-Squares[b]

(4) Trips

$$V = 0.070 - \underset{(-5.56)}{0.0067TC} + \underset{(2.41)}{0.0175T^{1/2}} + \underset{(2.19)}{0.0703P1} - \underset{(-2.95)}{0.0002E1} - \underset{(-2.87)}{0.0028Y}$$

$$+ \underset{(4.35)}{0.0085P2} - \underset{(-1.48)}{0.1007A2} - \underset{(-1.37)}{0.0966A5} - \underset{(-2.15)}{0.1508S5}$$

a. Where V = individual trips per capita to the study site; TC = sum of direct travel cost and estimated time cost per trip; D = number of days on site per trip; $T^{1/2}$ = square root of the number of trees per acre on-site; Y = household income in \$1,000s; E1 = city of residence, population in 1,000s; E2 = annual days of recreation at other sites; P1 = importance of trees on-site, 1-5 scale; P2 = annual days of primary recreation activity at all sites; P3 = does tree density on-site affect recreation satisfaction, categorical 0-1 variable; A2 = recreational activity, semi-developed camping; A5 = fishing; A6 = picnicking; S1 study site, Red Feather Lakes; S5 = Woodland Park; S6 = San Isabel Lake.
The t-statistics are shown in parentheses.

b. Shown for comparative purposes, the OLS equation explains 29 percent of the variation in number of trips per capita as indicated by R^2 adjusted for degrees of freedom. The overall equation is significant at the 0.01 level with an F value of 9.5. The t-statistics shown in parentheses indicate that the travel cost, tree density, income, preference, and population coefficients are significant at the 0.01 percent level using two-tailed tests.

these tests apply only asymptotically, the relatively large sample suggests that the t-values are usable for tests of significance. The general order condition of identification (Intriligator, 1978, p. 348) shows that the trip equation is just identified, while the travel cost and the site time equations are over identified.

COMPARISON OF RESULTS

Willingness to pay for the recreation use of existing sites should be approximately the same for both methods since they yield similar though not identical demand curves. The TCM estimates an ordinary Marshallian demand curve while the CVM estimates a Hicksian compensated demand curve. Both approaches specify that benefits are a function of the number of trips and the quality of experience at recreation sites, which are separable in consumption and subject to a budget constraint. If the specification of travel cost, quantity, and other variables are the same, theory suggests that there should be no statistically significant difference between values obtained by the two methods.

The data show that the CVM value is within the range of values for the alternative TCM models.[7] Holding tree density at its mean of 176.7 trees per acre, average benefits per trip are estimated as:

CVM	$20.80
TCM, OLS	$22.59
TCM, 2SLS	$17.72

On this basis, we cannot reject the hypothesis that the willingness to pay for the recreation use of existing sites estimated by the two methods are approximately equal. We conclude that the CVM can provide as close an approximation of the recreational economic welfare effects of forest recreation as the behavior based TCM.

Usually, managers are interested in changes in total benefits for comparison with changes in total costs of forest protection programs.

Comparison of the effects of changes in tree density on total benefit estimates can be made at two levels. Differences in total benefits can arise from differences in benefits per trip and in annual use. Table 2 compares estimates of benefits and use of front range forests from the two different TCM approaches as well as from CVM.

CVM estimates of the effect of tree density tend to be lower than TCM estimates for number of trips and higher for benefits per trip. These differences tend to offset each other when combined to estimate the total benefits foregone with a loss in the range of 10 to 30 percent of existing trees. Within this relevant range of decision-making, we cannot reject the

TABLE 2

Comparison of CVM and TCM Estimates

of Recreation Damages from Changes in Tree Density

Method	Percentage of Existing Trees Lost		
	10%	20%	30%
	(Damages in Percent)		
Number of Trips			
CVM[a]	1.5	3.5	6.2
TCM, OLS	3.5	6.5	9.5
TCM, 2SLS	4.1	7.6	10.9
Benefits per Trip			
CVM[a]	6.1	13.8	22.3
TCM, OLS	3.9	7.8	11.7
TCM, 2SLS	4.6	9.1	13.8
Total Benefits			
CVM[a]	7.5	16.8	27.1
TCM, OLS	7.2	13.9	20.3
TCM, 2SLS	8.5	16.1	23.2

a. The 95 percent confidence limit of the CVM estimate is approximately $\pm$ 40 percent.

hypothesis that the recreation benefit functions for tree density estimated by the two methods are equal. For example with a 20 percent loss of trees, the CVM estimate of the loss of benefits is 16.8 percent compared to the 2SLS TCM estimate of 16.1 percent. By comparison, the OLS TCM estimate is somewhat lower at 13.9 percent. We conclude that the CVM can provide as close an approximation of the recreational economic welfare effects of forest quality.

These results are supported by the growing body of economic literature on the recreational demand for forest quality throughout the United States. Moeller, et al., (1977) survey homeowners and recreation site managers who estimate a 12 to 52 percent reduction in recreation demand resulting from gypsy moth infestation in northeastern U.S. forests.

Michaelson (1975) applies the individual TCM to estimate the effect of mountain pine beetle damage to ponderosa pine as $2.65 per visitor day at six campgrounds in the Targhee National Forest in Idaho. The average elasticity of demand with respect to trees is calculated as 0.27.

Leuscher and Young (1978) apply the zonal TCM to estimate the effect of southern pine beetle damage to ponderosa pine on demand for recreation use of 19 campgrounds located on the shore of two reservoirs in Texas. Elasticity of demand with respect to trees is estimated as 0.64 to 0.68.

Wilman (1984) applies a hedonic TCM model to estimate the economic value to deer hunters from pine beetle damage to ponderosa in the Black Hills National Forest, South Dakota. Hunter success is a function of improved wildlife habitat resulting from the dead and down trees creating small open areas in the forest. Apparently, optimum forest density is less for deer hunting in the fall than for most summer recreation activities.

A study by Crocker (1985) employs CVM to estimate the economic value to recreation users of acid rain damage to ponderosa and jeffrey pine trees in the San Bernardino National Forest, located within 80 miles of Los Angeles.

Brookshire and Coursey (1987) compare CVM estimates of willingness to pay for additional trees and to accept compensation for fewer trees at a proposed neighborhood park serving a 1-square mile residential area in Colorado. After three iterations, willingness to pay is not significantly different from willingness to accept compensation. This supports the use of willingness to pay questions in CVM studies of forest quality.

In addition to the recreation use values reported in these studies, the general population, including recreation users and nonusers, may value the protection of forest quality (Aiken, 1985; Walsh, 1986). A sample of households in Colorado report they are willing to pay an average of $47 per year to protect forest quality in the state with recreation use value representing only 27 percent. Apparently, the public also is willing to pay for the option of recreation use in the future, the knowledge that it exists and is protected, and the satisfaction from its bequest to future generations. For this reason it seems that the estimates of recreation user demand and benefits of forest quality may represent a conservative estimate of its total value to society.

CONCLUSIONS

This paper addressed the problem of estimating the effects of forest quality on demand and benefits of recreation use. Alternative contingent valuation and travel cost procedures were applied to determine the sensitivity of the estimates to the choice of method. Specifically, we allowed respondents to adjust frequency of visits and value estimates simultaneously. It was shown that results vary depending upon the choice of one or the other or both models to use in the analysis. Apparently, a single CVM question or TCM equation may be incomplete as an estimate of value.

Second, when compared to the 2SLS TCM total benefit estimate, the CVM estimate that combines demand and benefit effects is not significantly different. Within the relevant range of decision-making, we cannot reject the hypothesis that the recreation benefit functions for tree density estimated by the two methods are equal. We conclude that the CVM can provide as close an approximation of the economic welfare effects of forest quality on recreation use.

These results are consistent with the findings of previous research on similar problems of environmental quality. A recent assessment of the state of the art by Cummings, et al., (1986) concludes that CVM willingness to pay values are likely to be comparable to TCM values when, as in this case, respondents are familiar with the resource, have prior experience valuing it, and face little uncertainty.

The values reported here should be considered first approximations subject to improvement with further research. Desvousges, et al., (1983) caution that neither approach provides the actual benefits associated with environmental quality. Both are estimates that are limited by their respective assumptions. It is important to acknowledge that judgement affects both approaches: in the questionnaire design and data analysis with the CVM and in the selection of a model specification for the TCM.

The estimates are sufficiently reliable, nonetheless, to demonstrate that the recreation use value of programs to protect forest quality would represent a substantial contribution to the present value of benefits from commercial timber production. Without information on the willingness to pay for recreation use values, insufficient resources would be allocated to the protection of forest quality. It is proposed that the benefit estimation procedures of federal agencies be enlarged to consider recreation use values of forest quality programs. Further research is recommended to test the general application of the methods.[8]

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FOOTNOTES

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2. Previously published studies comparing the consistency of recreation values estimated by alternative methods have generally obtained similar results. The CVM and TCM provide consistent estimates of the benefits of fishing, hunting, and camping trips to forest recreation sites in Maine (Davis and Knetsch 1966), multi-destination trips to national parks in the Southwest (Haspel and Johnson 1981), the recreation use value of water quality in the Northwest (Sutherland 1983) and in the Monongahela River, Pennsylvania (Desvousges, et al., 1983), and boating access to four reservoirs in east Texas (Seller, et al., 1984). The contingent valuation estimate of willingness to pay for goose hunting permits at the Horicon Marsh in Wisconsin are midway between the range of values derived from the travel cost method with travel time valued at 0, 25, and 50 percent of the wage rate (Bishop and Heberlein, 1979). Intended willingness to pay for deer hunting permits at the Sandhills Wildlife study area in Wisconsin are not significantly different from actual payment of cash in sealed bid auctions and referendum-type field experiments (Heberlein and Bishop, 1985). These results are supported by more than 60 studies of the value of 15 forest recreation activities throughout the U.S. (Sorg and Loomis, 1984). Adjusted for inflation, the average value per recreation day for one-third of the studies applying the contingent valuation method are within 25 percent of the average for two-thirds of the studies using the travel cost method. Similar results are shown for hunting and fishing in Idaho (Loomis, et al., 1986b).

3. Exclusion of nonresident tourists is expected to increase the average number of trips per year while reducing the price intercept and consumer surplus estimates. However, exclusion of the urban site B would have the opposite effect, reducing trips per year and increasing consumer surplus estimates. In addition, residents of the state tend to be more sensitive to changes in forest quality than tourists, reflecting knowledge of historic damages (Buhyoff, et al., 1982; Daniel and Vining, 1983).

4. Resource use by individuals staying overnight in campgrounds or resorts is between 1 and 2 acres, as is the case for picnickers. By comparison, fishermen use about 1 linear mile, hikers 4 miles, backpackers 6 miles, and off-road vehicle users 11 miles.

5. In addition, we tested the sensitivity of the results to alternative specification of the dependent variable, trips. We estimated the representative individual's own demand function, i.e. annual trips per individual to a study site, as suggested by Brown and Nawas (1973). The results, available on request, show that estimates of average benefits per trip are more variable, about 50 percent higher with OLS and one-third lower with 2SLS. Damages from loss of tree density at recreation sites are lower but within about 30 percent for the individual per capita OLS and 10 percent with 2SLS. This suggests that the 2SLS may partially overcome the limitations of the individual TCM.

6. With regional demand functions, the effect of substitution can be introduced by including the travel costs of trips to other sites in the equation. To test for the possibility of substitution among the 5 study sites, we estimated a visitation equation for each site in which the travel cost to reach each of the other sites is included as an independent variable. The hypothesis of a zero cross-price effect cannot be rejected by this test. In none of the 5 cases do any of the travel cost variables for other study sites prove statistically significant. Although substitutes undoubtedly exist, the 5 study sites are apparently far enough apart to represent essentially segmented markets. An alternative substitution variable is introduced representing the annual days of recreation at other sites. See Caulkins, et al., (1985).

7. The CVM value also is within the range of unit-day values recommended by the Forest Service Resource Planning (RPA) in the Rocky Mountain Region. Our CVM estimate is equivalent to $15.50 per 12-hour recreation visitor day (RVD) with on-site recreation activities averaging 6 hours per day and 2.7 days per trip.

8. Of significance here is the finding that trees throughout the forest may have aesthetic values. In addition to the number of trees onsite, respondents reported willingness to participate and to pay contingent on number of trees in the near view and far view, size of trees, visible insect damage, dead and down trees, distribution of trees, and presence of large specimen trees. For example, the price elasticity of demand for trees onsite is about 0.28 compared to 0.25 near view and 0.16 far view.

TOTAL AND EXISTENCE VALUES OF A HERD OF DESERT BIGHORN SHEEP

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INTRODUCTION

A herd of desert bighorn sheep inhabits the Pusch Ridge Wilderness Area (PRWA) in the Santa Catalina Mountains of the Coronado National Forest, 14 kilometers north of the center of Tucson, Arizona. The herd was a significant consideration in the designation of the wilderness area in 1978 (Krausman, Shaw, and Stair 1979).

The current size of the herd, 70 to 100 animals, is well below the 220 sheep reported in 1928. Three reasons for the decline in herd size have been suggested. First, recreational use of the Pusch Ridge area has increased (Purdy and Shaw 1981). Second, intensive urban development of land adjacent to the habitat is taking place, resulting in disturbances within a kilometer of prime habitat (Gionfriddo 1984). Finally, fire suppression has allowed, through succession, the establishment of vegetation that is less desirable for bighorns (Anon. 1985).

The juxtaposition of the herd's habitat and the growing Tucson urban area presents local, state, and federal agencies with difficult decisions regarding the intensity of urban development of lands adjacent to the PRWA, and the intensity and management of recreational use within the PRWA. Knowledge of the economic values of the herd to Tucsonans would be most useful in making these decisions.

The objectives of the research reported here were to: 1) estimate the total and existence values of the Pusch Ridge bighorn sheep herd to residents of the Tucson urban area; and 2) estimate the effects of socioeconomic and other preference-related variables on the total and existence values of the Pusch Ridge bighorn sheep herd.

VALUE CONCEPTS AND THE HERD

Total value of a resource, the appropriate value concept for benefit-cost analysis (Boyle and Bishop 1985), is the sum of use and existence values (McConnell 1983). Use values (Figure 1) include consumptive, nonconsumptive, and future (option) use values, all motivated by egocentrism. Existence value, however, is motivated by altruism and is not derived from direct use of the resource (Randall and Stoll 1983). Although total value is the appropriate concept for benefit-cost analysis, estimates of existence value are useful in addressing questions regarding the intensity of use (consumptive or nonconsumptive) of a wildlife resource. Attempts to estimate each of the components of value separately have had limited success (Brookshire, Eubanks, and Randall 1983; Walsh, Loomis, and Gillman 1984; Stoll and Johnson 1985).

Hunting of the herd is limited, with only one or two permits being issued each year through a lottery system. Thus, the consumptive use value of the Pusch Ridge herd is quite low and, for that reason, was not estimated in this study.

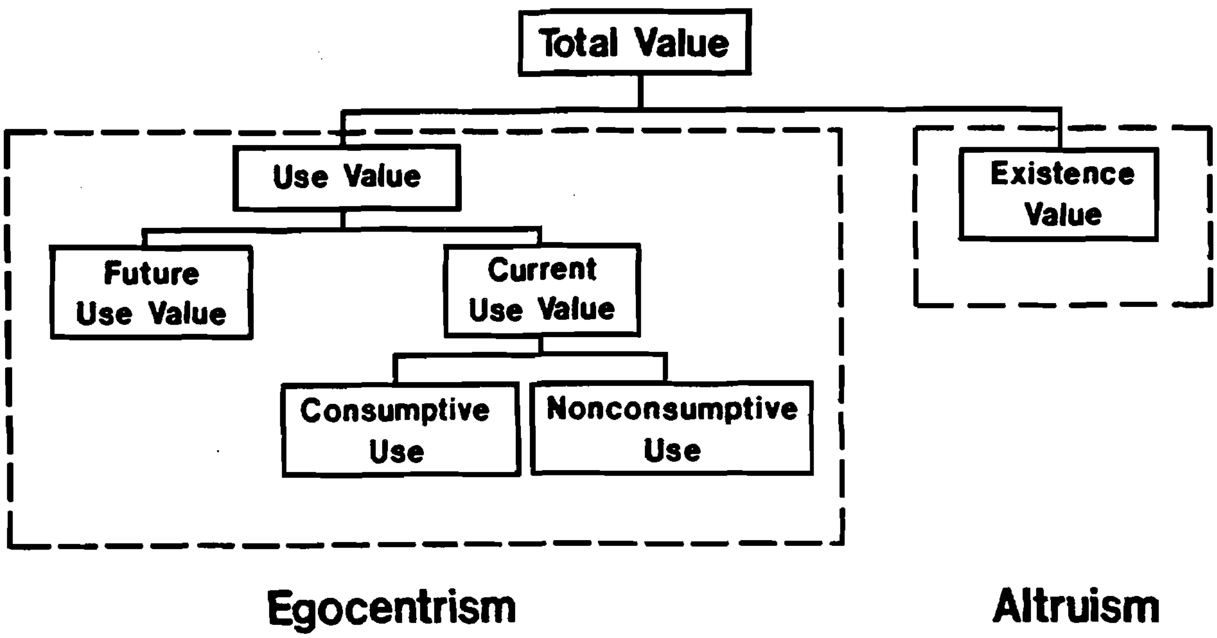
According to a 1980 survey of visitors to the PRWA the nonconsumptive use and the option values of the herd apparently were also low (Purdy and Shaw 1981). Sightings of bighorns were rare events, occurring on only one percent of the visits to the area. Furthermore, none of the respondents indicated that the primary reason for their visits was to see sheep.

Conversely, a number of factors indicate that the existence value of the herd may high. These factors include: 1) the strong, negative public reaction to the hunting of the herd; 2) the fact that bighorn sheep are not abundant in Arizona, giving them a marginal existence value higher than more common species; and 3) the proximity of the herd to Tucson makes it locally unique. These conditions, plus the indications of low use value, support a hypothesis that existence value is a major proportion of the total value of the herd.

FIGURE 1

WILDLIFE VALUES AND MOTIVES

(BASED ON RANDALL AND STOLL 1983)



METHODS

The contingent valuation method (CVM) was used to estimate willingness to pay (WTP) to avoid the loss of the herd. Brookshire, Randall and Stoll (1980) showed that for policy alternatives that propose a decrease in a natural resource the willingness to accept (WTA) compensation for the loss is the correct measure of welfare change for benefit-cost analysis. However, they concluded that a WTP format is a more effective means of collecting reliable data than WTA. Randall and Stoll (1980) showed that WTP measures of welfare change will be less than WTA measures when a change in the quantity of goods or services is the issue and the goods or services are lumpy or indivisible, as is the case here. They went on to show that the difference between WTA and WTP measures will be small if the income effect, the product of the price flexibility of income and the proportion of the individual's income represented by the value of the good, is small.

CVM SCENARIOS

Two contingent valuation scenarios were presented to the respondents. Scenario 1 was used to elicit bids for the total value of the herd.

Scenario 1:

> There is a herd of about 70 desert bighorn sheep living in the Pusch Ridge area of the Santa Catalina Mountains located nine miles north of Tucson. The next question presents an imaginary situation which asks for your best estimate of how you would respond.
>
> Suppose that the bighorns are threatened by human activity and development around Pusch Ridge. If something is not done, the bighorn sheep will not survive on Pusch Ridge and bighorn sheep will be eliminated from the Santa Catalina Mountains.
>
> Suppose that, in response to this problem, an independent, nonprofit foundation is set up to preserve the Pusch Ridge bighorns. The

> foundation will restore and maintain habitat for the bighorn sheep on Pusch Ridge and will be able to save this herd of bighorns from extinction.
>
> Imagine now that the foundation will be funded by selling annual supporting memberships All members will be provided with information on the herd's status and information which would greatly increase the chances of seeing a bighorn in the area. Members who do not wish to view the bighorns on Pusch Ridge, will have the satisfaction of knowing that they helped preserve the herd.

Respondents were asked whether they would become a member of the foundation. Those who said "yes" were then asked to report the maximum amount they would be willing to contribute, annually, to the foundation. Those who said "no" were asked for the reason for their response in order to distinguish true zero bids from rejection bids.

Existence value was estimated from responses to Scenario 2.

Scenario 2:

> Consider the hypothetical situation in question 1 again (Scenario 1). Continue to imagine that the foundation will be able to preserve the bighorns. This time, however, to eliminate disruptive activities that may cause stress to the sheep, the bighorns would not be available for public viewing.

Again, respondents were asked how much they would be willing to pay, annually, for foundation membership. This scenario was intended to elicit the respondent's existence value by removing motivations for present and future use (Boyle and Bishop 1985).

Open-end bid questions were used because iterative bidding is not possible with self-administered instruments and to avoid unresolved issues in the logit analysis of yes/no responses to pre-specified bids.[1]

CLASSIFICATION OF BIDS

A protocol for handling bid responses that were not, clearly, valid positive bids was developed. It was used to establish two set of bids, one for the estimation of the sample mean and median bids and the bid functions and the other for the calculation of the aggregate values of the herd.

To establish the first set of bids, positive bids of respondents who said they would become members of the foundation were accepted as valid. Although the highest bid, $1000, was 10 times as large as the second highest bid of $101, it was not discarded as an outlier or a rejection bid because studies have shown the strong support of wildlife users' for wildlife through organizational memberships and by their expenditures on wildlife-related goods (Shaw and Mangum 1984).

Zero bids were assigned to respondents who said they would not become members of the foundation and who gave as reasons one or more of the following responses: 1) the herd of bighorns is not worth anything to me; 2) I cannot afford to become a member at this time; or, 3) other causes have higher priority for me. Bids of zero by respondents who did not give one of the above reasons for their zero bids were considered to be rejection bids.

A second, enlarged set of bids was used to calculate the aggregate values. Some respondents said they would become a member of the foundation but did not give a bid, zero or positive. These uncertain bidders may: 1) not value the herd at all; 2) reject the valuation approach; or 3) be uncertain about the value they place on the herd. The fact that the herd may have positive value to them made it unreasonable to treat all of them as nonrespondents to the bid question in the calculation of the aggregate values. Hence, their bids were classified as zero bids or rejection bids on the same basis as described above for the certain bidders.

Median bids were used to calculate the aggregate values. Sample median bids were assigned to respondents who rejected the method, on the assumption that rejection of the method was motivated by a positive value, and to uncertain bidders who gave no reason for valuing the herd. Nonrespondents were treated in two different ways. In one set of estimates, the nonrespondents were assigned the median bid of the respondents. In a second set, they were assigned zero bids.

BID FUNCTIONS

Bid functions were estimated, using ordinary least squares (OLS), to investigate the effects of socioeconomic and other respondent characteristics on total value and existence value. Independent variables in the regression were household income (INCOME), education (EDUC), age (AGE), the number of conservation organization memberships (CO), knowledge of the bighorn sheep on Pusch Ridge prior to the survey (KNOWSHP), desire to see sheep on Pusch Ridge in the future (OPTION), previous use of the Pusch Ridge Wilderness Area (VISIT), and proximity of residence to Pusch Ridge (PROXIM). INCOME, AGE, and CO were entered in dollars, years, and number, respectively. EDUC was entered as an interval variable with the following values:

Education Level Completed	Value of EDUC
Less than high school	1
High school	2
1 - 3 years of college	3
College	4
Graduate studies	5

KNOWSHP, OPTION, and VISIT were entered as dichotomous dummy variables with a value of 0 for no and 1 for yes responses. PROXIM was also entered as a dichotomous variable with a value of 1 for the four zip code areas closest to the PRWA and 0 otherwise. With the exception of age, all of these variables were expected to have positive effects.

MOTIVATIONS

As another measure of the relative importance of existence value as a component of the total value of the herd, motivations for preservation of the a herd were elicited from the respondents. Respondents were asked to rank the three most important reasons for preserving the herd. The response categories by corresponding motive class were:

MOTIVE	RESPONSE
Egocentrism:	So that I will have the option to see one in the future.
	For hunting
Altruism:	For scientific or educational purposes.
	For future generations, including my children and grandchildren.
	For others who wish to see them.
	Because the bighorns have the right to live there.
	Because the bighorns are part of the ecosystem there.

DATA COLLECTION

Data were collected in 1985 using a mail survey of a sample of Tucson area households. Listings from the Tucson residential telephone directory were selected using a random start and a sampling interval to obtain a sample of 1000 households (Dillman, 1978). The "Total Design Method" recommended by Dillman (1978) was followed with the exception of a third mailing of the questionnaire which was prevented by an unexpected budget constraint.

RESULTS

The Sample

Five hundred fifty (550) useable questionnaires were received. The rate of response, adjusted for undeliverable questionnaires, was 59 percent. To evaluate the representativeness of the sample, the sample distributions of household income, education and age were compared with secondary data from Tucson Trends, a biennial survey of the Tucson area population (Valley National Bank and Tucson Newspapers Inc. 1986). Based on a Kolmogorov-Smirnov test, the sample distributions of the variables were significantly different, at the 5 percent level, from those reported in Tucson Trends. The comparisons indicate that our sample of household heads is older, more highly educated, and from higher income households than those sampled in the survey for Tucson Trends. There are some differences in the sampling frame between the two surveys which could partially account for these differences, but the degree to which that may have been the case could not be ascertained.

Value Estimates

Ninety-four percent of the respondents completed the total value scenario item and 92 percent answered the existence value scenario item. The distributions of positive, true zero, and rejection bids for total value and existence value are shown in Table 1.

TABLE 1

Classification of Bids for Total and Existence Values

Bids	Total Value	Existence Value
	(n=522) (%)	(n=502) (%)
Positive bids	47	42
True zero bids	33	37
Rejections bids	20	21
	100	100

The results of the two bidding scenarios are presented in Table 2.

TABLE 2

Bid Results for Total and Existence Values

	Total Value	Existence Value
Mean	$17.14	$15.14
Standard error	2.07	2.12
Standard deviation	47.18	47.52
Median	$16.51	$10.41
Cases	522	502

The small difference between the mean and median bids for total value indicate that the high bid of $1000 did not have an undue skewing effect. The difference between the mean and median bids for the existence value scenario indicates that the distribution of this variable is positively skewed. The mean existence bid is 89 percent of the mean total bid and the correlation coefficient between them is 0.96. The median existence bid is 63 percent of the median total bid. These results support the hypothesis that existence value is a major proportion of the total value of the herd for Tucson households.

Two estimates of aggregate total and existence values were calculated based on two assumptions regarding nonrespondents. One estimate was based on the assumption that the herd was of zero value to nonrespondents and the other on the assumption that the value of the herd to nonrespondents was equal to its median value to respondents. These estimates are shown in Table 3.

TABLE 3

Annual values of the bighorn sheep herd in the Pusch Ridge Wilderness Area to residents of Tucson, Arizona, per household and aggregate, under two assumptions regarding bids of nonrespondents.

	NONRESPONDENTS ASSIGNED:			
	ZERO BID		MEDIAN BID	
VALUE	HOUSEHOLD	AGGREGATE	HOUSEHOLD	AGGREGATE
TOTAL	$9.20	$2,162,909	$16.51	$3,883,152
EXISTENCE	$5.58	$1,313,154	$10.41	$2,448,432

The lower estimates, of course, are underestimates because they are based on the assumption of the herd having no value whatsoever to all nonrespondents. The assumption underlying the high estimates, that nonrespondents value the herd as the respondents do, probably leads to an overestimate of aggregate values.

ESTIMATED BID FUNCTIONS

Total and existence bid functions were estimated with OLS to determine the influence of various respondent characteristics. Linear, semi-log and double-log functional forms were tested. The double log form, shown below, achieved the best fit for the total bid function.

$$\begin{aligned} \ln(\text{TOTALBID}) = &- 5.025 + \underset{(5.266)}{0.554} \ln(\text{INCOME}) + \underset{(1.114)}{0.079}\ \text{EDUC} \\ &+ \underset{(0.722)}{0.127}\ \text{KNOWSHP} - \underset{(-0.953)}{0.005}\ \text{AGE} + \underset{(0.220)}{0.042}\ \text{PROXIM} \\ &+ \underset{(6.249)}{1.278}\ \text{OPTION} + \underset{(0.797)}{0.136}\ \text{VISIT} + \underset{(1.969)}{0.175}\ \text{CO} \end{aligned}$$

$R^2 = 0.28$ Adjusted $R^2 = 0.27$

F = 15.959 with 8 and 323 degrees of freedom

Significance = 0.01

Values of the t statistic shown in parentheses.

All of the signs on the coefficients are as expected. Only the coefficients on ln(INCOME), OPTION, and CO, however, are significantly different from zero at the .05 level, based on a one-tail test.

The coefficient of ln(INCOME), .56, is the price flexibility of income for the herd (Brookshire, Randall and Stoll 1980), an estimate of the percentage change in the bid that would result from a one percent change in income. Given the functional form of the equation, the coefficients on the other interval variables (AGE and EDUC), multiplied by 100, are estimates of the percentage change in the bid that would result from a one unit change in the corresponding variable. This interpretation does not apply, precisely, to the dichotomous variables (Halvorsen and Palmquist 1980). The coefficient on OPTION indicates that if an individual hopes to see sheep in the future, his bid for the total value of the herd would be 258 percent higher than if he does not have such a hope.

The bid function was estimated for existence value (EXBID), based on the same model as total value and is shown below.

$$\ln(EXBID) = -3.690 + \underset{(3.608)}{0.401\ \ln(INCOME)} + \underset{(2.114)}{0.157\ EDUC}$$

$$+ \underset{(1.709)}{0.324\ KNOWSHP} - \underset{(-1.827)}{0.009\ AGE} + \underset{(.210)}{0.041\ PROXIM}$$

$$+ \underset{(4.756)}{1.014\ OPTION} + \underset{(0.651)}{0.117\ VISIT} + \underset{(2.038)}{0.19\ CO}$$

$R^2 = .26$ Adjusted $R^2 = .24$

F = 13.407 with 8 and 305 degrees of freedom

Significance = 0.01

Values of the t statistic are shown in parentheses.

The signs on the coefficients are as expected except for age. All coefficients except those for VISIT and PROXIM are significantly different from zero at the .05 level, based on a one-tail test.

The price flexibility of income on the existence of the herd is 0.41. Income has slightly less effect on existence value than it does on total value.

The coefficient on OPTION is positive. Under Scenario 2, the herd is preserved but not available for viewing, seemingly removing egocentric motives such as an expressed desire to see sheep in the future. Thus, one might expect the coefficient on OPTION to be zero in the existence bid function. The fact that it isn't may be explained as follows. Individuals hoping to see a sheep in the future (OPTION) may also have a stronger overall interest in preservation of the herd and be motivated by both altruism, particularly intergenerational altruism, and egocentrism.

Specifically, the coefficient on OPTION indicates that the existence value of the herd is 176 percent higher for those who hope to see a bighorn sheep in the future than for those who do not.

Although the coefficients on AGE, KNOWSHP, and EDUC are not significant in the total bid function, they are significant in the existence bid function. Age would be expected to have a positive effect on existence value through its probable positive effect on the development of intergenerational altruism (Randall and Stoll 1983). We can not explain its negative effect. The positive effects of KNOWSHP and EDUC are as expected.

PRESERVATION MOTIVES

Respondents' rankings of the three most important reasons for preserving the herd are shown in Table 4. Reasons categorized as representing altruistic motives are obviously most highly ranked. This result supports the hypothesis that existence value is a high proportion of the total value of the herd.

On the assumption that the the most important reason given by respondents for preserving the herd is a satisfactory indicator of their motives, the observed distribution of the most important reasons for preserving the herd was tested against an expected uniform distribution using a chi-square test. The distributions were significantly different at the one percent level, indicating that reasons categorized as altruistic were, indeed, selected more frequently than those associated with egocentrism.

TABLE 4

Relative frequency distribution of respondents' rankings of three most important reasons to preserve the bighorn sheep herd in the Pusch Ridge Wilderness Area, Arizona.

REASON TO PRESERVE	RANK FIRST	RANK SECOND	RANK THIRD
		(percent)	
Egocentric:			
a. Option to see one	5	9	22
b. Hunting	1	1	5
Subtotal:	6	10	27
Altruistic:			
c. Scientific or educational purpose	6	10	14
d. Future generations	20	27	28
e. Bighorns have rights to be there	30	18	7
f. Bighorns are part of the ecosystem	32	28	8
g. For others to see	3	6	16
Subtotal:	81	89	73
Other:			
h. Other reasons	3	1	--
TOTAL	100% (n = 430)	100% (n = 412)	100% (n = 405)

DISCUSSION

The bids to the two scenarios, the differential influences of the independent variables on total value versus existence value (equations 1 and 2), and the reasons respondents gave for the importance of preserving the herd are strong indications that the existence value of the herd is a major proportion of its total value.

The price flexibilities of income of the bids for total value and for existence value are low, 0.56 and 0.41, respectively. The median household income of the sample is $30,000. Using the median sample bids as indicators of the value of the resource to the representative household, then the income effect is indeed small, 0.004 for total value and 0.001 for existence value. Hence, the estimates, aside from sampling and measurement errors, approximate WTA, the theoretically correct welfare measure in this case.

The price flexibilities of income also indicate that the herd is a normal good, but not a "treasured" good (Randall and Stoll 1980). That is, the value of the herd increases as income increases, but at a lower percentage rate than income.

Were the respondents bidding to preserve the herd or the herd and its habitat? Two reasons, "e", "Because the bighorns have the right to live there", and,"f", "Because the bighorns are part of the ecosystem" were ranked as the most important reasons by a combined proportion of 62 percent of the sample, Table 4. This result suggests that the values estimated are of the herd and its habitat.

However, a conclusion that the herd <u>and</u> its habitat were being bid upon does not mean that the estimated values represent the total value of the Pusch Ridge Wilderness Area. These estimates are for the value of those aspects of the area that contribute to the existence of the herd. Because the wording of the scenarios made no mention of other uses, values of the area for hiking, backpacking, and many other activities are presumably not included.

Two studies (Boyle and Bishop 1986; Stoll and Johnson 1985) were found in which the resource and valuation situations were similar enough to those of this study to provide for useful comparison of results.

Stoll and Johnson (1985) estimated the value of the whooping crane resource of the Aransas National Wildlife Refuge in Texas. The whooping crane is classified as an endangered species under the U. S. Endangered Species Program and is of national significance and interest. Values were estimated for refuge visitors, Texas residents, and out-of-state residents. The value estimates for refuge visitors and Texas residents are most comparable to our estimates and are shown in Table 5.

TABLE 5

Estimates of option/existence
and existence values of the whooping crane resource*

Value	Refuge Visitors	Texas Residents
Option/Existence Value	$16.33 (n=381)	$ 7.41 (n=249)
Existence Value	9.33 (n=30)	1.03 (n=73)

* Taken from Stoll and Johnson (1985)

Stoll and Johnson estimated existence value differently than we did. They attempted to isolate existence value by assuming that only those individuals who did not expect to visit the refuge in the future were expressing existence value. Thus, their estimates of option and existence value combined are most comparable, in method, to ours.

Boyle and Bishop (1986) estimated total and existence values of the bald eagle and the striped shiner to Wisconsin residents. The bald eagle is a national symbol and is endangered in Wisconsin. The striped shiner is a minnow that is relatively unknown to the general public and is not endangered. For the bald eagle, estimates were made for individuals classified as viewers and nonviewers of bald eagles. For both the eagles and the striped shiner, estimates were further categorized between those who had contributed to the Wisconsin Endangered Resource Donation (ERD) program and those who had not. Grand means were not reported. Their estimates are shown in Table 6.

TABLE 6

Bald eagle and striped shiner mean values*

Value	Contributor	Noncontributor
Bald Eagle		
Total Value		
Viewers	$75.31	----
Nonviewers	18.02	$11.84
Existence Value		
Viewers	28.38	25.97
Nonviewers	30.78	10.62
Striped Shiner	5.66	4.16

* Taken from Boyle and Bishop (1986).

Given the nature of the four wildlife resources, the relative magnitude of our estimated mean values are as expected, less than the bald eagle and whooping crane and greater than the striped shiner.

CONCLUSIONS

Existence value is a large proportion of the total value of the herd and its habitat. When the sample values ae projected to the population of metropolitan Tucson, total value falls within the range of 2.1 and 3.9 million dollars per year and existence value within the range of 1.3 to 2.4 million dollars per year. The proportion of total value that is existence value is in the range of 60 to 89 percent depending on whether medians or means are used as estimates. Altruism is the primary motive underlying Tucsonans' valuation of the herd and its habitat.

The value of the herd will increase if economic and population growth in the Tucson area continue. If the resulting housing demands are met through additional urban development adjacent to the herds' habitat, then a significant cost of that development might be elimination of the herd from its habitat. Local governmental officials, through land use planning and zoning decisions, may be faced with making tradeoffs between the locations of residential development and the continued existence of the herd.

Increasing recreational use of the Pusch Ridge Wilderness Area could have deleterious effects on the herd. Under such conditions, restrictions on recreational use of the PRWA would be considered by the Coronado National Forest officials. If the herd were the primary reason underlying the recreational use of the PRWA, then one could argue that restricting recreational use would have little impact on the value of the herd since existence value is a large proportion of its total value. That premise, however, does not appear to be true. In order to make a decision regarding changes in the recreational use of the PRWA, additional information about the value of the area for other recreational uses would be needed.

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FOOTNOTES

1. Personal conversation with Richard C. Bishop, May 15, 1985.