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Technical Memorandum Number EC 2008-04

The Dichotomous Choice Contingent Valuation Method: An Example Application

U.S. Department of the Interior
Bureau of Reclamation

April 2008

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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The Dichotomous Choice Contingent Valuation Method: An Example Application

Prepared by

David A. Harpman

Bureau of Reclamation
Economics and Resource Planning Group
Technical Service Center
Denver Colorado 80225
U.S.A.

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Purpose

The purpose of this document is to provide a conceptual and analytic understanding of the dichotomous choice contingent valuation method (DC-CVM). An fully solved example application is described. While by no means an exhaustive treatment of the subject, some of the difficulties and associated pitfalls are described. A number of useful references are furnished for further study.

What is DC-CVM?

The dichotomous choice contingent valuation methodology (DC-CVM) is frequently employed in nonmarket valuation studies to estimate the net economic value for natural resource amenities. This approach relies on a primary survey of individuals utilizing a carefully designed survey instrument. Respondents are presented with a hypothetical situation, including a price, and then must respond to a dichotomous choice (Yes or No) question. Using the data obtained from these surveys, the probability that an individual will respond "Yes" is estimated using logistic regression analysis. Using the estimated regression coefficients, the consumer surplus or net economic value can then be estimated.

Nonmarket Goods

Values for goods traded in the market are called market values and are the traditional measure of value associated with changes in water resource management. Familiar water resource examples are irrigation benefits and hydropower benefits. Values for goods which are not traded in the market (and thus not observable) are called nonmarket values. These may include changes in the quantity and quality of recreation or changes in the intrinsic value of a resource.

Recreation use is a commonly cited example of a nonmarket good. Certain types of recreation uses, such as fishing and hunting, are termed consumptive uses. A characteristic of consumptive use is that once a good is used by one individual, it is unavailable for use by another individual. For example if a recreational angler catches and keeps a fish, that fish is unavailable for other anglers to catch.

Some recreation use activities, such as hiking, are termed nonconsumptive uses. Hiking, bird watching, wildlife viewing and similar activities do not require the consumption of a resource. In the absence of crowding, other individuals can use or share in the use of the resource without diminishing it.

Nonuse values are a special case in which the nonmarket good is the status of the natural or physical environment. Nonusers, or individuals who never visit or otherwise use a natural resource may nonetheless be affected by changes in its status or quality. Monetary expression of their preferences for these resources is known as nonuse or passive-use economic value. Economists also use the terms passive-use value and intrinsic value to describe these preferences.

Stated and Revealed Preference

There are two major classes of techniques for measuring the value of nonmarket goods: revealed preference and stated preference approaches. Revealed preference approaches are based on the observed behavior of consumers. These are the decisions which people make regarding activities that utilize or are affected by an environmental amenity. These approaches focus on measuring direct use value. In contrast, stated preference methods elicit values directly from individuals, through survey methods. The stated preference methods are suitable for measuring both direct use and nonuse or passive use values.

Contingent Valuation

The most widely used stated preference valuation technique is called contingent valuation method (CVM). In its simplest terms, contingent valuation is a means of eliciting the maximum amount (in dollar terms) that an individual would be willing to pay for a resource of a specified quantity and quality. CVM ascertains value by asking people their willingness to pay (WTP) for a carefully specified change in environmental quality.

This technique is widely used in natural resource economics (Carson 2005). The CVM method is approved for use by federal water resource agencies (U.S. Water Resources Council 1983) and has been used extensively to estimate water use values (Ward 1987), the existence value, and the preservation value of wild and scenic rivers (Walsh, Sanders, and Loomis 1985).

Rather exhaustive descriptions of the contingent valuation methodology are found in classic works by Cummings et al. (1986) and Mitchell and Carson (1989). A much more recent treatment is provided by Boyle (2003).

History of CVM

Contingent valuation was first proposed by S.V. Ciriacy-Wantrup (1947) as a method for eliciting the value of a nonmarket good. The first reported application was by Robert Davis (1963) who used contingent valuation to estimate the value of big game hunting in the Maine woods. CVM studies became more numerous following publication of a highly influential paper by noted environmental economist John Krutilla (1967) and have proliferated in recent years.

Bibliographies of published CVM studies and papers listed 2,131 entries in 1995 (Carson *et al.* 1995) and over 5,000 by 2005 (Carson 2005).

Through the first 25 or more years of use, contingent valuation studies were primarily an academic exercise of little practical importance, except to economists. This situation changed abruptly when contingent valuation estimates began to be used in legal cases as the basis for damage payments by responsible parties.

The *Exxon Valdez* oil spill disaster in 1989 proved to be a pivotal event in the evolution of CVM. The oil tanker *Exxon Valdez* struck a reef in Prince William Sound, Alaska and spilled 11 million gallons of crude oil into the ocean. The federal Oil Pollution Act of 1990 was passed in response to this environmental disaster. Promulgated by the National Oceanic and Atmospheric Administration (NOAA), this legislation described the loss in nonuse values resulting from an environmental insult as a compensable loss and proposed the use of CVM to measure those losses.

A CVM analysis was conducted by Carson et al (1992) for the state of Alaska to determine lost existence value for U.S. residents resulting from the *Exxon Valdez* oil spill. Carson et al's analysis yielded an estimate of $3 billion in lost benefits. A 1991 lawsuit by the federal government was subsequently settled out of court for $1.15 billion. Because the case was settled out of court, it is impossible to ascertain the role of the Carson et al study in this outcome.

Following these events, *Exxon,* other oil companies and potentially liable industries funded research to discredit the theory and application of CVM (Cambridge Economics Inc. 1992). In response, NOAA commissioned a panel of experts chaired by two Nobel Laureates to advise and inform them on this subject. This has since become known as the "NOAA expert panel."

The January 15, 1993 issue of the *Federal Register* (Department of Commerce 1993) contained the findings of the NOAA expert panel. The panel found that, "...CV studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive-use values." (Department of Commerce, 1993:4610). The panel also issued a set of guidelines for conducting acceptable studies for this purpose.

The discourse which followed the NOAA panel has stimulated an impressive variety of research innovations encompassing all aspects of CVM. This has spanned the gamut from improvements in elicitation methods to explorations of self-selection bias. Both critics and practitioners agree this has greatly advanced the state of knowledge on this subject greatly improving the quality of modern CVM studies.

The CVM Controversy

Valid questions about CVM's accuracy and reliability remain and have given rise to vigorous debate among economists and non-economists alike. Very detailed assessments of this debate can be found in Carson, Flores and Meade (2001) and Venkatachalam (2004). A nontechnical overview of this discourse is found in the exchange between Carson, Meade, and Smith (1993), Desvousges et al. (1993), and, Randall (1993). The professionally influential *Journal of Economic Perspectives* published a symposium on the usefulness of CVM in its fall 1994 issue. A summary of the issues raised are discussed in Diamond and Hausman (1994), Portney (1994) and Hanemann (1994).

While there are a number of active CVM research threads, some of the more commonly encountered are:

- Embedding/scope
- WTP/WTA
- Size of WTP estimates
- Survey response effects

Embedding[1] refers to the research methodology of comparing the value of a particular good, such as protection of a particular trout stream, to a more inclusive good such a protecting an entire drainage basin. Embedding is said to occur when willingness to pay responses for the specific good being valued are approximately the same as those for the more inclusive good[2]. Diamond and Hausman (1994) assert that embedding occurs when individuals don't have a preference for a particular good and from the failure of respondents to consider their budget constraints when responding to a survey. Hanemann (1994) disputes this argument and points out that the studies cited as evidence by Diamond and Hausman diverge from the NOAA Panel's guidelines in a number of important ways. This debate continued in highly controversial paper by Kahneman and Knetsch (1992a), subsequent rebuttals by Smith (1992) and Harrison (1992) followed by a reply by Kahneman and Knetch (1992b). Research on this subject continues to the present day (e.g. Ahearn, Boyle and Hellerstein 2007).

In the judgement of some critics, estimated economic values obtained using CVM are implausibly large. This assertion seems somewhat value laden. Relatively small, household level estimates of nonmarket value, when expanded to the number of households can yield quite large

[1]This concept is also referred to using various terms such as part-whole bias, scope insensitivity and scale insensitivity.

[2]This line of research originated with Boyle et al (1994) who reported that estimates of nonuse values were insensitive to whether 2,000, 20,000 or 200,000 bird deaths were prevented in waste-oil holding ponds.

estimates of aggregate willingness to pay. A commonly cited example is that of the Kakadu study undertaken by Carson, Wilks and Imber (1994). The A$ 53.00 per household estimated WTP to prevent mining in the Kakadu National Park, when expanded by the number of households in Australia, yielded a total WTP value of A$ 1.50 billion. Popular critics of the study derided this estimate as being implausible. However, as wryly noted by Perman, Ma, McGilvray and Common (2003 page 427), "...this is approximately equivalent to one small glass of beer per week at Australian prices. It is not obviously implausible that an average individual would say, if asked, that he or she was prepared to make that kind of sacrifice to preserve part of the national heritage."

Another problem identified in some CVM studies is an unexpected difference in responses between WTP for environmental improvement and the willingness to accept (WTA) payment in return for giving up an environmental improvement. Economic theory suggests that WTP and WTA should be nearly the same, differing slightly for income effects. Usually, WTP estimated using CVM is considerably less than WTA for the same environmental improvement, which is inconsistent with consumer choice theory. A paper by Hanemann (1991) seems to have resolved this apparent contradiction. Hanemann showed that for commodities with limited substitution possibilities, WTA could be much larger than WTP. Related to this issue is the observation that WTA surveys tend to have both higher response rates and a consistently higher level of protest responses. Since some CVM survey questions are logically structured as WTA (for example, if damages are anticipated), practical questions remain. Current CVM practice involves using the WTP format and treating it as a lower bound for the theoretically correct WTA measure. As might be expected, research on this topic remains ongoing.

All surveys are vulnerable to different types of survey response effects. Much of the early literature on contingent valuation focused on the plethora of biases which are associated with survey research. In this context, the term "bias" denotes a survey related effect which causes WTP to be systematically over or under estimated. Such biases are associated with all phases of survey research– design, administration, return and analysis. The literature on survey research and the wide variety of biases that can befall CVM and other types of surveys is dauntingly vast. With respect to CVM surveys, a very small sampling of these biases includes the following:

- hypothetical bias
- starting point bias (Samples 1985)
- elicitation bias
- information bias
- strategic bias
- self-selection bias (Harpman, Welsh and Sparling 2004)

Rather than attempting to describe all of these biases and their manifestations in this document, the reader is advised of these many possible afflictions and directed to the excellent treatments by Carson, Flores and Meade (2001) and Venkatachalam (2004) for a systematic coverage.

To refocus attention on the underlying problem– nonmarket values cannot be observed in the market. Estimation of these real but unobserved values using CVM and other technologies is necessarily more difficult than collecting market data. There currently is and probably will always be some controversy associated with the application of CVM and other methods for measuring nonmarket values. This ongoing and healthy debate stimulates methodological improvements, helps to advance scientific understanding, and ultimately leads to enhancements in the validity, reliability and acceptability of these techniques.

CVM Elicitation

Three approaches are commonly used in contingent valuation studies to elicit willingness to pay from respondents. These are the open-ended approach, the iterative bidding approach, the payment card approach and the dichotomous choice approach.

Use of the open-ended technique is quite straightforward. The contingent market is first described to the respondent. Then, the respondents are asked to state how much they would be willing to pay for the good in question. The value stated is assumed to be the consumer's maximum willingness to pay.

The open-ended approach has been criticized for two reasons. First, this procedure presents consumers with a situation which does not reflect the way in which an actual market operates. In a market, the price is stated and the consumer must decide whether or not to purchase the good. Using the open-ended approach the respondent must supply the price. As a result of this unfamiliar situation, there is some potential for erroneous results to occur. Second, there are concerns that this technique may not yield a measure of maximum willingness to pay for the good being evaluated.

The iterative bidding approach is somewhat more market-like. First, the respondent is contacted and the hypothetical market is described. Then, the individual is asked whether or not he would pay successively higher dollar amounts for the good in question. The highest amount a person would agree to pay is recorded as his maximum willingness to pay. For example, an individual is asked if he/she would pay $7.00 for the good in question. If he says, "Yes," the amount is increased and the question is repeated. This process continues until a maximum willingness to pay is revealed. If the respondent says, "No" to the starting value, the amount is decreased until a "Yes", is received.

Two concerns have surfaced in the literature about the application of the iterative bidding technique. The first has been termed "social desirability bias" by Dillman (1978). Apparently, respondents may allow themselves to be bid up beyond their "true" willingness to pay in order to please the interviewer and appear to be generous toward the cause being evaluated. Respondents may believe that since they are being interviewed about the good it must be valuable and that their bids should reflect this. The other concern about this approach has been termed "starting point bias." Boyle, Bishop, and Welsh (1985), and others have found that the initial dollar amount used to start the iterative bidding process may influence the maximum willingness to pay obtained from the respondent. For this reason, iterative bidding questions must be carefully crafted. Samples (1985) found that it is possible to reduce starting point bias significantly by pre-testing using an open-ended survey instrument and then setting the starting bids in the iterative questions around the mean of the bids found in the pre-test.

In the payment card approach, a number of bid levels are specified and presented to respondents. Survey respondents are then asked to indicate, for example by checking a box next to the price, their willingness to pay for the hypothetical alternative. As with the iterative bidding approach, a number of biases have been documented. Respondent anchoring and ordering effects are frequently cited as weaknesses of this approach.

The dichotomous choice approach is said to be the most market-like methodology now available for eliciting willingness to pay. It is applied in the following manner. First, the respondent is contacted and the contingent market is described. Then, the respondent is asked a single question: "Would you be willing to pay $X.00 for this good, yes, or no?". An example DC-CVM question is illustrated in Figure 1.

Assume a day of angling on the Lamar River was identical to today's fishing trip except the average catch of Yellowstone cutthroat was increased by five fish per day for all members of your fishing party. There would be some increase in fisheries management costs associated with this improvement.

Would you be willing to pay <u>$7.00</u>[1] more in park fishing license fees per season to improve fishing on the Lamar River as described? (Please check one box)

Yes ☒ No ☐

[1]**The price shown is varied randomly across surveys**

Figure 1. Example DC-CVM question.

The DC-CVM elicitation approach is thought to approximate an actual market situation in which a consumer is faced with the decision of whether or not to purchase a particular good at a stated price. As in an actual market, there are only two outcomes: “Yes,” the individual purchases the good or, “No,” the individual does not purchase the good.

Advantages of DC-CVM

There are some recognized advantages associated with the use of dichotomous choice contingent valuation. Among the more commonly cited advantages are:

- Recommended by the NOAA Panel
- Incentive compatible
- Simulates a market
- Similar to voting

The application of dichotomous choice CVM was examined by the NOAA Expert Panel (1993) and its use was recommended over open ended and payment card elicitation approaches. This methodological endorsement is frequently and prominently cited by researchers.

Incentive compatibility is said to occur when a respondent’s optimal strategy is to reply truthfully to the question and not engage in some type of strategic behavior. DC-CVM has been shown to be incentive compatible. This satisfies some technical and theoretical economic concerns which, while frequently debated in economics journals, are decidedly outside the scope of this document. Interested readers are directed to Whitehead (2002) for a discussion of this topic.

DC-CVM is similar to actual situations faced by consumers in the market. A good is offered at a fixed price and the consumer must decide whether to make a purchase or not to make a purchase at the given price. This market-like process is familiar to consumers and is thought to enhance the validity of the responses obtained.

In the U.S. and other democratic countries, the populace is familiar with voting for the provision of public goods including the construction of new libraries, parks and so forth. DC-CVM is similar to a referendum in that consumers respond “yes” or “no” to the question posed to them. This process is familiar to consumers and is thought to enhance the validity of the responses they provide.

Disadvantages of DC-CVM

Naturally, there are also some disadvantages associated with the use of dichotomous choice contingent valuation. Among the more significant disadvantages are the following:

- Requires larger sample sizes
- More complex estimation

- Yea saying
- Sensitivity to survey design and analysis

The commonly used dichotomous choice models, including logit and probit, are computationally inefficient (Hanemann, Loomis and Kanninen 1991). In order to obtain accurate parameter estimates and acceptable goodness of fit measures for these models, relatively large sample sizes, on the order of 500 observations or greater, are required.

DC-CVM models are inherently nonlinear and must be estimated using maximum likelihood techniques (see Appendix 2). Estimation of these models is technically more demanding. As new software is developed, becomes more widely available and becomes less expensive, the analysis burden decreases and this becomes less of a disadvantage.

There appears to be at least some tendency for consumers to say "Yes" to environmental improvements at prices higher than they would actually be willing to pay. This is known as "yea saying." Some authors have argued this biases estimates of consumer surplus upward.

DC-CVM estimates of mean and median WTP can be relatively sensitive to survey design and econometric issues. Estimates of WTP can be influenced by the range of bids employed, outlying observations, protest responses and econometric practice. One thread of this discussion is summarized in Duffield and Patterson (1989), Cooper and Loomis (1992) and Alberini (1995).

Bid Design

The range of prices used in dichotomous choice questions is known variously as the "offer range" or the "bid range". The bid range used in dichotomous choice based surveys can significantly influence the survey result and therefore must be matched to the question being asked and the socio-economic characteristics of the survey respondents. Although much has been said about this subject, most of the literature focuses on three major themes. These are:

1. The mean bid and range of bids should reflect, on the average, respondent's willingness to pay for the good being valued.

2. The variance of the regression is related to the bid range. Therefore, the range of bids offered to respondents should be minimized.

3. The range of bids should be established in such a way that a "yes" response is seldom received for the uppermost bids. This will allow accurate estimation of the upper tail of the logit distribution thereby avoiding the problem of "fat tails" in the estimated distribution (see Ready and Hu 1995 for a discussion of this statistical problem).

A number of articles have appeared in the literature addressing this issue (Duffield and Patterson 1989, Cooper and Loomis 1992, Kanninen 1993, Kanninen and Kristrom 1993, Alberini 1995). Nonetheless, construction of a bid range appropriate for a particular use remains largely a matter of professional judgement and art. In practice, interviews, focus groups, survey pre-tests and the results of previous studies are often used for comparison and as reference when constructing bid ranges.

Modeling of Discrete Choice

Two probability distributions are commonly used as a basis for dichotomous choice modeling. These are the cumulative normal probability distribution and the cumulative logistic probability distribution. Dichotomous choice models based on the normal distribution are often called probit models. Dichotomous choice models based on the logistic distribution are typically referred to as logit models. These models are referred to in the literature as single bounded models. They are a special case of interval data model (see Appendix 1 for further details).

The logit model is currently the most widely used binary choice model primarily because the cumulative density function is a closed form analytic expression[3]. In the logit model the probability of participation (P) is described as:

$$P(Y = 1) = \frac{1}{1 + e^{-bx}} \tag{1}$$

where: P = probability of individual (i) responding “Yes” (Y=1)
b = a conformable vector of coefficients
x = a vector of explanatory variables.

Algebraic rearrangement of expression (1) yields (2):

$$\log\left[\frac{P}{1-P}\right] = bx \tag{2}$$

In this form, the dependent (left-hand side) variable is simply the logarithm of the odds that a particular choice will be made. The slope[4] of the cumulative logistic distribution is greatest at

[3]In contrast, the cumulative normal distribution must be evaluated numerically.

[4]The slope of the logit function is $\partial P/\partial x = P(1-P)b$.

the point where P = 0.5 . In terms of a regression model, this implies that changes in independent variables will have their greatest impact on the probability of choosing a given option at the midpoint of the distribution. The rather low slopes in the tails of the distribution imply that in these ranges large changes in **x** are necessary to bring about a small change in probability.

In dichotomous choice models of the type where P is always equal to 0 or 1, there are serious difficulties with the direct estimation of the logit model. This is because when P is either 0 or 1, the odds, P/(1-P), will equal 0 or infinity and the logarithm of the odds will be undefined.

Because the logit function is inherently non-linear, the dichotomous choice logit model must be estimated using maximum likelihood techniques. Maximum likelihood estimation is an optimization technique for identifying a coefficient vector maximizing the probability the explanatory variables produced the observed responses. Appendix 2 illustrates the derivation of the likelihood function for this model and describes the maximum likelihood estimation of the model.

The Logit Function

Figure 2 illustrates an example logit function. This function describes the probability of an individual responding "Yes" to a question such as the one described in Figure 1. As shown in Figure 2, the relationship between price and the probability of responding "Yes" is highly nonlinear. An individual's probability of responding "Yes" is highest for low prices and declines as the bid price increases. This relationship is logical and consistent with economic theory.

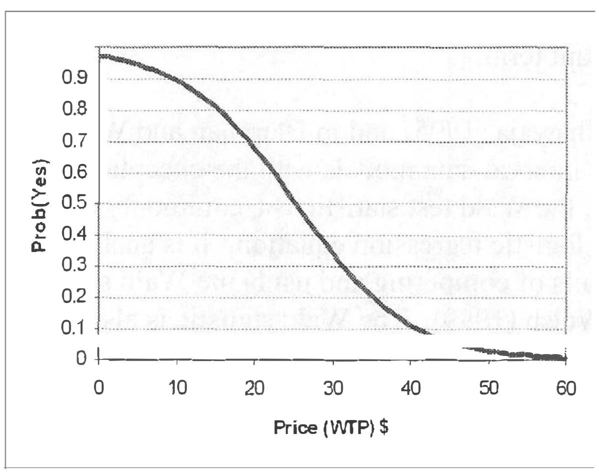

Figure 2. Plot of the logit function.

Goodness of Fit Measures

Researchers estimating a regression model are often concerned about the model's goodness of fit. In ordinary least squares regression analysis the R^2 goodness of fit measure is widely employed. For models estimated using maximum likelihood methods, Maddala's R^2 and McFadden's R^2 are often reported. Like other R^2 measures reported for maximum likelihood estimations, these two R^2 measures can be misleadingly low.

Maddala's R^2 (Maddala 1983, equation 2.44) is defined as $R^2 = 1 - (L_r/L_u)^{2/n}$ where L_r is the restricted likelihood function[5], L_u is the unrestricted likelihood function, and n is the sample size. Unlike the R^2 calculated in OLS regressions, the upper bound on Maddala's R^2 is less than 1.0. Since the maximum value attained by the likelihood function (L_{max}) is 1.0 and $1 \geq L_r/L_u \geq L_r/L_{max}$, the bounds on Maddala's R^2 are: $0 \geq R^2 \geq 1 - (L_r)^{2/n}$ (Maddala 1983, equation 2.49).

McFadden's R^2 is also known as the likelihood ratio index. It is defined as $R^2 = 1 - (L_u/L_r)$ where L_r is the restricted likelihood function, L_u is the unrestricted likelihood function. Like Maddala's R^2, while McFadden's R^2 can be as low as 0, it can never reach 1.0.

Statistical Significance Measures

The likelihood ratio test is the maximum likelihood analog to the F-test in linear regression models. The likelihood ratio statistic is widely used for testing the overall significance of relationships estimated using maximum likelihood methods. The likelihood ratio statistic is given by $\lambda = -2[\ln(L_r)-\ln(L_u)]$ where L_r is the restricted likelihood function and L_u is the unrestricted likelihood function. The likelihood ratio statistic is chi-square (χ^2) distributed with (k-1) degrees of freedom where k is the number of explanatory variables in the (unrestricted) equation including the constant term.

As noted in Kanninen and Khawaja (1995) and in Harpman and Welsh (1999), the likelihood ratio test is undefined for all interval data models with the exception of the single bounded case. For the interval data models, the Wald test statistic is a commonly used as a test for the joint significance of an estimated logistic regression equation. It is analogous to the F-test in the linear regression context. The details of computing and using the Wald statistic in this context are described in Harpman and Welsh (1999). The Wald statistic is also χ^2 distributed with (k-1) degrees of freedom.

[5]By convention, the term "restricted likelihood function" refers to the value of the likelihood function when all of the slope coefficients are restricted to be equal to 0.0.

More About Notation

A short digression about notation is useful in understanding the next sections of this document. In the logistic regression analysis context, the vector of explanatory variables multiplied by vector of coefficients may be expanded as shown in (3)

$$bx = b_0 + b_1x_1 + b_2x_2 + \cdots + b_nx_n \qquad \textbf{(3)}$$

In (3), b_0 is a constant term and b_1x_1 through b_nx_n are the other explanatory variables which typically include price, age, income and other variables.

In contingent valuation applications, one of these explanatory variables is always the price posed to respondents. This is oftentimes referred to as the bid price or offer price. This is the price an individual is asked to pay. Since P is often used to denote "Probability," the price or individual willingness to pay is often denoted as WTP.

As might be expected, economists are very interested in the coefficient on WTP (price). For reasons which will subsequently be made clear, they often collapse (3) into an expression consisting only of a so called "grand mean" denoted by alpha (α) and the price coefficient (b). This can prove confusing.

Assuming the price variable is x_1 and the price coefficient is b_1 , the grand mean is formed by summing the constant term (b_0) and all of the other terms, $b_2x_2 \dots b_nx_n$, evaluated at their means[6]. To reiterate, the grand mean includes the constant term and all of the explanatory variables except price. The resulting shorthand expression is shown in (4).

$$bx = \alpha - bx \qquad \textbf{(4)}$$

In this widely used notation, α is the grand mean, b is the price coefficient and x is the price or WTP.

The expression shown on the righthand side of (4) is used regularly in textbooks and articles on DC-CVM. For consistency with these sources, the same notation is employed throughout the remainder of this document.

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[6]Although the approach described here is used frequently in applied work, it is correctly applied only to linear functions. In the case of nonlinear functions, such as the logit function, Souter and Bowker (1996) have shown it can yield biased estimates of aggregate consumer surplus.

Consumer Surplus (CS) Measures

Use of the contingent valuation methodology results in an estimate of a Hicksian compensated demand function, the theoretically correct measure of social welfare (Hanemann 1984).

The estimated logit function is a cumulative probability density function. This function describes the (cumulative) probability that a consumer will respond "Yes" at various bid or price levels. The mean or expected value of the consumer surplus is usually written as E(WTP). The E(WTP) is the area under the logit function. This area is often reported as the "consumer surplus."

In general, the expected value of an arbitrary cumulative probability density function is computed over the domain from $-\infty$ to $+\infty$. Consumer willingness to pay (WTP) is typically defined as a non-negative measure. The domain of the logit function is not necessarily non-negative and, in many applications, some portion of the estimated function lies in the negative quadrant. For purposes of computing the expected value of consumer surplus, most economists use the domain from 0.0 to $+\infty$. Integrating over this domain yields what is correctly called the conditional mean[7] which is often denoted as $E(WTP|WTP \geq 0)$.

In early applications of the DC-CVM technique, the (conditional) mean was obtained by numerically integrating under the estimated logit function from 0.0 to $+\infty$ (for example, see Loomis 1988). Some authors advocated integrating only within the range of the data (Sellar, Stoll and Chavas 1985) although Boyle, Welsh and Bishop (1988) later pointed out this procedure led to a truncation of the cumulative density function and an underestimate of consumer surplus. Much of this discussion is summarized in a difficult to comprehend pair of articles by Hanemann (1984, 1985). Predictably, these were followed by a series of clarifying comments and replies (Kushman 1987, Hanemann 1987, Johansson, Kristrom and Maler 1989, Hanemann 1989). Table 1 illustrates expressions for the mean, median and conditional mean willingness to pay for the *linear* in parameters logit function.

In the expressions in Table 1, α is the "grand mean" for the estimated logistic regression and b is estimated coefficient for the price variable. As shown in this table, the expressions for the median consumer surplus and the mean consumer surplus are identical for the linear in parameters logit model.

[7]Conditional on the presumption $WTP \geq 0$.

Table 1. Measures of Consumer Surplus[8]

Measure	Integration Interval	Notation	Expression
Median	-∞ to +∞	Prob(WTP)=0.50	$\frac{-\alpha}{b}$
Mean	-∞ to +∞	E(WTP)	$\frac{-\alpha}{b}$
Conditional Mean	0.0 to +∞	E(WTP|WTP≥0)	$\frac{\ln(1+e^{\alpha})}{-b}$

The median consumer surplus is the willingness to pay that corresponds to a probability of 0.50. Simple algebra can be used to derive the expression for the median. Hanemann (1989) derived the expression for the conditional mean consumer surplus using the method of moments. A simpler approach, using standard calculus, is illustrated in Appendix 3.

The consumer surplus measures for the linear in parameters logit model, other specifications of the logit model and many other forms of dichotomous choice models (e.g. log-normal, weibull, etc.) can be found in Hanemann and Kanninen (1999).

Confidence Intervals for CS

Although beyond the scope of this report, confidence intervals for estimates of consumer surplus can be constructed using various methods. As illustrated in Table 1, all of the expressions for consumer surplus are nonlinear combinations of the estimated parameters from the logit function. The statistical properties of these consumer surplus measures are unknown. As a consequence, numerical approaches such as the bootstrap method (Efron 1979) and the Krinski and Robb method (Krinski and Rob 1986, Park, Loomis and Creel 1991) are typically used to estimate empirical confidence intervals around point estimates of consumer surplus. Cooper (1994) compares these and other approaches.

[8] To reiterate, these measures are valid only for the *linear* in parameters logit function.

In general, these methods are numerically based and computationally intensive. The details of implementing them are far beyond the scope of this manual.

Elwha Example

Introduction

The example DC-CVM application described in this document is derived from a published study completed by Professor John B. Loomis of Colorado State University (Loomis 1996). This application is timely, policy relevant, instructive and well-suited for our purposes. Dr. Loomis was kind enough to supply his data set for use in this example. The considerable help and assistance of Dr. Loomis in formulating this example is gratefully acknowledged.

Setting

The impetus for the Elwha Study was the Federal Energy Regulatory Commission (FERC) relicensing of Glines and Elwha Dams. Both of these facilities were constructed by the Olympic Power and Development Company. The Elwha Dam was completed in 1913 and the Glines Canyon Dam in 1927. Both facilities are located within what is now the Olympic National Park in the State of Washington (see location map Figure 3). Aside from these dams, the watershed is located almost entirely within the National Park and is generally acknowledged to be otherwise pristine. These two dams, which together can produce up to 28.1 MW of electricity, entirely blocked the migration of salmon and steelhead up the Elwha River. A hatchery was constructed at the Elwha Dam to compensate, but it was unsuccessful and was closed in 1922. As a consequence the anadromous fish stocks were largely extirpated. The livelihood and religious practices of the Elwha S'Kallum Tribe which depended on these fish was also decimated.

The Crown Zellerbach Company bought the Elwha Dam in 1919 and the Glines Project in 1936. In 1968 the Crown Zellerbach Company filed an application with the Federal Power Commission (FPC) for relicensing of these facilities. This precipitated a new analysis of the environmental and social impact of these facilities.

In aggregate, analysis of the environmental impacts of the Elwha Dams and their effect on Fisheries is rather extensive. Initially work was conducted by FERC and the General Accounting Office (GAO 1991). Further environmental analysis was conducted by FERC (1993) and by the Department of the Interior pursuant to the Elwha Act (USDOI 1993). The remedial actions identified during the relicensing process were quite costly relative to the amount of electricity produced. A lengthy process of analysis, legal wrangling, political intervention, public discourse and environmental compliance ensued. This process culminated in the issuance of a final environmental impact statement in which the preferred alternative was dam removal (USDOI 1995). A record of decision was issued in early 1996 and a second environmental impact statement was issued later in 1996 describing the preferred method of dam removal (USDOI 1996). The Department of the Interior purchased these hydropower facilities in 2000. A supplemental environmental impact statement was issued in 2005 (USDOI, 2005) and the decommissioning process is scheduled to begin in the spring of 2007. Some historical assessment can be found in Gowan, Stephenson and Shabman (2006).

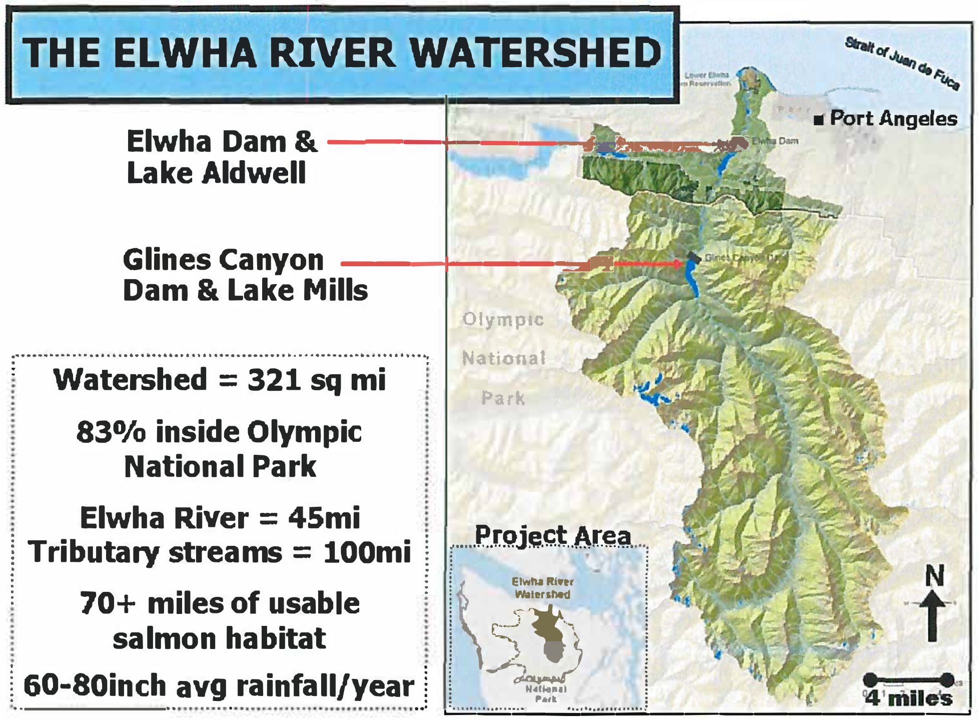

Figure 3. The Elwha River Watershed. Courtesy of American Rivers (Kober 2008).

Survey

As is often the case, the costs of the recommended environmental actions could be relatively easily estimated. Conversely, the economic benefits of dam removal were believed to be quite large but could not be so easily quantified.

In 1994, Dr. Loomis initiated a study designed to estimate the value of the environmental improvements resulting from a removal of Elwha and Glines dams. This study was based on a survey of three affected groups– the citizens of Clallam County, the county where the dams were located, residents of the remainder of Washington State and all United States taxpayers.

Development of the contingent valuation survey instrument was careful, systematic and painstaking. Initially, on-site information describing the effects of dam removal was developed with the assistance of subject matter experts. In order to ensure the saliency of the survey language, 5 focus groups were held at different locations across the United States. The draft survey instrument was also pre-tested on small groups of citizens and they were debriefed. This process provided additional information about their comprehension and attitudes towards different aspects of the survey and allowed for iterative improvements to the survey instrument.

The final version of the survey was administered by mail in 1994. Appendix 4 contains a black and white scanned version of the survey used in this study. This survey was randomly administered to three groups or treatments. Again, these three treatment groups were: the citizens of Clallam County, Washington, residents of Washington State outside of Clallam County and all United States tTaxpayers.

As shown in Appendix 4, respondents were furnished with location maps and detailed descriptions of the resource to be valued. The survey employed a DC-CVM question for valuation purposes. The payment vehicle posited in the DC-CVM survey was that dam removal would be funded through the use of Federal taxes. There were also a variety of socioeconomic questions and a number of other questions designed to identify the respondent's affinity with various affected resources.

Data

The number of surveys sent to each treatment group, the return rate and the number of observations ultimately obtained are shown in Table 2. A total of 2,500 surveys were mailed out. The response rates for each treatment group ranged from 55% (U.S.) to 77% (Clallum County). In general, these response rates are quite reasonable. The response rate in Clallum County, the geographic area most directly affected by the dam removals, is predictably higher than the other treatment groups.

For purposes of the example in this document, our focus is limited to the Washington State treatment group. This example is based on the actual data collected in Loomis (1996). The data described in this document are limited to those variables employed in the logistic regressions estimated by Loomis. There is a slight discrepancy in the data used by Loomis (1996) and used for the example described subsequently. Loomis (1996) reports the number of Washington State observations used in the logistic regression analysis was n=467. Perhaps due to an overly zealous removal of protest responses by this author, only n=459 observations are available for use in the example application which follows.

The data for the Washington State treatment group (n=459) used for the example analysis described in this document may be found in the following files:

- MBelwha04.txt (formatted for use by the MBmodel model)
- elwha04.xls (Excel format)

If these data were not supplied with this document, they may be obtained by contacting the author.

Table 2. Elwha Survey Treatments and Responses

Treatment	Surveys Sent	Return Rate (%)	Final Sample Size[9]
U.S.	1000	55	423
Washington State	900	68	467
Clallum County	400	77	284

After an extensive specification search, Loomis selected a logistic regression equation with four explanatory variables as best able to explain individual's willingness to pay to remove the dams. These explanatory variables were the price, the importance of the fishery to respondents (*fishimp*), the importance of electricity (*electimp*) to respondents and the importance of the Elwha S'Kallum Tribe (*indimp*) to respondents.

Selected descriptive statistics for these variables for the n=459 observations of Washington State treatment group are shown in Table 3.

Table 3. Selected Descriptive Statistics for the Washington State Treatment Group.

	Resp	*Bidamt* (price $)	*fishimp*	*elecimp*	*indimp*
mean	0.557734	38.79303	3.361656	2.625272	2.004357
median	1	30.00	3	3	2
standard deviation	0.497197	35.4442	0.714731	1.001687	1.004348
minimum	0	3.00	1	1	1
maximum	1	190.00	4	4	4

[9]Number of observations remaining after the protest responses have been removed from the sample.

Parameter Estimation

In the early years of DC-CVM, estimation of a logit model was a significant undertaking often requiring a custom programming effort. Econometric software has evolved rapidly and a large number of software programs are now available for logistic regression analysis. A subset of these are LIMDEP (www.limdep.com), EViews (www.eviews.com), SHAZAM (http://shazam.econ.ubc.ca) and R (http://www.r-project.org). Using one of these software packages or a similarly capable program and the elwha04.txt data set, a logistic regression equation can be estimated. The results should be the same as those shown in Text Box 1 which were obtained using the MBmodel program[10].

```
Multiple Bounded Regression Analysis              Ver 1.0.0  10/02/07

Logit model                                      run date    3/25/2008
data file = MBelwha04.dat                        run time = 1:54:28 PM

nobs =    459            d.f.     454            nbids    1
maxiter =  30            ctol    1.0E-005        eps = 1.0E-005
iter =    4              converge = True

Study = ELWHA DAM REMOVAL STUDY- WASHINGTON STATE EXCLUDING CLALLAM CO.


variable        est coef        std err        t-stat      prob(t)

const       -3.6494E+000        0.777704       -4.6925    3.5783E-006
price       -1.6951E-002        0.003608       -4.6984    3.4813E-006
fishimp         1.577091        0.205888        7.6599    1.1334E-013
elecimp     -7.0673E-001        0.129118       -5.4736    7.3095E-008
indimp          0.568792        0.128144        4.4387    1.1375E-005


log-likelihood =  -219.132617
Wald chi-square test ( 4 d.f)   110.707252

E(WTP|WTP>=0)        74.78
E(WTP) =      55.28

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Text Box 1. Logistic Regression Results for the Elwha Example.

As shown in Text Box 1, the estimated logit equation is highly significant (Wald Statistic 110.71). The coefficient for price is -0.016951 and negative. The negative sign on price indicates that as the price increases, the probability of responding "Yes" decreases as predicted by economic theory and logic. The coefficients for fishimp and indimp are positive. This indicates that individuals who consider the well-being of the salmon fishery and the Tribe

[10]MBmodel is an easy to use logistic analysis program developed by the author primarily for teaching and educational purposes.

important have a higher probability of responding "Yes" to the DC-CVM question, all other factors being held constant. The coefficient for elecimp is negative indicating that individuals who consider electricity more important than restoration of the aquatic environment have a lower probability of responding "Yes" to the DC-CVM question, all other factors being the same. Each of the variables in the equation has a t-statistic greater than 3.00 and is significantly different from zero at greater than the 99% level. The median of the WTP distribution is $55.28 and the conditional mean WTP is $74.78. The disparity between the median (unconditional mean) and the conditional mean indicates that some part of the distribution is located in the negative quadrant.

The Estimated Logit Equation

The estimated coefficients shown in Text Box 1 can be substituted into the logit equation to obtain the expression shown in (5).

$$P(Y=1) = \frac{1}{1+e^{-(-3.649355-0.016951 price+1.577091 fishimp-0.706734 electimp+0.568792 indip)}} \quad \textbf{(5)}$$

For purposes of visualization, it is useful to graph the estimated logit function so that probability is on the vertical axis and price is on the horizontal axis. In order to plot this 5 dimensional expression (probability, price, fishimp, electimp, and indimp), we must first reduce the number of dimension to 2 (probability and price). The mean values for each of the variables in equation (5) are shown in Table 3. By convention, we reduce the dimensionality of the problem by multiplying the mean values for each of the variables, other than probability and price, by their coefficients and adding the result to the constant term. This process yields the grand mean (α) described previously.

To form the grand mean, we multiply the coefficients for fishimp, electimp, and indimp times their respective mean values and add this to the constant term. This calculation is shown in equation (6).

$$\alpha = -3.649355 + 1.577091 \times 3.361656 - 0.706734 \times 2.625272 + 0.568792 \times 2.004357 \quad \textbf{(6)}$$

In this case, the grand mean or α=0.93697525.

Calculation of the grand mean allows us to reduce the problem to 2-dimensions price and probability. In 2-dimensions, the multivariate logistic equation (5) becomes (7).

$$P(Y=1) = \frac{1}{1+e^{-(0.93697525-0.016951 price)}} \quad \textbf{(7)}$$

Equation (7) can then be plotted in two dimensions (price and probability) as shown in Figure 4. As shown in this figure, a portion of the distribution is located in the negative quadrant.

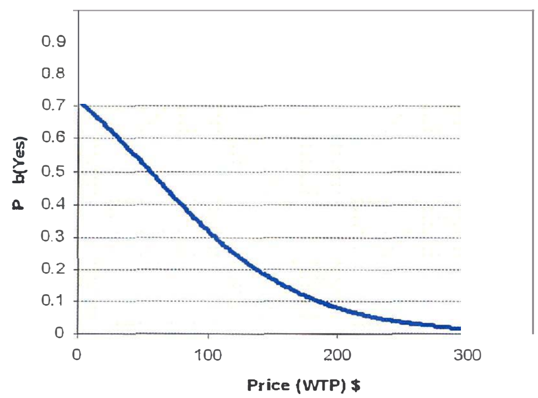

Figure 4. Plot of estimated logit function

CS Measures

The most commonly reported measures of consumer surplus are the mean, conditional mean and the median. The expressions for each of these measures were shown previously in Table 1. To reiterate, in Table 1, α is the grand mean and *b* is the estimated price coefficient.

For the logistic regression model estimated here, the grand mean (α) was calculated earlier. For the majority of economists, consumer surplus is a non-negative quantity. Consequently, the conditional mean consumer surplus is the most widely reported measure of willingness to pay. Using the expression shown in Table 1, the grand mean (α) and the estimated price coefficient (*b*), the (conditional) mean consumer surplus is calculated as illustrated in equation (8). This is identical to the result reported by the MBmodel program.

$$E(WTP|WTP \geq 0) = \frac{\ln(1 + e^{0.93697525})}{-(-0.016951)} = 74.78 \qquad \textbf{(8)}$$

The graphical equivalent of the conditional mean consumer surplus is illustrated in Figure 5.

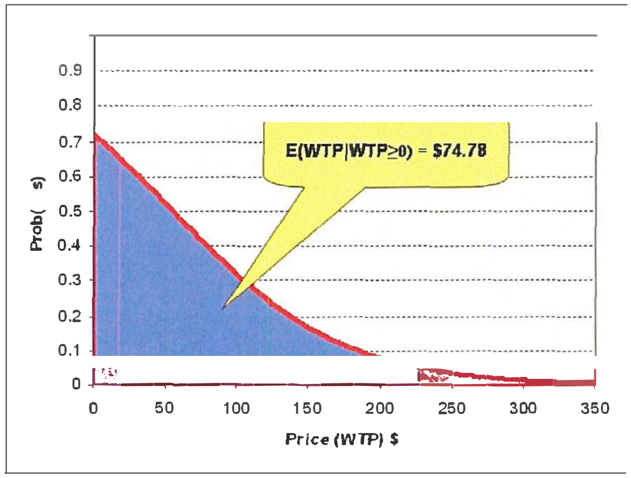

Figure 5. The (conditional) mean consumer surplus for the estimated logit function.

The median or unconditional mean consumer surplus is also reported in many studies. The median represents the expected value of the WTP distribution over the interval -∞ to +∞. Using the grand mean, calculation of the (unconditional) mean and median consumer surplus is shown in equation (9).

$$median = \frac{-(0.93697525)}{-0.016951} = 55.28 \quad \textbf{(9)}$$

CS Confidence Intervals

Confidence intervals for any one of the consumer surplus measures can be estimated using one of several the numerical techniques. A discussion of these methodologies is beyond the scope of this document. Text Box 2 displays the 90%, 95% and 99% empirical confidence intervals for the conditional mean consumer surplus computed using the Krinsky and Robb (1986) technique. The KR_MBL program used to estimate these confidence intervals was developed by the author based on code graciously provided by Park, Loomis and Creel (1991).

```
Multiple Bounded Regression Analysis               Ver 1.0.0  10/02/07

Logit model                                       run date   3/25/2008
data file = MBelwha04.dat                         run time = 1:55:07 PM


ESTIMATION OF KRINSKI & ROBB CONFIDENCE INTERVALS

cs formula used = Logit E(WTP|WTP>=0)
number of trials = 1000


Study = ELWHA DAM REMOVAL STUDY- WASHINGTON STATE EXCLUDING CLALLAM CO.


                           CONSUMER SURPLUS



                  CI            Trimmed         CI
                  Lower           Mean          Upper


      99% C.I.     56.16          77.33        133.08

      95% C.I.     59.05          76.85        111.87

      90% C.I.     61.40          76.48        101.91



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Text Box **2**. Confidence Intervals for the Conditional Mean Consumer Surplus.

As shown in Text Box 2, the 99% empirical confidence intervals for the conditional mean consumer surplus ranges from $55.42 to $132.50. We conclude the true value of mean consumer surplus falls within this interval 99% of the time. Alternatively, we can say we are 99% confident the true value of mean consumer surplus falls within this interval. Also notice that zero does not fall within this interval. This indicates the conditional mean consumer surplus is significantly different from zero.

Conclusion

The focus of this document is on the dichotomous choice contingent valuation method (DC-CVM), its statistical underpinnings and the mechanics of its application. The characteristics of the logit function and the estimation of logistic regressions are described. The nature of the relevant consumer surplus measures are explained, their mathematical expressions reported and the derivation of these measures is illustrated. Finally, a step-by-step application of the DC-

CVM method is presented. This application is designed to allow readers to understand and apply the methodology. The solved example replicates a well-known study of the economic value associated with the removal of the Elwha and Glines dams. The progress of economic science continues and the DC-CVM method is no longer regarded as the "state-of-the-art" in nonmarket valuation. Nonetheless, many future applications of this widely used methodology are expected. It is hoped this manual will provide economists, environmental scientists and policy makers some conceptual and technical insight into DC-CVM.

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Appendix 1. Interval Data Models

As described in this document, the logit model or single bounded logit model is widely used for DC-CVM. In the current economics and econometrics literature, the single bounded model is classified as a type of interval data model. The interval data models include the familiar single-bounded (SB) dichotomous choice model, the spike (SP) model, (Hanemann and Kristrom 1994), the one and one-half bound (OOHB) model (Cooper, Hanemann and Signorello 2002), the double-bounded (DB) model, (Hanemann, Loomis and Kanninen 1991) and the multiple-bounded (MB) model (Welsh and Bishop 1983, Welsh and Poe 1998, Vossler et al 2003, Aadland and Caplan 2003). The SP, OOHB, DB and MB models are statistically more efficient than the SB model (Hanemann, Loomis and Kanninen 1991).

It can readily be shown the SB, SP, OOHB and DB models are special cases of the multiple-bounded model. The likelihood function for the MB model encompasses all of these variants and software written to estimate the parameters of the MB model may be employed without modification to estimate the parameters of these special cases.

The single bounded model is a type of interval model and, as such, is a special case of the multiple bounded model described by Welsh and Bishop (1993). In the case of DC-CVM, a given respondent is presented with a scenario and asked if the would be willing to pay a stated price. They are then asked to respond "Yes" or "No."

In the single bounded logit model each respondent is presented with a single bid. The bid price divides the real number line into two intervals. One interval ranges from $-\infty$ up to the amount of the bid price. The other interval ranges from the bid price to $+\infty$.

An individual's response to a DC-CVM question reveals the interval containing their true WTP. If the respondent answers "Yes," to the dichotomous choice question, their true WTP must be at least equal to the bid price but less than $+\infty$. If the respondent answers "No," their true WTP is revealed to be less than the bid price but greater than $-\infty$. The interval containing a respondent's true WTP is defined by these lower and upper endpoints. We denote the lower end of the interval (the highest value they accepted) as the lower bid (BID_L) and the upper end of the interval as the upper bid (BID_U).

From the researcher's perspective, WTP is a random variable. In the multiple bounded (MB) logistic model, the probability that a respondent will answer "Yes" to any given bid price is defined as shown in (10).

$$P(Y = 1) = F(x) = \frac{1}{1 + e^{-bx}} \qquad \textbf{(10)}$$

The log-likelihood function for the MB model is given by (11) where Z=[1-F(x)].

$$Log(L) = \sum \log[Z_U - Z_L] \qquad \textbf{(11)}$$

In (11), Z_U and Z_L represent the logistic probabilities for any individual which correspond to a vector of explanatory variables containing BID_U and BID_L respectively.

The two possible outcomes of a DC-CVM question are "Yes" and "No." Recall that the limit of F(x) as $x \to +\infty$ is 0 and the limit of F(x) as $x \to -\infty$ is 1.0. Making use of these results and using the MB model notation, we illustrate the equivalence of the two possible outcomes in a dichotomous choice question with a bid price of "BID" as shown in (12) and (13).

$$P(Y = 1) = Z_U - Z_L = [1 - F(\infty)] - [1 - F(BID)] = \frac{1}{1 - e^{-(\alpha + bBID)}} \qquad \textbf{(12)}$$

$$P(Y = 0) = Z_U - Z_L = [1 - F(BID)] - [1 - F(-\infty)] = 1 - \frac{1}{1 + e^{-(\alpha + bBID)}} \qquad \textbf{(13)}$$

Using similar algebraic techniques, the equivalence of the SP and DB models with the more general MB model can also be readily demonstrated.

Not surprisingly, computer software programs for estimating the MB model can be used to estimate the parameters for the SB, DB, OOOHB and SP models and will obtain results which are identical to those obtained using routines written specifically for each of these cases. An added benefit is that maximizing (11) is computationally more efficient than maximizing the log-likelihood function for these special cases.

Appendix 2. Likelihood Function and Model Estimation

For dichotomous or binary processes there are only two outcomes; Yes=1 and No=0. To derive the logit model we will first assume that the probability of an individual (i) responding "Yes" to a dichotomous choice question is described by the logistic cumulative distribution shown in (14)

$$P(Y = 1) = F(bx) = \frac{1}{1 + e^{-bx}} \tag{14}$$

Where:

Y is the response {0,1} for any individual (i)
b is a vector of coefficients
x is a vector of explanatory variables

The probability of an individual responding "no" to the dichotomous choice question is then given by (15)

$$P(Y = 0) = 1 - F(bx) = 1 - \frac{1}{1 + e^{-bx}} \tag{15}$$

For all individuals (1..n) surveyed, the likelihood function (L) relating their responses (Y) to a posited set of explanatory variables (X) is then given by (16)

$$L = \prod_{i=1}^{i=n} \left[(F(bx))^{Y} (1 - F(bx))^{(1-Y)} \right] \tag{16}$$

Due to the properties of logarithms, maximizing the log of the likelihood function yields the same results as maximizing the likelihood function. The log of the likelihood function is much more tractable than (16). The log-likelihood of (16) is given by (17)

$$\ell = \sum_{i=1} \left[Y_i \log[F(bx)] + (1 - Y_i) \log[1 - F(bx)] \right] \tag{17}$$

The logit log-likelihood function has been shown to be globally convex (from above). As a practical matter, this means there is a single vector b which maximizes the likelihood function. Consequently, this model is efficiently maximized using Newton's Method (in the case of multiple explanatory variables, often referred to as the Newton-Raphson Method). The Newton-Raphson method is an iterative approach which is illustrated in (18).

$$b_{t+1} = b_t - \left[\frac{\partial^2 \ell}{\partial b_t \partial b_t} \right]^{-1} \times \frac{\partial \ell}{\partial b_t} \tag{18}$$

The Newton-Raphson Method proceeds to a solution as follows. Starting with an initial estimate of B_t, the gradiant (vector of first derivatives with respect to b) and the inverse hession (the inverse of the matrix of second partial derivatives with respect to b) are computed (at that b_t), multiplied together and subtracted from b_t to yield an updated estimate b_{t+1}. This updated estimate b_{t+1} is then substituted for b_t ... and so on. This iterative procedure continues until a convergence or stopping rule is invoked. Often, this rule is of the form shown in (19) where ϵ is some predetermined level of accuracy.

$$\left| \frac{\partial \ell}{\partial b} \right| \leq \varepsilon \tag{19}$$

At convergence, the resulting optimal value of b is the maximum likelihood estimate of the coefficient vector. This optimal b maximizes the likelihood that the posited explanatory variables (x) produce the observed pattern of responses (Y).

Appendix 3. Deriving Conditional Mean CS

The logistic or logit function is described by (20) where x is a vector and b is a conformable vector of constant coefficients.

$$F(x) = \frac{1}{1 + e^{-\delta x}} \tag{20}$$

This function, in various guises, is used in both population models and logistic regression analysis. In both situations, there is sometimes a need to find a closed form (analytic) solution (21).

$$\int_0^\infty F(x)dx = \int_0^\infty \frac{1}{1 + e^{-\delta x}} dx \tag{21}$$

Up until recently, this has eluded me and I have taken Hanemann's (1984) word for it. However, it turns out that this result can also be obtained with standard calculus.

First, recall that for any constant k, equation (22) holds.

$$\int kF(x)dx = k\int F(x)dx \tag{22}$$

Then, note that the logit function can be expressed in a number of equivalent forms. Of particular interest to us is (23)

$$\frac{1}{1 + e^{-\delta x}} \qquad \frac{e^{\delta x}}{e^{\delta x} + 1} \tag{23}$$

If we integrate the form shown on the right-hand side of (23) our task will be much easier. To do so, define k=b/b.

$$\int_0^\infty F(x)dx = \int_0^\infty \frac{b}{b} \frac{e^{\delta x}}{e^{\delta x} + 1} dx = \frac{1}{b}\int_0^\infty \frac{be^{\delta x}}{e^{\delta x} + 1} dx \tag{24}$$

Then, we can apply the rule for integrating 1/u so that we end up with

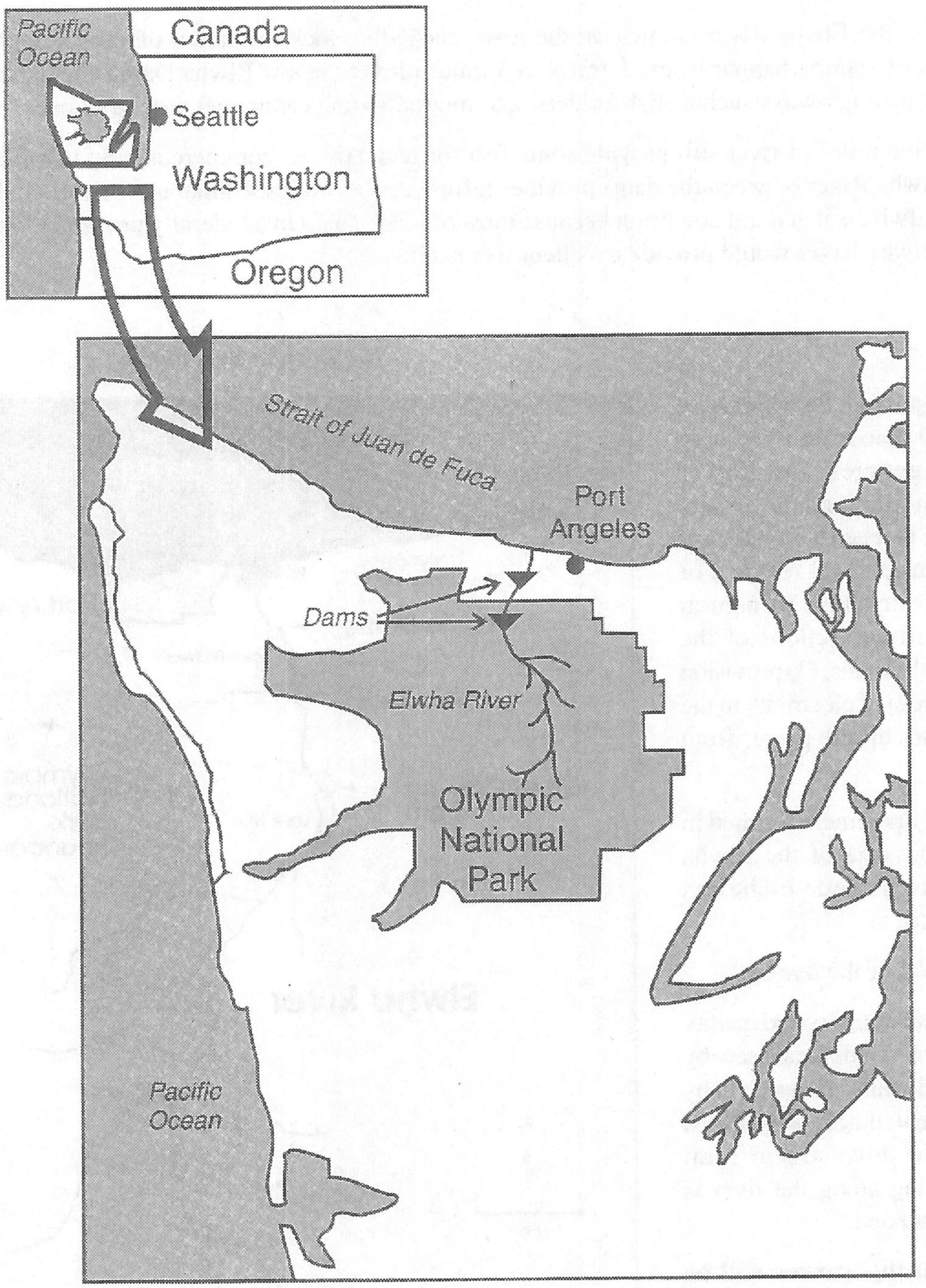
$$\int_0^{\infty} F(x)dx = \frac{1}{b}\ln(e^{bx} + 1) + c \qquad \textbf{(25)}$$

The expression on the right-hand side of (25) is identical to the relationship derived by Hanemann (1989).

Appendix 4. Elwha Survey

REMOVING DAMS FROM THE ELWHA RIVER:

WHAT DO YOU THINK?



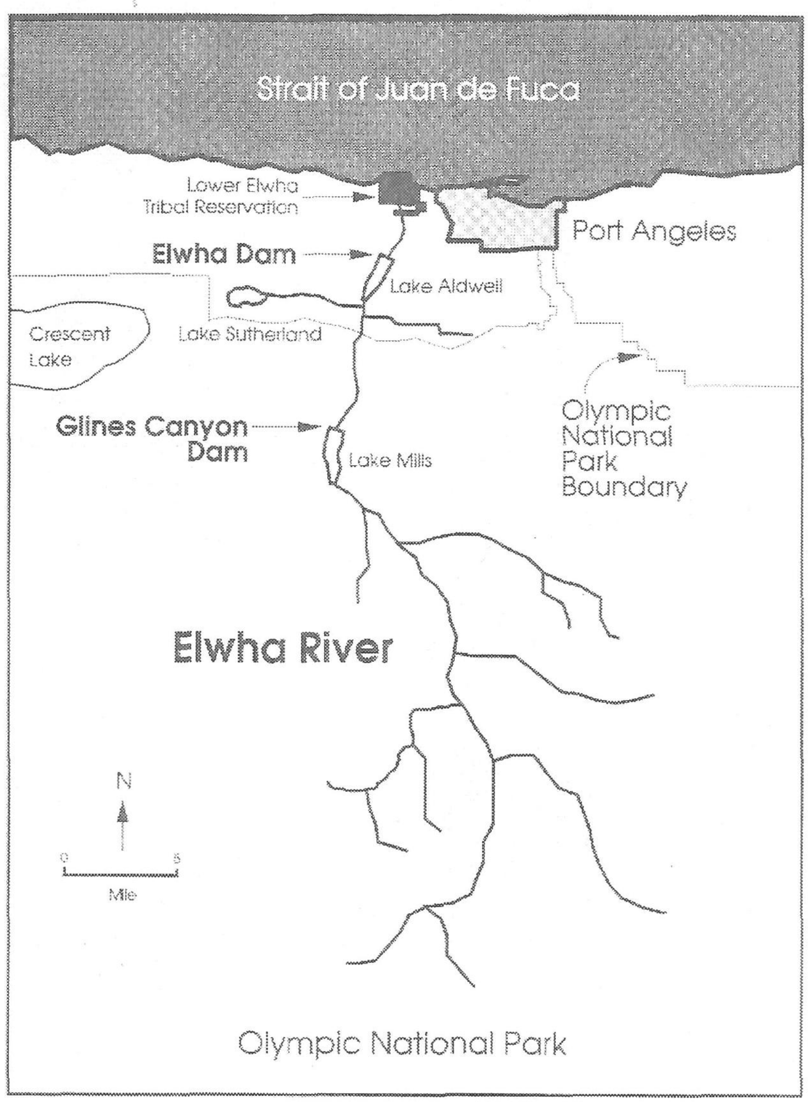
ELWHA RIVER, SALMON, AND OLYMPIC NATIONAL PARK

The Elwha River is the largest river system within Olympic National Park (located in the state of Washington). Before construction of Elwha and Glines Canyon dams in the early 1900s, the Elwha River provided 75 miles of habitat for several species of salmon and steelhead. The river and salmon were the basis of the Lower Elwha S'Klallam Indian tribe's food, culture, history, and economy for generations. As shown on the map, the tribe, as well as others, still use the lower portion of the Elwha River today.

The two dams on the Elwha River (shown on the map) currently block migration of salmon and reduce the number of miles of salmon habitat from 75 miles to 5 miles of river below Elwha Dam. The dams were built without any fish passage-ways such as fish ladders, and migrating fish cannot get around or over the dams.

The remaining five miles of river still provide some fish for recreational, commercial, and tribal anglers. The section of the Elwha River between the dams provides rafting opportunities. Unlike most rivers in the U.S., the majority of the Elwha is in natural condition because most of it is located in a federally protected National Park. Therefore, the Elwha River would provide excellent fish habitat.

The Elwha River Today



Recently, the National Park Service, other federal and state natural resource management agencies, the Lower Elwha S'Klallam tribe, and the owners of the dams have reached a preliminary agreement to consider: (1) removal of the dams; (2) restoration to natural condition of the two sections of the river affected by the dams; (3) provision of substitute sources of electricity to the company that uses all the power from the dams.

This preliminary agreement resulted in Congressional passage of the Elwha River Ecosystem and Fisheries Restoration Act to:

(1) **study** removal of the dams;

(2) maintain water quantity and quality to municipal and industrial users by drilling additional water wells or by water treatment, if necessary. Flood protection to downstream rural residents living along the river is also recommended.

Your answers to this survey will be used as input to federal agencies examining dam removal.

1. Have you read or heard about the decline in salmon populations in the United States?

   (circle one) YES NO

2. Prior to receiving this survey, had you read or heard about proposals to remove dams to improve fish habitat?

   (circle one) YES NO

3. Prior to receiving this survey, had you read or heard about plans to remove dams from the Elwha River to aid salmon migration?

   (circle one) YES NO

   If YES, please check all the information sources that apply:

   __ Newspaper Radio __ Magazines __ Visiting the area

   __ Friends, Neighbors TV __ Other, please specify ____________________

4. Compared to other environmental issues, how important is protecting rivers to you?

   (circle one) a. More important b. Just as important c. Less important d. Not sure

What Do Rivers Such as the Elwha Mean to You?

Think about why rivers such as the Elwha River might be important to you. The statements below summarize some possible reasons. How important is each reason to you?

Circle One Number for Each Reason

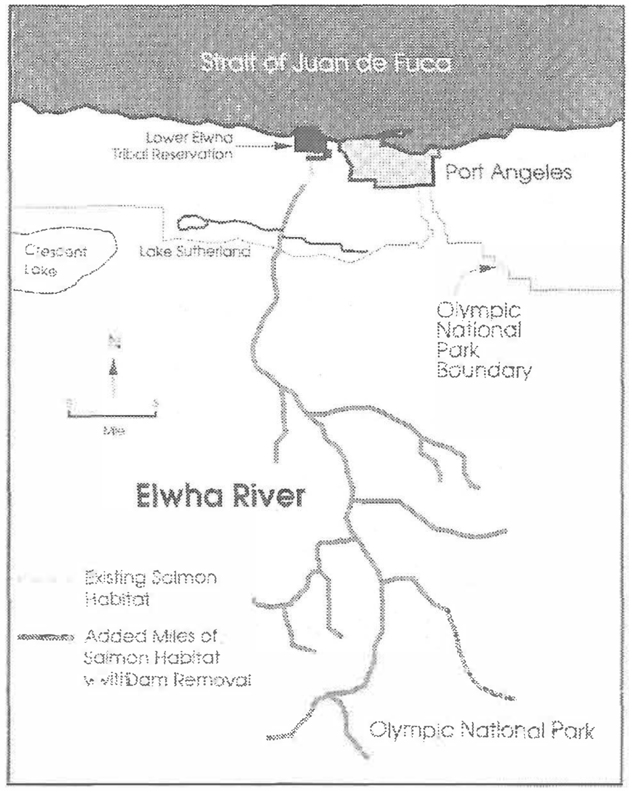
Reasons	Not Important	Slightly Important	Important	Extremely Important
1. To provide recreational opportunities		2	3	4
2. As a source of electricity		2	3	4
3. As habitat for fish		2	3	4
4. As habitat for birds and other wildlife		2	3	4
5. As a water supply		2	3	4
6. For its scenic beauty		2	3	4
7. To provide Native Americans with their traditional fishing areas		2	3	4
8. As a source of jobs		2	3	4
9. To know that future generations will have rivers with fish		2	3	4
10. As a source of inspiration		2	3	4

REMOVAL OF DAMS AND RIVER RESTORATION

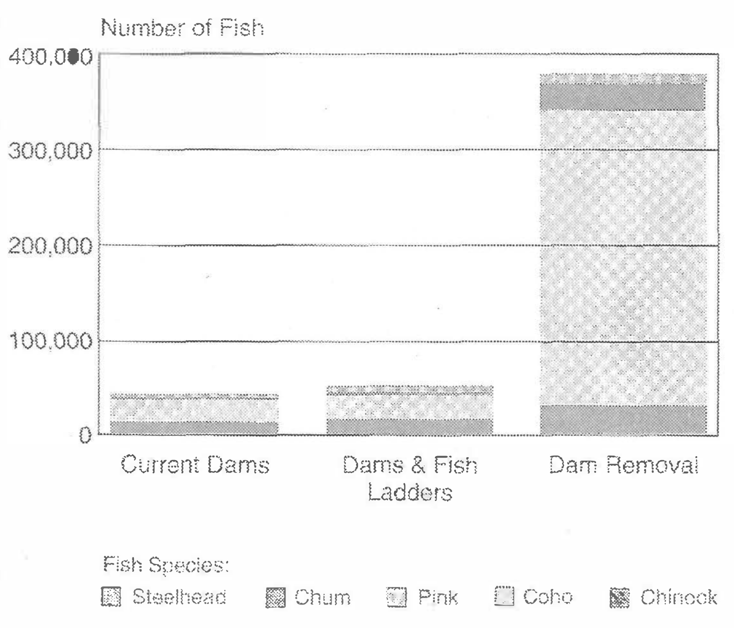
Scientists working on the Elwha River have concluded that removal of the two dams that currently block fish passage would make 70 more miles of the Elwha River available for salmon spawning. These restored miles of stream are shown on the map in dark blue. Since nearly all of these 70 additional miles of river are within Olympic National Park, they are in a natural condition and protected from any future development.

While removal of the dams will result in the loss of the two lakes formed by the dams, there are two other lakes nearby to provide lake recreation. Residents downstream of the dams to be removed will be provided with flood protection by a combination of measures including raising the existing levees. The electric power will be replaced primarily by expanding energy conservation programs for buildings and using other existing energy sources such as hydropower, geothermal, and natural gas. If needed, several new wells would be added and other measures taken to prevent any reduction in the quantity and quality of water to the city of Port Angeles and industrial users.

The Elwha River Without Dams



Estimated Salmon and Steelhead Populations From Elwha River With and Without Dams in Year 2014



Because Glines dam is more than 200 feet (20 stories) high and the canyon is very narrow at this point, fisheries biologists have concluded that fish passage facilities such as fish ladders would be relatively ineffective. Therefore, the addition of fish ladders or other fish passage facilities to the dam would result in only moderate increases in steelhead and chinook salmon from current conditions and little or no increase in other species. This can be seen by comparing the bars labelled **Current Dams** to **Dams & Fish Ladders** in the chart.

The bar labelled **Dam Removal** shows that restoration of the Elwha River ecosystem is expected to increase the number of salmon and steelhead by more than 300,000 by the year 2014. This large increase in several types of salmon would benefit fisherman as well as wildlife that feed on salmon, such as bald eagles.

FEASIBILITY AND COST OF DAM REMOVAL AND RIVER RESTORATION

When the U.S. Congress passed the Elwha River Ecosystem and Fisheries Restoration Act, it directed the Secretary of Interior to investigate whether removing dams on the Elwha River was necessary to restore the native fish populations and the ecosystem. Congress also asked the Secretary of Interior to determine whether dam removal is feasible. As stated in the final Elwha Report submitted to Congress, *"As a result of these investigations, the Secretary (of Interior) has determined that removal of both the Elwha and Glines dams is the only alternative that would achieve the goal of full restoration of the Elwha River ecosystem and native fisheries."* The report further stated that removal of the dams, while at the same time protecting downstream water users, is feasible.

Cost of Dam Removal

Removing the two dams so that fish can migrate upstream, restoring sections of the river that have been flooded by the two dams, and replacing the hydropower with electricity produced from other existing hydropower, geothermal, and natural gas will have substantial costs. Most of the costs would be incurred during the next 10 years.

To generate enough money to fund dam removal and restoration, various government agencies and several user groups, including recreation visitors, may be asked to share the costs.

Because Glines Dam is in a federally owned National Park, all U.S. households would also need to pay a **share** of the costs to generate enough revenue to fund removal of the dams and river restoration. This share would be paid by federal taxes over a ten year period and would end in the year 2005. The money raised could only be used for the Elwha River dam removal and river restoration.

What Do You Think?

As Congress begins to balance the benefits and costs of dam removal on the Elwha River, it is important that your views be known.

If a majority of people are not willing to pay the cost of dam removal, the dams would remain. Fish populations would be as shown in the bar chart under the **Dams & Fish Ladders** alternative.

If a majority of people agree to pay the costs, the dams would be removed, the river would be restored to a natural state, and fish populations would increase as shown in the bar labelled **Dam Removal.**

1. If an increase in your federal taxes for the next 10 years costs your household $_________ each year to remove the two dams and restore both the river and fish populations would you vote in favor?

   (please circle) YES NO

   If YES go to Question #1 in **Section II** in the **middle** of the next page.

   If NO go to the top of the next page (Section I) and answer Questions #1 and #2.

SECTION I

Instructions: If you voted NO please answer these next two questions. (If you voted YES, go to Section II below on Recreation Visitation).

1. We are interested in the main reason you voted NO. Please read all the reasons and then check just the **one**, most important reason below.

____ Removing the dams, restoring the river, and increasing fish populations is not worth this much money to me.

____ I cannot afford to pay this amount of money.

____ It is unfair to expect me to pay to remove the dams.

____ Dam removal would not work to increase fish populations on the Elwha River.

____ I want the dams to remain on the Elwha River because of the benefits the dams provide.

____ The dams should be removed but paid for from existing taxes.

____ I am opposed to paying for new government programs.

____ Other, please explain____

2. If the cost to your household was $1 per year to remove the dams, restore the river, and increase fish populations as shown in the graph, would you vote in favor? YES NO

(Go to Section II.)

SECTION II. RECREATION VISITATION

1. Have you visited any National Parks in 1994? YES NO

2. Have you ever visited Olympic National Park? YES NO

   If YES, about how many trips have you made so far in 1994? # of Trips

3. Have you ever been to or visited the Elwha River? YES NO

   If YES, about how many trips have you made so far in 1994? ______ # of Trips

4. If dams were removed from the Elwha River and it was fully restored to its natural condition, would it change how often you would visit the Elwha River? I would go: (check one)

   More often—> # ______ New or additional trips each year

   Less often—> # ______ Fewer trips each year

____ No change

   Don't know

5. If dams were removed from the Elwha River and it was fully restored, would it change how often you would visit **Olympic National Park**? I would go: (check one)

   More often—> # ______ New or additional trips each year

   Less often—> # ______ Fewer trips each year

____ No change

   Don't know

About You

These last few questions will help us in evaluating the representativeness of our sample. YOUR ANSWERS ARE STRICTLY CONFIDENTIAL AND WILL ONLY BE USED FOR THE ANALYSIS OF THIS STUDY. YOU WILL NOT BE IDENTIFIED IN ANY WAY!

1. Are you: Male Female

2. What is your zip code? ____________________

3. What is your age? _______ # of Years

4. Did you vote in the last election? YES NO

5. How long have you lived in your current state of residence? ______ # of Years

6. Have you gone fishing in 1994? YES NO
   If YES—> Approximately how many fishing trips so far in 1994? ______ # of Trips
   If NO—> Have you ever gone fishing? YES NO

7. Have you gone hiking or camping in 1994? YES NO

8. Are you currently a member of a conservation or environmental organization? YES NO

9. Is your ethnic background (circle one):

   a. Native American Indian
   b. White or Caucasian
   c. Black or African-American
   d. Hispanic or Latino
   e. Asian
   f. Other ________________________

10. What is the highest **year** of formal schooling you have completed? (circle one)

1 2 3 4 5 6	7 8 9	10 11 12	13 14 15 16	17 18 19 20
(Elementary)	(Jr. High)	(High School)	(College or Technical School)	(Graduate or Professional School)

11a. How many people are there in your family or household sharing the same budget? ______ # of People

11b. Of these people, how many earned money last year? ______ # of People

12. Including these people, approximately what was your household income (before taxes) last year? (check one)

less than $10,000	$40,000-49,999	___ $80,000-89,999
$10,000-19,999	$50,000-59,999	___ $90,000-99,999
$20,000-29,999	$60,000-69,999	___ $100,000-149,999
___ $30,000-39,999	___ $70,000-79,999	___ over $150,000

Thank you for completing the survey! If you have any additional thoughts on fish or river management please feel free to write them down on the back cover. When you are finished, please put the survey in our **stamped** return envelope and mail it back to us.