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Recreation Value of Water to Wetlands in the San Joaquin Valley: Linked Multinomial Logit and Count Data Trip Frequency Models

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The recreational benefits from providing increased quantities of water to wildlife and fisheries habitats is estimated using linked multinomial logit site selection models and count data trip frequency models. The study encompasses waterfowl hunting, fishing and wildlife viewing at 14 recreational resources in the San Joaquin Valley, including the National Wildlife Refuges, the State Wildlife Management Areas, and six river destinations. The economic benefits of increasing water supplies to wildlife refuges were also examined by using the estimated models to predict changing patterns of site selection and overall participation due to increases in water allocations. Estimates of the dollar value per acre foot of water are calculated for increases in water to refuges. The resulting model is a flexible and useful tool for estimating the economic benefits of alternative water allocation policies for wildlife habitat and rivers.

INTRODUCTION

A frequent problem faced in water hearings and allocation decisions is a lack of information about the economic value of water for maintenance of wetlands for recreational uses. This lack of economic value information has been apparent in the Bureau of Reclamation's refuge water supply environmental impact statement (EIS) in California where few estimates of the value of water in specific environmental uses were available. State agencies such as departments of fish and game also need this information in forming wetland habitat acquisition and management strategies. More efficient allocation of water might be facilitated if information on the economic value of water in environmental uses was available to decision makers.

To help fill this void in information, this paper develops linked models of recreation site choice and trip frequency to quantify the economic benefits of water to wildlife viewers, anglers and waterfowl hunters in the San Joaquin Valley. These recreation benefits are then related to alternative water allocations to National Wildlife Refuges and State Wildlife Management Areas in the San Joaquin Valley. We first describe the model structure, then the data sources and statistical estimation of the models and finally the simulation results.

MODELING SITE SELECTION AND TRIP FREQUENCY

The concern of this study is to model the demand for waterfowl hunting, fishing and wildlife-viewing trips to destinations in the San Joaquin Valley. This is a problem of modeling choices involving alternative destinations, activities and frequency of participation.

Several types of models have been used for recreational demand at alternative sites, including systems of demand equations [*Burt and Brewer*, 1971; *Cicchetti et al.*, 1974], varying parameter models [*Vaughan and Russell*, 1982], the hedonic travel cost model [*Brown and Mendelsohn*, 1984], and share models of demand [*Bockstael et al.*, 1985]. Most of the past recreation demand studies evaluate either increases in current users visitation rates with improved quality or the likelihood of visiting the improved site. Either approach by itself is an incomplete representation of total demand effects and therefore understates the change in total recreation benefits from an increase in water quantity or quality. The contribution of this paper is to present a model that reflects both increased number of visitors selecting a particular wetland and increased trip frequency in response to increased water supply to wetlands. First we turn to modeling the site selection portion of the overall model.

The Multinomial Logit Model for Site Selection

A relatively simple and widely used share model is the multinomial logit (MNL) model developed by *McFadden* [1974]. Consider the problem of choosing between J discrete alternatives. Given that a trip is to be taken, an individual's problem is to select the particular site which maximizes utility at that time. The utility received if the jth alternative is chosen is assumed to be $U_j = V_j + \varepsilon_j, j = \{1, 2, \cdots, J\}$, where V_j is the nonstochastic portion of the indirect utility received during choice occasion t if site j is visited. McFadden has shown that if the ε_j are independent and identically distributed extreme value type I random variables the probability (Prob_j) of choosing the jth alternative will be

$$\text{Prob}_j = \frac{\exp(V_j)}{\sum^{J} \exp(V_k)} \qquad (1)$$

selecting among a set of sites is to assume that the direct utility an individual receives from consuming a trip to site j during the tth choice occasion is $U_{tj} = V_{tj}(Y_t - P_j, Q_j) + \varepsilon_{tj}$, where Y_t is the available income at period t, P_j is the cost of visiting site j, Q_j is a vector of attributes of the jth site, and ε_{tj} is a random disturbance.

From *Hanemann* [1982], the expectation of indirect utility at the tth period is given by

$$E[U_t] = \ln\left(\sum_{j=1}^{J} e^{V_{tj}}\right) + C \tag{2}$$

In words, (2) states the expected utility on any given choice occasion t is the sum of the utility obtained from visiting any given site times the probability of visiting that site. In this equation, C is a constant. Expected total utility conditional on total trips is the sum over the number of trips of the utility in each period, where the number of periods is determined exogenously. Expected total utility can be used to define one of several possible welfare measures for the effect of price and quality changes at the sites. Let CV* be the dollar payment for individual i such that

$$\sum_{t=1}^{t=T} E_U[U_{it}(P',\ Y - \text{CV}^*,\ Q')] = \sum_{t=1}^{t=T} E_U[U_{it}(P,\ Y,\ Q)] \tag{3}$$

where P is the J vector of initial site prices, Q is the J vector of initial site attributes, P' are final prices, Q' are final site attributes and T is the number of choice occasions in which a trip was taken to any of the available sites taken during the season. CV* is the amount of income taken away for the price and quality changes that would set total (conditional on T trips) expected utility with the changes equal to expected utility without the changes. CV* is one particular measure of willingness to pay.

The last step to making this an operational econometric model of site selection is to choose the functional form of the V_{tj}. Perhaps the most commonly applied functional form is the linear conditional indirect utility function,

$$V_{tj} = \alpha_j + \beta(Y_t - P_j) + \gamma Q_j \tag{4}$$

Equation (4) is combined with (1) to construct the likelihood function to be estimated.

The linear form in (4) has the advantage of tractability, but it does imply several assumptions about the choice process [*Creel and Loomis*, 1991]. One assumption of note is the marginal utility of income is constant and equal to β. Income drops out as a factor in the selection between sites, because the site probabilities are homogeneous of degree zero in income (and any other factor which does not vary by site).

A further limitation of the multinomial logit model, which is unrelated to the functional form of the V_{tj}, is that the relative probabilities of any set of two alternatives are unaffected by the alternatives excluded from the set. This property is known as the independence of irrelevant alternatives and is often illustrated with the famous red bus–blue bus problem [see *Maddala*, 1983, pp. 61–62]. The nested alternatives and thus does not share the independence of irrelevant alternatives characteristic of the MNL model. As will be discussed later, this nested model structure was tried but added little in terms of explanatory power as measured by changes in the log likelihood.

Linking MNL Site Selection and Trip Frequency

The MNL model takes the total number of recreation trips as exogenous to the site selection problem. Several authors [*Feenburg and Mills*, 1980; *Caulkins and Bouwes*, 1982; *Morey et al.*, 1991] have employed models which treat the trip frequency problem and the site selection problems jointly as a series of discrete choices. *Bockstael et al.* [1985] note that it is not necessarily desirable to have total participation be the sum of a series of independent decisions to participate, which is the case in the empirical works noted. This criticism is related to the criticism of the linear functional form for the MNL model noted above.

An alternative method is to model trip frequency separately from the site selection model, and to use the trip frequency model to predict the total number of choice occasions. This approach treats trip frequency as if it were the result of a preseason decision regarding total participation. This allows for a pattern of interdependence between choice occasions. Since welfare changes at each choice occasion are available from the MNL site selection model, total seasonal welfare measures can be obtained by combining the trip frequency model's prediction of trips with the site selection model's per trip welfare measures (from (3)). Combining (2) and the linear specification of the conditional indirect utility function given in (4), one obtains total seasonal compensating variation conditional on T trips (CV* defined above), as

$$\text{CV}^* = \left\{-T\left[\ln\left(\sum_{j=1}^{j=J} \exp\,[V_j(p',\ q')]\right) - \ln\left(\sum_{j=1}^{j=J} \exp\,[V_j(p,\ q)]\right)\right]\right\}\beta_p^{-1} \tag{5}$$

where p' and q' are the postchange prices and qualities of the sites, and p and q are the initial prices (e.g., travel costs) and qualities. Here, β_p is the price coefficient, which is the negative of the marginal utility of income (which one may recall is constant given the linear specification of the conditional indirect utility function). In essence, (5) defines CV* as difference in expected utility with a price and/or a quality change divided by the marginal utility of income. The summation over T which is seen in (3) disappears because $E(U_{it})$ does not depend on T, so that we may use the multiplicative form. Expected total seasonal compensating variation unconditional on T may be found by taking the expectation over T of (5). Let us refer to this measure as CV′. It is obtained by replacing T in (5) by $E_T(T)$. This is the welfare measure used later in this paper.

that we use the trip frequency model to predict total seasonal trips to be combined with the MNL estimates of per-trip benefits to yield total seasonal benefits, accuracy of the trip frequency models predictions is important. Accounting for the nonnegative integer property of the dependent variable will improve accuracy in estimation over distributions which allow negative or fractional values. This implies that the density used to model total trips should have a domain restricted to the nonnegative integers.

Count data models, which are trip frequency models based on probability densities that have the nonnegative integers as their domain, are the logical alternative to censored normals, and have seen a good deal of application recently. Empirical uses of count data models in the recreation demand literature include the works of *Grogger and Carson* [1987], *Smith* [1988], and *Creel and Loomis* [1990].

The Poisson distribution is one of the most simple count data models. The density function for a Poisson random variable z is given by

$$f(z) = \frac{\exp(-\lambda)\lambda^z}{z!} \tag{6}$$

The single parameter of the Poisson distribution is λ which is both the mean and the variance of the distribution of trips. The most common way to use this distribution as an econometric model is to make the parameter λ a function of independent variables, X, and coefficients, β. The usual parameterization is

$$\lambda_i = \exp(X_i\beta) \tag{7}$$

where $i = \{1, 2, \cdots, N\}$ indexes individuals. If the dependent variable is λ, an $N \times 1$ vector, then $E(\lambda) = \exp(X\beta)$, and $V(\lambda) = \exp(X\beta)I$, where I is an $N \times N$ identity matrix. Estimation by maximum likelihood using the Newton-Raphson procedure is convenient and converges readily. Under the null assumptions, the parameter estimates have all of the usual maximum likelihood estimator (MLE) properties, including asymptotic efficiency, consistency and asymptotic normality.

The mean-variance equality restriction of the Poisson model is in some cases not supported by actual recreation data. However, even in this case *Gourieroux et al.* [1984] have shown that because the Poisson density is a member of the linear-exponential family of probability densities, the MLE parameter estimates are consistent estimates of the true parameters even when assumptions are not met, although the variances and hence t statistics may be in error.

DATA SOURCES

Survey Description

Data came from a survey of California residents. The survey started with a map that displayed the location of the five National Wildlife Refuges (NWRs), three state Wildlife Management Areas (WMAs) in the San Joaquin Valley (SJV) and the San Joaquin River (including its tributaries). This map facilitated respondent identification of their specific recreation locations. The survey asked about waterfowl recreation activities, detailed questions were asked about the most recent trip. These questions included location, expenditures and month of this most recent visit. While using the last trip may not always be representative, given the seasons of use in the SJV and the timing of our survey, no systematic bias is likely introduced. The last major section of the survey contained questions regarding demographics of the respondent and the respondent's household.

Survey Administration

The overall sample was split into two groups: one receiving a mail survey and another being interviewed over the telephone. To insure accurate information, the people interviewed over the phone were first sent the same questionnaire as received by people in the mail survey. Thus the second approach will be referred to as the telephone/mail combination approach. The rationale for using both of these approaches related to budget limitations. In order to increase our response rate, we used the *Dillman* [1978] total design method and repeat mailing approach.

The sample frame was carefully designed not only for overall statewide representativeness but also to insure that residents of the SJV were adequately represented in the sample. This was obviously important as SJV residents were the most likely to use the areas for the three recreational activities. Since total recreation benefits of an improvement in wetlands are influenced by entry of new participants, we need data on both current participants and nonparticipants to model the participation decision.

The telephone survey obtained a response rate of 51%, while the mail survey resulted in a 35% response rate of the deliverable questionnaires. Although the mail response rate is somewhat lower than ideal, tests such as chi square on the distribution of responses for participation in waterfowl hunting and fishing between the mail and telephone-mail combination showed no significant differences. In both the multinomial logit models and trip frequency models developed in the next section the mail only and telephone/mail combination survey data were aggregated together, resulting in an overall usable sample of 1141 records that were complete on all variables. As might be expected in a household survey, about two-thirds of the respondents reported zero trips to SJV recreation sites. It is important to include these zeros to avoid truncation bias in the trip frequency model and because these people may become visitors with improved quality of SJV sites.

In addition to the household survey data, information on monthly water flows in rivers and monthly water supplies to the NWRs and WMAs was used. Data on water supply to the NWR's and WMA's were obtained from *Bureau of Reclamation* [1987]. Water supply data were also supplied by the managers of the NWRs and WMAs. River flows were obtained from U.S. Geological Survey gauging station records.

SPECIFICATION OF THE SITE SELECTION AND TRIP FREQUENCY MODELS

The general specification of site selection and trip frequency models must be consistent since the two models are taking a trip to a particular site) which then becomes a variable in the trip frequency model. In this way, the net utility of a trip influences the total number of trips an individual takes in the trip frequency model.

Variables in the Site Selection Models

The site selection models seek to discover the determinants of site choice. Therefore typical explanatory variables are the travel and time costs of visiting the alternative sites, and quality characteristics of the sites. The survey records the zip code of each respondent. Distance to each of the sites was measured by road mileage from the population center of the three-digit zip code where the respondent lived to the sites. Travel cost was computed by multiplying round-trip distance by $0.20 per mile, the average cost per mile from our survey (1 mile equals 1.609 km).

Also expected to be important in site selection are the travel times to the sites, since individuals face a constraint on their allocation of free time in addition to a budget constraint, and recreational trips are relatively time-intensive goods. Unfortunately, a measure of travel time which is independent of distance was unavailable from the survey. As *Smith et al.* [1983, pp. 275–276] note, "until better information on the nature of time constraints facing individuals in their recreation decisions is available, the wage rate provides an equally plausible approximation for the opportunity cost of travel time." While more recent research [*MacKenzie*, 1990] evaluating the noncontinuous nature of labor-leisure trade-offs questions this approach, our survey data limitations require use of the wage rate to value travel time. We proceeded by computing the wage rate of individuals who were working, and used this wage to transform travel time to each of the sites into a monetary cost which was added to travel cost to form total trip cost for the site (the precise definitions of all relevant variables are given below). For individuals for whom we could not calculate a wage rate, including those who did not work, we left travel time out of the specification, since it is perfectly collinear with travel cost. Separate cost coefficients were used for these two groups of individuals (referred to as workers and nonworkers) in both the site selection and trip frequency models.

The other factor expected to be important is the quality of the sites for various recreation activities. We are especially interested in determining the impact of the quantity of water on visitation patterns and economic benefits received. The survey recorded the month of the visit to the site. If we assume that individuals determine which site to visit based on the sites' relative qualities at the time of the visit, a monthly measure of quality should be incorporated into the model.

Monthly data on water flows in the rivers, water applied to NWRs and WMAs, and bird use days at the NWRs and WMAs were used to generate measures of site quality. We expect that participants in wildlife viewing, fishing and waterfowl hunting may place different importance on various attributes, so we also specified models with separate coefficients for the consumptive and nonconsumptive wildlife activities. In this paper we present two alternative specifications: one that pools all participants, referred to as model 1, and another that includes separate coefficients for participants in any form of consumptive activity (fishing or hunting), referred to as model 2.

Water applied to the refuge or water flow in the rivers was a comparable quality variable for both refuges and rivers. In essence water is viewed as the limiting factor in determining the extent of refuge actually in a wetland condition and hence directly related to the amount of habitat. By directly using water as the quality variable the linkage to policy changes which directly involve water is also improved. The specification of the site quality measure (WATERQTY_{ij}) was the amount of water in month i applied (flow) at area j for NWRs and WMAs (or rivers) divided by the peak monthly application or flow at area j over the whole year (details given below). This ratio approach helps net out scale effects between different size refuges and rivers yielding a relative measure which can be meaningfully compared across refuges of different sizes. This measure performed quite well, being consistently significant and of correct sign in all model specifications. In addition, it had the highest contribution to the log likelihood function. When we measure policy-induced changes in water application or flow in any given month, the numerator of this ratio is increased, holding the peak flow or denominator constant. As quality at the jth site increases, the indirect utility of selecting that site increases and hence the probability of visiting that site increases in the site selection model.

In terms of model estimation, the linear specification of the conditional indirect utility function was used in both models 1 and 2. Letting i index individuals, j index sites and t index choice occasions, the conditional indirect utility function was specified as

$$V_{ijt} = \beta_{pw}\text{PW}_{ij} + \beta_{pnw}\text{PNW}_{ij} + \beta_{q}\text{WATERQTY}_{ijt} \tag{8}$$

The variables are defined as follows:

W_i	wage rate, equal to $\text{INC}_i\ \text{HHADULTS}_i^{-1}$ $((2000\ \text{h/yr})\text{PARTIME}_i)^{-1}$;
INC_i	household income;
HHADULTS_i	adult members of the household;
PARTIME_i	variable equal to 1 if individual worked full-time, 0.5 if part-time;
PW_{ij}	price or travel cost of visiting the jth site if wage was calculable, equal to $0.2\text{RTD}_{ij} + W_i\text{RTT}_{ij}/2$ if W was calculated, zero otherwise;
PNW_{ij}	price of visiting the jth site if W_i not calculable; equal to $\text{RTD}_{ij}0.2$, but equal to 0 if PW_{ij} is positive;
RTD_{ij}	round-trip travel distance between population center of three-digit zip code and site j;
RTT_{ij}	round-trip travel time, equal to $\text{RTD}_{ij}/(45\ \text{miles/h})$;
WATERQTY_{tj}	quality of site j during month t, equal to $\text{WATER}_{tj}/\text{PEAK}_j$;
WATER_{tj}	water flow or applied water at site j in month t, $t = \{1, 2, \cdots, 12\}$;
PEAK_j	peak water flow of applied at site j over the year, equal to $\max_t \{\text{WATER}_{tj}\}$, $t =$

likelihood function associated with a MNL model consistent with (8). The indicator variable reflecting which of the 14 sites is visited on the most recent trip is used along with the independent variables in the likelihood function. Thus indirect utility is revealed by which site the individual selects on a particular choice occasion.

Specification of the Trip Frequency Models

The data indicate that some people visiting the SJV engaged in multiple recreation activities on the same trip, e.g., bird viewing and fishing. Thus, we cannot treat their reported total annual trips of the three activity types as if they were discrete and separate trips when measuring the quantity variable in the trip frequency model. Since the site selection model yields benefits per trip, a reasonably accurate prediction of total trips is necessary to predict total benefits received.

Given the three activities we are concerned with there are seven possible distinct combinations of these activities that may be engaged in during a particular recreation trip: viewing, fishing, hunting, viewing and fishing, viewing and hunting, fishing and hunting, and viewing, fishing and hunting. From our data we know that all of these discrete activity combinations are engaged in by at least some people (though the combination of all three activities is quite rare).

We can view the problem of multiple activity trips in the annual data as a case of seven underlying discrete variables that are not observed (i.e., they are latent), though the sums of three particular subsets of them are. Let the 7 × 1 vector $D = \{v, f, h, vf, vh, fh, vfh\}$, where D is for discrete, be the annual number of trips that a person takes of each of the discrete activities. Then the variables V, F, and H, which are total trips during which viewing, fishing, and hunting were participated in, respectively, are defined by

$$\begin{aligned} V &= v + vf + vh + vfh \\ F &= f + vf + fh + vfh \\ H &= h + vh + fh + vfh \end{aligned} \tag{9}$$

These are the variables which the survey recorded.

If we assume a joint density for the underlying vector D, it is a simple matter to find the joint density for $P = \{V, F, H\}$ (P is for participation). Specifically, if we assume that the elements of the vector D are distributed as independent Poisson random variables, the elements of P are also distributed as independent Poisson random variables. Assume that the elements of D are distributed as shown in (10), where λ_d is the number of trips which included participation in activity d:

$$\begin{gathered} v \sim \text{Pois}\ (\lambda_v) \quad f \sim \text{Pois}\ (\lambda_f) \quad h \sim \text{Pois}\ (\lambda_h) \\ vf \sim \text{Pois}\ (\lambda_{vf}) \quad vh \sim \text{Pois}\ (\lambda_{vh}) \quad fh \sim \text{Pois}\ (\lambda_{fh}) \\ vfh \sim \text{Pois}\ (\lambda_{vfh}) \end{gathered} \tag{10}$$

Then the distribution of the elements of P are given by

$$V \sim \text{Pois}\ (\lambda_v + \lambda_{vf} + \lambda_{vh} + \lambda_{vfh})$$

The elements of P are independently distributed, so the joint distribution of the vector P is the product of the distributions of its elements. This is given by

$$\begin{aligned} f(V, F, H) = {} & [\exp\ (-\lambda_v - \lambda_{vf} - \lambda_{vh} - \lambda_{vfh})](\lambda_v + \lambda_{vf} \\ & + \lambda_{vh} + \lambda_{vfh})^V [\exp\ (-\lambda_f - \lambda_{vf} - \lambda_{fh} - \lambda_{vfh})](\lambda_f + \lambda_{vf} \\ & + \lambda_{fh} + \lambda_{vfh})^F [\exp\ (-\lambda_h - \lambda_{vh} - \lambda_{fh} - \lambda_{vfh})] \\ & \cdot (\lambda_h + \lambda_{vh} + \lambda_{fh} + \lambda_{vfh})^H \frac{1}{V!F!H!} \end{aligned} \tag{12}$$

This formulation is convenient, but it does have limitations. First, we are attempting to estimate the parameters of seven demand equations when only three combinations of the goods are observed. We may expect a good deal of variability in the estimators, and a low degree of fit in the model. This problem seems unavoidable, however, given the available data.

Secondly, the elements of D may be thought of as a set of demand equations, where the goods are consumed in nonnegative integer quantities. The Poisson formulation accounts for this feature of the consumption process.

Variables in the Trip Frequency Model

An estimable econometric model may be obtained by parameterizing each of the seven λ as functions of explanatory variables, and maximizing the likelihood function implied by (12). The λ parameters of (12) are the mean participation in each of these seven activities, which must be nonnegative. An often used parameterization is $\lambda = \exp\ (X\beta)$, where X is the vector of predictor variables in the trip frequency model (defined below). Since we are considering seven activities (the elements of D) we need to define seven X_d and seven β_d, such that $\lambda_d = \exp\ (X_d\beta_d)$, $d = \{v, f, h, vf, vh, fh, vfh\}$.

It is clear that λ_d should be a function of a constant and the person's income level. We also expect that it should be a function of the travel costs and travel times to the recreation sites in the SJV, and of the sites' qualities. There are 14 sites included in this study. Clearly, it is impossible to include the travel cost, travel time, and quality of each individual site as separate regressors. Because λ_d is mean participation in activity d it seems appropriate to use a weighted combination of the sites' travel costs, travel times, and qualities.

Recall from the discussion of the site selection models that expected utility per trip is given by (2). The right-hand side of (2) (minus the constant C) is known as the "inclusive value." Thus the inclusive value (IV) is directly related to the expected utility of a trip. Equation (8) show this expected utility per trip is a weighted (where the β are the weights) function of price of the trip (either PW_{ij} or PNW_{ij}) and the quality of the site (WATERQTY_{ij}). Therefore the IV is a weighted combination of travel costs, travel times, and qualities of each of the 14 sites in the multinomial logit model. Hence, IV is a compact way to reflect the influence of these three variables on trip frequency. The IV has been used as an independent variable in several previous studies, including *Bockstael et al.* [1985] and *Carson et al.* [1987].

The variables used in the trips frequency models are as follows:

C a constant term;
INC_i household income;
IV_i annual average of monthly inclusive values;
DV_i a zero-one dummy variable, equal to 1 if person ever views wildlife (not whether they viewed wildlife in the SJV in the last year);
DF_i, DH_i analogous to DV_i, except for fishing and hunting;
$\text{DVF}_i = (\text{DV}_i)(\text{DF}_i)$;
DVH_i, DFH_i analogous to DVF_i;
$\text{DVFH}_i = (\text{DVF}_i)(\text{DH}_i)$.

This series of participation dummy variables (DV_i through DVFH_i) allows for incorporation of the zero quantity observations that frequently occur when performing household surveys. The specification of the ith person's conditional mean participation in the discrete activity combinations is given by

$$\lambda_{vi} = \text{DV}_i[\exp\,(X_i\beta_v)] \tag{13a}$$

$$\lambda_{fi} = \text{DF}_i[\exp\,(X_i\beta_f)] \tag{13b}$$

$$\lambda_{hi} = \text{DH}_i[\exp\,(X_i\beta_h)] \tag{13c}$$

$$\lambda_{vfi} = \text{DVF}_i[\exp\,(X_i\beta_{vf})] \tag{13d}$$

$$\lambda_{vhi} = \text{DVH}_i[\exp\,(X_i\beta_{vh})] \tag{13e}$$

$$\lambda_{fhi} = \text{DFH}_i[\exp\,(X_i\beta_{fh})] \tag{13f}$$

$$\lambda_{vfhi} = \text{DVFH}_i[\exp\,(X_i\beta_{vfh})] \tag{13g}$$

where $X_i = \{C, \text{INC}_i, \text{IV}_i\}$.

As in the case of the site selection models, we estimated two specifications of the trip frequency model. Model 1 pools all of the seven discrete activities together, so that all of the β_d are set equal to each other. This corresponds to the first site selection model, where all activities were pooled together. The inclusive value is calculated using the coefficients of the first site selection model. Model 2 pools the β_d of all of the consumptive activities, but estimates a separate β for the activity of viewing only. It uses the coefficients of the second site selection model to calculate IV_i.

Thus the site selection and trip frequency models are grouped together into two alternative overall specifications of the site selection/trip frequency decision process. Specifically, if the MNL model estimates separate coefficients for consumptive and nonconsumptive users, so does the corresponding trip frequency model. Thus the models are linked logically, as well as statistically because each of the trip frequency models relies on the corresponding site selection model's estimates of individuals' inclusive values.

STATISTICAL RESULTS AND INTERPRETATION

Site Selection Models

TABLE 1*a*. Estimation Results of Multinomial Logit Site Selection Models: Model 1

Name	Estimate	Asymptotic t Statistic
TC (workers)	−0.0173	−6.46
TC (nonworkers)	−0.0621	−4.22
WATERQTY	0.822	3.05
Log L	−347	
Pseudo R^2	0.107	

the estimation results of two specifications of the site selection models. The first specification (model 1) estimates the same coefficients for both consumptive and nonconsumptive recreation. Model 2 allows the coefficients to vary between these two activities. A likelihood ratio test indicates we should accept the null hypothesis of equality of coefficients for consumptive and nonconsumptive recreation in site selection. A more in-depth comparison of these MNL and nested ones for this data can be found in the work by *Creel and Loomis* [1991] and is not repeated here to conserve space.

The pseudo R^2 reported in Table 1 is Cragg and Uhler's pseudo R^2 as discussed by *Maddala* [1983]. This takes the sample proportions visiting each site as the point of reference from which contributions to model fit are measured. Because the site selection models do not contain separate constants for each site, it is possible to obtain a negative R^2, as is seen in the models for nonconsumptive site selection (model 2). As the R^2 values indicate, it is likely that a larger sample of participants would have improved the prediction of the site selection model.

All of the site selection models give correctly signed coefficient estimates for all coefficients (prices are negative and water quantity is positive). The coefficients of models 1 and 2 are in general significantly different from zero, based on the asymptotic t statistics, except for quality in the nonconsumptive portion of model 2.

Trip Frequency Models

The estimation results of the trip frequency models are found in Tables 2*a* and 2*b*. A total of 1141 observations are used in both cases. The two trip frequency models' log

TABLE 1*b*. Estimation Results of Multinomial Logit Site Selection Models: Model 2, Separate Coefficients for Consumptive and Nonconsumptive Uses

Name	Estimate	Asymptotic t Statistic
	Nonconsumptive Uses	
TC (workers)	−0.0168	−3.85
TC (nonworkers)	−0.0384	−1.97
WATERQTY	0.664	1.42
Log L	−115	
Pseudo R^2	−0.0748	
	Consumptive Uses	
TC (workers)	−0.0176	−5.17
TC (nonworkers)	−0.0918	−3.59

TABLE 2*a*. Estimation Results of Count Data Trip Frequency: Model 1

Name	Estimate	Asymptotic t Statistic
C (workers)	−0.941	−13.93
INC (workers)	−0.0141	−0.18
IV (workers)	0.667	23.94
C (nonworkers)	0.125	1.53
INC (nonworkers)	−1.16	−5.17
IV (nonworkers)	0.661	15.77
Log L	−833	
R^2 for viewing	0.0633	
R^2 for fishing	0.0978	
R^2 for hunting	0.0694	

likelihoods are −833 and −784. As these numbers indicate, there is a gain by allowing for different coefficients for nonconsumptive and consumptive users in the trip frequency model. Tables 2*a* and 2*b* also report R^2 values for each of the three activity variables. These measures are defined as 1 minus the error sum of squares over the total sum of squares. One may note that both of the trip frequency models fit roughly equally well, and that none of them fit very well. As noted above, we did not expect a very good fit because we are trying to predict participation in seven mutually exclusive activities or combinations of activities having only observed three general categories of activities.

The coefficients on the inclusive values (reflecting net utility of taking a trip) are all of the correct sign (positive), and all are strongly significantly different from zero. The results for the constants and income are more mixed, but we have no strong prior beliefs about the signs of these coefficients. We should note that these models are all based on the Poisson distribution, and that if the assumptions of this distribution are not warranted, the asymptotic t statistics may well be inflated.

TABLE 2*b*. Estimation Results of Count Data Trip Frequency: Model 2

Name	Estimate	Asymptotic t Statistic
	Nonconsumptive Uses	
C (workers)	−0.408	−2.89
INC (workers)	−0.957	−4.49
IV (workers)	0.696	9.11
C (nonworkers)	−0.745	−3.83
INC (nonworkers)	−0.466	−1.13
IV (nonworkers)	0.645	6.82
	Consumptive Uses	
C (workers)	−1.15	−13.35
INC (workers)	0.292	3.22
IV (workers)	0.664	17.56
C (nonworkers)	0.769	8.26
INC (nonworkers)	−1.33	−4.31
IV (nonworkers)	0.665	13.35
Log L	−784	

BENEFIT MEASUREMENT AND POLICY ANALYSIS

Defining the Welfare Measure

Total utility is the product of utility per trip times the number of trips. Our use of a separate site selection model and trip frequency model assumes that utility per trip and total trips are stochastically independent. Thus for both of the general specifications used in this study, the expectation of total utility is the expectation of utility per trip times the expected number of trips. Recall that willingness to pay for a fixed number of trips is given by (5). Further recall that use of the linear conditional indirect utility function in the specification of the site selection models implies the marginal utility of income is constant. This assumption is not too restrictive as Table 3 shows that annual changes in income implied by our benefit estimates range from $150 to $650 per year. The marginal utility of income is probably constant within this range of income change.

We propose a welfare measure that divides the difference in expected utilities with and without the price or quality change by the constant marginal utility of income. Let p, q, p' and q' indicate site prices and qualities before and after the change, respectively. The per-trip expectation of indirect utility is given by the inclusive value (IV) which is a function of prices and qualities (p, q) in the choice set and the constant of integration C. The expected participation in a discrete activity is given by λ, which is defined as in (13) to be indirectly a function of p and q via IV. Then the dollar value of the total expected change in utility for a discrete activity type is given by CV', defined as

$$CV' = -\{\lambda(p', q')[\mathrm{IV}(p', q') + C] - \lambda(p, q)[\mathrm{IV}(p, q) + C]\}\beta_p^{-1} \quad (14)$$

One may note that (14) closely resembles (5). The differences are that the fixed level of T in (5) has been replaced by the expected level of trips under the two sets of conditions, $\lambda(p', q')$ and $\lambda(p, q)$, and that the constant of integration in (2) no longer drops out, because $\lambda(p', q')$ is not equal to $\lambda(p, q)$.

This welfare measure is for participation in any one of the seven discrete activity types. Because the levels of participation in each of the seven activity types are specified as stochastically independent, the total expected welfare change for an individual is the sum of CV′ over each of the seven discrete activity types. Of course, some individuals do not participate in any or some of the seven discrete activities. In this case, the model assigns a zero level to $\lambda(p', q')$ and $\lambda(p, q)$ (through the dummy variable in (13)) so that CV′ is zero for the activities that are not participated in.

One should note that this welfare measure is based on individuals' predicted or expected usage of the recreation sites, not actual usage in the period of the sample. When we examine changes in qualities, we need to account for the fact that individuals' participation levels at the particular site we are changing have not actually been observed at the contemplated changed levels of qualities (although participation of other individuals at different SJV sites that have a higher quality level is observed). Those who did not visit a particis reasonable to base a welfare measure on expected behavior, rather than the realized level of participation in a given time period.

Estimated Total and per-Participant Benefits in the Sample

Table 3 presents estimated per-participant use values for each of the activity types. A participant in an activity is defined as a person for whom the relevant dummy variable in (13) is positive. The values in the table are the sample average of estimated total values for each discrete activity divided by the number of participants in each discrete activity, which differ by activity. Estimated total use benefits were calculated by raising the prices of each site to a choke price such that there was virtually no predicted visitation to any site for any individual. Note that for an individual who participates in multiple activities, total benefits are the sum of benefits from all discrete activities participated in. We present the results for each of the two models estimated.

In general, the model that has separate coefficients for nonconsumptive and consumptive activities (model 2) results in higher use benefits for the nonconsumptive activity, and lower benefits for consumptive activities, than does the model which imposes cross-activity coefficient equality (model 1).

Sample Expansion to Total Recreation Benefits

In order to calculate the total benefits received by all potential visitors to these 14 sites it is necessary to expand the sample results to the population. The usual way this is done is to multiply the sample benefits by the inverse of the sampling rate. This, of course, puts a premium on the sample representativeness and statistical precision of the sample.

Before the sample expansion factor can be calculated we must adjust for the fact we obtained survey response rates of 35% to the mail and 51% to the telephone. If we take a conservative approach and assume that nonrespondents to the survey are also nonparticipants in wildlife viewing, fishing and hunting, we will understate recreation benefits. Nevertheless, we will adopt this conservative assumption here.

The next factor is whether to expand the sample to account for all households in California or just those residing in the SJV. While the samples were of all residents in California, both demand models (site selection and trip frequency) are credible models primarily for choices within the SJV. Competing substitute sites for southern California households are not explicitly modeled, although their presence is reflected in the reduced number of trips southern California households take to the SJV, as compared to other sites in California. However, if we expand to just SJV households this is overly conservative as we know that a substantial number of visitors to the SJV sites live outside the SJV. To ascertain which sample expansion area to use, we compared the resulting expanded visitation totals to published statistics on viewing, fishing and waterfowl hunting in the San Joaquin Valley developed by the *U.S. Fish and Wildlife Service* [1989], *Cooper and Loomis* [1988, p. 15] and the *Bureau of Reclamation* [1987]. Unfortunately, such comparisons did not provide a clear-cut resolution as to which sample expansion factor to use.

TABLE 3. Per-Participant Use Benefit Estimates by Activity (Dollars)

	Current Water Quantity		Optimum Water Quantity	
Activity	Model 1	Model 2	Model 1	Model 2
Viewing	128	152	150	173
Fishing	137	126	161	149
Hunting	159	149	185	174
Viewing/fishing	403	405	478	471
Viewing/hunting	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 4. Total Wildlife/Fisheries Recreation Benefits for Three Activities at 14 San Joaquin Valley Wildlife Areas and Rivers

Activity	Model 1	Model 2
Viewing	37	44
Fishing	34	32
Hunting	7	7
Total	78	83

Values are millions of dollars, computed as annual benefits based on the SJV residents sample expansion factor.

Given the uncertainty about which sample expansion to use, the benefit estimates for current quality conditions will be developed for both California-wide and SJV only sample expansion factors. The total recreation benefits under existing water quality for each of the two model specifications are shown in Table 4.

As can be seen from this table, the annual benefits are between $78 and $83 million in 1989 dollars (estimated using just the SJV sample expansion factors). Using the California-wide sample expansion these totals would be $895 million and $1 billion dollars. While the exact split of the benefits between viewing and fishing in Table 4 does vary somewhat by model type, the total benefits are within a few percentage points across models. Given the specificity of the data, we can conclude that the model structure is not a major determinant of the benefit estimates. That is, the estimate of total recreation benefits is relatively robust across model specification. Therefore model 1 will be emphasized in the following policy simulations.

Benefits of Increasing Water Flow to Wildlife Refuges/Management Areas and Rivers

The first simulation involved estimating the benefits of providing what fish and wildlife biologists considered to be optimum water supplies to the seven refuges and wildlife management areas in the SJV. The monthly pattern of water increases was obtained from the Bureau of Reclamation's refuge water supply investigations [*Bureau of Reclamation*, 1987] and is formally known as "supply level 4" in the November 1987 draft. This supply level involved increasing water supplies to all seven areas by a total of 62,880 acre feet (7.743×10^7 m^3) over the course of the year. This change in water quantity is incorporated into the MNL site selection also increases the magnitude of the inclusive value (i.e., net utility of a trip) variable that is included as a predictor in the trip frequency model. Hence total number of trips to the improved sites increases as well. Water quantity here is acting somewhat as a proxy for acres of wetland habitat and therefore viewing and waterfowl hunting quality. Table 3 compares per-participant benefits under existing water supply and the optimum supplies.

Given the increased benefits per visitor and the associated increase in number of visitors, we can calculate the increase in total benefits associated with increasing water and then express it on a per acre foot basis. For example, the 62,880 acre feet (7.743×10^7 m^3) of water allocated to the seven NWRs and WMAs would yield an increase in total recreation benefits of about $19 million dollars annually (if the sample benefits are expanded using the conservative SJV sample expansion factor). This equates to about $303 per acre foot of water (again using the conservative sample expansion factor, or a value about 10 times this if the sample is expanded to all California visitors to the SJV). Even the more conservative value is about double what the California State Water Bank paid farmers for their water so it can be reallocated to municipal and industrial uses in 1991. This value is also larger than recent estimates of the agricultural value of water in the SJV which are in the range of $67–119 per acre foot [*Berck et al.*, 1991].

But more important than the dollar values per se is the ability of this model structure to evaluate changes in water allocations between environmental uses. Of all of the refuges reviewed, Kern and Pixley in the Kern-Tulare Basin have some of the least dependable water supplies. In recent years these refuges have received either no supplemental water at all or a very small fraction of their optimum water supply (as identified in the Bureau of Reclamation refuge water supply investigation). We therefore evaluated increasing the water supply to just these two refuges to optimum. This requires 21,050 acre feet (2.595×10^7 m^3) of water spread over the year (with most of the water being used in the fall and late spring). This results in recreation benefits of about $7.34 million annually, with a value per acre foot of $348 (again using the conservative sample expansion factor). More important than the absolute dollar amount for this policy simulation is the relative value of water to these two refuges can be compared to the seven refuges as a whole. With about one-third of the 62,800 acre feet (7.743×10^7 m^3) going to these two refuges, they account for about 40% of the benefits. Thus our model structure can help determine the benefits of directing water to specific refuges (even down to specific months) so as to maximize the environmental benefits of a given amount of water.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This paper has discussed policy issues related to and techniques for modeling multiple-site recreation demand models for wildlife-based recreation in the San Joaquin Valley of California. Count data models of trip frequency and multinomial logit models for site selection were linked together. The models were estimated and then used to quantify recreation benefits from wildlife at the 14 SJV sites.

The limitations of the available data make the results of the models and the benefit estimates less precise than desirable. Because of these problems, we used a conservative approach to expanding the sample estimates to total recreation benefit estimates. In spite of this conservatism, we estimated considerable recreation values for wildlife viewing, fishing and waterfowl hunting in the San Joaquin Valley. The estimated increases in recreation benefits which would result from improved habitat conditions implied a recreational value per acre foot of water which is competitive with its economic value in many alternative uses, such as deliveries to agriculture.

An interesting and useful feature of the types of models used in this study is that they allow estimation of the benefits which would result from various allocations among sites and over the year of a given amount of water. This allows one to search for the economically optimal allocation of water over quite a range of alternative release times and locations. Of course, the actual allocation used must take into account biological needs, which have a dynamic impact on economic benefits.

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