A Repeated Nested-Logit Model of Atlantic Salmon Fishing

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Participation and site choice for Atlantic salmon fishing are modeled in the context of a repeated three-level nested-logit model. Consumer's surplus measures are derived for different levels of species availability in the Penobscot River, the most important salmon river in New England. For comparison, six other travel-cost models are estimated. These include restrictive cases of the nested-logit model, a partial demand model, and two single-site demand models. Comparisons across these models indicate the importance of modeling the participation decision, including income effects, and of adopting a nested-logit structure rather than a single-level logit structure.

Key words: Atlantic salmon fishing, nested-logit, travel cost model

Discrete-choice random-utility models are well suited to explain how an individual will choose among a discrete number of alternatives as a function of the costs and characteristics of those alternatives. Such models all share two components. Conditional indirect utility functions are specified for each of the alternatives, and each of these conditional indirect utility functions has a component that is random from the analyst's perspective. If each of the random components is independently drawn from a normal distribution, the model is a probit model; if each of the random components is independently drawn from an extreme value distribution, it is a logit model; and if the vector of random components is drawn from a generalized extreme value distribution, it is a nested-logit model.

In all discrete-choice random-utility models, the deterministic part of the conditional indirect utility function for each alternative is a function of the individual's income, the cost of that alternative and the characteristics of that alternative. Budget exhaustion implies that income and cost for alternative j enter the conditional indirect for alternative j in the separable form of income minus cost of alternative j; i.e., expenditures on the *numéraire* given alternative j is chosen. If expenditures on the *numéraire* enter each conditional indirect in a linear fashion with the same coefficient for each alternative, the probabilities associated with each alternative are not a function of the individual's income and the compensating variation, *CV*, associated with any change in costs or characteristics is equal to the corresponding equivalent variation, *EV*. In this case, the *CV* is not a function of the individual's income. Alternatively, if expenditures on the *numéraire* enter one or more of the conditional indirects in a nonlinear fashion, income effects are present. While logit models of recreational site selection that do not incorporate income effects are quite common, ones that include income effects are rare.[1] Reasons for not including income effects are that it complicates estimation, and the fact that, when income effects are incorporated, the *CV* and *EV* do not have closed-form solutions.

We develop and estimate a repeated three-level nested-logit model that explains, for each individual, both site choice and total number of Atlantic salmon fishing trips in a season. The season is divided into periods such that in each period

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[1] For an early example of a logit model of site choice without income effects, see the appendix in Morey (1981). Probit models of site choice are not common because the probit model becomes empirically intractable when there are more than a few alternatives.

the individual decides, at the first level, whether to fish; at the second level, in which region to fish (Maine or Canada); and, in the third level, at which site to fish in the region. In this sense, our model is a repeated discrete-choice model.[2] Income effects are included because values of environmental amenities are generally believed to be positively correlated with income. A generalized extreme value distribution is assumed (i.e., a nested-logit rather than a logit model) because our alternatives naturally fall into two groups (fishing sites and the nonfishing alternative) and two fishing subgroups (Maine sites and Canadian sites). Our specific generalized extreme value distribution accounts for this grouping by allowing the random components in the conditional indirect utility functions for the fishing alternatives to be correlated more with each other than they are with the random component in the conditional indirect for the nonfishing alternative, and by allowing the random components in the conditional indirects for the Maine (Canadian) fishing sites to be correlated more with each other than they are with the random components in the conditional indirects for the Canadian (Maine) sites. The nested structure is not plagued by the Independence of Irrelevant Alternatives (IIA) property.

To examine the importance of modeling participation, including income effects and nesting the choice structure, six other travel-cost models are also estimated and discussed. These are (*i*) a repeated discrete-choice logit model of participation and site choice with income effects; (*ii*) a repeated discrete-choice logit model of participation and site choice without income effects; (*iii*) a standard logit model of site choice without income effects and in which nonparticipation is not one of the alternatives; (*iv*) a partial demand (share) model of site choice; (*v*) a single-site linear demand function; and (*vi*), a single-site log-linear demand function. Within our set of seven models, the repeated nested model is found to provide the most theoretically and empirically defensible consumer's surplus estimates for changes in species availability.[3]

Recreational Atlantic Salmon Fishery

Maine is the focal point of an active Atlantic salmon restoration and management program. Before the 18th century, Atlantic salmon were abundant in most all coastal rivers and streams in Maine. By 1940, dams, habitat changes, and over-harvest reduced the population to a few hundred adults in several small coastal rivers. However, because of over twenty years and $5 million of restoration programs, the Atlantic salmon populations in Maine currently total 6,000 to 10,000 adults, and sport fisheries have become established on at least nine rivers. Salmon anglers expend 30,000 to 40,000 angler days at Maine rivers, and in recent years they have harvested 400 to 1,200 salmon annually (less than a third of the catch is harvested). Most of the restoration effort, angler activity, and catch in Maine (60–80%) is on the Penobscot River near Bangor, Maine. Recently, the U.S. Fish and Wildlife Service (1989) issued an Environmental Impact Statement (EIS) to continue to develop Atlantic salmon fisheries on the Penobscot River and 10 other New England rivers, with an annualized federal spending in excess of $6 million for 33 more years. The goal is to more than double the number of adult fish, catch, and angler days (Rowe, Michelson, and Morey).

Controversy has arisen about the value and management of Atlantic salmon in connection with the operation of hydroelectric facilities, as these facilities may block fish passage or otherwise impair salmon restoration.[4] The allocation of efforts to restore Atlantic salmon fisheries at competing rivers in New England is also controversial because many anglers feel that the efforts should be more widely distributed. While the management of the Penobscot River salmon fishery is of interest, limited work has been conducted to estimate the value of this resource to recreational anglers. Such estimates may en-

[2] Numerous authors have proposed and/or estimated repeated discrete-choice models of recreational demand. See Feenberg and Mills, Caulkins, Bishop, and Bouwes (1984 and 1986), Bockstael, Hanemann and Strand. Carson, Hanemann and Wegge, and Morey, Shaw, and Rowe. None, to our knowledge, has estimated a utility-theoretic repeated nested-logit model of participation and site choice that includes income effects. Morey, Rowe, and Shaw, for example, estimate a utility-theoretic repeated model without income effects that is similar but not equivalent to a single level logit model. Carson, Hanemann, and Wegge estimate a repeated nested model with income effects, but the income effects appear to be incorporated in a way that is inconsistent with income constrained utility-maximizing behavior.

[3] Other articles that empirically compare different travel-cost models with the same dataset include Ziemer, Musser, Hill, Morey (1984 and 1985). Caulkins, Bishop, and Bouwes (1984 and 1986), Smith, Desvousges, and Fisher, and Bockstael, Hanemann, and Kling. Comparisons using simulation data have been made by Kling (1988a,b and 1989), and Kling and Weinberg.

[4] The EIS calls for additional fish passage facilities at 105 dams. This has led to opposition to new facilities and movements to remove some existing facilities. For example, American Rivers recently named the Penobscot River among their top 10 endangered rivers due to a proposed new hydroelectric facility.

hance decision making regarding resource management and tradeoff issues. Prior Atlantic salmon recreational fishing valuation estimates vary widely and do not consider the effect of variability in catch rates.[5]

We use data from a 1988 survey of Maine Atlantic salmon license holders (Rowe, Michelson, and Morey). The survey data includes trip-taking records and supporting data for Atlantic salmon trips to rivers throughout Maine and in eastern Canada. Consumer's surplus is estimated for three possible resource changes at the Penobscot River assuming conditions on all other rivers remain unchanged (the model can also estimate values for changes in Atlantic salmon catch rates at other Maine rivers).

1. Eliminate Atlantic salmon fishing at the Penobscot River. This scenario may occur if the restoration program is eliminated.
2. Double the expected catch rate at the Penobscot River.
3. Halve the expected catch rate at the Penobscot River.[6]

The empirical analysis is conducted with data from a random sample of 168 Maine residents who held Maine Atlantic salmon fishing licenses in 1988.[7] Average number of salmon trips was 17.04, and 11.85 of these trips were to the Penobscot River. In total, the sample includes data on 2863 trips. Average household income of respondents was $39,500. About one-third of all anglers surveyed belong to an Atlantic salmon fishing club located near the Penobscot River.

To estimate the travel-cost models, we assume that an individual has the choice of eight distinct Atlantic salmon fishing areas: salmon rivers in Nova Scotia, salmon rivers in New Brunswick, salmon rivers in Quebec, and five separate river groups in Maine. Table 1 presents

Table 1. Sample Characteristics of Trips to Eight Atlantic River Groups

	Maine River Groups					Canada River Groups		
Variable	Machias E. Machias Pleasant Narraguagus	Dennys	Penobscot	Kennebec Androscoggin Sheepscot	Saco	Nova Scotia Rivers	New Brunswick Rivers	Quebec Rivers
Percent of sample trips	19.0%	0.8%	69.7%	4.6%	4.8%	0.2%	0.6%	0.4%
Average catch per trip (Maine trip = 1 day) (Canadian trip = 4 days)	0.048	0.0574	0.1024	0.0739	0.0387	0.9476	3.1433	2.36
Average hours of fishing per fish caught	93.74	96	54	65	124	38	9	17
Average cost per trip (including value of time)	$238.60	$246.40	$137.33	$202.60	$288.20	$805.63	$826.93	$884.86

[5] The draft EIS cited $88/day for on-site use values for Atlantic salmon fishing in Maine, but from unspecified sources. This estimate was dropped in the final EIS (US FWS). Contingent valuation (CV) work for on-site Atlantic salmon fishing use values at the Penobscot river include McLaughlin, and Kay, Brown, and Allee with values of $2 to $3 per day, Rowe et al. with values of $4 to $5 per day, but also citing important vehicle protest anchoring behaviors that suggest these results may be best perceived as lower bound estimates, and Boyle and Teisl with values of $8 to $13 per day, and $140 to $240 per season.

[6] Reduced catch might result from poor success of the restoration efforts, from improved fish passage systems or from the elimination of dams. Existing dams and inefficient passage systems often enhance catch as fish congregate below the dams seeking upstream passage.

[7] Trips by out-of-state anglers were omitted as these trips were often found to be for multiple purposes or to visit multiple sites. This omission reduced the sample of individuals by about 15%, and the sample of trips by about 5%. Valuation results with the full sample are only slightly larger than reported here.

average characteristics of fishing conditions for each river group for the 168 individuals in the sample. All of the rivers in each Maine group are in close proximity and have similar catch rates, which reflects geographic variations in the restoration programs. For most of the Maine groups, fishing occurs at only one or a few very specific sites. The primary fishing site or the center of several sites is used to determine travel distances. We believe this grouping of sites into eight alternatives allows for the most efficient use of the sample data to model participation and the choice among distinct fishing alternatives.

To simplify the analysis, we assume that all the trips to Maine rivers are for one day of fishing, and that all the trips to Canadian rivers are for four days of fishing. While not entirely true, these assumptions accurately characterize the majority of the trips in the sample.

Fishing costs to site j for an individual, p_j, are assumed to include transportation costs; on-site costs such as guide fees and lodging; and travel-time, fishing-time, and additional on-site time (e.g. waiting-time and time when one stays overnight at the site).[8] Fishing costs vary substantially across individuals for a given site and across sites for a given individual. They range from \$29 for a trip to the Penobscot River to \$1,728 for a trip to Quebec. Expenses are higher to visit Canadian rivers because of greater travel distances for Maine residents, longer trips, and higher costs on-site, including mandatory guide fees.

Average observed expenses for trips to different rivers (table 1) reflect the more frequent use of a site by local residents, reducing the variation in observed costs per trip across sites. The variation in expenses across sites is much greater for each individual. A large component of the costs are the value of the individual's time. For example, the average out-of-pocket plus time cost of a trip to the Penobscot River is \$137. Excluding the estimated value of time, this average drops to \$71.

Full income, y, is defined as the opportunity cost of the individual's available time for one year: i.e., $y = 365 \times 12 \times w$, where twelve hours is assumed to be the amount of time available per day for activities other than sleeping, eating, child-care, and so on. For the sample, the estimated full income varies from \$10,483 to \$86,862, with a mean of \$26,365.

Participation and Site Choice with Income Effects

Assume that the salmon fishing season is divided into T periods such that in each period the individual takes, at most, one fishing trip. In each period the individual decides both whether and where to fish. The individual chooses the alternative that provides the greatest utility. The utility the individual receives during period t if he chooses alternative j is

$$(1) \quad U_{jt} = V_j + \epsilon_{jt}, \quad j = 0, 1, 2, \ldots 8$$

where $j = 0$ is the nonfishing alternative, $j = 1 - 5$ are the Maine sites, and $j = 6 - 8$ are the Canadian sites. The term V_j depends on the cost and characteristics of alternative j and is deterministic from both the individual's and the researcher's perspective.

Alternatively, individuals know their own ϵ_{jt}, but the ϵ_{jt}'s vary from period to period and across individuals in a way the researcher cannot observe. Therefore, the ϵ_{jt}'s, and in turn the U_{jt}'s, are random variables from the researcher's perspective.

Assume the ϵ_{jt} are drawn from the following generalized extreme value CDF

$$(2) \quad F(\epsilon) = \exp[-e^{-s\epsilon_0} - [(e^{-s\epsilon_1} + e^{-s\epsilon_2} + \ldots + e^{-s\epsilon_5})^{t/s} + (e^{-s\epsilon_6} + e^{-s\epsilon_7} + e^{-s\epsilon_8})^{t/s}]^{1/t}].$$

This CDF generates a three-level nested logit model of participation and site choice where in each period the individual decides whether or not to fish; if they fish, then at which region (Maine or Canada); and, finally, the site to fish within the selected region (Morey 1993b).

Given the CDF in equation (2), the probability that an individual will choose not to fish in period t is

$$(3) \quad prob_0 = e^{V_0}/e^{V_0} + [(e^{sV_1} + e^{sV_2} + \ldots + e^{sV_5})^{t/s} + (e^{sV_6} + e^{sV_7} + e^{sV_8})^{t/s}]^{1/t}$$

The probability that he or she will fish at river $j (j = 1, 2, \ldots 5)$ in Maine is

$$(4) \quad prob_j = e^{sV_j}[(e^{sV_1} + e^{sV_2} + \ldots + e^{sV_5})^{t/s} + (e^{sV_6} + e^{sV_7} + e^{sV_8})^{t/s}]^{(1/t)-1} \cdot (e^{sV_1} + e^{sV_2} + \ldots e^{sV_5})^{(t/s)-1} / e^{V_0} + [(e^{sV_1} + e^{sV_2} + \ldots + e^{sV_5})^{t/s} + (e^{sV_6} + e^{sV_7} + e^{sV_8})^{t/s}]^{1/t}$$

[8] We adopt the common assumption that per hour opportunity value of time in travel and on-site activities, w, is 1/3 of the individual's total income divided by hours worked.

and the probability that he or she will fish at a river in Canadian province $j (j = 6, 7, 8)$ is

(5)
$$prob_j = e^{sV_j}[(e^{sV_1} + e^{sV_2} + \ldots + e^{sV_5})^{t/s} + (e^{sV_6} + e^{sV_7} + e^{sV_8})^{t/s}]^{(1/t)-1} \cdot (e^{sV_6} + e^{sV_7} + e^{sV_8})^{(t/s)-1} / e^{V_0} + [(e^{sV_1} + e^{sV_2} + \ldots + e^{sV_5})^{t/s} + (e^{sV_6} + e^{sV_7} + e^{sV_8})^{t/s}]^{1/t}.$$

Specifically assume that each $V_j, j = 1, 2, \ldots 8$, is a function of p_j, $Catch_j$ = the average catch rate at j, and ppy (per-period income, which is equal to full income divided by the number of periods) such that

(6) $$V_j = b_0(ppy - p_j) + b_{00}(C + ppy - p_j)^{.5} + b_1(Catch_j) + b_2(Catch_j)^{.5}; \quad j = 1, 2, \ldots, 8.$$

Note that $(ppy - p_j)$ is the amount of income the individual has left to spend on other commodities if he visits site j.[9] If a person does not fish, he will have ppy to spend on other commodities, and

(7) $$V_0 = b_3 + b_0(ppy) + b_{00}(C + ppy)^{.5} + b_4(yrs) + b_5(club) + b_6(age) + b_7(yrs)^{.5} + b_8(age)^{.5}$$

where yrs = the number of years the individual has been salmon fishing; $club$ = 1 if the individual belongs to an Atlantic salmon fishing club located near the Penobscot River (zero otherwise); and age is the individual's age.

If $b_{00} = 0$, $b_0 \neq 0$, the marginal utility of income is a constant and $Prob_j$ is not a function of ppy; i.e. when $b_{00} = 0$, there are no income effects.[10] Most estimated logit models do not allow for income effects, because when income effects are included there is no closed-form solution for the CV or EV. The term $b_{00}(C + ppy - p_j)^{.5}$, where $p_0 = 0$, incorporates income effects by allowing the marginal utility of income to be a simple function of the level of income. Incorporating income reflects that WTP may be dependent upon income, which is consistent with traditional economic theory and empirical findings including those in the present paper.[11]

Given the model, the log of the likelihood function for the 168 Maine residents is

(8) $$\ell = \sum_{i=1}^{168} \sum_{j=0}^{8} y_{ji} * \ln(prob_{ji})$$

where y_{ji}, $j = 1, \ldots, 8$, is the number of trips individual i took to site j and y_{oi} is the number of times individual i chooses not to fish ($y_{oi} = T - \Sigma_{j=1}^{8} y_{ji}$). We specifically assumed that T = 50. We based this assumption on the season length, the average length of trips to Maine and Canadian rivers, and the fact that only a few individuals took more than 50 trips.

The maximum likelihood estimates for this nine-alternative nested-logit model with income effects are (with asymptotic t-statistics in parentheses) b_0 = 0.00219 (0.693), b_{00} = 1.0887 (3.95), b_1 = −1.7492 (−6.28), b_2 = 5.9122 (10.2), b_3 = 8.8502 (11.5), b_4 = 0.09533 (2.60), b_5 = −.80525 (−14.7), b_6 = 0.17015 (9.40), b_7 = −1.2275 (−7.38), and b_8 = −1.8561 (−7.84), s = 1.3071 (15.0), t = 0.61172 (9.91).[12] The included explanatory variables (ppy, yrs, $club$, age, p_1 through p_8, and $Catch_1$ through $Catch_8$) are all significant determinants of the individuals' participation decisions and site selections. A modified R^2 (see Ben-Akiva and Lerman, p. 167) indicates that the model is explaining 66.0% of the variation in trip patterns. A likelihood ratio test indicates that income is a significant determinant of both where and how often the individual fishes.

The probability of visiting a specific river, given that a trip is taken, is a decreasing function of the cost of visiting that river and an increasing function of its catch rate. The probability of not fishing increases as the general cost of fishing increases, as the quality of fishing decreases and as income decreases. For example, the estimated elasticities of predicted number of

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[9] C is a constant that is sufficiently large to guarantee that $(C + ppy - p_j)$ is always positive for every individual in the sample. For estimation, C was set equal to 1,728, the largest price in the sample. Simulation results showed the results are insensitive to the choice of C, as long as it is large enough to guarantee that $(C + ppy - p_j)$ is always positive for every individual in the sample.

[10] When $b_{00} = 0$, per-period income, ppy, cancels out of the choice probabilities, equations (3)–(5), because per-period income just adds the constant amount $b_0 * ppy$ to each of the conditional indirect utility functions.

[11] There are many ways to incorporate income effects. As an alternative to our method of incorporating income effects, one could assume $b_{00} = 0$ and replace b_0 with b_{0j}, $j = 0, 1, \ldots, 8$. Loosely, this alternative approach would allow the marginal utility of income to vary across alternatives. Compared to the approach in this paper, which requires the estimation of one additional income parameter, this alternative would require the estimation of eight income parameters.

[12] A sufficient but not necessary condition for the CDF to be locally well-behaved is $s > t$. The likelihood function was maximized with respect to the parameters using the maximum likelihood procedure in Gauss (Maxlik). Copies of the drive program and data files (NSTL-3LV.CMD, MST4LGT.DAT and MST4LGT.DHT) are available from the first author.

Table 2. Estimated Trips: The Repeated Nested-Logit Model of Participation and Site Choice with Income Effects

Scenario	Statistic	Predicted trips to the Penobscot/Angler/Year
1 Elimination of the Atlantic salmon fishery at the Penobscot River	mean/median	0/0
	range	NA
2 Double catch rates at the Penobscot River	mean/median	13.94/11.77
	range	0.01 to 40.26
3 Halve catch rates at the Penobscot River	mean/median	7.00/4.50
	range	0.0 to 28.35
4 Current conditions	mean/median	9.73/6.90
	range	0 to 34

[a] NA = not applicable

trips with respect to income are all positive but less than one. The probability of fishing is an increasing function of how long the individual has fished, increasing if the anglers belong to a club and decreasing as their age increases. Overall, these results are consistent with a priori expectations.

The estimated probabilities, equations (3)–(5), can be used to predict how many trips individual i will take to the Penobscot River for any combination of costs, income, and catch rates. The mean (and median) predicted number of trips for the three scenarios and the current conditions are reported in table 2. The average number of Penobscot trips in the sample was 11.85, so the model is underestimating how many trips would be taken under current conditions. This is due in part to the imposed constraint of a maximum of 50 predicted trips per individual, whereas a few individuals actually took double this number. Also note the differences between the estimated mean and median values, which is due to a highly skewed distribution of the individual demand estimates.

The estimated multinomial logit model of participation and site choice can be used to determine the expected compensating (and equivalent) variation associated with each of the three different scenarios in which resource conditions are hypothetically changed. For our nested-logit model of participation and site choice, the individual's expected maximum utility in any single period is

$$(9) \quad V = V(ppy, yrs, club, age, \mathbf{P}, \mathbf{Catch}) = \ln[e^{V_0} + [(e^{sV_1} + e^{sV_2} + e^{sV_3})^{t/s} + (e^{tV_4} + e^{tV_5} + e^{tV_6})^{1/t}] + 0.57$$

where $\mathbf{P}$ is the vector of prices, $\mathbf{P} = [p_j]$, $\mathbf{Catch} = [catch_j]$, and 0.57 is Euler's constant. Define $\mathbf{P}^0$ and $\mathbf{Catch}^0$ as the prices and catch rates the individual currently faces. Define $\mathbf{P}^1$ and $\mathbf{Catch}^1$ as the prices and catch rates after a specific policy is enacted. For example, eliminating the current Atlantic salmon fishing at the Penobscot River is equivalent to raising p_1 to infinity, and doubling the Penobscot River average catch rate implies that $\mathbf{Catch}^1_1 = 2 * \mathbf{Catch}^0_1$.

Given this, the expected per-period compensating variation, *PPCV*, associated with any change from $\{\mathbf{P}^0, \mathbf{Catch}^0\}$ to $\{\mathbf{P}^1, \mathbf{Catch}^1\}$ is

$$(10) \quad V(ppy, yrs, club, age, \mathbf{P}^0, \mathbf{Catch}^0) = V(ppy - PPCV, yrs, club, age, \mathbf{P}^1, \mathbf{Catch}^1)$$

Expected per-period compensating variation, *PPCV*, is how much money you would have to give to (or take from) the individual after the policy equal to make expected maximum utility after the policy equal to expected maximum utility in the original state. Expected compensating variation for the entire season, CV, is obtained by multiplying *PPCV* by T.

Alternatively, the expected per-period equivalent variation, *PPEV*, associated with any change from $\{\mathbf{P}^0, \mathbf{Catch}^0\}$ to $\{\mathbf{P}^1, \mathbf{Catch}^1\}$ is

$$(11) \quad V(ppy + PPEV, yrs, club, age, \mathbf{P}^0, \mathbf{Catch}^0) = V(ppy, yrs, club, age, \mathbf{P}^1, \mathbf{Catch}^1).$$

Given the inclusion of income effects ($b_{00} \neq 0$), $CV \neq EV$ and that there are no closed-form solutions for the CV and EV; i.e., equations (10) and (11) cannot be analytically solved for $PPCV(PPEV)$. However, the estimated CV and EV for any proposed policy can be calculated for any individual as a function of exogenous variables in the two states.[13]

[13] We estimated the PPCV for each individual in our sample by using the optimization procedure in Gauss (Optimum) to search for the PPCV, for each individual, that minimized $M = |V(ppy, yrs, club, age, P^0, Catch^0) - V(ppy - PPCV, yrs, club, age, P^1, Catch^1)|$. If such an algorithm is not available, one can calculate an individual's PPCV by calculating M using an ascending (or descending) vector of PPCV values until $M = 0$.

While the income variable is statistically significant, there is little difference between the *CV* and *EV* estimates (less than 2% for the mean and median for all scenarios). Therefore, only the *CV* results are reported in table 3. For example, this model predicts that the individuals in the sample would pay on average $810 to avoid the elimination of current Atlantic salmon fishing conditions at the Penobscot River, and they would each have to receive on average $804 to voluntarily accept the loss of this fishery. Across individuals the *CV* estimates vary from zero to −$3,575, reflecting where the anglers live, their value of time, their age, and whether they belong to a local club. For example, individuals who currently have to incur a large cost to visit the Penobscot River experience little loss, as they rarely fish there and may, in some cases, inexpensively substitute to alternative sites. Individuals who reside nearby can fish often and inexpensively at the Penobscot River and therefore experience a more significant loss.

In table 3 the mean CV (and unreported EV) exceed the median values by 28% to 68% depending upon the scenarios, reflecting the highly skewed distribution of the individual values. Figure 1 plots the frequency of the individual CVs for the elimination of the Penobscot fishery in $100 increments. There is a long tail as a few individuals are predicted to experience very high losses. For example, the average CV for the six individuals with the largest CVs, in absolute terms, for the elimination of the Penobscot is $3436. These individual are all males, all club members with at least ten years of experience, all employed full time, and all have very low costs for taking a Penobscot River trip. These few individuals alone increase the sample mean by 14%.

This distribution is of interest for consumer's surplus estimation derived from travel cost models, but also for other resource valuation methods. For example, one concern in contingent valuation method (CVM) research is that a long tail of large WTP responses may be the result of error rather than of underlying value; this error may significantly upwardly bias the average consumer's surplus estimates (Rowe, Shaw, and Schulze; Mitchell and Carson). CVM practitioners often trim off high WTP responses or use a median value statistic to account for this concern. The findings here, which are based upon revealed rather than hypothetical behavior, suggest underlying value distributions may be highly skewed due to differences in characteristics of individuals. As a result, removing from consideration those individuals with high value responses may be inappropriate. Using a median value statistic may be more robust to variations in the sample and analysis, but this practice diminishes the impact of individuals who value the resource most highly, which is of importance to decision making based upon economic efficiency criteria.

At first glance, the similarity of the CV and EV estimates for a given policy might suggest that including income effects is not of significance. This, however, is not the case. Over the income range in the sample, from $10,000 to $86,000, the CV for the elimination of the current Atlantic salmon fishery at the Penobscot River, for a representative angler, decreases at an increasing rate from −$352 to −$652, or by 85%. Therefore, if the model is used to predict participation or values for situations where income is changed, the means, medians, and ranges will be significantly impacted.

Participation and Site Choice with Income Effects

How important is it to model participation and site choice as a three-level nest? The answer depends on the correlations among the random terms ϵ in the conditional indirect utility functions for the nine alternatives. These random terms are generated by the characteristics of the alternatives that are observed by the individual but not by the analyst. One might expect the random terms for a group of similar alternatives to be more correlated with each other than they are with the random terms for other alternatives. The CDF that generates our three-level nest (equation (2)) accounts for this by assuming (*i*) the random terms in the conditional indirects for the Maine (Canadian) sites are more correlated with each other than they are with the random terms in the conditional indirect for the Canadian (Maine) sites; and (*ii*) the random terms in the conditional indirects for the fishing sites are more correlated with each other than they are with the random term in the conditional indirect for nonparticipation.

The corresponding null hypothesis is that all of the random terms are equally correlated. Such a restriction is imposed by restricting t and s in (2) to equal one. In this case, the nest collapses to one level i.e., to a nine-alternative logit model rather than a nested-logit model. The maximum likelihood estimates for this nine alternative logit model with income effects are (with asymptotic

Table 3. Comparison of Yearly Compensating Variation Measures Derived from Six Different Travel-Cost Models*

		Repeated nested-logit model of participation and site choice w/income effects	Repeated logit model of participation and site choice w/income effects	Repeated logit model of participation and site choice w/o income effects	Standard logit model of site choice w/o income effects and nonparticipation alternative	CES partial demand model of site choice	Single site linear demand function of the Penobscot River
Measure		CV	CV	CV	CV_i	CCV	CV
number of observations		168	168	168	145	145	168
scenario	Statistic						
1 Elimination of the							
Atlantic salmon	mean	−$810	−$764	−$753	−$1455	$1042	$2124
fishery at the	median	−$497	−$451	−$426	−$406	−$355	−$1319
Penobscot River	range	$0 to −$3575	$−0.5 to −$3449	−$0.6 to −$3465	−$0.6 to −$8391	−$4.6 to −$6881	−$4 to −$11,337
2 Double catch rates	mean	$511	$654	$625	$800	$248	NA
at the Penobscot	median	$398	$523	$429	$344	$109	NA
River	range	$0.6 to $1619	$0.5 to $1972	$0.8 to $1920	$1.5 to $3561	$3 to $1360	NA
	mean	−$278	−$307	−$298	−$524	−$245	NA
3 Halve catch rates at	median	−$190	−$203	−$189	−$191	−$84	NA
the Penobscot River	range	$0 to −$1035	−$0.2 to −$1159	$0.3 to −$1142	−$0.4 to −$2586	−$2 to −$1371	NA

* NA = not available, i.e. this scenario cannot be calculated with this model. The results for the single site log-linear demand function for the Penobscot model are only reported in the text.

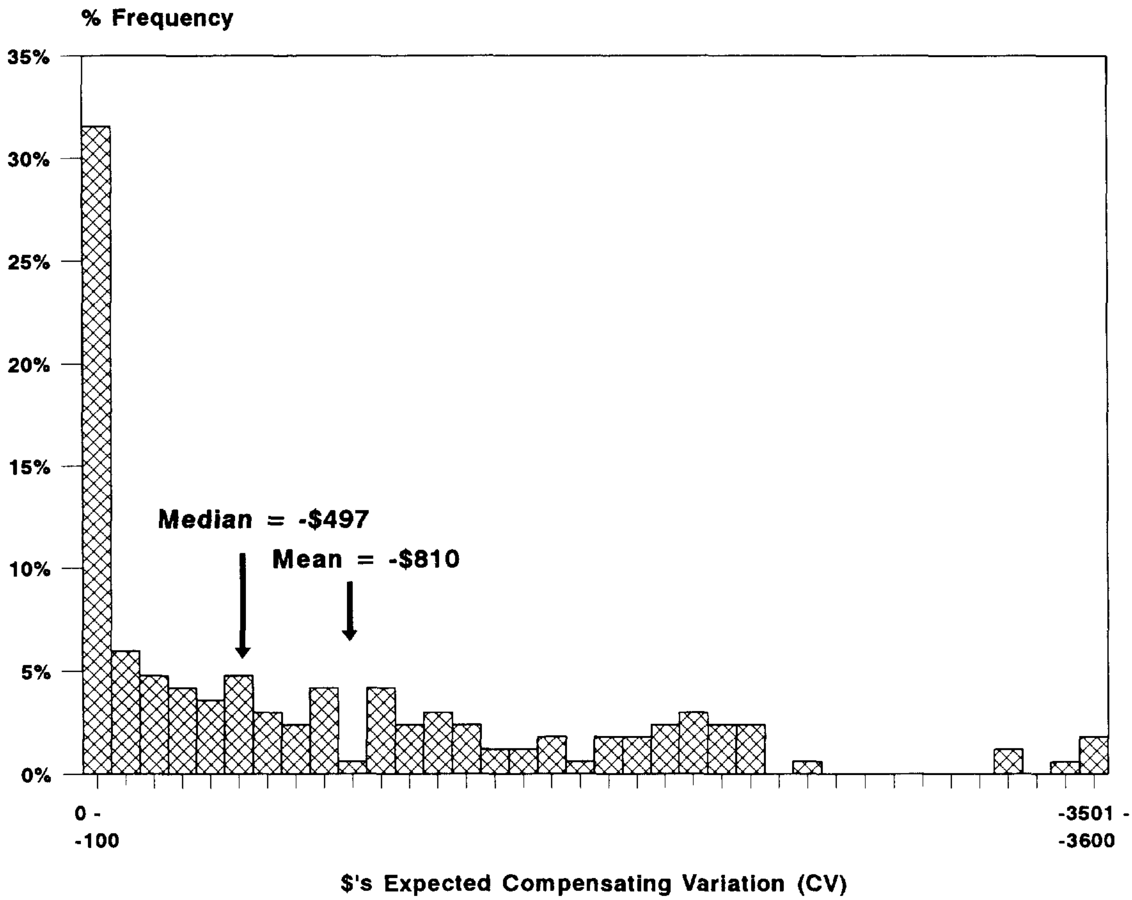

Figure 1. Frequency Plot of the Compensating Variations, CV's, for the Elimination of Atlantic Salmon Fishing at the Penobscot River

t statistics in parentheses): b_0 = 0.00683 (2.34), b_{00} = 0.89617 (3.43), b_1 = −1.1496 (−2.91), b_2 = 7.3789 (10.5), b_3 = 10.1123 (13.5), b_4 = 0.09752 (2.66), b_5 = −0.81200 (−14.8), b_6 = 0.19140 (11.2), b_7 = −1.2459 (−7.52) and b_8 = −2.1274 (−9.480). A likelihood-ratio test indicates that this model does not explain participation and sites choice as well as the nested model. Table 3 indicates how the CV estimates differ between the two models.

One implication of the nested-logit model explaining participation and site choice better than the logit model is the rejection of the Independence of Irrelevant Alternatives (IIA) property implicit in the logit specification. The IIA property implies the relative odds of not fishing versus visiting the Penobscot River is independent of how many other sites are available (Morey 1992b). This is an assumption that one would rather not make a priori and one that our nested model results indicate should not be made.

Participation and Site Choice without Income Effects

The next model modifies the previous model with b_{00} restricted to zero, i.e., a repeated logit model without income effects. This absence of income effects is typical of estimated repeated discrete-choice models. The maximum likelihood estimates for the nine alternative logit model are (with asymptotic t-statistics in parentheses): b_0 = 0.01668 (220), b_1 = −1.3461 (−14), b_2 = 7.3583 (58), b_3 = 10.635 (94), b_4 = 0.0949 (11), b_5 = −.8202 (−88), b_6 = 0.20604 (74), b_7 = −1.2402 (−31), and b_8 = −2.3124 (−64). The modified R^2 indicates that the model is explaining 65.7% of the variation in trip patterns.

When there are no income effects, CV = EV, and the repeated logit model of participation and site choice has a closed-form solution for the CV (=EV). Specifically, equation (10) can be solved for PPCV to obtain

$$\text{(12)} \quad PPCV = PPEV = (1/b_0)[V(ppy, yrs, club, age, \mathbf{P}^1, \mathbf{Catch}^1) - V(ppy, yrs, club, age, \mathbf{P}^0, \mathbf{Catch}^0)]$$

In the latter case, b_0 is the constant marginal utility of income and the income variable, *ppy*, cancels out of equation (12), thereby restricting WTP to be independent of one's income.

Table 3 reports the CV results for the logit model with income effects (column 2) and without income effects (column 3). The exclusion of income effects from the logit model only slightly reduces the estimated mean and median CV value estimates (by 1% to 18%, depending upon the scenario and statistic). As above, while these differences are small, it would be incorrect to conclude that excluding income is inconsequential.

Standard Logit Model of Site Choice without Income Effects and with Nonparticipation not an Alternative

To examine the importance of considering the decision to participate, the nonparticipation alternative can be removed from the last model (as well as continuing to exclude the income effect)[14] Such a model might be considered a standard logit model of recreational demand because most logit models of recreational demand do not model how often the individual will recreate, but rather just estimate the probability that a given site will be chosen if a trip is made. By precluding changes in the level of participation, such models provide biased consumer's surplus estimates of changes in resource quality. For example, when a resource degradation occurs, participants are forced to continue to take a trip, which may force greater welfare loss than simply forgoing participation.

The maximum likelihood parameter estimates for this eight alternative logit model are (with asymptotic t-statistics in parentheses): b_0 = 0.017179 (180), b_1 = −3.9297 (−43), and b_2 = 12.575 (82).[15] The modified R^2 indicates that the model is explaining 68.7% of the allocation of trips given the decision to participate. The probability of visiting a specific river, given that a trip is taken, is a decreasing function of the cost of visiting that river and an increasing function of that river's catch rate. As noted, this model cannot be used to estimate the predicted number of trips to the Penobscot River.[16]

Derivation of "per-trip" compensating variation, $PPCV_t$, from this model is straightforward The expected maximum utility in a given period if the individual is constrained to fish in that period is

$$\text{(13)} \quad V_t = V_t(ppy, \mathbf{P}, \mathbf{Catch}) = \ln\left[\sum_{j=1}^{8} \exp(V_j)\right] + 0.57722$$

Given our assumption of constant marginal utility of income b_0, then

$$\text{(14)} \quad PPCV_t = PPEV_t = (1/b_0)[V_t(ppy, \mathbf{P}^1, \mathbf{Catch}^1) - V_t(ppy, \mathbf{P}^0, \mathbf{Catch}^0)].$$

$PPCV_t(=PPEV_t)$ is usually referred to as a per-trip consumer's surplus measure; i.e., it is equivalent to the individual's per-period *CV* (=*EV*) if the individual knows he is constrained to take a trip both before and after the resource change. $|PPCV_t| \geq |PPCV|$, because, if one is constrained to participate in a period, changes in the sites are more important in that period. While not reported, the $PPCV_t$ are all larger, in absolute terms, than the corresponding *PPCV*s from the participation models.

Given that the model does not predict how many trips the individual will take after the change, how can it be used to approximate the CV (or EV)? The typical method of approximating the CV is to multiply the per-trip values for the resource change, $PPCV_t$, by some separate estimate of the number of trips. Morey (1993a) shows if the predicted number of trips are derived from a participation model consistent with the logit model of site choice, $PPCV_t$ multiplied by the predicted number of trips in the current state is a Laspeyres index that bounds

[14] Formally, j = 1, 2, . . . , 8 rather than j = 0, 1, . . . , 8. Given this change all of the equations remain the same except e^{V_0} = 0, equations (3) and (7) are now superfluous and the number of periods is irrelevant The reason for discussing this model is to focus on the cost of not modeling the participation decision Income effects could have been included in this model, but would cloud this discussion with unnecessary detail

[15] Note that the sample for this estimation could only include Maine license holders who actually fished at one of the sites This reduced the original sample of 168 to 145 individuals

[16] For each supply scenario, one could estimate demand for trips to the Penobscot River conditional on the total number of trips to all sites not changing when the supply conditions change Since the change in supply conditions will likely cause a change in this participation rate, these conditional demand estimates will, in most cases be biased upward for deteriorations and biased downwards for improvements While not reported here, these conditional estimates when compared with the unconstrained estimates derived from the repeated discrete-choice model, suggest such a bias

the CV from below and $PPCV_f$ multiplied by the predicted number of trips in the proposed state is a Paasche index that bounds the CV from above.[17]

Alternatively, one might obtain an approximation to each individual's CV by multiplying each person's $PPCV_f$ by his actual number of trips in the initial state. Denote this measure CV_f.[18] The mean, median and range of the CV_f for each of the three supply scenarios are reported in table 3. These CV_f's differ significantly from the CV estimates from the prior models. The variations are also dramatic on an individual-by-individual basis. For example, for elimination of the Penobscot fishery for the first ten individuals in the sample that fished, the estimated CV_f ranges from 0.17 to 4.05 times the CV from the logit model of participation and site choice without income effects. For the scenario which doubles the catch rate at the Penobscot, the range is 0.18 to 6.83. The CV_f bounds the CV from neither above nor below, and it is not a good approximation.

Three Other Travel-Cost Models

The following three models are continuous rather than discrete-choice models.

Partial Demand (Share) Model of Site Choice

Like the discrete-choice model of site choice in the last section, a partial demand model does not model the participation decision (see Morey 1981, 1984, 1985, and Morey and Shaw). However, the exclusion of the participation decision is fundamentally different in the discrete-choice and partial demand models. Participation in the discrete-choice framework is excluded by modeling the choice of site given the decision to make a trip. Alternatively, the partial demand (share) model assumes salmon fishing activities form a separable group and then only explains the allocation within this separable group as a function, in part, of the exogenously determined budget allocation to this group.

The partial demand model only explains and predicts the number (or proportion) of trips that an individual takes to each site as a function of his costs, his fishing budget, and the average catch rates. Any consumer's surplus measure derived from a partial demand model is a partial consumer's surplus measure in that it is derived implicitly assuming the individual will not adjust his fishing budget in response to the policy change. Hanemann and Morey prove for a given policy change the partial compensating variation, CV_p, derived from a partial model only provides a lower bound on the CV; and the corresponding partial equivalent variation, EV_p, bounds the EV from neither above nor below.

To develop a partial demand model of Atlantic salmon fishing, assume that these fishing activities are separable from all the other commodities; i.e.,

$$(15)\quad U = U(\mathbf{X}, \mathbf{B}, \mathbf{Y}, \mathbf{Catch}) = U(\mathbf{X}, B, u_p(y_1, y_2, \ldots, y_8, \mathbf{Catch}))$$

where U is expected utility, $\mathbf{Y}$ is a vector of the number of trips to each of the eight sites, $\mathbf{X}$ is a vector of the quantities consumed of each of the nonfishing commodities, and $\mathbf{B}$ is a matrix of the characteristics of the nonfishing commodities. Function $u_p = u_p(y_1, y_2, \ldots, y_8, \mathbf{Catch})$ is the direct partial utility function for fishing, and u_p is expected fishing utility. Given fishing budget FB, our expectation of the individual's choice of $\mathbf{Y}$ is the $\mathbf{Y}^*$ that maximizes $u_p(y_1, y_2, \ldots, y_8, \mathbf{Catch})$ subject to $FB = \Sigma p_j y_j$.

Assume a CES preference ordering for fishing utility

$$(16)\quad u_p = v_p(\mathbf{P}, FB, \mathbf{Catch}) = -e(P, Catch)/FB;$$

where (17) and (18) hold.

$$(17)\quad e(\mathbf{P}, \mathbf{Catch}) = \left[\sum_{j=1}^{8} h(j)^{-1/(\beta-1)} p_j^{\beta/(\beta-1)}\right]^{(\beta-1)/\beta}$$

$$(18)\quad h(j) = 1 + \alpha_1(catch_j) + \alpha_2(catch_j^1)^{1/2}$$

The CES preference ordering was chosen because it is simple and because it assumes no income effects.[19]

[17] Simulation results in Morey (1993a) show that these biases will be significant if the proposed change causes a significant change in the probability of participation. The bias can be significant even if one multiplies the $PPCV_f$ by the average of the predicted number of trips in the two states.

[18] Note that CV_f is not equal to {$PPCV_f$ × (Predicted number of trips in the current state)} because the CV_f is derived by multiplying $PPCV_f$ by the actual number of trips in the current state rather than the predicted number of trips in the current state.

[19] It assumes that fishing preferences are both homothetic and directly additive across fishing activities. Two implications of these assumptions are a site's expected share (budget or trip) is not a function of the fishing budget, and the partial compensating variation, CV_p, is equal to the partial equivalent variation, EV_p. For an example of a estimated partial model of recreational demand that includes income effects see Morey (1984).

Given the CES preference ordering, our expectation of the proportion of trips that the individual desires to spend at site j, s_j^*, is

$$s_j^* = \frac{y_j^*}{\sum y_k^*} = \frac{\left[\frac{h(j)}{p(j)}\right]^{\sigma}}{\sum_{k=1}^{q}\left[\frac{h(k)}{p(k)}\right]^{\sigma}}; \quad j = 1, 2, \ldots, 8 \tag{19}$$

where $\sigma \equiv 1/(1 - \beta)$

Assuming a multinomial specification for these shares (Morey 1981), the log of the likelihood function for the 145 Maine residents in the sample who fished is

$$\ell = \sum_{i=1}^{145} \sum_{j=1}^{8} y_{ij} * \ln(s_{ij}^*) \tag{20}$$

The maximum likelihood estimates are (with asymptotic t-statistics in parentheses): $\alpha_1 = -5.1622$ (−11.8), $\alpha_2 = 12.179$ (13.6) and $\sigma = 2.5372$ (237). The corresponding value for β is 0.60589. Both cost and catch rates are important determinants of where the individuals fish. The modified R^2 indicates that the model is explaining, given the fishing budgets, 39.1% of the variation in site selection.

The partial demand function (not reported) and the parameter estimates can be used to predict individual i's conditional demand for trips to the Penobscot for any given level of costs, catch rates, and fishing budget. For the initial fishing budget, these conditional demand estimates are biased downward for improvements and biased upward for deteriorations. The partial demand model does a better job of predicting demand for the Penobscot in the current state than does the repeated discrete choice model because it predicts demand conditional on the current fishing budget. Remember that the actual average for the Penobscot is 11.86 and the repeated nested model predicted 9.73. Estimated conditional demand for the Penobscot is 11.36. However, one would not expect this advantage to carry over to the alternative hypothetical scenarios.

For our CES partial demand model, the partial CV, CV_p, associated with a change from $\{\mathbf{P}^0, \mathbf{Catch}^0\}$ to $\{\mathbf{P}^1, \mathbf{Catch}^1\}$ is

$$CV_p = EV_p = FB^0 + e(\mathbf{P}^1, \mathbf{Catch}^1)/u_p^0 \tag{21}$$

where FB^0 is the chosen fishing budget in the current state and u_p^0 is fishing utility in the current state. As noted above, this CV_p only provides a lower bound estimate on the individual's CV because it does not allow the individual to adjust his fishing budget in response to the policy. Table 3 reports for each of the scenarios the mean and median CV_p estimates. For example, the mean CV_p for the elimination of Atlantic salmon fishing at the Penobscot River, −\$1,042, indicates on average an individual would have to be paid no more than \$1,042 to voluntarily accept this change.

Two Single-Site Demand Functions for Penobscot River

One might wonder whether it is worth the effort to develop and estimate a complicated model such as the repeated nested-logit model of participation and site choice with income effects. Perhaps estimation of a simple linear or log-linear demand function for the Penobscot would generate CV estimates similar to those obtained from the repeated models of participation and site choice. To check, assume there are only two commodities, Atlantic salmon fishing trips to the Penobscot River (y_1) and a Hicksian composite of all other goods. Further assume the Hicksian composite good is expressed in units such that its price is equal to one. Given this, first assume the following simple indirect utility function[20]

$$\begin{aligned} U &= V(y, p_1, yrs, club, age) \\ &= \exp(-\gamma p_1)[y + (1/\gamma)(\beta p_1 + \alpha + (\beta/\gamma)] \end{aligned} \tag{22}$$

where $\alpha = \alpha_0 + \alpha_1(yrs) + \alpha_2(club) + \alpha_3(age)$. Applying Roy's identity, the demand function for trips to the Penobscot River has the linear form

$$\begin{aligned} tp &= \alpha_0 + \alpha_1(yrs) + \alpha_2(club) \\ &\quad + \alpha_3(age) + \beta p_1 + \gamma y \end{aligned} \tag{23}$$

Observed trips to the Penobscot are assumed to be normally distributed with expectation tp.

The OLS parameter estimates for the 168 individuals in the sample, of which 67 did not visit the Penobscot, are (with asymptotic t-statistics in parentheses): $\alpha_0 = 20.4732$ (3.23), $\alpha_1 = 1.38340$ (3.00), $\alpha_2 = 9.75193$ (2.66), $\alpha_3 = -0.278321$ (−2.28), $\beta = -0.055790$ (−3.69), and $\gamma = 0.000011$ (0.09). As before, the variables *cost*, *yrs*, *club*, and *age* are all significant determinants of how many trips the individual

[20] Note that the catch rate at the Penobscot River cannot be included as an explanatory variable because the catch rate does not vary across individuals in the sample. If, for example, we had estimated catch at the Penobscot as a function of experience, the catch rate by experience level could have been included.

will take to the Penobscot River; income is not. The standard R^2 is 0.184.

The compensating variation, CV, for a price change from p_1^0 to p_1^1 is

$$(24)\quad CV = y - \exp(\gamma p_1^1)U^0 + (1/\gamma)[\beta p_1^1 + \alpha + (\beta/\gamma)].$$

Table 3 reports the mean, median and range of the individual CVs from this linear demand model for the elimination of Atlantic salmon fishing at the Penobscot.[21] These are all much larger, in absolute terms, than the CVs (or approximations to the CVs) from the five other models.

For comparison, a log-linear demand function for the Penobscot was also estimated. It is generated by the indirect utility function

$$(25)\quad U = V(y, p_1, yrs, club, age) = \frac{-e^{\alpha}p_1^{(1+\beta)}}{(1+\beta)} + \frac{y^{(1-\gamma)}}{(1-\gamma)}.$$

The mean, median and the range of the individual CVs from this log-linear demand model are −\$2,982, −\$2,258, and −\$388 to −\$12,437. These summary measures are much larger in absolute terms than the comparable measures for the linear demand model, but, since the dependent variable is logged, they are derived from the subsample of 101 individuals who visited the Penobscot. These single site models indicate functional form and stochastic specification are important. Simultaneously assuming a normally distributed error term and an extremely simple functional form for the demand equation leads to estimated compensating variations that are substantially different from our other estimates of the compensating variation.

If one wanted to pursue more sophisticated single-site models one might, for example, consider consistent probit/tobit models where the probit equation is used to determine if one fishes and the tobit model is used to determine how often. Shaw formulated a very sophisticated single-site model. However, neither the Shaw model nor a probit/tobit model is simple, particularly when it comes to welfare estimation, and neither can estimate EVs and CVs for changes in site characteristics, which is the focus of this paper.

[21] CVs for the other scenarios cannot be derived from this model because utility is not a function of the Penobscot catch rate

Conclusions

Our analysis suggest average CVs for changes in salmon catch rates at the Penobscot river are substantial. Nonetheless, given the limited number of such anglers (less than 1500 in 1988), the analysis also suggests the total value to anglers of the Penobscot fishery may be less than its development and maintenance costs. For example, the value of maintaining current conditions at the Penobscot river is estimated to be \$1.215 million per year (\$810 per angler per year from the repeated nested logit model times 1,500 anglers). In contrast, the EIS estimates annual costs of about \$1 million per year just to sustain the resource at levels about one-half that in 1988. It may well be that significant preservation values unrelated to recreational fish catch of Atlantic salmon are required to merit current resource expenditures.

The CV estimates vary depending upon the valuation model employed. The single-site demand models provided significantly larger valuation results, but may be the least defensible among the set of seven considered. The partial demand (share) model produced, as expected, estimated valuations that were the smallest for improvements and the largest for deteriorations.

Modeling the participation decision is found to be critical. Approximations to the CV derived from the standard logit model without the nonparticipation alternative, CV_f, differ significantly from the repeated logit CV estimates and bound them neither from above nor below. If the intent is to derive the consumer's surplus associated with a proposed scenario using a discrete-choice model, one should incorporate nonparticipation as one of the alternatives as this requires no more data than does estimating such a model without nonparticipation. Of course, if one's sample includes only individuals who fish (in our case, those with Atlantic salmon licenses), one cannot in general draw inferences about participation decisions of the remainder of the population. One can predict only how participation will change for the subset of the population that currently fishes.

Theoretically, both a partial demand model and a discrete-choice model that does not include nonparticipation as one of the alternatives are inferior to the repeated model that explains both participation and choice of site. However, if one had to choose between a share model CV_p estimate and a logit model without the participation decision CV_f estimate, the CV_p estimate may be the more defensible of the two because the CV_p is at least a lower bound on the CV, whereas the CV_f bounds the CV from neither above nor below.

Including income effects is found to be important and simple. Our results indicate valuation of the salmon fishery varies significantly with income. The only negative consequence of incorporating income effects is that the CVs and EVs no longer have closed-form solutions. However, as we show, one can numerically calculate the CV or EV for any individual and for any scenario as a function of the individual's characteristics and the estimated parameters of the discrete-choice model.

In addition, a likelihood-ratio test on our nested-logit model of participation and site choice rejects the stochastic assumptions implicit in the logit model. The extreme value distribution that generates the nonnested logit model assumes the random terms in the conditional indirect utility functions are all equally correlated. This is in contrast to the generalized extreme value distribution that generated our three-level nested-logit model. The generalized extreme value distribution assumes groupings of alternatives in which the random terms in each group are correlated more with each other than they are with the random terms of alternatives not in that group. We chose a grouping such that the nonfishing alternative is in a group by itself and the fishing alternatives are divided into two subgroups, Maine and Canada. This proved to be a significant and useful extension.

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References

Ben-Akiva, M., and S. R. Lerman. *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge: MIT Press, 1985.

Bockstael, N., M. Hanemann, and C. Kling. "Estimating the Value of Water Quality Improvements in a Recreational Demand Framework." *Water Resources Research* 23,5(May 1987):273–302.

Bockstael, N., M. Hanemann, and I. Strand Jr. *Measuring the Benefits of Water Quality Improvements Using Recreation Demand Models*, vol. 2, prepared for the Office of Policy Analysis, U.S. Environmental Protection Agency, Washington, D.C. 20460 (1984).

Boyle, K. J. and M. F. Teisl. *Angler Evaluations of Potential Management Programs for Atlantic Salmon on the Penobscot River. Basin Mills Hydroelectric Project.* Bangor Hydro Electric Company, Bangor, Maine, 1992.

Carson, R., M. Hanemann, and T. Wegge. *Southcentral Alaska Sport Fishing Economic Study*, report prepared by Jones and Stokes Associates, Sacramento, CA, for Alaska Department of Fish and Game, Anchorage, AK 99502 (1987).

Caulkins, P., R. Bishop, and N. Bouwes. "A Comparison of Two Travel Cost Models for Valuing Lake Recreation," mimeo, AEA Annual Meetings (1984).

——. "The Travel Cost Model for Lake Recreation: A Comparison of Two Methods for Incorporating Site Quality and Substitution Effects." *Amer. J. Agr. Econ.* 68(May 1986):291–97.

Feenberg, D., and E. Mills. *Measuring the Benefits of Water Pollution Abatement.* New York: Academic Press (1980).

Hanemann, M., and E. Morey. "Separability, Partial Demand Systems and Consumer's Surplus Measures." *J. Environ. Econ. and Manag.* 22(3)(May 1992):241–58.

Kay, D., T. Brown, and D. Allee. *The Economic Benefit of the Restoration of Atlantic Salmon to New England Rivers.* Department of Natural Resources, Cornell University. Prepared for the U.S. Fish and Wildlife Service, 1987.

Kling, C. "The Reliability of Estimates of Environmental Benefits from Recreational Demand Models." *Amer. J. Agr. Econ.* (November 1988):892–901.

——. "Computing Welfare Estimates of Environmental Quality Changes from Recreation Demand Models." *J. Environ. Econ. and Manag.* 15(September 1988b):331–40.

——. "The Importance of Functional Form in the Estimation of Welfare." *West. J. Agr. Econ.* 14(July 1989):168–74.

Kling, C., and M. Weinberg. "Evaluating Estimates of Environmental Benefits Based on Multiple Site Recreation Demand Models: A Simulation Approach." in *Advances in Applied Microeconomics Vol. 5: Recent Developments in the Modelling of Technical Change; and Modeling Demand for and Valuation of Recreation Resources*, (Link and Smith, Eds.), JAI Press Inc., Greenwich 1990.

McLaughlin, E. *A Socio-Economic Impact Report on the Effects of the Atlantic Salmon Sport Fishery on the Bangor Area and the State of Maine.* Report to the Maine Atlantic Sea-Run Commission. Bangor, Maine 1982.

Mitchell, R. C., and R. T. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* John Hopkins Press for Resources for the Future, Washington, D.C. 1989.

Morey, E. "The Demand for Site-Specific Recreational Activities: A Characteristics Approach." *J. Environ. Econ. and Manag.* 8 (December 1981):345–71.

——. "The Choice of Ski Areas: Estimation of a Generalized CES Preference Ordering with Characteristics." *Rev. Econ. and Statist.* 9(November 1984) 66:584–90.

——. "Characteristic, Consumer's Surplus and New Activities: A Proposed Ski Area." *J. Public Econ.* 26 (March 1985):221–36.

——. "What is Consumer's Surplus Per Day of Use? and What Does It Tell Us About Consumer's Surplus?"

Discussion paper, Department of Economics, University of Colorado, Boulder CO 80309, 1993a.

—— "Derivation of the Nested-Logit Model of Consumer Choice A Synthesis," Discussion paper, Department of Economics, University of Colorado, Boulder CO 80309, July 1993b

Morey, E., and W.D. Shaw. "An Economic Model to Assess the Impact of Acid Rain: A Characteristics Approach to Estimating the Demand for and Benefits from Recreational Fishing." in *Advances in Applied Microeconomics Vol. 5: Recent Developments in the Modeling of Technical Change; and Modeling Demand for and Valuation of Recreation Resources*, (Link and Smith, Eds.), JAI Press Inc., Greenwich (1990).

Morey, E., W. D. Shaw, and R D Rowe. "A Discrete Choice Model of Recreational Participation, Site Choice, and Activity Valuation When Complete Trip Data Are Not Available " *J. Environ Econ and Manag* 20 (March 1991).

Rowe, R. D., A. Michelsen, and E. Morey. *Fishing for Atlantic Salmon in Maine: an Investigation into Angler Activity and Management Options* RCG/Hagler, Bailly, Inc. report to Bangor Hydro-Electric Company. Boulder, Colorado. (September 1989).

Rowe, R D., W D. Shaw, and W Schulze "Nestucca Oil Spill." In *Natural Resource Damages Law and Economics* (Ward and Duffield, Eds.), John Wiley and Sons, New York (1992)

Shaw, D. "On-Site Sample Regression: Problems of Non-Negative Integers, Truncation and Endogenous Stratification." *J. Econometrics* 37(February 1988):211–23

Smith, V K., W. Desvousges, and A. Fisher. "A Comparison of Direct and Indirect Methods for Estimating Environmental Benefits." *Amer J Agr Econ.* (May 1986):280–90

U.S. Fish and Wildlife Service. *Restoration of Atlantic Salmon to New England Rivers* Department of Interior Final Environmental Impact Statement. U S FWS Region 5, Newton Corner, Massachusetts. 1989

Ziemer, R., W Musser, and R Hill "Recreation Demand Equation: Functional Form and Consumer Surplus " *Amer. J Agr. Econ* 62(February 1980):136–41.