Journal of Environmental Management (2002) **66**, 159–170
doi:10.1006/jema.2002.0573, available online at http://www.idealibrary.com on IDEAL®

Estimating recreational trout fishing damages in Montana's Clark Fork River basin: summary of a natural resource damage assessment

Edward R. Morey†, William S. Breffle*‡, Robert D. Rowe‡ and Donald M. Waldman†

† *Department of Economics, University of Colorado, Boulder, CO 80309-0256, USA*
‡ *Stratus Consulting Inc., P.O. Box 4059, Boulder, CO 80306-4059, USA*

Received 24 August 2001; accepted 12 March 2002

This paper summarizes a natural resource damage assessment for the State of Montana. Mining wastes have caused significant reductions in trout stocks in a 145-mile stretch of Montana's Silver Bow Creek and Clark Fork River. To estimate economic damages from decreases in catch rates, we develop and estimate an individual-based utility-theoretic model of where and how often an angler will fish as a function of travel costs, catch rates, and other influential characteristics of the sites and individuals. The model includes resident and nonresident anglers who currently fish in Montana, and allows them to have different preferences. Demand parameters and expected catch rates are simultaneously estimated. The value of time is endogenously estimated as a proportion of the wage rate. Catch rates are linked to trout stocks through a stock-catch function. Collection of the angler data involved a three-step process: anglers were intercepted at 26 study sites, a subsample of anglers was selected to reflect the population trip-taking proportions to the study sites, and these anglers received follow-up surveys through the fishing season. Avidity weights are used to correct for the higher level of avidity inherent in intercept samples.

Keywords: natural resource damage assessment, Superfund, recreation demand, trout stocks, catch rates, Montana rivers, mining injuries.

Introduction

Southwestern Montana contains some of the most popular cold-water trout fishing rivers and streams in the United States, such as Rock Creek, the Big Hole River, and the Madison River. However, among these trout fishing jewels, a century of heavy metal releases from mining waste has completely eliminated trout from the 20-mile long Silver Bow Creek between Butte, Montana and the start of the upper Clark Fork River, and has significantly reduced trout stocks in a 125-mile stretch of the upper Clark Fork River from its headwaters to Missoula (Lipton *et al*., 1995). The State of Montana filed suit in 1983, under federal Superfund law and its state counterpart, against the Atlantic Richfield Co. (ARCO), the current owners of the mining operations, for compensable damages and restoration costs for these recreational fishing and other damages. The intent of the research presented here was to conduct a natural resource damage assessment (NRDA) to estimate the compensable damages to the anglers who fish the cold-water trout rivers and streams of southwestern Montana. This paper summarizes the work of the economists working for the State of Montana, although space will not accommodate all of the

* Corresponding author. E-mail: bbreffle@stratusconsulting.com

0301–4797/02/$ – see front matter

details. For all of the specifics, see Morey *et al*. (1995). The economics assessment for ARCO was conducted by Desvousges and Waters (1995b).

We develop and estimate an individual-based utility-theoretic model of where and how often an angler will fish as a function of travel costs, expected catch rates, other characteristics of the fishing sites in the choice set, and characteristics of the individual. From this demand model of participation and site choice, we derive an estimate of each angler's annual expected compensating variation, E(*CV*), associated with increasing the expected catch rates to their no-injury levels. This E(*CV*) can be interpreted as the annual willingness to pay (*WTP*) for the expected catch rates that would exist in the absence of injury.

The model includes both resident anglers and nonresident anglers who currently fish in Montana, and allows them to have different preferences.[1] This issue is important because the cold-water rivers and streams of southwestern Montana are nationally known as premier trout fishing destinations that draw large numbers of nonresidents each year.

A goal in recreation studies is to cost-effectively collect relevant data on sites and anglers, while minimizing potential sampling biases. In this study, we used an intercept/subsample/follow (*ISF*) procedure: anglers were intercepted at 26 study sites, a subsample of anglers was selected to reflect the actual population trip-taking proportions to the study sites based on supplemental information, and these anglers received follow-up surveys through the fishing season. Because we have a choice-based sample, the sampled anglers have a higher level of avidity than the study angler population. We use avidity weights to correct for this bias. Thus, the *ISF* procedure, with independent information on avidity and site trip-taking proportions, cost-effectively collects the required catch rate and angler data and eliminates potential sampling biases.

Parameters in the travel-cost portion of the model were jointly estimated along with the sites' expected catch rates, which determine site choice. This method was used, rather than using just the simple observed average catch rates; the amount of catch data in the sample varies significantly across the sites in our choice set, being particularly low for many of the injured sites and thus resulting in unreliable averages at some sites. This joint estimation technique was developed by Morey and Waldman (1993, 1998). The joint estimation was controversial and criticized by the economists working for ARCO (Desvousges and Waters, 1995a; McFadden, 1995). The advantages and disadvantages of joint estimation are discussed in Morey and Waldman (2000) and Train *et al*. (2000). In summary, joint estimation is appropriate and improves efficiency if all important explanatory variables of site choice are included in the model, but may lead to biased parameter estimates if important explanatory variables are omitted. The damage estimates are significantly dependent on whether simple averages are used for the expected catch rates or catch rates are jointly estimated with the parameters in the travel-cost model, as discussed at the end of the paper.

[1] If one constrains resident and nonresident anglers to have identical preferences, nonresident anglers will have lower damage estimates than residents because nonresidents face higher trip costs.

Trout fishing in southwestern Montana: the choice set, data, and trip costs

To group fishing sites in the choice set, we divide southwestern Montana into four study regions around four population centers: Missoula (*M*), Butte/Dillon (*BU*), Helena (*H*), and Bozeman (*BZ*). We chose 26 river and stream sites within the four regions for intensive study, although trip data were collected for all trout rivers and streams in southwestern Montana that were visited by sampled anglers. The 26 intensively studied sites and the four regions in southwestern Montana are listed and defined in Table 1. The 26 sites include all of the injured sites: Upper Clark Fork 1–5 and Silver Bow Creek. The criteria for choosing the set of sites for intensive study included geographic dispersion over southwestern Montana, variability in expected catch rates, and variability in site size. For the study sample, approximately 73% of all resident trips and 82% of all nonresident trips to southwestern Montana were to the 26 sites. While we focus on angler choice in southwestern Montana, trips to Montana rivers and streams outside of southwestern Montana are also included in the trip data by assigning them to a broad region encompassing the rest of Montana.

Individual per-trip catch data were obtained for the 26 sites by intercepting and interviewing at the sites following a stratified random sampling procedure across sites, days, and times of the day from May through August 1992. From these interviews, catch data from 1344 individual fishing trips

Table 1. List of 26 intensively studied sites by region[a]

Missoula Nest (*M*)
Upper Clark Fork 1 (*UCF1*)—Bonner to Rock Creek
Upper Clark Fork 2 (*UCF2*)—Rock Creek to Flint Creek
Upper Clark Fork 3 (*UCF3*)—Flint Creek to L. Blackfoot
Middle Clark Fork (*MCF*)—Spurgin Rd. to Huson
Rock Creek (*RC*)—1 mile up from Clark Fork to Siria
Flint Creek (*FC*)—Maxville to Black Pine Rd.
Bitterroot 1 (*BT1*)—Maclay Br. to Chief Looking Glass
Bitterroot 2 (*BT2*)—Angler's Roost to Hannon Mem
Lolo Creek (*LC*)—Mormon Cr. to Lolo Hot Springs
Blackfoot (*BF*)—Bonner to Whitaker Br.
Little Blackfoot (*LBF*)—Cutoff Rd. to Elliston
Butte/Dillon Nest (BU)
Upper Clark Fork 4 (*UCF4*)—L. Blackfoot to Perkins L.
Upper Clark Fork 5 (*UCF5*)—Perkins L. to Pond 2 Outfall
Silver Bow Creek (*SBC*)—Ponds to Butte
Warm Springs Creek (*WSC*)—Fish Hatchery to Meyer's Dam
Big Hole 1 (*BH1*)—Pennington Br. to Brown's Br.
Big Hole 2 (*BH2*)—Melrose to Divide
Jefferson 1 (*J1*)—Willow Cr. to Cardwell
Jefferson 2 (*J2*)—Waterloo to Twin Bridges
Beaverhead (*BV*)—Barretts to Clark Canyon
Helena Nest (*H*)
Missouri (*MS*)—Dearborn R. to Holter Dam
Bozeman Nest (*BZ*)
Lower Yellowstone (*LY*)—Springdale to Livingston
Gallatin (*G*)—Shedd Br. to Spanish Cr.
East Gallatin (*EG*)—Spain L. Br. to Griffen Dr.
Madison 1 (*MD1*)—Cobblestone to Beartrap
Madison 2 (*MD2*)—Varney to Lyons

[a] Region and site abbreviations used with models are identified after each region or site name.

were collected. Anglers were also asked survey questions about their perceptions of expected catch rates at several of the sites. Based on fishing time observed during the intercept survey, anglers spent considerably less time fishing at the sites they perceive to have low catch rates than at the sites they perceive to have high catch rates, which indicates there is a strong relationship between demand for a site and angler perceptions about expected catch rates. For example, Madison 2 was given the highest average perceived catch-rate rating, and there are 847 h of fishing reported at that site. Upper Clark Fork 2 and 3 received the lowest perceived catch-rate rating, and only 69 hours were reported for those two sites combined. This difference in fishing hours is dramatic given that interviewers spent approximately half as much time collecting data at Madison 2 than at Upper Clark Fork 2 and 3.

Data on trips and angler characteristics were collected by on-site, telephone, and mail surveys using an *ISF* sampling procedure.[2] Approximately one-half of anglers initially intercepted on-site were targeted to be followed through the rest of the season. An in-field postcard survey was conducted at the 26 intensively studied sites concurrently with the intercept survey and was used as a method to count angler visitation at each site and to determine the follow-up sampling proportions for anglers intercepted at each of the 26 sites.

This subsampling was undertaken because the proportions of intercepted anglers at the sites may misrepresent actual proportions of anglers, as a result of limitations on survey agents' time. Because postcards were placed on every automobile at all sites, the postcard proportions of anglers across sites provide reliable estimates of the proportions of anglers at each of the 26 sites. The postcard survey includes questions relating to party size, the number of individuals participating in fishing and nonfishing recreational activities, time on-site, and other fishing data. It was used as a method to count angler and nonangler recreation visitation at each of the 26 intensively studied sites. All license plate numbers of automobiles on which postcards were placed were recorded to monitor postcard return rates. Response rates average 47% across all sites but differ across sites, which was taken into account in the estimation of site proportions. We demonstrate later that the implicit site weighting in the sampling plan appears to be sufficient.

Trip patterns for the 1992 fishing season were obtained for a sample of 443 anglers, comprising 291 residents and 152 non-residents. Multipurpose trips were not included.[3] Single-site trips to each of the 26 sites were coded to the specific site. Multisite trips where all of the sites were to one region were coded as a trip to that region but were not assigned to a specific site. Trips to sites in southwestern Montana other than the 26 intensively studied sites were designated as other sites by region, and trips to Montana rivers and streams outside of southwestern Montana were aggregated as the separate, fifth other region. All other trips were coded as a trip being taken, but no site or region was coded.

Of the 26 intensively studied sites, the 6 most popular sites in terms of seasonal visitation (Rock Creek, Bitterroot 2, both Big Hole sites, Missouri, and Madison 2) account for 52% of all the trips to the

[2] The response rates to these three surveys were 98%, 83%, and 63%, respectively.

[3] The exclusion of trips that were not primarily for the purpose of fishing may have an effect on the valuation, but modeling multipurpose trips was beyond the scope of this research. The proportion of trips that were for multiple purposes was much greater for nonresidents than for residents.

26 sites. The 5 injured upper Clark Fork sites and Silver Bow Creek account for only 6% of all of the fishing trips to the 26 sites, even though they run between two major population centers.

Larger rivers and streams attract and support more anglers than smaller rivers and streams. To account for this, a size index was created by multiplying the length of each study river/stream segment by the average flow in the segment, measured in cubic feet per second. The largest 7 sites account for 43% of trips to the 26 intensively studied sites over the season. The smallest 7 account for only 13%. Data on other site characteristics that influence trip taking were also collected. We found that the presence of campgrounds increases visitation. With two exceptions, whether a site is suitable for effective float fishing is determined solely by size. The two exceptions are the Gallatin, where floating is prohibited, and the Beaverhead, which is suitable for floating even though it is small.

The cost of a trip to site j has four components: transportation costs, lodging costs, variable per-trip equipment costs (such as tackle and guide fees), and the opportunity cost of the individual's time in travel and while at the site. Specifically, trip cost is determined by the driving distance to the site, the angler's wage rate, average equipment and lodging costs by one-way distance category (0–25 miles, 26–50 miles, 51–150 miles, and more than 150 miles), and average on-site time by distance category.[4] Distance and per-mile vehicle operating costs ($0·14 per vehicle occupant)[5] were used to determine transportation costs for residents and all nonresidents for whom driving was less expensive than flying, and airfares and car rental rates were used to calculate transportation costs for distant nonresidents. Trip costs vary significantly in percentage terms across sites for each resident angler but vary less significantly across sites for nonresidents. Time costs are converted to money costs by multiplying travel and on-site time by the opportunity cost of the individual's free time. The per-hour opportunity cost of the individual's free time is assumed to be some fraction of the individual's wage rate, β_W, which was estimated within the recreation demand model.[6]

The joint model of participation, site choice, and expected catch rates

The recreation demand model has two components: a travel-cost component and a catch-rate component. The travel-cost component is a repeated three-level nested logit model of participation and site choice. Because nested logit models of recreational demand are becoming increasingly common, only the specific details of the travel-cost component are presented here.

As noted above, the two components of the model were jointly estimated because the observed trip patterns contain information about expected catch rates (ceteris paribus, anglers take more trips to sites with high expected catch rates and fewer trips to sites with low expected catch rates). Our estimate of an expected catch rate is a weighted average of the site's observed average catch rate and the maximum likelihood catch rate parameter that would best explain trip patterns in the absence of any observed catch data (see Morey and Waldman, 1998). The weight on the site's observed average catch rate is a decreasing function of its sampling variation relative to the sampling variation in the observed trip patterns.

We assume the trout fishing season consists of 60 periods such that in each period an angler can take no more than one fishing trip. There is no stipulation that each period is of equal length; we chose 60 periods because only 10 of the 443 anglers in our follow-up sample took more than 60 trips.[7]

In each period, the individual simultaneously decides whether to fish at a river or stream in Montana and, if so, which one. The angler has 31 river and stream trout fishing sites from which to choose: 26 specific sites and 5 other sites. In each period, each angler must choose one of 32 alternatives where one of the alternatives is

[4] Mean equipment expenses were about $10 for all of the distance categories under 150 miles, and were $23 for anglers traveling more than 150 miles. On-site time averaged 3·5 h for trips less than 25 one-way miles, 6·3 h for trips of 26–150 one-way miles, and 8·7 h for trips in excess of 150 one-way miles. Categorical averages are used rather than individual-level measures so that the cost associated with on-site time would be an exogenous cost. A model such as the one in this paper could be extended to make on-site time endogenous.

[5] The State of Montana paid $0·275 per mile for job-related activities, and similarly the federal government allowed a tax deduction of $0·28 per mile. We allocated the vehicle operating costs across two anglers (the median number traveling together).

[6] By way of comparison, the ARCO economic analysis (Desvousges and Waters, 1995b) assumed $0·05 per mile and assumed one-third of the wage rate for travel time, but no opportunity cost for time spent on site. These and other factors result in much lower damages than reported here.

[7] Note that truncating the maximum number of trips to 60 will cause the estimates of both total trips and damages to be biased downward.

nonparticipation. The sites are grouped by regions that correspond to the major cities in southwestern Montana because resident anglers are more likely to visit sites near their homes. The angler's choice set for each period (other than nonparticipation), and the regional nesting structure for fishing, is presented in Table 1.

This recreation demand model determines the per-period probability that individual i will choose alternative j. The predicted number of trips angler i will take to site j is therefore the per-period probability that individual i will choose site j multiplied by 60, and the predicted number of trips angler i will take to all sites in Montana during the summer season is the sum of his or her predicted trips to the 13 sites.

The utility the individual receives during period p if he chooses alternative j is:

$$U_{jp} = V_j + \varepsilon_{jp}; \quad j = 0, UCF1, UCF2, UCF3, MCF, RC, FC, BT1, BT2, LC, BF, LBF, RMo, UCF4, UCF5, SBC, WSC, BH1, BH2, J1, J2, BV, RBUo, MS, RHo, LY, G, EG, MD1, MD2, RBZo, R5, \quad (1)$$

where j=0 is the nonfishing alternative. The full names of the 26 intensively studied sites are listed in Table 1. *RMo, RBUo, RHo*, and *RBZo* are collectives of all the other sites in the Missoula, Butte, Helena, and Bozeman regions. *R5* is a collective of all the river and stream sites in Montana that are not in one of the four regions in southwestern Montana, denoted region *5*.

The term V_j depends on the cost and characteristics of alternative j. Assume that the unobserved random components, ε_{jp}, are drawn from the generalized extreme value distribution with cumulative distribution function

$$F(\varepsilon) = \exp[-e^{-\varepsilon_0} - [(E_M)^{t/s} + (E_{BU})^{t/s} + (E_H)^{t/s} + (E_{BZ})^{t/s} + (E_5)^{t/s}]^{1/t}], \quad (2)$$

where s is a statistical parameter that influences the degree of unobserved correlation between the utility from trips to any two sites in the same region, t is a statistical parameter that influences the degree of unobserved correlation between the utility from trips to any two fishing sites,[8] and

$$E_M = e^{s\varepsilon_{UCF1}} + e^{s\varepsilon_{UCF2}} + e^{s\varepsilon_{UCF3}} + e^{s\varepsilon_{MCF}} + e^{s\varepsilon_{RC}} + e^{s\varepsilon_{FC}} + e^{s\varepsilon_{BT1}} + e^{s\varepsilon_{BT2}} + e^{s\varepsilon_{LC}} + e^{s\varepsilon_{BF}} + e^{s\varepsilon_{LBF}} + e^{s\varepsilon_{RMo}}, \quad (3)$$

$$E_{BU} = e^{s\varepsilon_{UCF4}} + e^{s\varepsilon_{UCF5}} + e^{s\varepsilon_{SBC}} + e^{s\varepsilon_{WSC}} + e^{s\varepsilon_{BH1}} + e^{s\varepsilon_{BH2}} + e^{s\varepsilon_{J1}} + e^{s\varepsilon_{J2}} + e^{s\varepsilon_{BV}} + e^{s\varepsilon_{RBUo}}, \quad (4)$$

$$E_H = e^{s\varepsilon_{MS}} + e^{s\varepsilon_{RHo}}, \quad (5)$$

$$E_{BZ} = e^{s\varepsilon_{LY}} + e^{s\varepsilon_{G}} + e^{s\varepsilon_{EG}} + e^{s\varepsilon_{MD1}} + e^{s\varepsilon_{MD2}} + e^{s\varepsilon_{RBZo}}, \quad \text{and} \quad (6)$$

$$E_{R5} = e^{s\varepsilon_{R5}}. \quad (7)$$

This generalized extreme value function generates a three-level nested logit model of participation and site choice. Given this cumulative distribution function (CDF), the per-period probability that an individual will choose not to fish is

$$\text{Prob}_0 = \frac{e^{V_0}}{(e^{V_0} + [(I_M)^{t/s} + (I_{BU})^{t/s} + (I_H)^{t/s} + (I_{BZ})^{t/s} + (I_{R5})^{t/s}]^{1/t}}, \quad (8)$$

where

$$I_M = e^{sV_{UCF1}} + e^{sV_{UCF2}} + e^{sV_{UCF3}} + e^{sV_{MCF}} + e^{sV_{RC}} + e^{sV_{FC}} + e^{sV_{BT1}} + e^{sV_{BT2}} + e^{sV_{LC}} + e^{sV_{BF}} + e^{sV_{LBF}} + e^{sV_{RMo}}, \quad (9)$$

$$I_{BU} = e^{sV_{UCF4}} + e^{sV_{UCF5}} + e^{sV_{SBC}} + e^{sV_{WSC}} + e^{sV_{BH1}} + e^{sV_{BH2}} + e^{sV_{J1}} + e^{sV_{J2}} + e^{sV_{BV}} + e^{sV_{RBUo}}, \quad (10)$$

$$I_H = e^{sV_{MS}} + e^{sV_{RHo}}, \quad (11)$$

$$I_{BZ} = e^{sV_{LY}} + e^{sV_{G}} + e^{sV_{EG}} + e^{sV_{MD1}} + e^{sV_{MD2}} + e^{sV_{RBZo}}, \quad \text{and} \quad (12)$$

$$I_{R5} = e^{sV_{R5}}. \quad (13)$$

The per-period probability the individual will choose site j in the Missoula region (j=*UCF1, UCF2, UCF3, MCF, RC, FC, BT1, BT2, LC, BF, LBF, RMo*) is

$$\text{Prob}_j = \frac{e^{sV_j}[(I_M)^{t/s} + (I_{BU})^{t/s} + (I_H)^{t/s} + (I_{BZ})^{t/s} + (I_{R5})^{t/s}]^{(1/t)-1}(I_M)^{(t/s)-1}}{e^{V_0} + [(I_M)^{t/s} + (I_{BU})^{t/s} + (I_H)^{t/s} + (I_{BZ})^{t/s} + (I_{R5})^{t/s}]^{1/t}}. \quad (14)$$

[8] A sufficient, but not necessary, condition for this density function to be well-behaved is $s \geq t \geq 1$. This condition is fulfilled.

The per-period probabilities for the intensively studied sites in the three other regions (Butte, Helena, and Bozeman) are defined similarly. The per-period probability the individual will choose a site in Montana that is not in one of the four regions in southwestern Montana is

$$\text{Prob}_{R5} = \frac{e^{sV_{R5}}[(I_M)^{t/s} + (I_{BU})^{t/s} + (I_H)^{t/s} + (I_{BZ})^{t/s} + (I_{R5})^{t/s}]^{(1/t)-1}\ (I_{R5})^{(t/s)-1}}{e^{V_0} + [(I_M)^{t/s} + (I_{BU})^{t/s} + (I_H)^{t/s} + (I_{BZ})^{t/s} + (I_{R5})^{t/s}]^{1/t}}. \quad (15)$$

Specifically, assume the V_j for a fishing trip to site j, where j is one of the 26 intensively studied sites, is a function of the following variables: the angler's per-period income, *PPY*; the angler's cost of a trip to site j, $COST_j$; the expected catch rate at site j, ECR_j; the size of site j, SZ_j;[9] a variable that takes the value one if there is a campground adjacent to the site and zero otherwise, D_{CG}; a variable that takes the value one if the river has low flow but is suitable for float fishing (only the Beaverhead) and zero otherwise, D_{LFF}; and a variable that takes the value one if the site is high flow but is unsuitable for float fishing (only the Gallatin) and zero otherwise, D_{HFNF}.[10] $COST_j$ is a function of β_W, which is estimated endogenously in the recreation demand model.

$$\begin{aligned} V_j = &[\beta_0(1-NRES) + \beta_{0NR}(NRES)](PPY - COST_j) \\ &+ [\beta_C + \beta_{CRSK}(1-NRES)SK \\ &+ B_{CNR}(NRES)](ECR_j) + \beta_{SZ}(SZ_j) + \beta_{CG}(D_{CG}) \\ &+ \beta_{LFF}(D_{LFF}) + \beta_{HFNF}(D_{HFNF}), \end{aligned} \quad (16)$$

where $NRES$=1 if the angler is not a resident of Montana and zero if the angler is a resident. Note (PPY-$COST_j$) is the amount of income the individual has left to spend on other commodities in period p if the individual takes a trip to site j. Resident and nonresident anglers are allowed to have different catch and price parameters. We feel that the estimated model included all the significant determinants of site choice, while the economists for ARCO disagreed.

[9] A site's size is defined as the site's average flow from May through August (in cubic feet per second) multiplied by the site's length. Sizes of the sites are important determinants of both the total number of fishing trips to southwestern Montana and which sites are chosen because, everything else constant, larger sites have more access points and more places to fish.

[10] A parameter for sites that are exceptionally aesthetically unattractive (only Silver Bow Creek) and a parameter for sites with both bad bank access and that are unsuitable for float fishing (only Upper Clark Fork 3) were both found to be insignificant determinants of participation and site choice.

If the trip is to a site in one of the four regions (Missoula, Butte, Helena, or Bozeman), but not to one of the intensively studied sites, assume

$$\begin{aligned} V_j = &[\beta_0(1-NRES) + \beta_{0NR}(NRES)](PPY \\ &- AveCOST_{Rk}) + \alpha_O, \end{aligned} \quad (17)$$

where the individual's cost of a trip to the *collective* site in region k is assumed to be the average of the individual's trip costs for the intensively studied sites in region k. Since the collective sites are catch-alls for trips to sites other than the intensively studied sites, there is unobserved variation across trips to each collective site in terms of site size, expected catch rate, and other characteristics. Therefore, characteristics cannot be included as explicit determinants of the utility an angler receives from a trip to a collective site. Their influence is replaced with a constant term, α_O.

If the trip is to a site that is not in one of the four explicit regions in southwestern Montana, assume

$$V_{R5} = [\beta_0(1-NRES) + \beta_{0NR}(NRES)](PPY) + \alpha_{R5}. \quad (18)$$

Note in this case there is no information about trip costs, so even though trip cost is positive it cannot be included as an explicit determinant of the utility the angler receives from a trip to this fifth region. Its influence must be accounted for by the fifth-region constant, α_{R5}.

If an individual does not take a fishing trip in period p, that individual will have *PPY* to spend on other goods, and V_0 is

$$\begin{aligned} V_0 = &[\beta_0(1-NRES) + \beta_{0NR}(NRES)](PPY) \\ &+ \beta_G(G) + \beta_{SK}(SK) + \beta_{MTF}(MTF) \\ &+ \beta_{FT}(FT) + \beta_A(A) + \beta_V(V) \\ &+ \beta_{PNR}(NRES) + \alpha_P, \end{aligned} \quad (19)$$

where G is the angler's gender (1=female), SK is self-assessed fishing skill, MTF is years fished in Montana, FT is reported hours of free time in a typical weekday, A is age, V is weeks of paid vacation, and α_P is a constant term. While each angler's utility is an increasing function of his or her income, the choice probabilities are not a function of income because an increase in income affects the utility from all of the alternatives equally. Ceteris paribus, resident and nonresidents are allowed to have different preferences for trout fishing in Montana relative to other activities. This feature, in addition to the separate catch and price parameters for residents and nonresidents, and along with the variation between residents and nonresidents in travel costs, skill, and other included variables, allows the model to reflect significant differences in preferences between resident and nonresident anglers.

The catch rate component of the model assumes the probability that a representative angler will catch a certain number of fish at a site depends on the expected catch rate for that site and the number of hours fished, and is increasing in both. Specifically, it assumes that catch is Poisson distributed as a function of the expected catch rate and the number of hours fished.[11] The Poisson distribution correctly restricts the observed catch to be a nonnegative integer and is consistent with the large number of observations with zero catch (almost half). Expected catch rates are the link between the catch rate and travel-cost components of the model in that they are parameters in both components.

We define x_{kj} as the reported catch for intercept trip k to site j and h_{kj} as the number of hours of fishing associated with that catch. Set $\lambda_{kj} = h_{kj}ECR_j$. Assume that catch has a Poisson distribution such that the probability of catching x_{kj} fish in h_{kj} hours of fishing is

$$\mathrm{Prob}(x_{kj}) = \frac{e^{\lambda_{kj}}\lambda_{kj}^{x_{kj}}}{x_{kj}!} \qquad (20)$$

$j=1, 2, \ldots, 25$ and $x_{kj}=0, 1, 2, \ldots$

Sites with high perceived catch rates have many observations on catch while sites with low perceived catch have only a few observations, even though approximately the same amount of time was spent interviewing at each of the 26 intensively studied sites (except Silver Bow Creek which received about 48 percent of the interviewing time received by other sites, enough to confirm that virtually no fishing was occurring). The number of observations on catch varies from 0 at Silver Bow Creek to 176 at Madison 2, and the reported fishing time for which we have catch data varies from 7 h at Warm Springs Creek to 847 h at Madison 2.[12]

[11] McConnell *et al.* (1995) first used the Poisson distribution to characterize catch. The expected catch rate for Silver Bow Creek is zero, as there are no fish due to high pollution levels. The expected catch rate for Madison 2 was normalized to its simple Poisson average catch rate (0·726). Madison 2 is the site with the most recorded fishing time. This anchors the expected catch rates for the other 24 sites on the zero expected catch rate for Silver Bow Creek and the simple Poisson average for Madison 2.

The simple average for a site with few hours of reported catch will be an imprecise estimate of the site's expected catch rate relative to sites with many hours of reported catch. For example, the simple average for Upper Clark Fork 4, 1·5 fish per hour (based on 21 h of reported catch from 9 trips) is, relatively speaking, an imprecise estimate of the site's expected catch rate, whereas the simple average for Madison 2, 0·72 (based on 847 h of reported catch from 172 trips) is a relatively precise estimate of the expected catch rate at Madison 2. Therefore, when one has limited catch data for some sites, we argue that assuming the expected catch rates are the simple observed averages is not the best way to proceed. Since data are available on both individual observed catch and individual trip patterns, the best statistical estimate of a site's expected catch rate is a weighted average of these two separate estimates, where the weight on a site's simple average observed catch rate is an increasing function of the number of hours of fishing at the site for which catch is reported.

For each of the 443 anglers in the recreation demand model data set, there is a record of how many fishing trips he or she took during the 1992 summer season, but not a complete record of where each angler went for each trip. An angler's fishing trips were allocated to one of the following 36 site categories on the basis of the information available for each trip:

T_{UCF1}, T_{UCF2}, …, T_{MD2}=Number of trips to each of the 26 intensively studied sites in Table 1 (26 variables).

T_{Xo}=Number of trips to a single site in one of four study regions, but not to an intensively studied site, where X=*RM* for Missoula, *RBU* for Butte, *RH* for Helena, and *RBZ* for Bozeman.

T_X=Number of trips where each trips involved multiple sites in one of four study regions, but no sites to other regions, where X is as defined as for T_{Xo}.

T_{R5}=Number of trips to rivers or streams in Montana that are outside of the 4 study regions.

T_O=Number of trips that involved multiple regions or where there is no information about the site(s) visited except that the trip involved trout fishing in Montana.

[12] When the number of observations is small, the simple average is often unduly influenced by a few extreme observations. For example, one of the individuals intercepted at Upper Clark Fork 4 reported catching 18 fish in 3 h. Eliminating this one observation drops the simple average from 1·5 to 0·77 fish per hour.

The number of periods the individual chose not to fish, N, is 60 minus the individual's total number of fishing trips.

The per-period probability of a trip to multiple sites in region k (k=*M, BU, H, BZ*) is modeled as the per-period probability that region k will be chosen. Denote this per-period probability Prob_{Rk}. For example, Prob_{RM} is the per-period probability the Missoula region will be chosen, where $\text{Prob}_{RM}=\text{Prob}_{UCF1}+\text{Prob}_{UCF2}+\cdots+\text{Prob}_{LBF}+\text{Prob}_{RMo}$.

Because of the intercept nature of the sampling, the 443 individuals in the data set take, on average, more trips than anglers randomly chosen from the population who fish for trout at rivers and streams in Montana. To adjust for overavidity, choice-based avidity weights were used (Manski and Lerman, 1977). All observed choices (fishing or nonfishing) were weighted, separately for residents and nonresidents, by the ratio of the population probability of the choice to the sample probability. Let $w_f=(1-NRES)\times w_f^r+NRES\times w_f^{nr}$ be the weight for a fishing trip, where w_f^r equals the ratio for residents, which is the mean number of trips per season for the population (based on state data) relative to the sample: 6·356/17·880=0·355, and w_f^{nr} is the same ratio for nonresidents: w_f^{nr}=1·342/3·816=0·352. Let $w_{nf}=(1-NRES)w_{nf}^r+NRES\times w_{nf}^{nr}$ be the weight for nonparticipation, where w_{nf}^r equals the ratio of the mean number of periods of nonparticipation in the population to the mean number in the sample for residents: w_f^r=(60−6·356)/(60−17·880)=1·274, and w_{nf}^{nr} is the same ratio for nonresidents: w_{nf}^{nr}=(60−1·342)/(60−3·816)=1·044. The impact of avidity weights on estimated consumer surplus is discussed in the section below on damage estimates.

The log likelihood function for the travel-cost component of the model is

$$\begin{aligned}L_{tc}=\sum_{i=1}^{443}\Bigg[&w_{nf}\{N\ln(\text{Prob}_0)\}+w_f\Bigg\{T_O\ln(\text{Prob}_O)\\&+T_{R5}\ln(\text{Prob}_{R5})+T_{RMo}\ln(\text{Prob}_{RMo})\\&+T_{RBUo}\ln(\text{Prob}_{RBUo})+T_{RHo}\ln(\text{Prob}_{RHo})\\&+T_{RBZo}\ln(\text{Prob}_{RBZo})+T_{RM}\ln(\text{Prob}_{RM})\\&+T_{RBU}\ln(\text{Prob}_{RBU})+T_{RH}\ln(\text{Prob}_{RH})\\&+T_{RBZ}\ln(\text{Prob}_{RBZ})+\sum_{j=1}^{26}T_j\ln(\text{Prob}_j)\Bigg\}\Bigg],\end{aligned}\quad(21)$$

where the T variables and all the probabilities (*Prob*) are indexed by i; the i subscript is suppressed for notational simplicity. This component of the log likelihood function is a function of all parameters in the model, the data on site characteristics, and the data for each of the 443 anglers on trips, trip costs, gender, age, residency, skill, years fished in Montana, free time, and weeks of paid vacation.

The catch component of the model adds the following term to the log likelihood function:

$$L_c=\sum_{j=1}^{26}\sum_{k=1}^{K_j}[-h_{kj}ECR_j+x_{kj}\ln(h_{kj}ECR_j)-\ln(x_{kj}!)],\quad(22)$$

where K_j is the number of intercept trips to site j with catch information. This component of the log of the likelihood function is a function of the expected catch rate parameters and the observed catch data. The likelihood function for the joint model of participation, site choice, and expected catch rates is $L=L_{tc}+L_c$.

The estimated model

Gauss was used to find those values of the parameters that maximize the likelihood function using FIML (see Morey, 1999). On the basis of asymptotic t statistics, all included variables are statistically significant.[13] The parameter estimates are reported in Table 2.

The 1991 National Survey of Fishing, Hunting and Wildlife-Associated Recreation (US DOI, 1993) estimates an average of 8·8 trips annually by residents to rivers and streams in Montana. Our model predicts 9·4. Both our model and the National Survey estimate 1·4 trips annually by nonresidents who currently fish in Montana. The correlations between the actual and predicted site proportions for the 26 intensively studied sites are 0·71 for the full sample, 0·70 for residents, and 0·67 for nonresidents.

As mentioned above, the opportunity cost of time is 11% of the angler's wage rate; this value was estimated as a parameter in the model, not preselected. This percentage is lower than the percentage used in many travel cost studies.[14] Estimating this percentage is preferred to forcing the percentage to take the value from another study or model. Estimates from one study should not, in general, be used in another travel-cost model: the estimated percentage can be sensitive to model specification and the assigned values to travel costs, and one

[13] Programs, specific parameter estimates, and their t statistics can be obtained from the second author.
[14] See, for example, McConnell and Strand (1981), Smith *et al.* (1983), and Bockstael *et al.* (1987).

Table 2. Parameter estimates

Parameter	Estimate	*t* statistics
Expected catch rates		
ECUCF1	0·434	6·967
ECUCF2	0·222	2·941
ECUCF3	0·423	4·783
ECMCF	0·447	8·883
ECRC	0·926	20·598
ECFC	0·877	9·268
ECBT1	0·240	5·546
ECBT2	0·739	14·833
ECLC	0·683	8·698
ECBF	0·267	6·203
ECLBF	0·731	5·244
ECUCF4	0·846	7·660
ECUCF5	0·784	8·851
ECWSC	0·771	5·429
ECBH1	0·899	17·930
ECBH2	0·812	14·428
ECJ1	0·280	6·994
ECJ2	0·326	7·696
ECBV	0·637	17·164
ECMS	0·760	17·577
ECLY	0·382	11·238
ECG	0·884	11·481
ECEG	1·051	11·184
ECMD1	0·413	11·602
ECMD2	0·7260	—
Parameter explaining the influence of the expected catch rates		
β_{ECR}	0·126	1·581
β_{ECRNR}	0·246	2·218
β_{CRSK}	2·604E-2	1·633
Parameters explaining the influence of trip costs		
β_{0}	7·224E-3	3·739
β_{0NR}	6·150E-4	3·819
β_{W}	0·110	3·479
Parameters explaining the influence of gender, age, skill, years finished in Montana, free time, vacation, and residency		
α_{P}	4·414	23·203
β_{G}	0·239	2·349
β_{A}	5·20E-3	2·565
β_{SK}	−0·480	−20·029
β_{MTF}	2·380E-2	10·412
β_{FT}	−0·040	−5·997
β_{V}	0·093	5·927
β_{PNR}	1·840	19·758
Parameters explaining the influence of size, campgrounds, and suitability for floating		
β_{SZ}	0·213	3·207
β_{CG}	0·131	3·368
β_{LFF}	0·100	2·151
β_{HFNF}	−0·168	−2·782
Other parameters		
α_{O}	0·431	3·270
α_{R5}	−0·052	−0·878
s	8·746	7·179
t	7·327	3·723

would expect the disutility associated with travel to sites to vary across sets of sites.

In terms of estimated expected catch rates, the top five sites include some of the most famous trout streams in the United States. In contrast, four of the ten sites with the lowest estimated expected catch rates are impacted sites in the upper Clark Fork River Basin (Upper Clark Fork 1–3 and Silver Bow Creek). Most of the expected catch rates estimated by the recreation demand model are similar to the simple Poisson catch rates, except at those sites with few observed hours of trout fishing. For example, the Beaverhead, with 464 hours of fishing over 172 trips, has a simple Poisson average catch rate of 0·6331, and a jointly estimated catch rate of 0·6366. In contrast, the simple average for Upper Clark Fork 4 is 1·5 trout caught per hour, based on only 21 hours of reported catch from 9 trips, but the model estimated catch rate is 0·85.

The relationship between trout stocks and expected catch rates

Biological injuries are related to economic damages through their impact on stock sizes which in turn affect angler catch rates. Stock estimates (trout per hectare) were available for 1992 for eight of the study sites (Don Chapman Consultants, 1995) and were combined with the estimated expected catch rates to estimate the stock-catch function: $ECR_j=0{\cdot}1539\ln(STOCK_j+1)$ with $R^2=0{\cdot}93$ and $t=9{\cdot}91$.

This functional form of the regression allows for a nonlinear stock-catch relationship and the regression predicts zero expected catch when stocks are zero.[15] The estimated function indicates decreasing rates of increase in expected catch rates from increasing fish stocks. The stock-catch model and estimates of baseline (no-injury) stocks were then used to predict expected catch rates at the injured sites under baseline conditions in the absence of past releases of heavy metals. Specifically, the baseline expected catch rate for each Clark Fork site was calculated by adjusting the current expected catch rate by the percent change in expected catch rates (from current to baseline conditions) predicted by the stock-catch model. For Silver Bow Creek, which currently has zero stock, the best estimate of the

[15] A linear model gave a much poorer fit. When an intercept term was included it was not statistically significant.

expected catch rate under baseline conditions is that predicted directly by the stock-catch model. Injuries have caused proportionately large reductions at all of the impacted sites except Upper Clark Fork 5. Aggregating across sites and adjusting for site lengths, expected catch rates would be almost twice as high under baseline conditions.

Use under baseline

The recreation demand model predicts that if baseline conditions were restored at the impacted Upper Clark Fork River and Silver Bow Creek sites, an average resident angler active in river and stream trout fishing in southwestern Montana would take 0·36 more trips per year to the impacted sites and 0·32 fewer trips to other sites in Montana. The predicted trips to the impacted sites under baseline conditions represent a 66% increase relative to the predicted trips under current conditions. The average nonresident angler would take 0·07 more trips to the impacted sites and 0·06 fewer trips to other sites. The net change is more than a doubling of the total number of trips to the impacted sites for nonresidents. In summary, when the impacted sites are returned to baseline conditions few new trips are predicted to be taken by existing anglers, but approximately 5% of trips to other sites are predicted to be substituted to the impacted sites.

The increase in visitation to the impacted sites under baseline conditions varies across sites, reflecting the variability in increased expected catch rates. For example, under baseline conditions the expected catch rate at Upper Clark Fork 2 would increase by 123%, and the site would have a higher expected catch rate than other well-known sites such as Bitterroot 1, Blackfoot, and the Jefferson River sites. Compared to current conditions, the predicted visitation increases by 83% under baseline conditions at Upper Clark Fork 2. Visitation at Upper Clark Fork 2 is predicted to exceed visitation at Jefferson 2, Yellowstone, Madison 1, and other popular sites. This reflects the relatively high expected catch rate at the impacted site under baseline conditions, the size of the site, and that this site is closer than other substitute sites for residents of nearby cities such as Missoula, Helena, and Butte. Remediating injuries would also have a substantial impact on Silver Bow Creek, making it an excellent small stream for trout fishing. That anglers will substitute fishing visits from other sites to the upper Clark Fork River and Silver Bow Creek sites indicates that anglers are currently taking trips to sites that, under baseline conditions, would be less desirable because of lower catch rates or increased travel distances.

E(*WTP*) for the absence of injuries

For anglers who are residents of Montana, the estimated expected annual willingness to pay, E(*WTP*), for the absence of injuries ranges from $0·01 to $42·96 with a mean of $6·31 and a median of $4·54 (in 1992 dollars). The standard deviation of mean E(*WTP*) for residents is $3·13.[16] For nonresident anglers who fish in Montana, estimated E(*WTP*) ranges from $1·19 to $40·35 with a mean of $14·17 and a median of $12·62. The standard deviation of mean E(*WTP*) for nonresidents is $6·59. E(*WTP*) varies across individual anglers because trip costs and the other determinants of E(*WTP*) vary across anglers. Consider the angler with the highest estimated E(*WTP*) ($42·96), and compare this angler to an angler with an E(*WTP*) that is effectively zero. The angler with an E(*WTP*) of $42·96 resides near Silver Bow Creek, is a 52-year-old male, reports a skill level of 6 on a scale of 1 to 7, and reports 11 h of free time on a typical weekday. This is an angler with low trip costs for the injured sites and a higher than average skill level and amount of free time. In contrast, the angler with an E(*WTP*) of effectively zero is a 42-year-old male who reports a skill level of 4, reports 5 h of free time on a typical weekday, and lives approximately 270 miles from the injured sites. This angler has high trip costs and lower skill and free time. The distributions of the resident and nonresident E(*WTP*) are similar to a log-normal distribution in that they have a long tail extending into higher E(*WTP*) values.

For residents, $6·31 is approximately 8% of the average trip cost, and $14·17 is only 2% of the average trip cost for nonresidents: nonresidents spend an average of $221 for lodging and $193 for equipment and guides, so $14·17 does not appear to be much to pay per year for the opportunity to have significantly better fishing along 145 miles at the injured sites. Viewed in terms of what it would cost

[16] Details on the calculation of E(*WTP*) for nested logit models without income effects can be found in Hanemann (1999) and Morey (1999). Standard deviations for the estimated mean of the per angler damages were estimated through repeated simulations of the recreation demand model using the Krinsky-Robb procedure.

to travel to substitute sites rather than the injured sites, the mean E(*WTP*)s would cover 36 additional round-trip miles of annual fishing travel by a resident, and 66 additional round-trip miles by a nonresident.

It is relevant, but not surprising, that nonresidents who currently fish the cold-water rivers and streams of southwestern Montana have higher estimated fishing damages per year in southwestern Montana than active resident anglers. These nonresident anglers, while taking fewer trips to southwestern Montana than resident anglers, spend more per trip on Montana fishing than most residents (e.g., the mean trip cost for nonresidents is \$840, whereas the mean trip cost for residents is only \$77) and have a lower estimated marginal utility of money; further, their selection of Montana fishing sites is more responsive to expected catch rates than is the case for residents.

Aggregate damage estimates

On the basis of State of Montana angler license data and data collected by the 1991 National Survey (US DOI, 1993; see also Morey *et al*., 1995), we estimate that approximately 71 000 resident anglers and 65 000 nonresident anglers were active in river and stream trout fishing in southwestern Montana in 1992. The residents anglers took an estimated 629 000 fishing trips to rivers and streams in Montana, and the nonresidents took an estimated 92 000 trips. Applying the mean annual damages of \$6·31 per resident angler results in aggregate annual damages to residents of \$448 000 (in 1992 dollars). Applying the mean nonresident annual damages of \$14·17 results in aggregate annual damages to nonresidents of \$921 000.

Sensitivity of damage estimates

When the model is estimated without the avidity weights, E(*WTP*) estimates are upwardly biased by more than an order of magnitude. If the simple average Poisson catch rates are used rather than estimating the expected catch rates as model parameters using both catch and trip data, the mean damage estimates are 58% lower for residents and 30% lower for nonresidents.

To test for potential differences between the sample and population proportions of trips to the 26 sites, site weights were constructed as the ratio of the population shares to the sample shares of trips to the intensively studied sites. Three different sets of weights were derived from three different estimates of the population shares, based on the number of anglers receiving postcards per interviewer visit, anglers receiving postcards per hour of interviewer time, and anglers who returned postcards. The model was re-estimated using each of these three sets of weights. Site weighting results in mean E(*WTP*)s ranging from \$5·93 to \$6·88 for residents, and from \$13·27 to \$15·32 for nonresidents. These alternative methods do not provide much variation in results, with the means of E(*WTP*) from the model that does not include the additional site weights falling in the middle of these ranges (which span $\pm 10\%$). This suggests that the implicit weights in the *ISF* procedure were reliable without the complications of further weights.

The model of participation and site choice was also estimated with only the 291 resident anglers. The estimated mean E(*WTP*) is \$5·97, 5% lower than the estimate from the model that includes both residents and nonresidents. The damage estimates for nonresident anglers are more sensitive to model specification, which is most likely due to sample sizes (291 residents versus 152 nonresidents) and more variation in trip costs among resident anglers than nonresident anglers. The nonresident travel-cost data do not have enough variation to estimate a completely separate model of participation and site choice for the 152 non-residents.

To further examine the sensitivity of the estimates, we estimate a site-choice-only model (without participation) separately for non-residents and for residents, which will result in a lower-bound estimate of E(*WTP*) for the absence of injuries (Morey, 1994 and 1999). With this model, the estimate is \$9·41 for non-residents and \$4·71 for residents.

Conclusions and epilogue

Mining wastes have injured Montana's Silver Bow Creek and Upper Clark Fork River. This paper describes the NRDA sampling and modeling procedures used to estimate damages to anglers, and presents results relevant to policy and Superfund litigation. In the model, residents and nonresidents are allowed to have different preferences. Nonresident anglers, who are often excluded in similar analyses, are found to have larger damages than resident anglers. A stock-catch function is estimated, linking expected catch rates, which are key in determining demand and economic values, to trout stock data and biological injuries. The potential need for weights in the likelihood function as a result of the *ISF* sample is investigated, and the *ISF* survey technique is found to be both cost-effective and appropriate if one has independent estimates of avidity and site proportions. Maximum likelihood expected catch rates are estimated endogenously in the model.

In June 1998, the State of Montana and ARCO entered into a partial settlement for the amount of $215 million for environmental damages. This settlement covers the State's claims for compensable damages, including those to anglers.

Acknowledgements

We thank Rob Brooks, Trudy Cameron, Rob Collins, John Duffield, Bob McFarland, Chris Neher, Douglass Shaw, and two anonymous reviewers for help and advice. This paper is based on work prepared by the authors and Hagler Bailly, Inc. for the State of Montana, Natural Resource Damage Program.

References

Bockstael, N. E., Strand, I. E. and Hanemann, W. M. (1987). Time and the recreation demand model *American Journal of Agricultural Economics* **69**, 293–302.

Desvousges, W. H. and Waters, S. M. (1995a). Volume II: Critique of the State of Montana's Recreation Study. Submitted to United States District Court, District of Montana, Helena Division, State of Montana v. Atlantic Richfield Company No. CV-83-317-HLN-PGH.

Desvousges, W. H. and Waters, S. M. (1995b). Volume III: Report on Potential Economic Losses Associated with Recreation Services in the Upper Clark Fork River Basin. Submitted to United States District Court, District of Montana, Helena Division, State of Montana v. Atlantic Richfield Company No. CV-83-317-HLN-PGH.

Don Chapman Consultants, Inc. (1995). Assessment of Injury to Fish Populations: Clark Fork River NPL Sites, Montana (Appendix G to Lipton *et al.*, 1995). Prepared for the State of Montana, Natural Resource Damage Litigation Program.

Hanemann, W. M. (1999). Welfare analysis with discrete choice models. Chapter 2, In *Valuing the Environment Using Recreation Demand Models* (C. Kling and J. Herriges, eds.), Edward Elgar Publishing.

Lipton, J., Bergman, H., Chapman, D., Hillman, T., Kerr, M., Moore, J. and Woodward, D. (1995). Aquatic Resources Injury Assessment Report, Upper Clark Fork River Basin. Prepared by RCG/Hagler Bailly, Inc. for the State of Montana, Natural Resource Damage Litigation Program.

Manski, C. F. and Lerman, S. R. (1977). The estimation of choice probabilities from choice-based samples. *Econometrica* **45**, 1977–1988.

McConnell, K. E. and Strand, I. (1981). Measuring the cost of time in recreation demand analysis: an application to sport fishing. *American Journal of Agricultural Economics* **63**, 153–156.

McConnell, K. E., Strand, I. and Blake-Hedges, L. (1995). Random utility models of recreational fishing: catching fish with a poisson process. *Marine Resource Economics* **10**, 247–261.

McFadden, D. (1995). Report on montana's and ARCO's travel cost reports. Submitted to United States District Court, District of Montana, Helena Division, State of Montana v. Atlantic Richfield Company No. CV-83-317-HLN-PGH.

Morey, E. R. (1999). TWO RUMs UnCLOAKED: Nested-logit models of site choice and nested-logit models of participation and site choice. In *Valuing the Environment Using Recreation Demand Models* (C. Kling and J. Herriges, eds), pp. 65–120. Northhampton, MA: Edward Elgar Publishing.

Morey, E. R. and Waldman, D. M. (1993). Measurement error in recreation demand models: the joint estimation of participation, Site choice and site characteristics, discussion paper, Department of Economics, University of Colorado, Boulder, CO 80309–0256.

Morey, E. R. and Waldman, D. M. (1998). Measurement Error in Recreation Demand models: The Joint Estimation of Participation, Site Choice and Site Characteristics. *Journal of Environmental Economics and Management* **35**, 262–276.

Morey, E. R. and Waldman, D. M. (2000). Joint estimation of catch and other travel-cost parameters: some further thoughts. *Journal of Environmental Economics and Management* **40**, 82–86.

Morey, E. R., Waldman, D. M. and Rowe, R. D. (1995). Assessment of damages to anglers and other recreators from injuries to the upper clark fork river basin. Prepared by Hagler Bailly Consulting, Inc. for the State of Montana Natural Resource Damage Litigation Program.

Smith, V. K., Desvousges, W. and McGivney, M. (1983). The opportunity cost of time in recreation demand models. *Land Economics* **59**, 259–277.

Train, K., McFadden, D. and Johnson, R. (2000). Discussion of Morey and Waldman's Measurement Error in Recreation Demand Models. *Journal of Environmental Economics and Management* **40**, 76–81.

U.S. DOI. (1993). 1991 National Survey of Fishing, Hunting and Wildlife-Associated Recreation: Montana. Prepared by US Fish and Wildlife Service, Washington, DC.