1990

Single-Stage and Two-Stage Decision Modeling of the Recreational Demand for Water

LeRoy T. Hansen
United States Department of Agriculture

Arne Hallam
Iowa State University, ahallam@iastate.edu

Single-Stage and Two-Stage Decision Modeling of the Recreational Demand for Water

LeRoy T. Hansen and J. Arne Hallam

Abstract *Past rivalry over access to water has usually been between the farmers who irrigate and new agricultural, industrial, and municipal demands. Recently, the recreational demand for water has become another consideration in water allocation decisions. We examine the significance of the recreational demand for water as a fishery resource by applying two different frameworks to the decision to fish. The consistency of the estimated responses to changes in fishery resources across both decision frameworks testifies to the importance of streams as a recreational fishery resource. Modeling behavior within the household production framework allows all downstream effects to be estimated, not just impacts at particular sites. Marginal values of water as a recreational fishery resource are estimated based on day values of fishing derived in prior research.*

Keywords. *Recreational demand, recreational fishing, stream fishing*

Agriculture, the single largest consumer of water in the United States, will face reduced allocations of streamflow if political pressures for recreational uses of the water become significant enough. State water managers have granted agriculture ownership or rights to water. Any water reallocation must work within water laws. Water rights are, in general, based on appropriation doctrine in the Western States and the riparian doctrine in Eastern States. Neither of these doctrines prevents States from reallocating water, although the State may be obligated to compensate those who forgo water rights. For more detail on water law, see (*8*).[1]

The effect of streamflow depletions on recreational fishing is estimated for all regions in the contiguous United States. Two approaches to modeling the decision to fish are applied. The consistency of results from the two approaches provides additional support for the estimated responses to variations in streamflow. The National Hunting, Fishing, and Wildlife-Associated Recreation (FHWAR) survey, with specific questions on the respondent's recreational fishing activities, provides the necessary observations on individual behavior (*22*). The effect of streamflow depletion is measured by the change in the number of days spent fishing given an acre-foot change in annual streamflow. Responses are estimated for individuals and aggregated across the relevant (downstream) population to estimate the total change in days fished per acre-foot change in flow. The days per acre-foot responses within each State are multiplied by prior estimates of the value of a day of fishing within the respective State to approximate the recreational fishery value of an acre-foot of streamflow.

Significant difficulties hamper the estimation of the recreational benefits of water. We do not overcome all difficulties and, therefore, do not provide a bottom line value of water for recreation. We cannot assess the water's value as a fishery resource, but instead offer insight into the significance and extent of water's recreational use as a fishery resource. The regional estimates of the recreational significance of water indicate the areas where recreational benefits are most significant and suggest to water managers which policies might be most beneficial to both consumers and recreational users of water.

At least five studies have attempted to estimate the recreational fishing value of streamflow. Amirfathi and others, Daubert and Young, Walsh and others, and Ward limited their analyses to a stream segment or to a drainage basin (*1, 6, 23, 24*). Johnson and Adams included the downstream recreational benefits but focused on only steelhead fish populations and not other species of fish (*10*).

Earlier works (except (*12*)) attributed fishery quality to the level of streamflow during a particular month or season, a contention that is valid only when those particular periods are most threatening to the health of the fishery. The aggregate nature of the present analysis and the "Montana Method" suggest that annual streamflow is the best indicator of the health and quality of a stream fishery (*20*). The Montana Method has shown that nature has evolved fisheries to do best in levels of pristine or natural streamflow. Natural flow is the flow that would occur without any upstream human diversions or impoundments. Depletion of streamflow reduces the productivity of the stream fishery.

Since 1964, the Montana Method has been tested in detailed field studies in many cold water and warm water streams of various sizes and across streams of various flow regimes. Fishery habitats are remarkably

---

Hansen is an economist with the Resources and Technology Division, ERS. Hallam is an associate professor of economics, Iowa State University, Ames. The authors thank Steve Crutchfield, Marc Ribaudo, Dick Brazee, Bruce Larson, C. Edwin Young, and other helpful reviewers.

[1] Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

similar in most of the streams which carry the same portion of their average seasonal flows Thus, reservoirs can damage fisheries by altering flow from normal seasonal variations However, reservoirs can improve fisheries by evening up flow variations between years [2] While better water management may improve some stream fisheries (see *23*), estimating these effects is beyond the scope of this analysis

This study improves upon earlier studies by including the effects of streamflow depletion on all recreational fishing and including all downstream fishery effects The recent efforts to estimate the recreational fishery value of streamflow reflects a recognition of the importance of streamflow as a recreational fishery resource The marginal value of recreational uses of streams will grow as demand for these resources grows because, in contrast to market goods, the number of streams and rivers cannot be increased

Preliminary Model Development

Fishing is not the only recreational use of streams, but it is considered to be the most significant (*2*) Fish live and move throughout a stream so that the stream offers a continuum of fishing sites A change in streamflow can affect the quality of fishing at all downstream sites Because of this, we estimate the response of streamflow changes by its impact on individuals, aggregating across individuals as opposed to measuring responses at individual sites and aggregating across sites This same reasoning has been applied by Russell and Vaughan (water quality) and Miller and Hay (hunter participation) (*19,16*)

This paper models individuals behavior within the household production framework (*3,7*) The household production framework accounts for the household's decisions on resource allocation by emphasizing that households use time, market goods, and available public goods in the production of "commodities," intangible items that directly enter the utility function In this case, we estimate a reduced-form commodity supply/demand equation The recreational fishing commodity is assumed to be produced using time, the available fishery resources, and technology Demand for the commodity is assumed to depend on personal characteristics and the availability of substitute commodities If time spent fishing corresponds linearly with the production level of the recreational fishing commodity, then, following work by Deyak and Smith, the reduced form commodity supply/demand equation can be written as

$$DAYS = f(FR,OR,PC), \qquad (1)$$

which describes the number of days an individual spends fishing (that is, the level of recreational fishing commodity produced) as a function of the available fishery resources (FR), the availability of other recreational commodities (OR), and the personal characteristics of the individual (PC) (*7*) Since this is an equilibrium relationship determined after setting "commodity" demand equal to commodity supply, price does not appear in the equation [3] The FHWAR survey contains information on individual fishing activities and on personal characteristics The Water Resources Council's Second National Water Assessment (SNWA) provides data on streamflow Other resource availability estimates are provided by the 1982 National Resources Inventory (NRI) (*20*)

Response Estimation

This analysis determines the significance of a unit of water to the downstream demand for fishery resources The design of the FHWAR survey allows two approaches, a two-stage approach and a single-stage approach, to be used to estimate the impact of streamflow changes on the expected number of days an individual fishes We test the significance of streamflow as a fishery resource in two different models, compare the results, and examine the significance and consistency of the estimated responses

The FHWAR survey obtained fishing participation responses from two separate samples which generated two different data sets The first survey screened the continental U S population at large More than 340,000 respondents were asked questions on their personal characteristics and whether or not they fished in 1980 The second survey followed up on a 35,615-person subsample of those who said in the screening survey that they had fished This second data set contains the same information on personal characteristics as the first data set However, it provides the number of days fished and other detailed information on the individual's fishing participation

The Two-Stage Approach

The two-stage approach views the individual's decision as a two-stage process, and thus, relies on two regression equations In the first stage, the individual decides, for the year, whether or not to fish, the prob-

---

[2] Catch rates and, therefore, fishing participation can move inversely to the annual flow variations in the short run For example, a dry year can lead to fish stocks being concentrated in small pools, and catch rates will rise A subsequent year of more normal precipitation and flow levels can then lead to lower catch rates because of the heavy harvesting and the poor fishery conditions in the prior year This same inverse relationship between the quality of the fishery and catch rates can be problematic to analyses relating observed flows to fishing behavior

[3] The independent variables of the reduced-form equation are the commodity supply and demand shifters (*7*) Alternatively, a reduced-form equation can be solved for equilibrium price by equating quantity in the commodity supply/demand functions For other applications of this approach, see (*16,19*)

ability of an individual fishing, P(fish), is estimated from the screening sample In the second stage, the number of days to fish is decided, the expected number of days fished, given that the individual fished, (D|fish), is estimated from the follow-up survey In the two-stage decision framework, the estimation of DAYS of equation 1 is described by

$$DAYS = P(fish)\ (D|fish) \qquad (2)$$

The model used to estimate P(fish), the probability of fishing, is applied to the population sample and can be described as

$$Y = g(FR,OR\ PC) \qquad (3)$$

where Y, the dependent variable, equals 1 if the individual fished and zero otherwise, FR is a vector of fishery resources, OR is a vector of measures of other recreational resources, and PC is a vector of personal characteristics of the individual (including income)

The model used to estimate (D|fish) is applied to the sample of those who fished and can be described similarly as

$$Z = h(FR,OR,PC) \qquad (4)$$

where Z is the number of days spent freshwater fishing (but not in the Great Lakes) and the independent variables are as described above The probit and tobit transformations of equations 3 and 4 (discussed below) generate, respectively, P(fish) and (D|fish) of equation 2

The Single-Stage Approach

The second approach views the individual's decision on the level of fishing as a single-stage procedure This approach requires a population sample that includes the number of days fished by those who fished (for example information from both the screening and follow-up survey) To get information from both the screening survey and the follow-up survey into one data set, observations in the screening survey on those who fished were replaced with a statistically representative sample of observations from the follow-up survey[4] Thus, in the single-stage framework, equation 1 is written as

$$W = m(FR,OR,PC), \qquad (5)$$

where W is the number of days spent freshwater fishing (but not in the Great Lakes) and the independent variables are as in equations 3 and 4

The applied methodology ignores the value side of the day spent fishing but provides information on the effect of shifts in the independent variables on the number of days fished by current and new participants As discussed earlier, estimation of this reduced-form commodity supply and demand equation fails to provide information on price However, marginal values for days of fishing have been estimated in previous studies (*4,9,12*) and can be applied to determine the value of marginal shifts in the independent variables

Statistical Considerations

A probit model is applied to the yes-no fishing decision of equation 3 to estimate P(fish) (*13,14*) The statistical model used to estimate equation 4 belongs to the family of censored response models The dependent variable in this model is days spent freshwater fishing outside of the Great Lakes, but the follow-up sample contains observations on all people who fished including those who fished only in the ocean or Great Lakes Thus, values of Z (equation 4) are clustered at zero, indicating a censored sample and the need to apply a tobit model to estimate (D|fish) (*11*)

The single-stage estimation (equation 5) uses observations on the population where W is either zero or greater than zero This sample is another censored sample indicating, again, the need for a tobit analysis

Quantifying Stream and Lake Fishery Resources

The vector of fishery resources FR, includes both lake and stream fishery resources Lake fishery resource availability is most dependent on the surface area of lakes Though factors such as water quality and boat wakes can affect the quality of lake fishing, these factors are not expected to have created variations in lake productivity across regions

Biologists have found the surface area of streams within a region to be the most important factor determining the potential availability of stream fishery resource But, the portion of streamflow depletion is also important Cover and feeding habitat are lost and spawning beds are degraded as streamflow is depleted

Examining the effects of streamflow depletions showed that field studies, carried out on cold water and warm water streams of various sizes throughout the United States, have proved a consistent relationship between the portion of natural flow remaining in the stream (or relative flow) and the fish standing crop (*17,19,24 25*)[5] The impact of diverting a given quantity of water per stream surface acre is more signifi-

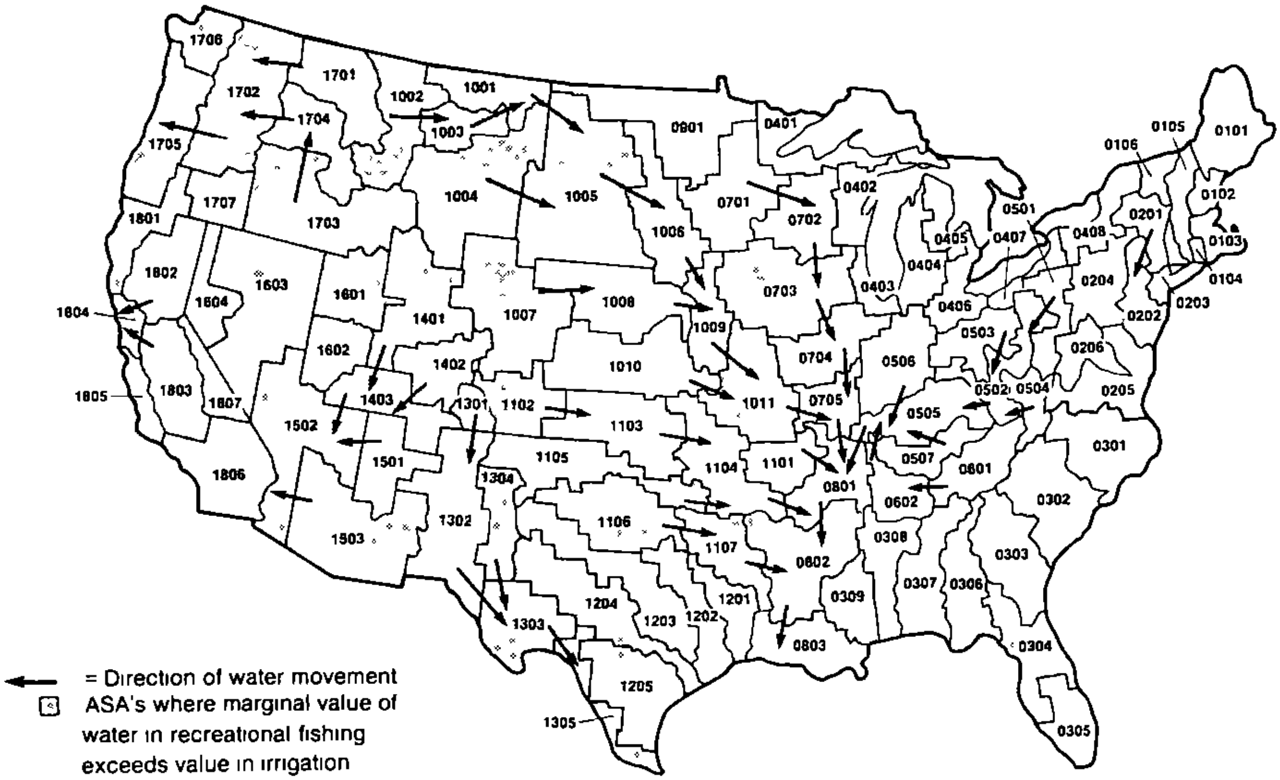
---

[4] Computer capacity constraints allowed only a subsample of the population sample to be used

[5] Fish standing crop is measured in terms of pounds of fish produced per stream surface acre

Figure 1

Areas where marginal value of water in recreational fishing exceeds value in irrigation



Water Resource Council's Aggregated Subareas (ASA's)

cant for smaller streams because the quantity is a higher portion of the smaller stream's natural flow However, the larger streams have a greater surface area so that the total effect of the diversion on the availability of fishery resources is unique to each region

The SNWA provides an estimate of relative flow for each of the 99 major drainage basins, or Aggregated Subareas (ASA's), in the United States (fig 1) The NRI furnishes county-level data on stream surface Fishery resources within a county are estimated as the product of relative flow and stream surface acres

The FHWAR survey divides the 48 contiguous States into 129 regions that identify where respondents live. Fishery resources potentially available in the 129 resident areas and in the FHWAR-delineated regions surrounding the resident areas are estimated by summing resources in the relevant counties

While the surface area and relative flow indicate the productivity of streams, the availability of fishery resources to any individual depends on the fishing pressure on the available resources Therefore, fishery resources for both streams and lakes are measured on a per capita basis

Two other factors affecting fishery resource availability are also included First, degradation of fish habitat due to loss of streamside tree cover is calculated based on data from the NRI Second, the availability of stream and lake fishery resources in the surrounding regions are adjusted for distance We do not have data on the distances individuals were from fishery resources outside of the resident areas We know that resident areas varied in size, so average distances to resources outside the resident areas must have varied [6] Based on the relationship between area and length (or distance), we proxy the average distance to resources outside the resident area with the square root of each resident area

Stream and lake fishery resources of the vector FR are quantified as

$$STREAMIN_j = \ln(COVER^{in}*FLOW^{in}*STREAM^{in}/POP^{in})_j$$

$$STREAMOUT_j = \ln((COVER^{out}*FLOW^{out}*STREAM^{out}/POP^{out})/AREA)_j$$

$$LAKEIN_j = \ln(LAKE^{in}/POP^{in})_j$$

$$LAKEOUT_j = \ln((LAKE^{out}/POP^{out})/AREA), \qquad (6)$$

---

[6] The travel times to fishery resources within the resident areas are assumed not to vary significantly across resident regions Any variation that does exist is assumed to be uncorrelated with variables included in the model

where

STEAMIN is the per capita stream fishery resources of the resident area,

STREAMOUT is the per capita stream fishery resources outside the resident area,

LAKEIN is the per capita lake fishery resources of the resident area,

LAKEOUT is the per capita lake fishery resources outside the resident area,

STREAM is stream surface area,

LAKE is lake surface area,

POP is population,

FLOW is relative flow or the portion of natural flow remaining,

COVER is 1 plus the proportion of the riparian vegetation being trees,

AREA is the square root of the total area of the resident area

The j subscripts identify values associated with individuals in the jth resident area, and the superscripts *in* and *out* signify the resources within and outside the resident region, respectively The natural logarithm of each of these resource measures, which tested superior to quadratic formulation, provides for diminishing marginal productivity of water resources in producing the recreational commodity

Thus, the right-hand side of equations 3, 4, and 5 are written as

$$\beta_0 + \beta_1 SEX + \beta_2 CITYKID + \beta_3 COUNTRYKID + \beta_4 RETIRED + \beta_5 WORK + \beta_6 INSCHOOL + \beta_7 AGE + \beta_8 AGESQUARED + \beta_9 EDUCATION + \beta_{10} HHOLDSIZE + \beta_{11} INCOME + \beta_{12} INCSQUARED + \beta_{13} URBAN + \beta_{14} SEAMILES60 + \beta_{15} SEAMILES + \beta_{16} STREAMIN + \beta_{17} LAKEIN + \beta_{18} STREAMOUT + \beta_{19} LAKEOUT, \qquad (7)$$

where the β's are the regression coefficients and the variables are as defined in table 1 Both age and

Table 1—Regression results for estimating P(fish), (D|fish), and the single-stage estimation of DAYS

Variable[1]	Two-stage		Single-stage
	P(fish)	(D|fish)	DAYS
SEX	0.133 (3.33)[2]	7.90 (8.10)	16.9 (12.1)
CITYKID	−.110 (1.68)[3]	−3.08 (2.14)	
COUNTRYKID			8.03 (5.41)
RETIRED	.180 (1.82)[3]		11.4 (3.82)
WORK		−4.11 (3.82)	
INSCHOOL		−4.18 (2.42)	9.99 (3.66)
AGE	.0115 (3.18)		2.13 (10.5)
AGESQUARED	−.000267 (5.38)		−.0262 (10.7)
EDUCATION			.559 (3.05)
HHOLDSIZE	.0812 (6.22)	−1.20 (4.39)	
INCOME	.00358 (7.29)	.0251 (2.25)	.0619 (3.60)
INSQUARED	$-4.16*10^{-6}$ (4.89)	$-5.39*10^{-5}$ (2.82)	−.000113 (3.74)
URBAN	−.135 (3.16)	−2.59 (2.94)	−6.16 (4.27)
SEAMILES60	−.155 (3.58)	−5.46 (5.61)	−6.16 (4.02)
SEAMILES	−.232 (2.75)	−5.15 (2.65)	−11.8 (3.87)
STREAMIN	.0863 (4.31)	2.33 (5.23)	3.56 (5.15)
LAKEIN	.0464 (2.48)	−.751 (1.82)*	1.59 (2.45)
STREAMOUT		.705 (2.53)	1.49 (3.36)
LAKEOUT		−.333 (1.60)*	−.823 (2.52)
CONSTANT	−.146 (1.06)*	17.3 (6.59)	−50.0 (9.41)
R-squared	.1029	.0348	.0792

[1] Variables significant at the 95-percent level unless otherwise noted

[2] t-statistic in parentheses

[3] Not significant at the 95-percent level

income are expected to have diminishing marginal effects on days fished, so quadratic forms of these variables are included The variables URBAN, SEAMILES60, and SEAMILES are used as proxies for prices of substitutes to the recreational fishing commodity

Because equation 7 is a reduced-form equation, the estimated coefficients cannot be interpreted as either demand or supply structural parameters Instead, the coefficients represent a combination of the supply and demand parameters (*7*, p 69)

Coefficients on STREAMIN, LAKEIN, STREAMOUT, and LAKEOUT are expected to be positive The relative sizes of coefficients on the stream and lake variables depend on which resource is the better recreational fishery resource Coefficients on SEAMILES and SEAMILES60 are expected to be negative since the proximity of the sea or the Great Lakes directly affects the price of a substitute for freshwater non-Great Lakes fishing. The effect of the variables describing personal characteristics is discussed in (*8*) and, therefore, is not detailed here

Results

Regression results from the two-stage analysis and the single-stage analysis both indicate that the availability of stream fishery resources is significant in explaining fishing behavior (table 1) The lack of significance of STREAMOUT in P(fish) may indicate that fishery resources that are not relatively close to home are not a significant factor in an individual's decision to fish

Most coefficients of other variables are significant at the 99-percent confidence level and are of the expected sign However, lake resources outside the resident region show a negative effect in the single-stage analysis While both the LAKEIN and LAKEOUT coefficients in (D|fish) are negative, the coefficients are insignificant One interpretation of a negative relationship between lake resource availability and days fished is that lakes are more important as an input in production of substitute recreational commodities However, estimation of the importance of lakes in other recreational activities is beyond the scope of this analysis

The probit and tobit coefficients in table 1 cannot be directly interpreted as marginal responses like OLS coefficients To better compare the measures of fishing behavior obtained from the two approaches, we estimated marginal responses for some important variables for an "average" individual (table 2)[7]

---

[7] See (*11*) for derivation of marginal effects from probit coefficients See (*19*) for derivation of marginal effects from tobit coefficients

Table 1 variables and definitions

Variable	Definition
P(fish)	Binary variable 1 if fished, 0 otherwise
(D|fish)	Days freshwater non-Great Lakes fishing of those who did fish
DAYS	Days freshwater non-Great Lakes fishing for any individual
SEX	Binary variable 1 if male, 0 otherwise
CITYKID	Binary variable 1 if the population of the area raised in was greater than 500,000, 0 otherwise
COUNTRYKID	Binary variable 1 if the population of the area raised in was less than 10,000, 0 otherwise
RETIRED	Binary variable 1 if retired, 0 otherwise
WORK	Binary variable 1 if employed, 0 otherwise
INSCHOOL	Binary variable 1 if in school, 0 otherwise
AGE	Age in years
AGESQUARED	Age in years squared
EDUCATION	Number of years attended school
HHOLDSIZE	Number of people living in household
INCOME	Income as a midpoint of (in $1,000) 0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-40, 40-50, and 57 5 otherwise
INCSQUARED	Income squared
URBAN	Binary variable 1 if 1980 Census classified area of resident as urban, 0 otherwise
SEAMILES60	Binary variable 1 if ocean or Great Lakes fishing is within 60 miles, 0 otherwise
SEAMILES	Binary variable 1 if ocean or Great Lakes fishing is within 120 miles but over 60 miles, 0 otherwise
STREAMIN	Per capita stream fishery resources of the resident area
STREAMOUT	Per capita stream fishery resources outside the resident area
LAKEIN	Per capita lake fishery resources of the resident area
LAKEOUT	Per capita lake fishery resources outside the resident area
CONSTANT	Regression constant

Table 2—Marginal effects for changes in selected variables

Variables[1]	Approaches	
	Two-stage	Single-stage
SEX	2.79	4.52
INCOME	–.0728	.00406
URBAN	–1.47	–1.65
SEAMILES	–2.73	–3.15
STREAM	$2.52*10^{-6}$	$2.13*10^{-6}$
LAKE	$1.07*10^{-8}$	$1.11*10^{-7}$
FLOW	.0130	.0110

[1]Variables defined in table 1 and equation 1.

The coefficient of determination (the R-square that is the ratio of explained to unexplained variation in the dependent variable) is not close to 1 for any of the estimated equations. But, a low R-square is characteristic of qualitative choice models. For example, Morrison has shown that with a binomial dependent variable where the probability of a success is 0.40, the maximum possible R-square is 0.167 (*17*, p. 70).

Marginal Responses to Stream Fishery Resource Availability

The change in days fished for a 1-percent change in streamflow is 0.0130 in the two-stage approach and is 0.0110 in the single-stage approach (table 2). This consistency across approaches enhances the likelihood that our estimated coefficients approximate the true relationship. Results from the single-stage approach are selected as superior to the responses estimated from the two-stage approach because of the low coefficients of determination for the P(fish) and (D|fish).[8] Estimating a single equation prevents losses in degrees of freedom.

For a better understanding of the change in days fished for a change in streamflow, marginal responses of the single-stage analysis are translated to a day-per-acre-foot estimate for each river basin. Responses within each drainage basin are totaled to provide an estimate of the total change in days fished for a 1-percent change in streamflow. Using the water volume associated with a 1-percent change in flow (provided by the SNWA), we determined the total population response for an acre-foot change in streamflow (table 3).

Table 3 indicates a considerable variation in the marginal effect of an acre-foot of streamflow. However, this variation is consistent with what one would expect. For example, in the southern half of Louisiana, which lies mostly in ASA 0803 (fig. 1), an additional acre-foot depletion of streamflow is estimated to reduce the number of days fished by all who might fish the waters a total of 0.008 day. Considerably farther upstream, in southern Nebraska, northern Kansas, and northeastern Colorado (ASA 1010 in table 3), the diversion of an acre-foot of water decreases the number of days people fish by an estimated 0.889 day. An acre-foot depletion of flow has a greater impact in the Plains than in Louisiana for three reasons. First, an acre-foot of water does not represent as significant a portion of total flow in Louisiana and, therefore, has a smaller impact on fishing opportunities. Second, because Louisiana has an abundance of fishing opportunities, marginal effects are small. Third, the estimated effect of depleting an acre-foot of water in the Plains must include the impact of one less acre-foot in all downstream ASA's (including effects in Louisiana).

The marginal response to an acre-foot change in streamflow is less than half a day in 69 of the 99 ASA's. The more water-abundant Eastern States tend to have the lower marginal responses despite the higher population densities. The ASA that contains Chicago, ASA 0403, has a relatively high marginal response at 2.4 which is probably due, in part, to the 25-percent depleted streamflow and the high population density.

Twelve of the 17 ASA's that have marginal responses greater than 1 lie primarily in Colorado, New Mexico, Utah, and Arizona. Each of these States makes extensive use of streamflow for irrigation. Although these States are not densely populated, the lack in availability of streamflow tends to result in high marginal water values. Less confidence should be placed in the response estimates for 1603 and 1503 because these regions have the most extreme of the fishery resource measure.

Marginal Values of Water as a Recreational Fishery Resource

Water's value as a recreational fishery resource is estimated by multiplying the day response to flow changes by the estimated values of a day of recreational fishing. We applied day value estimates derived by Hay and by Brown and Hay to our day response estimates (*4, 9*) (table 4). Both Hay and Brown and Hay (who used the recently released 1985 FHWAR survey) estimated values by State using the FHWAR survey. The day value estimates for bass fishing (Hay) were between $7 and $14 and averaged $14.60. Those for trout fishing (Brown and Hay) were between $10 and $35 and averaged $17.88 (1989 dollars).

The estimated value of water as a recreational fishery resource varies across ASA's from 14 cents to values over $300 per acre-foot.[9] Values vary because of dif-

---

[8]The change in days fished estimated from the two-stage approach relies on the predictive power of P(fish) and (D|fish) because differentiating equation 2 with respect to FLOW, $\partial DAYS/\partial FLOW = \partial P(fish)/\partial FLOW * (D|fish) + \partial(D|fish)/\partial FLOW * P(fish)$.

[9]The estimated values in ASA 1503 likely exceed the actual values because the estimated marginal response is probably out of our model's forecast range.

Table 3—Change in days fishing per acre-foot change in streamflow Drainage basins are listed by the Water Resources Council's Aggregated Subarea

	DAYS		DAYS		DAYS
ASA[1]	Acre-foot	ASA	Acre-foot	ASA	Acre-foot
101	0 029	0505	0 047	1202	0 375
102	069	0506	299	1203	481
103	667	0507	132	1204	874
104	373	0601	232	1205	314
105	119	0602	096	1301	8 085
106	025	0701	709	1302	5 466
201	466	0702	324	1303	2 049
202	289	0703	240	1304	9 649
203	502	0704	106	1305	439
204	165	0705	042	1401	3 994
205	291	0801	026	1402	3 836
206	398	0802	018	1403	3 583
301	145	0803	008	1501	8 770
302	205	0901	144	1502	3 539
303	143	1001	358	1503	150 229
304	216	1002	429	1601	712
305	410	1003	373	1602	338
306	152	1004	562	1603	26 189
307	059	1005	341	1604	950
308	052	1006	238	1701	056
309	052	1007	4 788	1702	021
401	076	1008	632	1703	147
402	184	1009	194	1704	035
403	2 365	1010	889	1705	011
404	276	1011	117	1706	016
405	283	1101	108	1707	036
406	379	1102	10 648	1801	111
407	423	1103	503	1802	263
408	101	1104	161	1803	2 267
501	269	1105	672	1804	981
502	119	1106	1 534	1805	655
503	454	1107	112	1806	10 456
504	281	1201	159	1807	1 747

[1] Aggregated subarea

ferences in marginal responses to streamflow changes and because of variations in the day values of recreational fishing In the more water-abundant Eastern States, marginal water values are usually less than $10 per acre-foot In the dryer, more populated areas of the West, marginal water values are at their highest

Water values are estimated for cold water and warm water recreational fishing, although an acre-foot change in flow is likely to partially affect both fisheries The day value most applicable is, of course, an average of the cold water and warm water day values weighted according to the change in cold water and warm water days This breakdown is beyond the scope of this analysis

Our estimated water values are compared with water values estimated by Ward and by Johnson and Adams to look for consistencies in the estimated values and to delineate differences in approaches (*10,24*) Comparisons with these two studies are practical because these studies also compare current flow levels with natural flow

Ward estimated the benefits of summer releases of water from upper reservoirs on the Rio Champ in northern New Mexico to increase the quality of the downstream fishery He estimated demand for streamflow based on travel cost modeling and the change in visitation rates anglers said they would make on viewing pictures of different streamflow levels The marginal value of an acre-foot of water for normal flow was estimated to be $29 57 (1989 dollars) Ward's region of study is the upper reaches of ASA 1302 The water leaving that study area continues through ASA 1302 improving the stream fisheries along the way until flowing into ASA 1303 The estimated marginal value of an acre-foot of water is $113 91 for bass and $64 26 for trout within ASA 1302 Our estimated water value should be higher than Ward's because it includes the fishery value of water while it is in Ward's

Table 4—Marginal values of an acre-foot of streamflow as a recreational fishery resource

ASA[1]	Bass[2]	Trout[3]	ASA	Bass	Trout	ASA	Bass	Trout
	Dollars/acre-foot			*Dollars/acre-foot*			*Dollars/acre-foot*	
101	0 59	0 29	0505	1 00	0 73	1202	10 48	10 18
102	68	56	0506	5 64	3 61	1203	13 44	13 05
103	9 46	6 78	0507	2 46	1 97	1204	24 42	23 71
104	5 95	3 40	0601	4 18	3 42	1205	8 76	8 51
105	1 51	1 09	0602	1 84	1 60	1301	221 20	158 31
106	36	25	0701	13 70	11 11	1302	171 15	119 84
201	7 31	4 86	0702	7 90	5 12	1303	57 24	55 58
202	4 70	3 05	0703	6 00	4 21	1304	325 34	175 80
203	8 80	5 19	0704	3 04	1 86	1305	12 26	11 90
204	2 60	1 53	0705	1 06	69	1401	97 27	50 64
205	5 52	3 87	0801	58	42	1402	94 01	48 36
206	7 50	5 21	0802	41	30	1403	89 18	44 65
301	2 79	1 73	0803	24	14	1501	219 76	109 28
302	3 16	2 02	0901	2 07	2 24	1502	88 24	44 00
303	2 76	1 55	1001	6 49	5 56	1503	3780 85	1876 19
304	4 13	2 20	1002	7 22	6 52	1601	9 37	8 66
305	7 83	4 10	1003	6 64	5 76	1602	3 98	4 20
306	3 07	1 79	1004	11 37	8 81	1603	577 46	325 53
307	1 16	1 02	1005	4 97	3 92	1604	20 94	11 80
308	97	1 15	1006	125 44	78 63	1701	94	68
309	77	89	1007	10 82	78 63	1702	38	27
401	1 35	93	1008	10 82	9 72	1703	2 58	1 81
402	4 14	1 90	1009	4 38	3 29	1704	63	45
403	69 16	39 24	1010	14 41	15 90	1705	19	14
404	4 08	3 09	1011	2 28	1 77	1706	38	20
405	4 17	3 20	1101	8 25	10 28	1707	42	48
406	6 90	3 74	1102	202 10	159 30	1801	3 57	2 00
407	8 31	3 73	1103	8 25	10 28	1802	8 51	4 76
408	1 49	1 03	1104	2 88	3 20	1803	73 31	40 98
501	4 93	2 86	1105	16 15	13 45	1804	31 73	17 74
502	2 45	1 45	1106	34 23	37 96	1805	21 18	11 84
503	10 20	4 14	1107	2 31	2 38	1806	338 16	189 05
504	5 46	3 44	1201	4 46	4 26	1807	56 49	31 58

[1] Aggregated subarea
[2] Based on net economic values by Hay (*9*)
[3] Based on net economic values by Brown and Hay (*4*)
[4] 1989 dollars

study area plus the value it generates when it continues downstream within ASA 1302

Johnson and Adams estimated the benefits of water to steelhead trout fisheries in the John Day River Basin A steelhead fishery production model was applied in conjunction with a contingent valuation model The fisheries production model accounts for the time difference between a change in flow and the change in the quality of fishing Our approach uses average flows to measure steady-state fishery productivity[10] The John Day Basin lies in the central part of ASA 1702 Johnson and Adams estimated water values for spring winter, and fall, making the comparison with our estimated annual value more difficult Another difference is that their analysis only considered the benefits to the steelhead fishery where we included all fishery benefits An acre-foot change in flow in ASA 1702 represents a change in flow in all areas of the drainage basin, not just in the John Day (unless all water in ASA 1702 originates in the John Day) So, the estimated benefits of an acre-foot of water in our analysis is an average of fishing benefits throughout the basin

Nevertheless, John Day summer, winter, and fall water values were estimated at 59 cents, 5 cents, and minus 8 cents within the study area and $2 62, 20 cents, and minus 36 cents (1989 dollars) when downstream benefits were included Our estimated value of an acre-foot of water in ASA 1702 is 19 cents and 13 cents within the basin and 38 cents and 28 cents when downstream values are included for bass and trout, respectively

---

[10] As we pointed out earlier low flow during years of below normal precipitation can result in increased catch rates for that year but lead to lower catch rates in the future as stocks are depleted and the productivity of the fishery falls

The comparison of our results with those of Ward and of Johnson and Adams is very rough given the differences in approaches of these studies (*10,24*) However, the relative magnitudes of the estimated benefits are consistent across the two regions

Marginal Response of Other Variables

Despite the differences in assumptions behind the two models, marginal responses are consistent, with some exceptions Marginal effects based on the two-stage approach are very close to those based on the single-stage approach for URBAN, SEAMILES, STREAM, and FLOW Some difference exists in the estimated effect of the individual's gender (SEX) Their difference, however, is less than 40 percent of the single-stage estimate Both approaches indicate that an increase in INCOME increases days fished at lower income levels and decreases days fished at higher income levels But, the two-stage results suggest that negative effects of increased income occur at a lower level of income The difference in marginal responses to lake resources is likely due to the lack of significance of LAKEIN in (D|fish)

Conclusions

Examined within a household production framework, the level of streamflow is highly significant as an input in the production of the recreational fishing commodity The estimated effect from a change in streamflow is consistent across the single-stage and two-stage estimation procedures

The total downstream change in fishing associated with an acre-foot change in streamflow varies across the United States due to variations in resource availability and variations in the number of people affected There is less than half a day change for 69 of the 99 ASA's The more water-abundant Eastern States tend to have the lower marginal responses despite the higher population densities

The variations in impact of water depletion can provide policymakers with an indication of regional variations in the importance of water in recreation Water values in recreational fishing allow comparisons of water values in alternative uses Based on fishing day values estimated in earlier studies, the value of water as a fishery resource is estimated These values vary across ASA's but usually fall between $10 and $35 per acre-foot The estimated values can be compared with consumptive values of water to aid in water allocation decisions

References

1 Amirfathi, Paraneh, Rangesan Narayanan, Bruce Bishop, and Dean Larson "A Methodology for Estimating Instream Flow Values for Recreation " Utah Water Research Laboratory, Utah State University, Logan, 1984

2 Bayha, Keith "Instream Flows—The Big Picture " Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Boise, Idaho, pp 95-131, 1976

3 Becker, Gary S "A Theory of the Allocation of Time," *The Economic Journal* 75(299), pp 493-517, Sept 1965

4 Brown, Gardner, and Michael J Hay "Net Economic Recreation Values For Deer and Water Fowl Hunting and Trout Fishing, 1980 " Working paper No 23, U S Fish and Wildlife Service, Mar 1987

5 Charbonneau, John J , and Michael J Hay "Determinants and Economic Values of Hunting and Fishing " Forty-third North American Wildlife Conference, Washington, DC Wildlife Management Institute, pp 391-403, 1978

6 Daubert, John T , and Robert A Young "Recreational Demand for Maintaining Instream Flows A Contingent Valuation Approach, *American Journal of Agricultural Economics* Vol 63, pp 665-75, Nov 1981

7 Deyak, Timothy, and V Kerry Smith "Congestion and Participation in Outdoor Recreation A Household Production Function Approach," *Journal of Environmental Resources and Management* Vol 5, pp 63-80, 1978

8 Hansen, LeRoy "Estimation of the Marginal Values of Water as an Instream Resource for Recreational Fishing A National Analysis " Ph D dissertation Iowa State University, Ames, 1986

9 Hay, Michael J "Net Economic Recreation Values for Deer, Elk, and Water Fowl Hunting and Bass Fishing, 1985 " Working paper No 85-1, U S Fish and Wildlife Service, 1988

10 Johnson, Neal S , and Richard M Adams "Benefits of Increasing Streamflow The Case of the John Day Steelhead Fishery " Water Resources Research 24(11), pp 1,839-46, Nov 1988

11 Judge, George G , William E Griffiths, R Carter Hill, and Tsoung-Chao Lee *The Theory and Practice of Econometrics* New York John Wiley and Sons, Inc , 1980

12 Loomis, John B "Consistency of Methods for Valuing Outdoor Recreation " Ph D dissertation Colorado State University, Fort Collins, 1983

13 McDonald, J F , and R A Moffit "The Use of Tobit Analysis," *Review of Economics and Statistics* Vol 62, pp 318-21, 1980

14 McFadden, D "Conditional Logit Analysis of Qualitative Choice Behavior," *Frontiers in Econometrics* P Zarembka (ed) New York Academic Press, pp 105-42 1974

15 McFadden, D , "Modelling the Choice of Residential Location," *Spatial Interaction Theory and Planning Models* A Karlquist and others (eds) Amsterdam North-Holland Publishing Co , pp 75-96, 1978

16 Miller, Jon R , and Michael J Hay "Determinants of Hunter Participation Duck Hunting in the Mississippi Flyway," *American Journal of Agricultural Economics* Vol 63, No 4, pp 677-84, 1981

17 Morrison, Donald G "Upper Bounds for Corrections Between Binary Outcomes and Probabilistic Predictions," *Journal of the American Statistical Association* Vol 67, No 337, pp 68-70, Mar 1972

18 Nickelson, Thomas "Development of Methodologies for Evaluating Instream Flow Needs for Salmonid Rearing " Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Boise, Idaho, pp 588-96, 1976

19 Russell, Clifford S , and William J Vaughan "The National Recreational Fishing Benefits of Water Pollution Control," *Journal of Environmental Economics and Management* Vol 9, pp 328-54, 1982

20 Tennant, Donald Leroy "Instream Flow Regimens for Fish, Wildlife Recreation, and Environmental Resources " Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Boise, Idaho, pp 359-73, 1976

21 U S Department of Agriculture, Soil Conservation Service and Iowa State University Statistical Laboratory National Resources Inventory, 1984

22 U S Department of Commerce, Bureau of the Census "Survey of Fishing, Hunting, and Wildlife-Associated Recreation, 1980 " 1982

23 Walsh, Richard G , Ray K Ericson, Daniel J Arosteguy, and Michael P Hansen "An Empirical Application of a Model for Estimating the Recreation Value of Instream Flow " Colorado Water Resources Research Institute Completion Report 101 Colorado State University, Fort Collins, Oct 1980

24 Ward, Frank "Optimally Managing Wild and Scenic Rivers for Instream Flow Benefits " Proceedings of the National River Recreation Symposium, Louisiana State University, Baton Rouge, 1985

25 Wesche, Thomas A "Development and Application of a Trout Cover Rating System for IFN Determinations " Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Boise, Idaho, pp 224-34, 1976

26 White, Ray J , Edward J Hansen, and Gaylord R Alexander "Relationship of Trout Abundance to Stream Flow in Midwestern Streams " Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Boise, Idaho, pp 597-612, 1976