United States
Department of
Agriculture

Economic
Research
Service

Agricultural
Economic
Report
Number 634

Water Allocation Tradeoffs

Irrigation and Recreation

LeRoy T. Hansen
Arne Hallam

It's Easy To Order Another Copy!

Just dial 1-800-999-6779. Toll free (in the United States and Canada). All other areas please dial 301-725-7937.

Ask for *Water Allocation Tradeoffs: Irrigation and Recreation* (AER-634).

The cost is $8.00 per copy. For non-U.S. addresses (including Canada), add 25 percent. Charge your purchase to your VISA or MasterCard, or we can bill you. Or send a check or purchase order (made payable to ERS-NASS) to:

ERS-NASS
P.O. Box 1608
Rockville, MD 20849-1608.

We'll fill your order by first-class mail.

Water Allocation Tradeoffs: Irrigation and Recreation. By LeRoy T. Hansen and Arne Hallam. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 634.

Abstract

Diverting water from streams for irrigation competes with its use as a recreational fishing resource. This report develops a procedure for estimating the marginal value of water used for fishing that includes the effects of upstream diversions on all points downstream. The downstream effects are dispersed across a wide geographic area and, until now, have not been estimated. The procedure is applied to all 99 major river basins of the contiguous States. The tradeoffs in water allocation are detailed in the 67 river basins where irrigation competes for water with recreational fishing. The results substantiate the role of water for recreational fishing and highlight the implications of a national perspective in water allocation decisions.

Keywords: Water, irrigation, household production theory, recreational fishing, recreational water demand

Washington, DC 20005-4788 June 1990

Contents

	Page
Summary	v
Introduction	1
Marginal Values of Water in Recreational Fishing and Irrigation	2
Capturing the Effects of Changes in Streamflow Levels Using a Household Production Model	6
Factors Affecting Demand for the Recreational Fishing Commodity	8
Factors Affecting Supply of the Recreational Fishing Commodity	8
Reduced-Form Equation for the Recreational Fishing Commodity	9
Data	9
Fishing Participation Data	9
Environmental Resource Data	10
Fishery Resources	11
Factors Affecting Availability of Fishery Resources	11
Fishery Resources Available to Each Household	13
The Reduced-Form Model	15
Regression Analysis	16
Effects of Streamflow Changes on Days Fished	17
Conclusion	18
References	19

Summary

Diverting water from streams for irrigation competes with water as a recreational fishing resource. This report develops a procedure for estimating the marginal value of water used for fishing that includes the effects of upstream diversions on all points downstream. The downstream effects are dispersed across a wide geographic area and, until now, have not been estimated. The procedure is applied to all 99 major river basins of the contiguous States. The tradeoffs in water allocation are detailed in the 67 river basins where irrigation competes for water with recreational fishing. The results substantiate the role of water for recreational fishing and highlight the implications of a national perspective in water allocation decisions.

Estimates of water's marginal value as a recreational fishery resource vary significantly across regions, from just a few cents per acre-foot of water to over $100 per acre-foot in four river basins. In most areas, the marginal recreational value of an acre-foot of water is less than $10. Marginal recreational water values are highest in the arid Southwestern States.

This analysis compares the value of water for irrigation to its recreational fishing value because irrigation is the single largest water consumer in the United States. While farmers have rights to water, these rights can be sold. For example, farmers have sold water rights to municipalities.

Much of the economic benefits of water used for recreational fishing occur considerably farther downstream from the diversion for irrigation. The recreational benefits foregone through the diversion of water may not be significant to the immediate area. However, each acre-foot of water flows across many fishing sites along the course of the stream, making its total recreational value important. Benefits generated by water passing through areas downstream accounted for over half of the fishing benefits estimated for 18 of the 48 river basins, or Aggregated Subareas (ASA's), that are upstream of another ASA.

Water Allocation Tradeoffs

Irrigation and Recreation

LeRoy T. Hansen
Arne Hallam*

Introduction

Most river basins west of the Mississippi River are water short (U.S. Department of Agriculture, 1981, p. 94). A region is defined to be water short when the available streamflow is insufficient to meet all of the demands for water given current prices. Past water allocation decisions have seldom considered water's value in nonconsumptive uses and, thus, cannot have been expected to have optimally allocated water. To check the efficiency of the present allocation of water, regional recreational fishing values of water are derived in this report and compared with the regional values of water in agriculture obtained from the National Agricultural Resources Interregional Model (NARIM). NARIM, developed by the Center for Agricultural and Rural Development at Iowa State University, is a linear programming model depicting the agricultural sector of the U.S. economy (English, Smith, and Oamek, 1986).

Through irrigation, agriculture is the single largest consumptive user of water in the United States. Economic theory and available data indicate that, in those areas where water consumption for irrigation is not restricted, water is applied as long as its use adds positively to the net revenue of the irrigators. The farmer has no incentive to limit water diversions for downstream uses under present water allocation systems.

Of the few studies that have considered the economic benefits of streamflow as a recreational fishing resource, all have concentrated on a river segment or on a drainage basin (Daubert and Young, 1981; Johnson and Adams, 1988). But diversion of streamflow for irrigation can affect many downstream basins and waterways.

The water diverted by farmers usually does not leave streams dry. A system of reservoirs helps allocate water from wet seasons to the dry periods when irrigation is greatest. However, annual streamflows are reduced by over 25 percent in one-third of all major river basins in the contiguous States (U.S. Water Resources Council).

---

*Hansen is an economist with the Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Hallam is an associate professor of economics at Iowa State University.

This study estimates the total fishing benefits an acre-foot of water generates as it passes downstream. Biologists have found that the relationships linking streamflow to fish habitat and fish habitat to the fishery resource provide the foundation for quantifying changes in stream fishery quality. Available data sources allow fishery resources to be identified on a sub-State or multicounty level.

Though streamflow offers many recreational opportunities, this paper focuses on fishing because the marginal fishing benefits are the most significant instream water uses when streamflows are not depleted by more than one-third (Bayha, 1976). Some recreational streamflow activities (for example, whitewater rafting) are enhanced when flows are below natural levels.

This report presents a practical method of valuing the recreational fishing benefits generated by a unit of water as it moves downstream. A reduced-form equation, describing consumer behavior within the household production framework, is used to determine how changes in fishery quality resulting from deviations in streamflow affect the number of days fished. The value of an acre-foot of water in recreational fishing equals the change in days fished multiplied by the average value of a day of fishing. (An acre-foot equals 325,850 gallons of water.)

Marginal Values of Water in Recreational Fishing and Irrigation

The estimated recreational fishing value of an acre-foot of water for each river basin, or Aggregated Subarea (ASA), is shown in table 1. The monetary values are based on estimates of the change in days fished due to a change in annual streamflow and a conservative estimate of $10 for the value of a day of fishing (Loomis, 1983; Charbonneau and Hay, 1978). Any other value for a day of fishing can be applied across river basins using the day response estimates.

In 81 of the 99 ASA's, the recreational value of an acre-foot of water is less than $10. Less confidence should be placed in the highest of the acre-foot values since they result from extreme values of the independent variables. Furthermore, it should be kept in mind that all values are estimates of the true values and, therefore, could be in error. Instream water values tend to be highest in populated, arid areas (fig. 1).

Estimates of water's 1980 shadow prices (net marginal value product) in irrigation are derived by NARIM simulation.[1] In 49

[1] The high marginal value of water for irrigation in ASA 1802 is probably not realistic. However, given the low recreational value of water, the actual value of water in agriculture probably exceeds the instream value nevertheless.

Figure 1

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

← = Direction of water movement.

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

Table 1--Marginal value of water in fishing and irrigation in ASA's

ASA	Days per acre-foot	Marginal value of water: Fishing[1]	Irrigation[2]	Downstream fishing areas
	Days	Dollars per acre-foot[3]		
101	0.029	0.29	---	NA
102	.069	.69	---	NA
103	.667	6.67	---	NA
104	.373	3.73	---	NA
105	.119	1.19	---	NA
106	.025	.25	---	NA
201	.466	4.66	---	2.89
202	.289	2.89	---	NA
203	.502	5.02	---	NA
204	.165	1.65	---	NA
205	.291	2.91	112.53	NA
206	.398	3.98	---	NA
301	.149	1.49	32.27	NA
302	.205	2.05	0	NA
303	.143	1.43	---	NA
304	.216	2.16	0	NA
305	.410	4.10	10.84	NA
306	.152	1.52	0	NA
307	.059	.59	13.95	NA
308	.052	.52	---	NA
309	.052	.52	---	NA
401	.076	.76	---	NA
402	.184	1.84	---	NA
403	2.365	23.65	---	NA
404	.276	2.76	---	NA
405	.283	2.83	---	NA
406	.379	3.79	---	NA
407	.423	4.23	---	NA
408	.101	1.01	---	NA
501	.269	2.69	---	1.19
502	.119	1.19	---	.47
503	.454	4.54	---	1.19
504	.281	2.81	---	1.19
505	.047	.47	---	.26
506	.299	2.99	---	.47
507	.132	1.32	---	.47
601	.232	2.32	---	.96
602	.096	.96	10.82	.47
701	.709	7.09	---	3.24
702	.324	3.24	23.17	2.40
703	.240	2.40	0	1.06
704	.106	1.06	0	.42
705	.042	.42	0	.26
801	.026	.26	28.21	.18
802	.018	.18	0	.08
803	.008	.08	7.01	NA
901	.144	1.44	0	NA
1001	.358	3.58	0	3.41
1002	.429	4.29	0	3.72
1003	.373	3.73	0	3.58
1004	.562	5.62	0	3.41
1005	.341	3.41	0	2.38

See footnotes at end of table.

Continued--

Table 1--Marginal value of water in fishing and irrigation in ASA's--Continued

ASA	Days per acre-foot	Marginal value of water: Fishing[1]	Irrigation[2]	Downstream fishing areas
	Days	Dollars per acre-foot[3]		
1006	.238	2.38	0	1.94
1007	4.788	47.88	2.21	6.32
1008	.632	6.32	24.15[4]	1.94
1009	.194	1.94	0	1.17
1010	.889	8.89	8.63	1.17
1011	.117	1.17	0	.42
1012	.108	1.08	4.58	.26
1102	10.648	106.48	0	5.03
1103	.503	5.03	27.11	1.61
1104	.161	1.61	62.27	.26
1105	.672	6.72	0	1.61
1106	1.534	15.34	0	1.12
1107	.112	1.12	0	.18
1201	.159	1.59	12.08	NA
1202	.375	3.75	0	NA
1203	.481	4.81	17.30	NA
1204	.874	8.64	0	NA
1205	.314	3.14	0	NA
1301	8.085	80.85	0	54.66
1302	5.466	54.66	0	20.49
1303	2.049	20.49	0	4.39
1304	9.649	96.49	13.57	20.49
1305	.439	4.39	0	NA
1401	3.994	39.94	0	36.83
1402	3.836	38.36	0	36.83
1403	3.683	36.83	0	35.39
1501	8.770	87.70	---	35.39
1502	3.539	35.39	0	NA
1503	150.229	1,502.29	0	35.39
1601	.712	7.12	0	NA
1602	.338	3.38	0	NA
1603	26.189	261.89	0	NA
1604	.950	9.50	0	NA
1701	.056	.56	0	.21
1702	.021	.21	0	.11
1703	.147	1.57	0	.35
1704	.035	.35	0	.21
1705	.011	.11	0	NA
1706	.016	.16	0	NA
1707	.036	.36	0	NA
1801	.111	1.11	0	NA
1802	.263	2.63	429.89	NA
1803	2.267	22.67	0	NA
1804	.981	9.81	0	NA
1805	.655	6.55	0	NA
1806	10.456	104.56	0	NA
1807	1.747	17.47	0	NA

NA = Not applicable because stream ends with the ASA.
-- = No significant use of water for irrigation in 1980.
1 Assuming $10 as the value of a day of fishing.
2 Values derived from the 1985 NARIM for 1980 agricultural prices.
3 All dollar values in 1980 dollars.
4 The NARIM splits six of the ASA's in two. Irrigation values were zero in the other parts of 1008, 1010, 1105, 1106, and 1204; and $13.32 in 1203.

of the 67 ASA's that irrigated in 1980, unconstrained water use resulted in a zero net marginal value product of irrigation water.

The marginal value of water for recreational fishing exceeds water's marginal value in irrigation in 52 of the 67 ASA's where irrigation takes place (table 1). The differences in agricultural and recreational marginal water values indicate areas where some water reallocation would likely move water to a higher valued use. However, the marginal recreational values for additional streamflow decreases as more water is allocated to streamflow. Furthermore, as water is diverted from agriculture, the marginal agricultural value of water increases. Thus, a higher marginal water value in recreation within an area does not imply that no water should be allocated to irrigators but that some reallocation should be considered.

The importance of a national perspective on water allocation is emphasized by the extent to which fishing benefits are generated considerably farther downstream. Of the 99 ASA's, 48 are upstream of one or more ASA's (fig. 1). Downstream marginal values (the estimated fishing benefits per acre-foot of water generated by water passing through downstream ASA's) constitute over half of water's marginal recreational fishing value in 18 of the 48 ASA's (table 1). Therefore, estimates of water's marginal recreational value within a local area can significantly understate the total marginal recreational value.

Downstream marginal recreational values of the water are often greater than the marginal consumptive value of water in the upstream ASA's. Of the 37 upstream ASA's that typically divert a significant portion of water for irrigation, 29 have downstream marginal recreational water values greater than water's value in irrigation. Unless decisions on allocating water to consumptive uses consider recreational benefits within the downstream drainage areas, significant recreational benefits may be overlooked.

While earlier analyses of the recreational value of streamflow focused on benefits at a particular site or within a particular region, policymakers should not take this to mean that local recreational benefits are the only or even the most significant benefits. The recreational benefits lost through the diversion of water from a small stream may be insignificant to the immediate area. However, the fact that each acre-foot of water can flow across many fishing sites can make its recreational value significant.

Capturing the Effects of Changes in Streamflow Levels Using a Household Production Model

The household production model identifies independent variables that determine supply and demand in the household's production or consumption of the recreational fishing commodity. Some of the variables are tastes, income, place of residence, skills, and availability of public fishery resources. The household production approach captures the dispersed effects of streamflow changes along the entire course of the waterway.

For those who stream fish, a stream represents more than one fishing site. While some sites on a stream will be closer to an individual than others, fishing quality can vary across these sites. Thus, an individual may choose to fish at a more distant site on a stream if it has superior fishing quality. When streamflow becomes permanently diminished by an upstream diversion, the productivity of the stream decreases at all sites. Any estimation of the demand for a unit of water as a recreational fishing resource is complicated by the fact that permanent alterations in flow affect not just one but all downstream sites. Since each individual can substitute among stream sites, demand at each site depends on fishing quality at upstream and downstream sites. Furthermore, the recreational fishing demand for water must represent a vertical summation of individual site demands for all sites downstream from the alteration.

While any approach to valuing water as a recreational fishing resource involves compromises, the household production approach is well suited to capturing the dispersed effects of streamflow changes since the model examines behavior in terms of a change in fishing resources at sites available to the individual. Also, the available data on recreational fishing support the selection of the household production approach.

The household production approach views the individual as receiving utility directly from consuming "basic commodities" produced by the individual or household using time, public goods, market goods, and the technology available to the household.[2] The "basic commodities" are internal to the individual and, thus, are not observable and cannot be defined with any standard unit of measure. For example, a "basic commodity" may be thought of as the self-satisfaction an individual receives from having a clean house. The cleaning solutions and time used to clean the house would be inputs used to produce the "basic commodity."

This analysis uses a reduced-form commodity supply/demand equation to estimate implicit demand for the recreational fishing basic commodity. The independent variables in the reduced-form equation are the determinants of supply and demand in the household's production or consumption of the recreational fishing commodity (Deyak and Smith, 1978; Miller and Hay, 1981; and Russell and Vaughan, 1982).

[2] Throughout this report, the terms "individual" and "household" will be used interchangeably.

Factors Affecting Demand for the Recreational Fishing Commodity

Determinants of demand for "basic commodities," in parallel with neoclassical consumer theory, are taste parameters, income, and the prices of substitute commodities. As a proxy for the price of substitute recreational activities, the analysis includes a variable indicating whether or not the respondent lives in an urban area. Other cross-price effects are not likely to be significant so that prices of other commodities are not included as demand determinants. The demand for the recreational fishing commodity can be represented by:

$$Q^D = f(\text{TASTES, INCOME, URBAN, PRICE}^D), \tag{1}$$

where Q^D represents the quantity of the recreational fishing "basic commodity" demanded, TASTE represents a vector of taste parameters, INCOME represents the household's full income constraint, URBAN represents the availability of inputs used to produce substitute commodities, and $PRICE^D$ represents the demand price or willingness to pay for the "basic commodity." Full income includes the individual's available time along with wealth and wage income.

Factors Affecting Supply of the Recreational Fishing Commodity

Within the household production framework, the individual not only consumes but produces the "basic commodity" using available time, skills, and market and public goods. The cost (and, therefore, supply price) of the recreational fishing "basic commodity" is represented by the individual's marginal cost of producing the unit. The marginal cost of producing a unit of the commodity ($PRICE^S$) depends on the individual's production skills (SKILL), the opportunity cost of the individual's time (WAGE), the price of market goods used to produce the commodity (GOODS), the amount of the "basic commodity" produced (Q^S), the amount of other commodities produced (COMM), and the availability of public fishery resources (PUBLIC) and, thus, is described by:

$$PRICE^S = h(\text{SKILL, WAGE, GOODS, } Q^S\text{, COMM, PUBLIC}), \tag{2}$$

where the vectors SKILL, GOODS, COMM, and PUBLIC and the variables $PRICE^S$, WAGE, and Q^S in equation (2) are as described above. In order to separate out effects of commodity production without having information on the household's production and consumption of other commodities (COMM), it is assumed that $PRICE^S$ is not affected by changes in production of these commodities (that is, no joint production). Furthermore, a day of recreational fishing does not require the purchase of market goods since previously purchased equipment is reusable and live bait, if used, is usually inexpensive. Because of no joint production and because a day of recreational fishing involves minimal or no purchases of goods, $PRICE^S$ is not dependent on GOODS.

Reduced-Form Equation for the Recreational Fishing Commodity

Utility maximization generates the reduced-form equation:

$$Q = g(\text{PERSONAL, PUBLIC}), \tag{3}$$

where Q is the quantity of the "basic commodity" produced/consumed, PERSONAL is a vector of variables representing taste, income, skill, home location, and wage characteristics of the individual, and PUBLIC is a vector of variables quantifying the available public fishing resources.

Estimating equation (3) is complicated by the inability to observe Q, the recreational fishing commodity. However, by asserting a fixed coefficient technology (in other words, a fixed relationship) between the time input and the commodity output, the number of days spent freshwater fishing becomes a proxy for the level of commodity production/consumption (Pollak and Wachter, 1975).

Data

Data on individuals' participation in recreational fishing and on environmental resource availability were analyzed using regression analysis. State subregions were defined by the structure of the participation survey, and available environmental resources were quantified for each region.

Fishing Participation Data

The survey of Fishing, Hunting, and Wildlife Associated Recreation (FHWAR) is a cross-sectional survey designed to collect information on individuals' personal characteristics and on their recreational activities (U.S. Department of Commerce, Bureau of the Census, 1982). The FHWAR survey was conducted in two parts. The first survey drew its sample from the continental U.S. population. This survey obtained 340,032 individual observations and specified whether or not an individual fished in 1980, but it did not indicate the number of days fished.

The second survey was a followup survey on a selected subsample of those who fished as identified in the first survey. The followup survey selected a subsample of 35,615 observations on individuals who fished. The second survey provides more detailed information on individuals' fishing activities including the number of days fished in fresh water (excluding Great Lakes).

Combining FHWAR Surveys

To quantify changes in days fished, responses of the fishing and nonfishing population (from the first survey) and information on the number of days fished (from the followup survey) are necessary. A single-stage analysis through use of a tobit model is applied (Tobin, 1958).[3] The tobit model allows the effect of streamflow on days fished to be estimated without the bias that could result from the cluster of dependent variable values at zero. The FHWAR survey was taken in two steps and, therefore, observations from both steps are grouped into a single set for the tobit analysis.

Because the followup survey sampled only a portion of those who fished as identified in the population survey, a one-for-one substitution of fishing respondents from the population survey cannot be made. The statistical procedure used to estimate the reduced-form equation and computer capacity limits constrained the number of observations used in the regression analysis to 4,325. Thus, 4,325 observations were randomly selected from the population survey; 1,890 were of individuals who had fished. These 1,890 observations were replaced with 1,890 randomly sampled observations from the followup survey, thus producing a population sample that includes information on the number of days fished by those who fished.[4]

Environmental Resource Data

The 1982 National Resources Inventory (NRI) provides an inventory of some of the available environmental resources (U.S. Department of Agriculture, Soil Conservation Service, 1984). For this model, the NRI provides estimates of the surface area of lakes and streams and of the riparian (waterside) vegetation of streams.

The Second National Water Assessment of the Water Resources Council (1978) estimates annual average flow and streamflow depletions caused by humans in 1980 for all 99 river basins or ASA's within the 48 contiguous States. Average annual flow represents the quantity of water that would flow through the stream during a year of average precipitation and subject to no

---

[3] A two-stage analysis was employed for comparative purposes. Results of the two-stage analysis indicated effects of streamflow on days fished were 19 percent higher than the results presented here. Thus, the results from the single-stage analysis appear to be conservative estimates.

[4] The FHWAR screening survey was designed to obtain a sufficient number of observations within each State for within-State analysis and, thus, applied a greater sampling frequency rate in States with smaller populations. The followup survey contained proportionally more individuals with a greater tendency to become involved in environmental recreational activities. Since neither the screening nor the followup survey is completely random, the selected sample will not be a random sample of the U.S. population. However, results are not expected to be biased given that maximum likelihood estimation has been shown to perform well in regression analysis of data from nonrandom samples without observation weights (Holt, Smith, and Winter, 1980).

flow depletions. Area population estimates are obtained from county population data of the 1980 Census (U.S. Department of Commerce, 1981).

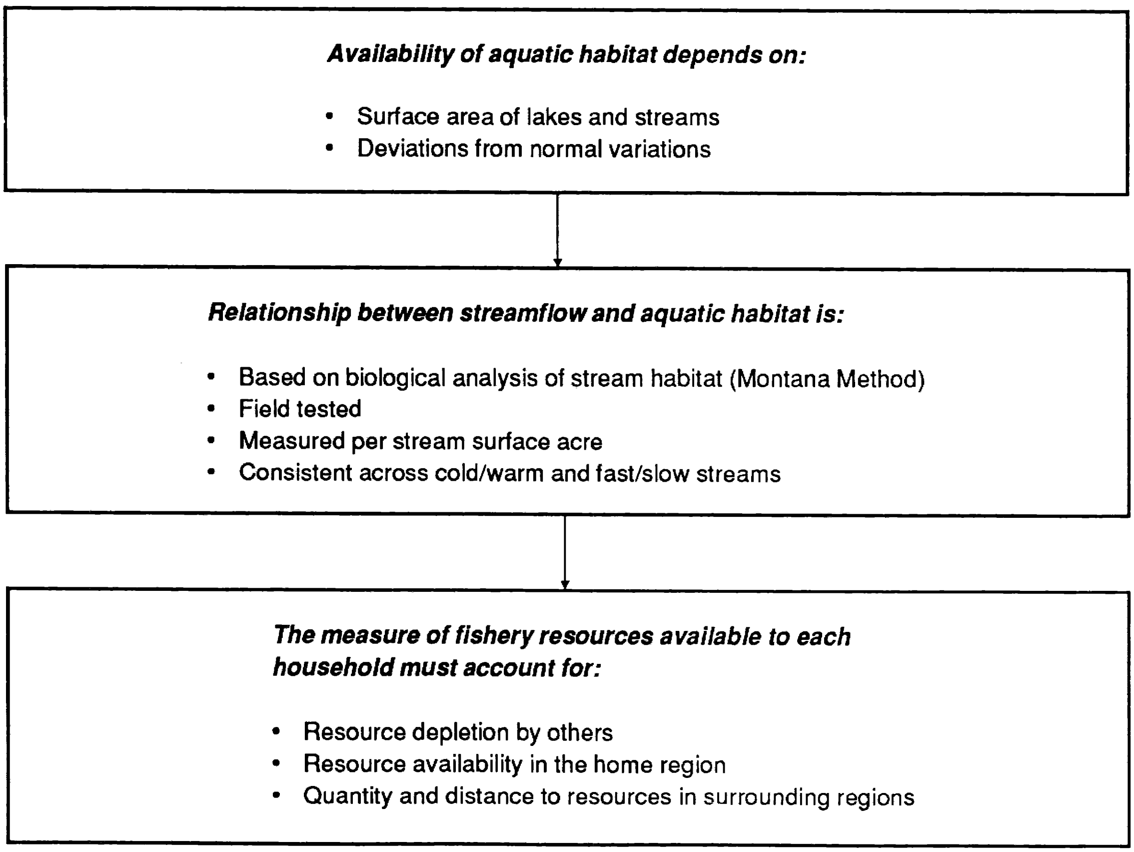
Fishery Resources

Measures of the availability of fishery resources within the regions defined by the FHWAR survey are developed using the data on environmental resources. The procedure (1) delineates the major factors affecting stream and lake aquatic habitat; (2) clarifies the relationship between streamflow and aquatic habitat; and (3) derives stream and lake fishery resource measures for each respondent, based on aquatic habitat availability. These measures are applicable within the household production framework (fig. 2).

Factors Affecting Availability of Fishery Resources

Surface area of lakes and streams is the major factor determining fishery resource availability. For streams, changes in flow from their natural level can also critically reduce aquatic habitat and thus fishery resource availability. Reductions in fish standing crop, a measurement of fish availability in pounds of

Figure 2
Development of the fishery resource measure



fish per surface acre of water and directly related to aquatic habitat, represent reductions in the availability of sport fishing resources.

Biologists have found the surface area of lakes and streams within an area to be the most important factor in determining fishery resource availability. Other factors affecting the quality of lake fishing include boat wakes or unseasonal variations in lakes' normal levels.

For streams, the proportion of average annual flow to natural flow (actual flow divided by natural flow) is the most significant factor affecting fishery quality per unit of stream surface area. Of the many proposed and field-tested methods of estimating stream aquatic habitat, the most popular to date is known as the Montana Method or Tennant's Criteria.

> Detailed field studies were conducted on 11 streams in 3 states between 1964 and 1974, testing the "Montana Method." This work involved physical, chemical and biological analyses of 38 different flows at 58 cross-sections on 196 stream-miles, affecting both coldwater and warmwater fisheries. The studies, all planned, conducted, and analyzed with the help of state fisheries biologists, reveal that the condition of aquatic habitat is remarkably similar on most of the streams carrying the same portion of their annual average flow. Similar analyses of hundreds of additional flow regimens near U.S.G.S. (U.S. Geological Survey) gauges in 21 different states during the past 17 years substantiate this correlation on a wide variety of streams (Tennant, p. 359, 1976).

Annual average flow refers to the total volume of water that would pass by a gauging station during a year of average precipitation. Streamflow typically varies throughout a year--high flows with spring rains or snow melts and low flows in the winter or dry season. Fish habitat is best maintained (for a given annual average flow) by flow variations within the year that match typical seasonal patterns. Streamflow also varies due to variations in annual precipitation. However, fishing quality usually varies inversely with variations in annual precipitation because fish populations become concentrated during years of low precipitation and are harder to find in years of above-average precipitation. Fish population dynamics are longrun phenomena and, therefore, water's value as a recreational fishing resource should not be based on shortrun flows (for example, during a selected week or a given year).

The relation between streamflow and fishery resources is finalized by the link between aquatic habitat and fish stocks. Changes in relative flow cause proportional changes in fish standing crop. The relationship between aquatic habitat and fish standing crop has been demonstrated in various biological studies that have included comparisons across coldwater and warmwater streams of various sizes (White, Hansen, and Alexander, 1976; Wesche, 1976; Nickelson, 1976).

Fish standing crop serves well as a measure of available fishery resources because both fish population and size affect standing crop. Fish standing crop captures natural variations in fish size and population densities across species and water bodies. The recreational fishing commodity is assumed to be produced from the sporting challenge offered by the fish species sought. Any reduction in fish standing crop represents a reduction in the natural fish stock and the associated sporting challenge. The number and size of fish are important only in that the size distribution of a particular fish species is normal for those specific waters.[5] For example, trout in a small mountain stream may never exceed 12 inches yet offer a unique fishing challenge. A larger stream with the same size distribution of trout would be disappointing.

Other factors that may affect stream aquatic habitat include unseasonable variations in stream levels, sediment and pollution loads, and dredging. Factors affecting aquatic habitat that are not accounted for in this analysis are assumed to be orthogonal to (in other words, show no correlation with) the independent variables used in this analysis.

Fishery Resources Available to Each Household

Two other factors important in determining the availability of fishery resources to the household are the exploitation of the fish stock (or fishing pressure) and the distance to the fishery resources for the household.

Exploitation of the potentially available fish stock is assumed to be proportional to the size of the surrounding population. Fishery resources within each given area are quantified on a per capita basis to account for harvesting of the surrounding fish stock.

Since location of or distance to fishing resources is an important commodity supply determinant, variations in the distances to fishery resources must be considered. The design of the FHWAR survey allows only an approximation of distances. The FHWAR survey divided the United States into 291 wildlife regions--regions of similar wildlife habitat--as general location measures. Respondents identified the wildlife regions in which they fished, and one or more wildlife regions were used to identify the location of the respondent's residence. In the less populated areas, the FHWAR survey included more than one wildlife region in respondents' residence areas to preserve anonymity. A

[5] Russell and Vaughan (1982) recognized distinct commodity demands associated with fishing for coldwater and warmwater game fish and for ruff fish. However, accounting for such variation in commodity demand is beyond the scope of this analysis.

total of 129 regions were identified to discriminate locations of respondents' residences.

The FHWAR survey's design allows the location of fishing resources to be defined as either in the residential area (RA) or in an outer fishing area (OFA), which is a collection of wildlife regions. Because no information is provided on the location of respondents' residences within the RA, the fishing resources within an RA (for residents of that RA) are defined without a measure of distance. This reduces the explanatory power of the model. Since our interest is on how streamflow affects participation, it is important to recognize that, historically, people tend to live near waterways so that even in drier RA's distances to fishing resources are not likely to be great or to vary significantly across RA's.[6]

Residents of RA's may fish both inside and outside of their areas. To estimate the available fishery resources outside the RA, the relevant wildlife regions are first defined. The irregular shape of both the RA's and the wildlife regions and the uneven population distribution within the RA's suggest that the selection of the relevant wildlife regions should consider more than tangency to the RA. Thus, the OFA for a given RA is defined to include wildlife regions where either the residents of the RA fished 5 percent or more of their time <u>or</u> 5 percent or more of the total days fished within a wildlife region were by residents from the given RA. The second criteria eliminates bias toward inclusion of only the wildlife regions with higher quality fishery resources.

The distance to OFA's varies across RA's because the sizes of the RA's vary. The larger the RA, the greater distance a resident of the RA is likely to be from the RA/OFA border. Variations in distances to OFA resources are approximated by the square root of the area of the RA.[7]

Stream and lake surface areas, average annual streamflow, riparian vegetation, and population are unique to each of the 129 RA's and OFA's, and distance is unique to each RA/OFA pair. Per capita stream and lake fishing resource measures are quantified for each RA/OFA pair by:

$$\begin{aligned} SFISH^{RA} &= (SAREA*FLOW*VEG/POP)^{RA} \\ LFISH^{RA} &= (LAREA/POP)^{RA} \\ SFISH^{OFA} &= (SAREA*FLOW*VEG/POP)^{OFA}/DIST^{OFA} \\ LFISH^{OFA} &= (LAREA/POP)^{OFA}/DIST^{OFA}, \end{aligned} \tag{4}$$

---

[6] A further complication of distances to the many sites within an RA is the consideration of variation in the quality of sites. This complication further emphasizes the appeal of using a per capita measure of resource availability.

[7] The relationship between distance and area is exemplified by the relationship between a circle's radius (R) and area (A) where $R = (A/\pi)^{0.5}$.

where:

SFISH represents the available fishery resources of streams,
LFISH represents the available fishery resources of lakes,
SAREA represents the surface area of streams,
LAREA represents the surface area of lakes,
POP represents the area's population,
FLOW represents the portion of average annual flow in the surrounding streams,
VEG represents one plus the proportion of riparian vegetation being trees,
DIST represents the square root of the total area of the RA, and the RA, OFA superscripts signify unique measures of resources of the residential area and the outer fishing area, respectively.

The Reduced-Form Model

Using the available data on the variables in the vectors PERSONAL and PUBLIC, the relationships developed above, and the number of days freshwater fishing (excluding Great Lakes) as a proxy for the commodity, equation (3) can be rewritten as:

$$\begin{aligned}\text{DAYS} = {} & \beta_0 + \beta_1\text{SEX} + \beta_2\text{FARMKID} + \beta_3\text{RETIRE} + \beta_4\text{SCHOOL} + \beta_5\text{AGE} + \\ & \beta_6\text{AGE**2} + \beta_7\text{EDLEVEL} + \beta_8\text{INC} + \beta_9\text{INC**2} + \beta_{10}\text{URBAN} + \\ & \beta_{11}\text{OMILE60} + \beta_{12}\text{OMILE} + \beta_{13}\ln(\text{SFISH}^{RA}) + \beta_{14}\ln(\text{LFISH}^{RA}) + \\ & \beta_{15}\ln(\text{SFISH}^{OFA}) + \beta_{16}\ln(\text{LFISH}^{OFA}), \qquad (5)\end{aligned}$$

where the ß's are the regression coefficients and the variables are as defined in table 2. The natural log is taken of the fishery resource measure to allow for diminishing marginal utility from greater amounts of the recreational fishing commodity.

Because equation (5) 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 (Deyak and Smith, 1978, p. 69).

Coefficients on SFISH and LFISH are expected to be positive for both the RA and OFA resource measures since an increase in available fishery resources is expected to increase the number of days fished. The relative sizes of coefficients of the stream and lake variables depend on which resource offers the better recreational fishery resource. Coefficients on OMILE and OMILE60 are expected to be negative since they represent a substitute fishery resource for freshwater fishing (excluding the Great Lakes). Given our interest in the environmental variables of PUBLIC and the earlier discussions of variables in the vector PERSONAL, no discussion on the PERSONAL variables is provided here.

Regression Analysis

The dependent variable of equation (5), days fishing, has a continuous range of values except for a lower limit of zero thus indicating the need for a tobit model (Tobin, 1958; and Judge and others, 1980, p. 609).

Table 2--Variables of the reduced-form equation

Variable	Definitions
Dependent variable:	
DAYS	The number of days spent freshwater fishing (excluding the Great Lakes)
Variables in the vector PERSONAL:	
SEX	Binary variable: 1 if male; 0 otherwise
FARMKID	Binary variable: 1 if the population of the area raised in was less than 10,000; 0 otherwise
RETIRE	Binary variable: 1 if retired; 0 otherwise
SCHOOL	Binary variable: 1 if in school; 0 otherwise
AGE	Age in years
AGE**2	Age in years squared
EDLEVEL	Number of years attended school
INC	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
INC**2	Income squared
URBAN	Binary variable: 1 if 1980 Census classified the location of the respondent's home as an urban area; 0 otherwise
Variables in the vector PUBLIC:	
OMILE60	Binary variable: 1 if ocean or Great Lakes fishing is within 60 miles; 0 otherwise
OMILE	Binary variable: 1 if ocean or Great Lakes fishing is within 120 miles but over 60 miles; 0 otherwise
$SFISH^{RA}$	An estimate of stream fishery resource availability within the RA
$LFISH^{RA}$	An estimate of lake fishery resource availability within the RA (excluding the the Great Lakes)
$SFISH^{OFA}$	An estimate of stream fishery resource availability within the OFA
$LFISH^{OFA}$	An estimate of lake fishery resource availability within the OFA (excluding the Great Lakes)

Maximum likelihood estimation of the tobit coefficients in the reduced-form equation indicates that stream fishery resources are a significant input in the production of recreational enjoyment (table 3). All estimated coefficients are significantly different from zero at the 99-percent confidence fishing level except coefficients of $LFISH^{RA}$ and $LFISH^{OFA}$ which are significant at the 95-percent level. All coefficients but that of $LFISH^{OFA}$ have the expected signs. A negative sign on $LAKE^{OFA}$ may indicate that distant lakes are a better input for substitute recreational commodities such as water skiing or swimming. The coefficient of multiple correlation (R-square) corrected for degrees of freedom is not high; however, this is characteristic of qualitative choice models.

Effects of Streamflow Changes on Days Fished

In estimating the change in days fished resulting from a change in streamflow, it must be kept in mind that a change in streamflow affects all downstream populations. Therefore, responses of downstream individuals estimated with the reduced-form equation are summed to determine the total change in days

Table 3--Estimated coefficients and t-statistics from the reduced-form equation

Variable[1]	Coefficient[2]	t-statistic
SEX	16.9	12.1
FARMKID	8.03	5.41
RETIRE	11.4	3.82
SCHOOL	9.99	3.66
AGE	2.13	10.5
AGE**2	-.0262	10.7
EDLEVEL	.559	3.05
INC	.0619	3.60
INC**2	-.000113	3.74
URBAN	-6.16	4.27
OMILE60	-6.16	4.02
OMILE	-11.8	3.87
$SFISH^{RA}$	3.56	5.15
$LFISH^{RA}$	1.59[3]	1.45
$SFISH^{OFA}$	1.49	3.36
$LFISH^{OFA}$	-.823[3]	2.52
CONSTANT	-50.0	9.41
R-square	0.0792	

[1] Variables are defined in table 2.
[2] All coefficients significant at the 99-percent confidence level unless otherwise noted.
[3] Significant at the 95-percent confidence level.

fished. The individual j's response to a change in relative streamflow, FLOW, based on the tobit estimation of equation (5), is:

$$[\partial(DAYS_j)/\partial FISH][\partial FISH/\partial FLOW] = (\beta_{13}/FLOW^{RA} + \beta_{15}/FLOW^{OFA}) * F(Z_j), \qquad (6)$$

where the variables are as described before and $F(Z_j)$ is the cumulative standard normal distribution function and Z is the normalized index (McDonald and Moffitt, 1980). Summing equation (6) across individuals of a given RA provides the equation for the total response within that RA:

$$\sum_{j=1}^{n} (\partial(DAYS_j)/\partial FLOW) = (\beta_{13}/FLOW^{RA} + \beta_{15}/FLOW^{OFA}) * \sum_{j=1}^{n} F(Z_j), \qquad (7)$$

where n represents the RA's population. The responses of individuals vary within each RA because the normalized index, Z_j, is estimated for each individual.

The value of $\sum_{j=1}^{n} F(Z_j)$ is derived for each RA by using the subsample of the relevant population in the FHWAR survey. The average of $F(Z_i)$, $\overline{F}(Z)$, is estimated for each RA. Equation (7) is then approximated by:

$$\sum_{j=1}^{n} (\partial(DAYS_j)/\partial FLOW) = (\beta_{13}/FLOW^{RA} + \beta_{15}/FLOW^{OFA}) * n * \overline{F}(Z) \qquad (8)$$

where n represents the population of the RA. The values of $\overline{F}(Z)$ and stream flow level are unique to each RA.

From equation (8), the change in days fished due to an acre-foot change in annual streamflow is derived for every ASA (river basin).

Conclusion

Current water policies do not account for downstream recreational benefits. From society's viewpoint, this omission may lead to suboptimal water allocation. The results of this study show that water has significant marginal value as a recreational fishing resource. If a more efficient allocation scheme were established for water, more water may be allocated to recreation and less to irrigation.

Most water allocation decisions are made by State governments. The results of this study indicate that downstream fishery benefits are often significant in areas outside State boundaries. Thus, a framework for increasing national economic benefits should involve downstream States.

References

Barnett, William A. "Pollak and Wachter on the Household Production Function Approach," J. Political Economy 85(5), 1073-86 (Oct. 1977).

Bayha, Keith. "Instream Flows--The Big Picture," Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Vol. 1, pp. 95-131. Bethesda, MD: American Fisheries Society, 1976.

Becker, Gary S. "A Theory of the Allocation of Time," Econ. J. 75(299), 493-517 (Sept. 1965).

Bockstael, Nancy, and Kenneth E. McConnell. "Welfare Measurement in the Household Production Framework," Amer. Econ. Rev. 73(4), 806-814 (Sept. 1983).

_______________, and Kenneth E. McConnell. "Theory and Estimation of the Household Production Function for Wildlife Recreation," J. of Environ. Econ. Manag. 8, 199-214 (Sept. 1981).

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

Daubert, John T., and Robert A. Young "Recreational Demand for Maintaining Instream Flows: A Contingent Valuation Approach," American J. of Agr. Econ., 63, 665-675 (Nov. 1981).

Deyak, Timothy A., and V. Kerry Smith. "Congestion and Participation in Outdoor Recreation: A Household Production Function Approach," J. of Environ. Econ. Manag. 5, 63-80 (Mar. 1978).

English, Burton C., Elwin G. Smith, and George E. Oamek. "An Overview and Mathematical Representation of the National Agricultural Resources Interregional Modelling System." Staff paper. Ames, IA: Center for Agricultural and Rural Development, Iowa State University, 1986.

Holt, D., T. M. F. Smith, and P. D. Winter. "Regression Analysis of Data from Complex Surveys," Royal Statistical Soc. Series A, No. 143 (1980).

Hori, Hajime. "Revealed Preference for Public Goods," Amer. Econ. Rev. 65, 978-991 (Dec. 1975).

Johnson, Neal S., and Richard M. Adams. "Benefits of Increasing Streamflow: The Case of the John Day River Steelhead Fishery," Water Resources Research 24(11), 1839-1846 (Nov. 1988).

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.

Loomis, John B. "Consistency of Method for Valuing Outdoor Recreation." Ph.D. dissertation. Colorado State University, 1983.

McDonald J. F., and R. A. Moffitt. "The Uses of Tobit Analysis," Rev. Econ Stat. 62, 318-321 (1980).

Miller, Jon R., and Michael J. Hay. "Determinants of Hunter Participation: Duck Hunting in the Mississippi Flyway," American J. of Agr. Econ. 63(4), 677-684 (Nov. 1981).

Morrison, Donald G. "Upper Bounds for Correlations Between Binary Outcomes and Probablistic Predictions," J. Amer. Stat. Assoc. 67(337), 68-70 (Mar. 1972).

Nickelson, Thomas. "Development of Methodologies for Evaluating Instream Flow Needs for Salmonid Rearing," Proceedings of the Symposium and Specialty Conference on Instream Flow Needs Vol. 2, pp. 597-612. Bethesda, MD: American Fisheries Society, 1976.

Pollak, Robert A., and Michael L. Wachter. "Reply: Pollak and Wachter on the Household Production Function Approach," J. Political Economy 83, 1083-86 (Oct. 1977).

______________, and Michael L. Wachter. "The Relevance of the Household Production Function and Its Implications for the Allocation of Time," J. Political Economy 83(2), 255-277 (Apr. 1975).

Russell, Clifford S., and William J. Vaughan. "The National Recreational Benefits of Water Pollution Control," J. Environ. Res. Manag. 9, 328-324 (Mar. 1982).

Tennant, Donald Leroy. "Instream Flow Regimens for Fish, Wildlife, Recreation, and Related Environmental Resources," Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Vol. 2, pp. 359-373. Bethesda, MD: American Fisheries Society, 1976.

Tobin, James. "Estimation of Relationships for Limited Dependent Variables," Econometrica 26(1), 24-36 (Jan. 1958).

U.S. Department of Agriculture. Soil, Water, and Related Resources in the United States: Status, Conditions, and Trends. 2 Vols. 1980 Appraisal. 1981.

______________, Soil Conservation Service, and Iowa State University Statistical Laboratory. National Resources Inventory, 1984.

U.S. Department of Commerce, Bureau of the Census. "Survey of Fishing, Hunting, and Wildlife Associated Recreation, 1980." Machine-readable data files FH2 and FH3, 1982.

________________, Bureau of the Census. 1980 Population Census, 1981.

U.S. Water Resources Council. The Nation's Water Resources 1975-2000. 4 Vols., 1978.

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, Vol. 2, pp. 224-234. Bethesda, MD: American Fisheries Society, 1976.

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, Vol. 2, pp. 597-612. Bethesda, MD: American Fisheries Society, 1976.

☆U.S. Government Printing Office : 1990 - 261-455/20530