EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF WATER IN RESERVOIRS COMPARED TO INSTREAM FLOW

by

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COLORADO WATER RESOURCES

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ABSTRACT

This report analyzed the value of water used for coldwater fishing at high mountain reservoirs and rivers located in the Rocky Mountains of Colorado. The study will contribute to an economic assessment of the tradeoff between providing recreation opportunities at high mountain reservoirs and maintaining instream flow for river recreation use. A representative sample of 130 fishermen at three high mountain reservoirs and three rivers were interviewed during the summer of 1978. The six study sites represent the range in size of reservoirs and rivers located at elevations of 6,000 to 11,000 feet in the Rocky Mountains. Fishermen reported willingness to pay contingent on changes in congestion and water level. Economic benefit functions were adjusted for the effects of crowding, water level, access, characteristics of participants, and costs of management. Policy implications were discussed with emphasis on application of the information to water management decisions.

Benefits from expanding access to high mountain reservoirs and rivers would accrue to current users because of the reduced congestion which would result at substitute sites. Providing access to 30 percent more high mountain reservoirs would increase existing reservoir fishing benefits by an average of $3.27 per user day, and providing access to 15 percent more river miles would increase existing river fishing benefits by $1.25 per user day. Once optimum capacity is reached, however, future expansion of fishing opportunities would be valued as average benefits of $10.26 per user day on reservoirs and $11.78 on rivers. When fishing becomes competitive with other water uses, the appropriate measure of value becomes marginal benefit. For reservoir fishing, the marginal benefit per acre foot was calculated as $1.80 per day with water drawdown ranging from

25 to 100 percent of maximum bankful. With 60 miles of river suitable for fishing, marginal benefits per acre foot increased from zero with no instream flow to a maximum of $13.08 with instream flow of 35 percent of maximum and fell to zero with 65 percent of maximum flow.

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SUMMARY

The purpose of this study was to develop and apply a procedure to measure the value of water used for coldwater fishing at high mountain reservoirs and rivers located in the Rocky Mountains of Colorado. Economic benefit functions show the effects of crowding, water level, access, characteristics of participants, and costs of management.

Water management agencies are interested in comparable measures of economic benefits to assess the tradeoff between providing recreation opportunities on high mountain reservoirs versus maintaining instream flow for river recreation use. In the past, most western communities and government agencies welcomed water diversion, reservoir construction, and related development projects as a source of new income and economic growth. As a result, 30 percent of the 12,500 miles of river in Colorado have been destroyed or substantially altered. Nearly 1,000 miles have been dewatered to provide irrigation, power, and domestic water supply; 300 miles have been inundated by reservoirs, and 2,600 miles have been polluted by mining, industrial, and residential development. Increased attention has focused in recent years on studies to improve water development policies for the future. The people involved in water and energy development in the west are interested in what can be learned about the recreation value of water in reservoirs compared to instream flow. Some level of recreation use may be compatible with water storage and delivery for irrigation, energy, industry, and domestic water supply.

A representative sample of 130 fishermen were interviewed at three high mountain reservoirs and three rivers during the summer of 1978. The six study sites were selected to represent the range in size of reservoirs and rivers

located at elevations of 6,000 to 11,000 feet in the Rocky Mountains. Willingness to pay questions were designed to measure consumer surplus which is the area under the demand curve above the cost of fishing. Trip cost was selected as a realistic payment vehicle. Payment of trip cost is familiar to all individuals who participate in outdoor recreation and has been applied successfully in other recreation benefit studies. Respondents reported willingness to pay contingent on changes in congestion and water level. The stepwise multiple regression procedure was utilized to develop net benefit fucntions adjusted for congestion. Benefit functions shifted with changes in water level and were constrained by marginal cost of fish stocking and management calculated as $2.50 per user day.

Individual fishermen on high mountain reservoirs and rivers who encountered no other persons reported average benefits of about $20 per day. With otherwise identical conditions, benefits declined to zero when 30 other persons were encountered per day. As long as the gains from additional fishermen exceeded the loss due to congestion cost, total benefits increased. Beyond optimum capacity, congestion costs exceeded the gain experienced by additional fishermen and total benefit diminished. For reservoirs, optimum capacity occurred in the neighborhood of 11 persons encountered per day, about one-third fewer than currently. For rivers, optimum capacity was 10 persons encountered per day, about one-sixth fewer than currently.

This report has shown that research procedures which measure the effects of congestion improve the resulting estimate of recreation benefits. Without adjusting for congestion, the average recreation benefit of reservoir fishing would have been reported as about $7 per user day, representing a $3.27 or 30 percent under-estimate of the $10.26 average benefit at optimum capacity.

Benefits of river fishing would have been under-estimated as $10.53 per day or $1.25 less than the $11.78 at optimum capacity.

These results have important implications for estimation of benefits from expanding recreation opportunities at mountain rivers and reservoirs which until recently were closed to public access. Incremental benefits would accrue to all individuals who have access to fish on high mountain reservoirs and rivers because of the reduced congestion which would result with substitution. Providing access to one-third more high mountain reservoirs would increase existing reservoir fishing benefits by an average of $3.27 per user day. Providing access to 15 percent more river miles would increase existing river fishing benefits by $1.25 per user day.

Results were applied to water valuation problems when recreation use is complementary and when it is competitive with other uses. Once fishing capacity of the high mountain reservoirs or rivers in a region has been reached, the appropriate measure of the value of fishing as a complementary part of multiple purpose development and management is the average benefit from the fishing opportunity provided. Fishing benefits would be valued as $10.26 per reservoir user day and $11.78 per river user day. Coldwater river fishing for trout with a fly rod while wading a stream bed requires more skill and effort, thus benefits exceed those from reservoir fishing for trout with spinning tackle cast from vantage points along the shore.

When fishing becomes competitive with other water uses, the appropriate measure of value becomes the marginal benefit of fishing. In an illustrative case study of a high mountain reservoir with storage capacity of 1,000 acre feet, marginal benefit per acre foot was $1.80 per day with water drawdown ranging from 25 to 100 percent of maximum water level. With 60 miles of western river suitable for fishing, marginal benefits per acre foot increased from zero with no instream flow to a maximum of $13.08 with instream flow of 35 percent of maximum, and fell to zero with 65 percent of maximum flow.

Marginal benefits per acre foot would vary among high mountain reservoirs and rivers to the extent that site specific conditions differ from those considered here. For example, increasing the linear miles of river with public access from 15 to 120 miles increases fishing benefits proportionately. An acre foot of instream flow can be used by fishermen in subsequent miles of river without diminishing its value to fishermen downstream.

Policy implications were discussed with emphasis on application of the information to water management decisions. One partial solution to the problem of allocating water among competitive uses in a river basin involves changing the timing of water storage in high mountain and plains reservoirs for irrigation and other purposes. In the past, many irrigation companies began filling high mountain reservoirs in the fall and waited until the following spring to fill reservoirs in the plains. Total benefits would increase if high mountain reservoirs were drawn down to a minimum pool sufficient to sustain fish life in late October after the high mountain fishing season. Water could be used to fill reservoirs on the plains and the augmented instream flow would increase river fishing benefits in the fall months. Fishing benefits would increase as the spring runoff fills high mountain reservoir storage capacity and reduces early instream flow to levels more suitable for fishing use. Water diversion and storage in high mountain reservoirs during May, June, and early July, when instream flow of western rivers approaches maximum bankful, would benefit both reservoir and river fishing.

Reservoir fishing is competitive with the drawdown of water in high mountain reservoirs to supplement low natural instream flow during late July, August, and early September. However, fishing and boating use of western rivers is complementary to irrigation when rivers serve as canals delivering water from high mountain reservoirs to irrigation systems located on the plains below. Opportunity cost of $34 to reservoir fishing would equal combined benefits of irrigation, fishing, and boating in August of a normal year, with release of an equal amount of water daily for 5.65 days after which the reservoir would be refilled. These results suggest that instream flow be maintained at 35 percent of maximum during these months by weekly rotation among strategically located high mountain reservoirs.

Benefits from high mountain reservoir and river fishing would vary to the extent that site specific conditions differ from those considered here. Nonetheless, the information should be of considerable value to water managers who are faced with serious problems in administering the use of basin resources. The contingent valuation approach was successful in meeting the objective of valuing the public benefits from expanding recreation opportunities at high mountain reservoirs and rivers. The findings represent a conservative estimate of possible total benefits of water in high mountain reservoirs and rivers. There may be long-run ecological benefits which are not included in recreation fishing values.

EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF WATER IN RESERVOIRS COMPARED TO INSTREAM FLOW*

Richard G. Walsh**

INTRODUCTION

The purpose of this report is to analyze the value of water used for coldwater fishing at high mountain reservoirs and rivers located in the Rocky Mountains of Colorado. Recreation economic benefit functions are related to several important variables, including: crowding, water level, characteristics of participants, recreation water access, and costs of management. Such information will contribute to an economic assessment of the tradeoff between providing recreation opportunities at high mountain reservoirs and maintaining instream flow to provide river recreation opportunities and to protect the natural ecosystem of western rivers. In the past, most western communities and government agencies welcomed water diversion, reservoir construction, and related development projects as a source of new income and economic growth. As a result, 30 percent of the 12,500 miles of river in Colorado have been destroyed or substantially altered. Nearly 1,000 miles have been dewatered to provide irrigation, power, and domestic water supply; 300 miles have been inundated by reservoirs; and 2,600 miles have been polluted by mining, industrial, and residential development.

Increased attention has focused in recent years on studies to improve water development policies for the future. The people involved in water and energy development in the west are interested in what can be learned about the benefits of recreation use of water in reservoirs compared to instream flow. Some level of recreation use may be compatible with water storage and instream delivery of water for irrigation, energy, industry, and domestic water supply.

Water management agencies are interested in the measurement of benefits from recreation use comparable to the measures of benefits from alternative uses.

The primary contribution of this study to the economic literature on economic benefits is to apply a procedure for estimating the effects of congestion. Most studies of economic benefits of reservoir and river recreation in the past have dealt with uncongested sites or have assumed that no congestion effects exist. Recently, it has been shown that the resulting estimates of benefits may be biased if there is excess demand or congestion present [Fisher and Krutilla, 1972; Freeman, 1979]. Conceptually, congestion is an external cost perceived as a deterioration in the quality of the recreation experience. Thus, recreation benefits are expected to be a decreasing function of the number of persons encountered per day. Net benefits from recreation use of reservoirs and rivers are maximized when the gain to the marginal user equals the marginal loss his presence imposes on other users. Given relevant technological and institutional constraints, water resources are allocated efficiently when the net benefits resulting from all uses are maximized. A particular water resource policy is preferred on efficiency grounds when the excess of total benefit over total cost exceeds that which would result from alternative policies. Comparable measurement of the benefit and cost from alternative uses of water in high mountain reservoirs and rivers would be more nearly approached by estimation of recreation benefit at optimum capacity [Krutilla and Fisher, 1975].

The objectives of the study were to measure:

(1) the effect of crowding on the recreation value of water in reservoirs and instream flow;

(2) the effect of the quantity of water in reservoirs and rivers on recreation value and participation;

(3) the effect of other characteristics of the environment and of recreation users.

This report presents the empirical results and conclusions of the project. The following section discusses the characteristics of the study areas and the recreation opportunities provided. Section three discusses the theory of congestion adjusted benefit function. Shifts in the benefit function would result from changes in water level associated with other conjunctive uses of water in high mountain reservoirs and rivers. Section four discusses the study design in which respondents reported willingness to pay contingent upon changes in congestion and water level. Section five presents the empirical results with respect to benefits and costs. Finally, policy implications are discussed, with emphasis on application of the information provided by the study to water management decisions.

The following publications and manuscripts were prepared as a result of this project:

Walsh, Richard G., "Congestion Adjusted Recreation Benefits of Water in Reservoirs Compared to Instream Flow," Draft submitted for journal publication, 1980.

Walsh, Richard G., "Estimating the Recreation Value of Water in Reservoirs Compared to Instream Flow," Colorado Water Resources Research Institute Conference, Colorado State University, Fort Collins, April 9, 1980.

The demand for recreation use of water resources has grown at an accelerated rate since World War II, and is projected to grow at a rate 25 percent greater than other recreation activities to the year 2000 [Cicchetti, Seneca, and Davidson, 1969]. Water-based recreation in the year 2000 is expected to be 2.5 times 1965 levels. The number of participants in fresh water fishing increased from 21.7 million in 1960 to 29.4 million in 1970, by an average of 3 percent or 768,600 per year. River-based fishing accounted for about one-third of this and its growth rate was about one-third less than for reservoir and lake fishing. Fishing in Colorado, of which 43 percent was river-based, was projected to increase from 7.7 million user days in 1968 to 11.1 million in 1985, by an average of 2 percent or 198,000 user days annually [Arosteguy, 1974]. Since the ability to augment the supply of water resources is severely constrained, diversion of instream flow is now, and will likely continue to be, an important problem.

STUDY AREAS

The study sites are located at elevations of 6,000 to 11,000 feet in the Rocky Mountains of Colorado, an area with increasingly congested recreation sites and competitive demands on water resources. Figure 1 shows the location of the six sites in northcentral Colorado. The sites represent the range in size of high mountain reservoirs and rivers in the state. Three West Slope sites were used primarily for cold water river fishing for trout with a fly rod while wading the stream bed. Three Front Range sites were primarily used for cold water reservoir fishing for trout with either fly rod or spinning tackle cast from vantage points along the shore.

The quality of fishing is affected by the quantity of water available at these sites. As the amount of water in a reservoir or river decreases, there is a loss of surface area and shrinkage of the shoreline. In rivers, the suitable habitat for fish in pools and riffles declines. A denuded and discolored rocky area is exposed along the bank of both reservoirs and rivers. Yearly stocking may be necessary to maintain a fishery with no provision for a minimum pool or instream flow. Variation in water level must be carefully timed to maintain a wild trout population. After trout have spawned in shallow water with a gravel bottom, lowering the water level would destroy eggs left in gravel above the water line. Other changes may occur with decreases in water level which also lower the quality of fishing experience. This would tend to reduce the number of persons willing to use cold water reservoirs and rivers for fishing, and their willingness to pay for the experience. Thus, total recreation benefits are expected to decrease with the loss of water available.

Opportunities for recreation use of high mountain reservoirs and rivers normally are provided from a combination of labor, capital, land, and scenic

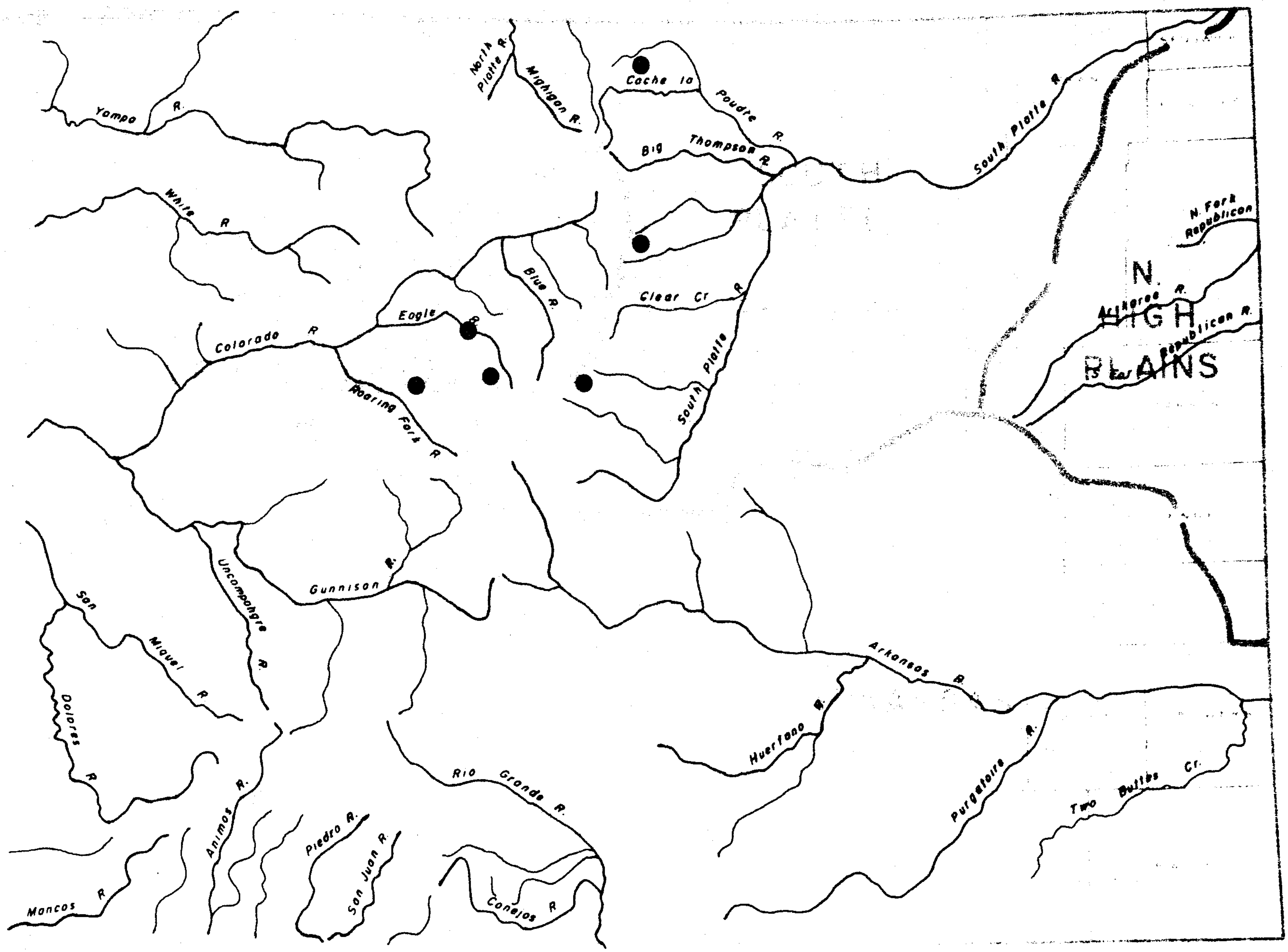

Figure 1. Location of the Study Sites, High Mountain Reservoirs and Rivers, Colorado, Summer, 1978.

resources as well as water [Young and Gray, 1972]. The related inputs may provide such facilities as: access roads and trails, parking areas, observation points, picnic and camp sites, water and sanitation equipment, landscaping, and as appropriate, boat launching and docking facilities. Other expenses include operation of fish stocking, licensing, and other use management programs, maintenance, cleanup, and public safety. The costs required to develop, operate, and maintain recreation facilities and use of high mountain reservoirs and rivers can be deducted from recreation benefits in order to obtain the recreation value of the natural resources of a site, the water, land, and scenic attributes. Costs of recreation use are especially important when investigating possible water reallocation to recreation.

The reservoir study sites were selected to obtain a representative sample of fishing opportunities at high mountain reservoirs [Aukerman, Springer, and Judge, 1977]. Parvin Reservoir is located 120 miles northwest of Denver and is the smallest of the three reservoir fishing sites studied, with 64 surface acres and storage capacity of 900 feet. Accessible by paved road, it is part of the Red Feather Lakes area where the Forest Service provides camping and fishing opportunities. Lefthand Reservoir is located about 50 miles west of Denver and is medium sized, with 100 surface acres and storage capacity of 1,500 acre feet. Accessible by dirt road, it is part of the Brainard Lake Recreation Area where the Forest Service provides camping and fishing opportunities. Jefferson Reservoir is located 60 miles southwest of Denver and is the largest reservoir studied, with 506 surface acres and storage capacity of 6,163 acre feet. Accessible by dirt road, the reservoir was semi-developed with minimal recreation facilities such as pit toilets, trash cans, and picnic tables.

Homestake Creek is located 120 miles west of Denver and is the smallest of the three river fishing sites studied, with a width of 30 feet and maximum flow of 460 acre feet per day. It flows northeast and joins the Eagle River near Red Cliff, 16 miles southwest of Vail. It provides camping and fishing opportunities near Interstate 70 which is the major east-west route through the Rocky Mountains of Colorado. The Frying Pan River is located about 180 miles west of Denver and is medium sized, with a width of 50 feet and a maximum flow of 1,165 acre feet per day. It flows west from the Continental Divide to the Roaring Fork River at Basalt, 18 miles northwest of Aspen. Its flow is controlled by Ruedi Reservoir on which the Forest Service provides camping and fishing opportunities. The Eagle River is located 110 miles west of Denver and is the largest river studied, with a width of 120 feet and maximum flow of 4,075 acre feet per day. Interstate 70 follows the stream bed from the Minturn interchange to the Colorado River near the entrance to Glenwood Canyon, and the river is easily accessible for fishing.

High mountain reservoirs and rivers offer the majority of two million residents of Colorado's Front Range metropolitan areas an opportunity for cold water fishing within 1 to 3 hours drive of their residence. Colorado residents accounted for over 80 percent of the users of the study sites. Tourists were primarily from the Northcentral and Western regions of the U.S. Severely cold surface water temperatures constrain water-based recreation to non-contact activities such as fishing and camping. The primary recreation activity during the summer of 1978 was fishing, which accounted for two-thirds of total time of users at the study sites. Camping was the second most important activity, acounting for 15 to 20 percent of total time. Boating was less than 2 percent and swimming less than 1 percent of total time. Other minor activities at the study sites included sightseeing, picnicking, photography, relaxing, hiking, backpacking, driving off-road vehicles, and miscellaneous.

THEORETICAL APPROACH

Congestion of a reservoir or river fishing site occurs when individual users encounter increasing numbers of other users. This reduces individual satisfaction from the experience of fishing. Therefore, willingness to pay diminishes and the consumer surplus measure of individual benefit falls. The presence of congestion at a high mountain reservoir or river has implications for measurement of the effects of water level on fishing benefits. In this section, a simple model is developed to analyze the effects of congestion on estimation of fishing benefits of reservoir and river use at optimum capacity. The model is then adapted to show how a change in water level shifts the congestion adjusted total benefit function and the estimation of optimum fishing capacity.

An empirical technique for determining the effect of crowding on benefits at a recreation site was developed by Fisher and Krutilla [1972] and applied to wilderness [Cicchetti and Smith, 1973 and 1976] and beach users [McConnell, 1977].[1/] The general procedure is firmly based in the economic theory of consumer demand. Congestion is viewed as one of a number of quality attributes of the recreation site, and enters an individual fisherman's utility function as a separate variable. Users are asked to report their maximum willingness to pay with varying numbers of persons encountered per day. Other important demographic information is recorded. A statistical benefit function is specified of the form:

Benefit = f(congestion, income, substitution, days, travel distance, tastes, etc.)

The effects of all other variables are controlled, and an average benefit function is derived in which congestion has a significant negative effect on individual benefit per day.

Figure 2 shows individual benefit per visitor day to be a declining function of number of persons encountered while engaged in recreation activity. The vertical intercept is the amount an individual would be willing to pay if he were the sole user of the reservoir or river fishing site, that is, if the site were uncongested. The horizontal intercept shows the maximum number of users who will eventually choose to participate, if use rates are unrestricted, since an individual user will participate so long as his benefit per day is positive. However, each additional user imposes losses in benefit on all previous users. The gain in benefit enjoyed by additional individuals is represented by the columns. The loss to existing individual users is represented by the rows. Assume that individual benefit per day declines by $1 for each additional person encountered at a recreation site. To find the economic optimum, locate the point where the loss in benefit to existing users from added congestion just equals the benefit gained by the additional user. The gain in benefit enjoyed by the sixth user is $5 represented by the shaded column. At that point, the loss to five existing users is also $5 represented by the shaded row. Thus, the optimum number of encounters is six.[2/] It can be seen that four users would be too few because at that point the loss to existing users would be $3 compared to a gain by the additional user of $7 benefit. Likewise, it can be seen that seven users would be too many because at that point the loss to existing users of $6 would exceed the gain of $4 in benefit to the additional user.

The marginal user considers only his private cost of congestion, namely, the cost imposed upon him by existing users. By ignoring his imposition of

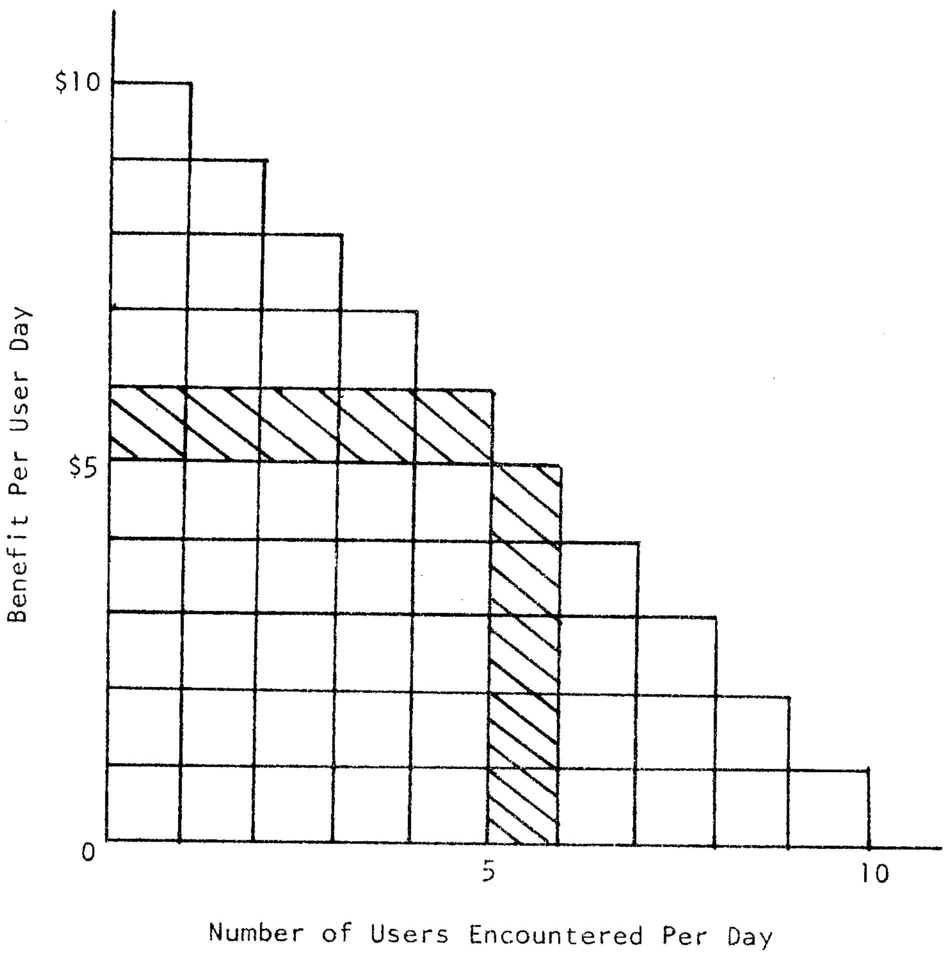

Figure 2. Effect of Crowding on Benefit per User Day and Optimum Capacity of a Recreation Resource.

congestion cost on existing users, there is created a divergence between private and social costs of congestion. As is generally the case for such externalities, the divergence between social and private costs results in over-use of the resource. The economic optimum level of resource use occurs where incremental benefit just equals incremental congestion cost.

That this is so can be easily shown by formal economic analysis. A total benefit function is derived, multiplying the number of users by indvidual benefits per user day at each level of congestion. Marginal benefit is simply the change in total benefit divided by the change in number of users. Total benefit functions are shown as the top portion of Figure 3 with marginal benefit functions as the lower portion. As long as the gain from admitting additional users exceeds the loss due to congestion costs, total benefit will increase. Beyond a point where congestion cost equals the gain experienced by the additional recreationist, total benefit diminishes with further admission. If there are no added costs of reservoir and river management or environmental degradation, optimum use occurs where total benefit is maximized and marginal benefit is zero.

Figure 3 shows a family of total benefit and marginal benefit curves depicting several threshold levels of water level in high mountain reservoirs and rivers.[3/] The largest total and marginal benefit functions shown are expected when water level is bankful. Below it are a family of total and marginal benefit curves depicting the expected effect of reservoir water drawdown and diversion of instream flow. These are based on shift coefficients derived from demand functions which contain water level as an independent variable.[4/] Each reduction in water level is expected to result in a lower carrying capacity and thus lower total benefit of recreation use.

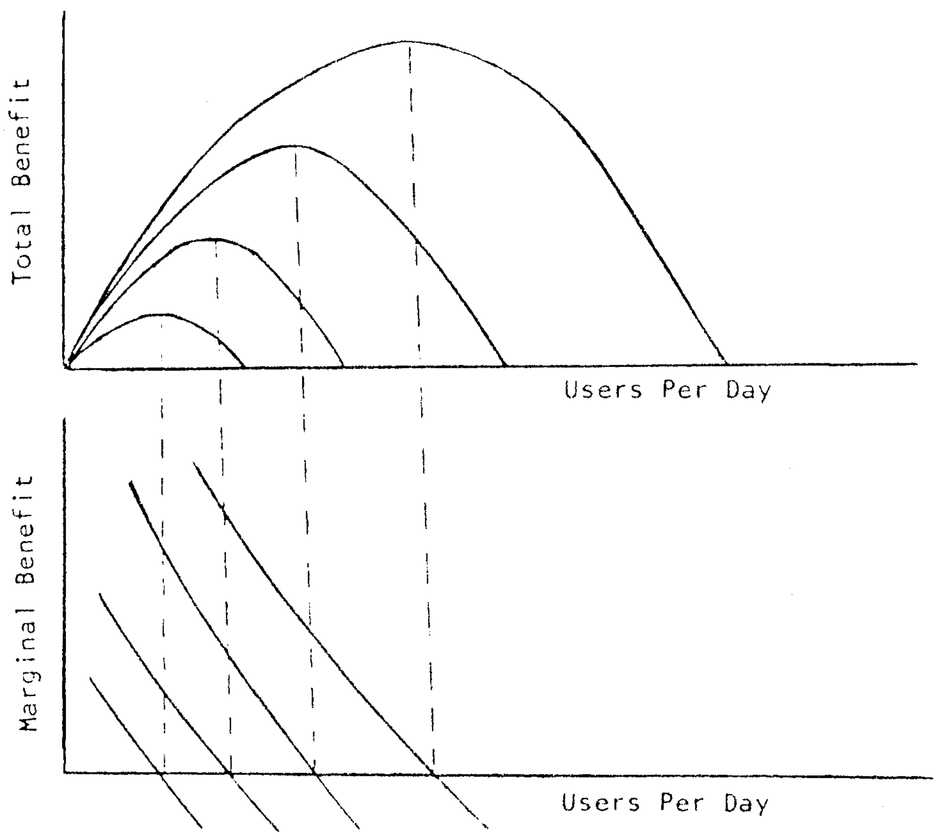

Figure 3. Effect of Reservoir and River Water Level on Congestion Adjusted Total and Marginal Benefit Functions.

When there are no costs other than those associated with congestion, optimum capacity will be at the point at which the total benefit is maximized and marginal benefit is zero for each water level. With the introduction of added costs of recreation management and environmental degradation, adjustments in optimum capacity will occur. Accordingly, it is desirable to distinguish these costs from the disutilities associated with congestion. We could do so in Figure 3 by introducing a separate marginal cost function (not shown) representing the change in these costs as intensity of use increases. If such costs should occur before the maximum total benefit is reached, marginal costs would intersect the marginal benefit schedule short of the congestion adjusted optimum level. Thus, added costs of recreation management and environmental degradation would become a constraint, and a perpendicular dropped from the intersection of the marginal cost and marginal benefit functions to the horizontal axis would indicate a new optimum carrying capacity.

STUDY DESIGN

The basic economic data for this study were obtained from two coordinated samples of reservoir and river users. A representative sample of 200 users were interviewed at 14 high mountain reservoirs on the Front Range of Colorado during the summer of 1978. A representative sample of 206 users were interviewed at nine river sites on the West Slope of Colorado from June 15 to August 15, 1978. Comparable subsamples of 60 cold water fishermen and 70 high mountain reservoir fishermen were drawn for the analysis in this report. The subsamples represent the range in size of reservoirs and rivers located at elevations of 6,000 to 11,000 feet in the Rocky Mountains of Colorado.

Following Knetsch and Davis [1966], the method of valuation was total direct trip costs. Respondents were asked to report the direct out-of-pocket costs of the trip. This was followed by a question which asked respondents to report the maximum amount they would be willing to pay rather than do without the recreation experience. Willingness to pay was defined as the maximum increase in total trip expenses[5/] above which the individual would decide not to participate, given the level of congestion and water on the day of interview. The direct costs actually paid were then subtracted from maximum willingness to pay so that the resulting value was a consumer surplus measure of existing benefits from high mountain reservoir and river fishing.

Subsequently, respondents were asked to report changes in the maximum amount they were willing to pay contingent upon changes in congestion and water level. Reservoir users estimated change in willingness to pay with congestion at five threshold levels: with no other person encountered, with 25 percent, 50 percent, 75 percent, and the maximum number of persons encountered above which they would discontinue the recreation activity. Reservoir users also estimated the change in willingness to participate at the site with a full reservoir and water drawdown to four threshold levels: 75 percent, 50 percent, 25 percent, and zero percent of maximum bankful. Maximum water level was obvious from clearly observed water lines resulting from maximum bankful conditions in the past. River users also estimated the change in willingness to pay with changes in congestion and instream flow. The only difference between the questions asked reservoir and river users was with respect to the interval of changes in the environmental amenities. River fishing values were expected to be more sensitive to congestion and water level. Accordingly it was deemed important to set the threshold levels at 20 percent intervals rather than 25 percent.

The approach was first applied by Davis in a 1963 study of the consumer surplus benefit of recreation activities in the Maine woods. He asked recreationists how much additional cost they would pay before deciding to discontinue the activities at the study site. The procedure has been successfully applied to value recreation resources in the Maine woods [Knetsch and Davis, 1966], a water basin in British Columbia [Meyer, 1974], water quality in Colorado [Walsh, Greenley, Young, McKean, and Prato, 1978], fishing in Washington State [Mathews and Brown, 1970], the Western Flyway [Hammack and Brown, 1974], wildlife in the Southeastern region [Horvath, 1974], and air quality in New Mexico [Randall, Ives, and Eastman, 1974] and at the Glen Canyon National Recreation Area [Brookshire, Ives, and Schultze, 1976].

The U.S. Water Resources Council [1979] recently recommended this contingent valuation approach to water-based recreation benefit estimation. The Council recommended two types of contingent valuation procedures: the iterative bidding game and the open-ended direct question. The preferred format for large water projects is an iterative bidding procedure in which respondents answer "yes" or "no" to questions asking if they are willing to pay a stated amount of money to obtain decreased congestion. The value is increased by random amounts until the highest amount that the respondent is willing to pay is identified. The Council recommended this technique on the basis that it has been applied effectively in several surveys [Knetsch and Davis, 1966; Randall, Ives, and Eastman, 1974; Brookshire, Ives, and Schultze, 1976; and Walsh, Greenley, Young, McKean, and Prato, 1978].

The second procedure is a noniterative technique in which the respondent is asked either to select his maximum willingness to pay from a list of stated values or to report his maximum willingness to pay. In this study, respondents were asked the open-ended direct question which the Council recommends for valuation of recreation on small water projects, typical of those on high mountain rivers: What is the maximum amount of money you would pay to obtain decreased congestion levels? The Council suggests that at present, insufficient evidence has been accumulated through research to conclude that noniterative bidding questions are as reliable as iterative bidding questions. However, preliminary results of a number of studies suggest that the noniterative technique can provide results comparable to the iterative technique [Mathews and Brown, 1970; Hammack and Brown, 1974; Walsh, Ericson, McKean, and Young, 1978].

Benefit functions are estimated for all members of a representative sample and extrapolated to the population using the reservoir and river sites. The purpose of the approach is to estimate the changes in consumer surplus benefits which would result from changes in the quality of resources used at a recreation site. It is important to note that the resulting congestion adjusted benefit function is not a demand curve; it is a direct measure of the change in benefits represented by shifts in the demand curve resulting from increased congestion [Bradford, 1970].

The contingent valuation approach appears to be gaining broad acceptance. It is generally recognized that the method requires careful wording of questions and well-defined situations with which the respondent is familiar. In several of the studies cited above more than one approach was used. No one method has emerged as superior in all cases, and there is need for further research to test the effectiveness of alternative willingness to pay formats.

ANALYSIS OF RESULTS

The two benefit functions developed in the analysis are shown in Table 1. The proportion of the variation in benefit per day explained by the independent variables included in the two equations ranged from 0.39 to 0.42. All parameters were significantly different from zero at the 5 percent level. The estimated benefit functions for high mountain reservoirs and rivers are shown in Figures 4 and 5, where individual benefits per day are measured along the vertical axis with number of persons encountered measured along the horizontal axis.[6/]

Ordinary least squares statistical methods were used to estimate the coefficients and the constant for each model. Then the models were simplifed to show the relationship between the two variables of interest. All variables other than the dependent variable, number of persons encountered, were set at their means and added to the constant.[7/] The following regression functions were obtained for the average benefits of high mountain reservoir and river fishing:

$$\text{Reservoir benefits} = 19.56 - 0.9897 \text{ Persons} + 0.0106 \text{ Persons}^2$$

$$\text{River benefits} = 20.06 - 0.8868 \text{ Persons} + 0.0050 \text{ Persons}^2$$

These functions indicate that an average fisherman who encounters no other persons can be expected to have benefits of about \$20 per day. With otherwise identical conditions, benefits decline by approximately 80 to 90 cents per day for each additional person encountered while fishing at high mountain reservoirs and rivers. Reservoir fishermen who encounter an average of 16 other persons as reported on the day interviewed, would have average benefits of about \$7 per day. River fishermen who encounter an average of 12

Table 1. Ordinary Least-Square Equation Estimates of the Effect of Crowding on Net Benefit Per Day of Fishing at High Mountain Reservoirs and Rivers, Colorado, 1978.

Variable	River Fishing	Reservoir Fishing
Constant	39.7800 (3.13)	9.3158 (3.16)
Crowding, Persons	-0.8868 (-4.55)	-0.9897 (-5.46)
Crowding Squared	0.00505 (2.73)	0.0106 (3.96)
Benefit Per Day of This Trip, Dollars	0.7542 (10.08)	0.6874 (10.27)
Direct Cost Per Day of This Trip	-0.5219 (-6.75)	
Education, Years	-1.5030 (-1.91)	
Persons Encountered at Study Site Today	0.3041 (4.63)	0.3025 (2.37)
Days at This Site on This Trip		-0.6814 (-2.08)
Member of Sportsman Organization	-12.4960 (-3.28)	
Adjusted R^2	.39	.42
F	25.33	32.41
Observations	282	231

a. Number in parenthesis below each coefficient represents student t-ratios for the null hypothesis. All variables are significant at the 95 percent confidence level.

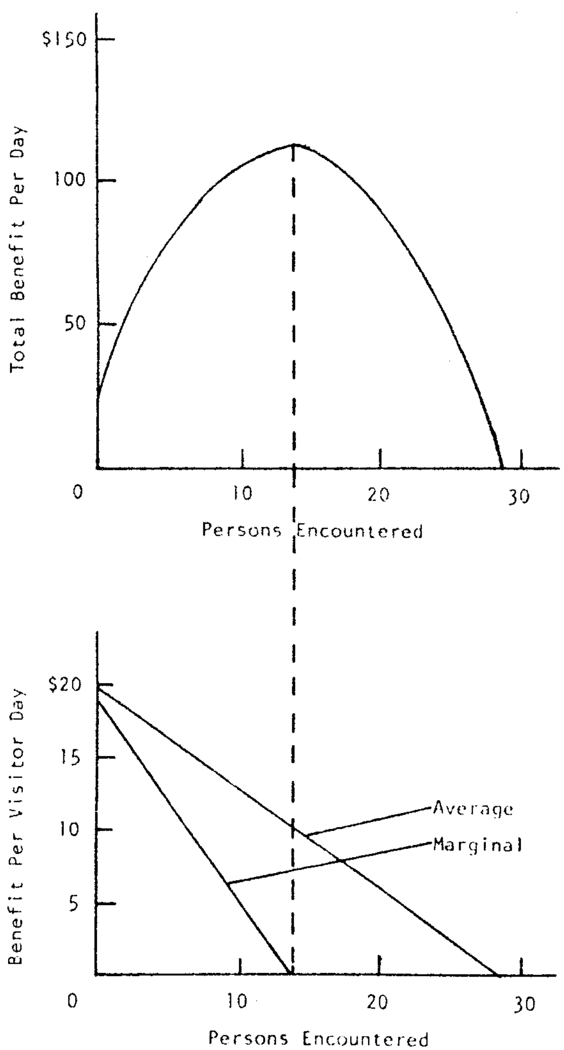

Figure 4. Total, Average, and Marginal Benefit Per Day of Fishing at Three High Mountain Reservoirs, Colorado, 1978.

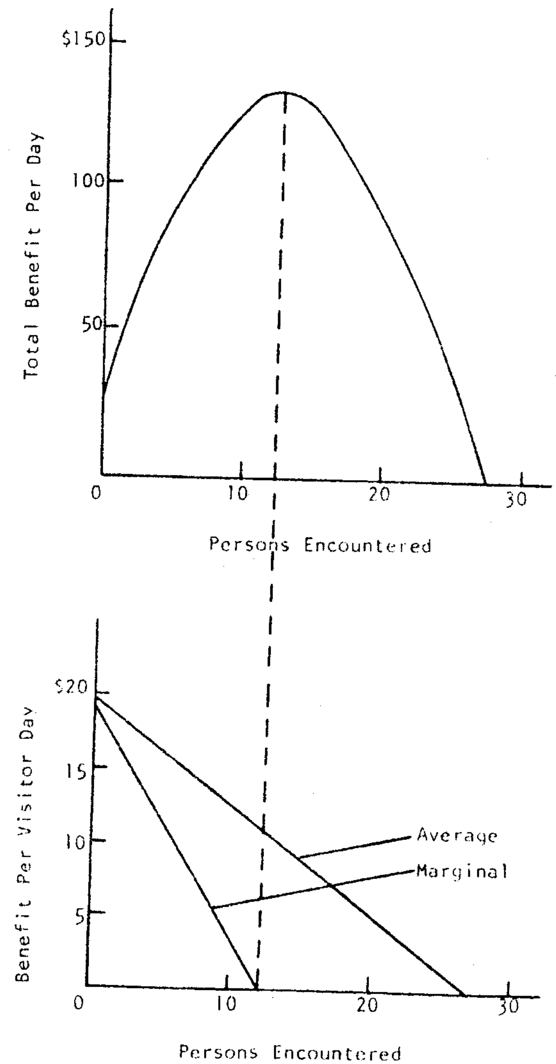

Figure 5. Total, Average, and Marginal Benefit Per Day of Fishing at Three Western Rivers, Colorado, 1978.

other persons as reported, would have benefits of about $10 per day. Both reservoir and river fishermen who encounter 30 other persons per day would receive virtually no benefits and would be expected to discontinue fishing at these sites.

The total benefit function takes the same standard textbook form as the total revenue function based on price times quantity; in this case, it is average benefit times number of encounters plus one, the observer. As long as the gain from additional users exceeds the loss due to congestion cost, total benefit increases. Beyond some point, congestion cost exceeds the gain experienced by additional users and total benefit diminishes. For both reservoir and river fishing, optimum capacity occurs in the neighborhood of 11 to 12 persons encountered per day. Total benefits are maximized where the cost of incremental congestion equals the benefit of incremental use, hence the marginal benefit function at that point is zero.

If there were no costs for reservoir and river fishing other than those associated with congestion, the optimum capacity would be at the point where total benefits are maximized and marginal benefits are zero. With the introduction of agency costs of management, optimum capacity would shift to the left. For high mountain reservoirs and rivers, these costs have been estimated by the Forest Service as approximately $2.50 per visitor day.[8/] With costs of $2.50 per user day, optimum fishing capacity would decline from 11-12 to 10-11 encounters per day. This would be the number of encounters where marginal benefit equals marginal cost. At this constrained optimum level of congestion, average benefits from reservoir fishing would rise slightly from $9.73 to $10.26 per user day, and benefits from river fishing would increase from $10.38 to $11.78.

APPLICATIONS

This study has shown that research procedures which measure the effects of congestion improve the resulting estimation of benefits from fishing on high mountain reservoirs and rivers. More meaningful comparison of alternative water uses is possible if the total benefits of each are estimated at optimum capacity. Table 2 shows that if congestion effects had been ignored, the average benefits from fishing at reservoirs would have been reported as $7.00 per user day compared to $10.53 for rivers. This was the average consumer surplus calculated from values reported by fishermen interviewed during the summer, 1978. For reservoirs, this would represent a $3.27 or 27.8 percent under-estimate of average benefits at optimum capacity calculated as $10.26 per user day. For rivers, this is a $1.25 or 10.6 percent under-estimate of average benefits at optimum capacity calculated as $11.78 per user day.[9/]

While both of these estimates fall within an acceptable range, the congestion adjusted values of $10 to $12 lend support to the U.S. Water Resources [1979] unit day standard ranging from $3 to $13 benefit per user day, with the higher end of the range assigned to the more unique experiences which high mountain reservoirs and rivers provide. However, the U.S. Forest Service 1980 Resources Planning Act (RPA) unit day standard of $6.25 benefit from coldwater trout fishing may be an under-estimate. This value was assigned to a 12-hour visitor day. For 6-hour fishing user days, the derived value would be $3.13 which seems low for high mountain reservoirs and rivers in Colorado, even with congestion.

This paper has demonstrated an empirical basis for estimating optimum capacity of recreation at high mountain reservoirs and rivers, as conceived by Fisher and Krutilla [1972] nearly a decade ago. For reservoirs, the optimum

Table 2. Effect of Congestion and Agency Costs on Carrying Capacity and Individual Benefits Per User Day of Fishing at High Mountain Rivers and Reservoirs, Colorado, 1978.

Persons Encountered and Individual Benefits	Three Mountain Rivers	Three Mountain Reservoirs
Persons Encountered Per Day		
Reported by respondents	11.5	16.0
At optimum capacity with congestion costs	11.7	11.3
At optimum capacity with agency costs of $2.50	9.9	10.6
Average Benefits Per Day		
Reported by respondents	$10.53	$ 6.99
At optimum capacity with congestion costs	$10.38	$ 9.73
At optimum capacity with agency costs of $2.50	$11.78	$10.26
Range of difference	$0.15-$1.25	$2.74-$3.27

number of encounters per day was calculated as 10.6 persons within 150 feet, about one-third fewer than currently. This is the level of use where marginal benefits would equal marginal costs estimated as $2.50 per day for recreation development and management. For rivers, the number of encounters at optimum capacity was calculated as 10 persons per day.[10/] This was one-sixth fewer than currently.

These results have important implications for estimation of benefits from expanding recreation opportunities at high mountain reservoirs and rivers which until recently were closed to public access. The recommended measure of benefits is the incremental benefits would accrue to recreation users of currently accessible reservoirs and rivers because of the reduced congestion which would result with substitution. For a discussion of conditions under which these benefits would occur, see Freeman [1979] and Cesario [1980]. Providing access to one-third more high mountain reservoirs would increase existing fishing benefits by $3.27 per visitor day because of reduced congestion at existing reservoirs. Providing access to 15 percent more river mileage would increase existing river fishing benefits by $1.25 per user day because of reduced congestion at existing rivers. These findings suggest that opportunities for fishing should be increased by providing access to more high mountain reservoirs and rivers. Once optimum capacity is reached, however, future expansion of fishing opportunities at reservoirs and rivers would be valued at the higher levels shown in Table 2 as average benefits of $10.26 per user day at reservoirs and $11.78 at rivers.

These estimates of congestion adjusted benefits from fishing assumed that average water level was 90 percent of maximum bankful capacity of reservoirs and 70 percent of maximum instream flow of rivers. This was the average water level estimated by respondents on the days interviewed during the summer, 1978.

Actual water available during the recreation months of July, August, and September may be much less than these levels. Figures 6 and 7 show a family of total benefit and marginal benefit curves for several threshold levels of the quantity of water. As can be seen, reducing the amount of water in rivers and reservoirs has a substantial effect on total benefits at optimum capacity.

Table 3 shows the effect of instream flow on benefit maximizing use levels for fishing.[11/] Table 4 shows comparable information for a typical high mountain reservoir. Simmons and Lord [1978] defined the relationship between instream flow and optimum recreation use as a "capacity constraint curve." This is shown for fishing on western rivers as column four of Table 4. The data indicate that the capacity constraint curve for fishing is curvilinear bell-shaped, rising at an increasing and then decreasing rate, becoming negative from 65 to 100 percent of maximum instream flow. The reservoir capacity constraint curve is linear, decreasing at a constant rate over the entire range of drawdown in water level. However, the capacity constraint curve would be curvilinear with respect to drawdown in acre feet of water storage volume. This is because water volume declines at an increasing and then decreasing rate with respect to drawdown of water level. Fishing capacity of a reservoir is primarily determined not by water volume but by the amount of usable shoreline and surface water area, which decline at about the same rate as water level.[12/] Actual fishing use of a river or reservoir may be more or less than the optimum carrying capacity levels shown, however, non-optimum use would result in a loss of total benefits. Optimum total benefits associated with each threshold level of water are shown as column six of the tables. Marginal benefits per acre foot of instream flow per day is shown as columns seven through eleven of Table 3. Marginal benefits per acre foot of water storage volume is shown as column seven of Table 4.

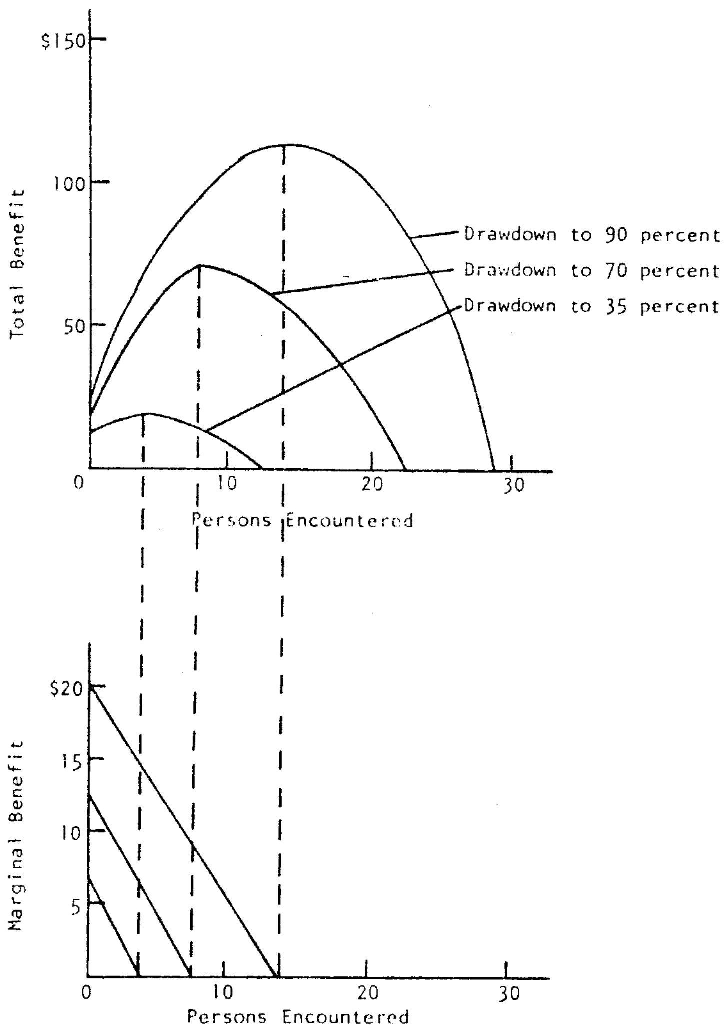

Figure 6. Water Drawdown Shifts Total and Marginal Recreation Benefits of Fishing Per Day at Three High Mountain Reservoirs, Colorado, 1978.

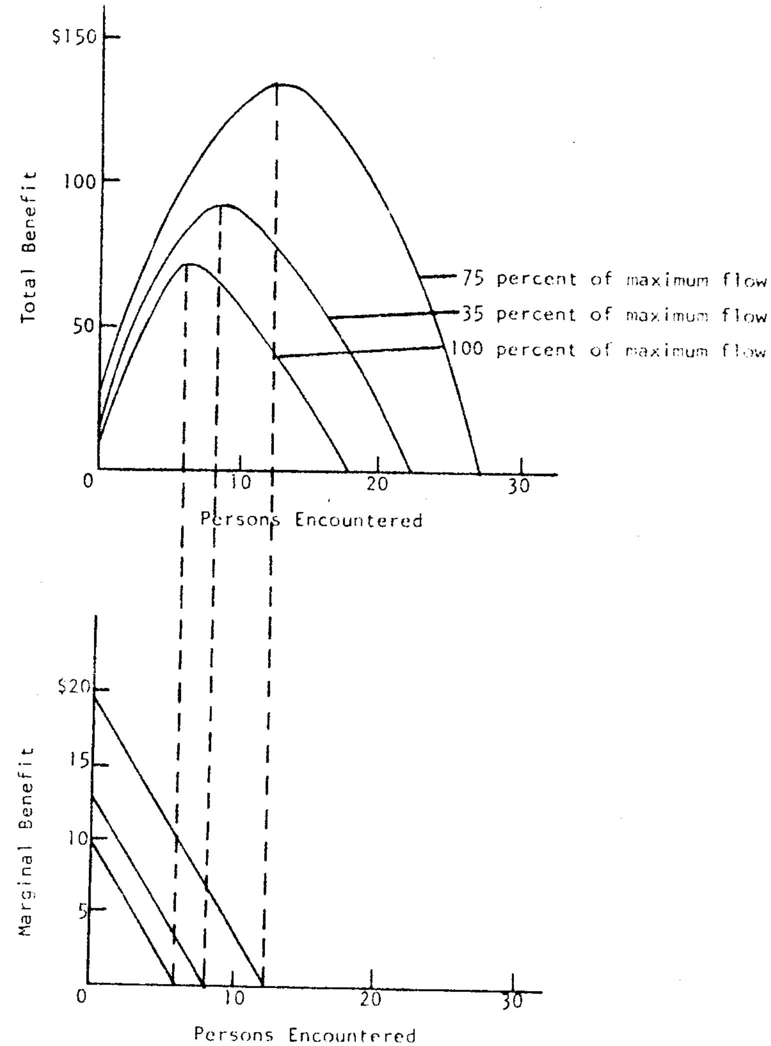

Figure 7. Instream Flow Shifts Total and Marginal Benefits Per Day of Fishing at Three Western Rivers, Colorado, 1978.

Table 3. Effect of Instream Flow on Congestion Adjusted Net Benefits from Fishing at Three Western Rivers, Colorado, 1978.

Percent of Maximum Flow	Instream Flow, Acre Feet Per Day	Optimum Encounters Per Mile Per Day	Optimum Users Per Mile Per Day[b]	Optimum Net Benefits Per User Day[c]	Total Net Benefits Per Mile Per Day	Marginal Net Benefits from Fishing: Per Mile for One Percent Change in Maximum Flow	Per Acre Foot of Instream Flow: 15 Miles	30 Miles	60 Miles	120 Miles
0	0	0	0	0	0					
5	80	1.5	1.8	$ 1.82	$ 3.28	$ 0.66	$ 0.62	$ 1.24	$ 2.48	$ 4.96
10	160	2.9	3.5	3.48	12.21	1.79	1.68	3.36	6.72	13.44
15	240	4.2	5.0	5.00	25.00	2.56	2.40	4.80	9.60	19.20
20	320	5.3	6.4	6.37	40.78	3.16	2.96	5.92	11.84	23.68
25	400	6.3	7.6	7.59	57.68	3.38	3.17	6.34	12.68	25.36
30	480	7.2	8.6	8.66	74.45	3.35	3.14	6.28	12.56	25.12
35	560	8.0	9.6	9.57	91.89	3.49	3.27	6.54	13.08	26.16
40	640	8.6	10.3	10.34	106.49	2.92	2.74	5.48	10.96	21.92
45	720	9.2	11.0	10.95	120.49	2.80	2.63	5.26	10.52	21.04
50	800	9.5	11.4	11.42	130.17	1.94	1.82	3.64	7.28	14.56
55	880	9.8	11.8	11.74	138.50	1.67	1.57	3.14	6.28	12.56
60	960	9.9	11.9	11.90	141.59	0.62	0.58	1.16	2.32	4.64
65	1,040	10.0	12.0	11.91	142.92	0.27	0.25	0.50	1.00	2.00
70	1,120	9.9	11.9	11.78	140.18	-0.55	-0.52	-1.04	- 2.08	- 4.16
75	1,200	9.7	11.6	11.50	133.40	-1.36	-1.28	-2.56	- 5.12	-10.24
80	1,280	9.4	11.3	11.06	124.98	-1.68	-1.58	-3.16	- 6.32	-12.64
85	1,360	8.9	10.7	10.47	112.02	-2.59	-2.43	-4.86	- 9.72	-19.44
90	1,440	8.3	10.0	9.73	97.30	-2.94	-2.76	-5.52	-11.04	-22.08
95	1,520	7.6	9.1	8.85	80.54	-3.35	-3.14	-6.28	-12.56	-25.12
100	1,600[a]	6.8	8.2	7.80	63.96	-3.92	-3.68	-7.36	-14.72	-29.44

a. Maximum weekly instream flow, Frying Pan River, 1978.

b. Cold water river fishermen use an average of one linear mile of river per day. Number of users per mile equaled 1.2 times number of encounters.

c. Net benefits adjusted for agency costs.

Table 4. Effect of Drawdown on Congestion Adjusted Fishing Benefits from Water in High Mountain Reservoirs, Colorado, 1978.

Percent of Maximum Water Level[a/]	Storage Volume, Acre Feet[b/]	Optimum Encounters Per Day[c/]	Optimum Users Per Day[d/]	Optimum Net Benefits Per User Day	Total Net Benefits Per Day	Marginal Net Benefits Per Acre Foot Per Day[e/]
0	0	0	0	0	0	
5	21.3	0.59	7.49	$0.57	$4.26	$0.20
10	42.6	1.18	14.98	1.14	17.07	0.60
15	63.9	1.76	22.35	1.71	38.21	0.99
20	85.2	2.35	29.84	2.28	68.03	1.40
25	106.5	2.94	37.33	2.85	106.39	1.80
30	132.7	3.53	44.83	3.42	153.31	1.80
35	163.5	4.11	52.19	3.99	208.23	1.80
40	199.2	4.70	59.69	4.56	272.18	1.80
45	239.5	5.29	67.18	5.13	344.63	1.80
50	284.6	5.88	74.67	5.70	425.61	1.80
55	334.5	6.46	82.04	6.27	514.39	1.80
60	389.2	7.05	89.53	6.84	612.38	1.80
65	448.5	7.64	97.02	7.41	718.91	1.80
70	512.7	8.23	104.52	7.98	834.06	1.80
75	581.4	8.81	111.88	8.55	956.57	1.80
80	655.2	9.40	119.38	9.12	1,088.74	1.80
85	733.5	9.99	126.87	9.69	1,229.37	1.80
90	816.7	10.58	134.36	10.26	1,378.53	1.80
95	904.5	11.16	141.73	10.83	1,534.95	1.80
100	1,000.0	11.75	149.23	11.40	1,701.22	1.80

a. Percent of maximum water level observable as the high water line, usually equal to design capacity.

b. Maximum volume, Dowdy Lake, Colorado. Drawdown of storage volume at five percent thresholds of water level was based on water engineering estimates from blueprints of bottom contours for eight high mountain reservoirs.

c. Within 150 feet of respondents.

d. Optimum number of encounters times a constant 12.3. See Note 2.

e. Rounded.

Complementary Value of Water for Fishing

These results can be applied to water valuation problems when fishing use is complementary and when it is competitive with other uses. Young and Gray [1972] reviewed the concept of the economic value of water and problems in its empirical measurement and concluded that recreation uses of water are most often complementary to other uses.

Instream flow which will be diverted later for irrigation, mining, industrial, or municipal purposes often can be used for recreation purposes without diminishing its value in the alternative uses. Once capacity of rivers in the region has been reached, the appropriate measure of the value of recreation as a complementary part of multiple purpose river development is the total net benefit from the fishing opportunity provided.

Thus, the maximum total net benefits of providing optimum public fishing access to 60 miles of western river with flow at 65 percent of the maximum 1,600 acre feet would be $11.91 per user day or total benefits of $8,575 per day. This is equivalent to a yield of $8.25 per acre foot of instream flow. Capitalized at 10 percent interest in perpetuity, this would represent an investment value of $85,750, which is equivalent to $82.45 per acre foot of instream flow. If the development plan also provides optimum public kayaking and rafting access to 60 miles of river with flow at 65 percent of maximum, total benefits would increase by 99.6 percent.

If development plans provide that instream water flow will be systematically reduced to 460 acre feet or 35 percent of maximum during the summer months, fishing benefits would fall to $9.57 per user day or total benefits of $5,513 per day. However, this is equivalent to a maximum yield of $9.85 per acre foot of instream flow. Capitalized at 10 percent interest in perpetuity, this would represent an investment value of $55,130, which is equivalent to $98.45 per acre foot. If the plans also provide optimum public kayaking and rafting access to 60 miles of river with flow at 35 percent of maximum, total benefits would increase by 68.3 percent.

If development plans provide that instream water flow will be systematically reduced to 240 acre feet or 15 percent of maximum, fishing benefits would fall to $5 per user day or total benefits of $1,500 per day. This is equivalent to a yield of $6.25 per acre foot of instream flow. Capitalized at 10 percent interest in perpetuity, this would represent an investment value of $15,000 which is equivalent to $62.50 per acre foot. If the development plan also provides optimum public kayaking and rafting access to 60 miles of river with flow at 15 percent of maximum, total benefits would increase by 59.1 percent.

Water stored in reservoirs for irrigation, mining, industrial, or municipal purposes can often be used for fishing without diminishing its value in alternative uses. Once fishing capacity of the high mountain reservoir system in a region has been reached, the appropriate measure of the value of recreation as a complementary part of a multiple purpose water development project is the total benefit from the fishing opportunity provided. Thus, the annual benefits of providing optimum public fishing access to a multiple purpose high mountain reservoir with storage volume of 1,000 acre feet drawn down to 90 percent of capacity would be $10 per user day or $165,400 per year.[13/] This is equivalent to an annual yield of $203 per acre foot of water stored. Capitalized at 10 percent interest in perpetuity, this could represent an investment of $1.65 million, which is equivalent to $2,000 per acre foot.

If development plans provide that reservoir water level will be systematically drawn down to 35 percent of maximum water level during the summer months, fishing benefits would fall to $4 per user day or $25,000 per year. This is equivalent to an annual yield of $153 per acre foot of water stored. Capitalized at 10 percent interest in perpetuity, this would represent an investment value of $250,000 which is equivalent to $1,500 per acre foot.

If development plans provide for non-vehicle access to a reservoir with storage volume of 600 acre feet, these fishing benefit estimates would decrease by 3.1 percent. If plans provide for public access to a fully developed reservoir with storage volume of 3,000 acre feet, these fishing benefits would increase by 1.21 times.

Marginal Value of Water for Fishing as a Competitive Use

When fishing becomes competitive with other uses of water, the appropriate measure of value becomes marginal benefit [Young and Gray, 1972]. Water managers would maximize the social benefit from water resources where the marginal benefit from water diversion for crop irrigation and other purposes equals the marginal benefit from fishing and other recreation use. Marginal benefit per acre foot of water is the change in total benefit divided by change in instream flow.

Marginal benefit of high mountain reservoir fishing averaged about $1.80 per acre foot per day with drawdown in water level from 100 to 25 percent of maximum storage capacity of 1,000 acre feet. This was equivalent to $216 per acre foot of the 120-day recreation season. With water drawdown to 20 percent of maximum water level, marginal benefit per acre foot fell to $1.40 per day.[14/] With water drawdown to 10 percent of maximum water level, marginal benefit per acre foot decreased to $0.60 per day.

In the case of fishing on western rivers, the marginal benefit function for instream flow had a decided bell shape.[15/] With 60 miles of river suitable for fishing, marginal benefits per acre foot increased from zero with no instream flow to a maximum of $13.08 with instream flow of 560 acre feet per day or 35 percent of maximum. With further increases in flow, marginal benefits from fishing declined. Marginal benefits fell to zero with instream flow of about 1,075 acre feet per day or 65 percent of maximum. Beyond this level, added instream flow resulted in negative marginal benefits from fishing. Marginal benefits were negative $5.12 with instream flow of 1,200 acre feet, and negative $14.72 with maximum instream flow of 1,600 acre feet per day.

Marginal benefits per acre foot would vary among high mountain reservoirs and rivers to the extent that site specific conditions differ from those considered here. For example, recreation benefits of instream flow are sensitive to the size of river and number of miles suitable for fishing. A typical river suitable for fishing has maximum instream flow of 1,600 acre feet per day. some rivers used for fishing are considerably smaller and larger than this. Increasing size of river reduces fishing benefits per acre foot of instream flow. The number of miles of river suitable for fishing depends on characteristics of individual rivers and public access to them. Table 3 shows that increasing the linear miles of river with public access from 15 to 120 miles increases fishing benefits proportionately. This is an important variable because an acre foot of instream flow can be used by fishermen in subsequent miles of river without diminishing its value to fishermen downstream.

Information on the marginal benefit of water used for fishing on high mountain reservoirs and rivers should be of considerable value to water managers who are faced with serious problems in administering the use of water resources. Partial solution to the problem of allocating water among competitive uses in a river basin involves changing the timing of water storage in high mountain and plains reservoirs for irrigation and other purposes. In the past, many irrigation companies began filling high mountain reservoirs in the fall and waited until the following spring to fill reservoirs in the plains [Aukerman, Carlson, Hiller, and Labadie, 1977]. Total benefits could increase if high mountain reservoirs were drawn down to a minimum pool sufficient to sustain fish life in late October after the high mountain fishing season. Water could be used to fill reservoirs on the plains and the augmented instream flow would increase river fishing benefits in the fall months.[16/] Fishing benefits would increase as the spring runoff fills high mountain reservoir storage capacity and reduces early summer instream flow to levels more suitable for fishing use.

Water diversion and storage in high mountain reservoirs during May, June, and early July, when instream flow of western rivers approaches maximum bankful, would benefit both reservoir and river fishing. The marginal benefit of each day of high mountain reservoir fishing equals $1.80 per acre foot for increases in water level from 20 to 100 percent of maximum bankful. Thus, if diversion of instream flow to high mountain reservoir storage provided an additional one-half month of reservoir fishing, marginal benefits would equal $27 per acre foot added to storage. If this water diversion reduced instream flow from 100 to 35 percent of maximum bankful during these months, river-based recreation benefits would equal $19 per acre foot of instream flow, including $13 fishing, $3.60 kayaking, and $2.40 rafting. These estimates assume 60 miles of river suitable for each of these recreation activities.

Marginal analysis has shown that while it is true western rivers provide maximum total benefits from excellent white water rapids for kayaking and rafting during spring and early summer when stream runoff is high, instream flow is much more valuable for boating as well as fishing during late July, August, and September to maintain minimum flow. The minimum optimum flow to maximize marginal recreation benefits per acre foot appears to be 35 percent of maximum flow. At this level, the sum of marginal recreation benefits is estimated as \$19.04 per acre foot, including \$13.08 fishing, \$3.60 kayaking, and \$2.36 rafting. Thirty-five percent of maximum is the optimum flow for fishing. At this level, marginal benefits from kayaking are only \$0.12 per acre foot less than at 50 percent of maximum flow which is the optimum for kayaking. Also, marginal benefits from rafting are only \$0.04 less than at 40 to 45 percent of maximum flow which is the optimum for rafting. Moreover, 35 percent of maximum flow is greatly superior to 65 percent of maximum instream flow with a sum of marginal benefits equal to \$5.37 per acre foot, and to 100 percent of maximum flow with a negative sum of marginal benefits estimated as -\$13.76 per acre foot. These comparisons assumed 60 miles of river suitable for each of these recreation activities.

Reservoir fishing is competitive with the drawdown of water in high mountain reservoirs to supplement low natural instream flow during late July, August, and September. However, fishing and boating use of western rivers is complementary to irrigation when rivers serve as canals delivering water from high mountain reservoirs to irrigation systems located on the plains below. Thus, when the decision is between allocating water to reservoir storage or instream flow, the appropriate procedure is to sum the marginal benefits of the combined usage of instream flow for river-based recreation and irrigation.

For example, Daubert and Young [1979] reported the marginal benefit to crop irrigation in August of a normal year as $15 per acre foot, the marginal benefits of river-based recreation are $19 per acre foot, including $13 fishing, $3.60 kayaking, and $2.40 rafting at 35 percent of maximum flow. The combined marginal benefits of these complementary uses of instream flow equal $34 per acre foot. Opportunity cost to reservoir fishing would equal $34 per acre foot with release of an equal amount of water daily for 5.65 days after which the reservoir would be refilled immediately. This would be the efficient water allocation decision in August of a normal year. In a drought year, when marginal benefits of crop irrigation approach $40 per acre foot, total instream benefits of $59 per acre foot would equal opportunity costs of releasing an equal amount of high mountain reservoir water daily for 7.6 days. These results suggest that instream flow could be maintained at 35 percent of maximum during these months by weekly rotation drawing water from first one then another strategically located high mountain reservoir, after which each would be allowed to refill.

CONCLUSIONS

The contingent valuation approach was successful in meeting the objective of valuing the public benefits from expanding recreation opportunities at high mountain reservoirs and rivers. Contingent valuation techniques have been successfully applied to the valuation of air and water quality in the past. The technique appears to be appropriate for valuation of a wide variety of non-market goods including the effects of congestion, reservoir water drawdown, and diversion of instream flow. It should be remembered, however, that contingent valuation measures the response of individuals faced with hypothetical situations. Thus, considerable care must be exercised in the design of questions and the conduct of surveys, to insure the results obtained are as realistic as possible.

In addition to the recreation benefits of water in high mountain reservoirs and rivers, there may be long-run ecological benefits that are not included in recreation fishing values. It is impossible now for biologists to predict what these might be, let alone put a dollar value on them and incorporate them into a benefit estimate. For this reason, it seems that present benefit figures represent a conservative estimate of possible total benefits of water in high mountain reservoirs and rivers. The inability of economic analysis to place a dollar value on ecological effects should be recognized in making decisions about development and use.

FOOTNOTES

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1. An extension of this technique was presented by Freeman and Haveman [1977] and by Freeman [1979]. In its simplest form, an <u>uncongested</u> demand curve for a recreation site is specified and below it a family of <u>constant</u> congested demand curves. The area between the demand curves represents the loss in consumer utility measured in dollars resulting from increased congestion. From this, a congestion cost function was developed as the difference between the maximum willingness to pay when there are no other users present and when there are an increasing number. Each point on the congestion cost curve represents the most an individual would be willing to pay in order to have congestion reduced to zero. The marginal congestion cost curve equals the congestion cost the marginal user imposes on existing users, plus the congestion cost the existing users impose on the marginal user. Optimum is defined as the point where this marginal congestion cost curve equals the uncongested willingness to pay curve. This formulation yields a solution similar to the procedure applied in this report.

2. Individuals experience congestion as number of encounters. For management purposes, encounters must be converted to persons present. Insufficient

resources were available to do a simulation analysis of the relationship between number of encounters and persons present in the study areas. Shichter and Lucas [1978] reported the results of simulation analysis of the Desolation Wilderness Area in California, with numerous rivers and lakes. They reported that the relationship was site specific and linear within the relevant range. The relationship between number of encounters and persons present in the study areas was provided by U.S. Forest Service and Colorado Wildlife Conservation Officers.

3. Simmons and Lord [1978] adopted the Fisher and Krutilla [1972] model to allow shifts in the congestion adjusted total and marginal benefit function with changes in instream water level. With water diversion, fewer users can be present without interfering with others because there is less area suitable for use.

4. An alternative procedure would be to include the independent variable, willingness to participate, as a shifter in the initial function from which congestion adjusted total and marginal benefit curves were derived. This more efficient approach would yield similar results.

5. Increased trip expense was chosen as a payment vehicle over the alternative entrance fee to avoid protest bids. General trip expenses were familiar to all respondents and were dissociated from specific resource ownership, management, and license fees, which may produce adverse reactions.

6. In this analysis, it is assumed that tastes for congestion avoidance are homogeneous. For a discussion of the ramifications of heterogeneous tastes, see Freeman and Haveman [1977].

7. Other variables which shift the congestion adjusted benefit function for river fishing include: direct cost, consumer surplus, and level of congestion experienced by respondents, distance traveled, length of stay, education, age,

sex, organization membership, and size of river. For example, with each additional $1 of trip cost per day, the river congestion adjusted benefit function declined by $0.52. With each 1,000 acre feet increase in maximum instream flow, the total congestion adjusted benefit function increased by $0.45. Other variables which shift the congestion adjusted benefit function for reservoir fishing included: the consumer surplus and level of congestion experienced by respondents, distance traveled, length of stay, size of residential community, and sex. For example, with each additional day per trip, the congestion adjusted benefit function declined by $0.68. The empirical results of this study suggest that income was not associated with willingness to pay to avoid congestion. Thus, non-price rationing of recreation use of reservoirs and rivers may be efficient. For a discussion of the effects of income distribution on equitable pricing to ration use rates, see Cory [1979-80].

8. Agency cost of $2.50 per user day was considered a reasonable average of several case studies of fish stocking and other management costs in 1979. Marginal costs could be as low as $1 per user day, depending on whether a reservoir or river is stocked or has natural reproduction. There is need for further research on the costs of providing fishing opportunities on high mountain reservoirs and rivers [Milton, 1980].

9. The results of this study have important implications for projection of benefits over a planning period representing the life of a multi-purpose water development project. With a normal growth in number of users from a low base, application of a constant value per visitor day would understate congestion adjusted total benefit during the early years and overstate it during later years of the planning period.

10. For river fishing, the optimum number of users per mile was calculated as 1.2 times encounters or 12 persons daily. This is where marginal benefits would equal marginal costs estimated as $2.50 per user day. This user-based estimate of optimum carrying capacity tends to support Colorado state capacity standards for river-based recreation [Colorado, 1974]. Following the adoption of the 1970 Colorado Outdoor Recreation Plan, the state adopted a capacity standard of four persons per mile fishing wild trout streams, 16 persons per mile fishing trout streams which are stocked. Our user-based capacity of 12 fishermen per mile lends support to the state standard as most rivers studied were stocked on a regular basis, however, some sections were designated as wild trout fishing and were not stocked.

11. See Walsh, et al., [October, 1980] for benefit maximizing use levels for kayaking and rafting on western rivers. The capacity constraint curve for kayaking is linear, decreasing at a constant rate over the entire range of in-stream flow. However, the capacity constraint curve for rafting is curvilinear, rising at an increasing and then decreasing rate. See Walsh, et al., [September, 1980] for the same information on a smaller undeveloped reservoir and a larger fully developed reservoir whose capacity constraint curves are linear with respect to water level and curvilinear with respect to volume in acre feet of water stored.

12. Reservoir capacity tends to be site specific and varies with conditions such as steepness of bank, amount of marsh, restricted fishing areas, and quality of fishing which may result in periodic changes in the location of fishermen along the shore. See Grubb and Goodwin [1968], Pankey and Johnston [1969], Kalter [1971], and Knetsch [1974]. The 1971 Colorado state capacity standard for reservoir fishing was 100 linear feet of shoreline per fisherman and a

turnover rate of 2 persons per day [Colorado, 1974]. For typical high mountain reservoirs with shoreline of 6,000 to 25,000 feet, this would average 155 fishermen per day, with a range from 60 to 250. This is reasonably close to our findings with respect to optimum economic capacity with encounters converted to 134 users per day of a typical high mountain reservoir. See Note 2.

13. With a 120-day fishing season from May 15 to September 15 at elevations of 6,000 to 11,000 feet.

14. By comparison, Walsh, et al., [September, 1980] shows marginal benefit of fishing use of a smaller undeveloped high mountain reservoir averaged $2.60 per acre foot per day, with drawdown in water level from 100 to 25 percent of maximum. Marginal benefit of fishing use of a larger fully developed high mountain reservoir averaged $1.20 per acre foot per day with drawdown over the same range.

15. This corrects an earlier estimate that marginal benefits from river fishing slope downward to the right with each added unit of flow having a value less than the previous one, which resulted from an assumption of constant demand across all flow levels [Daubert and Young, 1979]. The study of the Poudre River located on the northern Front Range of Colorado provides a replication of this study with respect to the mid-range of flows. Marginal benefits of fishing on the Poudre River fell to zero at 500 cubic feet per second (cfs) which is equivalent ot 992 acre feet in 24 hours, within 8 percent of our estimate of 1,075 acre feet per day for the Frying Pan River on the West Slope of Colorado. The difference may be explained by the fact that fishing on the Poudre River exceeded optimum capacity estimated as 12 fishermen per mile per day.

16. The relative drawdown of high mountain and plains reservoirs during late July and August would depend, in part, on the relative recreation benefits of water in each. There is a need to study the recreation and aesthetic benefits of water in reservoirs on the plains, which are unknown. In addition, all seepage and evaporation losses must be accounted for.

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