AN ABSTRACT OF THE THESIS OF

Neal S. Johnson for the degree of Master of Science in Agricultural and Resource Economics presented on July 28, 1987.

Title: A Bioeconomic Analysis of Altering Instream Flows: Anadromous Fish Production and Competing Demands for Water in the John Day River Basin, Oregon.

Abstract approved: ______ ________________________________

Richard M. Adams

The growing demand for water in the arid regions of the West increases the need for optimal allocation of water among competing uses. An efficient allocation of water between instream and out-of-stream uses has been impeded by institutional constraints and the scarcity of information regarding instream flow benefits. The objectives of this thesis were to provide preliminary economic data on the value of instream water in "producing" recreational fishing and to examine the effect of forestry, agriculture, and livestock practices on temporal streamflow patterns and anadromous fish production. The steelhead trout (Salmo gairdneri) sport fishery within the John Day River basin in north-central Oregon provided the setting for this research.

The interdisciplinary methodology employed in estimating the marginal value of water with respect to steelhead production consisted of two tasks. The first task involved valuing a marginal change in the quality of the steelhead recreational fishery. The contingent

valuation method (CVM) was selected for this purpose. Both open- and closed-ended willingness-to-pay (WTP) questions were included in a questionnaire administered to John Day River steelhead anglers during the 1986/87 steelhead fishing season. Survey data were analyzed to arrive at individual and aggregate bid functions relating WTP to expected angling success rates. Results indicate that, under current conditions, the average angler is willing to pay approximately $7.20 to catch an additional steelhead.

The second task of the instream water valuation methodology was directed at deriving a streamflow/steelhead production relationship. By including variables influencing steelhead production in a Ricker stock-recruitment model, it was possible to develop a model which could be estimated using linear regression techniques. Some difficulty arose, however, with interpretation of the model due to the unavailability of cohort escapement data and the subsequent use of standing crop data. While possibly masking the true magnitude of streamflow's effect on fish production, this drawback was not deemed limiting within the general context of the interdisciplinary methodology. Results of the biological model conformed to a priori expectations. Increases in summer and winter streamflows led to increased steelhead survival, whereas higher spring flows increased mortality levels. Other results indicate that the John Day Dam was responsible for a 31.5 percent decline in the population index for the 1969-1983 period.

Combining the economic and biological results into one equation yielded an estimate of the marginal value of summer instream water in "producing" recreational steelhead angling. Similar equations were developed for winter and spring flows. The marginal value of water in producing recreational steelhead fishing <u>within</u> the John Day basin was estimated at $0.56 per acre-foot for summer flows, $0.046 for winter flows, and -$0.075 for spring flows. By including out-of-basin benefits, these values increased to $2.26, $0.19, and -$0.30, respectively. In comparison, water's value in irrigation within the John Day basin has been estimated at between $10 to $24 per acre-foot. However, nonuse values of steelhead, as well as the increased production of other fish species (such as spring chinook salmon) were not included in the instream water values. In addition, no attempt was made at valuing instream water's contribution to boating, camping, or other benefit-producing activities.

A secondary objective of this thesis was to briefly examine the possible benefits accruing to other instream and out-of-stream users due to an alteration in streamflow patterns. In addition, the impact of activities by other resource users -- namely forestry, agriculture, and livestock production -- on anadromous fish production was reviewed. Improper management practices by these activities can negatively impact the aquatic and riparian ecosystems. While no firm conclusions were drawn, it appears the quality of these ecosystems, as opposed to the amount of streamflow, has the largest marginal impact on anadromous fish populations.

A Bioeconomic Analysis of Altering Instream Flows: Anadromous Fish Production and Competing Demands For Water in the John Day River Basin, Oregon

by

Neal S. Johnson

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed July 28, 1987

Commencement June 1988

APPROVED:

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Professor of Agricultural and Resource Economics in charge of major

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Date thesis presented July 28, 1987

ACKNOWLEDGEMENT

I am indebted to many individuals for their support, encouragement, and guidance throughout my two years of graduate study at Oregon State University. In particular, debts of gratitude are owed to:

Dr. Richard M. Adams for his constant guidance and encouragement in the preparation of the thesis;

Dr. David Glyer for his numerous suggestions pertaining to the quantitative aspects of the research;

Nancy MacHugh and Errol Claire of the Oregon Department of Fish and Wildlife for provision of important secondary data;

the Department of Agricultural and Resource Economics, the Robert Johnson Fellowship, and the Agricultural Research Foundation for financial assistance in carrying out the research;

the steelhead anglers of the John Day River who gave freely of their time in providing valuable primary data;

the graduate students, faculty, and staff in the Department of Agricultural and Resource Economics for providing an enjoyable atmosphere for studying and research.

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A BIOECONOMIC ANALYSIS OF ALTERING INSTREAM FLOWS: ANADROMOUS FISH PRODUCTION AND COMPETING DEMANDS FOR WATER IN THE JOHN DAY RIVER BASIN, OREGON

CHAPTER 1

INTRODUCTION

As the demand for water increases in the western U.S., water resource managers face the increasingly difficult task of allocating current water supplies as well as managing watersheds to ensure the existence of future supplies. Traditional, out-of-stream allocations, such as irrigation and industrial use, now face increasing competition from instream uses. In Oregon, recent attention has focused on instream flows under the recognition that these flows generate significant benefits to society in the form of fish and wildlife production, recreation, and hydroelectric generation.

Despite the potential benefits from instream allocations, meeting stated instream flow goals is hindered by institutional constraints and the common property nature of many watershed resources. Specifically, since instream uses were not recognized as "beneficial" until 1964, these rights are often junior to the more traditional out-of-stream uses. Thus, in years of low precipitation, instream flow requirements on fully or over-appropriated rivers may not be met. At the same time, utilization of other resources may negatively impact the quality and quantity of available water. Forestry, range, and agricultural practices have been shown to alter adjacent riparian habitats with detrimental affects to fish and wildlife production, water quality and temporal streamflow patterns. As "costs" not directly borne by these resource users, there is little incentive for improved management. In recognition of this problem, state legislators have enacted laws aimed at improving management practices. For the forestry industry, these laws take the form of the Forest Practices Rules. For agriculture and livestock there are no comparable laws. However, programs have been enacted which increase the incentive to properly manage riparian zones and conserve water. These include the Riparian Tax Incentive Program initiated in 1981 and the recent passage of Senate Bill 24, aimed at encouraging water conservation among water-rights holders.

Problem Definition

Within the scope of the broader problem outlined above are numerous subproblems. Among these is the correct identification and quantification of benefits produced by instream flows. Until recently, few economic studies existed which explicitly sought to estimate a streamflow/benefits relationship (Gibbons 1986). As a consequence, instream flow reservations have largely been based on biological and hydrological, rather than economic, criteria (Stevens 1966, Amirfathi et al. 1985, Ward 1987). In comparison, the value of water in traditional out-of-stream uses has been well documented (see Young and Gray 1972, Gibbons 1986). Due to this lack of a common denominator (e.g. economic value), the relative merit of instream vs. out-of-stream uses has been difficult to quantify, resulting in numerous conflicts and potential misallocations of water.

In the Pacific Northwest, these conflicts have intensified as a result of judicially and legislatively mandated increases in anadromous fish production as compensation for fishery losses suffered due to hydroelectric projects. While these increases can partially be met via expanded hatchery production, attention and efforts have also centered on maintaining and enhancing wild stocks of salmon (*Oncorhyncus* spp.) and steelhead trout (*Salmo gairdneri*). Enhancing these fishery resources may necessitate reallocating water to instream uses or improving habitat conditions, which, as noted above, can lead to conflicts with other resource users such as agriculture, forestry and livestock concerns.

In summary, the problem faced by resource managers, and which is addressed in this thesis, can be defined as follows: instream users of water, such as fisheries production, hydroelectric generation, boating, and camping, compete either directly or indirectly for water of adequate quantity and quality with more traditional resource users, such as forestry, agriculture, and range activities. Furthermore, achieving an economically efficient allocation of water among competing users has been and continues to be confounded by existing water institutions and the scarcity of information regarding the benefits of instream flow. Providing preliminary economic data on the value of instream water for an important Oregon watershed, the John Day River basin, is the focus of this thesis.

Objectives

There are two general objectives of this thesis. The primary objective is to measure the benefits accruing to an instream flow user group resulting from an alteration of instream flows on the John Day River. More specifically, the economic value that recreational steelhead anglers derive from improvements in fishing quality will be estimated. These improvements in fishing quality can be brought about by many factors, including increased steelhead production due to more favorable streamflow patterns. The empirical focus of this study is on measuring the relationship between streamflow, fish production, and angler success on the John Day River. By doing so, an estimate of a portion of the marginal value of instream water can be derived. The secondary objective of the thesis is to examine how other instream and out-of-stream water users may benefit from alterations in streamflow and how forestry, agriculture, livestock, and other resource users impact, either directly or indirectly, temporal streamflow patterns and anadromous fish production.

Study Area

The area chosen for study is the John Day River basin in north-central Oregon (see figure 1.1). Encompassing an area of 8010 square miles and ranging in elevation from 150 feet above sea level at the mouth of the John Day River to 9038 feet on Strawberry Mountain, the basin supports the largest runs of wild spring chinook salmon (*Oncorhyncus kisutch*) and summer steelhead in eastern Oregon (ODFW

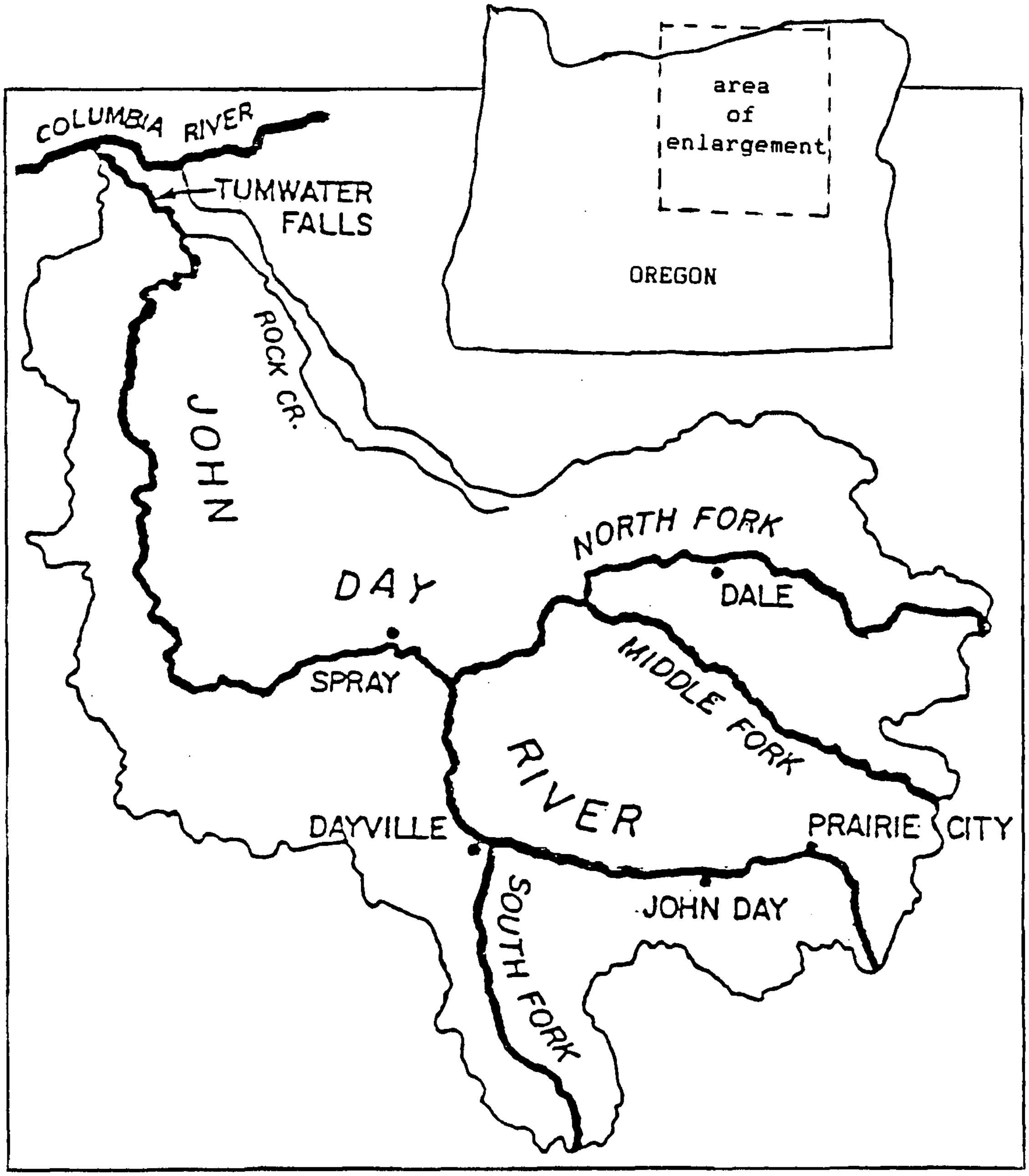

Figure 1.1. The John Day basin, Oregon.

1985a). Furthermore, the potential for increasing the size of these runs is considered to be high, with the maximum carrying capacity of the basin estimated at four times current levels (Bureau of Reclamation 1985). Current annual escapement levels in the John Day basin are 1,000 to 4,000 spring chinook and 7,500 to 21,000 summer steelhead. As one of their management objectives, the Oregon Department of Fish and Wildlife (ODFW), wants to increase future escapement to an average level of 5,700 spring chinook and 23,000 summer steelhead (ODFW 1985b).

Numerous factors have contributed to the decline of the anadromous fisheries within the John Day basin. As documented by explorers and settlers in the early 1800's, the John Day was once a relatively stable river with diverse and abundant riparian vegetation, good summer streamflows, and high water quality. Since these early reports, habitat degradation caused by mining, forestry, agriculture, and range activities have led to significant reductions in anadromous fish populations. These reductions have been further compounded by the construction of hydroelectric dams on the Columbia River (ODFW 1985b).

The John Day basin offers a particularly good setting for this study for several reasons. First, as mentioned above, the potential for enhancing fish production is high. In addition, the methods by which these enhancements are achieved focus on habitat improvements, as opposed to hatchery production. This has been necessitated by ODFW's desire to maintain the wild nature of the basin's current fishery stocks.

Second, the decrease in the John Day River's summer flows due to riparian damage, coupled with the basin's semiarid climate, exacerbates potential conflicts between instream and out-of-stream water users. The basin's economy, largely centered around agriculture and livestock production, heightens the need for an efficient and equitable solution to the problem.

Third, past and current studies have focused their attention on the John Day basin. Both the U.S. Army Corps of Engineers and the Bureau of Reclamation have examined the feasibliliy of a water storage facility within the basin. In addition, the Oregon Water Resources Department is currently developing a strategic multi-agency water management plan for the John Day basin. This is the first water basin in Oregon to undergo this new planning process.

Thesis Organization

The interdisciplinary nature of this study necessitates that a wide range of theoretical and applied topics be covered. To facilitate an understanding of the larger "problem", Chapter 2 presents a framework within which such an analysis can be performed. The framework selected is economic efficiency. As the criteria recommended by the United States Water Resources Council (1979) for evaluation of proposed water projects, it is the foundation of many water policy analyses.

In Chapters 3, 4, and 5, the "problem" is disaggregated into subcomponents. Chapter 3 focuses on the theoretical basis and methodology employed in valuing nonmarket resources, such as instream flow. While a complete review and discussion of these methodologies is beyond the scope of this thesis, Chapter 3 does attempt to show the range of economic tools available. To illustrate this point further, a review of instream water valuation studies is presented and briefly discussed.

Chapter 4, building on the theory presented in Chapter 3, estimates the benefits accruing to sport anglers resulting from an increase in the quality of the John Day steelhead fishery. This is the first step in a two-step procedure designed to derive a portion of the value attached to instream water. As a direct result, the marginal value of a sport-caught John Day steelhead is derived.

In Chapter 5, the discussion deviates from the economic context of the previous chapters in an attempt to derive a quantitative measure of how altering streamflow patterns will affect anadromous fish production. This is the second half of the two-step instream water valuation procedure. Construction of robust biological models is often plagued with statistical and data difficulties. Some of these data and estimation problems are discussed but, as is often the case, more questions are raised than are answered.

Chapter 6 combines the results of the previous two chapters to arrive at the value attached to instream water in the production of steelhead trout. In addition, the value of water in other uses, both instream and out-of-stream, are reviewed. Attention will then turn towards competing demands for fish habitat. Specifically, the affect of forestry, agricultural and range practices on anadromous fish production will be examined. Chapter 7 concludes the thesis with a summary of results, a discussion of policy implications and suggestions for future research.

CHAPTER 2

ALLOCATION OF STREAMFLOW: THEORETICAL CONSIDERATIONS

Optimal allocation of resources among alternative uses involves the traditional economic concepts of efficiency and equity of distribution. Water allocations, however, must in turn be tempered by the political and administrative feasibility of implementing that allocation. The weight given each of these criteria in evaluating a proposed project will vary according to the specific situation. The preferred criteria in water allocation, from society's viewpoint, appears to be economic efficiency. This is evidenced by the United States Water Resources Council (1979) guidelines governing the analysis of water projects. Unfortunately, information necessary to fully implement the economic efficiency criteria is often lacking. This is especially true with nonmarket or public goods which are not bought or sold in observable markets. The value of instream water is a case in point. As will be seen in Chapter 3, few studies have been conducted which have explicitly sought to value instream water. Hence, one of the stated objectives of this thesis is to derive a value for a component of the value of instream water. To gain a clearer understanding of what is meant by economic efficiency, and how this criteria can be applied to the allocation of streamflow among competing uses, this chapter presents several relevant concepts.

Economic Efficiency

The accepted definition of an economically efficient resource allocation is when the marginal value of utilization of the resource is equal across all uses. However, when applied to a nonconsumptive, reuseable resource, such as streamflow, the concept becomes more difficult to implement; a more concise definition is required. First, a clear definition of what constitutes the "use" of water is necessary.

Gibbons (1986) notes that water has several dimensions of use: quantity, quality, timing, and location. Thus, "use" of water may imply altering none, one, a few, or all of these dimensions. For example, diversion of streamflow for irrigation will decrease the quantity available for other uses. To complicate the analysis, a portion of this water may infiltrate into the groundwater table and eventually return to the stream. This return flow may be spatially as well as temporally removed from the original point of diversion. In addition, the quality of the water may be altered due to agricultural chemicals or sedimentation. At the other extreme, many uses of water don't alter any of these dimensions. Instream use of water to produce anadromous fish and recreational fishing experiences is a relevant example.

"Users" of water must likewise be more explicitly defined. Clearly, an individual instream user of water, such as a rafter, attaches a value to streamflow. When compared with the value in an out-of-stream use, however, this value may be several magnitudes lower. If the nonconsumptive use of instream water is not recognized as such, the definition of an efficient allocation of a resource, as stated above, would invariably require that the water be diverted for the more "beneficial" out-of-stream use. But instream water, as a public good, has the characteristic of generating collective benefits: as long as congestion or rivalry in consumption does not exist, one person's use of streamflow will not preclude another's use; hence the value of that water is equal to the summation of the individual values across all instream uses.

For purposes of the analytics in this chapter, instream users will be considered in aggregate and will be defined as those people who would benefit if the water was left instream. A temporal and spatial frame of reference must be attached to this definition. To illustrate this point, consider the case of a farmer who has the option of diverting streamflow from two different points along a stream, between which is a recreation site. By diverting water from the upstream location, water available at the recreation site will be reduced, with the resultant effect of possibly lowering recreation benefits. Diversion at the downstream point, however, will not lower these instream benefits, as the recreationists are no longer "users" of the water.

It is not necessary that instream water users derive benefits simultaneous with the occurance of flows. Benefits may accrue at a location temporally and/or spatially removed from the site of primary production. Such is the case with the John Day steelhead fishery. As a component of both the quality and quantity aspects of the aquatic ecosystem, streamflow combines with other inputs in the production of steelhead. The dynamic nature of this production process means that a multi-year lag exists between the time a positive or negative streamflow effect occurs and the time that anglers experience increased or decreased utility from the resultant stock of adult steelhead. In addition, these fish may be caught in a fishery outside of the John Day basin.

The temporal dimension of water use and supply deserves further attention at this point. In the short-run it is assumed that the available supply of water is fixed: in the absence of dams or other diversion devices, man cannot significantly influence this supply. In the long-run, man clearly has some influence (both positive and negative) on the temporal and spatial supply of water. Dams and irrigation projects, as well as improved ecosystem management (i.e., riparian improvements) are all examples of ways to alter the temporal supply of water. Referring to figure 2.1, S_{sr} represents the short run, fixed supply curve for summer water under natural conditions. Suppose a project could be undertaken to shift streamflow from another season to augment the summer supply. This additional supply has costs associated with it, as represented by the long-run marginal cost curve, S_{lr}. These costs are a combination of project costs and the opportunity cost of decreasing flows in other periods. As presented in figure 2.1, Q^* is the efficient long-run level of water supply. Thus, summer water supply should be increased by an amount equal to Q^*-Q_{fixed}.

Efficient allocation of water in the short- and long-run, as well as the benefit-cost analysis of proposed water projects, requires

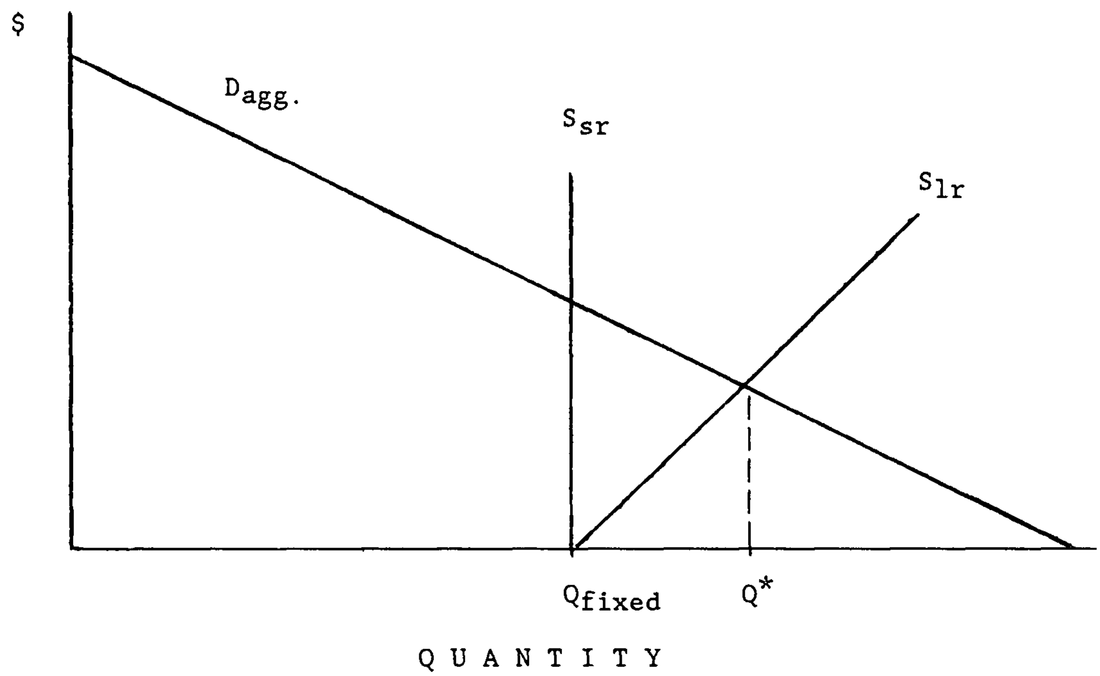

Figure 2.1. Graphical determination of optimal interseasonal supply of water.

information on the value of water in alternate uses. Where water is an intermediate good in the production of a market good, as is the case with irrigation water used in the production of agricultural commodities, assigning a value to water is a relatively straightforward economics problem. Valuation of instream water is more problematic. We now turn our attention to some topics relevant to the valuation of instream flow.

Measuring the Value of Instream Water

Instream water can enter a recreationist's utility function in several ways. First, for a recreationist who derives pleasure directly from the flow level, such as white-water boaters, it enters directly:

(2.1) $$U = f(X1, X2, \ldots, Xn, F)$$

Other recreationists, such as anglers, derive benefits from goods which are affected by streamflow. By influencing fish production and the "fishability" of a river, streamflow is, in effect, an input in the production of a final good, the quality of fishing. Instream flow would therefore enter the angler's utility function indirectly:

(2.2) $$U = f(X1, X2, \ldots, Xn, Q(F, E, K))$$

where Q(F, E, K) is a function relating the quality of fishing to streamflow (F), equipment (E), and the experience and knowledge of the fishermen (K). In this case the angler has a derived demand for streamflow. Of course, there is nothing to preclude an angler from having both a direct and indirect demand for streamflow. Since we have not made any assumptions as to when streamflow changes will occur (i.e., if flows will change during the fishing season) our interest is limited to the affect streamflow has on angler utility via its impact on fish production.

Fishing quality may be endogenously or exogenously produced. Quality is considered endogenously produced if the individual can influence the quality experienced by increasing other inputs. As applied to sport fishing, an individual can "produce" quality by investing in fishing lessons, buying better or more appropriate equipment, or by hiring a guide. On the other hand, if fishing quality is considered to be beyond the control of the angler it is exogenously produced. In reality, fishing quality has both endogenous and exogenously produced components.

As will be seen in Chapter 3, whether fishing quality is assumed to be endogenously or exogenously produced may have a bearing on the valuation methodology employed. For now, the discussion will focus only on the theoretical basis of measuring the benefits associated with an improvement in fishing quality.

Consumer Surplus

The appropriate measure of value in benefit-cost analysis is consumer surplus (Brookshire et al. 1980). Consumer surplus is a measure of the net benefits an individual or group receives from the consumption or purchase of a good. This concept is graphically presented in figure 2.2, where DD' represents an individual's demand

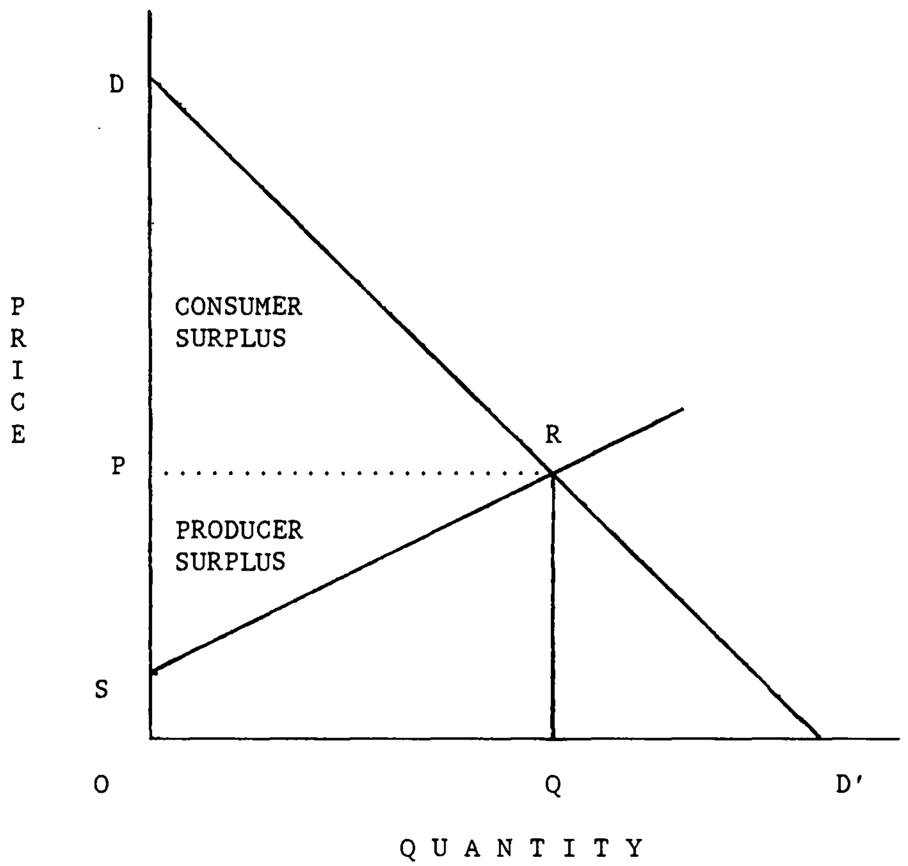

Figure 2.2 Consumer and producer surplus.

curve for a good. Total expenditures for the commodity will be equal to quantity times price, represented here as area POQR. However, total willingness-to-pay (WTP) for quantity Q is equal to the total area under the demand curve to the left of quantity purchased, area DOQR. Consumer surplus is the difference between the amount that the individual actually paid and his total willingness-to-pay, area DPR.

With a change in the provision of a level of a good or service will come an accompanying change in consumer surplus. Hicks (1939; see also Freeman 1979) has defined four measures of these changes: compensating variation, equivalent variation, compensating surplus, and equivalent surplus. Under the compensating measures, it is assumed the consumer has a right to his initial level of utility, whereas the equivalent measures assume the consumer only has a right to his subsequent utility level. As a consequence, only the compensating measures are consistent with the concept of (potential) Pareto improvements.

Use values are only one component of willingness-to-pay. Significant nonuse values have been attached to several recreation resources (see for example Brookshire et al. 1983). Weisbrod (1964) and Krutilla (1967) separate these nonuse components of WTP into option, existence, and bequest values. Option value is defined as the difference between the expected consumer surplus to be generated by recreation use and option price, which is the amount a consumer would be willing to pay, under conditions of supply and demand uncertainty, for an option for future use. As defined here it can be considered to be an "insurance premium" to guarantee the option of future use (Walsh et al. 1984). Depending on whether the consumer is risk averse, neutral, or seeking, option value can be positive, zero, or negative (Freeman 1985). Existence value is willingness-to-pay for the satisfaction of knowing that a resource exists, while bequest value is willingness-to-pay for the satisfaction of endowing future generations with a unique resource (Walsh et al. 1984).

Consumer Surplus Generated by an Improvement in Fishing Quality

Returning to the exogenous and endogenous concepts of a fishing quality production process, a graphical presentation is used to convey how an increase in fish production generates an increase in net benefits in a recreational fishery. These two examples are at opposite ends of a continuous spectrum of varying combinations of endogenous and exogenously determined fishing quality.

Figures 2.3 and 2.4 show an individual's indifference and demand curves, respectively, when fishing quality is an entirely exogenously supplied good. The angler is initially at point A on indifference curve I_0. An increase in the supply of fishing quality from Q_0 to Q_1 will shift him to point B on indifference curve I_1. In figure 2.4 this is represented by an outward shift in his income-compensated demand curve, from $Dc(Q_0)$ to $Dc(Q_1)$. If we make the simplifying assumption that the quantity of fishing days "consumed" remains constant, then the increase in consumer surplus will be equal to the area between these curves and above the price line, represented as the shaded area. Referring to figure 2.3, this increase in consumer surplus is equal to Y_0-Y_1, the amount the angler would be willing to

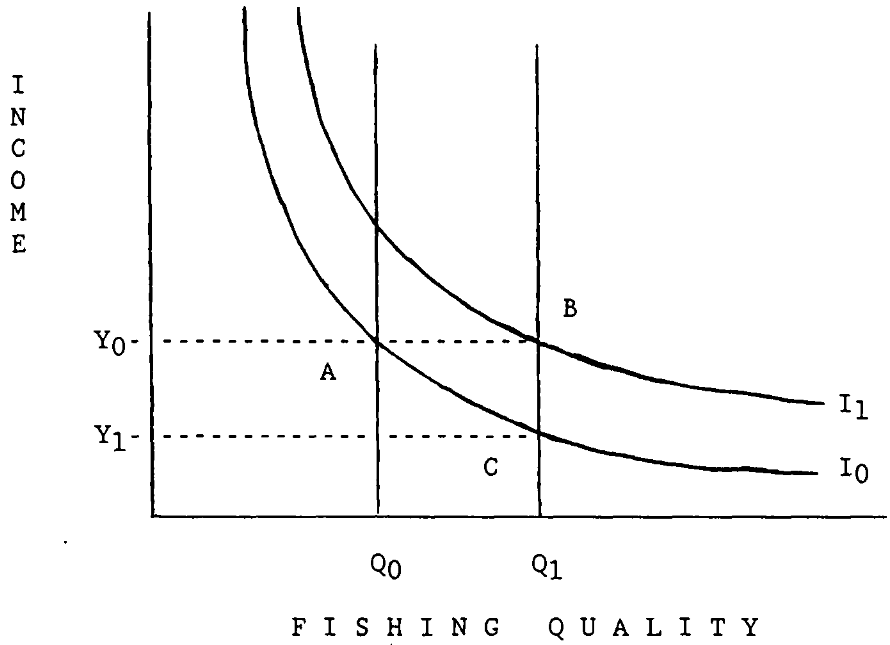

Figure 2.3. Angler's indifference mapping showing an improvement in exogenously supplied fishing quality.

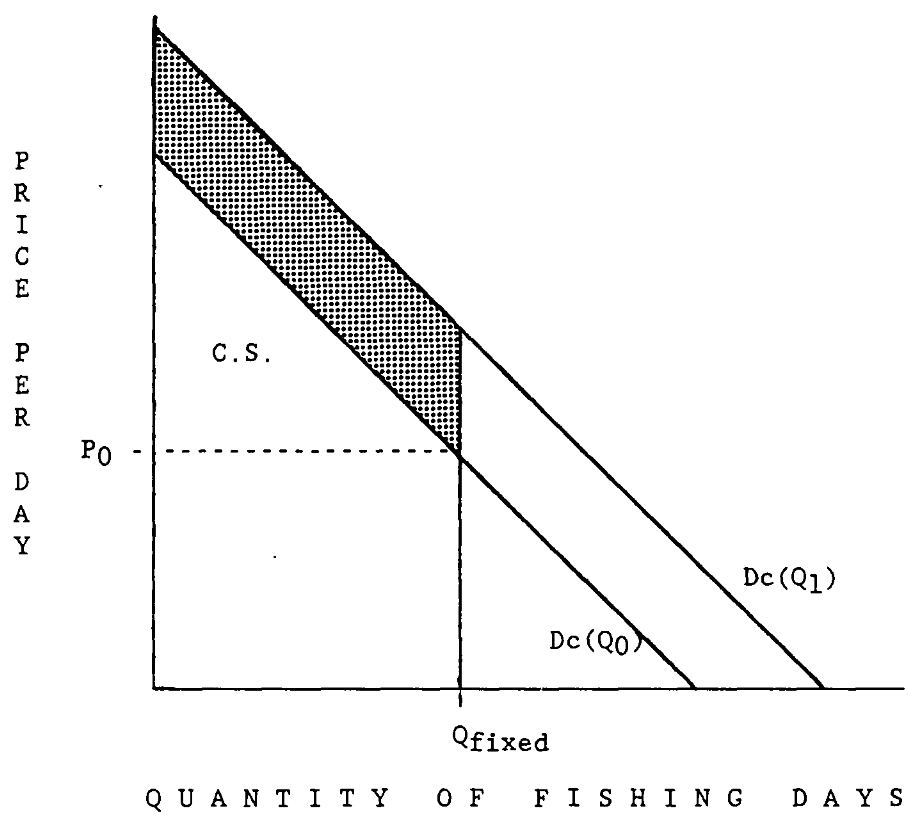

Figure 2.4. Consumer surplus generated by an increase in exogenously supplied fishing quality.

pay for the new supply level and still be as well off as before (i.e., remain on indifference curve I_0 at point C).

Now let's consider the case of an endogenously produced fishing quality. As before, figures 2.5 and 2.6 show an individual's indifference and demand curves, respectively, for recreational fishing. An increase in fish populations will decrease the angler's cost of producing a recreation day of fixed quality. The result will be an upward pivot in the price line in figure 2.5 and a downward shift in the marginal cost curve in figure 2.6. The resultant increase in consumer surplus is represented by the shaded area between the relevant marginal cost curves, bounded by the income-compensated demand curve. In figure 2.5, this is represented by the amount Y_0-Y_1.

While the theoretical concept of consumer surplus generated by an improvement in fishing quality is relatively straightforward graphically, actual application of the concept is hindered by a lack of market-generated data. Resolving this problem is the topic of the next chapter.

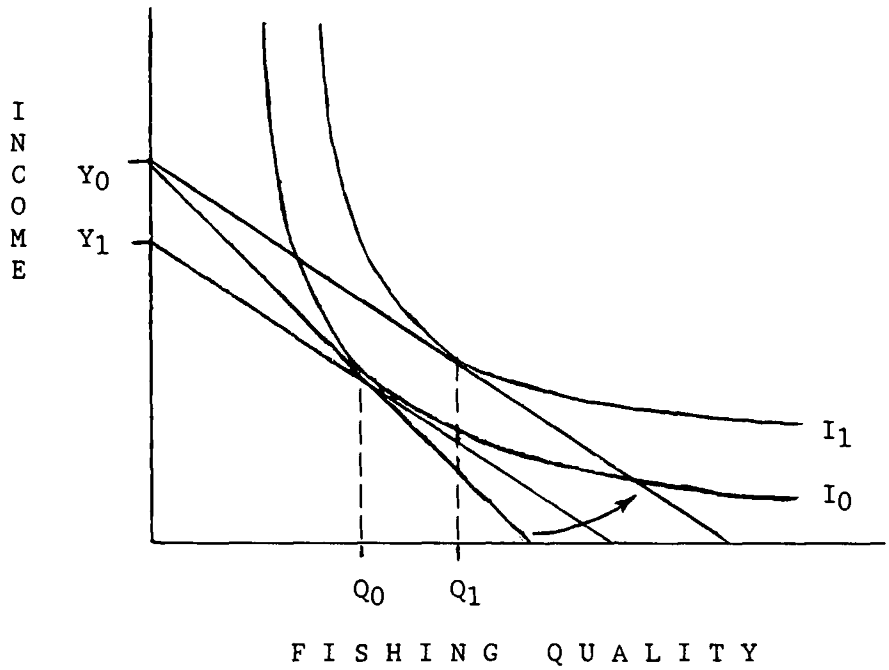

Figure 2.5. Angler's indifference mapping showing a decrease in the cost of endogenously produced fishing quality.

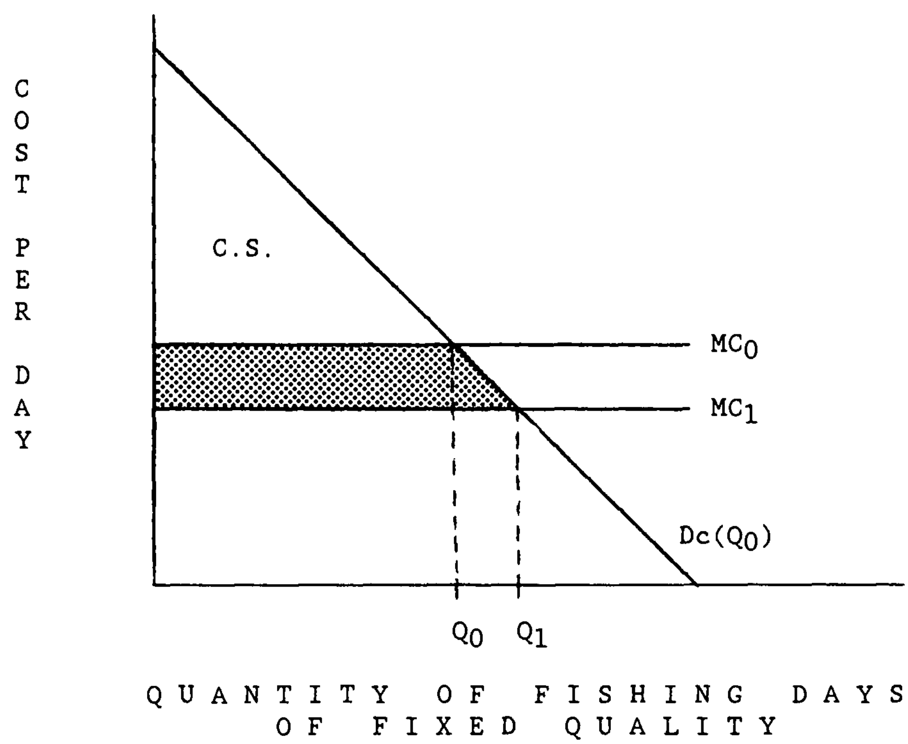

Figure 2.6. Consumer surplus generated by a decrease in the marginal cost of endogenously produced fishing quality.

CHAPTER 3

THREE NONMARKET VALUATION METHODOLOGIES

Over the last three decades, several methodologies have arisen to circumvent the lack of market data for public goods, either by indirectly imputing a price to the good in question or by directly querying consumers as to their willingness-to-pay. As these methodologies have been refined, a broad range of environmental amenities have been valued. Air and water quality (see Bockstael et al. 1985; Desvouges et al. 1983a 1983b; Greenley et al. 1981; Rowe et al. 1980; and Sutherland and Walsh 1985, among others), wildlife-based recreation (Bockstael and McConnell 1981; Brookshire et al. 1980, 1983; Hammack and Brown 1974; Peterson and Randall 1984), and the preservation of wilderness and endangered species (Walsh et al. 1984; Samples et al. 1986) are a few such examples. These methodologies have as their basis the economic theory of consumer behavior and utility maximization.

In this chapter three of these valuation techniques will be examined and evaluated for suitability in the present study. They are the travel cost method (TCM), the household production function (HPF) approach, and the contingent valuation method (CVM). In the latter half of this chapter, several studies that utilize these methodologies within the context of valuing instream water will be reviewed and critiqued with the intent of identifying the methodology most appropriate for valuing a change in the quality of the John Day steelhead fishery associated with a change in streamflow patterns.

Valuation Methodologies

Travel Cost Method

The travel cost method was first conceptualized by Harold Hotelling in 1949. In a letter to the National Park Service he suggested using travel costs as a proxy for the price of recreational goods. Marion Clawson (1959) later expanded on the idea. The basic travel cost model relies on the premise that the cost of visiting a recreation site varies across individuals according to the distance travelled. By observing the visitation rate from different distance zones and the travel costs incurred, a trip demand curve for the good in question can be estimated. This demand curve can then be used to arrive at a site demand curve from which consumer surplus can be estimated (see Clawson and Knetch 1966).

Since its inception, the TCM has undergone numerous changes. Foremost among these have been refinements in the specification of the cost variable--namely, the inclusion of the opportunity cost of time; the use of individual as opposed to zonal observations; inclusion of demographic variables; and the expansion of the single site model to include the effects of substitute sites.

While the above refinements have strengthened the TCM, the question here is how appropriate is the TCM in estimating the value of a particular component of a recreational experience, such as fishing quality? The answer to this will depend on the particular case or situation. Loomis (1986) identifies two theoretical and four data requirements for using the TCM in valuing instream flows. The theoretical requirements are: (1) that streamflow not be strongly separable from other private goods the individual consumes; and (2) weak complementarity exists. If the utility a recreationist derives from streamflow, or a streamflow produced good such as angling, is related to his expenditures on other private goods, such as transportation, the first requirement is met. As applied to this study, such a requirement means that an angler will be willing to travel further to enjoy a better catch rate. The second theoretical requirement, weak complementarity, relates to the existance of nonuse values. If nonusers place a value on the existence of John Day steelhead, but never plan on visiting the John Day to fish, this requirement will be violated. Actually, for purposes of this study, the existence of nonuse values is not the issue. Rather, it is whether these nonuse benefits increase given an increase in steelhead production.

The four data requirements identified by Loomis are: (1) visitors must live at varying distances from the recreation site, i.e., there must be variation in the prices (travel costs) imputed to the trip across anglers; (2) the sole or primary purpose of the trip must be to visit the recreation site in question; (3) there must be variations in flow levels (or catch rates caused by flow changes) during the season or between substitute sites; and (4) the recreationist (angler) must have knowledge of these changes prior to his trip and this knowledge must influence his visitation rate.

Unfortunately, meeting all six requirements for using the TCM when valuing instream water is difficult, though not impossible. The primary difficulty in applying the TCM to valuing changes in quality seems to lie in whether the recreationists know the fishing quality at a site prior to visiting it, and whether this knowledge affects their observable behavior (visitation rate). This seems to be a function both of information availability and attributes of the recreation experience. In a study on the effects of water pollution on the demand for recreational fishing in Yaquina Bay, Oregon, Stevens (1965, 1966; see also Stoevener et al. 1972) included a quality variable, angler success, as an argument in a TCM demand specification. By calculating "success elasticities" he was then able to obtain estimates of benefits arising from reductions in water pollution. Stevens found salmon anglers to be considerably more responsive to changes in success rates than bottomfish anglers, noting that bottomfishing seems to be a more casual type of angling while salmon fishing effort is more dependent on "bar" crossing conditions and angling success.

Several other studies have utilized the TCM to value changes in a quality attribute of a recreation experience. Samples and Bishop (1985) utilized a multiple-site travel cost method in valuing increases in salmon and trout sportfishing on Lake Michigan. Ward (1987) was also able to successfully use the travel cost method, this time to value instream water. His study will be summarized later in this chapter.

Household Production Function Approach

The household production function approach was first used by Becker (1965) and is closely related to the travel cost method. In this methodology, the household or individual is viewed as both a producer and consumer of goods. That is, for example, an angler will buy goods and/or services which he then combines to produce a fishing trip. This is similar to the TCM, the difference being how quality is treated. In the TCM, quality, i.e., angler success, is assumed to be an exongenously determined characteristic of the recreation trip. Therefore, the only input in producing a recreation experience is transportation expenditures and the opportunity cost of time. The HPF approach, on the other hand, assumes quality to be endogenously produced. Individuals may influence the quality experienced by purchasing variable and fixed inputs such as equipment, bait, guides, or renting a boat. Benefits arise when public policies or actions increase the stock level and lower the marginal cost of harvesting.

Bockstael and McConnell (1981) give a concise explanation of how to derive benefit estimates from a household production function, while a recent study by Kahn and Kemp (1985) illustrates its application to the estimation of demand and supply functions for sport fishing. However, both of these groups of researchers note serious problems in applying the HPF approach. As succinctly stated by Bockstael and McConnell, "The household production framework is an appealing device for evaluating benefits accruing from resource policy changes, yet its application is fraught with severe estimation problems." (Bockstael and McConnell 1981; p. 211). We therefore turn to review another nonmarket valuation alternative.

Contingent Valuation Method

The third nonmarket valuation technique evaluated for use in this study is the contingent valuation method. Davis (1963) is credited with being the first to use the CVM when he applied it, as well as the TCM, to the valuation of recreation in the woods of northern Maine. Whereas the TCM and HPF rely on observable data (i.e., travel costs and recreational expenditures) the CVM constructs a "contingent market". Unlike the two former approaches, the CVM can be used for estimating option, existence, bequest and other non-use components of consumer surplus. It can also be used to value a change in the provision of a good outside the realm of observed happenings.

While the hypothetical nature of CVM markets expands the range of environmental goods and services which can be valued, it also has the potential for introducing numerous biases. Consequently, of the three methodologies discussed here, the CVM has generated the most debate, as evidenced by the large volume of literature pertaining to its inherent weaknesses. Cummings et al. (1986) conduct an extensive review of these weaknesses and present an assessment of the state of the art of the CVM. Their conclusions are generally positive with regards to the use of the CVM as a valuation procedure.

As with the TCM and the HPF approach, an extensive review of the CVM is not attempted here. Instead, several of the more pertinent characteristics of the CVM, as they apply to this study, are outlined. Readers interested in further discussion are refered to Cummings et al. (1986).

Bradford (1970) and Brookshire et al. (1980) both present an intuitively appealing way of viewing the theoretical basis of the CVM. Consider an individual experiencing an initial level of an exogenously supplied good, Qo, and income, Yo, as in figure 3.1. This individual is currently on an indifference curve, denoted as I_0. By repositioning the x- and y-axis to intersect the individual's original allotment of income and the good, and by measuring decrements in income along the y-axis, the individual's indifference curve can be reinterpreted as a bid curve (figure 3.2). Movements along this bid curve represent uniform levels of consumer satisfaction (utility) between the good and levels of income. Referring to figure 3.2, WTPc(A) represents the consumer's Hicksian compensating variation, WTPc, to enjoy an increment in the provision of the good from Qo to Qa. Similarly, WTAc(-) represents his Hicksian compensating surplus to accept a decrement in quality from Qo to Q(-).

The thrust of the CVM is to construct a market where the above individual can "buy" an increment in the good or "sell" a decrement. Bidding games, open-ended questions and closed-ended dichotomous choice questions are the standard formats for these markets. Under the bidding game format, respondents are asked if they would be willing to pay a given amount (bid) to enjoy an increase in a previously specified good. If the respondent responds positively (negatively) the bid is raised (lowered) until a "no" ("yes") response is obtained. The open-ended format foregoes the bidding technique and asks outright the maximum amount the respondent would be willing to

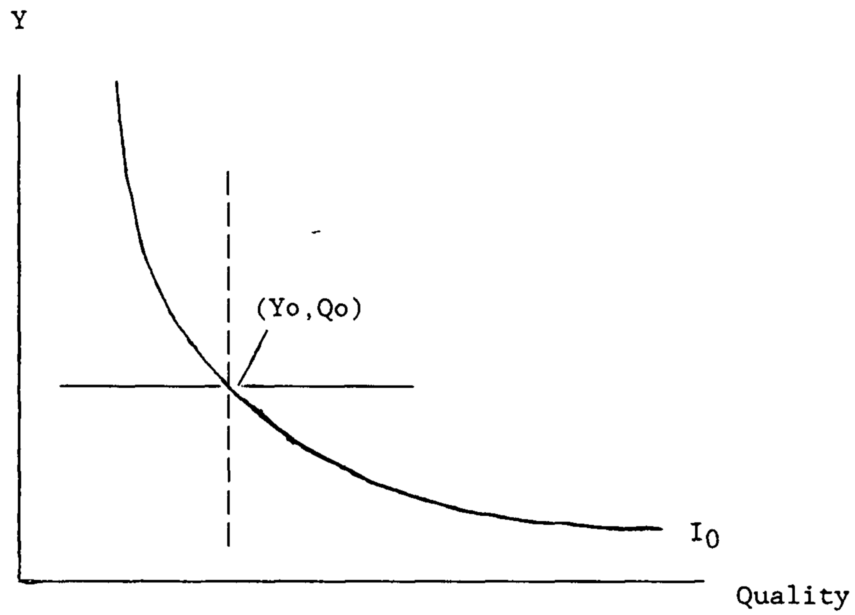

Figure 3.1. Individual's indifference curve.

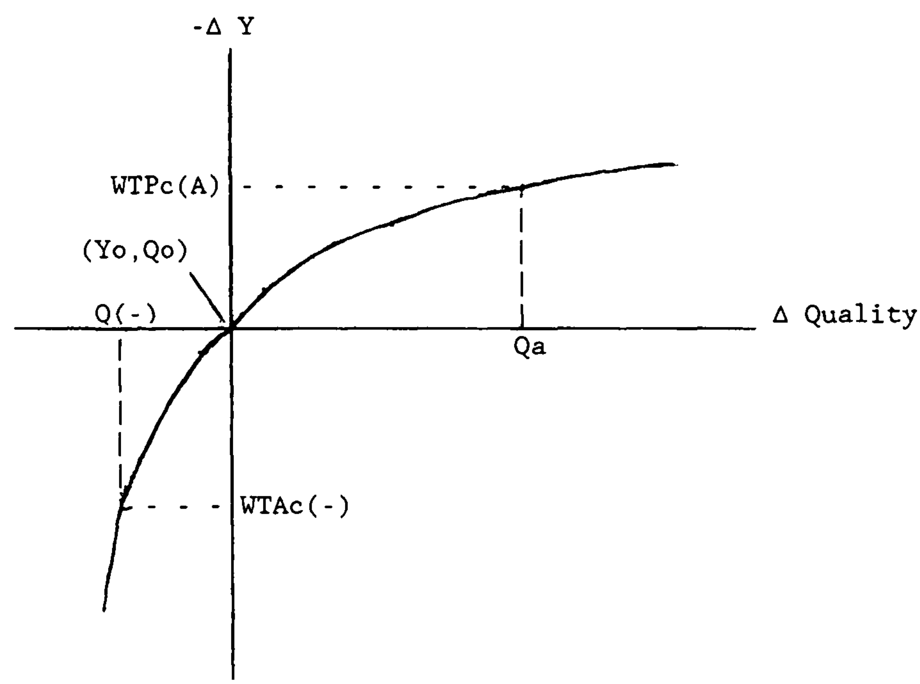

Figure 3.2. Individual's bid curve.

pay. In an attempt to more accurately simulate real markets, the closed-ended dichotomous choice offers a "take it or leave it" price for the good. These yes/no answers can then be analyzed in a discrete choice model such as the logit.

Applying Nonmarket Valuation Techniques to the Valuation of Instream Water: Specific Case Studies

There are an increasing number of studies appearing in the economics literature concerned with the economic benefits attached to water-based recreation. Representative studies include the valuation of salmon sport fishing (Sorhus et al. 1981, Donnelly et al. 1985), waterfowl hunting (Hammack and Brown 1974), and recreational boating (Sellar et al. 1986). The total value of a recreational experience, however, is rarely attributable soley to one input, such as fish catch or streamflow. The majority of these studies are therefore not directly useful for establishing a value for instream water. Fortunately, a subset of this literature attempts to link streamflow levels to economic benefits. Both Loomis (1986) and Gibbons (1986) have surveyed and summarized the existing streamflow/benefits literature. What follows is a review and critique of a representative selection from this literature. Each of these studies illustrates use of one or more of the nonmarket valuation techniques discussed earlier in this chapter.

Cache la Poudre River, Colorado

One of the first studies to explicitly quantify a flow/benefit relationship was conducted in the summer of 1978 by Daubert and Young (1979, 1981) on the Cache la Poudre River in northern Colorado. Three water-based recreation activities were valued: trout fishing, whitewater boating (kayaks, rafts, etc.), and shoreline recreation (picnicking, camping, and hiking). Respondents were shown color photographs and given corresponding physical stream characteristics of eight flow levels at four different sites. A hydrologic model (Bovee and Milhous 1978) was combined with a fish habitat model (Bovee and Cochnauer 1977) to provide anglers with technical information on the potential catch rate per hour. Utilizing an iterative bidding CVM format, respondents were asked how much they would be willing to pay in the form of either increased sales taxes or an entrance fee to ensure a specified flow level. Total bid functions for the three activities were then estimated using stepwise least squares regression. Marginal benefits of streamflow were obtained by taking the first derivative of these functions.

As might be expected, the marginal value of instream water for the Poudre River varied according to use and month. For fishing, the peak marginal value of $20.41 per acre-foot at 100 cfs occurred in July and August. Loomis (1986), using data in Daubert et al. (1979), derived the marginal value per acre-foot for the other two activities. At a flow level of 100 cfs the marginal value to shoreline users was $52.05, and for whitewater boaters, $2.43. The peak aggregate marginal value was therefore about $75 per acre-foot. The corresponding July and August marginal value of irrigation water withdrawn from the Poudre River was calculated (in $ per acre-foot) at

$9.00 and $15.00 respectively for a normal flow year and $45.10 and $40.00 respectively for a low flow year (Daubert et al. 1980), demonstrating that reservation of instream flows may be economically efficient.

The Daubert and Young study is of particular interest to this study because of the methodology used to link streamflow with benefits from trout fishing. Of particular note is the response to their methodology by professionals outside of economics. One weakness noted by Milhous (1983) is that the flow of benefits was assumed to occur at the same time as the streamflow. This ignores the possibility that by altering current flows, future benefits may also be affected. Aside from this criticism, Milhous notes that the willingness-to-pay functions developed by Daubert and Young correspond closely with suitability functions developed by hydrologists and fishery biologists: "The agreement between the recreation space suitability and willingness-to-pay functions is much greater than reasonably expected." He goes on to say that "the use of the suitability function to transfer the willingness-to-pay function from one river to another looks promising." This assessment, however, is overly optimistic on at least two counts. First, since the respondents in Daubert and Young's study were bidding on information supplied by a similar (if not the same) habitat suitability model, it is hardly surprising that the two functions gave similar results. Second, even if the suitability functions do closely approximate the shape of the bid curves, the magnitude of these bids would still remain unknown. Total or marginal value functions cannot and should not be inferred to be transferable from one recreation site to another.

Walsh et al.

In another study, also conducted in the summer of 1978, Walsh et al. (1980a and 1980b) valued fishing, kayaking and rafting at nine sites in western Colorado. Also using a CVM format, the net willingness-to-pay per day and the change in recreation user days due to changes in flows were evaluated at several flow levels. Their results indicate that the calculated total net benefits were maximized at 35 percent of bankful, where the marginal value per acre-foot was $16 for fishing, $4 for kayaking and $3 for rafting, yielding an aggregate marginal value of $23 per acre foot (Gibbons 1986). At higher flows, marginal values for fishing decreased, tending towards zero at 65 percent of bankful. The marginal value for whitewater boating did not decrease till 80 percnet of bankful, illustrating that different uses often have different optimum flows.

Utah State University

In 1982, a team of researchers at Utah State University surveyed recreationists at several river-based recreation sites in northern Utah and southern Idaho. Two seperate analyses of this data have appeared in the literature. The first analysis, by Narayanan et al. (1983), using a subsample of the data (excluding the southern Idaho site), estimated the value per user day. This was accomplished by use of the travel cost methodology. Respondents were also querried as to their probable actions if the flow dropped below their minimum acceptable level. A CVM question then asked how much the respondent would be willing to pay in the form of a per visit user fee to preserve the flow level. Combining the TCM and CVM results, they obtained marginal values of less than $.50 per acre-foot when flow was 56 percent of the 1982 flow. In the same study, a stochastic linear programming model was developed to analyze alternative instream flow strategies and their affects on agriculture. Results indicate that the average value of irrigation water in the study area was approximately $18 per acre-foot.

In the second analysis of the Utah data, the same group of researchers used household production function theory and a multi-site travel cost model (Amirfathi et al. 1985). The study area was broken into three sites. Results indicate that the marginal value of instream flow at a recreation site was dependant not only on the flow level at the site in question but also on the flow level at substitute sites. Results indicated that marginal benefits were zero for flows above 50 percent of 1982 levels. Flows below 30 percent of average flow showed significant marginal values ranging up to $74 per acre-foot at one of the sites.

Ward

In a study employing TCM, Ward (1987; see also Lukens 1986) valued angling and whitewater boating on a 21 km (34 mile) stretch of the Rio Chama River in New Mexico. Using data collected from 338 interviews conducted in 1982, seven separate demand equations were estimated for seasonal flow levels ranging from 50 to 4000 cfs.

Marginal benefits of streamflow were calculated as the difference between the area under the demand curves. These results were then integrated into a dynamic programming model to determine the optimal timing of releases from an upstream reservoir. Ward's results indicate that late summer streamflow provided recreational benefits equal to $27 per acre-foot in 1982 dollars. Since streamflow on this stretch of the Rio Chama is controlled by upstream reservoirs it is possible to directly control the flow level by releasing stored water. The City of Albuquerque owns a portion of this stored water and normally releases it to a downstream reservoir in the winter when evaporation losses are minimal. The opportunity cost of shifting these releases to the summer months was treated as being equal to the value of the water lost due to increased evaporation, about 2.5 percent. By using this method, Ward estimated the value of water "consumed" by anglers and white-water boaters at $900-$1100 per acre-foot for normal or dry years. This compares favorably to $40 per acre-foot in other uses.

Two comments regarding Ward's study are in order. First, as in Daubert and Young's study, the effect of altered streamflow on future fish populations and fishing quality was ignored due to lack of biological data. This omission would cause a downward bias in their benefit estimates. Secondly, use of a travel cost model worked well in their study because two conditions were met: (1) recreationists knew the flow level prior to making a trip; and (2) this knowledge affected their observable behavior. If either of these conditions were not met then another valuation methodology, such as the CVM, would have been required.

Comments

Several observations can be gleaned from the above review. First, there does not appear to be a dominant methodology for valuing instream water. Rather, researchers have had some success with all three methods (HPF, TCM, and CVM). This bodes well for future attempts at estimating the value of instream water.

Second, which methodology is employed depends both on the objectives of the research and the specific nature of the recreation site. For purposes of this study, the CVM was deemed more appropriate due to its ability to value changes in quality outside the realm of prior observations. In addition, the John Day steelhead fishery is not composed of one distinct angling area. This effectively ruled out use of the travel cost method. The household production function approach was discounted due to empirical estimation difficulties.

Third, the relationship between streamflow and fish populations has often been viewed in a static time frame. The streamflow/fish production interaction is not an instantaneous relationship and an attempt should be made to account for this in future valuation studies. As noted by Loomis (1986), "Much more interdisciplinary work between economists, and fishery biologists needs to be performed so that flow-fish production relationships become more readily available."

CHAPTER 4

VALUATION OF A CHANGE IN THE QUALITY OF THE JOHN DAY STEELHEAD SPORT FISHERY

> Here is no sentiment, no contest, no grandeur, no economics. From the sanctity of this occupation, a man may emerge refreshed and in control of his own soul. He is not idle. He is fishing, alone with himself in dignity and peace. It seems a very precious thing to me.
>
> John Steinbeck (1954)

"What is the value of a resource?" is a question often asked by policymakers and benefit-cost analysts. In the present case that question might be, "What is the value of a steelhead?" The answer to both of these questions is "It depends." Does interest lie in obtaining the average value of a fish or in the marginal value? If the marginal value is more appropriate, at what catch level should this be measured? For example, a policy which will increase the overall success rate in poor years but will have no affect in good years should be analyzed using the marginal value of a fish at the lower catch rates.

For purposes of this study the focus is on estimating benefits for improvements above the current angler success level. Such a focus is partially motivated by the Northwest Power Planning Council's stated objective of doubling the Columbia River's fish runs and ODFW's goal of increasing average John Day steelhead production from the current escapement level of 15,000 adults to 23,000 (ODFW 1985a).

Characteristics of the John Day Steelhead Sportfishery

The sport fishery for summer steelhead in the John Day River basin begins in late summer or early fall with the arrival of the first returning adults. The timing of their first entrance into the river is predicated on water conditions in the basin. Cooler temperatures in the higher elevations of the basin, decreased withdrawal of streamflow for irrigation, and significant levels of precipitation all combine to increase flows and lower water temperatures (Errol Claire, ODFW, personal communication, 1987). The rate of dispersion of returning adults throughout the basin will vary according to stream conditions and time of first entry into the basin. Typically, steelhead will migrate upstream as far as Kimberly before winter, overwinter in the lower and middle parts of the river, and then resume their upstream migration in late January or February. Spawning occurs from March in the lower basin through June in the higher tributaries. This characteristic of two migration periods essentially divides the fishing season into two periods, fall and late winter/early spring, though favorable weather may blur this distinction.

Questionnaire Design

The questionnaire (reproduced in Appendix A) was designed and pretested on the Alsea River salmon fishery in August and September, 1986. Survey questions fell into four general classes. The first class consisted of questions focusing on the current trip: purpose of trip, miles travelled, costs incurred, hours spent fishing, and number of fish caught. A second set of questions focused on past fishing experience on the John Day as well as the respondent's visitation rate for the current season. A third group of questions collected socioeconomic data such as age, sex, income range, and education. The respondent was also asked what alternate activity he would have undertaken if he had not gone fishing that day and the expected costs that would have been incurred in that activity.

The main body of the survey was devoted to collecting the angler's willingness-to-pay (WTP) and willingness-to-accept (WTA) values for stated increments or decrements in fishing quality. The procedure used to elicit WTP values for improvements in the fishing quality consisted of the following steps: First, the angler was given information on the average success rate on the John Day River in each of the preceding five years. The respondent was then asked to state his own expected catch rate on the John Day in an average year. This gave a base level of fishing quality at which to construct the contingent market. The respondent was then told that there were three postulated increases in the number of steelhead in the river: 33%, 67%, and 100% above the average level. Under each of these improvement levels the respondent was asked to state his new expected catch rate. This format allowed the angler to define the contingent market such that it reflected his own skill and experience level. It was hoped that by following this procedure there would be fewer biased responses due to the hypothetical nature of the market. Once the contingent market was defined the respondent was asked the following questions:

21A. If improvement A takes place would you be willing to pay $ __X__ for a John Day Steelhead Stamp? YES NO

21B. What would be the maximum fee you would be willing to pay? $_____

Question 21A was stated in a dichotomous choice fashion for two reasons. First, it more accurately reflects the real marketplace for fish and wildlife stamps, a market with which anglers are already familiar. Secondly, if enough surveys were collected a dichotomous choice model could be fitted to the data, allowing estimation of expected WTPc for improvement A. (The "c" in WTPc denotes this as compensating variation. Likewise, "e" denotes the equivalent surplus version of willingness-to-pay, WTPe.) The proposed stamp fee levels, ranging from $2.00 to $24.00, were systematically assigned to surveys prior to each week's surveying. These questionnaires were then randomly selected prior to an interview.

Several possible sources of bias need to be noted at this point. First, following the closed-ended question with an open-ended form introduces the possibility of respondents "anchoring" on the proposed fee level. This "anchoring bias" is conceptually analogous to the starting point bias often found in iterative bidding formats. In addition, two open ended questions (# 18 and # 19) eliciting WTPe and WTAc for decrements in fishing quality had already been posed, introducing another possible source of anchoring. Another bias may be attached to the use of a "John Day Steelhead Stamp" as the payment vehicle. These biases, and associated tests for their presence, will be discussed later.

Question 21B and all subsequent WTPc questions were asked in an open ended fashion:

22A. Now suppose that, instead of improvement A taking place, improvement B occurs. What would be the maximum ADDITIONAL amount you would be willing to pay for the stamp for this additional improvement from A to B? $__________

Under each improvement level the respondent was also asked to reveal his expected change in hours spent fishing and in the number of fishing trips taken to the John Day annually. If there was an increase (decrease) in either of these the respondent was asked from what activity he would take this time (or what he would do with this extra time). The intent of these questions was to collect information on substitute activities and to examine the possibility of increased fishing pressure and congestion, which might negatively impact the fishery and hence lower individual benefits.

Administration of the Survey

The rugged and undeveloped nature of the lower John Day River basin effectively limits angler access. This enabled easy identification of common fishing sites but also hindered access to administer surveys. The middle and upper stretches of the river are considerably easier to access. The sites at which surveys were collected are identified in figure 4.1.

Due to the fishery characteristics previously mentioned, surveying was conducted in both the fall and spring. The fall fishery

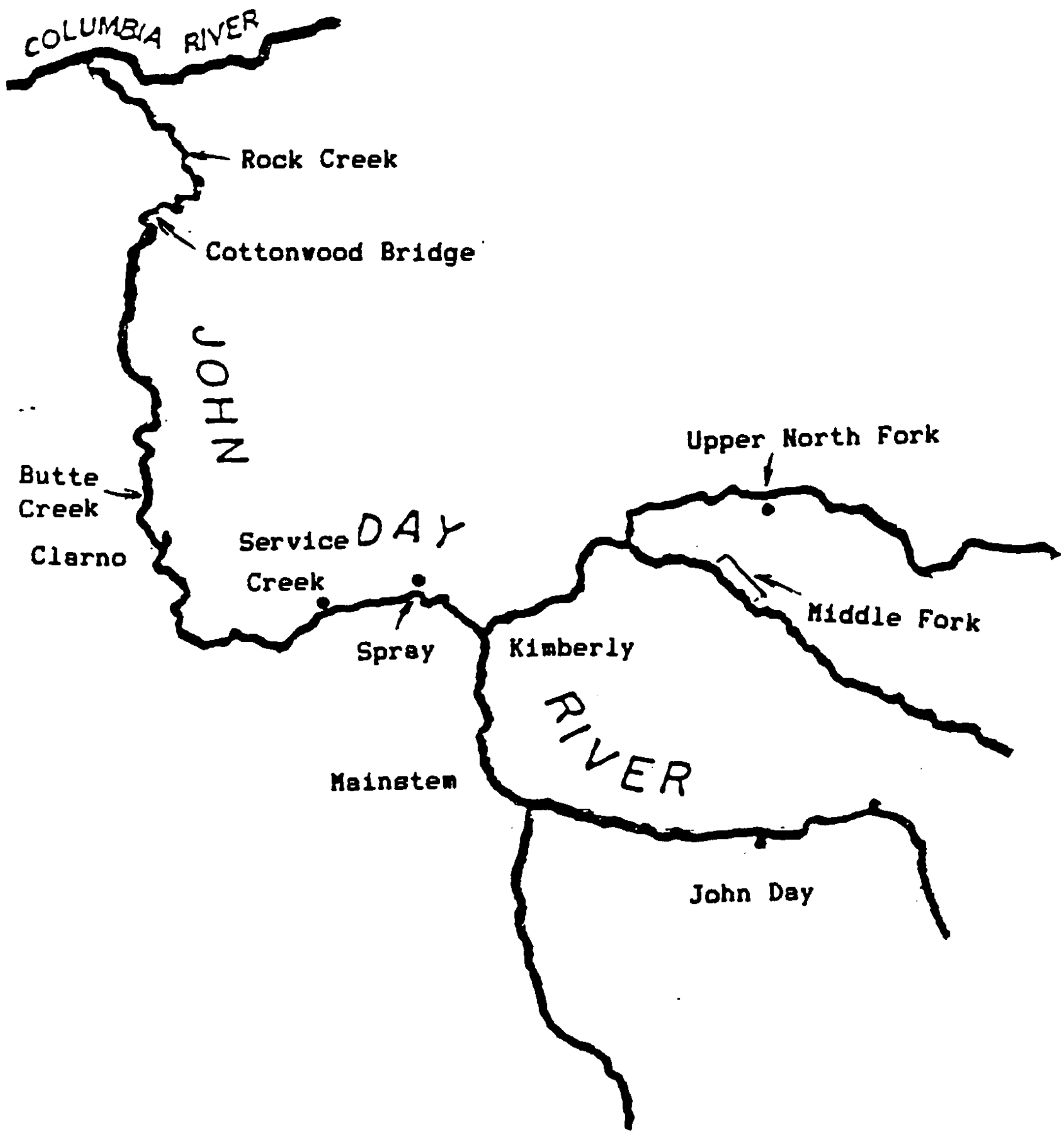

Figure 4.1. Survey sites.

survey concentrated on the lower and middle sections of the river (up to Kimberly). Surveying was resumed again during the spring fishery, focusing on the upper sections.

Most sampling was conducted during weekends when the density of anglers was greatest. On a typical sampling day, the interviewer would start visiting known fishing areas at around 8 a.m. This often entailed driving along roads adjacent to the river looking for parked cars, indicating a potential angler nearby. Anglers were approached and asked if they would be willing to participate in a voluntary survey concerned with steelhead fishing on the John Day River. Surveying continued in this fashion until darkness.

One of the acknowledged weaknesses of this study is the sampling procedure used in collection of the data. Ideally, a more statistically sound sampling procedure should have been employed. Such a methodology would have accounted for the varying spatial and temporal distribution of anglers throughout the season. This would have entailed having a team of interviewers scattered throughout the basin, each one selecting anglers at random or according to a systematic sampling scheme. In addition, sampling should have been more intensive during high use periods. Lack of funds, however, resulted in the use of only one interviewer, which, coupled with the large size of the basin necessitated a less intense sampling procedure.

The survey was administered to 67 steelhead anglers during the 1986-87 fishing season. Five other anglers declined to be interviewed, resulting in an acceptance rate of 93 percent. Reasons for refusal to participate included not wanting the word to get out on the "good fishing", not wanting to be "bothered", and a distrust of surveys. Administering the survey took 15-30 minutes each. Four surveys were deemed unuseable due to key questions which remained unanswered. The question which posed the most difficulty was # 20, which asked for the respondent's expected catch rate under each improvement level. Failure to answer this question resulted in an undefined contingent market.

Of the remaining 63 surveys, one was deemed to be only partially useable due to an apparent violation of the axioms of consumer behavior. The particular respondent (# 38) had marginal bids of $10, $20, and $170 for improvements in success from a base level of 6 hours per steelhead to 3, 2, and 1 hours per steelhead, respectively. While arguments could be raised supporting this bidding pattern, the survey was discarded for three reasons: 1) It was the respondent's first trip to fish the John Day, raising questions as to the accuracy of his stated catch rate; 2) a comment made by the respondent during the survey indicated that he thought he was bidding on a guaranteed, as opposed to an average, catch rate; and 3) given the magnitude of his bid for improvement level C, it was felt that the potential impact of including his responses, if biased, outweighed the consequences of excluding them and having them turn out to be true WTP values. Omitting this survey left 62 useable responses for analysis.

Analysis of Data

Test for Biases

Prior to estimating willingness-to-pay values for the postulated improvement levels, the data were examined for evidence of biases.

Anchoring bias. Given the data obtained in the survey, only the presence of anchoring bias can be statistically tested. The usual test for anchoring, or starting point, bias is to regress the final bid values against the originally offered price (or compensation, in WTA questions) (Boyle et al. 1985). Utilizing this test the following was obtained:

$$\text{WTPc(A)} = \underset{(2.34)}{9.58} - \underset{(-0.27)}{0.10}\ \text{FEE} \tag{4.1}$$

where WTPc(A) is the open-ended bid response for improvement A (question # 21B) and FEE is the proposed stamp fee in the preceding dichotomous choice question (# 21A). T-statistics are presented in parentheses. Using this procedure, the null hypothesis (of no anchoring bias) cannot be rejected. However, recalling the previous discussion, a prior question had elicited the respondent's willingness-to-pay, WTPe(-), to avoid a decline in success rate. Including this bid as an explanatory variable and retesting for anchoring bias produced the following:

$$\text{WTPc(A)} = \underset{(-0.24)}{-0.37} + \underset{(1.65)}{0.21}\ \text{FEE} + \underset{(20.87)}{0.97}\ \text{WTPe(-)} \tag{4.2}$$

The coefficient on FEE is significant at the 0.10 level; the null hypotheses can be rejected in this case. According to Freeman (in Cummings et al. 1986), anchoring on offered prices may not "bias" results as long as the mean bid offered is close to the true mean WTP. The mean of FEE is $10.32 whereas the mean WTPc(A) bid is $8.58. Thus, if anchoring bias exists, it may not be too severe of a problem, resulting in a slight upward bias of WTPc(A) in this case. Turning our attention to the coefficient on WTPe(-) it is clear that respondents based their WTPc(A) bid on their prior bid. This is consistent with economic theory: given an angler (or consumer) with certain tastes and preferences, it is likely that he would place similar values on marginal increments or decrements in quality (or quantity).

Payment vehicle bias. Prior studies, such as Daubert and Young (1981), have thrown out "protest" bids. These were either zero WTP or large WTA bids that were felt to be protests against either the payment vehicle or the contingent market in general. This was not done in this study even though 9 of the 62 useable questionnaires had zero WTPc bids for improvement A. The rationale for not excluding these bids focuses on whether one considers payment vehicle "bias" to actually be a bias. Zero bids may reflect the respondent's feelings towards a "John Day Steelhead Stamp". Since this stamp is an integral part of the contingent market, we felt it was inappropriate to throw out these "protest" bids. However, it should be noted that the intent of this study was to obtain estimates of increases in consumer's surplus due to an improvement in fishing quality, not to find out how much anglers would pay for a stamp to bring about this improvement.

In the context of Pareto improvements, it is not necessary to actually have these monetary transactions take place. Therefore, it may have been more appropriate to have stated the WTP questions as, "What would it be worth to you to have improvement A occur?"

Another bias which may be attributed to the use of a "John Day Steelhead Stamp" as the payment vehicle concerns respondents' prior experiences with fishing fees. Oregon steelhead anglers are currently required to purchase $5.00 salmon and steelhead tags in addition to a general $12 fishing license. Twenty-three (37%) of the respondents had WTPe(0) bids of $5, indicating "anchoring" on the current fee level. This dropped to 14 (22.5%) $5 bids for WTPc(A). Eliminating the "John Day Steelhead Stamp" as the payment vehicle might alleviate this problem. While removing potential problems with the payment vehicle, however, it introduces the increased possibility of hypothetical bias.

Computation of Willingness-to-Pay

Aggregate bid method. Two procedures were followed to derive estimates of expected willingness-to-pay for improvements in fishing quality. The first analysis follows the procedures of Brookshire, Randall, and Stoll (1980). This procedure is based on a concept developed in Bradford (1970) and briefly outlined in Chapter 3. By aggregating individual bid curves, a total bid curve can be obtained. Alternately, the mean bids and quality levels can be calculated to arrive at a mean individual bid curve. The latter approach is taken here.

An important issue arises in aggregating individual values to arrive at a mean bid. An angler who fishes more often is more likely to be included in the survey. This angler may also place a higher value on an increase in quality due to the quality/quantity interaction. At the same time, he may be nearer his seasonal limit (10 steelhead in northeastern Oregon) and consequently not value an increase in seasonal catch as highly as someone who only catches one or two steelhead per year. In attempts to test for this, no significant difference could be found between bids from frequent and infrequent John Day anglers. Thus, no adjustment was made in calculating the mean bids.

Results are presented in table 4.1. These results can be graphically represented two ways: 1) WTP vs. quality, represented as hours per steelhead; and 2) WTP vs. quality, represented as steelhead caught per hour (or per 100 hours). These are presented in figures 4.2, and 4.3, respectively.

The mean bid curve represented in figure 4.3 was fitted to a quadratic functional form:

$$(4.3) \qquad WTPc = \underset{(0.30)}{0.11} + \underset{(23.1)}{4.87}\, \Delta\, HRSFISH - \underset{(-25.1)}{0.52}\, (\Delta\, HRSFISH)^2 \qquad N = 4$$

where Δ HRSFISH is the improvement in the success rate (hours per steelhead). A constant term was included since the current success level was included as an observation (i.e., WTPc = 0, Δ HRS = 0). This gives a good mathematical representation of the individual mean bid curve, as evidenced by an adjusted R^2 of over 0.99.

To convert the mean individual bid function (4.3) into an

Table 4.1. WTP and mean expected catch rate summary.

Stock level	Mean expected catch rate /a (hrs/steelhead)	Mean bid /c (1986 $)
(-) /b	29.9	WTPe(-) = $7.04
Current conditions	9.3	
A	7.1	WTPc(A) = $8.58
B	5.0	WTPc(B) = $11.11
C	2.9	WTPc(C) = $13.59

a/ Expected catch rate was calculated as: $62 \Big/ \sum_{i=1}^{62} \frac{1}{CR_i}$

where CR_i = Hours per steelhead caught (from survey questions 16 and 20) for the ith respondent.

b/ Stock level (-) is the level at which the angler would stop fishing on the John Day. For anglers indicating they would not give up fishing on the John Day no matter what the catch rate, a value of 0 steelhead per hour was used in caluculating the mean expected catch rate.

c/ Mean bids were calculated as the average of the 62 useable surveys. For improvement levels B and C, the mean bids include the marginal bids for the previous improvement levels.

aggregate bid function, it is necessary to know how many anglers fish the John Day in a given year. This information is not directly available but can be approximated from available data sources. Total annual catch is estimated by ODFW from returned salmon-steelhead tags, with corrections made for nonresponse bias (ODFW 1987). Total angler hours were estimated by multiplying total catch by success rate (expressed in hours per steelhead; see table 4.2) By dividing the average total annual angler hours by the average hours per angler, an estimate of anglers fishing the John Day per season can be derived.

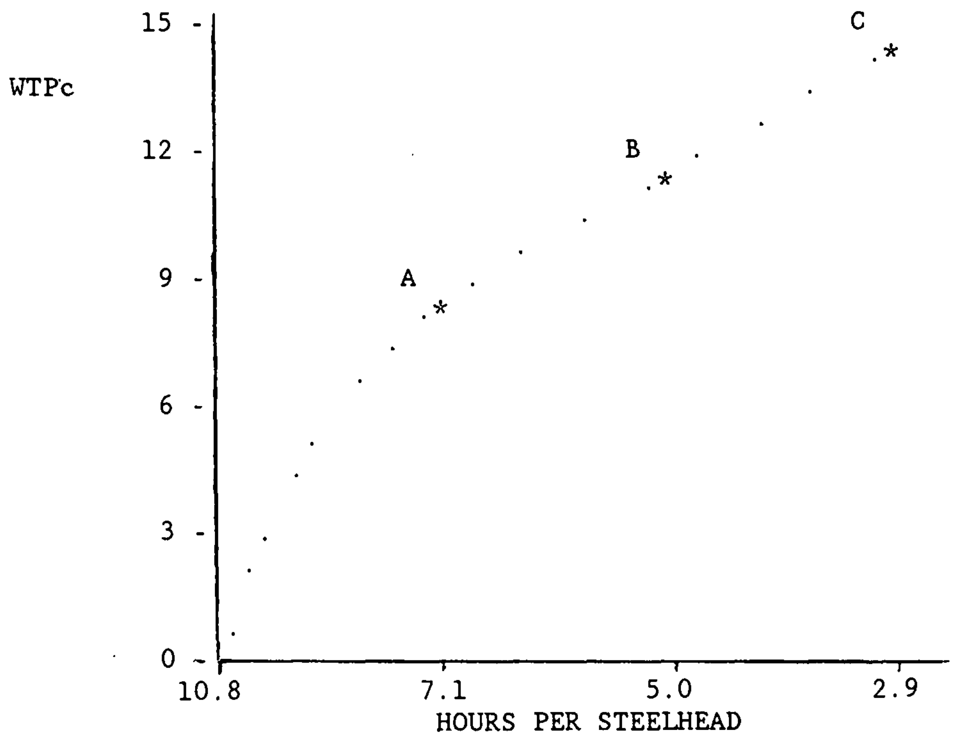

Figure 4.2. WTP vs. success rate (hours per steelhead).

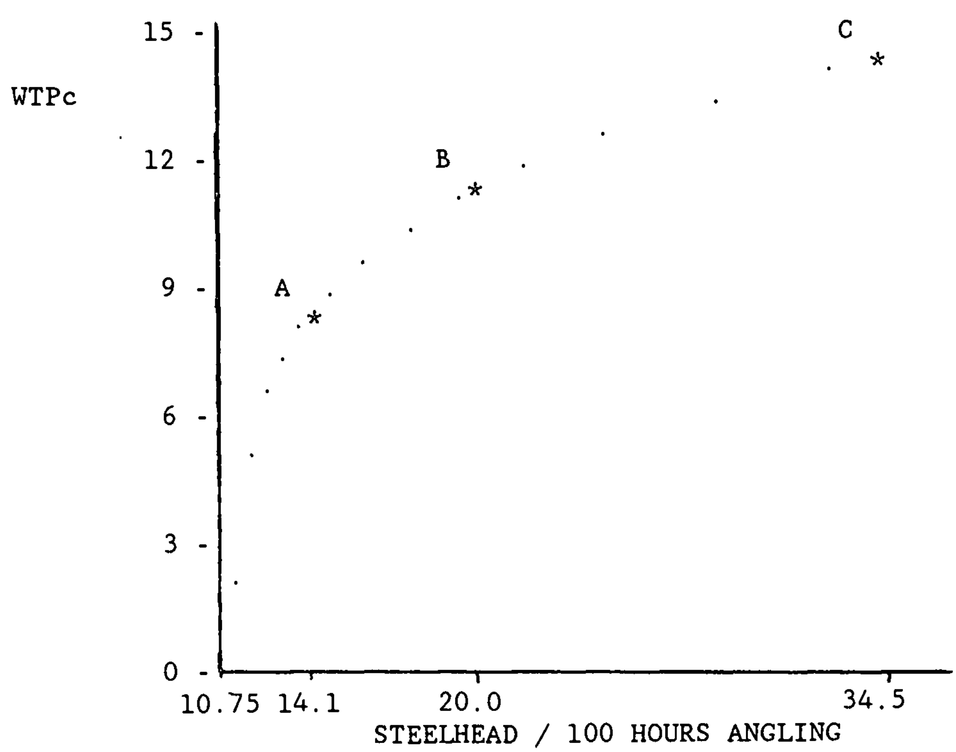

Figure 4.3. WTP vs. catch rate (steelhead / 100 hours fishing).

Table 4.2. Estimated steelhead catch and angler effort on the John Day River, 1971 - 1985.

Year	Hours per steelhead /a (A)	Estimated catch /b (B)	Total angler hours /c (C)	Estimated # of anglers /d
1971	11.8	1789	21,110	541
1972	24.4	2666	65,050	1668
1973 /e	28.5	5359	152,731	3916
1974	24.9	906	22,559	578
1975	12.7	2784	35,357	906
1976	21.8	1511	32,940	844
1977	15.8	2924	46,199	1185
1978	21.1	1475	31,122	798
1979	109.0	305	33,245	852
1980	34.2	669	22,880	587
1981	25.7	1721	44,230	1134
1982	15.4	2982	45,923	1177
1983	29.7	980	29,106	746
1984	13.8	1974	27,241	698
1985	13.9	2011	27,953	717
			Average =	888 /e
			Standard deviation =	300

a/ See Appendix E for a complete time series of success rates.
b/ Source: ODFW (1987).
c/ Calculated as (column A) x (column B). See text for further explanation.
d/ Calculated as (column C)/(39 hours per angler).
e/ Due to the large divergence between 1973 angling effort and the average it was treated as an unrepresentative outlier and ommited from estimation of average angling effort.

However, this first requires an estimate of average angler days and hours spent fishing per day. From the survey responses (question #14) average hours per angler was equal to 6.8 hours per day. (Surveys 1-11 were excluded from this computation due to questions # 14 and 15 being omitted on these questionnaires.) Average days per angler per season was more difficult to estimate. Since an angler who fished more often was more likely to be sampled, a weighting procedure was employed. The weighted average number of days fished per angler per season on the John Day was calculated as:

$$(4.4) \qquad \text{WT AVG DAYS} = 51 \Big/ \sum_{i=12}^{62} \frac{1}{\text{DAYS}_i}$$

where $DAYS_i$ is respondent i's expected days fishing the John Day during the 1986/87 season. Using this procedure an estimate of 5.7 days was obtained.

How accurate are these estimates of individual effort? A general idea of accuracy can be obtained by examining the expected catch per angler, as elicited in question # 15. From the survey responses the mean expected catch per angler was 8.3 steelhead. However, weighting these answers using a method similar to (4.4),

$$(4.5) \quad \text{WT AVG CATCH} = \sum_{j=12}^{62} [\ \text{CATCH}_j \ / \ \text{DAYS}_j\ ] \Big/ \sum_{i=12}^{62} \frac{1}{\text{DAYS}_i}\ ]$$

results in an estimate of 4.5 steelhead per angler. This is close to an estimate obtained by taking the product of average hours per angler (6.8 hours/day x 5.7 days/season = 39) and average catch rate (1/hours per steehead = 1/9.3 = 0.1075, where 9.3 is the average expected catch rate under current conditions), which yields 4.2 steelhead per angler. Therefore, using 39 hours per angler per season seems a good approximation of average annual individual effort. Using this value it is now possible to obtain an estimate of the number of anglers fishing the John Day each year. Table 4.2 presents the results. The average is 888 anglers with a standard deviation of 300.

A caveat must be attached to the above analysis. An underlying assumption is that a representative sample of the population of John Day anglers was included in the survey. However, the expected catch rate for the sample (9.3 hours/steelhead) is much higher than the average obtained from creel surveys conducted each year in the basin (approximately 17 hours/steelhead). There are several possible explanations for this. First, the creel surveys only count fish caught and kept, whereas the expected catch (question # 15) and the expected catch rate (# 16) incorporate total catch (caught and released plus kept). This would create a divergence between the two measures. Second, fishing on the John Day has been better than average over the last four years. Anglers, as with most respondents, base their expectations (of catch and catch rates) on more recent years. At the least, the above computations of expected average catch in a season demonstrates that answers to the various effort and catch rate questions appear to be internally consistent within the sample, lending validity to the respondents' answers.

Before using these estimates of angler effort to derive an aggregate bid curve, another issue must be addressed. An increase in success rates may be accompanied by an increase in angling effort, resulting in a larger increase in benefits than would otherwise be calculated by assuming a fixed number of anglers. Alternately, this increase in effort may also lead to congestion, lowering individual benefits (Anderson 1980). To test if effort increased with improvements in fishing quality, CATCH (from column B, table 4.2) was regressed against the catch rate, CR (here expressed as steelhead per 100 hours of angling effort), and catch rate squared, CR^2, resulting in the following equation:

$$\text{(4.6)} \qquad CATCH = \underset{(4.14)}{494\ CR} - \underset{(-1.38)}{24.4\ CR^2} \qquad R^2=0.58 \quad n=14$$

where t-statistics are presented in parentheses. The estimates indicate that increasing fishing quality (represented as CR) increases catch linearly, indicating fishing pressure is independent of the catch rate. If fishing pressure increased with success rate, a positive coefficient on CR^2 would be expected. An alternate test is to see if CATCH is a linearly homogeneous function of CR. To test this hypothesis, a double log function was fit to these variables:

$$\text{(4.7)} \qquad \ln(CATCH) = \underset{(0.262)}{5.82} + \underset{(0.162)}{0.986\ \ln(CR)} \qquad R^2=0.76 \quad n=14$$

where standard errors are presented in parentheses. Computing the t-statistic for the ln(CR) coefficient yields $t = (0.986 - 1.0)/0.162 = -0.086$. Therefore, we cannot reject the hypothesis that annual catch is a linearly homogeneous function of catch rate, lending further support that fishing pressure on the John Day does not increase noticeably with increases in success rates, given the catch rate levels used in the analysis. This, however, does not rule out increased fishing pressure under higher catch rates than those which have been observed. The aggregate bid function can now be represented as

$$(4.8) \quad \text{AGG. WTPc} = 98 + 4{,}325\ \Delta\ \text{HRSFISH} - 462\ (\Delta\ \text{HRSFISH})^2 \quad (\text{base}=9.3)$$

which is equation (4.3) multiplied by the annual user rate, 888 anglers. The estimated aggregate WTP for the three improvement levels are presented in table 4.3. It should be remembered that this is only the benefits accruing to current users of the resource. Any existence, option, or bequest value held by non-users is not represented in these values.

Table 4.3. Aggregate WTPc summary for three improvement levels.

Improvement level	Mean expected catch rate /a (hrs/steelhead)	Aggregate /b bid (1986 $)
Current catch rate	9.3	
A	7.2	$7,619
B	5.1	$9,866
C	3.0	$12,068

a/ see table 4.1 for derivation of catch rate.
b/ Obtained by multiplying the mean individual WTP by the estimated number of anglers fishing the John Day annually (888).

A reference level of angler success must be attached to the above bid equations. This presents a problem due to the divergence between observed and expected catch rates noted earlier. Specifically, it involves a choice of treating the base level as 17 hours per steelhead (the average from the ODFW creel surveys) or the average from the contingent valuation survey, 9.3 hours per steelhead. Since the bids were based on the respondents' perceived catch rate, the 9.3 value seems more appropriate. However, creel survey data are more readily available on a year-to-year basis. A rough approximation would be to convert the perceived catch rate to an observed rate by multiplying by a scaling factor (17/9.3). This would change equation (4.8) to

$$\text{(4.9)} \quad \text{AGG. WTPc} = 54 + 2{,}366\ \Delta\ \text{HRSFISH} - 138\ (\Delta\ \text{HRSFISH})^2 \quad \text{(base = 17)}$$

This results in two marginal bid functions, one for 9.3 hours and one for 17 hours:

$$\text{(4.10)} \quad \text{MARG. AGG. WTPc} = 4324 - 924\ \Delta\ \text{HRSFISH} \quad \text{(base=9.3)}$$

$$\text{(4.11)} \quad \text{MARG. AGG. WTPc} = 2366 - 276\ \Delta\ \text{HRSFISH} \quad \text{(base=17)}$$

Equation (4.9) is employed in Chapter 6 to derive the marginal value of instream water.

Dichotomous choice (logit) model. Recall that in the dichotomous choice (yes or no) question (# 21A), each respondent was asked if he/she would be willing to pay an amount, X_i, in the form of a John Day Steelhead Stamp, if fishing quality were to improve to level A.

These yes/no responses were analyized using a discrete choice model, specifically the logit (see Sellar, Chavas and Stoll 1986 for a concise explanation and an example as applied to recreational boating; see also Bishop and Heberlein 1979, Bishop et al. 1983, and Boyle and Bishop 1984). The logit model used here is specified as:

$$\text{(4.12)} \qquad \text{Prob(NO)} = \frac{1}{1 + \exp[-f(X_i,\ q_{i,o},\ \Delta\, q_{i,a})}$$

where X_i is the offered stamp fee level; $q_{i,o}$ is the initial catch level, calculated as (hours/day)$_i$ * (days/season)$_i$ * (steelhead per hour)$_{i,o}$; $\Delta\, q_{i,a}$ is the difference between individual i's catch at the initial level and improvement A, i.e., the increase in catch due to an improvement in the catch rate; and Prob(NO) is the probability of a "no" answer to the stated fee level, X_i.

Two functional forms were specified for $f(X_i,\ q_{i,o},\ \Delta\, q_{i,a})$: a linear form:

$$\text{(4.13)} \qquad f(X_i,\ q_{i,o},\ \Delta\, q_{i,a}) = \alpha + \beta_1 X_i + \beta_2 q_{i,o} + \beta_3 \Delta\, q_{i,a}$$

and a log-linear form:

$$\text{(4.14)} \quad f(X_i,\ q_{i,o},\ \Delta\, q_{i,a}) = \ln \alpha' + \beta_1' \ln X_i + \beta_2' \ln q_{i,o} + \beta_3' \ln \Delta\, q_{i,a}$$

These two specifications were estimated using the econometrics package SHAZAM (White 1978). Results are presented in table 4.4. As noted in Sellar et al. (1986), average willingness-to-pay for improvement A can be expressed as:

Table 4.4. Logit analysis results.

Functional form	Intercept (α)	Fee level (X_i)	Initial catch ($q_{i,o}$)	Increase in catch ($\Delta q_{i,a}$)
	Estimated coefficients /a			
Linear	-0.78	0.14	0.12	-0.62
	(-1.01)	(2.10)	(2.01)	(-2.48)
Log linear	-3.02	1.28	0.33	-0.53
	(-2.31)	(2.42)	(1.09)	(-2.29)

a/ t-statistics are presented in parenthesis. N = 62.

$$E(WTP) = \int_{0}^{Xi(max)} X\, g(x)\, dx \tag{4.15}$$

where g(x) is the probability density function corresponding to a yes response to the fee level, X_i. This is graphically represented by the shaded area in figure 4.4. Holding $q_{i,o}$ and $\Delta q_{i,a}$ constant at their means, and integrating over the range 0 to 24, E(WTP) was estimated for both the linear and log linear forms. Results indicate E(WTP) of \$9.14 and \$11.14, respectively (table 4.5).

An alternate method of estimating WTP is to analyze (4.9) at the Prob(NO) = 0.5 level (Hanemann 1984). Using this procedure, the median E(WTP) for the linear and log linear models was \$7.80 and \$8.60, respectively (table 4.5). This corresponds closely with the \$8.56 mean bid calculated using the open-ended method (table 4.1).

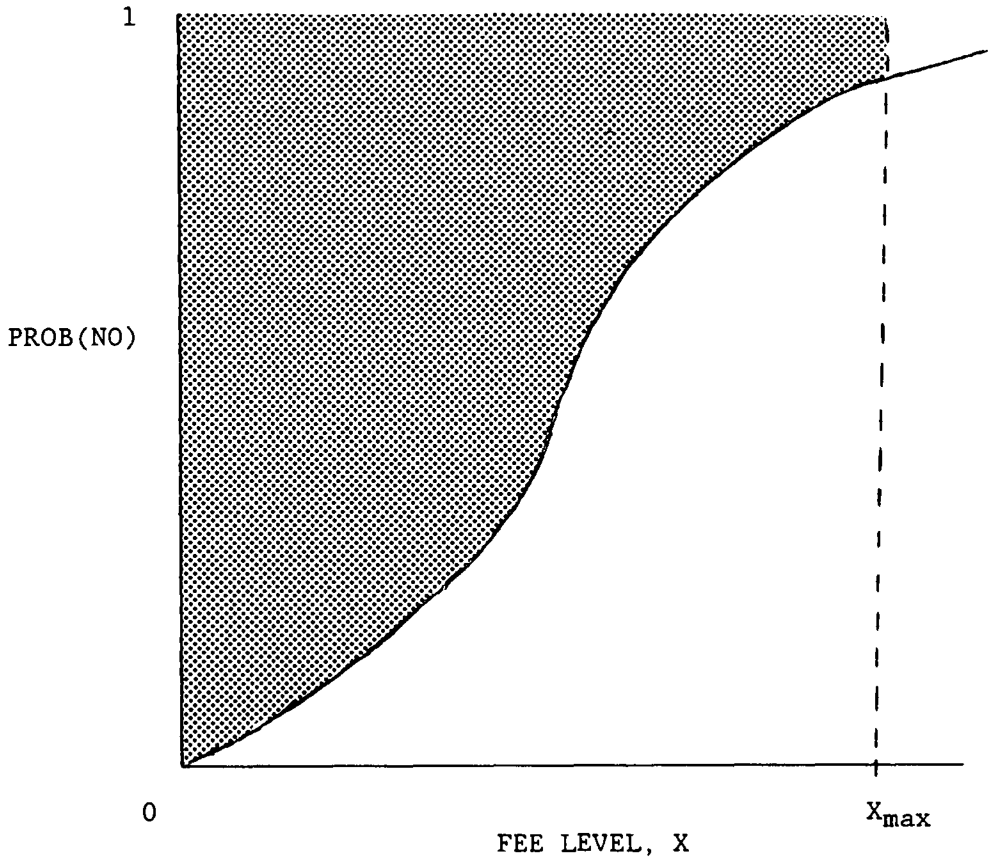

Figure 4.4. The logit model.

Table 4.5. Logit estimation of WTP for improvement level A.

Functional form	Average WTP /a	Median WTP /b	Prob(no) X=0	Prob(no) X=24
Linear	$9.14	$7.80	0.25	0.91
Log linear	$11.14	$8.60	0.00	0.78

a/ Using equation (4.12). See text for further explanation.
b/ Estimated by analyzing equation (4.9) at the P(NO) = 0.5 level.

The Marginal Value of a Steelhead

As alluded to by Steinbeck in the opening quote to this chapter, there is much more to fishing than catching fish. This point was illustrated by two of the questions posed during the survey. When asked at what catch rate they would stop fishing on the John Day River, 45 percent of the respondents reported that they would continue to fish even if they never caught a fish. Twelve percent reported that they didn't expected to catch any steelhead in an average year. (These were questions # 17 and # 15 respectively). Nevertheless, resource managers often want economic values assigned to actual catch.

Several options are available for estimation of the marginal value of a steelhead. Reiterating a point that bears repeating, the marginal value of a steelhead will depend on the catch rate at which it's measured and whose marginal value is measured, i.e., some anglers place higher values on an additional fish than others. For policy purposes, the average marginal value of a steelhead is appropriate. This is easily calculated from equation (4.3). Assuming the average angler spends 39 hours per season fishing the John Day, and has an average catch rate of 9.3 hours per steelhead, he will catch approximately 4.2 steelhead in a season. To catch an additional steelhead, i.e., a total of 5.2, this angler would have to have a success rate equal to 7.5 hours per steelhead. His willingness-to-pay for a 1.8 hour decrease in his success rate is $7.19. Hence, one may infer that the average value of an additional steelhead is $7.19 under current catch conditions.

Willingness-to-Accept Values

Question # 19 asked how much the respondent would have to be compensated (WTAc) to give up steelhead fishing on the John Day for one year. Answers to this question ranged from $0 to $1,000,000. In addition, several anglers indicated that they could not be "bought" for any price. These high WTAc values illustrate the strong feelings attached to the right to fish by eastern Oregonians. Due to the wide range in values, it is difficult to arrive at an "average" WTAc. The median value of $200 is probably most indicative of the typical response. No formal analysis of WTAc values was conducted. Several comments, however, are in order.

When answering the WTAc question, many of the respondents considered the cost of obtaining alternate fishing experiences of equal quality to compensate for not fishing for steelhead on the John Day for one year. One respondent, for example, indicated that a fishing trip to Alaska would be equal in value to access to the John Day steelhead fishery, whereas another angler wanted to be compensated for the added cost of travelling further to fish coastal rivers. Respondents who indicated small WTAc values often lived close to a substitute fishing site such as the Deschutes River or didn't think the John Day steelhead fishery was a unique resource. High WTAc values, on the other hand, were typically given by anglers who either lived in the basin or considered the John Day River their primary angling location.

Discussion

It is instructive to compare the marginal values of steelhead obtained above with values obtained in other studies. There are a series of nonmarket valuation studies which focus on the value of salmon and steelhead fishing in Oregon and Washington (see Brown and Shalloof 1986, Brown et al. 1964, 1976, 1980, Hsiao 1985, Sorhus 1980 and Sorhus et al. 1981). Several of these studies, using data collected via mail questionnaires in 1977, utilize the travel cost method to derive estimates of consumer's surplus.

The most recent study, by Brown and Shalloof (1986), represents an updating of the values computed by Brown, Sorhus, and Gibbs (1980) and by Sorhus (1980). They utilized a two-stage procedure to estimate the marginal value of steelhead and salmon. In the first stage of this procedure, an estimate of consumer's surplus per river was derived from a travel-cost based demand function. For the John Day River, their Gum-Martin estimate of consumer's surplus was $110,000, while their traditional consumer's surplus estimate was $194,000. The Gum-Martin estimate uses actual fishing trips per capita as opposed to the predicted number of trips. Such a procedure is less sensitive to errors in demand model specification than use of predicted trips, which may lead to over or under estimation of zonal participation rates (Gum and Martin, 1975). In the second stage, Brown and Shalloof regressed total consumer's surplus per river against the corresponding fish catch per river. Using this method, they concluded that the marginal <u>and</u> average value of a sport caught steelhead in Oregon and Washington was approximately $120, a sharply higher value than obtained from the contingent valuation procedures in this study. It is likely, however, that the estimation procedure employed by Brown and Shalloof (and hence the estimate of $120 per steelhead) is flawed if emphasis is on true average or marginal values. In regressing total consumer's surplus against the catch per river their approach abstracts from the possible dependence of consumer's surplus and catch on the number of fishing trips. The specified equation may have produced "good" results because of this collinearity with an excluded variable. In failing to account for this relationship between consumer's surplus and catch arising from the level of effort, Brown and Shalloof essentially calculated average consumer's surplus divided by steelhead. This value is thus conceptually different from the consumer's surplus generated by catching one more steelhead. To illustrate this point further, divide total estimated consumer's surplus for the state of Oregon ($15,816,000) by the steelhead catch for Oregon in 1977 (119,841) which yields a value of $132 per steelhead. This is very close to the $120 figure reported above and leaves little consumer's surplus left over to be attributed to the other utility-producing aspects of the fishing trip.

It is interesting to note that if one divides Brown and Shalloof's (1986) estimate of total Gum-Martin consumer's surplus for the John Day River in 1977 ($110,000) by the steelhead catch for the river (2,252), a value of $48.84 per steelhead is obtained. This is twice the value that would be obtained by dividing median WTAc(-) ($200) by the average expected catch, as indicated by the survey data

(8.3 for unweighted responses), which yields $24.[1] These values are not directly comparable since the latter value is estimated using expected catch, which includes released fish, whereas the former value is calculated using non-released steelhead only. It should be stressed that these values cannot be interpreted as average consumer's surplus generated per steelhead caught. The only correct interpretation is as "consumer's surplus divided by fish catch", where "fish catch" is subject to alternate definitions. To assign a true average or marginal value to steelhead using the above data would require knowing the proportion of consumer's surplus attributable to actually catching steelhead. This discussion serves to illustrate the current ambiguity in what constitutes the "value" of a salmon or steelhead.

Hsiao (1985) fitted the same data employed in the Brown and Shalloof study to a variety of travel cost models. In most of these models, Hsiao uses the same approach to calculate average and marginal values for a steelhead as noted above. One of his models, however, does provide some useful insights. Using a regional travel cost model, a marginal value of $30 was estimated for salmon. This value was considerably lower than estimates made via his other models. Hsiao attributes this lower value to model misspecification and poor data. After examining the specification of the model, it is this writer's opinion that this value should more accurately be interpreted

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[1] Given that median WTAc(-) is being employed, use of the weighted expected catch rate (4.5 steelhead) may be more appropriate. This yields $44.44 per steelhead, close to the $48.84 estimated using the travel cost method.

as the marginal consumer's surplus per trip divided by the salmon catch during that marginal trip. This value is still conceptually different from the marginal contribution to consumer's surplus of an additional sport-caught salmon, ceteris paribis. Clearly, the amount of consumer's surplus attributable to the fish itself is much smaller than previously reported.

Two studies lend support to the lower marginal value per steelhead reported in this study. Samples and Bishop (1985), utilizing a multiple-site travel cost model, estimated the average value of an additional sport-caught salmon or trout in the Lake Michigan sportfishery as approximately $6.75. The base level of success was 0.47 fish per trip.

The second supporting study was based on a survey conducted in 1984 by Cameron and James (1986a, 1986b, 1987). Utilizing maximum likelihood estimation techniques, Cameron and James fitted a qualitative choice model to responses from a "closed-ended" contingent valuation survey. While the study focused on the valuation of sport-caught coho and chinook salmon on the south coast of British Columbia, Canada, it is instructive to examine their estimates of the marginal contribution to respondents' WTP contribution generated by an additional salmon.

Several models were fit to the data, with slightly different results obtained in each estimation. The values reported here come from Cameron and James (1987). The marginal value of a chinook salmon was estimated as C$14.47 (Canadian $s), whereas negative marginal values were obtained for coho salmon. The coho values would appear to be incorrect unless one remembers that fishermen are faced with a per day catch limit. If chinook are a preferred fish, catching a coho may lower the prospects of later catching a chinook. To examine this "interaction effect", Cameron and James distinguished between a coho with and without a chinook being caught. When no chinook had been caught, a coho detracted from WTP by C$1.21. When a chinook had been caught, an extra coho lowered WTP by C$7.94. It is interesting to note, however, that if the largest fish caught was a coho it increased WTP by an average of C$4.35 per pound (the average size of a coho, if the largest fish caught, was 5.6 pounds). Chinook, when the largest fish caught, only contributed $.65 per pound. When Cameron and James computed the "average value" per salmon by dividing the mean WTP ($48.83) by the average catch (.5) they obtained a value approaching $100, close to the values obtained in the travel cost studies previously mentioned. Using this latter value would clearly lead to an overvaluation of the catch.

CHAPTER 5

A BIOLOGICAL MODEL OF THE SUMMER STEELHEAD LIFE CYCLE

Previous chapters have examined the demand for recreational fishing. More specifically, the marginal value of an increase in the quality of the John Day River steelhead sportfishery was derived. Attention is now turned towards the "supply" of this quality. The link between environmental factors, fishery productivity, and the quality of the fishery will be examined. Since this is largely a biological relationship, attention will shift temporarilly from economics to the field of biometrics. By combining the results obtained here with the economic results obtained in Chapter 4, one portion of the marginal value of instream water can be derived.

A Fishery Production Model

The quality of salmon and steelhead sport fisheries depends, in part, on the quantity of fish returning to spawn. These populations, in turn, are influenced by numerous environmental conditions throughout their life cycles. The influence of ocean conditions and streamflow on the survival of salmon (Oncorhynchus spp.) has been extensively studied (see Anderson and Wilen 1985, McCarl and Rettig 1983, Nickelson 1986, and Peterman 1978, 1981). The majority of these studies have focused on coho salmon (O. kisutch), whose life history is relatively uniform when compared to that of steelhead trout. Due to this and other behavioral differences, the functional forms employed in these studies are not directly transferable to the analysis of steelhead population dynamics. However, the basic stock-recruitment models utilized in these studies can be modified for the purposes of this thesis.

For steelhead, express the number of adult fish entering the John Day River in year t, N_t, as a function of parental stock size, P_{t-x}, where t-x indicates the year the parental stock spawned; environmental conditions affecting survival, E; and fishing pressure, FP:

$$N_t = f(P_{t-x}, E, FP) \tag{5.1}$$

A stock-recruitment model is required to express this relationship in a format amenable to quantitative analysis. Stock-recruitment models relate recruitment to the fishery as a function of parental stocks and generally include coefficients measuring density-dependent and density-independent mortality. Two commonly employed models are the Ricker (1954, 1975) and the Beverton-Holt (1957). The stock-recruitment relationship hypothesized by these alternate models are shown in figures 5.1 and 5.2. It has been hypothesized that the Beverton-Holt model more correctly specifies the stock-recruitment relationship for steelhead. However, when applied to the John Day steelhead fishery both models yield comparable results, as discussed below. For this reason and due to the comparative ease in transforming the Ricker model into a relationship amenable to regression analysis, the ensuing discussion will use the Ricker model. The Beverton-Holt model and results are summarized in Appendix F.

The Ricker stock-recruitment model expresses the relationship

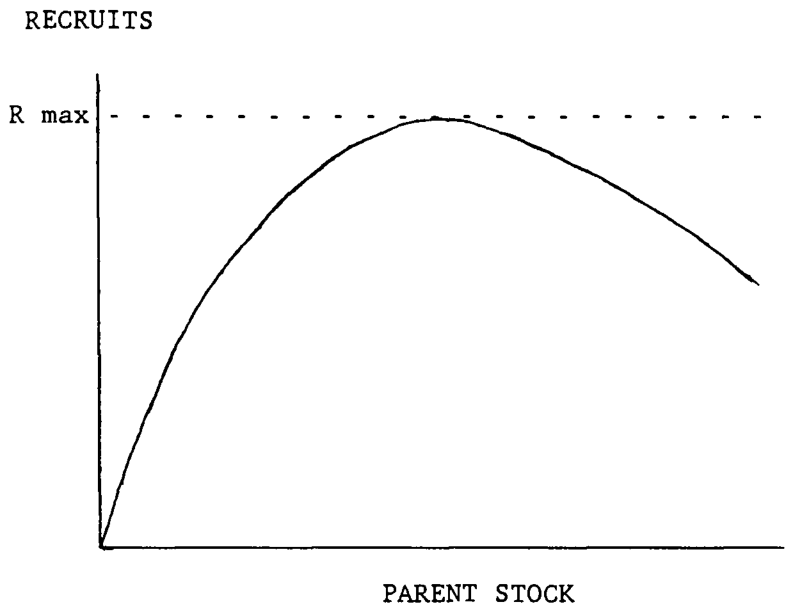

Figure 5.1. Ricker stock-recruitment relationship.

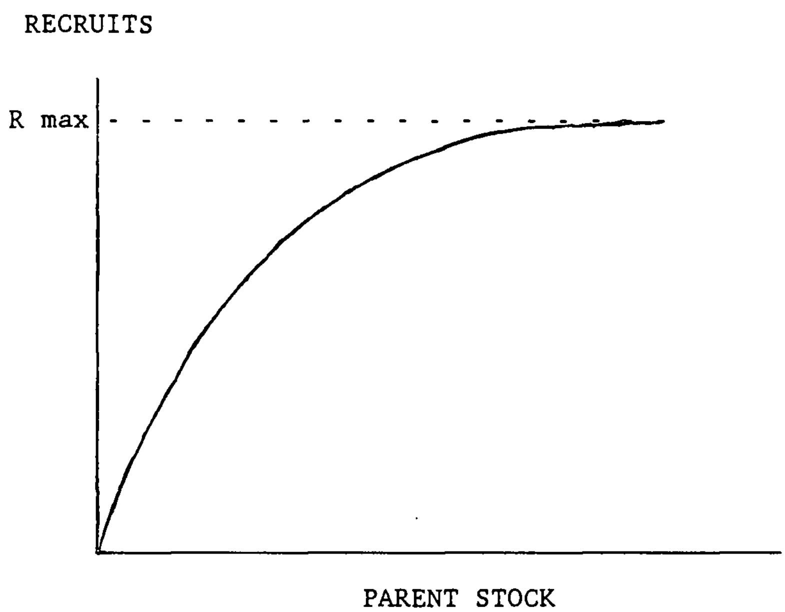

Figure 5.2. Beverton-Holt stock-recruitment relationship.

between the number of recruits (progeny) and the size of the parental stock (the spawners) as:

$$R = \alpha P e^{-\beta P} \tag{5.2}$$

where R = number of recruits to the fishery

P = size of parental stock

α = a dimensionless parameter

β = a parameter with dimensions of 1/P that relates stock density to mortality.

Since the interest here is on the number of adults returning to spawn, it is necessary to expand expression (5.2) to account for the mortality occurring between the spawning of the parental stock and the return of their offspring. To facilitate the ensuing discussion, figure 5.3 diagrams the hypothesized life history of summer steelhead in the John Day River basin. From this figure it can be seen that expression (5.2) only relates P_{t-5} to the potential number of progeny, R_{t-5}. Interest here, however, lies in the number of these recruits that survive to adulthood and return to the John Day basin, denoted as N_t.

As noted before, environmental factors and fishing pressure both contribute to the mortality which determines N_t. Mortality can act in either an additive or a multiplicative manner. Harvesting 100 fish regardless of the total population is an example of additive mortality whereas harvesting 10% of the population represents a multiplicative form. Mortality due to environmental conditions is usually multiplicative in fashion (Peterman 1981) and will be assumed to be so

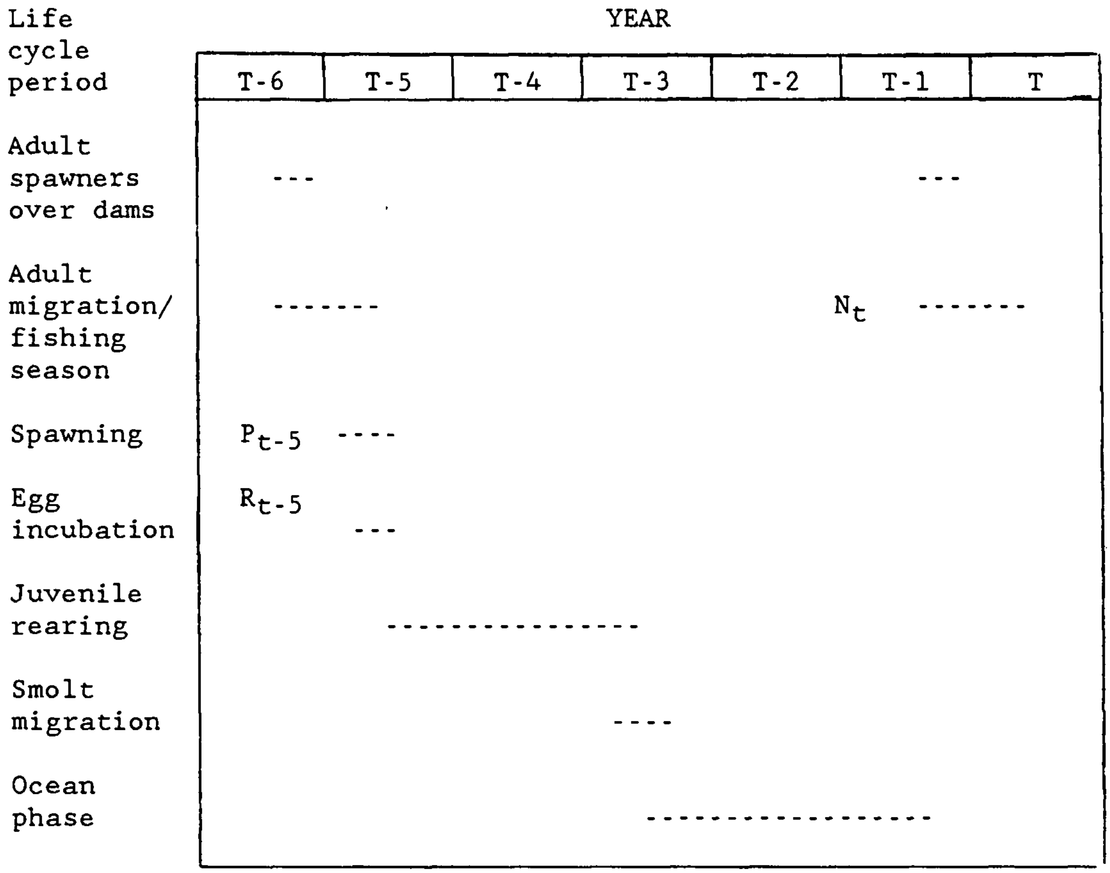

Figure 5.3. Hypothesized 2-fresh, 2-salt life cycle of John Day summer steelhead.

in this analysis. N_t can now be related to R_{t-5} by:

$$(5.3) \qquad N_t = R_{t-5} \prod_{i=1}^{n} (1-m_i)$$

where m_i is the conditional mortality rate associated with the ith environmental factor and $1-m_i$ is the corresponding conditional survival rate. Combining expressions (5.2) and (5.3) we obtain:

$$(5.4) \qquad N_t = \alpha P_{t-5} e^{-\beta P_{t-5}} \prod_{i=1}^{n} (1-m_i) * v'$$

where v' is a random error term. Specifying the error term as a multiplicative log-normal distribution is in keeping with the assumed multiplicative nature of the mortality (see Peterman 1981 for further explanation and empirical support). By taking the natural logs of both sides, this expression can be converted to a linear form and the parameters estimated via linear regression methods:

$$(5.5) \quad \ln N_t = \ln \alpha + \alpha' \ln P_{t-5} - \beta_0 P_{t-5} + \sum_{i=1}^{n} (\beta_i \times E_i) + v$$

where the β_i's are a measure of the mortality due to the ith environmental factor. Notice that a coefficient has been included on $\ln P_{t-5}$. The Ricker model assumes that this is equal to one. This arises by assuming all density dependent mortality can be represented via the β coefficient. The validity of this assumption will be tested later.

Data

Measurement of Stock Levels

Lacking direct measurement of adult escapement, another approach must be employed to estimate stock levels. As noted in Ricker (1975), fishing success is often related to stock level as follows:

$$C/E = qN \tag{5.6}$$

where C is catch, E is effort, and q is what is known as the catchability coefficient. Catch statistics are available from creel surveys conducted annually in the John Day basin since 1958 (Errol Claire, ODFW, unpublished data) and offer an index of stock level. Before adapting expression (5.6) to the present purposes of this research, however, it is necessary to make several assumptions. First, since catch per unit effort varies between individuals according to skill level, one key assumption is that the relative number of anglers in each ability group is constant over time. If this did not hold true, the estimate of N_t could be biased. Unfortunately, it is impossible to know the composition of anglers by ability group that were included in the creel surveys. However, given the large sample size of the creel surveys, any bias present due to the assumption of constant proportional ability groupings is probably small.

The largest source of possible error, as noted by Ricker (1975), is variability in the catchability coefficient. This variability may be due to water conditions during the fishing season, individual differences between fish, congestion of fishermen, or the temporary depletion of the stock in one area. Given that the creel surveys were taken over the entire season, it is assumed that any short-term changes in the catchability coefficient would tend to even out.[2] The index for parental stock, N_t, was defined as steelhead caught per 100 hours of fishing in year t.[3]

There are at least three options for measurement of the parental stock. First, it is obvious that the index of returning fish constructed from the success rate is also an index of the parent stock of those fish returning in five years, i.e., $N_{t-5} = P_{t-5}$. However, using the same estimates of fish populations for two different variables has the potential of leading to correlated errors between periods t-5 and t.

A second index of parental stock is redd counts. (A redd is the spawning nest dug out by the female.) Redd counts are available starting in 1959 (E. Claire, ODFW, unpublished data). These counts, however, are subject to unknown sampling error due to changes in water conditions during the spring sampling period.

A third index available is the dam counts on the Columbia River. Steelhead and other fish migrating upstream must pass through fish ladders where they are tabulated by species. By taking the difference

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[2] A variable measuring streamflow during the fishing season was originally included in the model to account for possible interseasonal changes in q due to different water conditions. This variable proved to be insignificant and was excluded from the final model.

[3] The steelhead fishing season spans two years, i.e. late 1986/early 1987. Stock subscripts for this population denote the latter year, i.e., N_{1987}.

between counts at two dams, the number of steelhead entering tributaries or being caught in the fishery between the dams can be estimated. Ideally, the "drop-out" numbers between John Day Dam and McNary Dam would be preferred. John Day Dam, however, was not completed until 1968. This limits the length of the time series available for use in estimating the biological models. Counts between The Dalles Dam and McNary would have to be employed instead. The Deschutes River, another major steelhead river, enters the Columbia in this stretch and would contribute considerable variation to the estimate of John Day steelhead escapement. A further drawback of dam counts arises when one considers that these fish must first pass through and survive the recreational fishery on both the Columbia and John Day before spawning.

The correlation between success rates, redd counts and dam counts was examined to evaluate which parent stock measure to use. The results, presented in table 5.1, indicate that redds are a better predictor of fishing success than "drop-out" numbers. The strong relationship between redd counts and fishing success is illustrated in figure 5.4, where both of these indices are plotted on the same graph. This strengthens the belief that both the success rate and redds are good indices of fish populations. The number of redds per mile, lagged 5 years, was thus included in the final model as a measure of parental stock, P_{t-5}.

Freshwater Environment

A hypothesis of this thesis is that low summer flows decrease

Table 5.1. Relationship between catch rate, redd counts, and dam "drop-out" numbers. John Day steelhead fishery, 1959-1985.

Dependent variable /a		Constant		Estimated coefficient /b	Independent variable /a	R2
CR	=	2.67 (2.43)	+	0.000086 (3.06)	DC	0.27
RC	=	5.52 (3.47)	+	0.000032 (0.78)	DC	0.02
RC	=	1.3625 (1.26)	+	0.922 (5.45)	CR	0.54

a/ CR = catch rate. Steelhead per hundred hours of fishing.
RC = redd count. Redds per mile.
DC = dam counts. Calculated as steelhead passage over The Dalles Dam in July and August less steelhead passage over McNary Dam during the same period. For data sources, see Appendix E.
b/ t statistics are presented in parentheses.

fishery productivity. There are other factors which also influence juvenile survival, some of which can be linked to streamflow. A representative streamflow pattern for the North Fork of the John Day as measured at Monument, Oregon, is shown in figure 5.5. Comparing this with the steelhead life cycle of figure 5.3 suggests a number of variables to include as sources of mortality. These variables and _a priori_ expectations of their affect are summarized below:

1. Spring streamflow, lagged 5 years, SP_{t-5}. High flows have the potential of scouring spawning beds and destroying newly laid eggs (Shepard and Withler 1958).

2. Summer flow, lagged 5 years, SU_{t-5}. Increased water temperatures and decreased habitat area resulting from low flows would increase mortality rates. Steelhead are most productive when stream

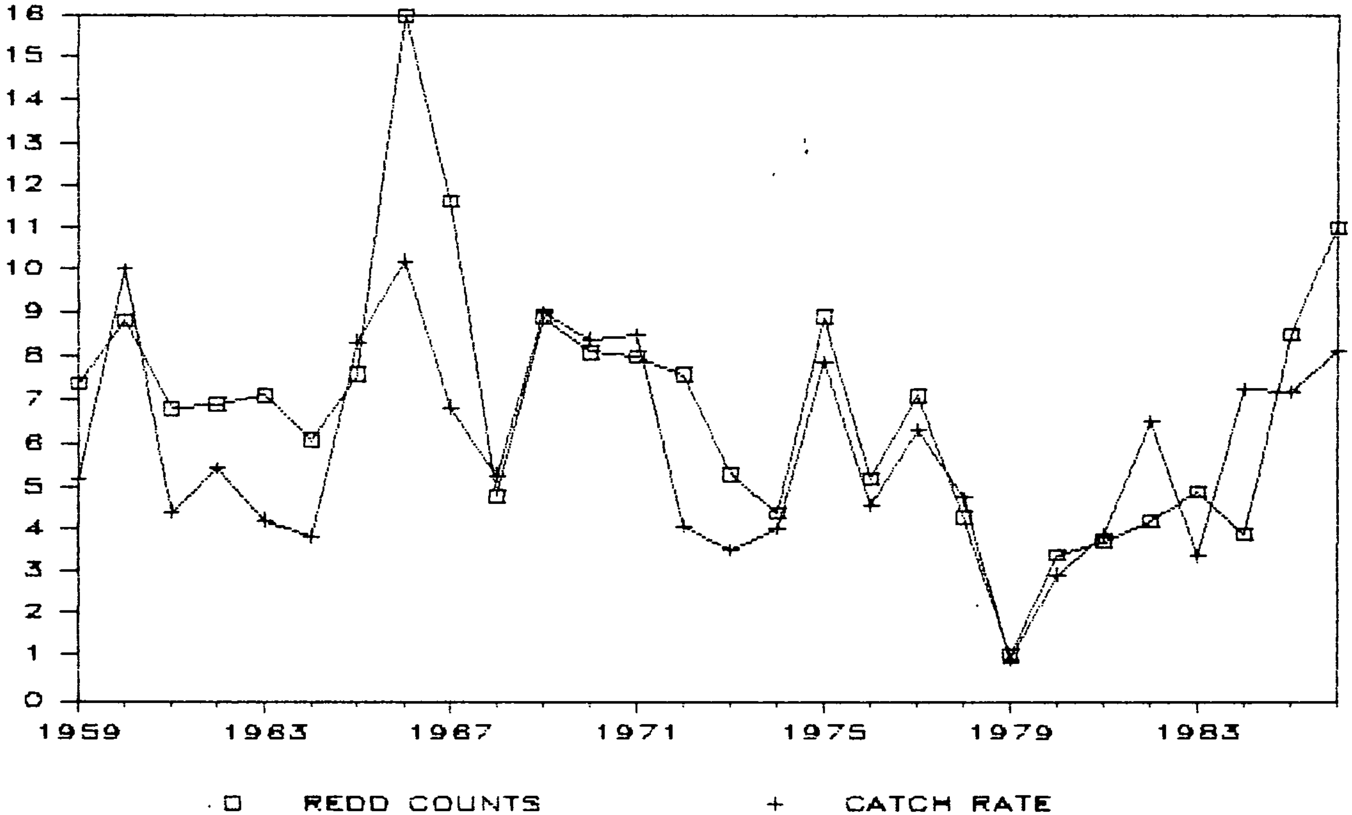

Figure 5.4. Redd counts and angler success, 1959-1986.

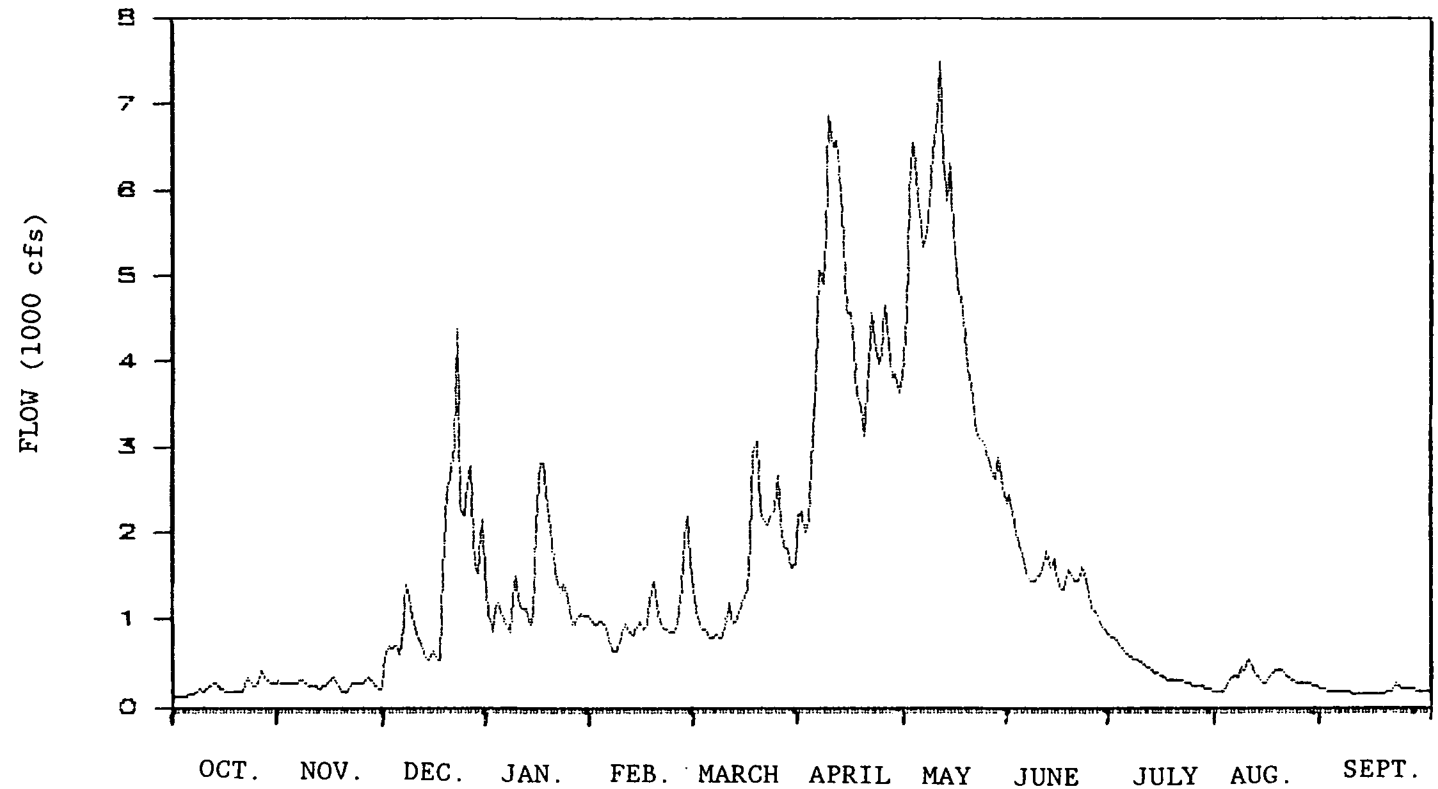

Figure 5.5. Streamflow pattern on the North Fork John Day River at Monument, Oregon, water year 1975-76.

temperatures are between 45 and 58^{o}F (Reiser and Bjornn 1979). Summer stream temperatures in the upper 70's and lower 80's have been measured on some stream reaches within the basin (Bureau of Reclamation 1985).

3. Winter flow, lagged 4 years, W_{t-4}. Cold air temperatures in the John Day basin during this period have the potential of causing anchor ice in the streams and a corresponding increase in mortality (Bureau of Reclamation 1985). Higher streamflows would reduce the probability of ice-ups and might also be indicative of warmer temperatures.

4. Spring flow, lagged 4 years, SP_{t-4}. High flows not only destroy eggs as mentioned above, but also destroy pool/riffle habitat, increasing competition for limited space (ODFW 1985b).

5. Summer flow, lagged 4 years, SU_{t-4}. By their second summer juvenile steelhead are better able to compete with other fish for useable habitat. Therefore, we might expect a lower relative influence of this flow on mortality than the previous summer's flow. Additionally, excluding this variable might lead to biased estimates of SP_{t-4} since summer and spring flows are correlated.

Other flows could be added but their inclusion is questionable and increases the possibility of spurious correlations. All flow data come from the United States Geological Survey (various years) which maintains several stream gages within the John Day basin. Since 40% of the steelhead are produced in the North Fork and 25% in the Middle Fork (see table 5.2), streamflow measurements at Monument, on the North Fork below the confluence of the Middle Fork (see figure 1.1),

Table 5.2. Distribution and escapement of steelhead trout and chinook salmon in the John Day River basin, Oregon.

	Steelhead		Chinook	
	Numbers	Percent	Numbers	Percent
Main Stem	1,400-4,200	20	270-750	15
South Fork	1,050-3,150	15	0	0
Middle Fork	1,750-5,250	25	270-750	15
North Fork	2,800-8,400	40	1,260-3,500	70
Total	7,000-21,000	100	1,800-5,000	100

Source: Bureau of Reclamation (1985) p.95.

were used to construct all of the flow variables. Spring flow (April - June) was defined as the average flow, expressed in cubic feet per second. Summer (July - September) and winter (January - March) flow variables were similarly constructed.

Marine Environment

Considerable variation in marine survival rates for anadromous species has been observed (Peterman 1981). This indicates the need to include an index of ocean productivity in any John Day steelhead model. Two possible indices of marine productivity are available: (i) upwelling and (ii) the relative production of other steelhead stocks.

Ocean upwelling plays an important part in ocean productivity for coho salmon (Oncorhynchus kisutch) (see Scarnecchia 1981, Clark and McCarl 1983, McCarl and Rettig 1983, and Nickelson 1986). A positive causal relationship between upwelling and steelhead production, however, has not been documented and, due to the life history of steelhead, is not expected to exist (N. MacHugh, ODFW, personal communication 1987). Studies examining the migration of steelhead indicate that they spend their ocean phase in the western Pacific where upwelling areas are comparatively small. Any influence from upwelling in the eastern Pacific would have to occur during first arrival in the ocean or immediately preceding return to the Columbia River. Appropriate time lags were included on the upwelling variable to test for these hypothesized relationships. The same upwelling index as used by Nickelson (1986) is employed here. It is the sum of the monthly upwelling volumes (in cubic meters per second per 100 meters) for March through September.

A second measure of ocean productivity would involve constructing an index based on the marine survival of summer- or winter-run coastal steelhead stocks. By measuring the percentage of smolts released in a year that survive the marine environment to return (escapement plus sport-catch), an indication of marine mortality can be obtained. Such an index was available for the winter steelhead stock on the North Fork of the Alsea River, Oregon (N. MacHugh, ODFW, unpublished data). Unfortunately, a complete time series was not available and several years of the index were based on escapement percentage only. While limiting the index's usefulness as a measure of marine mortality experienced by John Day steelhead, its relationship with the upwelling index was estimated. The results (table 5.3) indicate a significant correlation between the Alsea smolt survival index and upwelling volume two years after the smolts enter the ocean. This correlation,

Table 5.3. OLS estimation of relationship between ocean upwelling and marine survival of Alsea River winter steelhead, 1959-1982 North Fork release groups.

Dependent variable		Estimated coefficients /a			R^2
		Constant		Ocean upwelling volume$_{t+2}$	
Alsea STW index	=	3.09	+	0.0056	0.22
		(2.31)		(2.34)	
ln(Alsea STW index)	=	1.11	+	0.0012	0.26
		(4.31)		(2.56)	

a/ t statistics are presented in parentheses.

however, is not a direct cause and effect relationship, as the escaping adults have returned to spawn prior to this upwelling period (N. MacHugh, ODFW, personal communication, 1987). Still, given the good correlation, it might be possible to use the upwelling index as a "proxy" for Alsea winter steelhead survival. This essentially allows one to use a more complete time series. It must be kept in mind however, that any correlation found between upwelling and John Day steelhead survival is not necessarily a cause and effect relationship.

Migration Route Influences

Perils facing steelhead and salmon are not limited to their fresh water rearing habitat and the marine environment. Migration to and from the sea presents its own set of hazards. For fish in the Columbia River drainage, hydroelectric dams present a formidable obstacle. During the late 70's, average juvenile mortality was estimated at over 20% per dam and it's associated reservoir. In low flow years juvenile mortality was as high as 45% per dam. Adult mortality per dam varied from 2% in low flow to 20% in high flow years (Columbia River Fisheries Council 1981). Smolt mortality is due to several factors. Nitrogen supersaturation, leading to "gas bubble disease", is a problem in high flow periods when large amounts of water are released over the spillways. Installation of spillway flow deflectors has helped to reduce the level of nitrogen supersaturation. Mortality due to passage through turbines is also a problem which is being remedied. Installation of fish screens and juvenile bypass systems in the late 1970's and early 1980's has decreased the mortality linked to the turbines. A third cause of mortality is associated with the alteration of the flow regime of the Columbia River. Lower spring flows increase the time needed by smolts to reach the ocean. Dam operators have recognized this and have begun manipulating the flows to decrease this problem (Columbia River Fisheries Council 1981).

These continuing improvements in management practices and bypass facilities point towards including a variable which accounts for these management changes over time. Unfortunately, definition of such a variable would entail considerable study and was not attempted in this thesis. Instead, a dummy variable to account for the construction of the John Day Dam was employed. This variable is equal to zero for the years through 1968 and equal to one thereafter. To accomodate the hypothesized life cycle, a three year lag is used.

Estimation Problems Associated With Life Cycle Variability

Some anadromous species, such as coho, exhibit a relatively uniform life cycle. Steelhead, unfortunately, do not fall into this classification. The modified Ricker model developed above (equations 5.4 and 5.5) was used under the assumption that all returning adults are of the same cohort class. The life cycle presented in figure 5.3 assumed a 2-fresh / 2-salt life cycle, resulting in returning spawners 5 years old (allowing 1 year for the migration periods). Thus, a surviving steelhead fry emerging in 1981, for example, would be expected to return and spawn in 1986. A critical question concerns the variability in this life cycle and the implications for model estimation when large variability is present.

The problem faced is illustrated in a modified life table format in table 5.4. Assume, for illustrative purposes, that the stock of returning fish from a given parent stock is composed not only of five-year olds, but also of four and six year-olds. If we measure the standing crop of fish spawning in a given year, say 1981 (denoted as SC81), we would have a measure of the parental stock of four year-olds returning in 1985, of five year-olds returning in 1986, and of six year-olds returning in 1987.

A problem arises, however, in measuring how many steelhead of a given cohort survive to return, since these fish are scattered over (at least) a three year period. Ideally, if one is interested in knowing the number of fish from the 1981 cohort that survived to return and spawn, an estimate of CH81 is needed (table 5.4). In the present analysis, assuming a uniformly fixed 5 year life cycle, only

Table 5.4. Modified life table for John Day steelhead.

COHORT CLASS (year)	STANDING CROP /b (year of return) 1984	1985	1986	1987	1988	total /a
1978	N78,6					
1979	N79,5	N79,6				
1980	N80,4	N80,5	N80,6			CH80
1981		N81,4	N81,5	N81,6		CH81
1982			N82,4	N82,5	N82,6	CH82
1983				N83,4	N83,5	
1984					N84,4	
total /a	SC84	SC85	SC86	SC87	SC88	

a/ "CH" stands for cohort and "SC" stands for standing crop.
b/ Nt,x represents the number of x-aged adults returning to spawn in year t+x.

SC86 is used as a measure of CH81. Given the observed variation in life cycles, this is clearly erroneous and will lead to biased estimates.

Given proper data, it would be possible to circumvent this standing crop/cohort problem. An "age decomposition" of returning fish is possible by examining the scales of returning fish. Unfortunately, the record of scale samples for John Day steelhead is incomplete. Other attempts, such as assuming a constant distribution between returning age classes, were made to circumvent this problem but with no success.

In the end it was decided that the only remedy was to use an alternate interpretation of the model. Instead of measuring the impact of environmental factors on the survival of a specific cohort class, the estimated coefficients now indicate a variable's combined effect on survival and deviations from the hypothesized 5 year life cycle. A more detailed explanation and an example are presented in the results and discussion sections.

Results

The final model estimated was specified as:

$$(5.7)\quad \ln N_t = \ln \alpha + \ln (P_{t-5}) + \beta_0 P_{t-5} + \beta_1 SP_{t-5} + \beta_2 SU_{t-5} + \beta_3 W_{t-4} + \beta_4 SP_{t-4} + \beta_5 SU_{t-4} + \beta_6 D3 + \beta_7 (U_{t-1}+U_{t-2})$$

Equation (5.7) was estimated using ordinary least squares (OLS). The statistical package SHAZAM (White, 1978) was used in estimating both the Ricker and Beverton-Holt models. (See Appendix F for Beverton-Holt model results.)

Regression results showed problems when 1984 and later years were included in the analysis. The possible causes of this include changes in ocean survival and/or changes in migration mortality. Nickelson (1986) had similar difficulties when including 1984 data in his analysis of coho survival (Nickelson, personal communication, 1986). In addition, examination of scale samples from the 1983/84 sport fishery shows that returning fish were composed of a large percentage of 1-salts. Due to these unmeasured shifts in mortality and life cycle patterns, only the years 1964-1983 were used to estimate the model parameters. The years 1984-1986 were subsequently forcasted using the estimated coefficients from the 1964 to 1983 period.

Results also indicated that upwelling variables with a one and two-year lag were statistically significant whereas a three-year lag proved insignificant. Therefore, the estimated model included the sum of the upwelling volumes, as defined before, for the two years prior to adult return. This time lag is in agreement with the relationship observed for Alsea winter steelhead.

As previously hypothesized, the coefficient on ln (P_{t-5}) was not significantly different from one. It was subsequently restricted to equal one, and the equation reestimated. Results of the restricted and unrestricted OLS estimations are presented in Tables 5.5 and 5.6, respectively. With one notable exception, all coefficients had signs consistent with a priori expectations.

First examination of the negative coefficient on SU_{t-4} and the positive coefficient on SU_{t-5} might lead one to conclude a contradictory relationship with respect to increasing summer stream flows: alternately increasing survival of one cohort while decreasing survival for another. This would be a correct interpretation if the model used cohort data to measure survival. However, the previous discussion on use of standing crop in place of cohort data reveals another hypothesis: Increases in summer flows lead to greater growth rates, resulting in shifts away from a 5-year life cycle.

Current knowledge of salmonid life cycles indicates that increased growth rates in fresh water may result in earlier smolting. However, time spent in the ocean is believed to be solely dependent on ocean conditions, independent of size at smolting (Jay Nicholas, ODFW, personal communication, 1987). If this is true, then increasing the growth rate of 1+ age steelhead will reinforce the tendency of

Table 5.5. Restricted OLS Ricker model estimation. John Day summer steelhead 1964-1983. Dependent variable: $\ln(N_t)$

Variable /b	Estimated /a coefficients	Standardized coefficient	Elasticity at means
Constant	0.833 (0.492)		
P_{t-5}	-0.128 *** (0.0243)	-0.620	
$\ln(P_{t-5})$	1.00 /c	0.578	
SP_{t-5}	-0.000510 *** (0.000123)	-0.927	-1.375
SU_{t-5}	0.00382 ** (0.00135)	0.613	0.780
W_{t-4}	0.000316 ** (0.000101)	0.486	0.497
SP_{t-4}	-0.000239 (0.000119)	-0.457	-0.671
SU_{t-4}	-0.00254 * (0.00101)	-0.406	-0.523
D_{t-3}	-0.390 ** (0.139)	-0.356	
$U_{t-1}+U_{t-2}$	0.00109 ** (0.00029)	0.458	0.778

Observations = 20 (1964-1983) 11 degrees of freedom

R-squared = 0.897 Adjusted R-squared = 0.823

Durbin-Watson d-statistic = 1.87 rho = -.00745

a/ standard errors are presented in parenthesis.
Level of significance using two-tailed t-test: *0.05 **.02 ***.002

b/ See Appendix E for source and explanation of variables.

c/ The original estimated coefficient on ln(Pt-5) was 1.311 with a standard error of 0.943. This is not significantly different from one (t-statistic = 0.33). It was subsequently restricted to equal 1.00 and the equation reestimated.

Table 5.6. Unrestricted OLS Ricker model estimation. John Day summer steelhead 1964-1983. Dependent variable: $\ln(N_t)$

Variable /b	Estimated /a coefficients	Standardized coefficient	Elasticity at means
Constant	0.463 (1.23)		
P_{t-5}	-0.161 (0.105)	-0.782	
$\ln(P_{t-5})$	1.311 (0.943)	0.758	
SP_{t-5}	-0.000509 ** (0.000128)	-0.926	-1.374
SU_{t-5}	0.00376 * (0.00142)	0.604	0.768
W_{t-4}	0.000298 * (0.000119)	0.458	0.469
SP_{t-4}	-0.000220 (0.000138)	-0.420	-0.618
SU_{t-4}	-0.00254 * (0.00105)	-0.406	-0.523
D_{t-3}	-0.379 * (0.149)	-0.345	
$U_{t-1}+U_{t-2}$	0.00108 ** (0.00031)	0.454	1.292

Observations = 20 (1964-1983) 10 degrees of freedom

R-squared = 0.898 Adjusted R-squared = 0.807

Durbin-Watson d-statistic = 1.86 rho = -.00881

a/ standard errors are presented in parenthesis.
Level of significance using two-tailed t-test: *0.10 **.05

b/ See Appendix E for source and explanation of variables.

juveniles to smolt after two years in fresh water. Hence, the only way to shift away from the assumed 5-year life cycle would be for average ocean age composition to shift towards a greater percentage of 1-salt fish. Evidence of shifts in life cycles can be found in recent analyses of scales from steelhead caught in the John Day sportfishery (see table 5.7). If a positive link can be found between size at

Table 5.7. Age composition of John Day steelhead. /a

	Freshwater age				Ocean age						Repeat spawners	
	2		3		1		2		3			
Year	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
1955-61	15	55.6	12	44.4	0	0	23	85.2	4	14.8	-	-
1982-83	25	58.1	18	41.9	21	46.7	24	53.3	0	0	5	11.1
1983-84	30	71.4	12	28.6	38	88.3	4	9.3	1	2.3	1	2.3
1985-86	7	70.0	3	30.0	5	50.0	5	50.0	0	0	-	-
Fall 86	5	71.4	2	28.6	6	75.0	2	25.0	0	0	-	-

	Age at escapement /b					
	4		5		6	
	(n)	(%)	(n)	(%)	(n)	(%)
1985-86 /c	2	20.0	8	80.0	0	0
Fall 86 /d	5	71.4	1	14.4	1	14.4

source: Data for 1955-61, 1982-83, and 1983-84 come from ODFW (1985a, unpublished memorandum. Data for 1985-86 and fall 1986 were obtained from N. MacHugh, ODFW Research Section, Corvallis, Oregon.
a/ Based on scales of fish taken in the sport fishery.
b/ Age at escapement equals freshwater age + ocean age + one year for migration. Only 1985-86 and fall 1986 data are decomposable to yield total age.
c/ Scales from 11 steelhead were analized. The complete results were:
Fall fishery: W 2/1, W 2/2, W 2/2.
Spring fishery: W 2/1, W 2/2, W 2/2, W 2/2, W 3/1, W 3/1, W 3/1, H/2.
d/ Scales from 8 steelhead were analized. The complete results were:
Fall fishery: W ?/1, W 2/1, W 2/1, W 2/1, W 2/1, W 2/1, W 3/1, W 3/2.
W denotes wild fish; H denotes hatchery fish; first number denotes freshwater age; last number denotes ocean age.

smolting (or another smolt characteristic influenced by increased summer streamflows) and length of stay in the ocean, the analysis of benefits from altering stream flow patterns would be complicated on at least two counts. First, one year of ocean mortality will be eliminated, ultimately leading to improved catch rates in the sport fisheries. Secondly, 1-salt fish are, on average, smaller than 2-salts. This will have negative consequences on the value of the fishery if anglers place a higher value on larger fish. The implication drawn from these possibilities is that these observed shifts in ocean age deserve more study.

Discussion

The emphasis of this chapter has been on estimating the influence of environmental conditions on the production of John Day steelhead trout. While the interest here lies primarily with the effect that alterations in streamflows have on the success rate experienced by sport anglers, several brief observations will be made before turning attention in that direction.

Choice and Specification of a Stock-Recruitment Model

Two comments regarding the selection and use of stock-recruitment models are in order. First, the choice of a Ricker stock-recruitment model as opposed to the Beverton-Holt model has not affected the results. This is evidenced by the close agreement between the estimated coefficients obtained from the two models. A second comment regarding the practice of restricting the coefficient on $\ln(P_{t-5})$ in the Ricker model to equal one is in order. Past studies (such as Anderson and Wilen 1985) have implicitly or explicitly made this restriction. However, this may lead to inaccurate t-statistics on P_{t-5}. The results give t-statistics of -1.54 and -5.28 in the unrestricted and restricted models, respectively. This may be due to the coefficient on P_{t-5} "adjusting" for the restriction on the logged version of P_{t-5}. In fact, in restricting $\ln(P_{t-5})$ to a larger number the t-statistic on P_{t-5} also increases. Alternately, the low t-statistic in the unrestricted model may merely be due to collinearity between the two variables. While this doesn't affect the results, the cause of the discrepancy in t-statistics is of concern in studies which have hypotheses concerned with the influence of parental stock numbers and density on juvenile recruitment.

The Influence of Ocean Upwelling on Ocean Survival

A significant correlation was found between upwelling volume and John Day steelhead productivity (significant at the .02 and .002 level for the Ricker and Beverton-Holt models, respectively). As noted before, it is unlikely that upwelling in the eastern Pacific significantly affects John Day steelhead productivity. However, the ocean environment is complex and a link may exist between the upwelling variable and an (unmeasured) variable which does influence ocean productivity. This correlation between upwelling and ocean productivity of both John Day summer and Alsea winter steelhead stocks points towards further research in this area.

Mortality Due to John Day Dam

The mortality due to the John Day Dam can be calculated as:

(5.8) $$\text{mortality} = 1 - \exp[-0.0379] = 31.5\%$$

This is in agreement with the observed combined juvenile and adult mortality levels reported by the Columbia River Fisheries Council (1981). The magnitude of this mortality points towards the importance and potential impact of improving dam bypass facilities on the Columbia River. As previously noted, efforts at reducing dam mortality began in the late 1970's (Columbia River Fisheries Council 1981). This may partially explain the robustness problems encountered when 1984 and later years were included in the estimated time series (another cause, for 1983/84 steelhead, was the shift towards a 1-salt life cycle). Examination of residuals when 1984 and later years were estimated using the estimated coefficients for 1964-1983 reveals a positive trend in these later years. If future fish returns continue to be greater than those predicted by the study model, this would lend support to the notion that mortality due to Columbia River dams has decreased.

Influence of Streamflow on Steelhead Production and Angler Success

With the exception of SU_{t-4}, all coefficients had signs corresponding to a priori expectations. The next step is to use these results to predict the effect that alterations in streamflows have on fish populations and angler success rates. Use of the streamflow-steelhead production elasticities will provide a convenient means of doing this. Since angler success rates were used as an index of adult escapement the interpretation is relatively straight forward. The streamflow-angler success elasticities can be defined as

$$\frac{\%\ \Delta \text{ in angler success}}{\%\ \Delta \text{ in streamflow}}$$

Tables 5.5 and 5.6 report these values for ocean upwelling and each of the streamflow variables, as calculated at the mean value of the relevant variable. Elasticities at other flow levels can easily be calculated as the product of the coefficient and the flow level in question. The interpretation of these elasticities is relatively straightforward. Spring streamflow, for example, if increased 1 percent will lead to a 0.52 percent reduction in angler success four years later and a 1.38 percent reduction in angler success the next year. Summer flow, in contrast, if increased 1 percent, will increase angler success five years later by 0.78 percent.

The interpretation of the elasticity of SU_{t-4} is more difficult. As previously hypothesized, this flow period may shift steelhead away from the assumed 5-year life cycle. If so, one would anticipate an increase in success rates during another year, most probably the year prior to the anticipated return date. This was not tested in the model, and may actually be impossible to estimate given available data.

One caveat must be attached to the above streamflow/angler success elasticities. As included in the model, the flow variables measure the <u>average</u> flow over three month periods. This ignores critical periods during these months when a marginal increment in flow is more productive (or destructive, for spring flows) when compared to marginal increments in other periods. Whether this makes a large difference from a management standpoint will depend on how accurate the identification of critical periods is and to what degree managers can "target" additional flows to occur in these periods. The more accurate the identification and targetting, the more the magnitudes of the above elasticities should be increased.

Concluding Comments

The above biological models provide a means of linking streamflow to the production of steelhead trout and the effect on the quality of the sportfishery. A caution, however, should be attached to the use of the preceding results. It is tempting to say that this model shows where changes should be made to increase the production of steelhead. Certainly the model identifies sources influencing the survival of steelhead. However, it is important to realize what the model doesn't say. In selecting variables to measure environmental sources of mortality, emphasis was on those which exhibited variability and were measureable. Thus the rationale for inclusion of streamflows, upwelling, and the dummy variable for the John Day Dam. Other unmeasurable or unvarying sources of mortality were not included. Hence, the impact of Bonneville and The Dalles Dams could not be quantitatively measured. Other sources of mortality were omitted as well. Indeed, it may well be that the best way to increase steelhead production is not to change streamflows but to alter some other aspect of the ecosystem.

CHAPTER 6

BENEFITS AND COSTS OF ALTERATIONS IN STREAMFLOWS: A SUMMARY

The preceding chapter examined the effect streamflow has on the production of steelhead trout, with the aim of estimating the resultant change in value experienced by recreational anglers due to an improvement in streamflow patterns. That estimate, presented at the beginning of this chapter, is one component of the marginal value of instream water. Up until now, the analysis has had a relatively narrow focus, abstracting from the multiple use nature of water resources and associated ecosystems. Further, there has been no discussion of mechanisms for achieving these streamflow alterations, or even if this is the most efficient means of increasing anadromous fish production. The discussion is now expanded to touch on some of these topics.

The purpose of this chapter is four-fold. First, the results of Chapters 4 and 5 will be combined to arrive at the benefits generated in the steelhead sportfishery due to changes in streamflow. Interest here lies mainly in the value attached to instream water during the summer months. Nevertheless, values for streamflow alterations in the spring and winter will also be estimated. Second, other instream and out-of-stream water users that might benefit from an alteration of instream flows will be summarized and the potential magnitude of these values discussed. Third, methods of altering temporal streamflow patterns will be discussed. Lastly, the impact of agricultural, range, and timber activities on anadromous fish production will be reviewed.

Instream Benefits

The Value of Water in the Production of Steelhead Fishing

Chapter 4 derived the value of marginal changes in the quality of the John Day steelhead fishery. By combining these results with the streamflow/fish production results of Chapter 5, a value function for instream water can be obtained.

The angler success/streamflow elasticities are

$$\frac{\%\ \Delta\ \mathrm{HRSFISH}}{\%\ \Delta\ \mathrm{FLOW}_i} = \epsilon_i = \beta_i \times \mathrm{FLOW}_i \qquad (6.1)$$

where β_i is the coefficient on the ith streamflow variable, FLOW_i, and HRSFISH is the catch rate in hours per steelhead. By multiplying through by $\%\ \Delta\ \mathrm{FLOW}_i$ and rearranging,

$$\Delta\ \mathrm{HRSFISH} = \beta_i \times \Delta\ \mathrm{FLOW}_i \times \mathrm{HRSFISH} \qquad (6.2)$$

This can be inserted into equation (4.9), repeated here as

$$\underset{(\mathrm{base} = 17)}{\mathrm{AGG.\ WTPc}} = 54 + 2366\ \Delta\ \mathrm{HRSFISH} - 138\ (\Delta\ \mathrm{HRSFISH})^2 \qquad (6.3)$$

to arrive at

$$\mathrm{AGG.\ WTPc} = 54 + 2366\ (\beta_i \times \Delta\ \mathrm{FLOW}_i \times \mathrm{HRSFISH}) - 138(\beta_i \times \Delta\ \mathrm{FLOW}_i \times \mathrm{HRSFISH})^2 \qquad (6.4)$$

Since the base angler success rate is already specified as 17 hours per steelhead, this equation simplifies further to

$$(6.5)\ \text{AGG. WTPc} = 54 + 40{,}222\ (\beta_i \times \Delta\ \text{FLOW}_i) - 39{,}882\ \beta_i^2 \times \Delta\ \text{FLOW}_i^2$$

A marginal benefits function can be derived by taking the first derivative of (6.5) with respect to Δ FLOW$_i$ to yield

$$(6.6)\quad \text{MARG. WTPc} = 40{,}222 \times \beta_i - 79{,}764\ \beta_i^2 \times \Delta\ \text{FLOW}_i$$

However, recall that only flow for the North Fork John Day is included in the biological model. Since 65% of the steelhead stock is produced in the North and Middle Forks, equation (6.6) should be adjusted by a factor of 0.65, yielding:

$$(6.7)\quad \text{MARG. VAL. WATER} = 26{,}144 \times \beta_i - 51{,}847\ \beta_i^2 \times \Delta\ \text{FLOW}_i$$

Equation (6.7) is a useful format for calculating the marginal value of instream water. Calculations of the marginal value of water for summer, spring and winter are shown in table 6.1, column A. These values can be thought of as minimum marginal values of the water in the production of John Day steelhead fishing. The assumption that streamflow has to be changed over the entire 3-month period, rather than some shorter "critical" period, has led to a downward bias in the estimates.

Many John Day-reared steelhead are caught in the Columbia River sport and Indian gill-net fisheries. The value of additional catches in these fisheries due to improved streamflows is not represented in the above analysis. The Bureau of Reclamation (1985), in a study which will be discussed more in-depth later in this chapter, assumed that 1.5 John Day steelhead are caught in the various fisheries per each escaping John Day steelhead. Using this estimate and assuming the marginal value per additional sport caught steelhead ($7.19) can be transferred to these additional fisheries, one can obtain a more comprehensive estimate of the marginal value of instream water. Following similar lines of reasoning as employed in the previous analysis, one arrives at:

$$(6.8) \quad \text{MARG. VAL. WATER} = \Delta \text{ FISH CATCH} \times \text{MARG. VAL. FISH}$$
$$= [\beta_i \times \Delta \text{ FLOW}_i \times \text{ESCAPEMENT} \times 1.5 \times 0.65] \times \$7.19$$
$$= \beta_i \times \Delta \text{ FLOW}_i \times \$105{,}154$$

where ESCAPEMENT has been assumed to be 15,000. Results are shown in table 6.1, column B. As can be seen, the value of instream water is sensitive to what benefits are included in the measurement. Excluding out-of-basin benefits leads to an undervaluation of John Day River streamflow.

Instream water values estimated using the above procedure will depend on the assumptions made regarding the catch:escapement ratio as well as the total escapement level. For example, the 1.5 catch:escapement ratio is probably high given the current large runs of summer steelhead in the upper Columbia River basin. In addition, the 15,000 John Day escapement figure is probably low. A more accurate estimate of the current Columbia River catch:escapement ratio would be 0.5:1. Of the John Day steelhead which do escape the Columbia River fisheries, 15 percent, on average, are caught in the

Table 6.1. Marginal value of instream water in production of John Day Steelhead.

Period	β_i	Mean flow level (cfs)	\$ acre-foot /a	
			A	B
Spring	-0.000510	2,700	- \$ 0.075	- \$ 0.30
Summer	0.00382	204	\$ 0.56	\$ 2.26
Winter	0.000316	1,573	\$ 0.046	\$ 0.19

a/ Calculated by assuming a 1 cfs change over a 3-month period. Converted to acre-feet by dividing by 178.

John Day fishery (Errol Claire, personal communication, 1987). Thus, for every 150 returning John Day steelhead adults, 50 are caught in the Columbia River fisheries and 15 are caught in the John Day fishery. This gives out-of-basin benefits 3.33 times larger than in-basin benefits, resulting in a marginal value of summer flow equal to \$2.42 per acre-foot. This is close to the \$2.26 value obtained previously.

At this point several implicit assumptions in the above analyses should be noted. One assumption is that a given increase in flows at the Monument gage station is due to an equivalent increase in flows upstream. That is to say, a 100 acre-foot increase in flows at Monument is assumed to be due to an additional 100 acre-feet entering the river upstream. The validity of this assumption depends on the hydrologic characteristics of the river. A second assumption made is that increases in stream flowoccur "naturally". This is to stay consistent with the biological model which used naturally occuring flow patterns. However, if additional water was added to the river entirely at one point the analysis could change considerably.

Reiterating a caution expressed at the end of the previous chapter, it should be noted that the above benefits are due to changes in streamflows, ignoring any benefits arising from habitat improvements which may be simultaneously undertaken. That is, it is useful to think of fish production as relying on inputs of various components of habitat. Streamflow, water quality, adjacent riparian cover, the dynamics of the stream, and other ecosystem attributes all combine to "produce" fish. Therefore, the above values assigned to instream water have been estimated under the assumption that the relationship between streamflow and these other inputs remains constant. Given current and future habitat improvement projects planned for the John Day basin, this assumption is questionable. Considerable research is needed to quantify a streamflow-habitat/steelhead production relationship. However, the values for changes in angler success rates, as derived in Chapter 4, are valid, since they don't rely on how the improvement is brought about.

Other Recreational Fisheries

Steelhead are just one of several fish species which would benefit from an improvement in streamflow patterns. Resident game fish within the basin include rainbow, brook, Dolly Varden, and cutthroat trout, whitefish, brown bullhead, channel catfish, and smallmouth bass. In addition, a significant population of wild spring chinook salmon exists within the basin (ODFW 1985b). While this study does not attempt to measure the potential benefits accruing to these fisheries, several observations are in order.

While the basin's chinook sportfishery was closed in 1977, basin-produced salmon are caught in recreational and commercial fisheries outside of the basin. For small increases in commercial harvests, Huppert et al. (1985) suggest approximating the marginal net economic value of a commercially caught salmon as equal to 90% of the ex-vessel price. Yet another approach to benefit estimation would assume a reopening of the John Day's salmon sportfishery, and employ appropriate nonmarket valuation techniques.

Other Water-Based Recreation

Angling is not the sole water-based recreation activity within the John Day basin. A 157-mile segment of the mainstem John Day downstream from Service Creek is designated as part of the Oregon Scenic Waterways System. This segment of the river as well as other portions of the mainstem are used by river-boaters (canoes, rafts, drift, and jet boats). Several of the instream flow valuation studies summarized in Chapter 3 estimated values to campers and boaters resulting from an increase in streamflow. In this study, given the large number of possible streamflow scenarios and the specific focus on fisheries, a similar estimation was not attempted. However, a study by the Bureau of Reclamation (1985) examined the benefits associated with a proposed reservoir and riparian improvement project on the upper Middle Fork of the John Day. In assessing the benefits due to proposed increases in streamflow, the Bureau of Reclamation concluded that, "It is certain that the additional flows proposed for the John Day River would be a positive factor for recreation, but the magnitude of the flow increases would not provide significant benefit increases." (Bureau of Reclamation 1985, p. 56) For their proposed project, August flows 10 miles downstream would have been increased from the current average of 10 cfs to 50 cfs (Bureau of Reclamation 1985). Whether an alteration in streamflow produces benefits for instream water users other than anglers will depend on both the magnitude of the resultant flow changes on the mainstem and whether, for example, increased summer flows are left in the river after passing through the juvenile salmonid rearing areas or are diverted for agricultural use.

Out-of-Stream Benefits: Agriculture

The John Day basin has approximately 59,000 irrigated acres (1980 acreage). Most of this acreage is in the Dayville to Prairie City area and on the lower sections of the North Fork, where considerable orchard production exists. While agricultural diversions for irrigation have the potential to negatively affect anadromous fish stocks, agriculture would also stand to benefit from improved summer streamflows. This was supported by the previously cited Bureau of Reclamation (1985) study. Dependable water supplies for irrigation typically are exhausted by mid-July or early August and critical periodic shortages occur every third or fourth year. As a result, current cropping patterns (see table 6.2) include a high percentage of grain and forage crops which mature even when the water supply is

Table 6.2. Actual cropping patterns, selected reaches of John Day River basin, 1982.

	Percent of total acreage						
	Alfalfa	Grain	Pasture	Pot-atoes	Sun-flowers	Mint	Orchard
Monument to Kimberly	52.7	1.4	22.7	--	--	15.5	7.7
Kimberly to Service Creek	58.2	33.0	8.8	--	--	--	--
Service Creek to Twickenham	85.5	--	14.5	--	--	--	--
Twickenham to Clarno	50.9	11.3	32.7	2.6	2.5	--	--

Source: Bureau of Reclamation (1985), p. 23.

inadequate. Where climatic conditions are favorable, an assured water supply would allow more profitable crops such as mint, orchards, potatoes, and sunflowers to be grown. This shift to more profitable crops would be reflected in the value of irrigation water.

The Bureau of Reclamation (1985) used two procedures to estimate irrigation benefits from increased water supplies in the basin. By correlating values from another farming area in Oregon with similar cropping patterns, irrigation water was valued at $24.00 per acre-foot. An alternate method, employing a farm budget for a representative 320-acre family farm, valued irrigation water at $10.40 per acre-foot. By including mint in a mint-grain-alfalfa crop rotation, the average value of water for full supply was increased to

$54 per acre-foot. As is the case with fish production, the value of additional irrigation supplies will vary by location within the basin.

Mechanisms for Altering Streamflow Patterns

The storage of water in high runoff periods, to be released during periods of water shortage, has traditionally been achieved via the construction of dams and reservoirs. Two previous studies have studied the benefits and costs attached to the construction of such a dam and reservoir within the John Day basin.

In 1982 the U.S. Army Corps of Engineers (1982) noted that water storage in the basin had the potential "for producing electrical energy, augmenting low flow to improve water quality and conditions for fish, reduce flood damages, and supply water for irrigation" (Army Corps of Engineers 1982; p. 1). However, the dam sites evaluated would have inundated or blocked access to significant anadromous fish habitat. In addition, augmenting low flows downstream from the dam sites would have had little impact on anadromous fish production because little productive habitat exists in these reaches. Partially due to the negative impacts on fish stocks, none of the projects were deemed economically justifiable (U.S. Army Corps of Engineers, 1982).

The latest study, conducted by the Bureau of Reclamation (1985), realized the need to place any reservoir above the juvenile rearing areas. After studying several possible dam sites in the upper North and Middle Fork basins, a detailed analysis was conducted on the Phipps Meadow site on the Middle Fork. While the primary goal of the proposed project was the enhancement of anadromous fish production, other water based needs, such as irrigation, recreation, and flood control were also included in the benefit-cost analysis. The project consisted of two components: a dam and reservoir capable of holding 10,000 acre-feet of water, to be used to enhance summer flows, and a 23-mile riparian habitat restoration project downstream from the dam. Benefits and costs were calculated for the separate components and in combination. Final results indicate that, while the total project was not cost effective, with a benefit/cost ratio of 0.88, considerable benefits could be attributed to the riparian component, which had a B/C ratio of 7.7. The impact of the proposed project on steelhead and chinook production is shown in table 6.3. The majority of the increase in anadromous fish production can be attributed to the riparian restoration component.

Table 6.3. Annual anadromous fish benefits attributable to flow releases and riparian habitat restoration from the potential Phipps Meadow reservoir, Middle Fork John Day River, Oregon.

Species	Adult Escapement	Net Increase
Without the project		
Steelhead	1710	
Spring Chinook	550	
With the project		
Flow enhancement only		
Steelhead	2693	983
Spring Chinook	803	253
Riparian enhancement only		
Steelhead	4650	2940
Spring Chinook	1500	950
Flow and riparian enhancement		
Steelhead	6191	4481
Spring Chinook	1890	1340

Source: Bureau of Reclamation (1985), page 97.

As an aside, it is worth noting that the Bureau of Reclamation's study valued each escaping adult steelhead and chinook salmon spawner at $279 and $282, respectively. This value was obtained by assuming that 1.5 steelhead and 2 spring chinook are caught in the various fisheries per escaping spawner. The discussion at the end of Chapter 4 raises doubts as to the validity of these values and the benefit/cost ratios obtained. This further highlights the need of obtaining reliable and theoretically consistent estimates of fish values.

Riparian Improvements

Early explorers and settlers reported that the John Day River was once a relatively stable river with diverse and abundant riparian vegetation, good summer streamflows, and high water quality. Since these reports, habitat degradation caused by mining, forestry, agricultural, and range activities have led to significant reductions in anadromous fish populations (ODFW 1985b). Similar changes have been reported in other areas of the West (Platts 1981). Reversing these impacts has the potential of yielding significant benefits via increased fish and wildlife production (Hall and Baker 1982, Kauffman and Krueger 1984). In addition, riparian restoration may lead to increased summer flows. Winegar (1977, 1978) reported an unexpected increase in streamflow after riparian vegetation was improved in a 9.6 km section of a heavily eroded gully. In addition to increased flows and improved water quality, the stream no longer consistently freezes solid in the winter. In view of the potential importance of riparian management in fisheries improvement, the next section presents a more detailed treatment of this issue.

The Impact of Adjacent Resource Utilization on the Production of Anadromous Fish

Up to this point attention has focused almost entirely on identifying and valuing the impact of streamflow on anadromous fish production. Streamflow, however, is just one characteristic of aquatic and land ecosystems necessary for the production of these species. As a consequence, altering streamflow alone, without consideration of other environmental inputs, may not be the most efficient means of increasing fish production.

Table 6.4 shows the current land use patterns for Grant County, Oregon. Grant County encompasses the upper mainstem, the South and Middle Forks, as well as a high percentage of the North Fork John Day

Table 6.4. Existing land use, Grant County, Oregon.

Land use	Acres	Percent of total
Timber	1,604,968	55.3
Range	1,248,731	43.0
Irrigated cropland	30,410	1.0
Dry cropland	7,965	0.3
Urban	4,621	0.2
Other /a	4,425	0.2
Total	2,901,120	100.0

source: Bureau of Reclamation (1985), p. 41, as derived from Grant County, Oregon, Draft Comprehensive Plan, February 1980.
a/ Excludes the Strawberry Mountain Wilderness Area (34,560 acres) and Condon Fossil Beds (34,560 acres).

drainages. The large share of land devoted to range and timber is indicative of the economic base of the region and shows the degree of conflict possible between anadromous fish production and these other resource users.

Given the multiple use nature of public lands, decisions concerning anadromous fish habitat must consider the impact of any proposed policy or project on other resource users. Conversely, management decisions made by other resource users, such as agriculture, forestry and livestock, should incorporate the needs of anadromous fish production.

Forestry

Timber management practices and the construction of logging roads have been shown to adversely affect anadromous fish production. Negative impacts include: increased sediment load, increased summer and decreased winter stream temperatures, a reduction in large woody debris within the stream, changes in water chemistry, and an increased biochemical oxygen demand due to an increase in fine organic debris. Most studies on the impact of forestry practices on anadromous fish have focused on changes in habitat. The resultant effects on salmonid populations have not been fully assessed (Huppert et al. 1985). Examination of redd counts in the North Fork John Day drainage over a 25-year period (1959-1983) reveals a 73% decline in spawning densities on stream reaches impacted by increased timber harvest and road construction. Unlogged, roadless areas experienced smaller declines of 46%, reflecting a general decrease in escapement numbers (ODFW

1985b).

Agriculture

Most agriculture production in the John Day basin takes place downstream of juvenile rearing areas (Bureau of Reclamation 1985). However, as reported by ODFW (1985b), several areas have experienced decreased habitat for spawning, rearing and migrating fish due to excessive irrigation diversions. Agriculture may also adversely impact the riparian habitat along streams. This will be discussed further under the impact of livestock grazing, below.

Livestock Grazing

At the intersection of aquatic and land ecosystems is the riparian zone. The riparian ecosystem can be defined as "those assemblages of plant, animal, and aquatic communities whose presence can be either directly or indirectly attributed to factors that are stream-induced or related" (Kauffman and Krueger, 1984, p.430). It has been identified as possibly the most productive habitat in North America (Johnson 1977). It was not until the early 1970's, however, that the importance of this ecosystem to wildlife and fisheries resources became fully apparent (Platts 1981). As a result, the last two decades have seen an increase in attention given to the impact of cattle use and other activities on riparian zones. Kauffman and Krueger (1984) have reviewed the relevant literature and summarize the impact of livestock on riparian vegetation, instream ecology, and terrestrial wildlife. Platts (1981) also reviews and summarizes the literature, concentrating on the effects on anadromous fish habitat.

Annual changes in the riparian ecosystem due to livestock grazing are subtle and difficult to detect, accumulating over several years of improper grazing management. Riparian damage affects fish habitat in several ways. Removal of streamside vegetation reduces stream shading, leading to higher summer and lower winter stream temperatures. Other negative impacts include increased streambank erosion, altered stream channel morphology, and decreased food supply (Platts 1981). Storage of water in streambanks and adjacent plains may also be decreased, resulting in lower summer and higher spring streamflows.

Alternatives to destructive range management practices do exist. As reported in Hall and Baker (1982), fencing of riparian zones to exclude cattle is one course of action which will yield positive results. Several studies have found increases of 300% or more in salmonid abundance after fencing areas that had been heavily grazed. In a study on Camp Creek in the John Day basin, a total of 10.4 km of stream were fenced to exclude cattle. The result was increased vegetation and stream shading, lower summer stream temperatures and a 94% increase in juvenile steelhead/rainbow trout (as reported in Hall and Baker 1982).

Preventing riparian damage via fencing is not always a feasible alternative. The cost of fencing long and narrow stream areas is often prohibitive and excluding cattle from productive areas runs counter to the multiple-use purpose of many public lands. Consequently, there is considerable resistance from land owners and managers (Hall and Baker 1982). Recent attention, therefore, has focused on alternate livestock grazing strategies. Platts (1981) has noted that modifying existing strategies and/or developing environmentally compatible ones will be difficult. Research is being expended in this area and the results indicate certain changes in management may be effective. Most involve altering the temporal and spatial use pattern of riparian areas.

Gillen et al. (1985) suggest that in relatively large range pastures, the start of grazing on a particular meadow may be altered by as much as 2 weeks by varying the point where the cattle enter the pasture. This suggests the possibility of reducing riparian damage by utilizing an internal pasture rotation that could be alternated every couple years. To reduce the impact of livestock on riparian areas during the late summer, when upland forage is less palatable, Marlow and Pogacnik (1985) recommend basing stocking rates on forage available in the riparian zone rather than on an average for the entire pasture or allotment. Marlow (1985) further observes that riparian damage due to livestock trampling is heaviest early in the grazing period when moisture content of the banks is highest. Additional research on alternate grazing strategies, their costs and resultant benefits to anadromous fish should prove beneficial.

Incentives for Improved Management

The common property nature of water resources provides no incentive for land owners to manage riparian zones or conserve water in a manner which is economically efficient from society's point of view. In an attempt to correct this, several programs have been introduced to increase the incentives for proper management. One program, the Riparian Lands Tax Incentive Program, ORS 308.025, was initiated in 1981 and is administered by ODFW. It encourages land owners to rehabilitate riparian lands by providing a complete property tax exemption for private lands within 100 feet of a streambank which are managed for the protection or restoration of healthy riparian habitat. In addition, an income tax credit is available for up to 25% of private expenditures on instream habitat improvement projects (ODFW 1985b). A second measure, Senate Bill 24, passed in 1987, encourages water-rights holders to conserve water by allowing them to sell or lease a portion of the conserved water. The remainder of the water is allocated to instream needs.

CHAPTER 7

CONCLUSION

As the demand for water in arid regions of the West continues to grow, the importance of accurate measures of water's value in alternate uses will increase. Current economic methodologies are available to value water accurately in traditional out-of-stream applications such as agricultural and municipal uses. Valuation of instream water has proven more difficult. The root of the problem lies in the nonmarket nature of most goods which incorporate instream water as an input. Advances in nonmarket valuation methodologies promise to lessen this difficulty. This is evidenced by several recent studies which have successfully applied these techniques to the task of valuing instream flow. However, certain components comprising the total value of instream water present more obstacles than others. Estimating water's value in "producing" recreational fishing is a case in point. Due to a lack of readily available biological data on the streamflow/fish production/angler success relationship, economists often have to make simplifying assumptions to estimate streamflow benefits.

Summary

There were two general objectives of this thesis. The primary goal was to combine existing economic and biological methodologies in a common framework to give more realism to the temporal relationship between streamflow and the resultant benefits accruing in a recreational fishery. The steelhead fishery within the John Day River basin of north-central Oregon provided an excellent setting for this purpose. Objectives of the Northwest Power Planning Council and the Oregon Department of Fish and Wildlife to increase the summer steelhead trout and spring chinook salmon runs within the basin, as well as current conflicts between out-of-stream and instream uses of water, heighten the need for information on the value of instream water in this area. While the procedure and results of this study are best described as preliminary and exploratory, the analysis can provide some guidance to policy and future research concerning such decisions.

A two-stage procedure was employed in estimating the marginal value of water with respect to fish production: (1) valuation of a marginal change in the quality of the steelhead recreational fishery, and (2) quantification of the relationship between streamflow and fish production. The linkage between these two components was angler success rates. A hypothesis of this procedure was that streamflows affect fish production, which in turn influence angler success rates, which subsequently results in a change in the value placed on the fishery by anglers. By combining these relationships, it was possible to place a value on streamflow.

The contingent valuation method (CVM) was employed in valuing the sportfishery. Both open and closed-ended WTP questions were employed. This allowed analysis of the data via two techniques. Final result indicated that, under current conditions, the average angler is willing to pay approximately $7.20 to catch an additional steelhead during the fishing season. The values obtained for increased steelhead production only reflect net benefits accruing to users of the resource. Nonuse benefits, such as increased existence or bequest values, can be measured via the CVM, but this was not attempted in the present study.

Given the characteristics of the John Day steelhead fishery, the contingent valuation methodology appears to have been the most appropriate technique available. Other methodologies -- namely the travel cost method and the household production function approach -- were deemed inadequate due to their inability to value changes in quality outside the range of observed phenomena. The CVM itself suffers from many drawbacks, none of which proved to be severely limiting. The main "bias" observed in the CVM portion of this study related to the choice of a payment vehicle. The purpose of this study was not to establish what anglers would pay to bring about an improvement. Rather, it was to estimate how much better off they would be _if_ an improvement did occur. The negative response observed in some bids due to this payment method may have contributed to a downward bias of this estimate.

Sufficient biological data were available to estimate a relationship between streamflow and resultant adult escapement levels. By including variables influencing steelhead mortality in a Ricker stock-recruitment model, it was possible to develop a model which could be estimated using linear regression techniques. However, some difficulty arose with interpretation of the model due to the unavailability of cohort escapement data and the subsequent use of standing crop data. While possibly masking the true magnitude of streamflow's effect on fish production, this drawback was not deemed limiting within the context of the general interdisciplinary methodology.

Results of the biological model conformed to a priori expectations. Increases in summer and winter streamflows led to increased steelhead survival, whereas higher spring flows increased mortality levels. The estimated coefficients on two of the environmental variables -- namely upwelling and the second summer's streamflow, proved difficult to interpret. Lacking strong prior empirical evidence as to what the true effect of these variables should be, several areas for further research were suggested. Other results indicate a strong adverse impact from the John Day Dam. For the 1969-1983 period, it was estimated that this dam was responsible for a 31.5% decline in the population index, angler success.

Combining the economic and biological results into one equation yielded an estimate of the marginal value of summer instream water in "producing" recreational steelhead angling. Similar equations were developed for winter and spring flows. As was demonstrated in Chapter 6, the marginal value of instream water is sensitive to what benefits are included in the estimation and when during the year this flow occurs. For example, the marginal value of water in producing recreational steelhead fishing within the John Day basin was estimated at $0.56 per acre-foot for summer flows, $0.046 for winter flows, and -$0.075 for spring flows. By including out-of-basin benefits, these values increased to $2.26, $0.19, and -$0.30, respectively. In comparison, water's value in irrigation has been estimated at between $10 to $24. However, nonuse values of steelhead, as well as the increased production of other fish species (such as spring chinook salmon) are not reflected in the above values for instream water. In addition, no attempt was made at valuing instream water's contribution to boating, camping, or other activities.

The second objective of this thesis was to briefly examine the impact of an alteration in streamflow patterns on other instream and out-of-stream users. In addition, a review of the impact of activities by other resource users -- namely forestry, agriculture, and livestock production, was conducted. Management practices by these activities can negatively impact the aquatic and riparian ecosystems. While no firm conclusions are drawn here, it appears the quality of these ecosystems, as opposed to the amount of streamflow, has the largest marginal impact on anadromous fish populations.

Policy Implications

The results of this study have several implications for future resource management policies. As was shown in Chapters 4 and 6, there is a large divergence between the marginal values for steelhead used in current policy formulation and those obtained in this study. This discrepancy appears to have arisen due to the vague definition of what constitutes the "value" of a fish. Previous studies have attributed virtually all of the consumer surplus generated by a recreational fishery to the fish catch. Furthermore, current policies treat the marginal value of salmon and steelhead as equal to their average value. This study demonstrates that these assumptions are erroneous. This implies that fisheries managers and policymakers may be overvaluing anadromous fish enhancement projects, with a resultant ineffecient allocation of public funds. This conclusion, however, must be tempered by the realization that many enhancement projects arise from the legally mandated requirement to compensate for losses suffered due to hydroelectric projects. Still, an attempt should be made to clearly define and substantiate benefit estimates employed in project analyses.

Estimates of the value of instream water, when viewed in conjunction with the potential negative impact of forestry, agriculture, and livestock on anadromous fish production, tend to support several current policy directions. For example, both the Riparian Lands Tax Incentive Program and Senate Bill 24 encourage more efficient resource utilization by enabling landowners/managers and water rights holders to capture part of the benefits from habitat and streamflow improvements. With regards to forestry, the Forest Practices Rules are aimed at preventing damage to riparian zones by mandating proper management practices. An additional policy direction would be to introduce comparable rules for agriculture and livestock production. These rules would serve to internalize what are currently external costs of poor management practices. This is in contrast to traditional, capital intensive, approaches to the problem such as the construction of flow-augmenting reservoirs or hatcheries.

Implications for Future Research

Several directions for future research are suggested by the results of this thesis. On the economic front, attention might be turned towards further refinement of nonmarket valuation techniques as they are applied to valuing instream water. Further research could be expended on identifying the components of an angling experience. Anglers rarely base the total value of their angling experience soley on the number of fish caught, i.e., other aspects of the trip also have value. Focusing exclusively on the catch rate component when considering a policy designed to increase the value of a fishery ignores other attributes which contribute to net benefits. Generalizing such benefit assessments will require more data and information from economists than has traditionally been available. Where enough data can be collected, the closed-ended valuation techniques of Cameron and James (1987) may prove useful.

Further research into the use of user-defined CV markets may prove successful in decreasing hypothetical bias. Allowing respondents to define key components of the market may prove especially fruitful where actual or perceived quality varies across individuals. Given the problems associated with payment vehicle "bias", a user-defined payment vehicle may also be an area worth researching. This is particularly relevant for studies whose purpose is not to set optimal or revenue-maximizing fee levels but to obtain a general measure of consumer surplus generated by an increase in recreation quality.

This thesis measured only the net benefits accruing to anglers in the John Day steelhead fishery. Given the unique characteristics of the Pacific Northwest's anadromous fish stocks, an attempt should be made at determining nonuse values attached to these resources. The contingent valuation methodology will prove useful in this endeavor.

In terms of biological modelling, several areas of further research have already been suggested in Chapter 5. Further attempts at estimating other salmon or steelhead stocks via the methodology employed here may prove enlightening.

Finally, in the general area of interdisciplinary research, more effort needs to be expended in integrated research, both between economists and biologists as well as among other disciplines in general. The possibilities for expanding knowledge and gaining new insights appears quite high. With regard to the problem addressed in this thesis, the research suggests a need to look at all dimensions of habitat, not just streamflow. Thus, work between forest and rangeland management specialists, hydrologists, fisheries biologists, as well as economists, may lead to improved management of the aquatic and surrounding ecosystems with resultant increases in society's well being.

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APPENDICES

APPENDIX A

JOHN DAY STEELHEAD SURVEY

JOHN DAY STEELHEAD SURVEY No.______

INTERVIEWER ____________________

LOCATION ____

DATE AND TIME ________________ __________ AM PM

My name is ________________. I'm from Oregon State University. I am conducting a survey to gather information on the steelhead sportfishery within the John Day Basin.

The following questions are designed to give us information on the nature and extent of peoples' fishing experiences.

1. Including past years, how many trips have you made to the John Day to fish for steelhead? __________

2. On this trip how many miles do you estimate you will drive round-trip? ____________

3. Do you plan to engage in other activities besides fishing while on this trip? YES NO

   IF YES: What other activities?

4. How many days do you expect to be away from home? ________

5. During this time how much did you plan to spend? Please include such costs as gas, food, lodging, any guide fees, expenditures for fishing equipment, and any expenditures on other activities. $___________

6. On this trip how many days do you expect to spend fishing on the John Day or any other river? ________

7. How many of these days do you expect to spend fishing on the John Day? ___________

8. If fishing on other rivers on this trip, which rivers and for what species?

RIVER	SPECIES

9. On this trip, how many hours have you spent fishing on the John Day? ___________

10. How many steelhead have you caught on the John Day during this time? __________

11. (IF THE RESPONDENT IS FISHING ON OTHER RIVERS REPEAT QUESTIONS 9 AND 10.)

RIVER	HOURS	# FISH CAUGHT (AND SPECIES)

12. How many trips to the John Day River do you estimate you have or will make between Aug. 1, 1986 and April 15, 1987 for the purposes of fishing for steelhead? __________

13. How many days total do you expect to spend fishing on the John Day during these trips? ___________

14. How many hours do you spend fishing in an average day?__________

15. How many steelhead do you expect to catch on the John Day in an average year? ___________

16. TABLE 1 shows fishing results on the John Day for the last 5 years. These are expressed in terms of the average number of hours required to catch one steelhead. Given your past experience and where you feel you stand in relation to the average fisherman, what would you expect your catch rate to be, in hours per fish caught, while fishing the John Day River during an average year?__________

(THIS ANSWER TO BE USED IN QUESTION # 20.)

17. If habitat conditions worsened and the quality of the fishing were to decline, at what catch rate for you, in hours per steelhead caught, would you stop fishing on the John Day?

____

I would now like to ask you some questions to estimate how much you value your steelhead fishing experience. The questions concern potential stream habitat improvements in the John Day Basin. If carried out, these will maintain or increase fish populations in an average year. One way of paying for these improvements would be for anglers to purchase a John Day Steelhead Stamp.

18. What would be the maximum amount you would be willing to pay for a stamp to prevent your present catch rate from declining to the level at which you would stop fishing the John Day? $____________

19. How much would someone have to pay you to have you give up fishing on the John Day for a season (Sept. 1 - April 14)? $____________

20. Table 2 gives your average catch rate under current conditions of _________ (FROM QUESTION 16) hours per steelhead caught. Suppose we have three possible improvement levels in the number of steelhead in the John Day River. Under A we increase the number of steelhead by 33%; under B we increase them by 67%; and under C we double the number of steelhead in the John Day. What would you expect your catch rate to be, in hours per steelhead caught, under each of these improvements?

FILL IN TABLE 2 WITH THE RESPONDENT'S ANSWERS. ALSO FILL IN BELOW.

CURRENT CATCH RATE: ______________

+33%: ______________ [20A]

+67%: ______________ [20B]

+100%: ______________ [20C]

The following questions ask what you would be willing to pay to bring about improvements A, B, and C.

21A. If improvement A takes place would you be willing to pay $_________ for a John Day Steelhead Stamp? YES NO

21B. What would be the maximum fee you would be willing to pay? $__________

21C. Given that improvement A takes place, would you expect to have spent

(a) more (b) less or (c) the same

number of hours fishing the John Day on this trip.

IF MORE: How many more hours? __________

What activities would you take this time from?

IF LESS: How much less? __________

What would you do with this time instead?

21D. Would you take (a) more (b) less or (c) the same

number of trips to fish the John Day?

IF NOT (C): How many more (or less)? _________

What activities would you take this time from?
or (What would you do with this time instead?)

22A. Now suppose that instead of improvement A taking place improvement B occurs. What would be the maximum ADDITIONAL amount you would be willing to pay for the stamp for this additional improvement from A to B? $____________

22B. Given that improvement B takes place, would you expect to have spent

(a) more (b) less or (c) the same

number of hours fishing the John Day on this trip.

IF MORE: How many more hours? __________

What activities would you take this time from?

IF LESS: How much less? __________

What would you do with this time instead?

22C. Would you take (a) more (b) less or (c) the same

number of trips to fish the John Day?

IF NOT (C): How many more (or less)? _________

What activities would you take this time from?
or (What would you do with this time instead?)

23A. Now suppose that instead of improvement B taking place improvement C occurs. What would be the maximum ADDITIONAL amount you would be willing to pay for the stamp for this additional improvement from B to C? $____________

23B. Given that improvement C takes place, would you expect to have spent

(a) more (b) less or (c) the same

number of hours fishing the John Day on this trip.

IF MORE: How many more hours? __________

What activities would you take this time from?

IF LESS: How much less? __________

What would you do with this time instead?

23C. Would you take (a) more (b) less or (c) the same

number of trips to fish the John Day?

IF NOT (C): How many more (or less)? _________

What activities would you take this time from?
or (What would you do with this time instead?)

For statistical purposes we would like the following information.

24. Age (years): _______

25. Sex: M F

26. Years of education: _______

27. If you weren't fishing today what would you be doing instead?

How much would you have spent in this activity? $___________

28. Could you have worked today if you were at home? YES NO [28A]

IF YES: How much could you have earned? $__________ [28B]

29. Is your personal income:

less than $15,000 _____ [1]
$15,000 - $30,000 _____ [2] (CHECK ONE)
more than $30,000 _____ [3]

30. Would you be willing to participate in a mail or telephone survey later in the season? YES NO

IF YES FILL IN LAST PAGE

No.__________

NAME ____________________________

PHONE (PLEASE INCLUDE AREA CODE IF OUTSIDE OREGON): ____________

ADDRESS: STREET ____

CITY ________________________________

STATE ________________ ZIP ________________

If you would like to make any comments regarding either this survey or any aspect of the fishing in this area please do so on a seperate sheet of paper. Thank you for your participation.

TABLE 1
JOHN DAY CATCH RATE

SEASON	AVERAGE CATCH RATE (HOURS PER STEELHEAD)
1981-1982	15.4
1982-1983	29.7
1983-1984	13.8
1984-1985	13.9
1985-1986	12.3
5-YEAR AVERAGE	17.0

TABLE 2

EXPECTED CATCH RATE UNDER IMPROVEMENT LEVELS A, B, AND C

CURRENT CATCH RATE	A +33% INCREASE IN THE NUMBER OF STEELHEAD IN THE JOHN DAY RIVER	B +67% INCREASE IN THE NUMBER OF STEELHEAD IN THE JOHN DAY RIVER	C +100% INCREASE IN THE NUMBER OF STEELHEAD IN THE JOHN DAY RIVER
CATCH ONE STEELHEAD FOR EVERY ______ HOURS OF FISHING	CATCH ONE STEELHEAD FOR EVERY ______ HOURS OF FISHING	CATCH ONE STEELHEAD FOR EVERY ______ HOURS OF FISHING	CATCH ONE STEELHEAD FOR EVERY ______ HOURS OF FISHING

APPENDIX B

RAW DATA FROM JOHN DAY STEELHEAD SURVEY

#	DATE	TIME	1	2	3	4	5	6	7	9	10	12	13	14	15
1	10-09-86	12:10	4	400	1	7	175	5	5	10	0	2	9		
2	10-09-86	14:30	12	320	1	7	150	5	5	5	0	4	9		
3	10-09-86	17:30	5	415	1	9	450	9	9	50	1	3	17		
4	10-10-86	15:42	1	800	1	4	200	1	1	1	0	3.5	6		
5	10-11-86	09:00	50	260	1	3	55	3	3	2	0	6	15		
6	10-11-86	10:35	500	140	1	2	100	2	2	4	0	20	15		
7	10-11-86	15:35	10	350	1	2.5	50	0.5	0.5	1	0	4	4		
8	10-12-86	12:05	30	250	0	2	50	2	2	2	0	4	7		
9	10-12-86	12:35	875	104	1	1	8	1	1	3	0	25	25		
10	10-12-86	13:15	2	55	0	1	11.1	1	1	2	1	10	10		
11	10-12-86	13:50	40	55	0	1	20	0.5	0.5	2	0	25	25		
12	10-18-86	9:47	25	125	0	1	25	1	1	2.5	0	10	10	6	8
13	10-18-86	10:07	100	150	0	1	10	1	1	2	0	6	6	6	6
14	10-18-86	11:25	1	640	1	36	400	10	4.5	0.5	0	1	4.5	4	0
15	10-18-86	12:30	18	100	0	1	20	1	1	4	2	20	20	6.5	5
16	10-18-86	13:11	20	600	1	4	100	4	4	21	15	5	12	5	12
17	10-18-86	16:42	7	160	0	1	3	1	1	3	0	1	1	6	0
18	10-19-86	9:35	1	50	1	1	10	1	1	2	0	3	3	7	NA
19	10-19-86	12:00	200	275	0	4	115	4	4	10	0	10	13	10	10
20	10-19-86	12:30	200	120	0	1	0	1	1	1	0	5	5	8	1
21	10-19-86	14:24	7	100	0	1	5	1	1	4.5	0	4	4	6	2
22	10-19-86	14:58	250	70	0	1	19	1	1	4	0	9	12	7	5
23	10-25-86	10:21	1	300	1	2	30	1.5	1.5	3	0	3	6	8	0
24	10-25-86	10:52	100	150	0	1	20	1	1	3	1	10	10	7	10
25	10-25-86	11:32	3	280	0	2	100	2	2	6	0	5	10	8	2

NA: Not Answered. WQ: Wouldn't quit fishing at any catch rate.

#	DATE	TIME	1	2	3	4	5	6	7	9	10	12	13	14	15
26	10-25-86	12:00	50	120	0	1	NA	1	1	0.5	0	5	5	2.5	1
27	10-25-86	12:39	12	150	0	2	80	2	2	9	0	9	18	8	9
28	10-26-86	9:30	8	300	0	1	50	1	1	1	1	8	8	8	10
29	10-26-86	11:11	2	150	0	1	20	1	1	2.5	0	6	6	8	0
30	10-26-86	13:00	5	100	0	2	50	2	2	18	2	12	13	12	10
31	10-26-86	13:40	4	100	0	2	50	2	2	16	4	12	13	2	10
32	10-26-86	15:11	20	350	0	1	35	1	1	2	0	5	6	8	3
33	10-27-86	9:30	15	160	0	1	20	1	1	3	0	10	10	6	10
34	10-27-86	13:52	300	46	1	1	9	1	1	0.5	0	70	70	3	20
35	11-03-86	8:53	5	220	0	1	10	1	1	1.5	0	10	10	7.5	5
36	11-03-86	9:24	2	220	0	1	20	1	1	2	0	6	6	8	NA
37	11-08-86	8:34	30	150	0	1	20	1	1	0.5	0	6	6	5	6
38	11-08-86	9:30	1	120	0	1	10	1	1	1.5	0	6.5	6.5	8	NA
39	11-08-86	10:30	150	110	0	1	15	1	1	0	0	10	10	6	10
40	11-08-86	10:51	10	180	0	1	120	1	1	0	0	6	6	6	6
41	11-08-86	12:05	25	190	0	1	20	1	1	1	0	11	11	6.5	20
42	11-08-86	13:20	6	140	0	1	20	1	1	4.5	1	10.5	15	6	5.5
43	11-08-86	13:55	300	175	0	2	45	2	2	2	1	22.5	45	10	50
44	11-09-86	8:35	6	120	0	1	25	1	1	0	0	3	5	6	3
45	11-09-86	9:15	10	150	0	1	50	1	1	1	0	4	4	10	4
46	11-09-86	13:30	40	50	0	1	5	1	1	3	0	12	12	8	3
47	11-09-86	14:10	100	70	0	1	20	1	1	3	0	10	17.5	5.5	2.5
48	11-10-86	12:18	700	120	0	1	9	1	1	3	0	20	20	8	10
49	3-21-87	9:14	12	20	0	1	5	1	1	4	0	20	20	8.5	10
50	3-21-87	9:54	18	55	0	1	11.5	1	1	1	0	10	10	4.5	2.5

#	DATE	TIME	1	2	3	4	5	6	7	9	10	12	13	14	15
51	3-21-87	11:42	7	100	0	1	10	1	1	3	0	3	3	3.5	0
52	3-21-87	12:15	10	230	0	1	45	1	1	5	0	15	1	8	10
53	3-21-87	12:53	20	150	0	1	12.5	1	1	5	0	2	2	8	0
54	3-21-87	13:58	75	8	0	1	3.5	1	1	2	0	25	25	3.5	1.5
55	3-21-87	17:09	60	234	1	2	35	2	2	0.5	0	66	66	13	40
56	3-22-87	8:41	250	1	0	1	1	1	1	3	0	30	30	6	19
57	3-22-87	12:19	4	50	0	1	3	1	1	2.5	0	4	4	6	0
58	3-22-87	12:40	1	160	0	1	25	1	1	1	0	1	1	3.5	0
59	3-22-87	13:07	50	200	0	1	10	1	1	4	0	10	10	9	12
60	3-22-87	13:56	200	135	0	1	22	1	1	5.5	1	20	30	6	20
61	3-28-87	9:39	40	180	0	1	20	1	1	1.5	0	11	11	8	1.5
62	3-28-87	10:06	6.5	120	0	1	10	1	1	3	0	7	7	8	4.5
63	3-28-87	11:10	25	180	0	1	25	1	1	4	0	8	15	10	20
64	3-28-87	11:49	250	150	0	1	8	1	1	4	1	8.5	8.5	3	12
65	3-28-87	12:19	1	160	0	1	10	1	1	5	1	1	1	5.5	NA
66	3-28-87	13:04	10	170	1	1	15	1	1	4.5	1	9	9	8	3
67	3-28-87	13:35	50	250	0	1	30	1	1	1	0	5	5	5	10

#	16	17	18	19	20	20A	20B	20C	IBID	21A	21B	21C	21D
1	12	WQ	10	50	12	10	8	6	8	1	10	0	1
2	12	WQ	10	50	12	10	8	6	14	1	14	3	0
3	20	WQ	5	50	20	15	13	12	4	1	4	12	3
4	5	20	10	2000	5	3.5	3	2.25	12	1	12	10	6
5	17	40	5	500	17	15	13	8.5	2	1	5	-2	2
6	20	WQ	5	100	20	15	10	3	14	0	5	-2	0
7	17	27	5	1000	17	14	12	8	10	1	10	0	2
8	17	WQ	5	50	17	8	6	4	6	1	6	0	0
9	25	WQ	3	200	25	20	15	10	10	0	3	0	0
10	5	10	5	100	5	4	3.5	3	8	1	8	0	0
11	4	4	0	NO PRICE	4	4	4	4	2	0	0	0	0
12	13.9	18	5	500	13.9	10	6.5	3	15	0	0	0	0
13	30	60	0	0	30	6	4.5	3	9	1	9	0	6
14	10	WQ	0	0	10	8	6	5	10	0	1	0	0
15	15	WQ	5	1000	15	7	7	6	12	1	25	0	5
16	1.5	10	5	1000	1.5	1.5	1.5	1.5	14	0	10	0	0
17	NA	WQ	0	10	NA	NA	NA	NA	9	0	0	0	0
18	NA	NA	3	NA	NA	NA	NA	NA	5	1	5	0	
19	10	WQ	10	200	10	6.5	4	2	18	1	20	0	0
20	30	46	1	0	30	25	20	15	17	0	1	0	0
21	17	17	5	0	17	17	17	15	7	0	0	0	0
22	30	WQ	5	100	30	20	10	6	12	0	5	-3	9
23	20	50	2	50	20	10	5	2	20	0	2	8	3
24	4.5	8	50	250	4.5	3.75	3	2.25	12	1	50	0	0
25	15	25	5	50	15	15	15	15	11	0	5	0	0

#	16	17	18	19	20	20A	20B	20C	IBID	21A	21B	21C	21D
26	17	WQ	5	50	17	10	5	3.5	6	0	4	2	2.5
27	17	20	2	20	17	15	10	2	7	0	2	-6	3
28	13	13	0	1000	13	5	1	0.5	5	1	5	0	8
29	29	WQ	5	5000	29	21	15	11	11	0	5	0	0
30	10	10	10	1000	10	6	3	1	3	1	10	7	3
31	5	WQ	3	200	5	5	4	3	24	0	5	0	8
32	17	WQ	5	200	17	12	9	6	15	0	5	5	2
33	8	16	20	500	8	8	6	4	9	1	15	0	2
34	4	WQ	3	3000	4	3.46	2.73	2	13	0	3	0	0
35	15	WQ	20	200	15	10	5	3	11	1	20	0	0
36	17	48	5	100	17	14	11.5	8.5	18	1	25	0	0
37	10	WQ	10	200	10	8.4	6.7	5	21	0	10	-1	2
38	6	8	10	1000	6	3	2	1	13	0	10	-1	0
39	6	15	5	2000	6	4	2.5	1	16	1	16	-2	3
40	4	20	2	2000	4	3	2	1	8	1	8	-2	3
41	7	10.5	100	3000	7	5.8	4.7	3.5	4	1	100	0	5.5
42	20	30	5	2000	20	16.7	13.3	10	10	0	5	0	5.5
43	5.5	WQ	5	10000	5.5	5	4	3	16	0	0	0	0
44	15	20	10	2000	15	10	5	2	3	1	5	0	3
45	10	20	5	50	10	9	6	4	9	0	2	0	2
46	16	WQ	5	500	16	10	6	4	17	0	10	-2	0
47	20	50	2	200	20	20	15	9	19	0	2	0	0
48	5	WQ	2	5000	5	4	3	2	13	0	5	2	-5
49	17	17	10	200	17	6	3	1	5	1	10	0	20
50	40	40	2.5	NO PRICE	40	35	27.5	20	8	0	5	0	0

#	16	17	18	19	20	20A	20B	20C	IBID	21A	21B	21C	21D
51	17	WQ	0	10	17	13	11	8	7	0	0	2	7
52	26	27	0	500	27	20	15	7	11	1	15	0	0
53	8	WQ	0	4500	8	7	6	5	7	0	0	0	0
54	10	WQ	0	100	10	8.33	6.67	5	15	0	0	2	5
55	20	WQ	0	19000	20	18	13.5	10	9	0	1	0	0
56	10	WQ	5	NO PRICE	10	NA	NA	NA	13	NA	NA	NA	NA
57	15	WQ	0	0	15	NA	NA	NA	17	NA	NA	NA	NA
58	30	30	0	0	30	30	22	15	10	0	0	0	2
59	34	WQ	0	1000000	34	28	24	17	3	1	3	0	0
60	2.5	12	0	NO PRICE	2.5	2	1.5	1	5	1	5	0	0
61	17	50	10	100	17	10	6	4	2	1	10	-	0
62	12	WQ	10	150	12	10	8	6	15	0	5	0	+
63	4	10	5	100	4	3	2	1	3	0	2	-4	8
64	20	WQ	5	1000000	20	10	10	10	4	0	2	0	0
65	17	17	0	0	17	14	11	8.5	13	0	0	0	0
66	15	WQ	7	300	15	10	8	4	6	1	7	+	3
67	9	12	2	18	9	7.5	6	4.5	12	0	0	1.5	1.5

#	22A	22B	22C	23A	23B	23C	24	25	26	27	28A	28B	29	30
1	5	0	0	0	0	0	32	1	14	0	1	100	2	1
2	3	2	2	3	0	2	78	1	10	5	0	0	2	1
3	1	0	0	0	0	0	38	1	12	65	1	125	2	1
4	3	10	6	5	0	0	29	1	12	200	1	160	2	1
5	2	-1	2	3	-1	1	40	1	12	16	0	0	3	1
6	0	-1	0	0	-1	-10	57	1	11	11	1	15	3	1
7	5	0	0	5	0	0	48	1	16	50	1	0	3	1
8	2	0	0	2	0	0	57	1	12	0	0	0	2	1
9	0	0	0	0	0	0	60	0	12	0	0	0	1	1
10	0	0	0	0	0	0	40	0	15	0	1	36	1	1
11	0	0	0	0	0	0	45	1	12	0	0	0	1	1
12	5	0	0	5	0	5	50	1	12	0	0	0	2	1
13	0	0	0	1	0	0	63	1	9	0	0	0	1	0
14	1	0	0	1	0	0	60	1	12	400	0	0	3	1
15	0	0	0	5	1.5	2	24	1	14	15	0	0	2	1
16	5	0	1.5	0	0	0	41	1	18	15	1	450	1	1
17	0	0	0	0	0	0	39	1	17	7	0	0	3	1
18	1	0	0	1	0	0	28	1	12	10	0	0	1	0
19	10	0	0	10	0	0	47	1	12	0	0	0	3	1
20	0	0	0	0	0	0	35	1	13	5	1	50	2	1
21	0	0	0	0	0	0	40	1	19	0	1	150	3	1
22	3.5	0	0	1.5	0	0	50	1	13	4	0	0	2	1
23	1	8	0	0	0	0	31	1	15	5	0	0	2	1
24	25	0	0	25	-4	0	31	1	16	0	0	0	2	1
25	5	0	0	0	0	0	41	1	14	20	0	0	3	1

#	22A	22B	22C	23A	23B	23C	24	25	26	27	28A	28B	29	30
26	2	0	0	2	0	0	65	1	13	0	1	0	3	1
27	0	-1.6	0	0	0	0	53	1	12	0	0	0	2	1
28	0	0	4	0	0	0	39	1	12	2	1	1000	3	1
29	0	0	0	0	0	0	39	1	14	5	0	0	3	0
30	2	0	5	3	0	5	30	1	12	50	0	0	2	1
31	1	0	0	4	0	0	31	0	11	0	0	0	1	1
32	0	0	1	0	0	0	36	1	16	5	0	0	2	1
33	5	2	2	0	0	0	29	1	16	5	0	0	2	1
34	0	0.3	0	0	0.45	0	56	1	16	15	0	0	2	1
35	0	0	0	0	0	0	63	1	12	10	0	0	2	1
36	10	0	0	10	0	0	61	1	13	5	0	0	2	1
37	5	-1	2	5	-1	0	36	1	17	40	1	70	2	1
38	20	0	0	170	-3	6	43	1	16	0	1	0	3	1
39	1	-1	3	1	-1.5	3	40	1	12	0	1	27.5	1	1
40	2	0	2	2	0	2	34	1	12	5	1	72	1	1
41	10	0	3.5	10	0	0	41	1	17	10	1	50	3	1
42	0	0	0	0	0	0	44	1	10	20	0	0	2	1
43	0	0	0	0	0	0	47	1	14	45	0	0	2	1
44	3	-3	0	2	-2	0	44	1	12	0	1	0	3	1
45	1	0	2	2	0	1	24	1	12	5	0	0	2	1
46	2.5	0	0	0	-2	0	40	0	12	0	1	40	3	1
47	0	0	0	0	0	0	50	1	13.5	0	0	0	1	1
48	1	0	0	4	0	0	52	1	12	75	0	0	2	1
49	0	0	0	5	5	5	28	1	12	0	0	0	2	1
50	0	0	0	0	0	0	35	1	13	5	0	0	2	1

#	22A	22B	22C	23A	23B	23C	24	25	26	27	28A	28B	29	30
51	5	2	0	0	0	0	39	1	14	10	1	150	2	1
52	10	0	0	10	+	6	37	1	12	0	1	0	3	1
53	0	0	0	0	0	0	32	1	14	40	0	0	2	0
54	1	0	2	1	0	2	33	1	15	0	0	0	2	1
55	1	0	0	1	0	0	34	1	14	1.25	0	0	1	1
56	NA	NA	NA	NA	NA	NA	69	1	0	0	0	0	1	0
57	NA	NA	NA	NA	NA	NA	76	1	NA	0	0	0	1	0
58	5	0	0	0	0	0	34	1	13	0	0	0	3	1
59	2	0	0	5	0	3	32	1	12	30	0	0	2	1
60	0	0	0	5	0	20	58	1	12	2	1	80	3	1
61	5	-	0	5	-	-	37	1	12	5	1	0	1	1
62	2	0	0	3	0	0	33	1	10	50	0	0	1	1
63	3	0	0	5	0	0	26	1	12	7.5	1	75	2	1
64	0	0	11	0	0	10	39	1	1	6	0	0	1	0
65	0	0	0	0	0	0	49	1	12	30	0	0	3	1
66	1	+	0	2	0	0	35	1	12	20	0	0	3	1
67	0	0	0	0	0	0	38	1	12	2	0	0	2	1

APPENDIX C

SUMMARY OF SURVEY RESPONSES

SUMMARY OF SURVEY RESPONSES

Survey question #	Question description	Mean response (or % yes)
1.	Past trips to John Day River to fish for steelhead.	82
2.	Round trip miles on current trip.	192
3.	Multipurpose trip?	22.5%
4.	Days away from home on current trip. Percent on one day trip.	2.2 70.9%
5.	Expected expenditures.	$50.88
6.	Expected days fishing on the John Day and other rivers during current trip.	1.7
7.	Expected days fishing on John Day.	1.6
9.	Hours spent fishing on John Day during current trip.	4.4
10.	Steelhead caught on John Day during current trip. Percent reporting zero catch.	0.53 77.4%
12.	Expected number of trips to John Day to fish for steelhead this season (8/1/86 - 4/15/87).	11.0
13.	Expected number of days spent fishing on the John Day this season.	12.8
14.	Average number of hours spent fishing per day (excludes surveys 1 - 11).	6.8
15.	Expected steelhead catch on the John Day in an average year (excludes surveys 1 - 11).	8.3

Survey question #	Question description	Mean response (or % yes)
16.	Expected catch rate on John Day during average year.	
	Calculated as (A): $\frac{\Sigma \text{ Hrs per steelhead}}{N}$	14.8
	Calculated as (B): $\frac{N}{\Sigma \text{ 1/ Hrs per steelhead}}$	9.3
17.	Catch rate at which angler would give up fishing on the John Day. Calculated from equation (B).	29.9
18.	WTP to avoid decline in catch rate to level given in # 17.	$7.04
19.	WTA to give up fishing on John Day for one season (calculated as geometric mean).	$360
	Percentage reporting: $0	9.7%
	1 - 20	4.8%
	21 - 75	9.7%
	76 - 100	14.5%
	101 - 499	17.7%
	500 - 999	8.1%
	1000 - 3000	19.4%
	over $3000	16.1%
20-23.	See Chapter 4 for summary.	
24.	Age.	42
25.	Sex, percentage male respondents.	93.5%
26.	Years of education.	12.9
27.	Amount that would have been spent in alternate activity.	$21.24
28.	Percentage indicating they could have worked instead of going fishing.	35%
	Amount above individuals could have earned.	$120
29.	Personal income level: less than $15,000	29%
	$15,000 - $30,000	50%
	more than $30,000	21%

Region of residence vs. survey location.

Survey location	Region of residence R1	R2	R3	R4	R5	Total
F1	2	0	15	5	0	22
F2	0	3	1	0	0	4
F3	4	6	5	2	1	17
F4	4	0	0	0	0	4
F5	1	0	10	0	0	11
F6	3	0	0	0	0	3
Total	13	9	31	7	1	62

Region of residence:

R1: John Day basin: Condon, John Day, Prairie City
R2: West side: Prineville, Redmond
R3: East and north side: La Grande Pendleton, Umatilla
R4: Portland and vicinity
R5: Out of state: Moses Lake, Washington

Survey location:

F1: Rock Creek - Cottonwood Bridge
F2: Butte Creek - Clarno
F3: Service Creek - Kimberly
F4: Mainstem, Kimberly - John Day
F5: Upper Middle Fork
F6: Upper North Fork

APPENDIX D

COMMENTS MADE BY SURVEY RESPONDENTS

COMMENTS MADE BY SURVEY RESPONDENTS

No contingent valuation study would be complete without letting the respondents, who give so freely of their time, contribute their own two cents worth. A representative sample of comments obtained during the John Day Steelhead CVM survey are reproduced below. Where the comments are the respondent's own words this is indicated by " ".

"I hope they don't ruin or commercialize the John Day. It's a good wild river."

Drift boats are okay but I'm against jet boats. Also, on the lower end of the river where there are lots of geese, they fly up and get killed by the power lines.

It would help if they would improve it.

The fishing's been great.

"Tell the game commission to stick it in their ass. This river will take care of itself. We don't need people coming up here to poison it. It's a perfect bass and steelhead river. Leave it goddamned alone."

Survey's fine. Fishing should be improved.

Keep the motorized boats out.

There needs to be an area like this with no restrictions (ie. barbless hooks). Get the gill nets out of the Columbia.

Good idea to check on the fishing.

"The first thing I wanted to know is who the information went to - I didn't want it [to go] to D.F.W. Those people have a hard time reading a watch, let alone pulling figures together. [With all] the money already spent on fishing management, there should be signs all up and down the roads, 'Danger', for all the fish that jump out on the road."

"I object to the steelhead tag [proposed in the survey]."

Concerned about smolts getting diverted into irrigation canals and the enforcement of fish screen regulations.

"Where are the fish at?"

"No, uh, uh."

"Nope."

I would like to have more public and developed access.

"No. I'm satisfied with this. I like what they're doing on the upper John Day."

"Survey was interesting. I enjoy the fishing."

"IT'S COLD!"

Get rid of the gillnetting.

Access to stream to fish is a problem. Would like to see access given by land owners.

Don't think the fishing is any good for trout or steelhead.

Would like to stick to fishing the main stem. [Comment offered by angler fishing the Middle Fork.]

Survey was interesting. Fish and Wildlife should stay out of it and everything will be okay. They're just lining their pockets. Not using the money effectively. No special permits for fishing or hunting.

"Not yet."

Be worth it if they did do habitat improvements.

"No, not really. [The fishing] could be better."

"Wish it would pick up."

"Slow today."

Don't post it. I don't mind restrictions, but stocking and then posting the fishing bothers me. [I assume this was in reference to the trout fishery - N.J.]

"Nah."

APPENDIX E

DATA SET FOR JOHN DAY STEELHEAD MODEL

DATA SET FOR JOHN DAY STEELHEAD MODEL

			Streamflow (cfs)						
YEAR	Hrs/f	Redds	W	SP	SU	F	D	U	StW /a
1955						1118	0		
1956	8.1		2389	5011	248	289	0		
1957			1742	3784	167	540	0		
1958	6.3		2659	4557	256	445	0		9.5
1959	19.2	7.4	1469	2130	165	296	0		4.8
1960	10	8.8	1157	2832	144	228	0	371	6.0
1961	22.6	6.8	1457	1806	101	170	0	265	5.1
1962	18.3	6.9	1062	3057	152	621	0	430	6.4
1963	23.6	7.1	1486	2603	169	196	0	361	4.4
1964	26.2	6.1	542	2544	220	1218	0	636	10.9
1965	12	7.6	3211	4094	311	180	0	765	6.5
1966	9.8	16	620	1298	100	435	0	764	4.7 *
1967	14.6	11.6	1244	2629	172	175	0	819	2.65 *
1968	18.9	4.8	880	998	127	693	0	644	4.3 *
1969	11.1	8.9	1774	3748	252	207	1	652	4.8 *
1970	11.9	8.1	2373	2650	232	518	1	709	5.2 *
1971	11.8	8	2168	3444	230	394	1	424	
1972	24.4	7.6	3195	3438	225	246	1	540	3.7 *
1973	28.5	5.3	730	1247	73	1625	1	791	
1974	24.9	4.4	2727	4370	287	151	1	604	
1975	12.7	8.9	1362	3814	419	633	1	744	8.2
1976	21.8	5.2	1326	3440	292	171	1	524	5.2
1977	15.8	7.1	223	1257	114	727	1	613	7.3
1978	21.1	4.3	2009	2563	301	208	1	481	8.5
1979	109	1	1954	4287	194	276	1	385	5.0
1980	34.2	3.4	1481	3067	319	394	1	593	3.1
1981	25.7	3.7	1500	2799	227	738	1	481	1.7
1982	15.4	4.2	3292	4617	595	820	1	441	6.4
1983	29.7	4.9	3828	4286	482		1	177	12.1
1984	13.8	3.9					1	406	3.4
1985	13.9	8.5					1	311	
1986	12.3	11.0					1		
1987	6.1						1		

a/ "*" indicates index only includes escapement, i.e., the percentage caught in the sport fishery is not included. To estimate the index's relationship with ocean upwelling, as reported in table 5.3, the escapement-only data was adjusted by a factor of 1.5.

Definition and source of variables.

Variable	Definition	Source
Hrs/f	Hours per steelhead caught. Calculated from creel survey data.	Errol Claire, ODFW, unpublished data
N_t	Steelhead caught per 100 hours of fishing. Measurement of stock level. Calculated using Hrs/f.	
Redds	Steelhead spawning redds per mile as measured in index area.	Errol Claire, ODFW, unpublished data
P_{t-5}	Parent stock measurement. Redd counts lagged 5 years.	
Stream flows	Average stream flow, expressed in cubic feet per second (cfs) as measured at the U.S.G.S. gaging station at Monument, Oregon, on the North Fork of the John Day River.	United States Geologic Survey (various years)
W	Winter flow. January - March	
SP	Spring flow. April - June	
SU	Summer flow. July - September	
F	Fall flow. October - December	
D	Dummy variable indicating existence of John Day Dam impeding down- and upstream migration	
U	The sum of the monthly upwelling volumes (measured in cubic metres per second per 100m) for March through September at 42°N, 125°W.	Nickelson (1986)
StW	Catch plus escapement index for Alsea winter steelhead; the percentage of juveniles released in the North Fork in year t that later return to the Alsea River.	Nancy MacHugh, ODFW, unpublished data

APPENDIX F

BEVERTON-HOLT MODEL

BEVERTON-HOLT MODEL

The Beverton-Holt (1957) stock-recruitment relationship is specified as:

$$R = \frac{1}{\alpha + \beta / P} \tag{F.1}$$

where R is the number of recruits to the fishery, P is parental stock size (redd counts), and a and B are parameters which convey information on the magnitude of density-independent and density-dependent mortality, respectively. Equation (F.1) was incorporated in an equation similar to equation (5.4):

$$N_t = \frac{1}{\alpha + \beta / P} \prod_{i=1}^{n} (1-m_i) * v' \tag{F.2}$$

The natural logs of this equation were taken to arrive at:

$$\ln N_t = \ln \frac{1}{\alpha + \beta / P} + \sum_{i=1}^{n} (B_i * E_i) + v \tag{F.3}$$

Including the same environmental variables as used in Chapter 5 yielded the following equation:

$$\ln N_t = \ln \frac{1}{\alpha + \beta / P} + \beta_1 SP_{t-5} + \beta_2 SU_{t-5} + \beta_3 W_{t-4} + \beta_4 SP_{t-4} + \beta_5 SU_{t-4} + \beta_6 D3 + \beta_7 (U_{t-1}+U_{t-2}) \tag{F.4}$$

Equation (F.4) was estimated using non-linear least squares. The econometrics package SHAZAM (White 1978) was used. Results are presented in table F.1. As has been previously mentioned, the estimated coefficients on the environmental variables are in close agreement with those obtained with the Ricker model. It is interesting to note that the Bo coefficient is not significantly different from zero. This may imply that changes in parental stock numbers have little or no impact on recruitment. Alternately, it could also reflect misspecification of the stock-recruitment relationship.

Table F.1. Nonlinear Beverton-Holt model estimation. John Day summer steelhead 1964-1983. Dependent variable: ln(Nt)

Variable /b	Estimated coefficients /a	Standard error	T-ratio
α	0.165 **	0.060	2.74
β_0	-0.00080	0.220	-0.004
SP_{t-5}	-0.000478 ***	0.000103	-4.65
SU_{t-5}	0.00374 **	0.00116	3.23
W_{t-4}	0.000354 **	0.000090	3.93
SP_{t-4}	-0.000258 *	-0.000109	-2.36
SU_{t-4}	-0.00264 **	-0.000830	-3.18
D_{t-3}	-0.404 **	-0.125	-3.23
$U_{t-1}+U_{t-2}$	0.00108 ***	0.000244	4.43

a/ Level of significance using two-tailed t-test: *0.10 **.02 ***.002

b/ See Appendix E for source and explanation of variables.

Observations = 20 (1964-1983)   11 degrees of freedom

Log-likelihood function = 4.64

Durbin-Watson d-statistic = 1.91   rho = -.00083