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Improved Economic Evaluation of Commercially and Sport-Caught Salmon and Steelhead of the Columbia River

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IMPROVED ECONOMIC EVALUATION OF COMMERCIALLY AND SPORT-CAUGHT SALMON AND STEELHEAD OF THE COLUMBIA RIVER*

William G. Brown
Douglas M. Larson
Richard S. Johnston
Roy J. Wahle

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WILLIAM G. BROWN, DOUGLAS M. LARSON, and RICHARD S. JOHNSTON are professor, graduate research assistant, and associate professor, respectively, Department of Agricultural and Resource Economics, Oregon State University, Corvallis. ROY J. WAHLE is Chief, Operational Improvements Studies Section, Columbia Fisheries Program Office, National Marine Fisheries Service, Portland, Oregon.

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SUMMARY

Traditionally, with respect to addressing public policy issues, measured benefits from improving a fishery have been based upon estimated profits, or potential profits, to the commercial fishermen. However, in addition to possible benefits to commercial fishermen, an increased commercial harvest gives benefits to consumers of fish in terms of increased supply and lower prices. A method for measuring these benefits to consumers of fresh and frozen salmon is developed in this report. These benefits from increased commercial catch (or losses from decreased catch) are applicable to chinook and coho salmon, the most important species of the Columbia River. Although varying somewhat according to the year and the algebraic form of demand assumed, small increases in salmon production for recent years were predicted to yield consumer benefits of $0.80 or more per pound of added commercial harvest.

Values for the Oregon salmon-steelhead (S-S) sport fishery were recomputed, using additional knowledge gained since the original study (Brown, Singh, and Castle) was published in 1964. An estimated figure of $22 per day of S-S fishing (1974 price level) is recommended as the lowest value to be used for a fishery threatened by some water-related project or alternative. A similar value may also be appropriate for some fishery enhancement or improvement projects when the purpose of those projects is to ameliorate the effects of earlier water-related projects on the fishery. However, it should be noted that a new survey of S-S sport anglers is badly needed to provide a better value estimate of S-S sport fishing, given the major changes that have occurred in the sport fishery since the 1962 survey.

IMPROVED ECONOMIC EVALUATION OF COMMERCIALLY AND SPORT-CAUGHT SALMON AND STEELHEAD OF THE COLUMBIA RIVER

INTRODUCTION

Increasing demands over the years for the utilization of rivers and streams for hydroelectric power, irrigation, flood control, navigation, waste disposal, and other purposes, have presented severe hazards to the anadromous fish of the Columbia River System. Procedures for estimating monetary benefits resulting from the above water uses have long been available; however, administrators have faced a more difficult task when trying to place a monetary value on the anadromous fishery resources of the Pacific Northwest. Although substantial progress was made several years ago in evaluating the salmon (*Oncorhynchus spp.*) and steelhead trout (*Salmo gairdneri*) sport fishery (reported by Brown, Singh, and Castle), this earlier research is somewhat out of date, being based upon expenditures by anglers in 1962. Furthermore, important improvements in estimating values of outdoor recreational resources have been made since the Oregon salmon and steelhead study was published in 1964 (Brown, Nawas, and Stevens; Brown and Nawas).

Although updating the 1964 Oregon salmon and steelhead study would be helpful, the presently used methods and data for valuing the commercially caught salmon also need improvement. Difficulties with present methods of valuing the commercial catch arise from the common property nature of the fishery. Unlimited entry allows additional men and boats to enter the fishery, thereby reducing the catch per boat to the point where the cost of harvest approaches the ex-vessel value of the catch (Gordon; Crutchfield).

Because this problem causes the net economic value of the fishery to tend toward zero (from the standpoint of the commercial fishermen), economists have attempted to deal with this problem by estimating a "potential" net economic value, based upon an assumed efficient harvest of the fish. Some have suggested that the potential net economic yield of commercially caught salmon would be around 90 percent of the gross value to the fishermen (Crutchfield; Fry; Richards).

An assumed efficient harvest of the salmon is preferable to assuming that the commercial catch has zero net economic value, in which case no justification for protection or enhancement of the resource could be made. However, a "potential" value, based upon an assumed efficient harvest of the fish, has not been entirely satisfactory for several reasons. For one thing, use of a "potential" net economic value is somewhat less convincing in competing for public funds than the use of an actually realized value, especially since the usual "potential" value would require a severely limited entry into the fishery for actual realization of the potential value. (In fact, to make the "potential" value an actual value, many economists have campaigned for limited entry, and have succeeded in obtaining limited entry in some fisheries in Canada and Alaska.) But implementation of limited entry raises additional problems of equity and regulation, and Washington and Oregon have not yet chosen the limited entry route for salmon.

Another disadvantage of relying entirely upon a potential net value for Columbia River salmon is that such a potential net value would not be entirely comparable to values estimated for the sport fishery (since estimated sport fishery values are based upon benefits realized by the "consumers" of sport angling, the sport anglers themselves). Therefore, a primary objective of this study was to develop improved methods for valuing the commercial and sport catch of Columbia River salmon.

ESTIMATED BENEFITS TO CONSUMERS FROM COMMERCIALLY CAUGHT COLUMBIA RIVER SALMON

A necessary first step in estimating benefits to consumers from commercially caught salmon is to estimate the demand function for the commercial catch. Then, the demand function can be used to compute the prices consumers would be willing to pay for specified quantities of salmon, and the corresponding savings associated with increased production (or losses associated with decreased production).

Demand Functions Estimated by OLS

Based upon annual data (Appendix Tables 1 and 2) on quantity and price of fresh and frozen salmon, per capita income, and the price of beef steak, the following demand function was fitted by ordinary least squares (OLS):

$$(1) \quad \widehat{PF_t} = \underset{(13.03)}{0.00040990INC_t} + \underset{(1.52)}{0.15881PR_t} - \underset{(-4.67)}{1.5406QF_t}$$

$$n = 28$$
$$R^2 = 0.931$$
$$D\text{-}W = 1.35.$$

In the preceding equation, PF_t denotes the wholesale price of fresh and frozen chinook salmon in New York for the t^{th} year, deflated by the wholesale price index (Appendix Table 2); INC denotes U.S. per capita disposable personal income, deflated by the consumer price index (CPI) (Appendix Table 2); PR denotes the price of round steak, deflated by the CPI (Appendix Table 2); and QF denotes U.S. per capita consumption of fresh and frozen salmon (Appendix Table 1).

Certain limitations of the data in Appendix Tables 1 and 2 should be noted. The average retail price per pound of all fresh and frozen salmon would have been more accurate than using the wholesale price of chinook salmon in New York; however, the New York wholesale price was the only price available over all the years 1947-1974. Since it was thought that the price variable might be most subject to measurement error, price was used as the dependent variable.[1/] (However, for sake of comparison, a demand model with quantity as the dependent variable is listed in the Appendix, Equation (A-3). Also listed in the Appendix, Equation (A-1) is the same as (1) except that the non-significant constant term was retained in (A-1).)

Another limitation pertains to the per capita consumption variable, QF. Actual data on U.S. fresh and frozen salmon consumption were not available, but non-canned salmon figures were available and were used as a proxy for the fresh and frozen figures, although the non-canned figures also include small amounts (about 3 percent) of other salmon products such as cured and dried salmon.

1/ Unbiased parameter estimates can still be obtained from OLS when the dependent variable is subject to measurement error. However, if the explanatory variables are subject to measurement error, the OLS estimates will be biased and inconsistent (Johnston, pp. 281-283). Another reason for using QF as explanatory is that QF is influenced by biological factors affecting landings.

Despite the above limitations, fairly reliable parameter estimates appear to have been obtained in (1). Values of t, given in parentheses below the estimated coefficients, were very highly significant for the income and quantity variables, being 13.02 and -4.67, respectively. However, these significance levels may be overstated, since the Durbin-Watson statistic (D-W) was 1.35, falling in the indeterminate range at the 5 percent probability level.

One disadvantage of (1) and (A-1) is the linear functional form assumed. The linear form of (1) implies, based upon 1974 per capita deflated income of \$3,220 and deflated 1974 round steak price of \$1.249, that if the price of fresh and frozen salmon rose to about \$1.52 per pound, none would be purchased - an unlikely conclusion. Therefore, a more realistic algebraic form of demand function was fitted to the data:

$$(2) \qquad \widehat{\ln PF_t} = \underset{(2.46)}{-0.90058} + \underset{(7.40)}{0.00044722INC_t} + \underset{(0.44)}{0.10215PR_t} - \underset{(-4.44)}{2.4479QF_t}$$

$$n = 28$$
$$R^2 = 0.912$$
$$D\text{-}W = 1.15.$$

The variables in (2) are the same as previously defined for (1). The effects of the per capita income and quantity variables are again highly significant statistically. However, the D-W statistic is only 1.15, indicating a significant departure from independence of the OLS residuals. Therefore, the t values of (2) would be expected to overstate the actual significance of the estimated coefficients (Johnston, pp. 246-249).

For (2), $R^2 = 0.912$, slightly lower than for (1). However, the two R^2 values are not really comparable, the R^2 for (1) being the proportion of variation explained of the PF (price) variable in the real numbers, whereas R^2 for (2) represents the proportion of variation explained of ln PF. A more comparable R^2 value can be obtained from (2) by taking the antilogarithms of the predicted values of (2), subtracting the observed PF_t values to obtain deviations, e^*_t, in the real numbers, then using the formula:

(3) $$R^2 = 1 - \sum_{t=1}^{28} (e_t^*)^2 \div \sum_{t=1}^{28} (PF_t - \overline{PF})^2.$$

Using (3), $R^2 = 0.893$ was obtained for Equation (2), indicating a slightly better fit in the real numbers for (1), which is not unexpected since deviations about PF in the real numbers are minimized for (1), but not for (2).

There are, of course, many other algebraic forms of the demand function that will provide a curvilinear relationship between price and quantity. One curvilinear function sometimes used is the "log-log" or constant elasticity function of the form

$$\widehat{PF} = \alpha(INC)^{b_1} (PR)^{b_2} (QF)^{b_3}.$$

The above function was fitted to the data and is presented in the Appendix, Equation (A-2). Although (A-2) has about the same goodness of fit as measured by R^2 as for (2), the constant elasticity property imposed by (A-2) seems rather undesirable. According to (A-2), the elasticity of demand for fresh and frozen salmon is $1 \div 0.3475 \doteq 2.88$, which remains constant for all positive values of PF and QF. On the other hand, the elasticity of demand ranges from 1.31 to 4.21, according to (2), as QF is varied from 0.311 to 0.097, the highest and lowest values for the per capita consumption of non-canned salmon in Appendix Table 1. For average QF $\doteq$ 0.20, the elasticity of demand is about 2.04.

As discussed earlier, price of fresh and frozen salmon seemed a more logical choice for the dependent variable than did quantity, assuming that there was more error of measurement associated with price than quantity. However, even if quantity is fitted as a function of price, income, and the price of round steak, a highly significant statistical relationship still exists between price and quantity, as shown by Equation (A-3) in the Appendix.

Demand Functions Estimated by Two-Stage Least Squares

The preceding estimated demand functions can be criticized on grounds that the price and quantity of fresh and frozen salmon are somewhat interrelated, a higher price tending to divert more salmon to the fresh and frozen use and away from canned salmon. This argument may not be entirely valid in recent years, because nearly all of the Columbia River salmon are reported to be "non-canned", that is, consumed primarily in the fresh and frozen form. Nevertheless, the quantity variable could be correlated with the true error term associated with demand equations (1), (2), (A-1), and (A-2), resulting in biased parameter estimates from OLS.

One method of dealing with this difficulty would be to use the predicted value of quantity, denoted by QF^*, as an explanatory variable in place of the actually observed QF, where QF^* has been regressed as a function of all exogenous variables hypothesized for the system (Johnston, pp. 380-381). We hypothesized a simple set of exogenous variables consisting of per capita income, price of round steak, and annual per capita landings of chinook and coho salmon in the U.S., including Alaska, adjusted for imports and exports. The first stage consisted of fitting quantity per capita as a function of the preceding three exogenous variables:

(4) $$\underset{}{QF^*_t} = \underset{(2.03)}{0.1734} + \underset{(1.13)}{0.00002532INC_t} - \underset{(-1.90)}{0.1243PR_t} + \underset{(5.25)}{0.2702LN_t}$$

$$n = 28$$
$$R^2 = 0.775$$
$$D\text{-}W = 2.60.$$

All variables are defined the same in (4) as earlier for (1), except for LN_t, per capita domestic landings of chinook and coho, minus exports and plus imports of fresh and frozen salmon. Fitting price as a function of income, round steak price, and predicted quantity, QF^*, from (4), the second stage estimates were:

(5) $$\widehat{PF}_t = \underset{(12.34)}{0.00038183INC_t} + \underset{(2.70)}{0.30276PR_t} - \underset{(-5.59)}{2.0658QF^*}.$$

$$n = 28$$
$$R^2 = 0.942$$
$$D\text{-}W = 1.39.$$

The constant term had a t value less than one; therefore, it was deleted in (5), resulting in higher values of t for the explanatory variables in (5). Surprisingly, the R^2 value of 0.942 is higher than for the corresponding OLS model, Equation (1), where R^2 was 0.931.[2/] Thus, QF^* had a slightly higher statistical significance than QF, as shown by the higher R^2 and a higher t value for QF^* in (5).

Again, the linear functional form of (5) does not seem very appropriate, especially for low QF and high PF values. Fitting the exponential model, the second stage estimated equation was:

$$(6) \qquad \widehat{\ln PF_t} = \underset{(-1.21)}{-0.4331} + \underset{(5.41)}{0.0003434 INC_t} + \underset{(0.69)}{0.1404 PR_t} - \underset{(-5.72)}{3.7898 QF_t^*}.$$

$$n = 28$$
$$R^2 = 0.932$$
$$D\text{-}W = 1.62.$$

In (6), predicted quantity, QF^*, again gave a slightly higher R^2 value than did the actually reported QF values in Equation (2). Another possible advantage of (6) is the higher D-W statistic of 1.62, nearer the value of 2.0 expected for independent regression residuals. However, the D-W statistic given below (6) was computed from residuals defined as $\hat{e}_t = (\ln PF_t - \ln PF_t)$. Taking the antilogarithms and using $e_t^* = (PF_t - \widehat{PF_t})$, a D-W = 1.83 was obtained, even closer to the more ideal value of 2.0. (For the models of this study with a transformed dependent variable, usually not much difference was found between the D-W statistic computed for the transformed variables and the D-W computed in the real numbers.)

As mentioned earlier for (2), the $R^2 = 0.932$, printed by the OSU SIPS computer program for (6), is not really comparable to the $R^2 = 0.942$ for the linear demand function, (5). Computing the residuals in terms of the real numbered values of price and predicted price, R^2 was recomputed from Equation (3), giving $R^2 = 0.923$. Thus, a slightly better fit in the real numbers was obtained from (5) compared to (6), but (6) was still preferred over (5), based upon the properties of its algebraic form.

2/ The R^2 values for (1) and (5) were computed as $R^2 = 1 - \sum_{t=1}^{28} e_t^2 \div \sum_{t=1}^{28} (PF_t - \overline{PF})^2$, thus giving comparable R^2 values, whether the regression is forced through the origin or not.

The two-stage estimate of the constant elasticity function is given in the Appendix, Equation (A-4). Again, a slightly higher $R^2 = 0.929$ was obtained from the use of predicted quantity, QF_t^*, in (A-4), compared to $R^2 = 0.913$ in (A-2).

Estimated Benefits to Consumers from Commercially Caught Salmon

Estimated Benefits from the Linear Demand Function

To illustrate estimated benefits to consumers, the linear demand model, Equation (5), is easiest to use, although it does not provide the best estimate of benefits. Suppose that we wish to estimate benefits to consumers from increased salmon production at national fish hatcheries. For convenience, assume the round steak prices and per capita incomes existing in 1973 (Appendix Table 2). Substituting the deflated 1973 steak price = \$1.312 per pound and 1973 per capita income = \$3,227 into (5),

(7) $$\widehat{PF} \doteq 1.73435 - 2.0658QF^*.$$

The graph of (7) is shown in Figure 1. With an average U.S. per capita production and consumption of 0.20, the price is estimated to be $\widehat{PF} = 1.73435 - 2.0658 (0.20) \doteq \$1.32119$ per pound, point A in Figure 1. For illustration, assume a 50 percent increase in commercial catch and consumption. Then, $\widehat{PF} = 1.73435 - 2.0658 (0.30) \doteq \$1.11461$ per pound, point E in Figure 1. Thus, a price reduction of \$1.32119 - \$1.11461 = \$0.20658 per pound is predicted with the 50 percent increase in commercial catch. Thus, the average savings per person with increased production would be \$0.20658 (0.20) = \$0.041316, plus an additional saving represented by the area of the triangle BCD = 1/2(\$0.20658)(0.10) ≐ \$0.010329. Thus, total per capita benefit would be \$0.041316 + \$0.010329 ≐ \$0.0516. Multiplying the 1971 U.S. population by the per capita savings, or benefit, gives \$0.0516(209,844,000) ≐ \$10.8 million (in 1967 dollars).

The above procedure can be used to justify the operation of a specific hatchery. For example, suppose that we wished to estimate the benefit to consumers of the fiscal year 1973 production of the Little White Salmon National Fish Hatchery. One possible production alternative would have been for the hatchery to have released 1,422,470 spring chinook and 5,778,800 fall chinook salmon (Brown and Hussen, p. 10). Based upon marking studies of fall chinook salmon, the average commercial

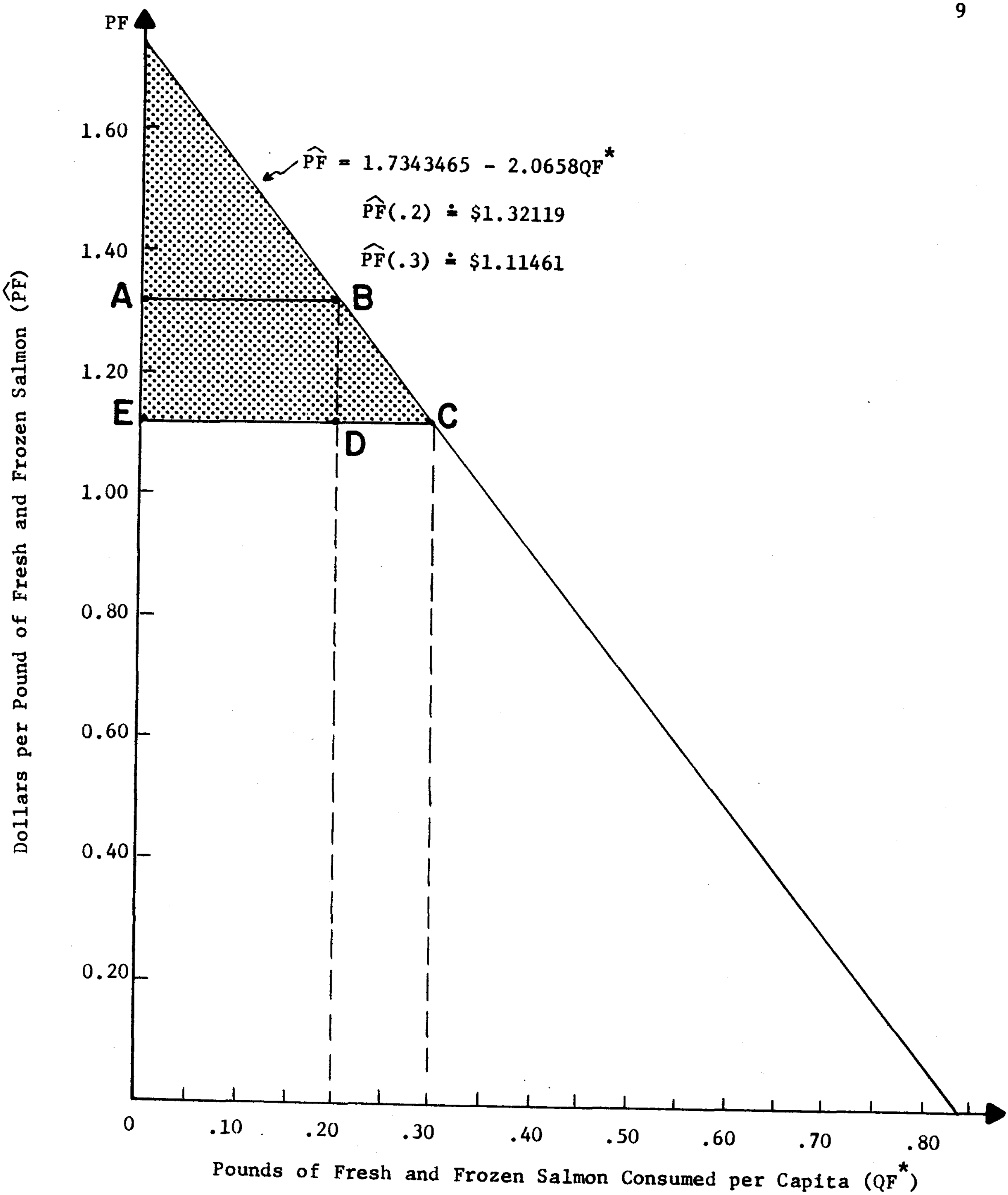

Figure 1. Estimated demand for fresh and frozen salmon and increased consumer benefits, ABCE, with a 50 percent increase in average commercial catch of Columbia River salmon.

catch per 1,000 fall chinook smolts released from the Little White Salmon Hatchery was estimated to be 69.125 pounds (Brown and Hussen, pp. 10-11). An additional 18 pounds of fall chinook salmon per 1,000 released were estimated to be caught by sport anglers. Thus, about 79 percent (69.125 ÷ 87.125 ≐ 79 percent) of the fall chinook were estimated to be harvested by commercial fishermen.

Study results of marked spring chinook salmon were not yet available, so the same harvest per pound of fish released was assumed for the spring chinook. Since spring chinook salmon had been released at 14.67 smolts per pound, compared to 100 per pound for the fall chinook salmon, a commercial catch of (100/14.67) • (69.125) ≐ 471.2 pounds per 1,000 smolts released was assumed. Thus, a release of 1,422,470 spring chinook and 5,778,800 fall chinook salmon should result in a commercial catch of 1,422.47(471.2) plus 5,778.8(69.125) ≐ 1,069,727 pounds.

What would be the benefit of this estimated commercial catch of 1,069,727 pounds from the Little White Hatchery? Assuming an average commercial catch with per capita consumption of 0.20 with the Little White Hatchery production, we can estimate per capita consumption without Little White to be $QF^* = 0.20 - (1{,}069{,}727 \div 209{,}844{,}000) \doteq 0.1949023$.

With the Little White Salmon Hatchery's production and per capita consumption, QF^*, equal to 0.20, substitution into (7) yields a predicted price, $\widehat{PF}$, equal to $1.32119, as previously shown for Figure 1. However, without the Little White production, the fresh and frozen quantity, QF^*, would drop to $QF^* \doteq 0.1949023$, causing price in (7) to increase to $\widehat{PF} = 1.73435 - 2.0658(0.1949023) \doteq \$1.33172$. Thus, without Little White's production, consumers would have to pay more, about $1.33172 - $1.32119 ≐ $0.01053 more per pound consumed. Since there would be, based on 1973 population, about 209,844,000(0.1949023) ≐ 40.9 million pounds, consumers would have to pay about $0.01053(40,900,000) ≐ $431,000 more per year on the 40.9 million pounds without the Little White production. But total costs for the Little White Hatchery for fiscal year 1973 were computed to be only $214,910 (Brown and Hussen, p. 3). Also, recalling that the commercial catch represented only about 79 percent of the total harvest of Little White chinook salmon, total cost allocated to the commercial catch would be only 0.79($214,910) ≐ $169,779.

Dividing the estimated benefits to consumers of the commercially caught Little White salmon by the Little White production costs for this commercial catch, the benefit-cost ratio would be

$$\text{B-C ratio} = \frac{\$431,000}{\$169,779} \doteq 2.54.$$

(The above benefit-cost ratio is slightly underestimated because the consumer benefits corresponding to triangle BCD in Figure 1 were not included, but including the triangular area in this case increases the B-C ratio only slightly, to 2.57.) Also, benefits are in 1967 dollars, worth about 1.3 times as much as 1973 dollars, thus increasing the B-C ratio to over 3. However, as mentioned before, the linear functional form of (5) and (7) is a serious limitation.

Estimated Benefits from the Exponential Demand Function

Essentially the same procedure used for the linear demand function was followed for the exponential function, except that the function was integrated between appropriate limits to find the area below the demand curve. Substituting 1973 per capita income and round steak price levels into (6), (6) becomes

$$\widehat{PF} = 2.3614e^{-3.7898QF^*}. \tag{8}$$

The graph of (8) is shown in Figure 2. To find estimated benefits to consumers of a 50 percent increase in the average commercial catch of Columbia River salmon, (8) was integrated to find the area corresponding to ABCE in Figure 1. The area ABCE, corresponding to the per capita consumer benefit of the assumed 50 percent increase in commercial catch, was \$0.0861671. Multiplying this per capita benefit by the 1973 population, total increased consumer benefits were \$0.0861671 (209,844,000) $\doteq$ \$18.1 million.

In a similar manner, (8) can be used to estimate the benefits of the commercial catch of salmon from the Little White Salmon National Fish Hatchery. Expected 1973 commercial catch of chinook salmon from the Little White Hatchery was earlier estimated to be 1,069,727 pounds. Assuming the average commercial catch corresponding to average annual per capita consumption of 0.20 pounds if the Little White Hatchery were in production versus the per capita consumption without Little White's

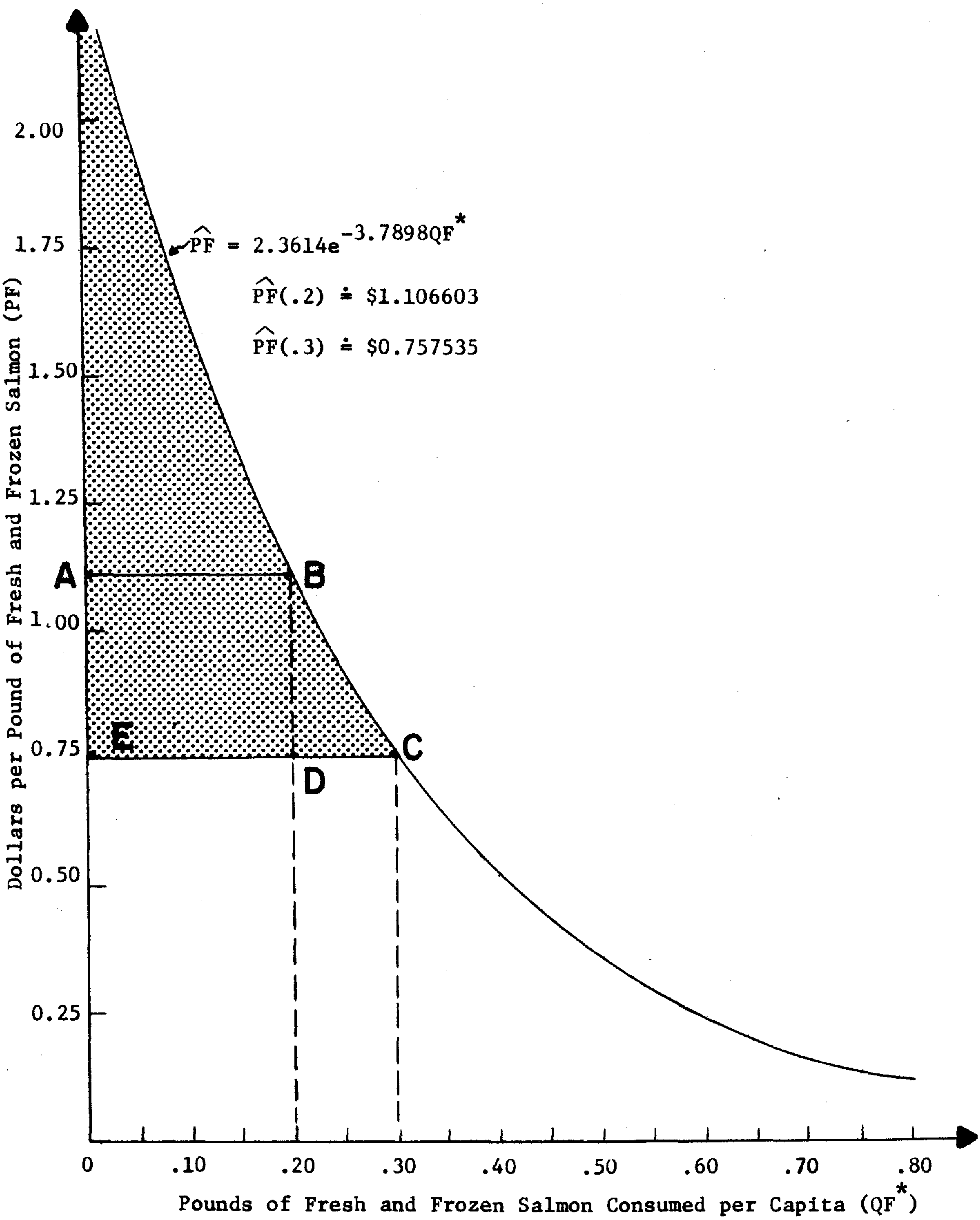

Figure 2. Estimated demand for fresh and frozen salmon and increased consumer benefits, ABCE, with a 50 percent increase in average commercial catch of Columbia River salmon.

production, $QF^* = 0.1949023$, substitution of QF^* into (8) gives the following:

$$\widehat{PF} \doteq \$1.106603 \text{ with Little White's production;}$$

$$\widehat{PF} = \$1.128189 \text{ without Little White's production.}$$

Thus, without Little White's contribution, consumers would have paid more per pound, $1.128189 - $1.106603 = $0.021586. Multiplying this savings times the assumed national consumption, a total savings to consumers from the Little White production would be:

$$\text{Benefit} = \$(0.021586)(209{,}844{,}000)(0.1949023) \doteq \$882{,}848.$$

The estimated benefit-cost ratio for the 1973 commercial catch contribution of Little White would be:

$$\text{B-C ratio} = \frac{\$882{,}848}{\$169{,}779} \doteq 5.20.$$

<u>Estimated Benefits from the Constant Elasticity Demand Function</u>

Using Equation (A-4) in the Appendix and 1973 per capita income and round steak prices, (A-4) can be written as:

(9) $$\widehat{PF} = 0.407173(QF^*)^{-0.6247}.$$

From (9), predicted price with $QF^* = 0.20$ is $1.112823. For QF^* increased 50 percent to 0.30, predicted price is lowered to 0.863817. With the lower price and larger quantity, the net gain in consumer welfare is estimated to be ($0.06088964)(209,844,000) ≐ $12.8 million. This value is about $2 million more than that estimated from linear demand equation (7), but less than the $18.1 million estimated from the exponential demand function, (8).

Concluding Remarks Regarding Consumer Benefits from Commercially Caught Salmon

There are two important reasons to estimate benefits to consumers in computing values for commercially caught salmon. First, the estimated consumer benefits are above and beyond any "potential" benefit or profit that could be realized by commercial fishermen harvesting the salmon most efficiently. Therefore, the benefits to consumers should be added to the potential value to the commercial fishermen on the production side. Considering both consumer benefits and potential profit to producers, a considerable increase of the commercial salmon values results since, heretofore, only potential profits or benefits to producers have been used, e.g., (Wahle, Arp, and Olhausen).

A second important reason for considering consumer benefits is because consumer benefits represent benefits actually being realized, whether the commercial catch is harvested efficiently or not. Thus, any objections about use of a "potential", but unrealized, benefit to commercial fishermen would not be valid for criticizing the use of consumer benefits.

How large are incremental consumer benefits relative to potential benefits to the producers (commercial fishermen)? The relative magnitudes may vary, depending upon the size of the commercial catch and the corresponding consumption of fresh and frozen salmon. However, potential benefits to fishermen should increase proportionately less with large landings because they would receive a smaller price. Nevertheless, ex-vessel prices may represent a good approximation of potential value to fishermen (Richards; Crutchfield, Kral, and Phinney).

For 1972, the reported ex-vessel troll price for chinook salmon at Washington ports was \$0.75 per pound. Assuming that 90 percent of the dressed troll catch would be converted to actual consumption, the 1972 per capita consumption of 0.165 pounds would imply an average value of the corresponding commercial catch of about $\$0.75 \div 0.90 \doteq \$0.84$ per pound of fresh and frozen fish consumed. Thus, an incremental value of something less than \$0.84 per pound of fresh and frozen salmon consumption would be expected under efficient harvesting (since price should decline with increased catch).

Incremental consumer benefits from increasing the 1972 fresh and frozen fish available for consumption can be computed by substituting the 1972 per capita income and round steak figures into (6), and by integrating the resulting function between the appropriate limits, as outlined earlier. Following this procedure, for an increase of 1 percent in the 1972 consumption of fresh and frozen salmon, the predicted price would decline from $PF \doteq \$1.17389$ to $PF \doteq \$1.16657$, giving consumers a price savings of about \$0.00732 per pound. Multiplying this savings times total 1972 consumption gives \$0.00732(.165)(208,512,000) ≐ \$252,000 for the increased consumption of 344,000 pounds, or a consumer savings of \$252,000 ÷ 344,000 ≐ \$0.73 per pound of increased production. Thus, an incremental value of \$0.73 per pound to consumers is predicted for a 1 percent increase in 1972 production, not far below the potential value to commercial fishermen under an efficient harvesting system.

The preceding computations show that consumer benefits from protection and enhancement of the salmon fishery resource are far from negligible, and should be included in the benefit-cost evaluation of hatchery or fishery improvements.

AN UPDATE OF THE 1962 EVALUATION OF THE OREGON SALMON-STEELHEAD SPORT FISHERY

Measurement of benefits to consumers in the preceding section provides an improved basis for valuing commercially caught salmon, but an improved basis is also needed for valuing the sport-caught salmon and steelhead. Although estimates of value were published in 1964 by Brown, Singh, and Castle, these estimates are rather dated, being based upon 1962 expenditures by anglers. Furthermore, improved estimating procedures have been developed since the sport value estimates were published (Brown, Nawas, and Stevens; Brown and Nawas). Thus, there are two main difficulties with the 1964 publication by Brown, Singh, and Castle which will be adjusted for in this section: (1) a more accurate measure of the effect of distance will be used, and (2) the 1962 expenditure and value levels will be updated by means of the consumer price index (CPI). In addition, the influence of fishing success on sport values will be considered.

Improving the Estimate of the Separate Effects of Cost in Money Versus Cost in Time

It was noted as early as 1963 by Knetsch that a serious bias in the derived demand curve for outdoor recreation results from assuming that the lower participation rates by people living further away is a function only of increased cost of travel. Based upon Knetsch's astute observation, a separate distance variable was introduced into the original demand functions for the salmon-steelhead sport fishery (Brown, Singh, and Castle, pp. 36-40). However, use of the traditional zone average observations led to inefficient estimates and difficulty in measuring the separate effects of travel time or distance versus monetary costs of travel, for reasons noted by Brown, Nawas, and Stevens, and Brown and Nawas.

Although a new survey of anglers is badly needed, time permits only a rather crude adjustment of the 1962 data here. Based upon improved estimation using individual observations, an analysis of 1968 hunting expenditures and patterns in Oregon showed as high, or higher, significance levels for distance as compared to variable cost per hunting trip for four out of five hunting zones (Brown, Nawas, and Stevens, p. 79). Therefore, this information will be utilized to re-estimate the 1962 salmon-steelhead demand equation. To use this information, it will be assumed that distance and cost have an equal statistical effect; that is, that the coefficients for the standardized distance and transfer cost variables are equal.[3]

It was originally intended to measure the effect of travel time by using average miles traveled per subzone as a proxy for travel time, Variable X_{4j} (Brown, Singh, and Castle, Table 12, p. 36). Although not published in 1964, the result in standardized variables was:

$$\text{(10)} \qquad \widehat{\ln DYS_j} = \underset{(0.1297)}{0.7054INC_j} + \underset{(0.2313)}{0.2948MLS_j} - \underset{(0.2551)}{1.1692CST_j}.$$

$$n = 35$$
$$R^2 = 0.6534$$

where DYS_j denotes salmon-steelhead (S-S) days of fishing taken per unit of population of subzone j; INC_j is average family income of subzone j; MLS_j is average miles per S-S trip of subzone j; and CST_j is average S-S variable cost per day of subzone j.

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[3] Standardized variables and coefficients are obtained if the correlation coefficients are used in solving the normal equations for the regression coefficients. Alternatively, each variable can be standardized before starting the regression analysis, where the i^{th} observation of the standardized variable, X, is defined as:

$$X_i = \frac{X_i - \overline{X}}{\sqrt{\sum x_i^2}}.$$

Numbers in parentheses below the regression coefficients for the standardized explanatory variables are the standard errors. All coefficients have the expected sign, except for the distance variable MLS_j. Also, the coefficients for income and variable cost are highly significant. Average distance per S-S trip, MLS_j, was not significant statistically, and was of the "wrong" sign because of the difficulty in separating out the effect of the monetary cost of travel versus the time "cost", especially when using the inefficient zone averages, as in (10). Aggregating the data into zones loses information and increases multicollinearity. In fact, the difficulty in estimating the separate effects of distance and variable fishing costs forced Brown, Singh, and Castle in 1964 to redefine the distance variable to reduce the intercorrelation between average distance per trip and variable costs.

Good indicators of the degree of multicollinearity are the so-called "Variance Inflation Factors", the main diagonal elements of the inverted correlation matrix of the explanatory variables. These were 1.5057, 4.7844, and 5.8197 for INC_j, MLS_j, and CST_j of (10), respectively. Main reason for increased variance of the coefficients for distance (MLS_j) and variable costs (CST_j), in (10), was the high intercorrelation between MLS_j and CST_j, $r_{23} = 0.87286$. (Other correlations were $r_{12} = 0.28222$, $r_{13} = 0.49330$, $r_{1y} = 0.211790$, $r_{2y} = -0.526645$, and $r_{3y} = -0.563864$.)

As mentioned earlier, more efficient estimation of the demand for Oregon big game hunting, utilizing individual observations instead of zone averages, indicated that distance usually exerted at least as much effect on participation as did variable trip costs (Brown, Nawas, and Stevens, p. 79). Therefore, it seems reasonable to impose the condition that the coefficients for MLS_j and CST_j in (10) be equal. Imposing this restriction (Johnston, pp. 155-159),

$$(11) \qquad \ln DYS_j^* = \underset{(0.1301)}{0.52127 INC_j} - \underset{(0.0672)}{0.39906 MLS_j} - \underset{(0.0672)}{0.39906 CST_j}.$$

$$n = 35$$
$$R^2 = 0.5456$$

Converting to non-standardized variables, the equivalent of (11) is:

(11a) $$\ln DYS_j^* = 0.83276 + 0.006424INC_j - 0.003905MLS_j - 0.06882CST_j.$$

The t values and R^2 would be exactly the same for (11a) as for (11).

Re-estimation of Salmon-Steelhead Sport Values

Substituting the 1962 subzone average incomes, average miles traveled per trip by subzone, and the average S-S variable cost per day, by subzone, into (11a),[4/] a total estimated consumer surplus of $15.5 million is obtained. (Since this consumer surplus is in terms of 1962 dollars, this would amount to about 1.5894 (15.5) ≐ $24.6 million in 1974 dollars, adjusting by the consumer price index.)

Based upon the 1962 survey of Oregon salmon-steelhead sport anglers (Brown, Singh, and Castle, p. 43), there were an estimated (2832) • (399.5) ≐ 1,131,400 days of angling for salmon and steelhead. Dividing $15.5 million by 1,131,400 gives about $13.70 per day of S-S fishing (in terms of 1962 dollars). In terms of 1974 dollars, multiplying 1.5894 times $13.70 gives $21.77 per S-S day.

The above estimate of average value per day of S-S fishing has obvious limitations. For one thing, the data are 13 years old. There may have been significant structural changes in the demand for S-S fishing since 1962. Secondly, the above estimated values were based upon rather crude assumptions and analysis. For example, the estimation of Equations (11) and (11a) was based upon the subzone populations given in Appendix Table 1 (Brown, Singh, and Castle, p. 42), which incorrectly allocates the main zone population among the subzones. An improved allocation of population among subzones significantly changes the impact of income, but does not appear to have much effect on the final estimates of value. Nevertheless, a more complete analysis of this and other aspects of the estimation and evaluation

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4/ All these data are given in Appendix Table 1 (Brown, Singh, and Castle, p. 43). The dependent variable of (11a) had been multiplied by 1,000 before division by the subzone populations. Since the sampling rate was approximately 1/399.5, the predicted quantity from (11a) should be multiplied by 0.3995 to give the expected per capita number of S-S days for a particular subzone.

needs to be made. Despite these obvious limitations, the above estimate of around $22 for an average 1974 S-S fishing day is thought to be "in the ball park," even though more current information would be highly desirable.[5/]

HOW THE ESTIMATED SPORT AND COMMERCIAL VALUES SHOULD BE USED

General Considerations

Given the properties and limitations of the preceding sport and commercial values, some care needs to be exercised in applying these values to actual estimation of benefits from water-related projects. In general, it needs to be kept in mind that the $21-$22 per day estimate of value for 1974 S-S sport fishing represents an average value across all S-S fishing, based upon 1962 fishing conditions and patterns. What is not presently known is how much the estimated 1974 sport fishing value of $22 would change as location, species, and fishing success change.[6/] Therefore, the average estimated value of $22 per S-S day in 1974 can easily be misinterpreted.

Use of the average value per S-S day of sport fishing is especially hazardous in trying to arrive at a needed value per fish. Since there was a catch of about 1,017 salmon and steelhead reported by the anglers in the 1962 survey, counting immature salmon ("jacks") as one-third of a mature salmon or steelhead (Brown, Singh, and Castle, p. 43), the estimated 1962 sport value per fish would be $15.5 million divided by 399.5(1,017) ≐ 406,300, or about $38 per fish. (The anglers surveyed in 1962 represented about 1/399.5 of the total S-S sport fishing.) Thus, for 1974, the average value would be, supposedly, 1.5894($38) ≐ $60 per fish.

5/ Values were estimated for the 1967 salmon sport fisheries of Washington, using a different approach (Mathews and Brown). These values were based on a questionnaire designed to estimate the price necessary before sportsmen would forego salmon fishing in selected areas of Washington. This study recommended that $28 per fishing day should be an absolute minimum for evaluating salmon fisheries threatened by alternative water-based industries.

6/ Pioneering research by Stevens (1965, 1966) indicated a significant increase in per capita angler trips with increased average number of salmon taken per angler trip. Salmon anglers, given sufficient time to adjust, appear to react to changes in success with a response close to unit elasticity, although the short-run response is considerably smaller (Stevens, 1965, p. 108).

But this average value per fish could vary widely, depending upon the species, location, fishing success, etc.

A 1974 average value of $60 per sport-caught salmon or steelhead may be reasonable if evaluating a salmon fishery threatened by alternative water-based industries. But for computing the value of fishery enhancement, it has sometimes been suggested that a value less than that based upon consumer surplus should be used, e.g., a value equal to the single price that a revenue-maximizing owner of the resource would charge. (A lower than average value per fish, for additional fish beyond the average quantity of fish, could be inferred from economic theory, at least if possible increases in fishing success do not increase the demand for fishing.) However, the logic of the revenue-maximizing price as the value for fishery enhancement seems unclear. A more valid approach would appear to be that used by Schuler (1974). Given those costs to be allocated over the direct beneficiaries (reflected in the budget constraint), generate the optimal relative prices and quantities for each "merit" good resulting from the program. Schuler then modified this procedure to reflect distributional considerations.

For the Columbia River fishery, it needs to be kept in mind that much of the so-called "fishery enhancement" effort has really been an attempt to bring the fishery partially back to the level existing before dam construction on the Columbia. If so, then rather high values for improvement of the fishery may be justified, although the justification for such improvement projects would seem to rest as much on political as on economic considerations. However, if demand estimates for a specific fishery were available, along with estimates of elasticity with respect to fishing success, direct estimates of benefits or losses associated with specific water policy alternatives could be made (Stoevener, Stevens, Horton, Sokoloski, Parrish, and Castle, pp. 71-83). Unfortunately, such site-specific demand estimates are not usually available, although research is needed to provide such estimates. In the meantime, it may sometimes be possible to estimate the change in fishing days associated with a particular water-related project, then to measure the benefit or loss from the project according to the predicted change.

Another possibility for some projects would be to estimate incremental benefits, based upon consumer benefits from the commercial catch. In cases of small incremental changes in fish numbers, the estimated benefits to consumers from the commercial catch is more appropriate for estimation of benefits or losses from changes in fish numbers, as illustrated earlier.

Application to a Specific Fishery

The preceding general considerations can be illustrated by estimating the sport and commercial values of a specific fishery. As an example, consider the fall chinook fishery of the Columbia River. A marking experiment was begun in 1962 by the Columbia Fisheries Program Office, National Marine Fisheries Service, to estimate the contribution of hatchery-reared fall chinook salmon to the commercial and sport fisheries of the Pacific Coast. The marking portions of the study began in 1962 with the 1961 brood, and ended in 1965 with the 1964 brood. Sampling for these marked fall chinook was started in 1963 and ended in 1969 (Worlund, Wahle, and Zimmer; Rose and Arp; Arp, Rose, and Olhausen; and Wahle, Arp, and Olhausen).

Based upon data from the preceding marking experiment, the harvest of fall chinook, averaged over the four brood years, was distributed as follows:

Ocean commercial........	56.5 percent
Ocean sport.............	20.2 percent
River commercial........	23.2 percent
River sport.............	0.1 percent

For illustration, suppose that it were proposed to close the river commercial (gill net) fishery below Bonneville. In 1974 a total of 1,189,200 pounds was landed by this fishery. Assuming the Indian fishery catch to remain constant at 903,700 pounds for 1974, what would be the loss in consumer benefits? Since the 1,189,200 pounds for the gill net fishery are round weights, the fresh and frozen equivalent weight should be around $0.73(1,189,200) \doteq 868,000$ pounds, or about $868,000 \div 211,265,000 \doteq 0.00411$ pounds per capita. Thus, if the gill net fishery were abolished, the 1974 per capita consumption is assumed to drop from 0.180 (Appendix Table 1) to $0.180 - 0.00411 \doteq 0.17589$.

Substituting the 1974 per capita income and round steak prices (Appendix Table 1) into Equation (6), (6) can be written as:

$$PF = 2.3350e^{-3.7898QF^{*}}. \tag{12}$$

For the reported 1974 consumption of 0.180, predicted price, PF, is about \$1.18039 per pound. Without the Columbia River gill net fishery, and with per capita consumption, QF^{*}, equal to about 0.17589, PF $\doteq$ \$1.19892. Thus, an increased price to consumers of (\$1.19892 - \$1.18039) $\doteq$ \$0.01853 per pound is predicted. Multiplying increased price times the new total consumption gives \$0.01853 • (0.17589)(211,265,000) $\doteq$ \$688,600, a net loss to consumers from having to pay a higher price.

What would be the offsetting benefits to the sport fishery from eliminating the Lower Columbia gill net fishery? Very little, unless there were dramatic increases in catch and effort in the fall chinook sport fishery, which does not appear likely, since less than 0.3 percent of the marked fish (brood years 1961, 1962, 1963, and 1964) were caught in the Columbia River by sport anglers. Even assuming twice the success and twice the effort in the Columbia River fall chinook fishery, a 1974 estimated sport catch of (2)(2)(0.003)(1,189,200) $\doteq$ 14,300 pounds would have resulted. If the catch averaged 20 pounds per fall chinook, a total sport catch of about 715 fish would be estimated. Using the upper limit (for fishery enhancement) of \$22 per day of salmon fishing, and assuming an average three days of fishing per salmon, a value for the sport catch of (3)(\$22)(715) = \$47,190 would be estimated. But only three-fourths of this amount would be attributable to the assumed closure of the gill net fishery, or about \$35,392, since 179 fish would have been caught without closing the commercial fishery. Thus, under the given assumptions, the increased benefit to the sport fishery would be only about \$35,392 ÷ 688,600 = 5.1 percent of the loss to consumers!

Another word of caution regarding the sport values should be noted. Suppose there exists a river fishery to be enhanced and the present fishery requires, say, 10 days of fishing per salmon caught. Suppose further that the water-related project will increase the sport catch by 1,000 salmon per year. What would be the value of the additional 1,000 salmon? From earlier calculations, the average value per day of S-S fishing could be as high as \$13.70 in 1962 dollars, or about

\$22 in 1974 dollars. Some may try to compute a value per salmon as 10 • (\$22) = \$220, but such an estimated value may be erroneous because it appears unlikely that the extra 1,000 salmon would immediately induce an additional 10,000 days of fishing. More nearly correct would be to first ask, "How many additional days of fishing can really be expected from the additional 1,000 fish?"[7/] If this question can be answered approximately, say, 2,000 days, then a fair approximation would be to use 2,000(\$22) ≐ \$44,000 as an estimate of the benefit from the additional 1,000 fish. (Of course, in the longer run, more than 2,000 fishing days might result from the additional 1,000 fish.)

SUMMARY AND CONCLUSIONS

Research Findings

1. An approach for evaluating the commercial salmon catch, based upon benefits received by consumers from fresh and frozen salmon production, has been developed. Essentially, this method estimates the incremental savings or benefits realized by consumers for specified water-related projects or specified policy alternatives.[8/]

2. These estimated consumer benefits are based upon estimates of demand for fresh and frozen salmon and are, therefore, applicable primarily to chinook and coho salmon, the most important species of the Columbia River.

3. Level of estimated consumer benefits varies somewhat, depending upon the year considered and the algebraic form of demand assumed. Using the preferred exponential form of demand functions for recent years, small increases in salmon production were predicted to give consumer benefits of \$0.80 or more per pound for the added production.

7/ More research is obviously needed to help answer this type of question.

8/ After this report had been written, an excellent study by Schuler (1974) came to our attention. Schuler's approach was to price and allocate hatchery production between the sport and commercial catch, based upon maximization of consumer surplus, subject to budget constraints sufficient to cover specified levels of hatchery production costs. In addition, Schuler considered the impact of different desired weights for more equal general income distribution upon the optimal price and allocation solution.

4. The above estimated consumer benefits are entirely in addition to any actual or potential benefits accruing to the commercial fishermen. (The potential benefits on the production side, usually estimated to be about equal to the ex-vessel price, have traditionally been the only basis for valuing the commercial catch.)

5. Values for the Oregon salmon-steelhead (S-S) sport fishery were recomputed, using additional knowledge gained since the original study (Brown, Singh, and Castle) was published in 1964. An estimated figure of $22 per day of S-S fishing (1974 price level) is recommended as the lowest value to be used for a fishery threatened by some water-related project or alternative. A similar value may also be appropriate for some fishery enhancement or improvement projects when the purpose of those projects is to ameliorate the effects of earlier water-related projects on the fishery.

Limitations and Needed Further Research

1. Although estimated consumer benefits for commercially caught salmon appear very useful, additional research is needed to better estimate potential benefits to producers (commercial fishermen). Essentially, estimates of demand at the ex-vessel level are needed.

2. Although the updated average value per S-S fishing day by sport anglers appears reasonable, a more thorough analysis of the 1962 survey data might be useful. In the longer run, a new and improved survey of sport anglers is badly needed to provide estimates of value for incremental changes in the S-S sport fishery in a manner similar to the method developed in this report for the commercial fishery.

3. Validity of any estimates of economic value depend crucially upon the underlying data used for the analysis. Better statistical data are badly needed on prices paid, from ex-vessel to retail, and on quantities going into various uses for the various species of salmon. Similarly, better data on sport catch and effort, by species, are needed for the various salmon-steelhead fisheries.

REFERENCES

Arp, A. H., J. R. Rose, and S. E. Olhausen, Contribution of Columbia River Hatcheries to Harvest of 1963 Brood Fall Chinook Salmon (*Oncorhynchus tshawytscha*). National Marine Fisheries Service, Columbia Fisheries Program Office, Portland, Ore., Econ. Feas. Rep. No. 1, Dec. 1970, 33 pages.

Brown, William G., Ajmer Singh, and Emery N. Castle, An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fishery. Ore. Agr. Exp. Sta. Tech. Bul. 78, Corvallis, Sept. 1964, 47 pages.

__________ and Farid Nawas, "Effect of Aggregation Upon the Estimation of Outdoor Recreation Demand Functions." Am. J. Agr. Econ. 55(1973):246-249.

__________, Farid Nawas, and Joe B. Stevens, The Oregon Big Game Resource: An Economic Evaluation. Ore. Agr. Exp. Sta. Spec. Rep. 379, Corvallis, Mar. 1973, 110 pages.

__________ and Ahmed Hussen, A Production Economic Analysis of the Little White Salmon and Willard National Fish Hatcheries. Ore. Agr. Exp. Sta. Spec. Rep. 428, Corvallis, Dec. 1974, 15 pages.

Bureau of Labor Statistics, Monthly Labor Review. U.S. Government Printing Office, Washington, D.C., March 1947 - Feb. 1955.

Council of Economic Advisors, Economic Report of the President, 1975. (Annual report, transmitted to Congress, Washington, D.C., Feb. 1975.)

Crutchfield, James A., "Valuation of Fishery Resources." Land Economics 38(1962): 145-154.

__________, K. B. Kral, and L. A. Phinney, An Economic Evaluation of Washington State Department of Fisheries Controlled Natural-Rearing Program for Coho Salmon (*Oncorhynchus kisutch*). Washington Dept. Fish. Res. Div., Olympia, 1965. 26 pages. (Processed.)

Fry, Donald H., Jr., "Potential Profits in the California Salmon Fishery." California Fish and Game, Oct. 1962, 48:256-267.

Gordon, H. Scott, "The Economic Theory of a Common Property Resource: The Fishery." J. Pol. Econ., April 1954, pp. 124-142.

Johnston, J., Econometric Methods, 2nd ed. New York: McGraw-Hill Book Co., 1972.

Knetsch, Jack L., "Outdoor Recreation Demands and Benefits." Land Economics 39(1963):387-396.

Mathews, Stephen B. and Gardner S. Brown, "Economic Evaluation of the 1967 Sport Salmon Fisheries of Washington." Tech. Rep. 2, Wash. Dept. of Fisheries, Olympia, April 1970.

National Marine Fisheries Service, Fisheries of the United States, 1972. Current Fishery Statistics No. 6100, Washington, D.C., March 1973.

__________, Basic Economic Indicators: Salmon, 1947-72. Current Fishery Statistics No. 6129, Economic Research Laboratory, Washington, D.C., August 1973.

__________, Fisheries of the United States, 1973. Current Fishery Statistics No. 6400, Washington, D.C., March 1974.

__________, Fisheries of the United States, 1974. Current Fishery Statistics No. 6700, Washington, D.C., March 1975.

__________, Food Fish - Market Review and Outlook. Current Economic Analysis F-20, Washington, D.C., March 1975.

Richards, Jack A., An Economic Evaluation of Columbia River Anadromous Fish Programs. Ph.D. dissertation, Oregon State University, Corvallis, 1968, 274 pages.

Rose, J. H. and A. H. Arp, Contribution of Columbia River Hatcheries to Harvest of 1962 Brood Fall Chinook Salmon (*Oncorhynchus tshawytscha*). National Marine Fisheries Service, Columbia Fisheries Program Office, Portland, Ore. April 1970. 27 pages. (Processed.)

Schuler, Francis M. Jr., Distributional Considerations in the Allocation of the Production Costs of Marketable Public Outputs, with an Application to the Columbia River Salmon Hatcheries. Ph.D. dissertation, University of Rhode Island, Kingston, 1974, 186 pages.

Stevens, Joe B., A Study of Conflict in Natural Resource Use: Evaluation of Recreational Benefits as Related to Changes in Water Quality. Ph.D. dissertation, Oregon State University, Corvallis, Aug. 1965, 205 pages.

__________, "Recreation Benefits from Water Pollution Control." Water Resources Research, 2(1966):167-182.

Stoevener, H. H., Joe B. Stevens, H. F. Horton, A. Sokoloski, L. P. Parrish, and E. N. Castle, Multi-Disciplinary Study of Water Quality Relationships: A Case Study of Yaquina Bay, Oregon. Ore. Agr. Exp. Sta. Spec. Rep. 348, Corvallis, Feb. 1972, 135 pages.

U.S. Bureau of the Census, Statistical Abstract of the United States: 1972 (93rd ed.), Washington, D.C., 1972.

__________, Statistical Abstract of the United States: 1975 (96th ed.), Washington, D.C., 1975.

U.S. Department of Agriculture, Agricultural Statistics, 1973. U.S. Government Printing Office, Washington, D.C., 1973.

__________, Economic Research Division, Livestock and Meat Situation. Washington, D.C., 1955-1974.

Wahle, Roy J., Arthur H. Arp, and Steven K. Olhausen, Contribution of Columbia River Hatcheries to Harvest of 1964 Brood Fall Chinook Salmon (*Oncorhynchus tshawytscha*). Economic Feasibility Report No. 2, Columbia Fisheries Program Office, NMFS, NOAA, U.S. Department of Commerce, Portland, Oregon, Feb. 1972, 31 pages.

__________, Robert R. Vreeland, and Robert H. Lander, "Bioeconomic Contribution of Columbia River Hatchery Coho Salmon, 1965 and 1966 Broods, to the Pacific Salmon Fisheries." Fishery Bulletin, Vol. 72 (1974), pp. 139-169.

Worlund, Donald D., Roy J. Wahle, and Paul D. Zimmer, "Contribution of Columbia River Hatcheries to Harvest of 1961 Brood Fall Chinook Salmon (*Oncorhynchus tshawytscha*)," Fishery Bulletin, Vol. 67 (1969), pp. 361-391.

APPENDIX

Fitted Equations of Alternative Models of Demand for Commercially Caught Columbia River Salmon, and Basic Data Analyzed

(A-1)

$$\widehat{PF}_t = \underset{(-0.42)}{-0.1103} + \underset{(9.77)}{0.0004222INC_t} + \underset{(1.28)}{0.2126PR_t} - \underset{(-3.69)}{1.453QF_t}.$$

n = 28
R^2 = 0.931
D-W = 1.19

(A-2)

$$\widehat{\ln PF_t} = \underset{(-9.94)}{-10.371} + \underset{(8.31)}{1.2335 \ln INC_t} + \underset{(0.62)}{0.1769 \ln PR_t} - \underset{(-3.27)}{0.3475 \ln QF_t}.$$

n = 28
R^2 = 0.913 (in logs)
R^2 = 0.890 (in real numbers)
D-W = 1.01

(A-3)

$$\widehat{\ln QF} = \underset{(-2.58)}{-1.4254} + \underset{(1.28)}{2.6736INC_t} + \underset{(0.46)}{0.1756PR_t} - \underset{(-3.38)}{1.2470PF_t}.$$

n = 28
R^2 = 0.656
D-W = 2.00

(A-4)

$$\widehat{\ln PF_t} = \underset{(-7.62)}{-8.7394} + \underset{(5.63)}{0.9653 \ln INC_t} + \underset{(0.59)}{0.1544 \ln PR_t} - \underset{(-4.29)}{0.6247 \ln QF_t^*}.$$

n = 28
R^2 = 0.929 (in logs)
R^2 = 0.912 (in real numbers)
D-W = 1.44

Appendix Table 1. Reported Data Related to Demand for Commercially Caught Columbia River Salmon

Year	Wholesale price of chinook per lb. a/	U.S. per capita consumption of non-canned salmon (lb.) b/	U.S. per capita disposable personal income c/	Retail price of round steak per lb. d/	Total available chinook & coho per capita in U.S. (lbs.) e/
	($)		($)	($)	
1947...	0.306	0.311	1,178	0.756	0.777
1948...	0.392	0.232	1,290	0.905	0.746
1949...	0.417	0.275	1,264	0.853	0.559
1950...	0.501	0.240	1,364	0.936	0.811
1951...	0.530	0.275	1,469	1.093	0.772
1952...	0.519	0.255	1,518	1.112	0.725
1953...	0.496	0.268	1,583	0.914	0.594
1954...	0.564	0.253	1,585	0.906	0.624
1955...	0.565	0.241	1,666	0.902	0.515
1956...	0.635	0.174	1,743	0.882	0.469
1957...	0.642	0.190	1,801	0.936	0.384
1958...	0.733	0.207	1,831	1.042	0.436
1959...	0.773	0.168	1,905	1.073	0.372
1960...	0.849	0.129	1,937	1.055	0.269
1961...	0.869	0.179	1,984	1.036	0.335
1962...	0.950	0.140	2,065	1.078	0.329
1963...	0.915	0.193	2,138	1.064	0.315
1964...	0.882	0.179	2,283	1.039	0.278
1965...	0.865	0.189	2,436	1.084	0.337
1966...	0.907	0.181	2,604	1.108	0.278
1967...	0.938	0.171	2,749	1.103	0.275
1968...	1.039	0.182	2,945	1.143	0.287
1969...	1.202	0.202	3,130	1,267	0.135
1970...	1.347	0.170	3,376	1.302	0.268
1971...	1.272	0.136	3,605	1.361	0.209
1972...	1.348	0.165	3,843	1.477	0.204
1973...	1.835	0.097	4,295	1.746	0.097
1974...	2.058	0.180	4,637	1.798	0.232

SOURCE:

a/ Current Fishery Statistics No. 6129, Basic Economic Indicators: Salmon, 1947-72, Table II-6. Data for 1947-49 was estimated from the ex-vessel price by means of the regression:

$$\widehat{PF} = -.20327 + 5.8951 \text{ ex-vessel}$$
$$(-2.35) \quad (12.11)$$
$$R^2 = .880$$

Ex-vessel price data used in the regression were obtained from the same source, Table II-6. Data for 1970-74 from Food Fish - Market Review and Outlook, Current Economic Analysis F-20.

b/ Current Fishery Statistics No. 6129, Basic Economic Indicators: Salmon, 1947-72, Table II-1. Data for 1970-74 are revised as per phone conversation Dec. 2, 1975, with Dick Kinoshita of the NMFS Economics Research Division in Washington, D.C. He is the person who originally calculated the series.

c/ Agricultural Statistics, 1972, Table 685; and Agricultural Statistics, 1973, Table 670. Figures for 1971-73 from Agricultural Statistics, 1974. Figures for 1974 from Economic Report of the President, 1975.

d/ For 1947-54, from Monthly Labor Review. For 1955-74, from Livestock & Meat Situation.

e/ Chinook and coho landings and balance of trade figures from Current Fishery Statistics No. 6129, Basic Economic Indicators: Salmon, 1947-72, and from Current Fishery Statistics, Fisheries of the U.S., 1972, 1973, 1974. Population figures from Agricultural Statistics, 1972 (Table 643) and 1973 (Table 631), and from Statistical Abstract of the United States, 1974.

Appendix Table 2. Population, Consumer Price Index, and Deflated Data Used in Estimating Demand for Commercially Caught Columbia River Salmon

Year	Deflated wholesale price of chinook per lb. a/	Deflated U.S. per capita disposable personal income b/	Total U.S. resident population c/ (1,000)	Deflated retail price of round steak per lb. b/	Consumer price index (1967 = 100)
	($)	($)		($)	
1947...	0.400	1,761	144,083	1.130	66.9
1948...	0.473	1,789	146,730	1.255	72.1
1949...	0.530	1,770	149,304	1.195	71.4
1950...	0.612	1,892	151,868	1.298	72.1
1951...	0.582	1,888	153,982	1.405	77.8
1952...	0.586	1,909	156,393	1.399	79.5
1953...	0.568	1,976	158,956	1.141	80.1
1954...	0.644	1,969	161,884	1.125	80.5
1955...	0.644	2,077	165,069	1.124	80.2
1956...	0.700	2,141	168,088	1.084	81.4
1957...	0.688	2,136	171,187	1.110	84.3
1958...	0.775	2,114	174,149	1.203	86.6
1959...	0.815	2,182	177,135	1.229	87.3
1960...	0.895	2,184	179,979	1.189	88.7
1961...	0.920	2,214	182,992	1.156	89.6
1962...	1.002	2,279	185,771	1.190	90.6
1963...	0.968	2,332	188,483	1.160	91.7
1964...	0.931	2,457	191,141	1.118	92.9
1965...	0.895	2,578	193,526	1.147	94.5
1966...	0.909	2,679	195,576	1.140	97.2
1967...	0.938	2,749	197,457	1.103	100.0
1968...	1.014	2,826	199,399	1.097	104.2
1969...	1.129	2,851	201,385	1.154	109.8
1970...	1.220	2,903	203,806	1.120	116.3
1971...	1.117	2,972	206,212	1.122	121.3
1972...	1.132	3,067	208,230	1.179	125.3
1973...	1.354	3,227	209,844	1.312	133.1
1974...	1.325	3,220	211,265	1.249	144.0

a/ Deflated by the wholesale price index (Statistical Abstract of the United States, 1971, 1974).

b/ Deflated by the consumer price index (Statistical Abstract of the United States, 1971, 1974).

c/ From Agricultural Statistics, 1972 (Table 643) and 1973 (Table 670). Preliminary 1974 figures from Statistical Abstract of the United States, 1974.