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Estimated Costs and Benefits of Water Supply Improvements at the Little White Salmon National Fish Hatchery

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SUMMARY

The main purpose of this study was to estimate benefits that would accrue from expenditures for water supply improvements. To this end, it was assumed that returns of adult fish to the Spring Creek and Little White Salmon National Fish Hatcheries were positively correlated with smolt survival and salmon harvest in the various fisheries. Furthermore, because of the similar nature and close proximity of the two hatcheries for the 1961-69 brood years, it was assumed that the major cause of the difference in survival and returns to the hatchery was the difference in water quality, the Spring Creek hatchery having higher quality spring water, as compared to the colder (and sometimes muddy) river water in winter months at the Little White hatchery. However, completed water quality improvements at Little White should make its winter water quality more comparable to that of Spring Creek during the 1961-69 brood years.

Assuming only a 20 percent increase in survival and harvest, estimated annual benefits from the water quality improvements (pipes, pumps, dams, and other structures) were $109,000, 1973 price level. This estimated benefit was about 77 percent more than the estimated total costs of $61,700 (1973 price level). Spreading costs over a number of years, an annual benefit-cost ratio of more than 10 to 1 was estimated. The projected 20 percent increase in harvest of Little White Salmon from the water improvements is thought to be quite conservative because returns to the Spring Creek hatchery actually averaged more than 240 percent of returns to Little White for the 1961-1969 brood years.

ESTIMATED COSTS AND BENEFITS OF WATER SUPPLY IMPROVEMENTS AT THE LITTLE WHITE SALMON NATIONAL FISH HATCHERY

William G. Brown and Douglas M. Larson

INTRODUCTION

Although the large sum of money - about $3 million per year - spent for operation and maintenance of the 21 salmon (*Oncorhynchus spp.*) and steelhead trout (*Salmo gairdneri*) hatcheries funded by the Columbia Fisheries Program is a substantial justification in itself for economic analysis of various possible production alternatives at the hatchery level, probably an even stronger justification results from the fact that many of the hatcheries are severely limited in funds for needed improvements in the hatchery production system. One example of a needed improvement for some hatcheries is the water supply. During the winter and early spring months, water pumped directly from the river is often too cold and/or muddy for good fish growth. On the other hand, at some locations stream water can become too warm during the summer months, resulting in serious disease problems.

In this study, improvements in the water supply for the Little White Salmon National Fish Hatchery are analyzed for estimating associated benefits and costs. This hatchery is on the Little White Salmon River, a tributary of the Columbia River, about 60 miles above Portland. The Little White Salmon Hatchery is of medium size, having the capacity to release from 150,000 to 158,000 pounds of salmon per year, depending upon the species produced. The hatchery employs a manager (who also directs the operation of another nearby salmon hatchery), an assistant manager, a clerk, three persons for fish production, and one person for maintenance.

Facilities of the Little White Salmon Hatchery include troughs and incubators for the hatching of salmon eggs. The hatchery has a rearing pond capacity of nearly 76,000 cubic feet.

Returns to the Little White Salmon and Spring Creek National Fish Hatcheries are compared. The Spring Creek Hatchery, about 15 miles further up the Columbia than the Little White Hatchery, had similar facilities as the Little White Hatchery until converted to a water re-use system in the early 1970s. However, even before being put on a water re-use system, the Spring Creek Hatchery had an excellent source of clean spring water with a nearly constant temperature of 46° to 47° F. throughout the year. On the other hand, temperature of the Little White Salmon River water drops to 41° or 42° F. during the winter months, too cold for good growth of the fall chinook fingerlings.

RETURN OF FALL CHINOOK SALMON (*Oncorhynchus tshawytscha*) TO THE HATCHERY, BY BROOD YEARS

Average numbers of fall chinook salmon returning to the hatchery per 100 pounds of smolts released for the 1961-69 brood years are shown in Table 1. As might be expected from the better quality water at the Spring Creek Hatchery, more salmon per pound released returned to the Spring Creek Hatchery, except for one brood year, 1967. It can also be seen from Table 1 that there is much variability in the returns to the hatchery from one brood year to the next, and the returns for the last four brood years, 1966-1969, at Spring Creek were lower than the average of the first five brood years, 1961-1965.

Given the increasing size of the released smolts (see Table 1), it was expected that survival of the smolts would be enhanced, and the returns to the hatchery should have thereby increased over time, instead of decreasing. Therefore, an extensive analysis of other factors was undertaken, factors which might have caused the diminishing returns to the hatchery and/or the difference in returns between the two hatcheries.

One such factor considered was the possible effect of nitrogen supersaturation. This phenomenon, associated with the proliferation of dams on rivers, has been thought by some to be a major contributor to the demise of the Columbia River salmon runs. It occurs primarily because the extreme turbulence and pressure resulting from water falling several hundred feet cause nitrogen to be dissolved in the water at higher than normal levels. In fact, higher than known lethal levels of nitrogen have been observed in the water of some spill basins (Environmental Protection Agency).

Table 1. Average Number of Fall Chinook Salmon Returning to Hatchery Per 100 Pounds of Smolts Released from the Little White Salmon and Spring Creek National Fish Hatcheries, by Brood Year a/

Brood year	Hatchery	Size of smolts released (fish per lb.)	Average no. of fish returning to hatchery per 100 lbs. released
1961	Little White	180.5	8.507
1962	" "	227.0	3.600
1963	" "	199.8	20.461
1964	" "	177.0	3.278
1965	" "	140.9	3.663
1966	" "	147.9	7.788
1967	" "	125.1	10.047
1968	" "	114.9	5.297
1969	" "	93.8	2.156
LITTLE WHITE AVERAGE			7.200
1961	Spring Creek	227.5	32.326
1962	" "	172.1	6.402
1963	" "	215.5	42.332
1964	" "	154.6	17.666
1965	" "	132.3	26.581
1966	" "	106.2	8.107
1967	" "	115.7	6.367
1968	" "	99.1	8.527
1969	" "	100.5	8.449
SPRING CREEK AVERAGE			17.417

a/ Unpublished reports of the data were made available to the authors by Steve Leek, hatchery biologist, Little White Salmon National Fish Hatchery.

In a free-flowing river, supersaturated water returns relatively quickly to normal levels, but the increasing number of dams on the Columbia River and its tributaries have compounded the problem in two ways. First, the dams have transformed the formerly free-flowing Columbia into a series of reservoir pools, retarding the equilibration of the supersaturated water with the air. Secondly, the dams slow down the upstream progress of returning adult salmon, as well as the outgoing juveniles, thus exposing the fish to higher than normal levels of nitrogen for longer periods of time.

Although nitrogen supersaturation was likely a problem for Columbia River anadromous fish in some years, there is a difference of opinion as to how serious the present problem is. There have been some modifications made in the dams in recent years to reduce the nitrogen saturation from water spillage.

Since the smolts from a given brood year are released in the spring of the following year, an index of nitrogen saturation was estimated from the amount of water spilled over Bonneville Dam for the appropriate months and years. (Computations are explained in the Appendix.) Also, indices of fishing pressure, both off-shore and in various parts of the Columbia River, were constructed in an attempt to explain some of the variability of returns of fish to the hatchery. The estimated effects of fishing pressure were of the expected negative direction, and these indices did help to explain a considerable part of the variation in returns of the salmon to the hatchery. (More details concerning the computation of the indices of fishing pressure and the impact of fishing pressure on returns of salmon to the hatchery are given in the Appendix.) The nitrogen supersaturation variable, however, did not seem to help explain returns.

For purposes of the economic analysis, return of salmon to the hatchery per 100 pounds of smolts released, R, was fitted as a function of the specified hatchery, H, and time, T. (Variable H was assigned a value of zero for Little White and a value of one for the Spring Creek Hatchery.) This equation was chosen to analyze economic benefits of water quality improvements because of its simplicity in explaining variations in returns of fall chinook due to hatchery difference and the cumulative effects of other factors over time.

(1)
$$\hat{R}_t = 14.108 + 10.22H - 1.727T$$
$$(2.32) \quad (-2.02)$$
$$n = 18 \qquad R^2 = 0.386.$$

In Equation (1), values of t are given below the regression coefficients. Although there is considerable variation in R_t not accounted for in Equation (1), the coefficient of H is statistically significant at the 0.05 probability level, and that for T is nearly so. According to the coefficient for H, slightly more than 10 more salmon returned to the Spring Creek Hatchery per 100 pounds of smolts released than returned to the Little White Hatchery, on the average. According to the coefficient for T, almost two fewer salmon returned to the hatcheries each year, per 100 pounds of smolts released, as time progressed from 1961 to 1969. For example, for the Spring Creek Hatchery, the predicted return of fish per 100 pounds released for brood year 1961 would be $14.108 + 10.22(1.0) - 1.727(0) \doteq 24$ salmon. But for brood year 1969, the predicted return would be only $14.108 + (10.22)(1.0) - 1.727(8) \doteq 10.5$. Thus, according to Equation (1), the predicted return of fall chinook salmon, per 100 pounds of smolts released, declined rather drastically over the nine years for which data were available.

Two things should be noted at this point. First, although an attempt was made to evaluate the effect of the native American fishery on the hatchery fish, the fish returning to Little White Hatchery may have been at a selective disadvantage relative to those returning to Spring Creek. This may have been because of the location of the Indian fishery near Little White Hatchery, compared to that near Spring Creek; i.e., the fishermen near Little White may have been able to take a larger proportion of returning adults than those near Spring Creek. As no catch figures by the native Americans in either of these two locations have been recorded, the possible effect of this factor could not be estimated.

Second, it appears from the data in Appendix Tables 2-5 that the fish from Little White Hatchery return to the hatchery later than do the Spring Creek fish; hence, they would be subject to more natural mortality. Testing whether the mean difference in age at return between the hatcheries was significantly different from zero, the difference was found to be statistically significant at the 0.001 probability level. It is hypothesized that this difference was due, in large part, to the higher quality water at Spring Creek, resulting in healthier and larger smolts at release. The smaller smolts from Little White required more time to mature in the ocean; hence, they endured more pressures to survive. So this difference in age at return does lend strength to the argument that water quality differences contributed substantially to differences in return rates.

As mentioned earlier, an extensive analysis of fishing pressure and other factors was made in an attempt to explain the decline in returns to the hatchery. (Details are given in the Appendix.) Although some regression equations containing variables representing these factors had more overall explanatory power, they required a bit more interpretation of the meaning of the hatchery coefficient than did Equation (1), and the estimated effect of hatchery difference was approximately the same. In addition, the hatchery coefficient in Equation (1) most closely approximated the actual mean difference in returns to the hatcheries due to all causes. In any case, the difference in returns between the two hatcheries, about 10 more salmon per 100 pounds of smolts released, does provide some basis for inferring an increase in productivity from an improved water supply for the Little White Hatchery.

ESTIMATED BENEFITS AND COSTS OF WATER IMPROVEMENTS AT THE LITTLE WHITE HATCHERY

Water supply improvements were made at Little White during 1958-73, consisting of installation of pipes, valves, dams and water collection structures, and related capital improvements. Although improvements were made, no marking program was in effect at the time to enable us to evaluate the subsequent effect of these improvements on survival and catch in the Columbia River and ocean.

The first major water improvement investments were made in 1958 and 1959, allowing spring water to be used to improve the salmon egg hatching operation. Then, in 1970 and 1973, additional water improvement facilities were constructed to permit the re-circulation of cleaner, warmer spring water for rearing the fall chinook fingerlings during the critical winter months. Thus, one would expect post-1970 growth rates and survival at Little White to increase to a level more like that for the Spring Creek Hatchery, as indicated by returns in Table 1.

Since the main difference in returns to the two hatcheries appeared to be due primarily to the higher water quality at the Spring Creek hatchery for the 1961-69 brood years of Table 1, it would seem quite conservative to assume that at least a 20 percent increase in survival and harvest of Little White fall chinook salmon would result from the water supply improvements made at Little White during the period 1958-1973. As can be seen from Table 1, returns to Spring Creek Hatchery averaged about 17.4 salmon per 100 pounds of smolts released, compared to only about 7.2 for Little White. If returns to Little White were brought up to those at Spring Creek, it would represent an increase of $(17.4 - 7.2) \div 7.2 \doteq 1.42$, or an increase of 142 percent. Thus, an increase of 20 percent would be less than 1/7 of the average difference in returns to the hatcheries.

Estimated Benefits from Improved Water Supply Facilities

For fiscal years 1973 and 1974, 107,842 and 101,328 pounds of fall chinook salmon smolts were released, respectively, by the Little White Hatchery. Based upon earlier reports of marking studies for fall chinook salmon (Worlund, Wahle, and Zimmer; Rose and Arp; Arp, Rose, and Olhausen; Wahle, Arp, and Olhausen), an average commercial catch per 1,000 fall chinook smolts released was estimated to be about 69.1 pounds, assuming 100 smolts per pound (Brown and Hussen, p. 7). In addition, about 17.9 pounds of mature salmon per 1,000 smolts were estimated to be caught by sport anglers. Thus, $69.1 + 17.9 \doteq 87$ pounds of fall chinook salmon were estimated to be harvested per 1,000 smolts released, or about 8.7 pounds harvested per pound of released smolts (1,000 smolts/(100 smolts/lb.) = 10 lbs.).

If an annual release of about 100,000 pounds of fall chinook salmon smolts is assumed, then an annual harvest of about 870,000 pounds of salmon could be expected. If the water supply improvements at Little White resulted in only a 20 percent increase in survival and harvest, then an additional 174,000 pounds of fall chinook salmon per year could be harvested. What would be the value of such an additional harvest of salmon?

To answer this question, one must first ask "Value to whom?" There is value to the sport angler, value to the commercial angler, and value to citizens who merely wish to see the salmon and steelhead runs preserved. Another, rather conservative, estimate of value would be the value of additional salmon to the consumers of commercially caught salmon. According to recent research, one of the better estimates of demand for commercially caught salmon was the following (Brown, Larson, Johnston, and Wahle, p. 7):

$$\widehat{\ln PF_t} = -0.4331 + 0.0003434INC_t + 0.1404PR_t - 3.7898QF^*_t, \tag{2}$$

where 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; INC denotes U.S. per capita disposable personal income, deflated by the consumer price index (CPI); PR denotes the price of round steak, deflated by the CPI; and QF^* denotes U.S. per capita consumption of fresh and frozen salmon.

For 1973 deflated per capita income and round steak prices, Equation (2) can be written as:

$$\widehat{PF_t} = 2.3614e^{-3.7898QF^*_t} . \tag{3}$$

For the 1973 per capita consumption of fresh and frozen salmon, QF_t, equal to 0.097 (Brown, Larson, Johnston, and Wahle, p. 29), predicted price, $PF_t \doteq$ \$1.6350 per pound. However, if an additional 174,000 pounds per year were harvested as a result of the water supply improvements at Little White, then net pounds consumed per capita would increase slightly by about 0.8(174,000) ÷ 209,844,000 ≐ 0.00066335. Consequently, a slight price reduction of about 0.4 cents per pound would be expected. This savings to consumers would have been about \$0.004(20,500,000) ≐ \$82,000 in 1967 dollars, or about 1.331(\$82,000) ≐ \$109,000 in 1973 dollars.

It should be noted that the above method of estimating benefits, based upon savings to consumers, is a conservative approach. Estimated benefits, based upon the value of sport-caught salmon, would be somewhat higher (Brown, Larson, Johnston, and Wahle, pp. 15-24).

Costs of Water Supply Improvements and Benefit-Cost Ratios

Actual costs for pipe, dams, and other water collection facilities were incurred mainly from 1958 to 1973, and totaled about $38,900. However, since construction costs had increased markedly over this period of time, all costs were adjusted to a 1973 basis by using various construction and building cost indices published by Engineering News Record. On a 1973 price level basis, total costs were estimated to sum to about $61,700.

Assuming a 25-year depreciation, an interest rate of 8 percent, and 5 percent for repair and maintenance, an annual charge of around $10,500 was estimated. Thus, for 1973 prices, the annual benefit-cost ratio was estimated to be:

$$B\text{-}C \doteq \frac{\$109{,}000}{\$\ 10{,}500} \doteq 10.4.$$

It should be noted that the above B-C ratio was based upon the assumption that a 20 percent increase in survival and harvest would result from improved water quality at the Little White Hatchery. But in Table 1, returns to the Spring Creek hatchery averaged about 17.4 salmon per 100 pounds of smolts released, compared to only about 7.2 for Little White. Thus, if returns to Little White were increased to those of Spring Creek, it would represent an increase of $(17.4 - 7.2) \div 7.2 \doteq 1.42$, or an increase of 142 percent. Thus, the assumed increase in harvest of 20 percent appears fairly conservative, given that the difference in average returns between the hatcheries is much greater. Also, the estimate of benefits is rather conservative, being based only on savings to consumers with the increased production. Not counted in the benefit estimate is the potential increase in revenue to commercial fishermen, resulting from the high elasticity of demand in Equations (2) and (3). Also not counted are potential increases in benefits to sport fishermen and to citizens who wish to see the salmon runs preserved.

SUMMARY AND CONCLUSIONS

Over a nine-year period, 1961-1969, returns by brood year to two rather similar salmon hatcheries, except for differences in quality of water supply, showed more than double the return to the hatchery with higher quality water, the Spring Creek National Fish Hatchery. The salmon hatchery with lower quality river water, the Little White Salmon National Fish Hatchery, had to release its fall chinook smolts at a later date, due to reduced growth caused by a cold (and sometimes muddy) hatchery water supply during winter months. However, water quality improvements at Little White should now make their winter water quality more comparable to that of Spring Creek during the 1961-1969 period.

Assuming only a 20 percent increase in survival and harvest, estimated annual benefits from the water quality improvements (pipes, pumps, dams, and other structures) were \$109,000, 1973 price level. This estimated benefit was about 77 percent more than the estimated total costs of \$61,700 (1973 price level). On an annual basis, a benefit-cost ratio of more than 10 to 1 was estimated.

Although it was necessary to assume that returns to the hatchery would be positively correlated with survival of the smolts and harvest of the salmon in the various fisheries, and to assume that the major cause of the difference in survival and returns to the hatchery was due to difference in water quality, the similar nature and close proximity of the two hatcheries make the assumptions appear reasonable. Also, although only a 20 percent increase in harvest of Little White hatchery salmon was assumed, the Spring Creek Hatchery, with higher quality water, averaged more than 2.4 times the return to the Little White hatchery during the nine-year period.

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APPENDIX

AN EXAMINATION OF POSSIBLE FACTORS AFFECTING RETURNS OF FALL CHINOOK SALMON TO THE HATCHERY

In our attempts to estimate the effects of various influences upon the returns to Little White and Spring Creek Salmon Hatcheries, a number of factors were examined, among them the effects of time, nitrogen levels of the water in the Columbia River, size per pound of the fingerlings at release, and the fishing pressure exerted upon returning salmon by various angler groups, both on the Columbia River and in the ocean. Many of these influences are extremely hard to isolate and measure, so proxy variables were used in some cases. For instance, the water spill over Bonneville Dam was used to approximate the nitrogen supersaturation caused by water spilling over Columbia River dams. Also, we were interested in looking at the fishing pressure exerted by native Americans fishing on the Columbia River. For this purpose, we concentrated on the catch above Bonneville Dam, where they fish.

After formulation of variables to represent these possible effects, our statistical estimation showed the following equations to be best able to explain variations in the returns of salmon to the hatchery:

(A-1) $$R_t = \underset{(3.08)}{180.03} + \underset{(2.34)}{8.7846H} + \underset{(1.51)}{333.85T} - \underset{(-1.46)}{0.0061604\ FO_t} - \underset{(-2.74)}{246.93\ FR_t}$$

$$n = 18$$
$$R^2 = .628$$

where R_t denotes number of fall chinook salmon returning to Little White and Spring Creek Salmon Hatcheries per hundredweight released; H denotes a dummy variable differentiating between returns to Little White and returns to Spring Creek; T is a time variable whose integer values represent numerous factors which trend together over time; FO_t denotes an index of fishing pressure exerted by vessels fishing off the Western U.S. coast; and FR_t denotes an index of fishing pressure exerted by anglers fishing on the Columbia River. Values of t are given in parentheses below the regression coefficients.

Additional variables which proved insignificant in explaining R_t were indices of nitrogen content in the Columbia River (the spill index) and fishing pressure exerted by native Americans fishing above Bonneville Dam on the Columbia River. Both these variables took the correct sign as predicted theoretically, but their t-values were considerably below 1.0.

Another regression equation of interest was:

$$\text{(A-2)} \qquad \ln R_t = \underset{(3.03)}{0.044849} \ln H - \underset{(-1.22)}{0.16803} \ln FO_t - \underset{(-3.34)}{6.4040} \ln FR_t$$

$$n = 18$$

$$R^2 = .569$$

whose non-linear specification would seem perhaps more realistic for describing the relationship among the variables. All variables are defined as in (A-1), and in this case their natural logarithms are fitted. Figures in parentheses under regression coefficients are the t-values.

Although the regression equations listed above explain with a fair degree of success the returns of fall chinook to the hatcheries, one important limitation must be noted. The equations were fitted with only 18 observations, covering 9 brood years of fall chinook production for each hatchery. This could explain why some of the variables in the original model were not statistically significant; perhaps with more observations, the spill index in particular would be more important in the model.

COMPUTATION OF VARIABLES

Spill Index

The spill index was computed as a proxy for nitrogen content of the Columbia River water, and was arrived at by taking unpublished figures for amount of water passing Bonneville Dam for the month of release of each brood year from the hatcheries, and subtracting 140,000 cu. ft./min., which is the amount of water the turbines at Bonneville Dam can handle. The residual represents the amount of water spilling over the dam and contributing to increased nitrogenation. Numbers less than zero were set equal to zero. See Appendix Table 1 for the numbers used in the spill index.

Appendix Table 1. Index of Water Spill Over Bonneville Dam, 1962-1970 (Cubic Feet Per Minute)

Year	Spring Creek		Little White		Brood year a/
	Month of release	Spill index	Month of release	Spill index	
1962	April	84,300	May	161,100	1961
1963	April	34,000	May	119,100	1962
1964	April	1,900	May	151,500	1963
1965	April	108,800	June	341,400	1964
1966	April	19,200	June	199,300	1965
1967	March b/	8,500	June	431,300	1966
1968	April	0	June	229,500	1967
1969	March b/	205,500	June	192,200	1968
1970	March b/	13,200	June	198,900	1969

a/ Fingerlings from a given brood year are released the following spring.

b/ At the time of the analysis, figures were not available for March water flow through Bonneville Dam, so April figures were substituted.

Offshore Fishing Pressure (FO)

A tally of vessels fishing in the U.S. salmon fleet off the West Coast (Basic Economic Indicators: Salmon, 1947-1972, NMFS) was used for this index. The vessels were broken into two categories, troll and non-troll, with the non-troll category including purse seine and other vessels. Since the vessels in these two categories catch different proportions of the salmon catch, a relative weighting scheme was used whereby the number of vessels in each category was weighted by the proportion of their contribution to the yearly total catch. This gave, then, a weighted "number of vessels" fishing offshore each year. Expressed as a formula,

(A-3) $$\text{WNV} = (\text{Percent troll landings} \times \text{no. of troll vessels} + \text{percent non-troll landings} \times \text{no. of non-troll vessels}) \div 100,$$

where WNV is the weighted "number of vessels" referred to above. This was, in turn, adjusted for each hatchery and brood year, according to what percent of each brood year returned as 2-year olds, 3-year olds, 4-year olds, and 5-year olds (from unpublished data obtained from Little White and Spring Creek Salmon Hatcheries, reproduced in Appendix Tables 2-5). For example, for Little White Hatchery the returns of the 1962 brood year consisted of 2 percent 2-year olds, 39 percent 3-year olds, 57 percent 4-year olds, and 1 percent 5-year olds (see Appendix Table 5). For this particular brood year, the FO calculated was then:

$$\text{FO (1962 L.W.)} = .02 \times \text{WNV}_{64} + .39 \times \text{WNV}_{65} + .57 \times \text{WNV}_{66} + .01 \times \text{WNV}_{67}.$$

In general,

$$\text{FO}_t = \sum_{i=t+2}^{t+5} (\text{percent salmon returning in year i})(\text{weighted "number of vessels" in year i}) \div 100.$$

Data and computation are given in Appendix Table 6. The FO for Spring Creek and Little White Hatcheries varies, since their fish return figures were slightly different. It should be noted that Canadian fleet figures were not used, as they were not readily available, although they do make a substantial contribution to the offshore fishing pressure.

River Fishing Pressure (FR)

A base fishing pressure index was computed, using unpublished figures on Columbia River catch and escapement of fall chinook.[1/] The index consisted of the total number of fall chinook caught on the Columbia River, divided by the minimum run of fall chinook for each year. This index was then adjusted to the brood years for each hatchery in the same manner as was done for the offshore fishing pressure index, using Appendix Tables 3 and 5. The data and computation for FR are shown in Appendix Table 7.

One comment should be interjected at this point about comparability of the indices FR and FO. The Columbia River runs are fairly well monitored in terms of both catch and escapement, so that we could express FR as a percentage catch rate. FO, on the other hand, was much fuzzier, due to the lack of comparable data on offshore runs and the multitude of forces exerting pressure on the sea-run salmon. Hence, to get some handle on these forces, we used an index with units of number of vessels.

[1/] Status Report: Columbia River Fish Runs, and Commercial Fisheries, 1938-1970. 1974 Addendum, Vol. 1, No. 5. Produced jointly by the Fish Commission of Oregon and the Washington Department of Fisheries, January 1975, 44 pp. This was not published for release to the general public.

Appendix Table 2. Spring Creek Hatchery, Fall Chinook Returns, by Age, 1964-1973 a/

Sampling year	Age			
	2 years	3 years	4 years	5 years
1964..........	170	10,374	3,004	10
1965..........	1,092	1,334	2,849	44
1966..........	1,413	11,165	736	32
1967..........	960	3,437	1,316	22
1968..........	518	8,351	2,202	21
1969..........	112	5,079	6,694	9
1970..........	283	2,892	1,229	164
1971..........	231	5,819	1,900	0
1972..........	139	3,508	2,341	67
1973..........	373	4,437	6,409	133

a/ Unpublished reports of the data were made available to the authors by Steve Leek, hatchery biologist, Little White Salmon National Fish Hatchery.

Appendix Table 3. Spring Creek Hatchery - Fall Chinook Returns, by Age and Brood Year, 1961-1969 [a]

Brood year	2-year		3-year		4-year		5-year		Total return number
	Number	Fraction of total	Number	Fraction of total	Number	Fraction of total	Number	Fraction of total	
1961	—	—	10,374	.78265	2,849	.21494	32	.00241	13,255
1962	170	.07516	1,334	.58974	736	.32538	22	.00973	2,262
1963	1,092	.08033	11,165	.82132	1,316	.09681	21	.00155	13,594
1964	1,413	.20011	3,437	.48676	2,202	.31185	9	.00128	7,061
1965	960	.05937	8,351	.51648	6,694	.41400	164	.01014	16,169
1966	518	.07589	5,079	.74407	1,229	.18005	0	0	6,826
1967	112	.02253	2,892	.58177	1,900	.38222	67	.01348	4,971
1968	283	.03300	5,819	.67852	2,341	.27297	133	.01551	8,576
1969	231	.02276	3,508	.34568	6,409	.63155	—	—	10,148

a/ Unpublished reports of the data were made available to the authors by Steve Leek, hatchery biologist, Little White Salmon National Fish Hatchery.

Appendix Table 4. Little White Hatchery - Fall Chinook Returns to Hatchery by Age and Year, 1964-1973 a/

Sampling year	Age			
	2 years	3 years	4 years	5 years
1964.............	39	3,429	1,601	0
1965.............	372	687	2,035	77
1966.............	62	7,166	1,055	45
1967.............	156	448	3,892	26
1968.............	111	423	927	213
1969.............	125	2,361	1,531	25
1970.............	110	2,185	1,689	85
1971.............	52	723	3,899	19
1972.............	49	161	2,473	49
1973.............	46	1,054	832	83

a/ Unpublished reports of the data were made available to the authors by Steve Leek, hatchery biologist, Little White Salmon National Fish Hatchery.

Appendix Table 5. Little White Hatchery - Fall Chinook Returns to Hatchery, by Age and Brood Year, 1961-1969 a/

Brood year	2-year		3-year		4-year		5-year		Total return number
	Number	Fraction of total	Number	Fraction of total	Number	Fraction of total	Number	Fraction of total	
1961........	--	--	3,429	.62244	2,035	.36940	45	.00817	5,509
1962........	39	.02220	687	.39101	1,005	.57200	26	.01480	1,757
1963........	372	.03195	7,166	.61548	3,892	.33428	213	.01829	11,643
1964........	62	.04241	448	.30643	927	.63406	25	.01710	1,462
1965........	156	.07107	423	.19271	1,531	.69749	85	.03872	2,195
1966........	111	.02656	2,361	.56483	1,689	.40407	19	.00455	4,180
1967........	125	.01997	2,185	.34915	3,899	.62304	49	.00783	6,258
1968........	110	.03246	723	.21334	2,473	.72971	83	.02449	3,389
1969........	52	.04976	161	.15407	832	.79617	--	--	1,045

a/ Unpublished reports of the data were made available to the authors by Steve Leek, hatchery biologist, Little White Salmon National Fish Hatchery.

Appendix Table 6. Computation of Offshore Fishing Pressure Index, FO

Year	Total landings, chinook & coho	Troll landings		Other landings		Number of troll vessels	Number of other vessels	Weighted "number of vessels" a/	Brood year	FO for Spring Creek Hatchery	FO for Little White Salmon
		Total	Percent	Total	Percent						
	(1,000 lbs.)	(1,000 lbs.)		(1,000 lbs.)							
1963...	55,310	29,269	.529	26,041	.471	4,213	11,113	7,463	1961	7,408	7,464
1964...	66,803	34,579	.518	32,224	.482	4,228	10,670	7,333	1962	7,649	7,663
1965...	67,831	39,639	.584	28,192	.416	5,099	11,300	7,679	1963	7,692	7,788
1966...	65,978	42,579	.645	23,399	.355	5,498	11,578	7,656	1964	8,131	8,428
1967.,,	64,471	35,923	.557	28,548	.443	6,086	10,393	7,994	1965	9,292	9,799
1968...	63,624	39,280	.617	24,344	.383	7,102	11,117	8,640	1966	10,193	10,336
1969...	49,354	29,170	.591	20,184	.409	8,726	12,478	10,261	1967	10,044	9,726
1970...	75,393	39,775	.528	35,618	.472	7,177	14,355	10,565	1968	9,557	10,004
1971...	68,270	50,382	.738	17,888	.262	7,316	14,633	9,233	1969	10,305	10,315
1972...	58,539	37,266	.637	21,273	.363	7,477	14,954	10,191	—	—	—
1973...	62,900	40,295	.641	22,605	.359	7,657	15,314	10,406	—	—	—

a/ Weighted "number of vessels" = (% troll landings × no. of troll vessels + % other landings × no. of other vessels) ÷ 100.

SOURCE: National Marine Fisheries Service, Basic Economic Indicators: Salmon, 1947-1972. Current Fishery Statistics No. 6129, Economic Research Laboratory, Washington, D.C. August 1973.

Appendix Table 7. Computation of Columbia River Fishing Pressure Index, FR

Year	Total fall chinook caught	Minimum run	Percent of minimum run caught	Brood year	Fishing pressure, Little White	Fishing pressure, Spring Creek
1963.......	124,600	267,200	.466	1961	.518	.503
1964.......	179,000	372,200	.481	1962	.501	.530
1965.......	232,300	399,200	.582	1963	.477	.464
1966.......	155,200	347,800	.446	1964	.515	.505
1967.......	200,800	385,000	.522	1965	.508	.511
1968.......	178,700	346,300	.516	1966	.524	.513
1969.......	234,600	467,500	.502	1967	.561	.558
1970.......	291,500	525,500	.555	1968	.556	.563
1971.......	272,400	480,200	.567	1969	.592	.584
1972.......	182,600	331,600	.551	—	—	—
1973.......	327,900	544,300	.602	—	—	—

The basis for computation of this index was the percent catch of the minimum fall chinook run. See Footnote 1, page 17, for reference. They were adjusted per brood year by taking into consideration the returns to the hatcheries (Tables 3 and 5).

Sample calculation: FR Little White (1964) = (.04241)(.446) + (.30643)(.522) + (.63406)(.516) + (.01710)(.502) = .515.