445

FACTORS INFLUENCING THE RETURN OF FALL CHINOOK SALMON (*Oncorhynchus tshawytscha*) TO SPRING CREEK HATCHERY

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by

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Spring Creek Hatchery, Washington.

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ABSTRACT

This preliminary study is primarily concerned with a definition of the problems that must be considered in isolating the factors influencing the relatively high survival rates of chinook salmon *(Oncorhynchus tshawytscha)* at Spring Creek Hatchery, Washington. The tabulation and study of basic data relating to the distribution of egg take, releases of fry and fingerlings, and adult returns were the first steps in this analysis.

An index of production based on female returns adjusted for the effects of the Columbia River gill net fishery was related to the releases of fry and fingerlings which had been spawned 4 years earlier. Returns for the brood years 1941-49 were first investigated, since construction completed for the 1950 brood altered the available facilities at Spring Creek Hatchery. A multiple correlation coefficient of 0.891 ($P<0.01$) gave indication of a reasonably consistent relationship between releases of fry and fingerlings (in pounds) and subsequent returns. A correlation of 0.890 between returns and fingerling releases only gave strong evidence that variations in return were controlled almost entirely by fingerling releases. Some qualification of this result is necessary since in 1948 and 1949 at the time when large numbers of fry were released into the Columbia River, water temperatures in the river were near freezing in contrast to the constant temperature of 46° F. of Spring Creek water. It is highly probable that such a temperature differential could induce mortalities.

When the study is extended to more recent years it is apparent that survival rates since 1950 have been greatly reduced. When the pounds of fingerlings released are taken into consideration, even the large returns in 1958 and 1959 do not exhibit survival rates comparable to those maintained in the 1940's. Factors coincident with this reduction are considered--incidence of tuberculosis and coagulated yolk disease, increased crowding of fingerlings, and change in diet.

In light of the findings of the present study, additional studies are proposed.

INTRODUCTION

Spring Creek Hatchery, a Federal installation located on the Columbia River near the town of Underwood, Wash., is primarily concerned with the production of fall chinook salmon *(Oncorhynchus tshawytscha)* although other salmonids are included in the operations from time to time. The Spring Creek chinook run was originally developed from eggs taken from Big White Salmon River, and a substantial run of fall chinook now returns to Spring Creek

Note.--Charles O. Junge, Jr. resigned from Fisheries Research Institute, November 1961. Lloyd A. Phinney now with Washington State Department of Fisheries.

each year, furnishing the main supply of eggs for Spring Creek Hatchery and supplementing the egg supply at other Columbia River hatcheries. Runs to Big White Salmon River are still utilized as an additional source of egg supply. Almost all of the fish hatched at this station are released into the Columbia River at the hatchery or into Big White Salmon River. In recent years large numbers of green and eyed eggs in excess of hatchery capacity have been transferred to other hatcheries and other agencies.

During the last several years it has become increasingly apparent that the rate of return of adult chinook salmon to Spring Creek Hatchery greatly exceeds that to any other hatchery in the Columbia River system. If the factors influencing these returns can be discovered, it is likely that improved techniques can be devised to increase production at other existing hatcheries and to design better hatcheries in the future. In view of the critical condition of the stocks of fall chinook salmon in the Columbia River system and the rapidly increasing effects of expanding hydroelectric projects in this system, the solution of this problem has become a matter of great urgency.

Before the general problem can be approached, however, some specific questions must be answered, and basic data must be examined to obtain at least a partial understanding of what the problems really are. For example, in recent years large numbers of unfed fry have been released in late winter and relatively large numbers of hatchery reared fingerlings in the spring. The direction of future study obviously depends on a knowledge of the relative survival of these two groups. In addition, there is a question whether the returns to Spring Creek Hatchery could be affected by such factors as relative availability to the fisheries, straying from other hatcheries, or naturally produced runs. If comparisons of return rate are to be made between Spring Creek Hatchery and other hatcheries or with naturally produced stocks, some quantitative measure of the relative effects of these factors may be of value, even though existing evidence may be sufficient to demonstrate that none of these factors has a controlling influence on the returns.

On January 4, 1960, the Fisheries Research Institute of the University of Washington contracted with the Bureau of Commercial Fisheries for work on the following four aspects:

1. An assembly of all relevant data.
2. Preliminary analysis of these data (future analysis may be needed under aspect 4).
3. An evaluation of the problems involved.
4. An outline of specific experiments with an order of priority.

Because of the time required by the first three aspects and because of the number and type of problems arising under the third aspect, proposed studies for the fulfillment of the fourth aspect have been somewhat general and no order of priority has been suggested.

DEVELOPMENT OF BASIC DATA ON THE RELEASE OF YOUNG AND THE RETURN OF ADULT SALMON

Any study of hatchery operations requires information on the number of fish planted and the number returned. Two sources of such data were obtained from the Little White Salmon Hatchery office staff. The "Production Sheets" which were tabulated from the standard monthly reports, provided yearly records of individual releases or transfers of fish and eggs from Spring Creek Hatchery beginning in brood year 1939. These are reproduced in a slightly modified form in appendix table 1 for eggs taken at Spring Creek and in appendix table 2 for eggs taken at Big White Salmon River. Releases of the 1939 brood are not included in the reproduced tables since no information on source of eggs is available.

In appendix table 3, fish are grouped according to size (number per pound) at time of release in the two areas; and the total number, total weight, and the size distribution for all fish released at Spring Creek and Big White Salmon River are listed for each brood year since 1940. Fry[1] and fingerling releases are

[1] Fry (and fingerlings) are defined as fish smaller than (or larger than) 500 per pound. The justification for these definitions is given in a later section.

listed by numbers released in appendix table 4 and by pounds released in appendix table 5.

For the most part, standard annual reports on Spring Creek Hatchery (submitted under various titles) furnished the necessary information on the adult returns to both Spring Creek and Big White Salmon River. Records for Spring Creek Hatchery returns are complete since all fish entering the hatchery ladder are counted and the total number of males, females, and "jacks" (2-year-old males) is recorded; there is no possibility of natural spawning at Spring Creek Hatchery. Such is not the case, however, at Big White Salmon River. Fish entering this system cannot be accurately counted unless they migrate upstream to the hatchery rack site. In some years many fish spawn below the rack since it is located some distance above the mouth of the stream.

There are several years when the number of fish handled at the Big White Salmon rack in spawn-taking operations was unrecorded in the annual reports and the number of females could be estimated only from the reports on eggs taken and the average number of eggs per female. Appendix table 6 lists the number of males, females, and jacks handled in operations at Spring Creek Hatchery and the Big White Salmon River rack. These figures do not include any estimates of the number of natural spawners in Big White Salmon River. No information was available for 1943.

A rough estimate of the number of females which spawned naturally in the river was made (appendix table 7). These estimates are based on two assumptions. The first is that the estimated total number of natural spawners is reasonably correct. The second is that the sex ratio of the fish handled at the rack on the river is representative of the sex ratio in the natural spawning population and not the result of selection for a particular sex or size of fish. One exception will be mentioned later. Using the sex ratio of the fish handled at the rack, the number of naturally spawning females was obtained for the return years 1948 through 1950, 1952, 1954, 1957, and 1958.[2] For the return years 1951, 1953, 1955, and 1956, estimates of the total egg deposition, but no estimates of numbers of fish, are found in the reports. This estimated egg deposition has been converted to number of females, assuming 5,000 eggs per female. In 1945 very few fish spawned naturally, and, since no actual figure was given, it has been assumed that no natural spawning occurred. In 1946 the annual report lists the natural spawning fish as being predominantly males, so no natural spawning females have been added to the number of females handled in the hatchery operations. The figure for the 1947 return is a minimum one since it includes only those fish which were counted past the rack or which remained between the racks when operations ended. Large numbers of fish are known to have spawned below the racks, but their numbers were not estimated.

SELECTION AND ADJUSTMENT OF VARIABLES FOR STUDY

A major aim of the present study is to relate adult production quantitatively with fry and fingerling releases. In order to study such a relationship it is first necessary that such variables be defined.

Index of Adult Production

An adequate measure of adult production from the releases of each brood year is a primary requirement. Development of such a measure for hatchery-produced fall chinook salmon is complicated by several variations: age at maturity, degree of straying to and from the parent stream, and fishing intensity (ocean troll, river gill net, and ocean and river sport).

Effects of variation in age at maturity.--Returning fall chinook salmon vary in age

[2] No estimates for 1957 and 1958 were found in the annual reports. The figures for these 2 years were derived from estimates of a total of 3,500 fish spawning in both years (by Clyde Adams, hatchery superintendent, and Irvin Brock, hatchery foreman).

from 2-year-old jacks to 5-year-old males and females with an occasional fish maturing after its fifth year. In lieu of any specific age data on the returning fish it is important to develop an index of production which will be least affected by this variation. The modal age at return is usually considered to be 4 years, but the numbers returning at other ages could introduce significant bias if it is assumed that production of any brood year may be measured by the return 4 years later. Some variation could be eliminated by omitting the jack returns, but classification of jacks may be somewhat arbitrary and the number of 3-year-olds, particularly males, may be excessive.

In the present study, production for each brood year has been measured by the number of females returning 4 years later.[3] Holmes[4] lists the age of returns of marked fish of Spring Creek stock in his study of fingerling chinook salmon mortalities at Bonneville Dam. Omitting jacks but not older males, approximately 15 percent returned as 3-year-olds, 70 percent as 4-year-olds, and 15 percent as 5-year-olds. The sex of these fish is not indicated, but if no less than 70 percent of the females return as 4-year-olds, any important change in production of a brood year should be reflected by returns of females 4 years later. Scale samples taken by Oregon Fish Commission in the 1959 Columbia River gill net fishery showed 75 percent of the females were 4-year-olds as compared with only 51 percent 4-year-old males. Length data on 1959 returns to several hatcheries do not confirm this result, and this anomaly will be discussed in a later paragraph of this section.

It is unfortunate that more data on age distribution of fish returning to Spring Creek Hatchery are not available, but some length-frequency graphs of Little White Salmon stocks[5] are of interest (fig. 1). The mode has been placed arbitrarily at 19.5 inches for 2-year-olds, 31.5 inches for 3-year-olds, and 37.5 inches for 4-year-olds. These values are in reasonable agreement with modal length of marked returns released as fingerlings. The size distribution for adult males returning in 1955, 1956, and 1957 illustrates the dominance of the 1953 brood, which returned as 2-year-olds in 1955, 3-year-olds in 1956, and 4-year-olds in 1957. In this respect, with a 4-year lag the total male returns in 1956 would incorrectly classify the 1952 brood as the dominant producer. The size distribution for females, however, shows no such pattern though there is an indication of an increased return of 3-year-olds in 1956. The total number of females returning in 1957 correctly classifies the 1953 brood as the very dominant producer if a 4-year lag is used.

Recent evidence of an increased return of 3-year-old fall chinook to Columbia River hatcheries must be examined with respect to use of a 4-year lag on female returns as an index of adult production for earlier years. In the remainder of this section we will present evidence for this change, consider indications that only returns in recent years are affected by this change, and note the probable effects of this change on the present analysis.

From the size distributions of both male and female adults returning to Little White Salmon Hatchery in 1958 and 1959 (fig. 1) it appears that the modal age of return has shifted from 4 years to 3 years for the 1955 and 1956 brood years. The similarity of the distributions in 1958 and 1959 indicates that the peaks at the 3-year level in 1958 did not occur due to a dominant 1955 brood, otherwise large peaks should appear as 4-year-olds in 1959.

It might be postulated that the position of the modes in 1958 and 1959 could have been influenced by release of large numbers of yearling chinook of the 1954 and 1955 brood years. Four-year-old fish released as yearlings would be expected to be similar in size to 3-year-old adults from fry or fingerling releases, since effective growing time in salt water would be nearly the same. At Spring Creek Hatchery, however, no yearling releases were made during this period, and the similarity between

[3] The use of female returns lagged 4 years was suggested by R. E. Noble for the study of two hatcheries operated by the Washington Department of Fisheries.

[4] H. Holmes. Loss of salmon fingerlings in passing Bonneville Dam as determined by marking experiments. Manuscript. U.S. Fish and Wildlife Service, 1952.

[5] H. E. Johnson. U.S. Fish and Wildlife Service, unpublished data.

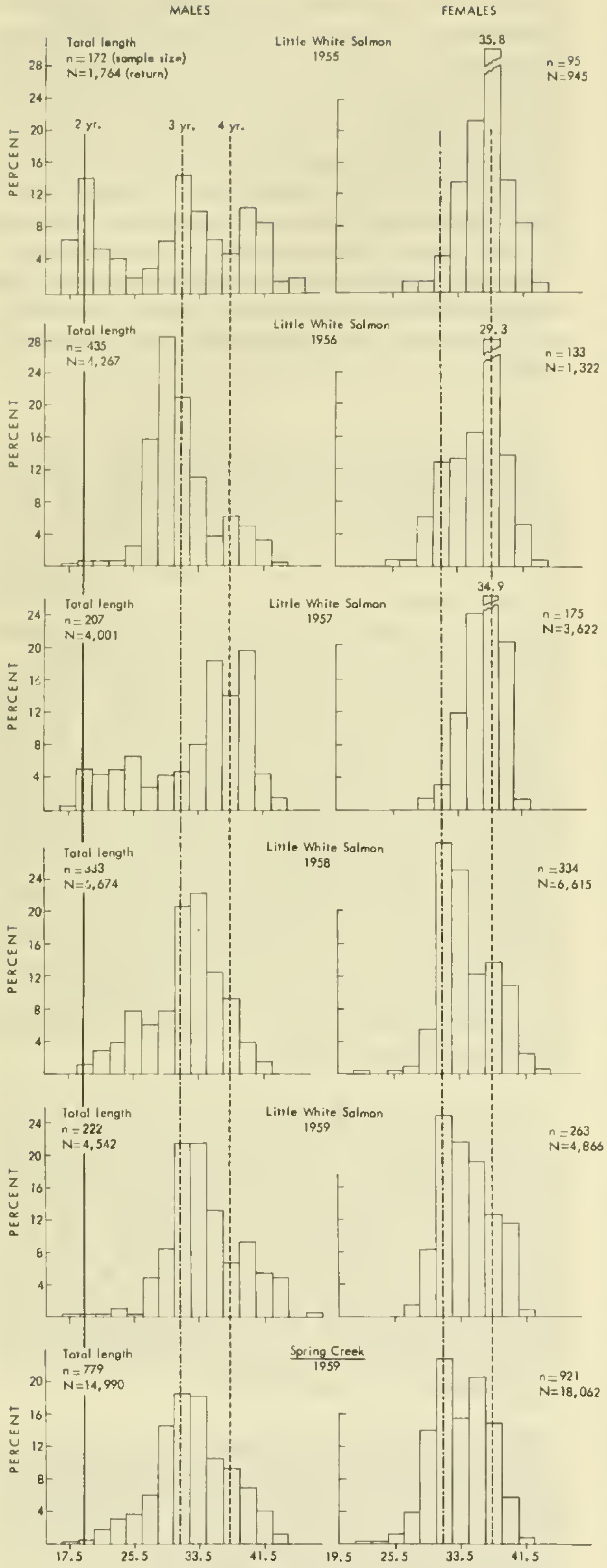

Figure 1.--Length-frequency of fall chinook salmon at Little White Salmon and Spring Creek hatcheries grouped in 2-inch intervals and expressed in percentages. Vertical lines indicate apparent modal lengths of 2-year-old, 3-year-old, and 4-year-old fish.

the 1959 returns at Spring Creek Hatchery[6] and Little White Salmon River gives some evidence that at Spring Creek Hatchery the 1955 brood as well as the 1956 brood actually had heavy returns as 3-year-olds. In 1957, 2-year-old returns at Spring Creek Hatchery were more than twice as great as jack returns in any other year (appendix table 6). If this had been primarily the result of a dominant 1955 brood, a more pronounced bimodal distribution, particularly for male returns, would have been expected in 1959 since a large return of 4-year-olds would have been expected. Further evidence of earlier maturity is given by the numbers of 3-year-old marked adult return to Spring Creek Hatchery in 1959--an unprecedented return with respect to other marked chinook studies in Columbia River.

Similarity in size distribution of returns to these and other Columbia River hatcheries in 1959 gives some indication that maturation rates may be dominated by oceanographic conditions. Anomalies of fish behavior due to uncommon oceanographic changes from 1956 to 1958 along the coasts of Oregon, Washington, and British Columbia have been very apparent during this period. Increased jack returns were observed in Puget Sound and British Columbia streams. Tropical species were observed in northern waters, and major changes in migration routes for temperate species were noted. It is therefore likely that a recent change in the maturation rate of Columbia River fall chinook was a result of rather rare oceanographic conditions which were not observed for any other period within the range of years encompassed by the present study.

The most significant effect which a change in maturation rate for the 1955 and 1956 broods would have on the return data would be an unduly high return in 1958 accredited to the 1954 brood, since 3- and 4-year-old returns in 1958 would constitute the major returns of the 1955 and 1954 broods, respectively. The returns in 1958 would also be unduly high since 1 year of mortality would be eliminated for the 3-year-olds. This factor would also act to increase the returns in 1959 from the 1956 brood (incorrectly accredited to the 1955 brood when a 4-year lag is used).[7] Improper designation of age at return of 1955 and 1956 brood years does not materially affect the present analysis since a regression study relating releases and returns 4 years later included only brood years 1941-49 when facilities at Spring Creek Hatchery were constant. For the more recent years we will examine only the level of return, for the number of fingerlings and fry released during this period of questionable age allocation was relatively constant.

Effects of local straying.--The problem of local straying is particularly difficult at Spring Creek Hatchery since eggs are taken at Big White Salmon River as well as at Spring Creek, and the fry and fingerlings are released in the respective areas. For this reason Spring Creek and Big White Salmon River are treated as one unit. Additional variation or error is introduced, however, since the number of natural spawners which contribute to the return in Big White Salmon River can only be estimated roughly. Furthermore, in some years even the number of hatchery spawned fish from Big White Salmon River is not given and must be estimated from the number of eggs taken. Further variation is introduced by production from natural spawning. Also, when fingerlings are reared at Spring Creek Hatchery and released in Big White Salmon River, it is questionable whether a significant portion returns to either stream.

At Spring Creek Hatchery, returns as well as releases have been accurately recorded, and for most of the analyses Spring Creek Hatchery alone has been considered as a unit. In order to determine the adaquacy of this treatment, releases and returns at Spring Creek Hatchery only have been compared with combined releases and returns at Spring Creek and Big White Salmon River. This comparison is presented in a later section.

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[6] Floyd Anders. Bureau of Commercial Fisheries, unpublished data.

[7] If the 1957 brood was unaffected by these changes, a greatly reduced return in 1960 could result despite a good production for the 1956 and 1957 broods, because the major returns for 1956 may have returned in 1959 as 3-year-olds and the 1957 brood may produce primarily 4-year-olds returning in 1961.

Effects of fisheries.--Relative returns to Spring Creek Hatchery may be affected by variations in the ocean troll fishery, sport fishery, and the gill net fisheries in the Columbia River below Bonneville Dam (zones 1 - 5) and above Bonneville Dam (zone 6). Although the ocean fishery, particularly the sport fishery, has increased very significantly since 1950, it is not possible to correct for this change since the contribution of Columbia River stocks to this fishery is unknown. It is also difficult to correct for the zone 6 gill net fishery above Bonneville Dam since a large and unknown portion of this fishery is above Spring Creek Hatchery. In 1956, however, this fishery was closed below Hood River Bridge, and, in 1957, the area above Bonneville Dam was closed. This closure had an impact on the data, although no correction for it has been made.

The female returns to Spring Creek Hatchery and Big White Salmon River have been adjusted for the gill net fishery below Bonneville Dam, which is the most important river fishery. By treating the Bonneville count as the escapement and the sum of Bonneville count and catch below Bonneville as total run (ignoring lower river escapement), the percent escapement has been calculated for each year (appendix table 8). Dividing the number of females returning to Spring Creek Hatchery by the percent escapement gives an estimate of the number of Spring Creek Hatchery females entering the river. Multiplied by a constant value E, which is the average percent escapement for the years involved, these values are brought to the same order of magnitude as actual returns (appendix table 9, last three columns). These values, which correct variations in the major gill net fishery below Bonneville Dam, will be referred to as "adjusted returns". Total female returns to Spring Creek Hatchery or Big White Salmon River have been adjusted in the same way (appendix table 9). These data are given for the brood years 1941-55 (1959 return).

The effect of the adjustments may be seen when adjusted and unadjusted female returns to Spring Creek Hatchery are plotted for the return years 1945 and 1959 (fig. 2). A strike in 1952 increased the escapement considerably so that the adjusted value in that year is greatly reduced. The effects of increased closures which were initiated in 1956 are not readily apparent until 1958. In 1959, as a result of a poor run, the fishermen reduced their effort in the first part of the season, and a slight delay in the peak of the run permitted an unprecedented percentage escapement during the closed period.

The Bonneville counts used to estimate percentage escapement include jacks, whereas adjustments are on adult female returns. No standard was used in the classification of jacks passing Bonneville Dam; therefore, subtracting jacks from the total count would probably introduce more error than their inclusion. For example, in 1957, when the jack return at Spring Creek Hatchery was 8,402 and the jack count over McNary Dam was 13,415, only 9,879 jacks were counted over Bonneville Dam.

Insofar as the gill net fishery is closed during the peak of the Columbia River run of fall chinook, a concentration of the Spring Creek run at this time could greatly reduce their availability to the fishery. Such an occurrence would invalidate the adjustment made in appendix table 8. Results of a tagging experiment conducted by Oregon Fish Commission at Bonneville Dam in 1956 were studied by the Bureau of Commercial Fisheries (U.S.

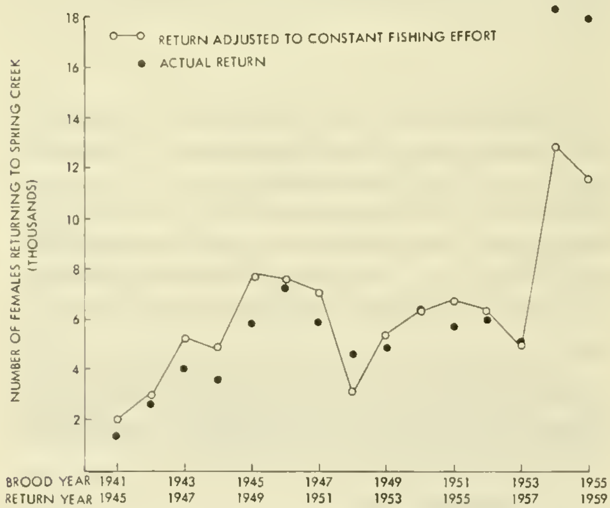

Figure 2.--Comparison of adjusted and unadjusted female returns to Spring Creek Hatchery as defined in appendix table 9.

Fish and Wildlife Service, 1960, vol. II, p. H-2) for evidence of such an effect, and it was concluded that Spring Creek Hatchery fish probably contribute to the fishery in proportion to their abundance. Preliminary data on 1959 returns of 3-year-old marked Spring Creek Hatchery releases (adipose-right pectoral) gives confirming evidence, with approximately 35 percent of the marked fish recovered in the river taken by the fishery[8] and 30 percent of the total run taken by the fishery[9]. Returns of marked chinooks in 1960, 1961, and 1962 should give a more precise evaluation.

Variables Concerned with Hatchery Releases

For many years biologists have attempted to determine when juvenile chinook salmon should be released in order to yield the best survival to adulthood. Experimentation including the release of marked fish has led to contradictory results, and opinions on this subject are widely divergent. In a multiple regression study by Washington Department of Fisheries [10] on the tagged adult returns at two hatcheries against releases at ages of 30 days or less, 60 days, 90 days, etc., very high multiple correlation coefficients were obtained. At both hatcheries it was indicated that releases in the vicinity of 90 days were very much more productive than any others, and releases before 30 days gave no significant indication of production (partial correlation coefficients very close to zero).

A similar study of Spring Creek Hatchery data would have been desirable, but major changes in hatchery facilities in 1950 and in 1953 made it necessary to divide the data into three parts, the brood years 1941-49, 1950-52, and 1953-55. As a result, only the first period (1941-49) contributed sufficient data for any correlation study, and, with only 9 years of data, no more than two independent variables, fry and fingerling releases, could be used. The fry size (500 per pound) is comparable to the size of 30-day-old chinook - the apparent age below which no significant production was indicated in the Washington Department of Fisheries study.

For many of the Spring Creek Hatchery releases in the 1940's no date of release was given, so it was necessary to classify by average weight rather than by age at release. This classification rules out the use of the 1939 and 1940 brood years. In 1939 no weights or time of release were given. In 1940 only the total weight for all fish released was given, and this weight included large numbers released in Big White Salmon River and large numbers released over a 2-month period at Spring Creek Hatchery without specified dates or numbers for the individual releases.

Since only two groups (fry and fingerlings) may be used in a regression study and since each group encompasses a wide range of sizes, there is some advantage in using pounds of fingerlings (or fry) released as the independent variable instead of number released. If the number released is used, the inherent assumption that eventual survival is independent of size within each group (fry or fingerlings) may inhibit any correlation with returns. On the other hand, the use of pounds released is equivalent to a weighting process which assumes that within each group survival is proportional to the weight of a fish at the time of release, and the correlation with returns may be improved. That this is actually the case can be seen when adjusted female returns to Spring Creek Hatchery are plotted against total numbers (fry and fingerlings) released in Spring Creek Hatchery and total pounds released (figs. 3 and 4), with respective correlation coefficients of 0.022 (not significant) and 0.682 ($P<0.05$). Insofar as economic factors are to be considered, the use of poundage is obviously more meaningful since costs are more closely related to pounds of fish released than numbers.

[8] Estimated from recoveries in the Columbia River gill net fishery, 30 percent of which was sampled by Oregon Fish Commission and Washington Department of Fisheries, and from hatchery recoveries.

[9] Catch plus Bonneville count was used as the total run as in appendix table 7.

[10] Washington Department of Fisheries, unpublished manuscript, 1958.

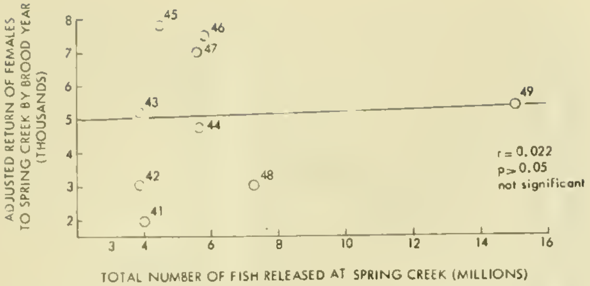

Figure 3.--Correlation between total release (fry and fingerlings, in numbers of fish) and adjusted return of females as defined in appendix table 9, by brood year (1941-49).

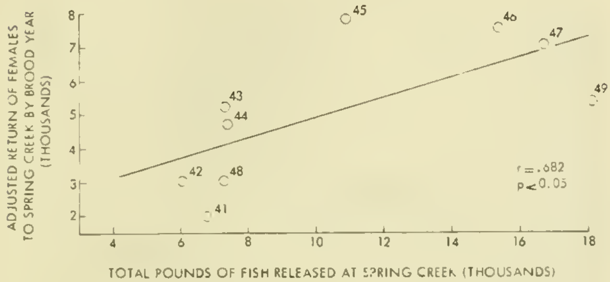

Figure 4.--Correlation between total release (fry and fingerlings, in pounds) and adjusted return of females as defined in appendix table 9, by brood year (1941-49).

ANALYSIS OF DATA

Regression Studies, 1941-49 Brood Years

In the process of defining the variables to be studied some indication of the relative survival of fry and fingerling releases is obtained. For this purpose, deviations from the regression line in figure 4 may be compared with the relative pounds of fry and fingerling releases at Spring Creek Hatchery (appendix table 5). Points below the regression line are all associated with high percentages of fry releases (89, 100, 100, 73 percent fry by pounds for brood years 1941, 1942, 1948, 1949, respectively), whereas the points above the line are associated with much smaller percentages of fry (67, 55, 25, 25, 22 percent for brood years 1943, 1944, 1945, 1946, 1947, respectively). This result indicates that the return per pound of fingerlings released is somewhat higher than the return per pound of fry released. Generally, a pound of fry contains 5 to 10 times as many fish as a pound of fingerlings, so it appears that the survival rate for fingerling releases is many times greater than the survival rate for fry releases.

Variations of this type, however, may be studied more effectively by making use of multiple regression techniques. "Adjusted returns" will refer to the number of females returning 4 years after the releases for the specified brood year, adjusted for the effects of the gill net fishery below Bonneville Dam. The following notation will be used:

x_1 = pounds of fingerlings released at Spring Creek Hatchery (range from zero in 1942 and 1948 to 13,155 in 1947)

x_2 = pounds of fry released at Spring Creek Hatchery (range from 2,765 in 1945 to 13,239 in 1949)

y = adjusted returns (range from 1,992 for the 1941 brood to 7,846 for the 1945 brood)

The multiple correlation coefficient ($r_{y.x_1x_2}$) is 0.891 ($P<0.01$). The direct correlation between pounds of fingerlings released and return (r_{yx_1}) is 0.890 (see fig. 5a), so that the partial correlation between fry releases and return is very close to zero. Insofar as the ranges of x_1 and x_2 are large and of the same magnitude, the resulting correlations indicate that variation in returns is controlled almost entirely by fingerling releases. This is in agreement with the results of the Washington Department of Fisheries study previously mentioned.

Incomplete results of a marking experiment[11] which was initiated on the 1956 brood at Spring Creek Hatchery also show a much greater survival rate for fingerling releases. In this experiment equal numbers of two groups of unfed fry were marked by removing the adipose and left pectoral fins and the adipose

[11] Bureau of Commercial Fisheries, experiment now in progress. Preliminary tabulations from marked returns reported by Oregon Fish Commission, Washington Department of Fisheries, and Bureau of Commercial Fisheries.

and right pectoral fins. The adipose-left pectoral group was released as unfed fry, and the adipose-right pectoral group was released after a 3-month rearing period. Preliminary tabulations show the following recoveries of marked fish: 33 adipose-right pectoral and 3 adipose-left pectoral in the Washington-Oregon ocean troll fishery, 22 adipose-right pectoral and 1 adipose-left pectoral in the Columbia River gill net fishery, and 124 adipose-right pectoral and 6 adipose-left pectoral at hatcheries. From the combined recoveries the indicated survival rates for fingerling and fry releases are in the ratio of 18 to 1 (179 to 10). Some qualification of the results of the regression study as well as the marking experiment is necessary, however, since in 1948 and 1949 when very large releases of fry were made and at the time of the release of the marked fry of the 1956 brood, water temperatures in Columbia River were near freezing in comparison with the constant temperature of 46° F. for Spring Creek. Possible effects of such a temperature differential will be discussed in a later section. All studies that have been considered here give evidence favoring fingerling survival under existing conditions, although a precise evaluation of the relative survival rates should await the returns of marked releases of the 1957 and 1958 broods.

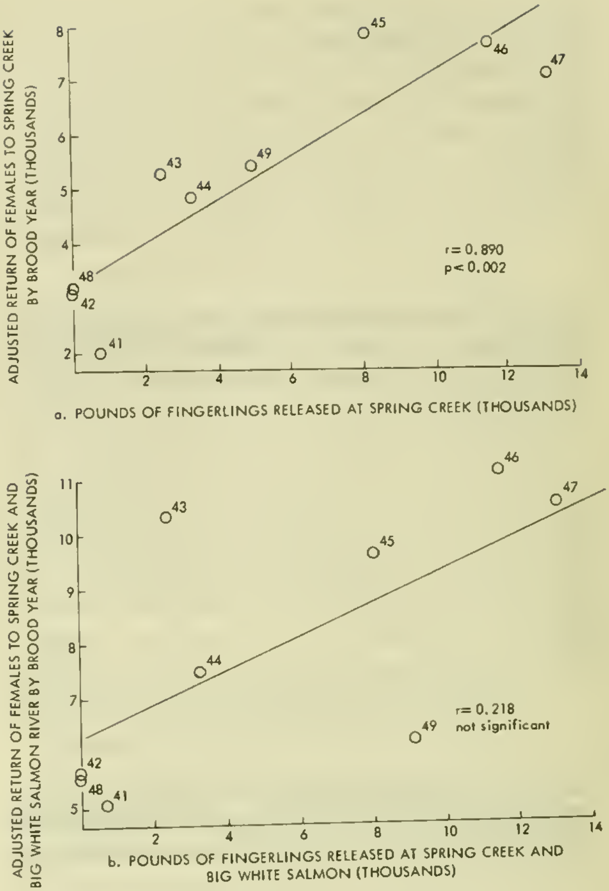

Figure 5.--Correlation between fingerling releases in pounds and adjusted return of females by brood year (1941-49).

Two graphs have been prepared to observe the possible effects of local straying on the correlations between pounds of fingerlings released and adjusted returns of females, and to study whether or not the use of Spring Creek Hatchery data as a unit is justified (fig. 5). In figure 5a releases and returns at Spring Creek Hatchery are compared only, and in figure 5b combined releases and returns at Spring Creek Hatchery and Big White Salmon River are plotted. These graphs indicate that Spring Creek Hatchery alone repsents a better unit of study than the combined river systems. The correlation coefficient using Spring Creek Hatchery data only is highly significant ($P < 0.002$) and actually much greater than the correlation for the combined data, which is not even significant.

A consideration of the probable factors affecting the widely divergent points for 1943 and 1949 broods in figure 5b is of interest. In 1943, due to high water, almost the entire run to Big White Salmon River was permitted to spawn naturally (24,000 eggs taken), and the large return to Big White Salmon River in 1947 (actually much larger than indicated, because a large but unknown number again spawned naturally) probably reflects the productivity of natural spawn. The large natural spawning in 1947 also was followed by a large return to Big White Salmon River in 1951. Good natural spawning in 1950 and 1951, however, did not produce high returns in 1954 and 1955, although a localized gill net fishery may have greatly reduced returns in these years. The observed intensity of this fishery in 1955 resulted in a closure below Hood River Bridge in 1956.

For the 1949 brood year relatively large numbers of fingerlings of Spring Creek

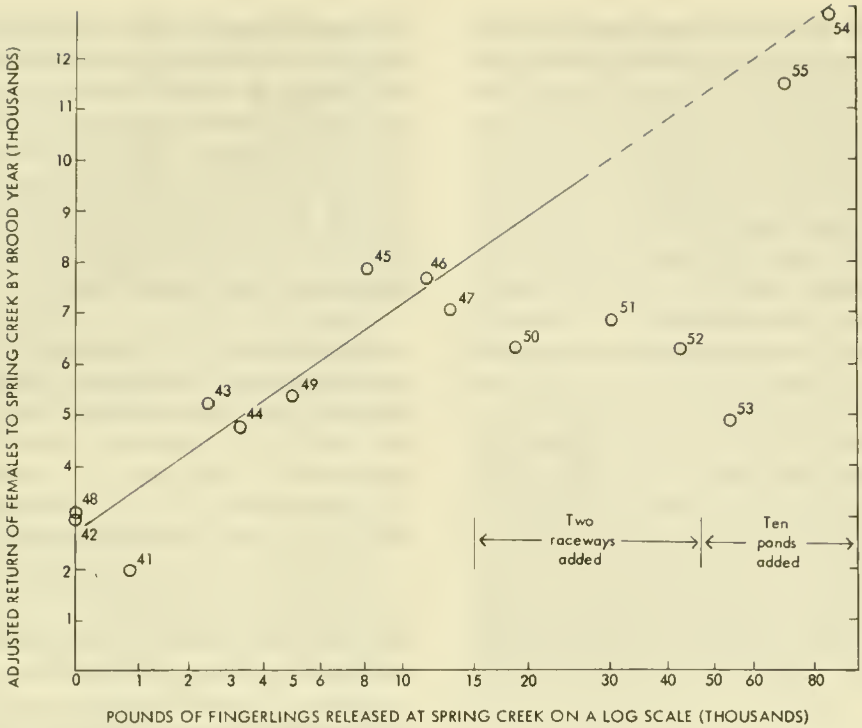

Figure 6.--Correlation between fingerling release (in pounds) at Spring Creek Hatchery and adjusted return of females as explained in appendix table 9.

Hatchery stock were reared at Spring Creek Hatchery but released in Big White Salmon River. Ricker (1959)[12] lists a number of examples where similar transplants produced few returns, and although Spring Creek Hatchery stocks were originally from Big White Salmon River, it is not unlikely that returns from such a transplant would be greatly reduced either from straying or increased mortality.

Relationship Between Fingerling Releases and Returns for Brood Years 1949-55 and Indications of Reduced Survival Rate in Recent Years

In 1950, 3 raceways were added at Spring Creek Hatchery and 10 circular ponds were installed. In figure 6 adjusted returns of females to Spring Creek Hatchery are plotted against pounds (graphed on logarithmic scale) of fingerlings released at Spring Creek Hatchery for the brood years 1941-55. Following each increase in rearing capacity, there was an increase in the pounds of fingerlings reared. The brood years represented in figure 6 are therefore conveniently separated according to available capacity.

The reduction in return per pound of fingerlings released since 1950 is very marked, particularly when the effects of the logarithmic scale on pounds released are taken into account. For example, for the 1945, 1946, and 1947 broods total releases of about 10,000 pounds produced an adjusted return of about 7,000 females, whereas for the 1954 and 1955 broods (representing the record-producing returns of 1958 and 1959) almost eight times as many pounds of fingerlings (about 80,000 pounds) produced less than twice the returns (about 12,000 females). If the returns in 1958 and 1959 involved significantly more 3-year-olds, the actual production for the 1954 and 1955 broods may be little better than is indicated for the brood years 1950-53.

[12] W. E. Ricker. "Evidence for environmental and genetic influence on certain characters which distinguish stocks of the Pacific salmons and steelhead trout." Unpublished manuscript, Fisheries Research Board of Canada, 1959.

The severity of this downward trend is even more apparent where the adjusted return per thousand pounds of fish released (fry and fingerlings) is plotted by brood year and return year (fig. 7). The inclusion of fry releases in this plot should favor the values for recent years since the percentage of fry released after 1950 was greatly reduced (fig. 8). The relatively low values for 1941 and 1942 brood years (fig. 7) are associated with releases which were almost 100 percent fry, and the average level for these 2 years is very close to the value for 1948 when only fry were released. The deviations from the regression line indicated that in the 1940's the return per pound of fingerlings released was greater than the return per pound of fry (fig. 4). Figure 7 shows, however, that compared with the years 1941, 1942, 1948, and 1949, when a very high percent of fry were released, the return per pound released has been much less since 1950

Figure 7.--Return rate of females to Spring Creek Hatchery.

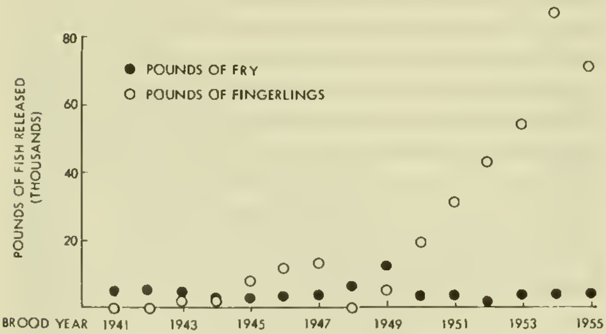

Figure 8.--Pounds of fingerlings and fry released at Spring Creek Hatchery.

with increasingly higher percentage of fingerlings. It would appear then, that a pound of fingerlings in recent years does not produce the return comparable to that from a pound of fry in the 1940's. If, however, the downward trend in figure 7 is due to genetic or disease factors which affect both fry and fingerling releases, the survival rate of fry in recent years could also be reduced.

The regularity and extent of the downward trend exhibited in figure 7 suggests the existence of a time-related factor that affects the index of production used here without necessarily affecting the actual production. An examination of any such apparent factors does not confirm this hypothesis. For example, if unadjusted female returns are used, the same trend as in figure 7 is observed except for returns for 1952 when results of a strike obviously require adjustment.

Relatively large numbers of fish were released in Big White Salmon River in earlier years, and it might be suspected that increased local straying from Big White Salmon River could have increased the return to Spring Creek in the 1940's. By using combined releases and adjusted returns to Spring Creek and Big White Salmon River to remove this effect, the same trend as figure 7 (using Spring Creek Hatchery data only) is obtained. If a relatively constant percent of wild fish stray to Spring Creek Hatchery, a larger escapement of wild stocks in earlier years could increase returns, but appendix table 8 shows that escapement of wild stocks as measured by Bonneville counts is of the same magnitude for the brood years 1945, 1946, 1947, as for the brood years 1953, 1954, and 1955.

Increased fishing intensity in the ocean fisheries may have affected returns, as can be noted from the declining total run in the Columbia River (appendix table 8). For the 1945 and 1946 brood years, however, the total run was only about twice the total run for brood years since 1951, whereas the return per pound of fish released (fig. 7) for 1945-46 broods was more than five times as great as for brood years since 1951. In addition, the downward trend in the run in the river in these years was presumably influenced by reduced production as a result of reduced escapement, but values in figure 7 are based on return per pound of fish released and are independent of escapement. Furthermore, returns for brood years since 1952 have been given increased protection by a closed fishery above Bonneville Dam, and no adjustment has been made for the effects of this closure. It is likely that the downward trend is somewhat exaggerated by factors unrelated to production, but none of the factors considered here, separately or collectively, can account for the magnitude of this trend.

FACTORS COINCIDENT WITH CHANGE IN PRODUCTION RATE

Any attempt to study causal relationships influencing a severe time trend such as is exhibited in figure 7 usually requires controlled experimentation. In the present investigation little more can be done than to list observed factors which are coincident with the period of this trend. Work by specialists in fields related to any such factors has been examined to determine whether or not observed factors are possible causes of a decline and therefore merit future investigation. No extensive coverage of the literature has been made.

Incidence of Infection with Acid-Fast Bacteria (Tuberculosis)

Infection with acid-fast bacteria, commonly called tuberculosis, was first observed in 1952 by Wood and Ordal (1958) in adult chinook salmon at the Bonneville Hatchery. The infection since then has been noted at other Columbia River hatcheries in varying degrees of intensity. Ross, Earp, and Wood (1959) found the disease at Spring Creek Hatchery in 1957. Of a total of 300 random liver samples collected from normal-appearing fish, 2.3 percent (7) were found to be infected with acid-fast bacilli. Ten liver specimens were collected from abnormal-looking salmon, and nine were found to be diseased. During the 1957 commercial season in the Columbia River, a total of six marked fish (anal-right ventral) from the 1953 Spring Creek Hatchery brood were examined. Five of these showed no indication of acid-fast bacilli in liver smears, and one showed only a slight infection (Wood, 1959). Random samples were again collected at Spring Creek Hatchery in 1958 and 1959.[13] The infection increased to 35 percent in 1958. In 1959 it was possible to obtain a random sample of unmarked fish and a separate sample of the marked fish. The unmarked fish showed a 23.5 percent infection (11 of 46), whereas 52 percent (77 of 148) of the marked fish were infected in varying degrees.

The increased rate of infection for marked over unmarked fish at several hatcheries gave early indication that the disease was probably of hatchery origin since wild fish may contribute to the unmarked returns. Studies have shown that the longer the fish are reared and fed in the hatchery, the higher the percent infection (Wood and Ordal, 1958). The causative agent has been shown to be in infected salmon carcasses and viscera used in the diets of young fish in the hatchery.

This disease is known to affect normal sexual maturation and growth. Wood (1959) demonstrated a significant reduction in the average length of heavily infected fish over lightly or noninfected fish. Significant differences in length were shown for spring chinook of known age and steelhead at the Willamette Hatchery, and a silver salmon at Klaskanine Hatchery.

Coagulated Yolk Disease

Outbreaks of coagulated yolk disease (white-spot) have been reported by Johnson.[14] In the 4 brood years covered in his report, 1953-56, mortality at Spring Creek Hatchery varied from about 1 percent in 1954 and 1956 to 15 percent in 1953. Mortality in 1955 was 5 percent. In 1959 a mortality of 3 to 5 percent was attributed to coagulated yolk. The mortalities in the 1957 and 1958 brood years were about 1 percent.[15] It is of interest to note that the

[13] A. J. Ross. U.S. Fish and Wildlife Service, unpublished data.

[14] Harlan E. Johnson. Coagulated yolk disease in fall chinook salmon at Lower Columbia River Hatcheries. Typed report to Regional Director, U.S. Fish and Wildlife Service, Portland, Oregon. September 4, 1957, 6 p.

[15] Data for the 1957, 1958, and 1959 brood years were obtained from Harlan Johnson. (Personal communication.)

highest mortality rate is associated with the 1953 brood, which had the poorest return in recent years (see fig. 6).

Normally the disease makes its first appearance shortly after the fry have hatched. Johnson also reports an occasional occurrence just prior to hatching but has never noted it earlier in the egg stage. Yolk material has been found in the body cavities long after the fish have started feeding. A cause and a cure for the disease have not been discovered. Delayed mortality after the release of the fish has never been investigated.

Increased Crowding

Since 1949 the rearing capacity in cubic feet of the rearing space used at Spring Creek Hatchery has increased less than fourfold. The pounds of fingerlings reared have increased over sevenfold. The available water from Spring Creek has remained at a constant level of 3,500 gallons per minute since 1950. The result has been an increase in pounds of fish reared per cubic foot of space and per gallon of flow.

For the last few brood years (not included in the analysis) Columbia River water has been used to increase the flow of water through the raceways. This was considered necessary to remove waste products and maintain proper oxygen concentration during periods of high fish density. In the spring of 1960 the pumps supplying the river water failed for a short time.[16] An immediate effect was noticed. The fish showed distress, and an increase in mortality occurred. This mortality occurred during a year when fewer pounds of fish were being reared than in the 1952 and 1955 brood years, and in the earlier years no additional water was utilized. Though apparent mortalities in the ponds were normal for the 1952 and 1955 broods, the possibility of damage to some of the fish resulting in delayed mortalities cannot be overlooked.

[16] From personal communication with Clyde Adams, superintendent of Spring Creek Hatchery.

Composition of Diet

In appendix table 10 the total pounds of food fed at Spring Creek Hatchery and the composition of diet in percent is given for the brood years 1943-45. Data for earlier years are not available. In order to keep yearly data on a comparative basis, the data in appendix table 10 include only food fed during the months of February through May when the hatchery was almost exclusively concerned with rearing fall chinook fingerlings. In addition, appendix table 10 includes only the diet for fish of Spring Creek Hatchery origin.

The abrupt change in diet composition since 1950 is immediately apparent and was coincident in time with reduced adult return (fig. 6). In general, the change involved the substitution of salmon eggs and salmon flesh for melts, horsemeat, and salmon viscera, though for the 1954 and 1955 broods salmon viscera were restored to the diet. It is possible that either the elimination of important components or the introduction of deleterious components resulted from this change. The possible infection with acid-fast bacteria by feeding salmon products has been noted. Studies at Leavenworth Hatchery (Robinson, Palmer, and Burrows, 1951) on sockeye salmon *(O. nerka)* indicate that no benefits were derived from feeding a high percentage of salmon eggs in the diet when water temperatures were in the vicinity of 45° F. Mortalities were high, and growth rate was not particularly good until water temperatures increased. Burrows, Palmer, Newman, and Azevedo (1952) found somewhat similar effects using both sockeye and chinook salmon.

Handling of Fry and Fingerlings

Prior to the 1949 brood year, total numbers of fish released were estimated by subtracting the known mortalities from the number of fish placed in the ponds after hatching, which in turn had been estimated by subtracting the egg mortality from the original number of eggs. Before a release of fed fish was made, a random sample of fish was taken and the number of fish per pound was determined. When unfed fry were released, a constant weight of

1,000 fish per pound was assumed. In this way handling was reduced to a minimum. The present hatchery policy, however, requires that all fish be weighed at time of release.

Fingerlings are weighed by being crowded into a confined area and dipped out of the ponds into a weighing basket submerged in the water. The weighing basket is then removed from the water, most of the water is allowed to drain from the basket in order to obtain an accurate weight. At this time the fish are subjected to the hazards of pressure and abrasion.

Fry are usually released directly from the egg trays. The egg trays are collected and weighed. The total weight of fry is obtained by subtracting the weight for each tray from the total weight of fry plus tray. This handling involves little more than is necessary to remove the fish from the tray. After the fish are weighed, both fry and fingerlings are released through a long hose which extends from the hatching room or the ponds directly into the river.

Some question may be raised as to the probable effect on accuracy of the change since 1949 in evaluating pounds of fingerlings released. Estimating numbers released by subtracting only the observed mortalities should result in an overestimate of numbers and pounds released in the earlier years. As a result, the return per pound of fish released should be even higher for the earlier years than is indicated by figure 7.

TEMPERATURE EFFECTS

Water temperature plays an important role in fish cultural operations. Two possible effects of temperature are discussed in the following sections: The effect of temperature during the egg and early fry stage and the effect of temperature differentials between Spring Creek and Columbia River at time of release. It should be pointed out that the source of water for the Spring Creek Hatchery is a spring with a constant temperature of 46° F. In the last few years, this constant temperature has been altered somewhat by the introduction of Columbia River water during the rearing period.

Egg and Early Fry Stage

Seymour (1956) conducted experiments on chinook salmon over a wide range of constant temperatures. The results of 2 years' experiments indicated that the overall mortality (from the time the egg was fertilized to after the resulting fish started feeding) was lowest at about 45° F. Mortality increased rapidly above 50° F. and below 40° F. "Abnormality" was lowest among fish reared at a constant temperature between 45° and 50° F. Seymour also made counts of meristic characteristics (vertebrae and dorsal and anal fin ray counts) of fish held at the constant temperatures. Plots of these counts relative to the temperature showed turning points in the curve in the vicinity of 45° and 50° F. Seymour states in his abstract that "taking into consideration both mortality and growth rate, the optimum temperature was about 52° F. for eggs and 58° F. for fingerling."

Disregarding the effect on growth, the optimum temperature found by Seymour for egg and early fry stage appears to be very close to the Spring Creek temperature. Insofar as the basic structure of the organism, both physiologically and anatomically, is developed during egg and early fry stages, the constant temperature of 46° F. at Spring Creek may be an important factor in the eventual survival rate of the fish.

Temperature Differential at Time of Release

Several workers have described the effect on salmon of sudden emersion from warmer to colder water. Varma (1950) subjected silver salmon *(O. kisutch)* to a sudden transfer from water of 58° F. to water of 35° F. These fish were between 3 and 4 inches in length, and had not been fed for 1 day prior to the experiment. In the experiment an initial shock marked by a loss of equilibrium by the fish was quite pronounced within 10 minutes. By this time the fish seemed to be "paralyzed" and the respiration rate seemed to be irregular. Death did not occur until the fourth day. By the 10th day 4 of the 12 fish used were dead and the remaining 8 were in "bad shape".

Brett (1952) conducted experiments on temperature tolerance of all five species of

Pacific salmon found in local waters. The chinook salmon used in the experiment averaged less than 2 inches in length. These fish were chinook stock from the Dungeness Hatchery, Washington State Department of Fisheries. The eggs were all hatched under Brett's supervision and then acclimated to various water temperatures, including 41° F. and 50° F.[17] Though these fish were then subjected to water temperatures either higher or lower than temperatures at the normal time of release, a 50 percent mortality occurred within 12 hours when fish acclimated to 50° F. were placed in water of 76° F. Fish acclimated at 41° F. and placed in water of 72.5° F. showed a 50 percent mortality within 4 hours. Brett also subjected chinook salmon acclimated at 50° to 32° F. water. Fifty percent mortality was reached more than 18 hours after placing in the 32° F. water. The overall mortality is not known as Brett was concerned only with the length of time necessary to kill half of the fish. Brett (1952, p. 283-284) found that size influenced the mortality of fish subjected to a sudden decrease in temperature. The dead fish were smaller than the survivors, and the difference between the two groups was statistically significant. No size influence could be demonstrated in the mortality occurring with an upward change in temperature.

The temperature regime of the Columbia River may range from a low of 32° F. in late January or early February, to a high of over 70° F. in late summer. The Columbia River temperature at Bonneville Dam (U.S. Army Corps of Engineers, 1948-58) relative to the constant 46° F. of Spring Creek Hatchery water is shown for the period of January to July, 1948-58 (fig. 9). These temperatures are grouped into three arbitrary categories: "ideal" (46° ± 3° F.), "safe" (40° to 42° F., 50° to 52° F.) and "critical" (less than 40° F., more than 52° F.). It should be noted that in the 11 years included in the figure, the period from mid-March to mid-April has always been "safe" or "ideal". In most years, the first week of February (time of fry release) has been in the "critical" range. In the first week of May, frequently the modal time of fingerling

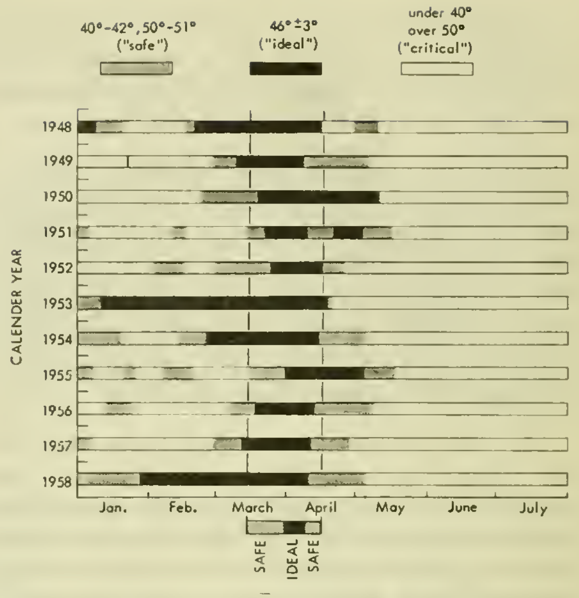

Figure 9.--Daily water temperatures (°F.) of Columbia River as measured at Bonneville Dam, January - July, 1948-58, classified as "ideal", "safe", and "critical" for chinook releases at Spring Creek Hatchery. Period from mid-March to mid-April always "safe" in these years.

releases, temperatures are often "critically" high. Actual water temperatures at the time of fry and fingerling release into the Columbia River from Spring Creek Hatchery may be found in appendix table 11, which shows the extreme temperature differences often existing between Spring Creek Hatchery and the Columbia River when releases are made. For example, in the 1955 brood year a large fry release was made into the Columbia River when its temperature was 34° F. Later in the same year a substantial number of fingerlings were released into 56° F. water.

The findings of Varma and Brett suggest that the temperature differential between hatchery water and river water may produce heavy mortality following release into the Columbia. This differential may be of particular concern with regard to releases on recently hatched, unfed fry. These fish are not completely developed, and the sudden shock to their system may be very serious. A short tempering to the necessary temperature probably will meet with little success. This has been indicated by Brett (1941) on brook trout *(Salvelinus fontinalis)*. No benefit could

[17] All temperatures have been converted from Centigrade to Fahrenheit degrees.

be shown from tempering these fish for a short time prior to release into water considerably warmer than their acclimation temperature. It was shown that the upper lethal temperatures could be raised by several degrees if the fish were acclimated at an intermediate temperature for a period of time.

PROBLEMS AND SUGGESTED STUDIES

In the development of the present study, some insight has been gained with respect to the problems stated in the initial proposal, but a number of additional problems have also taken on importance. These problems will be discussed in the present section, and the need for future study with respect to various aspects of these problems will be considered.

Initial Problems

At the outset of the present study, three problems seemed of major importance. These were: The relative survival of fry and fingerling releases, the relative contribution of Spring Creek Hatchery stocks to the various fisheries, and the magnitude of straying into Spring Creek Hatchery. Additional work on each of these problems is still required, but scale studies and analysis of returns of marked fish which are now in the ocean should be sufficient. It should be pointed out, however, that the problem of "relative contribution" considered here is not intended to cover the general problem of hatchery contribution which will require a carefully planned program of study involving all Columbia River hatcheries.

Relative production of fry and fingerling releases.--At the present time evidence from regression studies and from experiments with marked fish strongly suggests that the survival rate for fingerling releases greatly exceeds the survival rate for fry. A precise estimate of the relative survival rates, however, must await returns of marked releases. In order to rule out possible effects of marking, a scale study to determine a means of identifying fry and fingerling releases as returning adults would be of great value.

Insofar as the 1956 Spring Brook fry were released into near freezing water, returns from the 1957 and 1958 broods, which were also marked, should be studied. Whether or not fry releases should be continued is a separate problem needing careful consideration.

Contribution to fisheries.--Recoveries of the 1959 marked returns to the Columbia River indicated a high contribution to the gill net fishery. This return involved only 3-year-old fish, but marked returns in 1960, 1961, and 1962 should be adequate to determine precise estimates of the contribution to this fishery. Ocean recoveries should supply some information on the relative contribution to the ocean troll and sport fisheries. Of course, if the modal age has changed to 3 years, contribution to ocean fisheries will be drastically reduced. In this respect, the same situation may be occurring at other Columbia River hatcheries. A more thorough study of scales to determine the age of adult returns at various hatcheries is necessary.

Straying.--Although straying of marked fish from other sources has been observed at Spring Creek Hatchery, quite a few marked Spring Creek Hatchery releases have been taken in other areas. It is therefore indicated that straying from, as well as to, Spring Creek Hatchery should be investigated. Marked returns of Spring Creek Hatchery releases should be available in the next 2 or 3 years, and data on returns to Spring Creek Hatchery of marked fish from other sources should be sufficient for such a study. In studying straying to Spring Creek care should be taken to eliminate any releases of marked fish which could be considered as transplants, because straying has generally been observed under such conditions (Ricker, 1959; see footnote 12). Our preliminary studies of scales taken at Spring Creek indicate that an intensive scale study might be of value in estimating the extent of straying.

Additional Problems

Reduction in productivity.--It is obviously beyond the scope of the present study to suggest detailed experiments dealing with the highly specialized problems of disease, nutrition, rearing density, genetics, etc. We strongly suggest, however, that a centralized program involving specialists in the related fields be inaugurated for the study and control of such factors. We recognize that much basic work is progressing in these fields, but a centralized program could coordinate the study of interrelated factors and assure the application of the best known procedures at each hatchery.

Some suggestions of a nontechnical nature may be given. For example, it has been proposed that the pasteurization of all salmon products used in hatchery diets may reduce the incidence of infection with acid-fast bacteria; but, considering the extent of infection throughout the Columbia River hatcheries, a continuation of work on this disease is necessary. There are strong indications, however, that other factors are affecting survival. The cause of coagulated yolk disease is unknown, and the possibility that it may influence eventual survival cannot be ruled out. The need for increased study of this disease is apparent. Also, indications of the present study suggest that specialists should examine the changes in rearing densities and diet that have occurred at Spring Creek Hatchery in the last 10 years and begin pertinent studies. We strongly recommended that the handling of fingerlings at the time of release be eliminated since relatively inexpensive devices are now available for counting fish with adequate precision. Little work should be required to evaluate the use of such devices at hatcheries.

Relationship between problems at Spring Creek Hatchery and problems at other hatcheries.--A major purpose for the study of Spring Creek Hatchery is to determine means of increasing production at other Columbia River hatcheries; therefore, the need for a comparative study of other hatcheries is obvious. For such a study adequate data on releases and returns must be available. The Little White Salmon Hatchery and Willard Hatchery located on the Little White Salmon River should satisfy this condition, and we suggest that a study, similar to the present Spring Creek Hatchery study, be made of this hatchery as well as other suitable hatcheries.

Apparent change in modal age of maturity.--It is unfortunate that for the present investigation it is necessary to base an analysis of age of return on assumptions involving length measurements of adults returning to another hatchery and length measurements at Spring Creek Hatchery for a single year, 1959. Scales were taken in conjunction with length measurements, but reading of scales has been incomplete and fragmentary. Preliminary study indicates that Spring Creek scales are easily read for age, and the need for prompt reading of these and scales from fish of the 1960 returns is apparent. Some problems in reading scales from adults returning to the Little White Salmon Hatchery have been observed, but the use of scales from marked returns should be sufficient to solve these problems. Excellent sampling techniques have been developed by Anders[18] for the 1959 return at Spring Creek Hatchery, and we suggest that these methods be standardized for general use. In view of the effect of age of return on the relative contribution to ocean fisheries, the determination of the age composition in the Columbia River as well as at a number of hatcheries is important. If the present sampling of the gill net fishery is supplemented by sampling at Bonneville Dam, this should be possible.

Disposition of eggs.--Centralized planning is important not only for rearing techniques but also for determination of the most efficient disposition of the eggs taken, i.e., that disposition which in the long run will result in the largest production of adult salmon. In 1958 over 80 million eggs were collected from fish returning to Spring Creek. Of these, less than 8 million were reared at Spring Creek Hatchery. Less than 6 million were released as unfed fry. The remaining 66 million were distributed among other Columbia River hatcheries (appendix table 1). Some releases of marked fish have shown survival rates to adulthood in the vicinity of one-half of 1 percent, and it is very likely that fingerling releases in the 1940's experienced such a survival rate. Such a survival rate on 80 million eggs would produce more adult salmon

[18] Floyd Anders. Bureau of Commercial Fisheries, unpublished manuscript.

than are to be found in the entire run of fall chinook salmon returning to the Columbia River in recent years. We realize that neither the facility nor technical knowledge is presently available to realize this potential, but the eventual attainment of such a survival rate is not unlikely if research and applied techniques are coordinated. In any case, it would seem advisable to make use of present knowledge in determining the disposition of the eggs.

The following examples are not given as direct suggestions but merely as illustrations of the types of problems that might be considered in the disposition of eggs. In the Klickitat River, fishways were constructed to open up spawning areas to salmon. A run of fall chinook using imported stocks was successfully produced. In 1958 all of the fall chinook females utilizing the fishways were trapped and taken to Klickitat Hatchery for spawning. Only those fish jumping the falls were able to spawn naturally. Considering the purpose of building the fishway, it would seem preferable to permit a reasonable number of fish to spawn naturally and supplement the eggs at Klickitat Hatchery with eggs from Spring Creek Hatchery. None of the 1958 brood were transferred to the Klickitat Hatchery (appendix table 1). In 1959 over 3½ million eggs were transferred to Klickitat Hatchery from Spring Creek Hatchery, but all chinook females entering the fishways were removed as in 1958.

Even in recent years a fair amount of interchange between Spring Creek and Big White Salmon Hatcheries' stocks has occurred (appendix table 1). For example, in 1949, 1950, 1951, 1953, and 1956, Spring Creek Hatchery stocks were planted as fry or fingerlings in the Big White Salmon River. In 1949, 1953, 1955, and 1958, Big White Salmon stocks were released at Spring Creek Hatchery. The advisability of such a procedure might be considered by geneticists.

The increased return at Big White Salmon River following large natural spawning has been mentioned. It is advisable to determine the spawning potential in this river and permit more natural spawning when needed.

Continued experimentation on lake rearing of fall chinook fry may yield another important source of production. The success of fall chinook plants in Capitol Lake in Olympia, Wash., is well known. Impoundments using Columbia River water may be productive if properly controlled.

Continuation of fry releases. Time, place, and manner of release.--In evaluating the advisability of continuing fry releases, firstly, the productivity of such releases should not be compared with the productivity of fingerling releases at Spring Creek Hatchery but with the productivity of eggs transferred from the hatchery, since transference is the only alternative at the present time. Secondly, relative costs of various alternatives should be compared. In addition, the possibility of increasing the survival of fry releases by altering the time, place, or manner of release should be studied.

Time of release should be coordinated with conditions in the Columbia River and in the estuary. At the present time little is known about factors affecting survival in the estuary, and study is greatly needed. In the river, temperature and the extent of predation at the time of release should be considered. Effects of temperature differential at time of release can be minimized by acclimating the fish to the desired temperature, but such a process should be a matter of days, not minutes. In any case, no attempt should be made to release or acclimate fry to near freezing temperatures. If low temperatures in the Columbia River require that the fish be held several weeks, feeding may be necessary. The release of unfed fry has often been considered advantageous. For chinook salmon, however, there is little evidence that any benefit is gained by this procedure. With respect to predation on delayed releases, Thompson (1959) has found that the activity of predatory fish is minimal even as late as March if temperatures are in the vicinity of 40° F.

A primary consideration in determining the place of release is genetic in character. Genetic adjustments of stocks to fixed environmental conditions are well known. Such adjustments will be limited if stocks experiencing one environmental condition are continually mixed with stocks undergoing different environmental factors. For this reason, it may be desirable to release reared fingerlings only at Spring Creek Hatchery and find a different location for the release of fry. At a station for releasing fry, it might be desirable to have a constant temperature water source near 45° F., with pumped Columbia River water available for gradually acclimating the fry before release. Returning adults would require trapping facilities that would minimize straying. Whether or not transfers from Spring Creek Hatchery should be as eggs or as fry needs to be studied. Carson Depot Springs located on the Washington shore of the Columbia River a few miles above Bonneville Dam is at present being developed by the U.S. Fish and Wildlife Service and should satisfy the requirements reasonably well. As an experimental station, Carson Depot Springs might be of value in the study and development of procedures best suited for the release of fry.

Brett (1952) has shown that juvenile chinook salmon will consistently orient themselves with respect to temperature. Brett (1956, p. 85) further states that "sensitivity to small gradients of temperature may act as a directive factor." If migrating juvenile salmon pass through a temperature gradient in entering a large river like the Columbia River from a relatively small tributary it is not unlikely that some time will be spent in a relatively small portion of the area containing this temperature gradient. Large concentrations of fry could collect in such areas even in tributaries with natural spawning, but particularly in hatchery streams where large releases are made. Probable effects of predation are self evident. We suggest that a study be made of streams with natural runs as well as hatchery streams to observe the time and manner in which fry pass through such areas of temperature gradient. Possible effects of predation should be investigated.

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Appendix table 1.--Distribution of Spring Creek stock from Spring Creek Hatchery

Brood year	Eggs collected	Date distributed	Number distributed	Life stage	No./lb.	Pounds distributed	Distribution area
1940	6,685,000	4/?/41	1,004,000	?	--	14,137	Big White Salmon River
		?/41	5,001,000	?	--		Columbia River at Spring Creek
1941	14,230,000	11/21/41	3,000,000	EE.[1]	--	--	Carson Hatchery
		11/29/41	3,000,000	EE.	--	--	Little White Salmon Hatchery
		?/42	3,423,000	Fry	1,025	3,340	Big White Salmon River
		?/42	505,400	Fry	697	725	Columbia River at Spring Creek
		?/42	1,536,250	Fry	643	2,391	" " " " "
		?/42	1,775,000	Fry	610	2,911	" " " " "
		?/42	219,830	Fing.	285	770	" " " " "
1942	13,870,000	?/42	660,000	GE.[2]	--	--	Oregon--Bonneville
		?/42	6,690,000	EE.	--	--	" "
		?/42	557,172	EE.	--	--	Carson Hatchery
		?/42	100,000	EE.	--	--	Leavenworth
		?/43	2,650,000	Fry	675	3,926	Columbia River at Spring Creek
		?/43	1,280,000	Fry	602	2,127	" " " " "
		?/43	200,000	Fing.	152	1,313	Bonneville Dam--marked
1943	7,367,500	[3] 12/7/43	249,480	EE.	--	--	Carson Hatchery
		[3] 2/?/44	200,000	Fry	1,000	200	Gordon Creek
		[3] 2/?/44	2,626,000	Fry	1,000	2,626	Big White Salmon River
		[3] 3/?/44	2,231,715	Fry	813	2,744	Columbia River at Spring Creek
		[3] 4/27 & 5/5- 16/44	1,153,065	Fry	537	2,147	Columbia River at Spring Creek
		[3] 4/18, 6/21, 7/3/44	378,115	Fing.	258	1,465	" " " " " (marked)
		[3] 7/2-3/44	138,000	Fing.	141	981	" " " " "
1944	6,782,000	[3] 11/23/44	250,000	EE.	--	--	Carson Hatchery
		[3] 11/27/44	200,000	EE.	--	--	Delph Creek
		[3] 11/3/44	1,500	EE.	--	--	Oregon City High School
		[3] 2/1-9/45	4,088,000	Fry	1,000	4,088	Columbia River at Spring Creek
		[3] 3/15,4/19,5/5-16/45	1,621,620	Fing.	487	3,331	" " " " "
		[3] 6/28-29/45	200,000	Fing.	153	1,306	Gordon Creek
1945	6,662,000	11/?/45	1,250,000	EE.	--	1,039	Gordon Creek
		[3] 2/23-26/46	300,000	Fry	1,000	300	" "
		[3] 2/14-22/46	2,765,000	Fry	1,000	2,765	Columbia River at Spring Creek
		4/26/46	400,000	Fing.	281	1,423	" " " " "
		[3] 4/?-7/?/46	1,366,780	Fing.	203	6,723	" " " " "
		?/46	150,000	Fing.	186	805	WDF--Klickitat River
1946	12,365,000	10/10/46	5,153,000	GE.	--	5,273	Carson Hatchery
		11/22/46	500,000	EE.	--		Estacada Hatchery
			200,000	Fry	1,000	200	Gordon Creek
		1/27-2/14/47	100,000	Fry	1,000	100	Estacada Hatchery
			3,875,000	Fry	1,000	3,875	Columbia River at Spring Creek
		4/29/47	800,000	Fing.	217	3,687	" " " " "
		5/8-7/19/47	1,208,110	Fing.	153	7,886	" " " " "
1947	18,233,890	?/47	5,857,000	GE.	--	--	Oregon Fish Commission
		9/27-10/4/47	4,891,895	GE.	--		Carson Hatchery
		10/10/47	206,400	GE.	--	4,043	Little White Hatchery
		1/22-2/8/48	3,627,000	Fry	1,000	3,627	Columbia River at Spring Creek
			500,000	Fry	1,000	500	WDF-unspecified
			200,000	Fry	1,000	200	Gordon Creek
		3/31/48	200,000	Fing.	366	546	Columbia River at Spring Creek
		4/15/48	550,100	Fing.	197	2,790	" " " " "
		5/13-28/48	1,190,000	Fing.	140	8,510	" " " " "
		7/14/48	89,000	Fing.	68	1,309	" " " " "
1948	17,798,400	9/23-10/7/48	9,516,000	GE.	--	8,449	Carson Hatchery
		1/24-2/15/49	7,312,000	Fry	1,000	7,312	Columbia River at Spring Creek
1949	26,373,185	?/49	7,430,515	GE.	--	--	Little White Hatchery
		10/3/49	632,700	GE.	--	2,743	Estacada Hatchery
		11/2-11/10/49	2,596,270	EE.	--		Carson Hatchery
		1/23-2/10/50	11,614,600	Fry	1,075	10,804	Columbia River at Spring Creek
		2/9-2/13/50	200,000	Fry	1,075	186	Gordon Creek
		5/15-5/17/50	1,002,260	Fing.	239	4,196	Big White Salmon River
		5/18/50	957,000	Fing.	194	4,933	Columbia River at Spring Creek

See footnotes at end of table.

Appendix table 1.--Continued

Brood year	Eggs collected	Date distributed	Number distributed	Life stage	No./lb.	Pounds distributed	Distribution area
1950	30,538.465	?/50	11,766,000	GE.	--	--	Carson Hatchery
		?/50	4,965.050	GE.	--	--	Little White Hatchery
		10/ 4/50	297,000	GE. }	--	2 497	{ Estacada Hatchery
		11/ 9/50	3,000,000	EE. }	--		{ WDF--unspecified
		1/21/51	200,000	Fry	1,010	198	Gordon Creek
		1/24/51	725,000	Fry	1,011	717	Big White Salmon River
		1/30-2/ 6/51	4,390,000	Fry	1,010	4,348	Columbia River at Spring Creek
		4/11/51	3,154,485	Fing.	192	16,429	" " " " "
		5/10/51	187,565	Fing.	93	2,017	" " " " "
		5/16/51	71,740	Fing.	177	406	" " " " "
1951	27,654,498	9/29-10/11/51	11,754,900	GE.	--	11,302	Carson Hatchery
		10/6-10/15/51	436,920	GE.	--	408	Estacada Hatchery
		10/8-11/ 9/51	3,000,000	EE.	--	2,884	WDF-unspecified
		1/21/52	1,028,000	Fry	1,000	1,028	Columbia River at Spring Creek
		1/21-2/ 1/52	200,000	Fry	1,000	200	Gordon Creek
		2/ 4/52	960,000	Fry	850	1,129	Columbia River at Spring Creek
		2/11/52	2,660,000	Fry	1,000	2,660	Big White Salmon River
		2/20/52	310,000	Fry	553	561	Columbia River at Spring Creek
		2/27/52	496,000	Fry	547	906	" " " " "
		2/27/52	490,000	Fry	544	900	Big White Salmon River
		4/1-4/ 8/52	1,018,800	Fing.	226	4,500	Columbia River at Spring Creek
		4/22-4/24/52	3,926,986	Fing.	150	26,192	" " " " "
1952	27,509,845	10/ 3/52	3,040,000	GE.	--	2,835	WDF--unspecified
		10/ 3/52	412,000	GE.	--	384	Estacada Hatchery
		11/28/52	979,470	GE.	--	914	WDF--unspecified
		11/18/52	11,712,030	EE.	--	7,343	Willard Hatchery
		1/22/53	1,936,620	Fry	1,113	1,740	Columbia River at Spring Creek
		1/28/53	270,200	Fry	1,112	243	" " " " "
		2/12/53	295,000	Fry	1,113	265	" " " " "
		4/17/53	1,150,000	Fing.	200	5,750	" " " " "
		4/30/53	4,555,687	Fing.	156	29,250	" " " " "
		5/ 1/53	1,206,304	Fing.	156	7,754	" " " " "
1953	27,041,760	11/ 4/53	200,000	EE.	--	120	Estacada Hatchery
		11/ 5/53	100,000	EE.	--	63	Quilcene Hatchery
		11/12/53	1,000,000	EE.	--	614	WDF--Toutle River
		11/13/53	2,000,000	EE.	--	1,228	WDF--Klickitat Hatchery
		11/19/53	8,395,880	EE.	--	5,261	Willard Hatchery
		2/10/54	3,590,000	Fry	1,316	2,728	Columbia River at Spring Creek
		4/17/54	911,292	Fing.	257	3,539	" " " " "
		4/30/54	41,250	Fing.	165	250	Big White Salmon River
		5/ 5/54	1,024,803	Fing.	172	5,973	" " " "
		5/ 6/54	955,719	Fing.	171	5,589	Columbia River at Spring Creek
		5/13/54	3,798,987	Fing.	159	23,893	" " " " "
		6/21/54	1,645,110	Fing.	90	18,215	" " " " "
		6/21/54	215,322	Fing.	102	2,111	" " " " "(marked)
		12/16/54	14,165	Fing.	20	691	" " " " "
1954	34,983,000	9/14/54	60,000	GE.	--	50	Salmon Nutrition Lab.
		10/ 6/54	1,565,000	GE.	--	1,565	Carson Hatchery
		11/ 3/54	30,000	EE.	--	20	Oregon--Rock Springs Hatchery
		11/5-11/30/54	4,136,000	EE.	--	2,757	Willard Hatchery
		11/ 5/54	100,500	EE.	--	67	Quilcene Hatchery
		11/ 8/54	201,000	EE.	--	134	Estacada Hatchery
		11/10/54	2,965,000	EE.	--	1,151	Carson Hatchery
		11/18/54	5,000,000	EE.	--	3,102	WDF--Klickitat Hatchery
		11/19/54	2,000,000	EE.	--	1,235	WDF--Elokomin Hatchery
		11/19/54	2,000,000	EE.	--	1,235	WDF--Toutle Hatchery
		2/ 2/55	4,639,635	Fry	1,133	4,095	Columbia River at Spring Creek
		3/15/55	81,534	Fing.	381	214	Little White Hatchery
		4/20/55	1,496,000	Fing.	187	8,000	Columbia River at Spring Creek
		5/ 5/55	720,000	Fing.	144	5,000	" " " " "
		5/11/55	1,430,000	Fing.	130	11,000	" " " " "
		5/18/55	615,000	Fing.	123	5,000	" " " " "
		5/27/55	3,809,250	Fing.	110	34,551	" " " " "
		6/ 7/55	440,000	Fing.	88	5,000	" " " " "
		7/ 5/55	494,000	Fing.	76	6,500	" " " " "
		8/ 9/55	519,364	Fing.	45	11,631	" " " " "

See footnotes at end of table.

Appendix table 1.--Continued

Brood year	Eggs collected	Date distributed	Number distributed	Life stage	No./lb.	Pounds distributed	Distribution area
1955	29,429,198	9/16/55	50,000	GE.	--	50	Salmon Nutrition Lab.
		9/24/55	20,000	GE.	--	14	Carson Hatchery
		9/29/55	365,000	GE.	--	257	Willard Hatchery
		11/ 8/55	35,000	EE.	--	23	Oregon--Rock Creek
		11/ 8/55	3,200,000	EE.	--	2,060	WDF--Klickitat Hatchery
		11/ 9/55	750,000	EE.	--	483	WDF--Toutle Hatchery
		11/10/55	900,000	EE.	--	580	WDF--Elokomin Hatchery
		11/10-11/21/55	2,026,167	EE.	--	1,334	Carson Hatchery
		11/10-11/21/55	1,968,200	EE.	--	1,335	Willard Hatchery
		11/22/55	100,000	EE.	--	68	Quilcene Hatchery
		12/ 1/55	65,000	EE.	--	45	Salmon Nutrition Lab.
		2/ 8/56	500,000	Fry	1,244	402	Willard Hatchery
		2/10/56	1,500,000	Fry	1,244	1,206	Little White Hatchery
		2/10/56	5,009,160	Fry	1,244	4,027	Columbia River at Spring Creek
		2/13/56	1,500,000	Fry	1,242	1,208	Carson Hatchery
		4/ 6/56	100,000	Fing.	260	385	Eagle Creek Hatchery Site
		4/24/56	6,657,120	Fing.	160	41,607	Columbia River at Spring Creek
		5/ 3/56	1,174,500	Fing.	135	8,700	" " " " "
		5/18/56	311,780	Fing.	119	2,620	" " " " "
		6/ 1/56	1,181,216	Fing.	84	14,062	" " " " "
1956	30,681,000	9/23/56	330,000	GE.	--	330	Willard Hatchery
		9/26/56	100,000	GE.	--	100	Carson Hatchery
		11/ 7/56	2,000,000	EE.	--	1,334	Eagle Creek Hatchery
		11/ 7/56	35,000	EE.	--	25	Oregon Game Commission--Roseburg
		11/ 8/56	1,500,000	EE.	--	1,000	Little White Hatchery
		11/ 8/56	1,250,000	EE.	--	834	Carson Hatchery
		11/ 9/56	250,000	EE.	--	167	Willard Hatchery
		1/22/57	7,800	Fry	1,000	8	Salmon Nutrition Lab.
		2/ 5/57	3,756,000	Fry	1,050	3,577	Columbia River at Spring Creek
		2/ 5/57	16,500	Fry	1,031	16	Salmon Nutrition Lab.
		2/ 7/57	3,920,000	Fry	1,050	3,734	Willard Hatchery
		2/ 9/57	3,650,000	Fry	1,050	3,476	Carson Hatchery
		2/19/57	143,850	Fry	1,050	137	Columbia River at Spring Creek
		4/22/57	1,448,000	Fing.	181	8,000	" " " " "
		2/ ?/57	[4] 274,410	Fry	950	289	Big White Salmon River
		5/ 9/57	8,936,466	Fing.	169	52,808	Columbia River at Spring Creek
		5/23/57	296,475	Fing	--	2,010	" " " " "
1957	26,918,664	10/ 3/57	581,744	GE.	--	568	Little White Hatchery
		10/28/57	1,700,000	EE.	--	1,162	Eagle Creek Hatchery
		10/29/57	100,000	EE.	--	69	Willard Hatchery
		10/30/57	2,000,000	EE.	--	1,368	Carson Hatchery
		11/ 1/57	30,000	EE.	--	21	Oregon Game Commission
		11/ 7/57	2,000,000	EE.	--	1,368	Willard Hatchery
		11/ 7/57	400,000	EE.	--	274	WDF--Klickitat Hatchery
		11/ 8/57	1,000,000	EE.	--	684	Ox Bow Hatchery
		11/13/57	1,200,000	EE.	--	821	WDF-Toutle Hatchery
		11/14/57	1,500,000	EE.	--	1,026	WDF-Elokomin Hatchery
		2/ 4/58	25,200	Fry	1,050	24	Salmon Nutrition Lab.
		2/ 6/58	6,955,290	Fry	1,050	6,624	Columbia River at Spring Creek
		5/ 2/58	7,725,015	Fing.	123	62,805	" " " "
		5/ 7/58	237,465	Fing.	140	1,697	" " " " (marked)
1958	80,991,486	9/23/58	100,000	GE.	--	67	Salmon Nutrition Lab.
		9/30/58	177,957	GE.	--	127	Little White Hatchery
		9/30/58	18,714,373	GE.	--	9,635	Willard Hatchery
		10/ 8/58	9,690,000	GE.	--	9,690	" "
		10/ 8/58	4,778,740	GE.	--	3,144	Eagle Creek Hatchery
		10/10/58	13,028,900	GE.	--	8,593	Carson Hatchery
		10/27/58	6,440,560	EE.	--	4,340	WDF--Washougal Hatchery
		10/30/58	3,000,648	EE.	--	2,022	WDF--Elokomin Hatchery
		11/ 6/58	2,300,200	EE.	--	1,550	WDF--Toutle Hatchery
		11/ 6/58	480,816	EE.	--	324	WDF--Kalama Hatchery
		11/ 6/58	960,143	EE.	--	647	WDF--Lewis River Hatchery
		11/13/58	3,821,300	EE.	--	2,575	WDF--Elokomin Hatchery
		11/21/58	1,000,216	EE.	--	674	OFC--Klaskanine Hatchery
		11/21/58	301,252	EE.	--	203	Fish. Res.--Warm Springs, Oregon
		2/ 5/59	245,480	Fry	1,101	223	Columbia River at Spring Creek (marked)
		2/ 5/59	5,544,920	Fry	1,100	5,041	Columbia River at Spring Creek
		5/ 8/59	237,718	Fing.	144	1,647	" " " " "
		5/ 8/59	7,653,974	Fing.	121	63,039	" " " " " (marked)

[1] Eyed eggs. [2] Green eggs. [3] Dates of these releases taken from the "Monthly Lot Reports." [4] Reared in the Big White Salmon Ponds. Estimated number and weight of fish which were flooded out of the ponds during February.

Appendix table 2.--Distribution of Big White Salmon stock from Spring Creek Hatchery

Brood year	Eggs collected	Date distributed	Number distributed	Life stage	No./lb.	Pounds distributed	Distribution area
1940	19,026,000	?/40	2,190,000	GE.	--	--	Carson Hatchery
		?/40	1,677,000	EE.	--	--	" "
		?/41	2,544,380	EE.	--	--	Tyee Springs Creek
		1-2/ ?/41	8,750,000	Fry	908	9,634	Big White Salmon River
		5/41	1,709,000	Fry	579	2,952	" " " "
1941	10,650,000	?/42	5,571,000	Fry	1,025	5,437	Big White Salmon River
		?/42	284,000	Fry	861	330	" " " "
		?/42	1,388,750	Fry	1,141	1,217	" " " "
		?/42	2,197,800	Fry	590	3,727	" " " "
1942	13,664,000	?/43	9,390,000	Fry	1,005	9,340	Big White Salmon River
		?/43	70,200	Fry	675	104	" " " "
		?/43	1,971,520	Fry	627	3,145	" " " "
1943	24,000	2/ 7/44	22,000	Fry	1,000	22	Big White Salmon River
1944	6,020,000	[1] 2/17-23/45	5,205,320	Fry	1,000	5,205	Big White Salmon River
1945	10,724,000	[1] 2/7 -25/46	9,178,000	Fry	1,000	9,178	Big White Salmon River
1946	10,772,000	10/ 9/46	920,000	GE. }	--	1,324	{ Little White Hatchery
		11/29/46	500,000	EE. }	--		{ WDF--Cowlitz River Hatchery
		1/28-2/ 7/47	7,630,000	Fry	1,000	7,630	Big White Salmon River
1947	14,008,200	10/ 6/47	2,250,000	GE. }	--	3,170	{ WDF
		10/ 7/47	662,000	GE. }	--		{ Oregon Fish Commission
		10/ 8/47	397,005	GE. }	--		{ Estacada Hatchery
		10/10/47	562,800	GE. }	--		{ Little White Hatchery
		1/23-2/ 6/48	6,797,000	Fry	1,000	6,797	Big White Salmon River
1948	8,302,000	10/ 9/48	519,000	GE.	--	441	Estacada Hatchery
		2/2-2/10/49	200,000	Fry	1,000	200	Gordon Creek
		2/15/49	200,000	Fry	1,000	200	WDF--Washougal River
		2/15/49	300,000	Fry	1,000	300	WDF--Klickitat River
		1/31-2/18/49	5,172,000	Fry	1,000	5,172	Big White Salmon River
1949	3,006,000	2/2-2/ 8/50	2,557,100	Fry	1,050	2,435	Columbia River at Spring Creek
1950	5,090,520	1/24/51	300,000	Fry	1,010	297	Big White Salmon River
		1/31/51	1,450,000	Fry	1,012	1,433	" " " "
		2/ 1/51	2,275,000	Fry	1,012	2,249	" " " "
		2/ 2/51	333,580	Fry	1,014	329	" " " "
1951	5,926,396	2/1-2/ 7/52	3,400,000	Fry	1,000	3,400	Big White Salmon River
1952	14,574,000	1/31/53	1,584,780	Fry	1,075	1,474	Big White Salmon River
		2/12/53	11,883,400	Fry	1,075	11,061	" " " "
1953	1,289,700	2/10/54	1,242,000	Fry	1,075	1,155	Columbia River at Spring Creek
1954	2,786,000	2/ 3/55	1,823,850	Fry	1,050	1,737	Big White Salmon River
		2/25/55	60,000	Fry	600	100	WDF--unspecified
		3/ 3/55	152,700	Fry	509	300	WDF--Klickitat Hatchery
		3/10/55	387,300	Fing.	443	874	WDF-- " "
		3/15/55	43,434	Fing.	381	114	Little White Hatchery
1955	464,400	12/ 6/55	35,000	EE.	--	25	Salmon Nutrition Lab.
		5/ 3/56	187,200	Fing.	144	1,300	Columbia River at Spring Creek
		6/ 1/56	199,036	Fing.	88	2,262	" " " " "
1956	1,000,000	[2] 2/ ?/57	224,518	Fry	947	237	Big White Salmon River[3]
		5/ 9/57	633,228	Fing.	188	3,377	" " " " [3]
1957	4,953,700	4/29/58	4,399,920	Fing.	216	20,370	Big White Salmon River[3]
1958	9,336,959	10/ 8/58	1,546,660	GE.	--	1,028	Eagle Creek Hatchery
		10/ 8/58	999,083	GE.	--	683	Willard Hatchery
		2/ 5/59	2,237,400	Fry	1,100	2,034	Columbia River at Spring Creek
		5/ 8/59	3,982,473	Fing.	207	19,239	Big White Salmon River[2]

[1] Dates of release obtained from monthly lot reports.
[2] Estimated number of fry lost from ponds during a flood.
[3] Reared in the Big White Salmon Ponds.

Appendix table 3.--Size distribution of fish released at Big White Salmon River (B.W.S.) and the Columbia River at Spring Creek (S.C.)

Brood year	Area planted		Fry			Fingerlings				Total	
			Fish per pound			Fish per pound					
			> 900	899-700	699-500	499-300	299-200	199-100	< 99	By area	By year
1940	S.C.	No.	--	--	--	--	--	--	--	[1] 5,001,000	--
		lb.	--	--	--	--	--	--	--	--	?
	B.W.S.	No.	8,750,000	--	1,709,000	--	--	--	--	[2] 11,463,000	16 464,000
		lb.	9,634	--	2,952	--	--	--	--	--	--
1941	S.C.	No.	--	--	3,816,650	--	219,830	--	--	4,036,480	--
		lb.	--	--	6,027	--	770	--	--	6,797	20,848
	B.W.S.	No.	10,382,750	284,000	2,197,800	--	--	--	--	12,864,550	16,901,030
		lb.	9,994	330	3,727	--	--	--	--	14,051	--
1942	S.C.	No.	--	--	3,930,000	--	--	--	--	3,930,000	--
		lb.	--	--	6,053	--	--	--	--	6,053	18,642
	B.W.S.	No.	9,390,000	--	2,041,720	--	--	--	--	11,431,720	15,361,720
		lb.	9,340	--	3,249	--	--	--	--	12,589	--
1943	S.C.	No.	--	2,231,715	1,153,065	--	378,115	138,000	--	3,900,895	--
		lb.	--	2,744	2,147	--	1,465	981	--	7,337	9,985
	B.W.S.	No.	2,648,000	--	--	--	--	--	--	2,648,000	6,548,895
		lb.	2,648	--	--	--	--	--	--	2,648	--
1944	S.C.	No.	4,088,000	--	--	1,621,620	--	--	--	5,709,620	--
		lb.	4,088	--	--	3,331	--	--	--	7,419	12,624
	B.W.S.	No.	5,205,320	--	--	--	--	--	--	5,205,320	10,914,940
		lb.	5,205	--	--	--	--	--	--	5,205	--
1945	S.C.	No.	2,765,000	--	--	--	1,766,780	--	--	4,531,780	--
		lb.	2,765	--	--	--	8,146	--	--	10,911	20,089
	B.W.S.	No.	9,178,000	--	--	--	--	--	--	9,178,000	13,709,780
		lb.	9,178	--	--	--	--	--	--	9,178	--
1946	S.C.	No.	3,875,000	--	--	--	800,000	1,208,110	--	5,883,110	--
		lb.	3,875	--	--	--	3,687	7,886	--	15,448	23,078
	B.W.S.	No.	7,630,000	--	--	--	--	--	--	7,630,000	13,513,110
		lb.	7,630	--	--	--	--	--	--	7,630	--
1947	S.C.	No.	3,627,000	--	--	200,000	--	1,740,100	89,000	5,656,100	--
		lb.	3,627	--	--	546	--	11,300	1,309	16,782	23,579
	B.W.S.	No.	6,797,000	--	--	--	--	--	--	6,797,000	12,453,100
		lb.	6,797	--	--	--	--	--	--	6,797	--
1948	S.C.	No.	7,312,000	--	--	--	--	--	--	7,312,000	--
		lb.	7,312	--	--	--	--	--	--	7,312	12,484
	B.W.S.	No.	5,172,000	--	--	--	--	--	--	5,172,000	12,484,000
		lb.	5,172	--	--	--	--	--	--	5,172	--
1949	S.C.	No.	14,171,700	--	--	--	--	957,000	--	15,128,700	--
		lb.	13,239	--	--	--	--	4,933	--	18,172	22,368
	B.W.S.	No.	--	--	--	--	1,002,260	--	--	1,002,260	16,130,960
		lb.	--	--	--	--	4,196	--	--	4,196	--
1950	S.C.	No.	4,390,000	--	--	--	--	3,226,225	187,565	7,803,790	--
		lb.	4,348	--	--	--	--	16,835	2,017	23,200	28,225
	B.W.S.	No.	5,083,580	--	--	--	--	--	--	5,083,580	12,887,370
		lb.	5,025	--	--	--	--	--	--	5,025	--
1951	S.C.	No.	1,028,000	960,000	806,000	--	1,018,800	3,926,986	--	7,739,786	--
		lb.	1,028	1,129	1,467	--	4,500	26,192	--	34,316	41,276
	B.W.S.	No.	6,060,000	--	490,000	--	--	--	--	6,550,000	14,289,786
		lb.	6,060	--	900	--	--	--	--	6,960	--
1952	S.C.	No.	2,501,820	--	--	--	1,150,000	5,761,991	--	9,413,811	--
		lb.	2,248	--	--	--	5,750	37,004	--	45,002	57,537
	B.W.S.	No.	13,468,180	--	--	--	--	--	--	13,468,180	22,881,991
		lb.	12,535	--	--	--	--	--	--	12,535	--
1953	S.C.	No.	4,832,000	--	--	--	911,292	4,970,028	1,659,275	12,372,595	--
		lb.	3,883	--	--	--	3,539	31,593	18,906	57,921	64,144
	B.W.S.	No.	--	--	--	--	--	1,066,053	--	1,066,053	13,438,648
		lb.	--	--	--	--	--	6,223	--	6,223	--
1954	S.C.	No.	4,639,635	--	--	--	--	8,070,250	1,453,364	14,163,249	--
		lb.	4,095	--	--	--	--	63,551	23,131	90,777	92,514
	B.W.S.	No.	1,823,850	--	--	--	--	--	--	1,823,850	15,987,099
		lb.	1,737	--	--	--	--	--	--	1,737	--

See footnotes at end of table.

Appendix table 3.--Continued

Brood year	Area planted		Fry			Fingerlings				Total	
			Fish per pound			Fish per pound					
			> 900	899-700	699-500	499-300	299-200	199-100	< 99	By area	By year
1955	S.C.	No.	5,009,160	--	--	--	--	8,330,600	1,380,252	14,720,012	--
		lb.	4,027	--	--	--	--	54,227	16,324	74,578	74,578
	B.W.S.	No.	--	--	--	--	--	--	--	--	14,720,012
		lb.	--	--	--	--	--	--	--	NONE	--
1956	S.C.	No.	3,899,850	--	--	--	--	10,680,941	--	14,580,791	--
		lb.	3,714	--	--	--	--	62,818	--	66,532	70,435
	B.W.S.	No.	498,928	--	--	--	--	633,228	--	1,132,156	15,712,947
		lb.	526	--	--	--	--	3,377	--	3,903	--
1957	S.C.	No.	6,955,290	--	--	--	--	7,962,480	--	14,917,770	--
		lb.	6,624	--	--	--	--	64,502	--	71,126	91,496
	B.W.S.	No.	--	--	--	--	4,399,920	--	--	4,399,920	19,317,690
		lb.	--	--	--	--	20,370	--	--	20,370	--
1958	S.C.	No.	8,027,800	--	--	--	--	7,891,692	--	15,919,492	--
		lb.	7,298	--	--	--	--	64,686	--	71,984	91,223
	B.W.S.	No.	--	--	--	--	3,982,473	--	--	3,982,473	19,901,965
		lb.	--	--	--	--	19,239	--	--	19,239	--

[1] Total weight and average size of this plant unknown.
[2] Includes a plant of 1,004,000 fish for which total weight and average size is unknown.

Appendix table 4.--Numbers of fry and fingerlings released at Big White Salmon River and Columbia River at Spring Creek

Brood year	Big White Salmon		Spring Creek		Total	
	Fry	Fingerling	Fry	Fingerling	Fry	Fingerling
1941	12,864,550	None	3,816,650	219,830	16,681,200	219,830
1942	11,431,720	"	3,930,000	None	15,361,720	None
1943	2,648,000	"	3,384,780	516,115	6,032,780	516,115
1944	5,205,320	"	4,088,000	1,621,620	9,293,320	1,621,620
1945	9,178,000	"	2,765,000	1,766,780	11,943,000	1,766,780
1946	7,630,000	"	3,875,000	2,008,110	11,505,000	2,008,110
1947	6,797,000	"	3,627,000	2,029,100	10,424,000	2,029,100
1948	5,172,000	"	7,312,000	None	12,484,000	None
1949	None	1,002,260	14,171,700	957,000	14,171,700	1,959,260
1950	5,083,580	None	4,390,000	3,413,790	9,473,580	3,413,790
1951	6,550,000	"	2,794,000	4,945,786	9,344,000	4,945,786
1952	13,468,180	"	2,501,820	6,911,991	15,970,000	6,911,991
1953	None	1,066,053	4,832,000	7,540,595	4,832,000	8,606,648
1954	1,823,850	None	4,639,635	9,523,614	6,463,485	9,523,614
1955	None	"	5,009,160	9,710,852	5,009,160	9,710,852
1956	[1] 498,928	[2] 633,228	3,899,850	10,680,941	4,398,778	11,314,169
1957	None	[2] 4,399,920	6,955,290	7,962,480	6,955,290	12,362,400
1958	"	[2] 3,982,473	8,027,800	7,891,692	8,027,800	11,874,165

[1] Estimated number of fry which escaped from the Big White Ponds during a flood.
[2] Reared in the Big White Ponds until released into the Big White Salmon River.

Appendix table 5.--Pounds of fry and fingerlings released at Big White Salmon River and Columbia River at Spring Creek

Brood year	Big White Salmon		Spring Creek		Total	
	Fry	Fingerling	Fry	Fingerling	Fry	Fingerling
1941	14,051	None	6,027	770	20,078	770
1942	12,589	"	6,053	None	18,642	None
1943	2,648	"	4,891	2,446	7,539	2,446
1944	5,205	"	4,088	3,331	9,293	3,331
1945	9,178	"	2,765	8,146	11,943	8,146
1946	7,630	"	3,875	11,573	11,505	11,573
1947	6,797	"	3,627	13,155	10,424	13,155
1948	5,172	"	7,312	None	12,484	None
1949	None	4,196	13,239	4,933	13,239	9,129
1950	5,025	None	4,348	18,852	9,373	18,852
1951	6,960	None	3,624	30,692	10,584	30,692
1952	12,535	"	2,248	42,754	14,783	42,754
1953	None	6,223	3,883	54,038	3,883	60,261
1954	1,737	None	4,095	86,682	5,832	86,682
1955	None	"	4,027	70,551	4,027	70,551
1956	[1] 526	[2] 3,372	3,714	62,818	4,240	66,195
1957	None	[2] 20,370	6,624	64,502	6,624	84,872
1958	"	[2] 19,239	7,298	64,686	7,298	83,925

[1] Estimate of the pounds of fry which escaped from the Big White Ponds during a flood.
[2] Reared in the Big White Ponds until released into the Big White Salmon River.

Appendix table 6.--Number of fish handled in spawning operations at Spring Creek and Big White Salmon River

Return year	Spring Creek			Big White Salmon			Total		
	Males	Females	Jacks	Males	Females	Jacks	Males	Females	Jacks
1941	2,888	2,893	1,168	([1])	2,130	--	--	5,023	--
1942	2,906	2,997	179	2,975	2,920	[2] 305	5,881	5,917	484
1943	2,026	1,528	517	--	--	--	--	--	--
1944	1,402	1,381	306	647	1,244	157	2,049	2,625	463
1945	1,625	1,424	761	1,787	2,189	393	3,412	3,613	1,154
1946	4,476	2,704	595	2,950	2,264	492	7,426	4,968	1,087
1947	4,592	4,012	1,494	--	2,950	--	--	6,962	--
1948	5,118	3,723	4,026	2,348	1,681	714	7,466	5,404	4,740
1949	5,288	5,795	584	516	645	38	5,804	6,440	622
1950	5,140	7,239	677	826	1,058	199	5,966	8,297	876
1951	3,541	5,665	2,750	717	1,134	60	4,258	6,799	2,810
1952	6,303	4,697	2,740	1,080	2,692	113	7,383	7,389	2,853
1953	4,217	4,928	2,289	309	230	97	4,526	5,158	2,386
1954	7,388	6,572	2,934	435	572	96	7,823	7,144	3,030
1955	[3] 6,836	[3] 5,763	[3] 1,294	55	86	91	6,891	5,849	1,385
1956	6,498	6,133	2,915	381	238	29	6,879	6,371	2,944
1957	[4] 11,367	[4] 5,278	[4] 8,402	547	924	94	11,914	6,202	8,496
1958	21,706	18,360	3,148	814	1,992	180	22,520	20,352	3,328
1959	14,990	18,062	1,456	1,331	1,826	68	16,321	19,888	1,524

[1] Figures not available for blank spaces.
[2] Includes "some" partially spent females.
[3] These figures do not include 175 unsexed fish which entered the lower holding area but did not enter the spawning pond.
[4] These figures do not include 116 unsexed fish which died in the lower holding area.

Appendix table 7.--Number of females returning to Spring Creek and Big White Salmon River including estimates of the number of females spawning naturally in Big White Salmon River

Return year	Big White Salmon		Total return	
	Handled	Spawned[1] naturally	B.W.S.[2]	S.C.
1945	2,189	--	2,189	1,424
1946	2,264	--	2,264	2,704
1947	2,950	[3] 927	3,877	4,012
1948	1,681	396	2,077	3,723
1949	645	645	1,209	5,795
1950	1,058	2,286	3,344	7,239
1951	1,134	1,600	2,734	5,665
1952	2,692	1,653	4,345	4,697
1953	230	500	730	4,928
1954	572	156	728	6,572
1955	86	100	186	5,763
1956	238	100	338	6,133
1957	924	2,065	2,980	5,278
1958	1,992	2,335	4,327	18,360
1959	1,826	2,831	4,657	18,062

[1] This is the number of females estimated to have spawned naturally in Big White Salmon River. Derivation for each year is explained in the text.
[2] Number handled plus the estimated number of females which spawned naturally.
[3] This figure includes only those fish which were counted past the spawning racks or which remained between the racks when spawning operations were terminated. Heavy spawning occurred below the racks but no estimates were made of the numbers of spawners.

Appendix table 8.--Percent escapement of the total Columbia River fall chinook run over Bonneville Dam

Return year	Commercial catch[1] (Zones 1-5)	Escapement (Bonneville count)[1]	Total[2]	Percent escapement (E_i)	Constant fishing adjustment factor[3] ($\bar{E}/E_i$)
1945	485,257	226,353	711,610	31.81	1.399
1946	504,662	327,295	831,957	39.34	1.131
1947	595,622	307,955	903,577	34.08	1.305
1948	586,666	310,590	897,256	34.62	1.285
1949	369,751	180,891	550,642	32.85	1.354
1950	338,060	250,482	588,542	42.56	1.045
1951	247,868	137,617	385,485	35.70	1.246
1952	102,534	220,396	322,930	68.25	0.652
1953	152,825	104,371	257,196	40.58	1.096
1954	125,726	106,784	232,510	45.93	0.969
1955	176,258	105,318	281,576	37.40	1.190
1956	176,869	136,268	313,137	43.52	1.022
1957	145,135	131,813	276,948	47.59	0.935
1958	143,960	249,158	393,118	63.38	0.702
1959	84,638	195,000	279,638	69.73	0.638
		Ave. or $\bar{E}$ = 44.49			

[1] Commercial catch and Bonneville count taken from Biologists' Report on the Columbia River Commercial Fisheries, prepared for Columbia River Regulations Hearing, January 14, 1960. Prepared by Oregon Fish Commission and Washington Department of Fisheries.

[2] Total does not include those fish spawning in tributary streams or the main Columbia River below Bonneville Dam.

[3] If fishing effort were at a constant level, permitting an escapement of 44.49 percent, which is the average from 1945 to 1959, then multiplying actual hatchery returns by the adjustment factor ($\bar{E}/E_i$) adjusts them to the value that would occur if fishing effort were at this constant level.

Appendix table 9.--Adjustment of female returns to Spring Creek (S.C.) and Big White Salmon River (B.W.S.) according to fishing intensity of Zones 1-5 as determined by percent escapement over Bonneville Dam

Brood year	Return year	Total return		Constant fishing adjustment factor[1] ($\bar{E}/E_i$)	Adjusted returns ($\bar{E}/E_i$) X actual returns		
		B.W.S.	S.C.		S.C.	B.W.S.	Total
1941	1945	2,189	1,424	1.399	1,992	3,063	5,055
1942	1946	2,264	2,704	1.131	3,058	2,561	5,619
1943	1947	3,877	4,012	1.305	5,236	5,059	10,295
1944	1948	2,077	3,723	1.285	4,784	2,669	7,453
1945	1949	1,209	5,795	1.354	7,846	1,747	9,593
1946	1950	3,344	7,239	1.045	7,565	3,494	11,059
1947	1951	2,734	5,665	1.246	7,059	3,406	10,465
1948	1952	4,345	4,697	0.652	3,062	2,833	5,895
1949	1953	730	4,928	1.096	5,401	800	6,201
1950	1954	728	6,572	0.969	6,368	706	7,074
1951	1955	186	5,763	1.190	6,858	221	7,079
1952	1956	338	6,133	1.022	6,268	345	6,613
1953	1957	2,980	5,278	0.935	4,935	2,795	7,730
1954	1958	4,327	18,360	0.702	12,889	3,037	15,926
1955	1959	4,657	18,062	0.638	11,524	2,971	14,495

[1] If fishing effort were at a constant level, permitting an escapement of 44.49 percent each year, which is the average from 1945 to 1959, then multiplying actual returns by the adjustment factor ($\bar{E}/E_i$) adjusts these returns to the values that would occur if fishing effort were at this constant level.

Appendix table 10.--Summary of food fed to fish of Spring Creek origin at Spring Creek, February through May

Brood year	Pounds of food	Food composition, in percent							
		Liver	Salmon viscera	Salmon eggs	Salmon flesh	Fish meal	Melts	Horse-meat	Canned salmon
1943	18,148	22	24	--	16	--	11	27	--
1944	14,357	20	27	--	--	--	14	39	--
1945	22,196	27	30	--	--	--	16	24	3
1946	21,781	20	35	--	--	--	13	24	8
1947	28,216	25	36	--	--	--	1	22	16
1948	None	--	--	--	--	--	--	--	--
1949	25,255	51	26	--	--	9	14	--	--
1950	32,709	34	--	55	1	5	5	--	--
1951	56,550	23	--	36	41	--	--	--	--
1952	74,420	23	--	39	38	--	--	--	--
1953	109,926	22	--	40	38	--	--	--	--
1954	150,640	21	8	32	39	--	--	--	--
1955	129,967	22	15	25	38	--	--	--	---

Source: Monthly Lot Reports, 1944-56.

Appendix table 11.--Water temperatures of the Columbia River at Bonneville Dam at the time of fish release from Spring Creek into the Columbia River

Brood year	Release date	Number released	Fish per pound	Temperature
		Thousands		°F.
1947	1/22-2/8/48	3,627	1,000	37-42
	3/31/48	200	366	48
	4/15/48	550	197	49
	5/13-5/28/48	1,190	140	50-55
	7/14/48	89	68	58
1948	1/24-2/15/49	7,312	1,000	32-34
1949	1/23-2/10/50	12,615	1,167	32-33
	5/18/50	957	194	55
1950	1/30-2/6/51	4,390	1,010	32-35
	4/11/51	3,154	192	50
	5/10/51	188	93	54
	5/16/51	71	177	52
1951	1/21/52	1,028	1,000	37
	2/4/52	960	850	39
	2/20/52	310	553	39
	2/27/52	496	547	38
	4/1-4/8/52	1,019	226	46-48
	4/22-4/24/52	3,927	150	51-52
1952	1/22/53	1,937	1,113	45
	1/28/53	270	1,112	44
	2/12/53	295	1,113	44
	4/17/53	1,150	200	48
	4/30/53	4,556	156	53
	5/1/53	1,206	156	53

Appendix table 11.--Continued

Brood year	Release Date	Number released	Fish per pound	Temperature
		Thousands		°F.
1953	2/10/54	3,590	1,316	39
	2/10/54	1,242	1,075	39
	4/17/54	911	257	50
	5/ 6/54	956	171	53
	5/13/54	3,799	159	55
	6/21/54	1,860	91	56
	12/16/54	14	20	48
1954	2/ 2/55	4,640	1,133	39
	4/20/55	1,496	187	47
	5/ 5/55	720	144	50
	5/11/55	1,430	130	52
	5/18/55	615	123	53
	5/27/55	3,809	110	56
	6/ 7/55	440	88	57
	7/ 5/55	494	76	57
	8/ 9/55	519	45	66
1955	2/10/56	5,009	1,244	34
	4/24/56	6,657	160	52
	5/ 3/56	1,175	135	50
	5/ 3/56	187	144	50
	5/18/56	312	119	55
	6/ 1/56	1,181	84	56
	6/ 1/56	199	88	56
1956	2/ 5/57	3,756	1,050	34
	2/19/57	144	1,050	38
	4/22/57	1,448	181	52
	5/ 9/57	8,936	169	54
	5/23/57	296	148	54
1957	2/ 6/58	6,955	1,050	44
	5/ 2/58	7,725	123	52
	5/ 7/58	237	140	56

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Created in 1849, the Department of the Interior—America's Department of Natural Resources—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States—now and in the future.