(Reprinted from Research Briefs, Fish Commission of Oregon, Volume 11, Number 1, June, 1965.)

Timing of Willamette River Spring Chinook Salmon Through the Lower Columbia River

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INTRODUCTION

The Willamette River, with a drainage area of 11,200 square miles, is the largest tributary of the Columbia River below the Snake River (Figure 1). Although the Willamette basin represents only about 4% of the entire Columbia River drainage, its importance as a producer of spring chinook salmon *(Oncorhynchus tshawytscha)* is demonstrated by Table 1 which shows that approximately 20% of the spring chinook migrating through the Columbia River enter the Willamette system to spawn. Principal spring chinook spawning tributaries of the system are the McKenzie, Middle Willamette, North and South Santiam, and Clackamas rivers. The Molalla, Pudding, and Calapooya rivers also support small runs.

The Willamette race of spring chinook receives a large amount of public attention because there is a popular sport fishery in the lower river. Commercial fishing has not been permitted on the Willamette River during the spring months since 1913 but Willamette fish are taken in the Columbia River gill-net fishery as well as in the ocean.

At least 75% of Oregon's human population resides in the Willamette Basin. In recent decades many environmental changes have occurred in

TABLE 1. **COMPARISON OF THE WILLAMETTE RIVER SPRING CHINOOK RUN AND TOTAL COLUMBIA RIVER SPRING CHINOOK RUN, 1946-63.**

Year	*Willamette① Run*	*Total Columbia River Spring Chinook Run②*	*Per Cent Entering Willamette River*
1946	68,600	192,450	35.6
1947	59,000	244,450	24.1
1948	40,100	165,850	24.2
1949	37,850	176,000	21.5
1950	24,800	144,400	17.2
1951	49,600	249,150	19.9
1952	67,500	313,350	21.5
1953	96,800	326,200	29.7
1954	44,400	233,100	19.0
1955	32,500	313,500	10.4
1956	77,600	293,900	26.2
1957	52,800	306,350	17.2
1958	62,800	255,400	24.6
1959	53,400	190,900	28.0
1960	24,200	158,100	15.3
1961	27,500	188,350	15.0
1962	38,200	236,150	16.1
1963	48,100	198,100	24.3
Average	50,300	245,500	20.5

① Derived by adding Willamette Falls fishway count, Clackamas River escapement, and Willamette sport fishery catch.
② Includes Willamette River run, Bonneville Dam count of spring chinook, and commercial catch below Bonneville Dam. Excludes unknown sport catch on the main Columbia River below Bonneville Dam and fish entering the Cowlitz River.

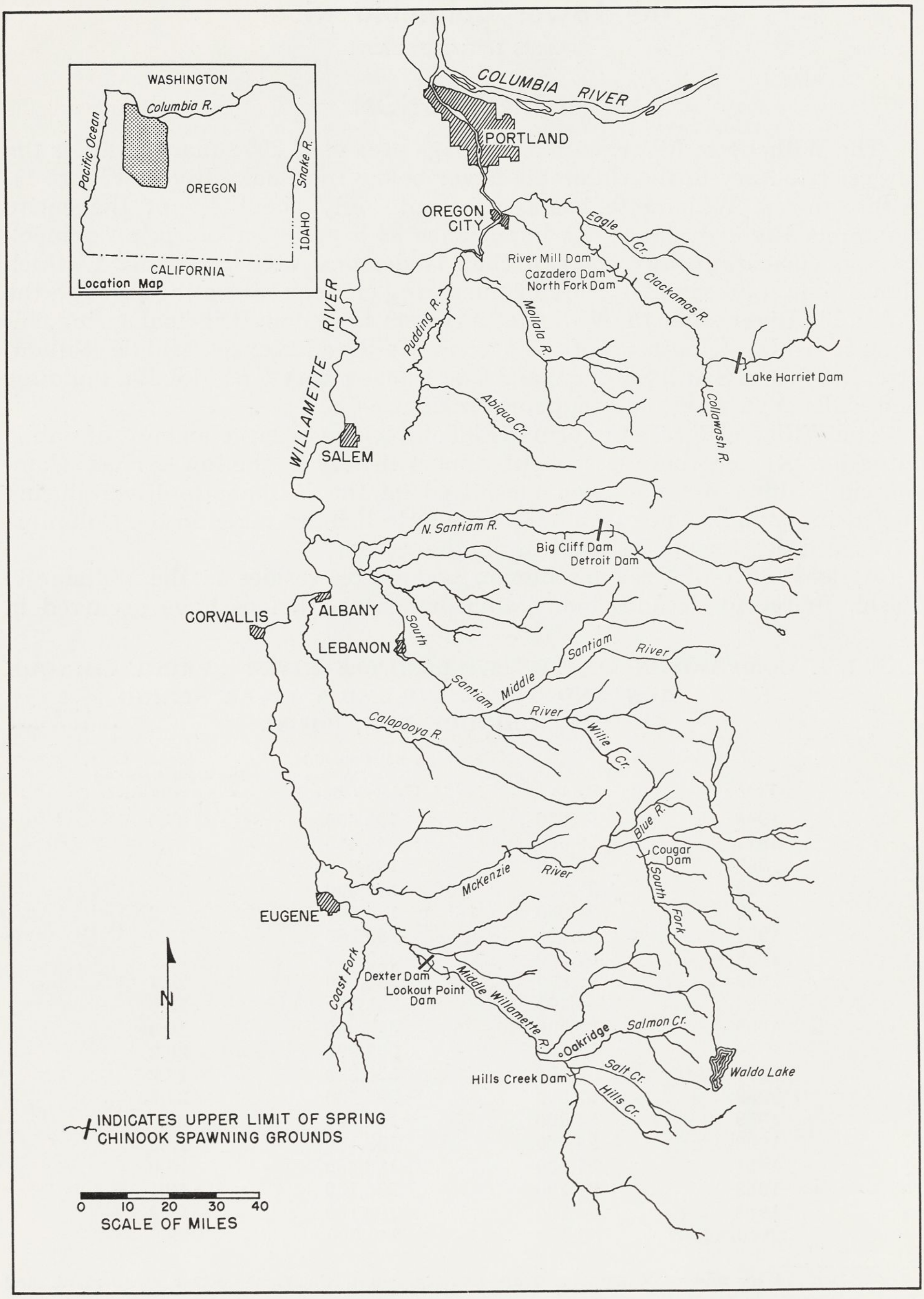

FIGURE 1. WILLAMETTE RIVER SYSTEM.

the system due to increased agriculture, industrialization, and construction of dams, all of which have adversely affected anadromous fish populations. Even so, the Willamette River remains Oregon's major spring chinook stream. Increased inroads on the productive capacity of the river, however, may make it necessary to afford this race of spring chinook special protection in the future. To do so will require an understanding of the time of migration of the fish destined for the Willamette River.

There has been no study specifically designed to define the Willamette spring chinook migration through the Columbia River and into the Willamette system. However, information available from other studies and correspondence does provide some background on the general timing of these stocks.

The purpose of this paper is to summarize pertinent information on the migration of Willamette spring chinook to provide a basis for future management of the fishery.

Correspondence prior to 1900 (Abernethy, 1886) established the presence of spring chinook in the Clackamas River in February, with the bulk of the fish entering in March and early April (as determined by the commercial fishery in operation at that time). Results from marking experiments by Rich and Holmes (1929) indicated that chinook entered the Willamette from February through May. Craig and Townsend (1946), reporting on U. S. Fish and Wildlife Service inventories of the Willamette spring chinook sport catch in 1941 and 1942, stated that the adults make a rapid migration through the lower Columbia River in February, March, and April. They felt that Willamette chinook contributed to the winter commercial fishery in the Columbia and undoubtedly were caught after April 30, when the spring season normally opens, but that no great numbers were taken since most of the run was already in the Willamette. Preliminary analysis of returns of spring chinook tagged on the lower Columbia during March and April in 1948 and 1949 indicated that Willamette runs generally had passed through the lower Columbia by April 15 (Fish Commission of Oregon, 1950) and that the bulk of the tagged fish recovered in the Willamette system had entered the Columbia during late February, March, and April. Wendler (1959) asserted, on the basis of tag recoveries in 1955, that 50% of the Willamette fish passed through the lower Columbia River before March 30.

METHODS

Information from three sources was used to document the timing of spring chinook runs in the Willamette River: (1) recoveries from tagging experiments; (2) recoveries of fin-marked fish; and (3) patterns of peak sport catch.

Tagging Studies

Spring chinook were tagged on the lower Columbia River from 1948 to 1963. Through 1956 tagging was conducted jointly by the Washington Department of Fisheries and the Oregon Fish Commission. Tagging was then discontinued and resumed in 1960 during an Oregon Fish Commission test-fishing program.① The first tagging was at Clifton and later in the McGowan-Astoria area up to Altoona and at Woody Island (Table 2, Figure 2). All the fish were captured by gill nets except those taken in a commercial-type trap at McGowan. Before 1960 Petersen-type plastic discs were fastened at the origin of the dorsal fin and spaghetti-tube tags were applied just below and slightly forward of the insertion of the dorsal fin. During test-fishing operations from 1960-63, fish were tagged with nylon dart-type tags between the origin and insertion of the dorsal fin. A total of 5,593 spring chinook from all sources was tagged in the years 1948-63, about 98% of them in March and April (Table 2). Recoveries were from sport and commercial fisheries, hatcheries, and miscellaneous sources (spawning grounds, traps, etc.).

TABLE 2. **NUMBERS OF COLUMBIA RIVER SPRING CHINOOK TAGGED, 1948-63.**

Tagging Location	*Date*	*Month Tagged*						
		Dec.	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May 1-15*	*Total*
Clifton	3/31-4/29/48				3	279		282
Clifton	3/10-4/26/49				112	266		378
McGowan	5/11-12/52						2	2
McGowan	3/4-5/15/53				74	199	65	338
Astoria-Altoona	12/2/54-4/25/55		9	28	551	898		1,486①
Woody Island	11/27/55-3/30/56	4	5		511			520①
Woody Island (Test Fishing)	3/15/60-4/24/63				720	1,867		2,587
Total Number Tagged		4	14	28	1,971	3,509	67	5,593

① Tagged during a winter steelhead program. Wendler (1959) reported on chinook and Korn (1961) on steelhead.

Marking Experiments

Mark recoveries were from releases of approximately 1.5 million spring chinook fingerlings from brood years 1946-58. Virtually all the fingerlings were released into the Middle Willamette River and tributaries. Exceptions were in 1951 and 1953 into the Row River (tributary of the Coast Fork Willamette River) in an attempt to establish a spring run in that stream, and the 1953-brood fish of McKenzie River origin put back into the McKenzie River. These marking experiments were designed primarily to: (1) determine effect of time of liberation on survival of fingerlings; and (2) compare survival of fish fed normal hatchery diet with those fed the Oregon pellet diet.

Recoveries of marked fish were made while sampling landings of the Columbia River gill-net fishery at various canneries in Astoria and Portland during the winter and spring commercial seasons. Fish were also checked for marks during test fishing in March and April 1960-63. Because only sporadic sampling programs were conducted on the sport fishery, most of the sport returns were on a voluntary basis.

① Annual program to determine time of migration of spring chinook used in setting the opening date for the commercial gill-net season.

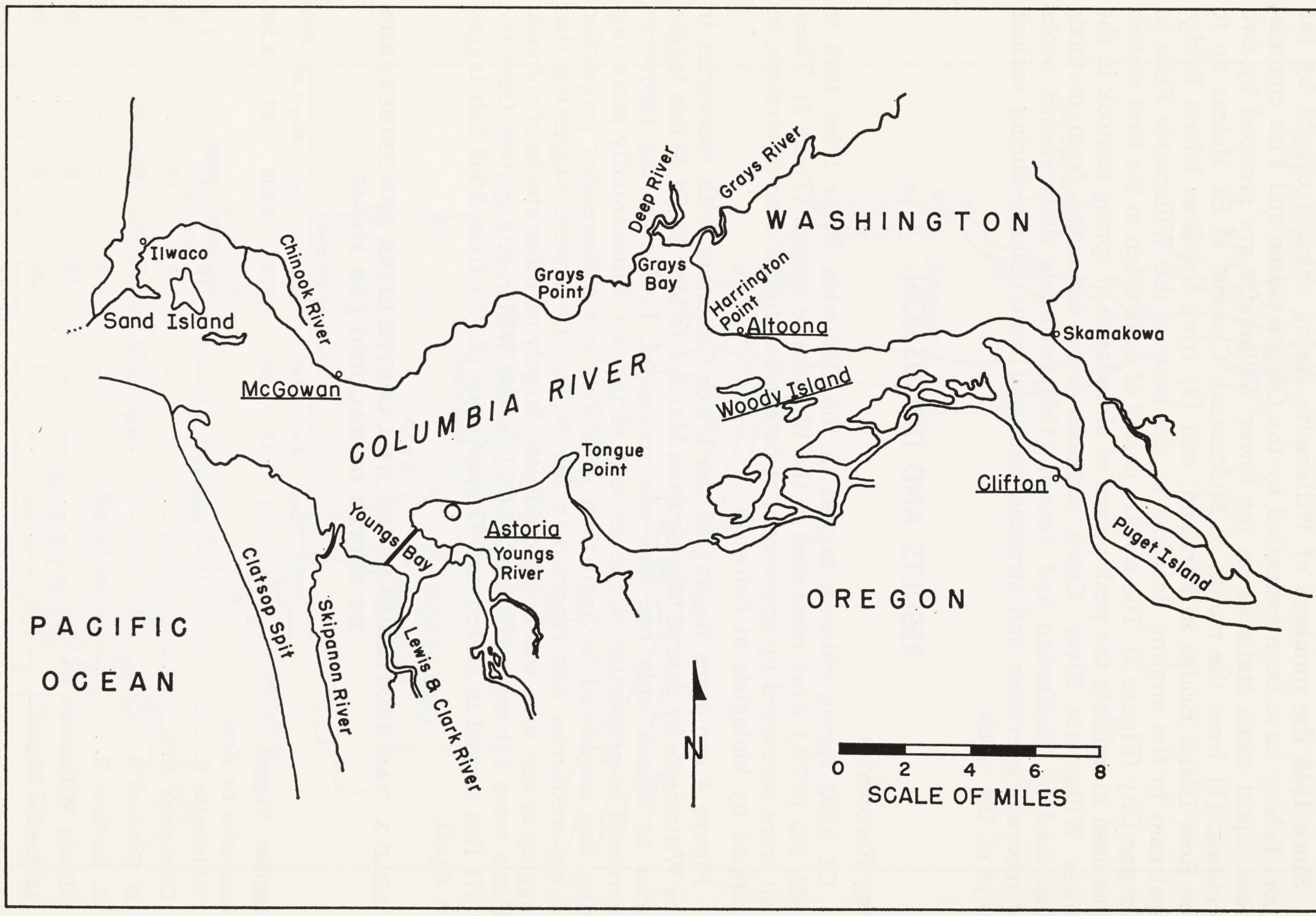

FIGURE 2. LOWER COLUMBIA RIVER TAGGING SITES, 1947-63.

Peak Periods of Sport Catch

Since 1946 the numbers of Willamette spring chinook caught by the sport fishery have been estimated by the Oregon Game and Fish commissions. Sport catch statistics on the lower Willamette are grouped by two sections: (1) from the mouth of Multnomah Channel at St. Helens up to the Ross Island Bridge in Portland; and (2) from the Ross Island Bridge upstream to the angling deadline at the base of the Willamette Falls in Oregon City (Figure 3). The weekly period of peak catch in the first section was used to indicate the peak period of abundance of spring chinook in the lower Willamette River. Catch statistics were estimated from methods described by McKernan and Jensen (1946) utilizing daily record books of moorage operators and airplane counts of boats fishing during various days of the week.

RESULTS AND DISCUSSION

Tag Recoveries

Of 5,593 spring chinook tagged in the Columbia River from 1948 to 1963, 205 (3.7%) were recovered in the Willamette system (Table 3). These fish were recovered by sportsmen, at hatcheries, found dead in streams, or trapped by biologists at fishways.

Figure 4 compares tagging in the lower Columbia with recoveries in the Willamette by date of tagging from March 1 to May 13. Of 46 fish tagged prior to March, only one fish was recovered. In March, tag recoveries increased in proportion to the amount of tagging. Substantially more tagging was conducted in April than in March, but a decreasing proportion of tag recoveries was reported in the Willamette system suggesting that tagging at this time was being conducted largely on other stocks of chinook. There were 131 tag recoveries (6.6%) in the Willamette system from the 1,971 fish tagged in March and 73 recoveries (2.1%) from 3,509 fish tagged in April.

TABLE 3. **TAG RECOVERIES IN THE WILLAMETTE RIVER AND TRIBUTARIES BY MONTH OF TAGGING FOR 1948-63.**

	Month of Tagging						Total
	Dec.	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May 1-15*	
Number Tagged	4	14	28	1,971	3,509	67	5,593
Recoveries by Area							
Willamette R.	....	....	....	79	37	....	116
Clackamas R.	....	....	....	9	15	....	24
N. Santiam R.	....	....	....	7	8	....	15
S. Santiam R.	....	....	....	4	....	....	4
Middle Willamette R.	....	....	....	12	8	....	20
McKenzie R.	....	....	1	20	5	....	26
Total Recoveries	....	....	1	131	73	....	205
Per Cent Recovered	....	....	3.6	6.6	2.1	....	3.7

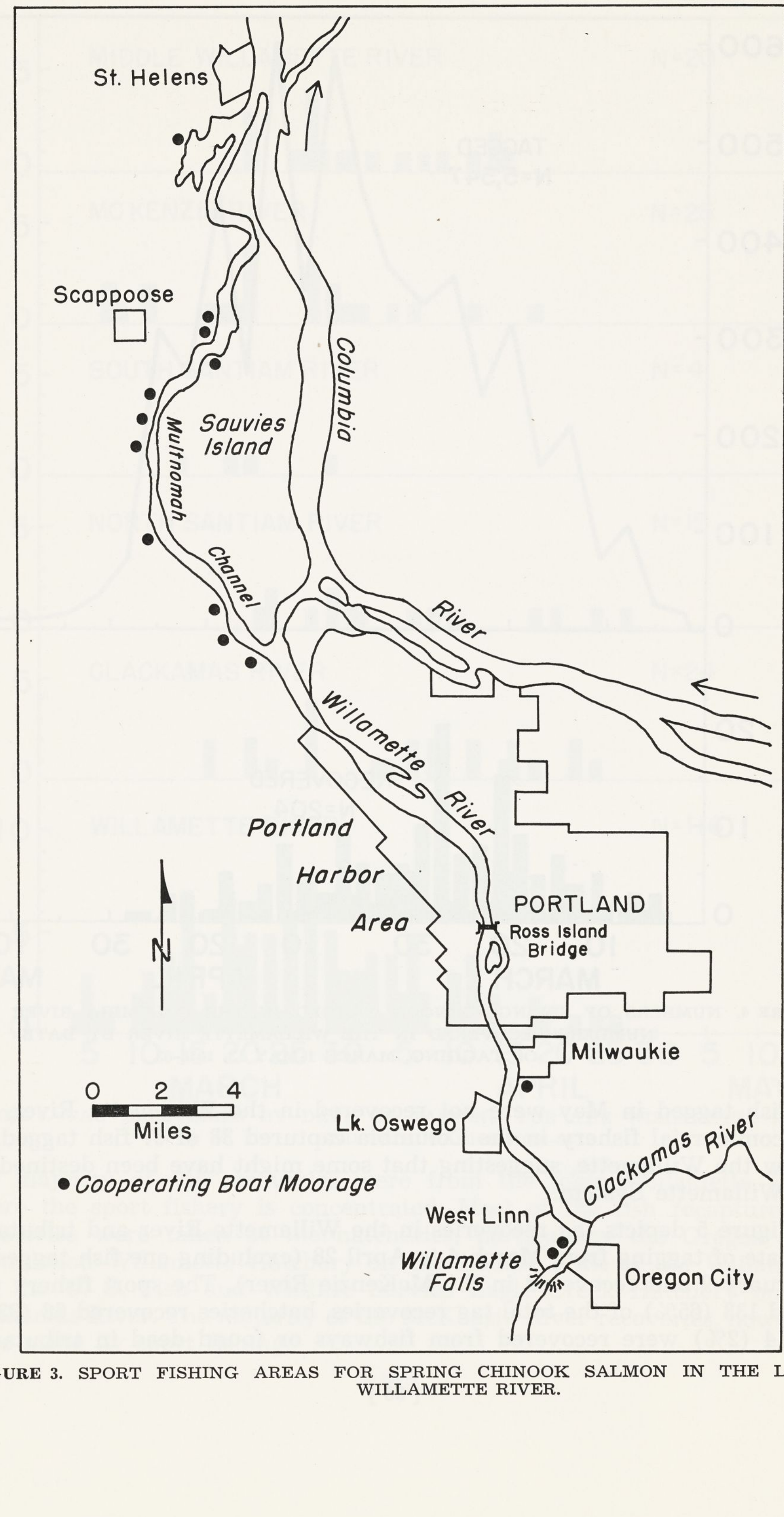

FIGURE 3. SPORT FISHING AREAS FOR SPRING CHINOOK SALMON IN THE LOWER WILLAMETTE RIVER.

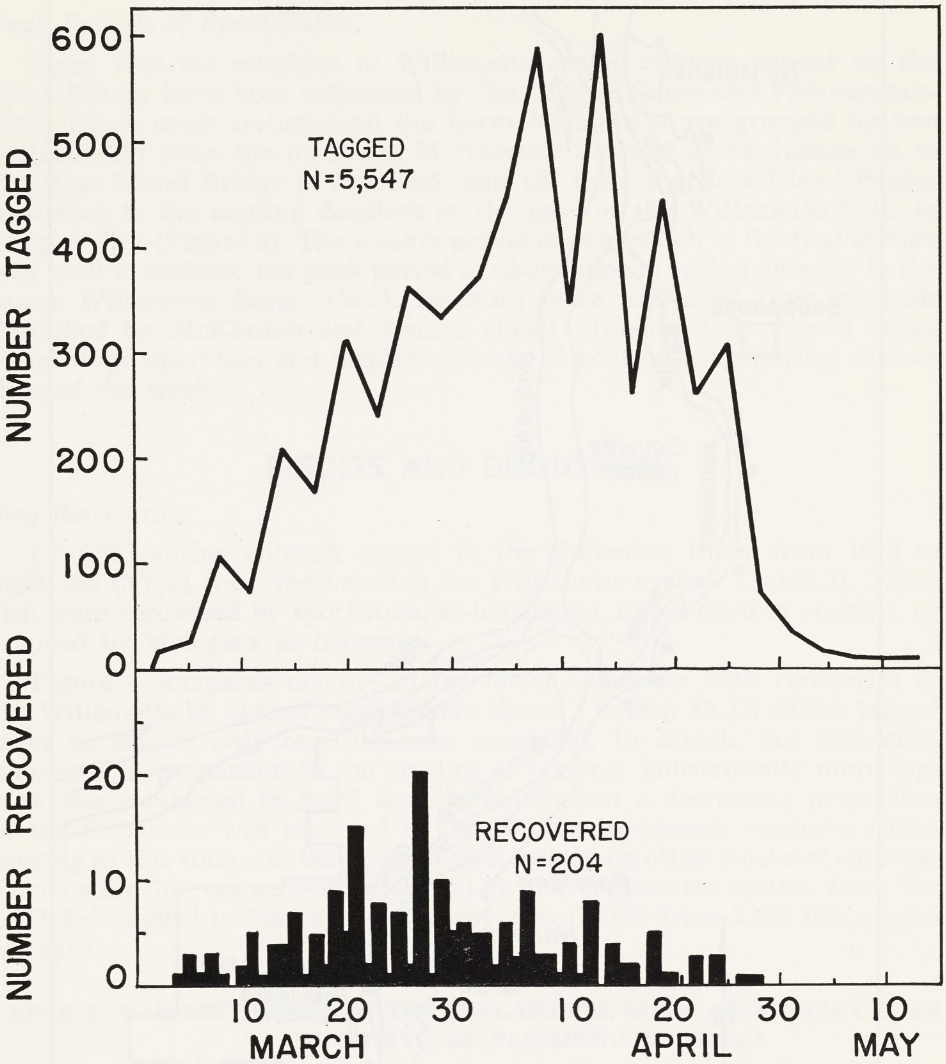

FIGURE 4. NUMBERS OF SPRING CHINOOK TAGGED IN THE COLUMBIA RIVER AND NUMBERS RECOVERED IN THE WILLAMETTE RIVER BY DATE OF TAGGING, MARCH 1-MAY 13, 1948-63.

Fish tagged in May were not recovered in the Willamette River, but the commercial fishery in the Columbia captured 38 of 67 fish tagged, all below the Willamette, suggesting that some might have been destined for the Willamette System.

Figure 5 depicts tag recoveries in the Willamette River and tributaries by date of tagging from March 4 to April 28 (excluding one fish tagged on February 9 and recovered in the McKenzie River). The sport fishery provided 133 (65%) of the total tag recoveries, hatcheries recovered 68 (33%), and 4 (2%) were recovered from fishways or found dead in tributaries.

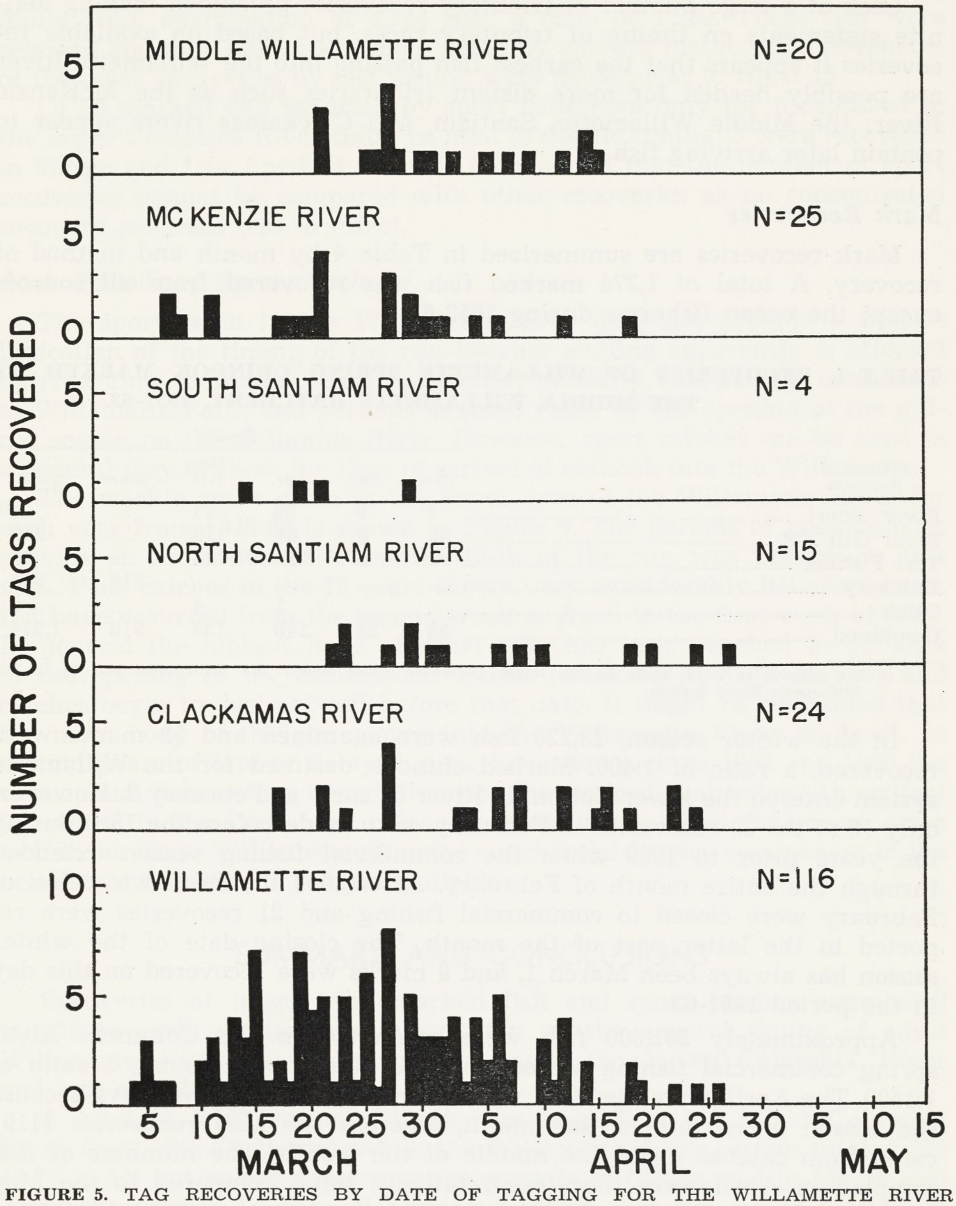

FIGURE 5. TAG RECOVERIES BY DATE OF TAGGING FOR THE WILLAMETTE RIVER AND TRIBUTARIES, 1948-63.

The majority of the recoveries were from the main Willamette River where the sport fishery is concentrated. Most of the fish recaptured in tributaries were taken at the hatcheries, particularly the Oregon Fish Commission Willamette Hatchery on the Middle Fork of the Willamette and the U. S. Fish and Wildlife Service Eagle Creek Hatchery on the Clackamas River. The majority of the McKenzie River recoveries, however, were made by sport fishing.

Lack of a large number of tributary recoveries precluded making definite statements on timing of tributary races, but based on available recoveries it appears that the earliest fish passing into the Willamette River are possibly headed for more distant tributaries such as the McKenzie River; the Middle Willamette, Santiam, and Clackamas rivers appear to contain later arriving fish.

Mark Recoveries

Mark recoveries are summarized in Table 4 by month and method of recovery. A total of 1,274 marked fish was recovered from all sources except the ocean fisheries during 1953-63.

TABLE 4. **RECOVERIES OF WILLAMETTE SPRING CHINOOK MARKED AT THE MIDDLE WILLAMETTE HATCHERY, 1951-63.**

	Month					
Method of Recovery	*Feb.*	*Mar.*	*Apr.*	*May 1-15*	*Other*	*Total*
River Sport	3	9	56	11	....	79①
River Gill Net	50	9	81	119	....	259
Test Fishing	....	5	10	....	....	15
Hatchery	....	....	....	....	916	916
Other	....	....	1	4	....	5
Combined	53	23	148	134	916	1,274

① Six recoveries were made in the lower Columbia River below the Willamette and 73 in the Willamette River system.

In the winter season, 23,220 fish were examined and 59 marks were recovered, a ratio of 1:400. Marked chinook destined for the Willamette system entered the lower Columbia River as early as February 2. However, only 10 of the 29 recoveries in February were made before the 15th during the years prior to 1959 when the commercial fishing season extended through the entire month of February. After 1958 the first two weeks of February were closed to commercial fishing and 21 recoveries were reported in the latter part of the month. The closing date of the winter season has always been March 1, and 9 marks were recovered on this day in the period 1951-63.

Approximately 301,000 fish were examined in the Columbia River spring commercial fishing season and 200 marks were found, a ratio of 1:1500. The April recoveries (81) were from only 1 to 4 fishing days because the season opens late in the month, whereas the May recoveries (119) came from catches up to the middle of the month. The numbers of fish sampled in April were therefore relatively small compared to the May sampling. More marks would have probably been recovered in April than May had equal fishing days been allowed each month. The observed change in the marked to unmarked ratio from February-March to April-May indicates a dilution of Willamette River chinook by other races as the season progresses. This suggests that Willamette fish are relatively more abundant early in the spring compared to the main portion of the Columbia River spring run.

During test-fishing operations from 1959-63, 15 marked chinook were found from examination of 4,214 fish, a ratio of 1:280. These fish were released and may have been taken again by another method. Three-fourths of the mark recoveries by test fishing were made prior to April 15.

Of 79 marked fish reported by sport fishermen only the 6 captured in the lower Columbia River could be used to denote timing; 5 were recovered in March and 1 in April. It must be emphasized that the number of sport recoveries cannot be compared with other recoveries as no concentrated recovery program was in effect.

Peak Periods of Sport Catch

The sport catch in the Willamette River does not provide a precise indication of the timing of the run because angling apparently is affected by river flow, Columbia River backwater, turbidity, fish passage conditions at Willamette Falls, and perhaps in some years by the opening of the gill-net season on the Columbia River. However, sport catches can be used in a general way to show the time of arrival of chinook into the Willamette.

The weekly sport catch in the lower area of the Willamette River for each year from 1946-63 is shown in Figure 6. The periods of peak catches provide an indication of when the bulk of the run was present in this area. Peak catches in the 18 years shown vary considerably between years, but have occurred from the second week in April to the first week of May. In general the highest level of sport take has been reached in advance of the opening of the commercial season (week of April 27-May 3) and catches begin to decline well before that date. It might be concluded that the main body of the run moves into the Willamette River in April. In certain years of late or delayed runs, however, such as 1955 and 1960 the commercial fishery may have influenced the week of peak catch. An artifact is created in the later peak catches because many sport fishermen cease to fish the lower Willamette after the commercial fishery commences in the belief that fish are no longer available.

SUMMARY AND CONCLUSIONS

Recoveries of tagged and marked fish and sport catches were used to add to early preliminary information on the general timing of adult Willamette River spring chinook through the lower Columbia River and into the Willamette River.

A total of 5,593 spring chinook was tagged in the lower Columbia River from 1948-63. Recoveries in the Willamette River system totaled 205 (3.7%). All but one of the recoveries were from fish tagged in March and April. Recoveries by date of tagging indicate that the major portion of the Willamette spring chinook run is present in the lower Columbia River in March and early April. Approximately 92% of the recoveries were from fish tagged before April 15.

About 1.5 million fin-clipped spring chinook were released into the Middle Willamette River (or its tributaries) from brood years 1946-58. Recoveries were obtained from commercial and sport fisheries, test fishing, and at the Fish Commission's Willamette River Hatchery. Approximately 324,000 chinook were examined for marks from 1951 to 1963 during

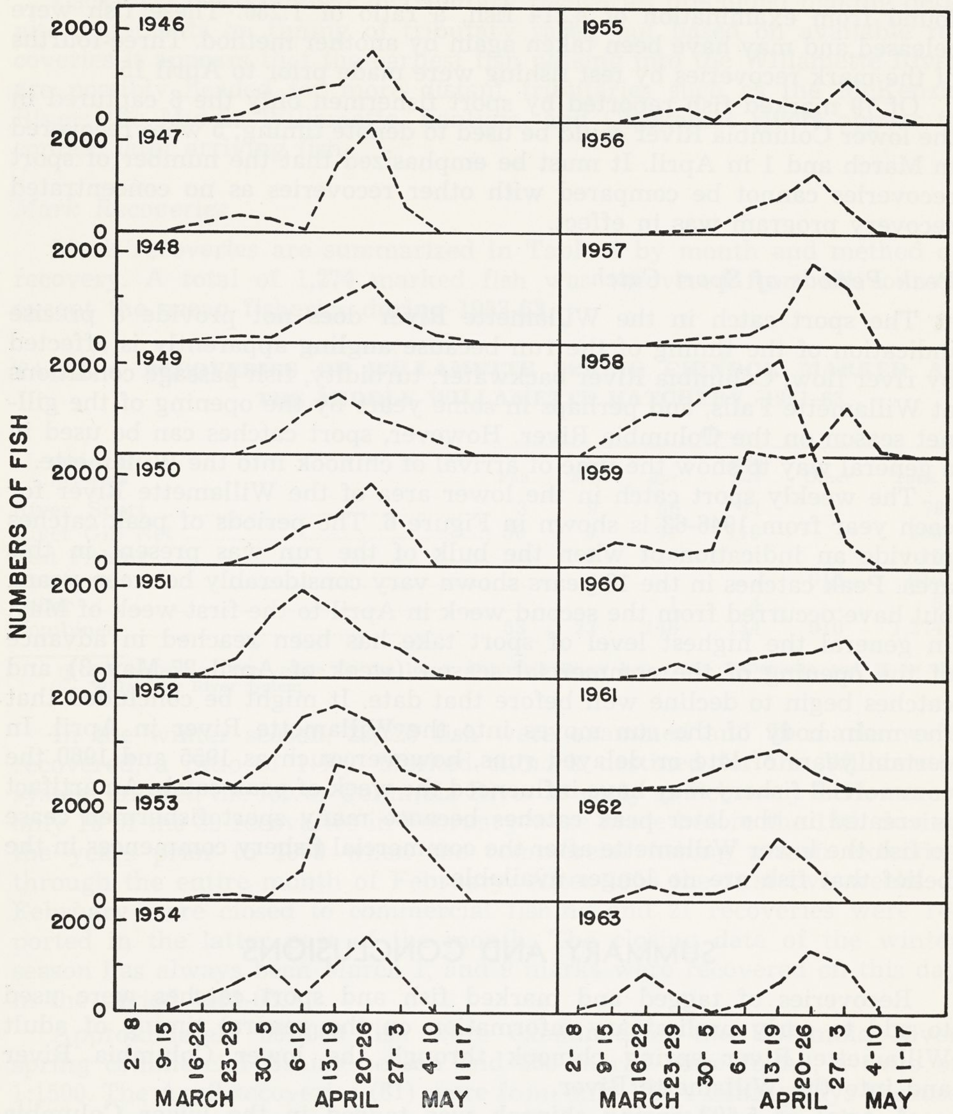

FIGURE 6. WEEKLY SPORT CATCH OF SPRING CHINOOK IN THE WILLAMETTE RIVER BELOW ROSS ISLAND BRIDGE, MARCH 2-MAY 18, 1946-63.

winter and spring commercial fishing seasons. In the winter seasons (February-early March), 23,220 chinook were checked and 59 marks recovered, a ratio of 1:400. In the spring seasons (late April-May, 301,000 were examined and 200 marks were recovered, a ratio of 1:1500. Examination of 4,214 chinook during test fishing in March-April 1959-63 yielded 15 marked chinook, a ratio of 1:280. Seventy-nine sport recoveries of marked fish were reported, but only 6—5 in March and 1 in April—were from the lower Columbia River and could be used in an analysis of timing. Mark recoveries indicated that the Willamette Hatchery stocks pass through the lower Columbia River from February through May with a suggestion of an earlier timing than the other components of the Columbia River spring run.

Sport catch data from the lower Willamette indicated that although chinook are caught from February to June, the weekly peak catch has been in April.

Results from these three sources—recoveries from tagging experiments, recoveries of marked fish, and study of sports catch—may be modified to an unknown extent by the commercial gill-net fishery. However, these data analyzed in this report indicate that the majority of Willamette spring chinook migrate through the lower Columbia during late March and early April and show peak abundance in the lower Willamette in April. This confirms work of earlier investigators such as Rich and Holmes (1929) and Craig and Townsend (1946) who noted the time of migration of the Willamette run at approximately this same period.

ACKNOWLEDGMENTS

The writer wishes to thank his co-workers for providing mark recovery information and for data on the sport catch in the Willamette River.

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(Reprinted from Research Briefs, Fish Commission of Oregon, Volume 10, Number 1, ~~Nov.~~ June, 1964.)

Fecundity of Columbia River Chinook Salmon

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INTRODUCTION

In 1959 the Oregon Fish Commission studied the fecundity of chinook salmon *(Oncorhynchus tshawytscha)* of the Columbia River. This information was collected to obtain a measure of potential productivity in order to relate escapement to future runs. It was also postulated that these data might be used to separate races of chinook by differences in fecundity, both within the Columbia and between this and other river systems. Samples were collected from Columbia River commercial catches throughout the main fishing seasons—spring, summer, and fall—to include the various runs or races of chinook in the river.

METHODS

Samples of ovaries were obtained from various fish processing plants in Astoria and Portland, Oregon. They were selected from two fish at every odd-inch fork-length interval (measured to the nearest lower inch) if available. The possibility of change in fecundity with time of migration through the river was monitored by obtaining samples from spring, summer, and fall runs. A total of 62 fish was sampled (Table 1). Scales were also taken from each fish for age determination.

The egg skeins were preserved in 10% formalin and subsequently transferred to 50% isopropyl alcohol in three gradual steps. Egg counts were recorded on a Veeder hand counter. Separate counts were made of "normal" and "abnormal" (noticeably small or off-colored) eggs, but only counts of normal eggs were used in the statistical analyses.

One skein of eggs from each of 7 fish was counted a second time and all were within 1% of the first counts. This was merely a check on the accuracy of the count; hence the first counts were used in the analyses.

TABLE 1. **EGG COUNTS OF OVARIES FROM 62 FEMALE CHINOOK SALMON TAKEN BY SAMPLING OF COLUMBIA RIVER GILL-NET FISHERY, MAY-AUGUST, 1959.**

Date	*Fork Length (Inches)*	*Age*	*Normal Eggs*	*Abnormal Eggs*
5/1	23	4_2	2,148	170
5/5	23	4_2	3,214	209
5/1	25	4_2	2,839	307
5/1	25	4_2	3,069	70
8/24	25	....	2,600	3
5/1	27	....	3,429	294
5/1	27	4_2	2,959	....
5/1	27	5_2	4,022	....
6/24	27	4_2	3,017	124
8/24	27	4_2	4,339	73

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TABLE 1—Continued

Date	*Fork Length (Inches)*	*Age*	*Normal Eggs*	*Abnormal Eggs*
5/1	29	4_2	4,445	330
5/1	29	4_2	4,183	286
6/23	29	4_2	2,925	35
6/23	29	4_2	4,034	72
7/16	29	4_2	4,142	39
8/19	29	3_1	5,107	8
8/19	29	3_1	4,375	1
5/1	31	4_2	3,907	303
5/1	31	4_2	5,434	....
6/23	31	4_2	3,794	140
6/23	31	4_2	4,857	101
7/16	31	4_1	5,516	144
7/15	31	4_2	4,930	35
8/19	31	3_1	3,961	497
8/19	31	4_2	5,120	3
5/1	33	5_2	4,690	127
5/1	33	5_2	4,935	....
6/23	33	5_2	5,074	91
6/23	33	4_2	5,419	92
7/9	33	4_1	5,054	194
7/9	33	4_2	6,531	21
8/19	33	4_1	4,589	14
8/19	33	4_1	5,366	3
5/1	35	5_2	6,838	....
5/1	35	5_2	6,126	155
6/23	35	5_1	3,874	10
6/23	35	5_1	4,455	98
7/14	35	4_2	6,531	21
7/9	35	5_1	5,256	43
8/19	35	....	6,035	2
8/19	35	....	5,374	11
5/1	37	5_2	6,227	....
5/1	37	5_2	5,230	....
6/23	37	5_1	5,674	61
6/23	37	5_1	5,905	21
7/9	37	5_2	5,125	137
7/14	37	5_1	5,926	127
8/19	37	4_1	5,584	27
8/19	37	4_1	5,401	51
5/5	39	5_2	6,238	....
5/5	39	....	7,705	....
6/23	39	5_1	6,428	56
6/23	39	5_1	7,195	425
7/15	39	5_1	6,482	28
7/15	39	5_1	6,812	57
8/19	39	4_1	6,098	33
8/25	39	....	7,402	39
6/23	41	5_1	6,162	267
7/16	41	5_1	5,439	39
8/25	41	....	7,280	26
8/26	41	....	7,571	5
8/25	41	....	6,048	30

The length-fecundity relationships were determined by computing the regressions using fork length as the independent variable, *X*, and numbers of eggs as the dependent variable, *Y*, according to the techniques outlined by Snedecor (1959, p. 122). The general equation of the regression for these analyses was as follows:

$$\hat{Y} = a + bX$$

where $\hat{Y}$ = estimated number of eggs for a given fork length,

a = value of $\hat{Y}$ when X = 0,

b = increase in the numbers of eggs per inch increase in fork length, and

X = fork length.

The correlation coefficients, *r*, expressing the degree of relationship between length and fecundity were determined according to the procedures outlined by Snedecor (1959, p. 160). Also, r^2, the proportion of the variation in fecundity which can be attributed to changes in fork length, was computed. Various regressions and correlations were computed by season and age for the entire Columbia River sample, and then for the subsamples, as well as for the other river systems (Table 2). The length-fecundity regressions were then analysed for possible significant differences between age, season, and river system following the analysis of covariance procedures outlined by Snedecor (1959, p. 394).

RESULTS

Relation Between Size of Fish and Fecundity

Ricker (1932) stated that the relationship between the numbers of eggs and length of fish is curvilinear for the eastern char or brook trout *(Salvelinus fontinalis)*. However, Rounsefell (1957) and others have indicated that a straight line adequately describes this relationship in *Oncorhynchus*. Linear regression is much more frequently used than curvilinear regression, because it is much easier to calculate and use. The Columbia River data were tested for linearity following the procedures outlined by Li (1957, p. 295) prior to the analysis of covariance tests, and were found not to deviate significantly from linearity.

Fish taken over the entire period from May through August had a fork length range of 23 to 41 inches (odd intervals only) and a range in fecundity from 2,148 to 7,705 eggs. The mean was 33.3 inches and 5,090 eggs. It is noted that this mean is not from a random sample, but is from one where two fish were taken for each odd-inch interval. The length-fecundity relationship was computed as $\hat{Y} = -2{,}733 + 235X$ (Figure 1). The significant correlation coefficient, r = 0.87, indicated that 76% of the variation in egg count could be accounted for by the differences in length.

TABLE 2. **SUMMARY OF BASIC DATA FOR LENGTH-FECUNDITY RELATIONSHIPS OF CHINOOK SALMON.**

Sample Identification	*Sample Size*	*Length (Inches)*		*Egg Count*		*Linear Regression Equation (Y = a+bX)*	*Correlation Coefficient*	*Y Variation due to X Variation (%)*	*Significant Correlation Coefficients*	
		Mean	*Range*	*Mean*	*Range*				*5%*	*1%*
Columbia River										
Season										
April-May	19	30.8	23–29	4,613	2,148– 7,705	Y = —3,634+268X	0.92	85	0.46	0.58
June	14	34.0	27–41	4,915	3,017– 7,195	Y = —3,936+260X	0.86	74	0.53	0.66
July	12	35.0	29–41	5,588	4,142– 6,926	Y = 179+155X	0.65	42	0.58	0.71
August	17	34.3	25–41	5,424	2,600– 7,571	Y = —2,207+222X	0.88	77	0.48	0.61
Total	62	33.3	23–41	5,090	2,148– 7,705	Y = —2,733+235X	0.87	76	0.25	0.32
Age										
3_1	3	29.7	29–31	4,481	3,961– 5,107	Y = 15,597—374X	0.78	61	1.00	1.00
4_2	20	28.8	23–25	4,065	2,148– 6,531	Y = —4,504+297X	0.86	74	0.44	0.56
4_1	8	34.5	31–39	5,302	4,589– 6,098	Y = 1,747+103X	0.62	38	0.71	0.83
5_2	10	34.6	27–39	5,451	4,022– 6,838	Y = —694+177X	0.69	48	0.63	0.77
5_1	12	37.8	35–41	5,884	3,874– 7,195	Y = 4,248+268X	0.59	35	0.58	0.71
Total	53	32.8	23–41	4,940	2,148– 7,195	Y = —2,290+220X	0.84	71	0.27	0.35
Klamath River①	106	31.6	21–42	3,760	1,718– 8,406	Y = —1,860+178X	0.67	45	0.19	0.25
Sacramento River①	50	36.0	23–44	7,422	4,795–11,012	Y = 2,708+131X	0.39	15	0.28	0.36
Total all Rivers	218	33.1	21–44	4,980	2,148–11,012	Y = —4,490+286X				

① Data from McGregor (1922, 1923a and b).

Variation by Season

Length-fecundity regressions were computed and plotted by month and compared with the over-all regression (Table 2 and Figure 2). The summer season was separated into June and July as there is a progressive change in the nuclear scale patterns. These regressions had highly significant correlations with the exception of July which was still significant at less than $P = 0.05$. Comparison of the seasonal length-fecundity regressions was made by an analysis of covariance (Table 3). If we assume that the data represented random samples from normal populations with equal variance, the variation among the regression coefficients or the slopes was not significant ($F_{.05} = 1.34$ with 3 and 54 degrees of freedom). Since we must adjust for varying values of length, the seasonal differences were also examined by using the test of adjusted means, but the differences were again not significant ($F_{.05} = 1.65$ with 3 and 57 degrees of freedom). We may conclude that there was no significant difference in the length-fecundity relationships between the different seasons.

TABLE 3. **SUMMARY OF ANALYSES OF COVARIANCE OF LENGTH-FECUNDITY RELATIONSHIPS FOR CHINOOK SALMON.**

Analysis	*Computed F*	*Degrees of Freedom*	*Significant F Values 5%*	*1%*
Variation between seasons (Columbia River)				
Difference between regression coefficients	1.34	3 & 54	2.78	4.17
Difference between adjusted means	1.65	3 & 57	2.77	4.15
Variation between ages (Columbia River)				
Difference between regression coefficients	1.66	3 & 42	2.83	4.29
Difference between adjusted means	0.35	3 & 45	2.81	4.25
Variation between rivers (Columbia, Klamath, & Sacramento)				
Difference between regression coefficients	3.86①	2 & 212	3.04	4.71
Difference between adjusted means	147.20①	2 & 214	3.04	4.71

① Significant

Relation Between Age and Fecundity

Age of the samples was determined by examination of the scales under a microscope. Ages were designated according to the nomenclature established by Gilbert and Rich (1927). This consists of two figures with the second written as a subscript. The first figure indicates the year of life in which the fish was captured and the subscript the year it migrated from fresh water to the sea. Thus a 4_1 (sub one) migrated to the ocean in its first year and was captured in its fourth year. A 4_2 (sub two) left fresh water in its second year and returned in its fourth.

Ages could be assigned to 53 of the 62 fish. Of these, 3 were designated as being in their third year of life, 28 in their 4th year, and 22 in their 5th year. Because of the paucity of data on the 3-year fish, they were deleted from the statistical analysis of aged fish.

The length-fecundity regressions for age groups 4_2, 4_1, 5_2, and 5_1 were computed and plotted so that they might be compared with the over-all regression (Table 2 and Figure 3). The analysis of covariance test indicated no significant differences between slopes ($F_{.05} = 1.66$ with 3 and 42 degrees of freedom) or adjusted means ($F_{.05} = 0.35$ with 3 and 45 degrees of freedom) of the regressions for the different ages (Table 3).

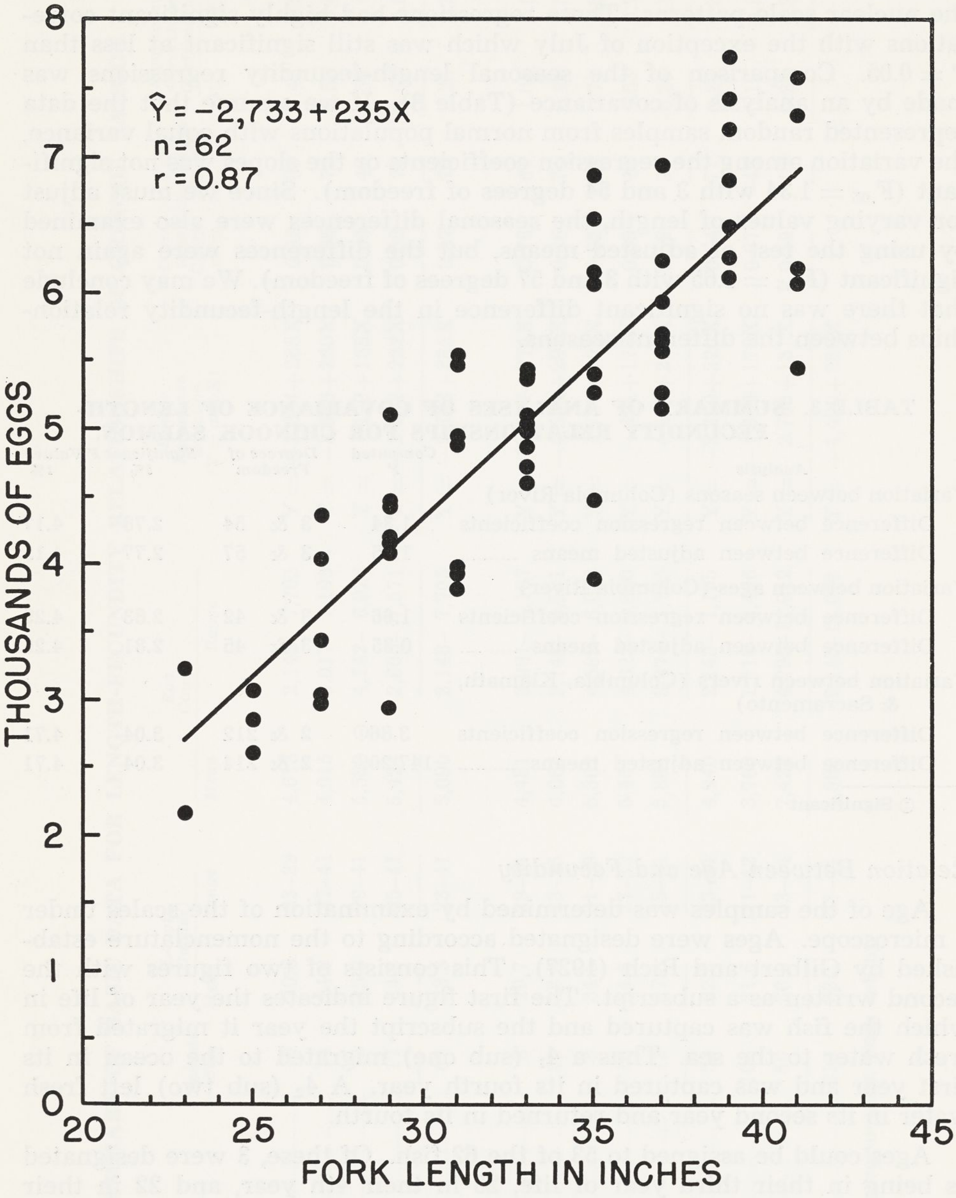

FIGURE 1. RELATION OF NUMBER OF EGGS TO BODY LENGTH FOR COLUMBIA RIVER CHINOOK SALMON.

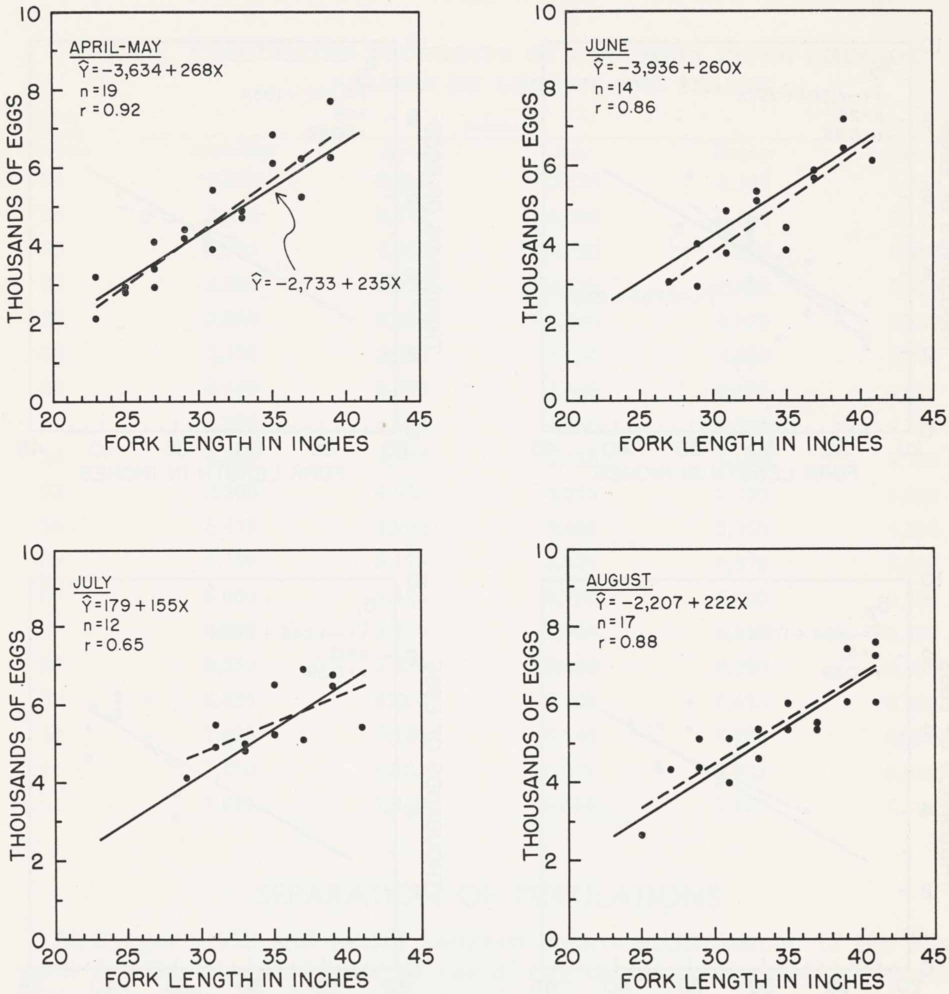

FIGURE 2. RELATION OF NUMBER OF EGGS TO BODY LENGTH FOR COLUMBIA RIVER CHINOOK SALMON BY SEASON. (SOLID LINE REPRESENTS COMBINED REGRESSION FOR ALL SEASONS AND DOTTED LINES THE INDIVIDUAL SEASONAL REGRESSIONS.)

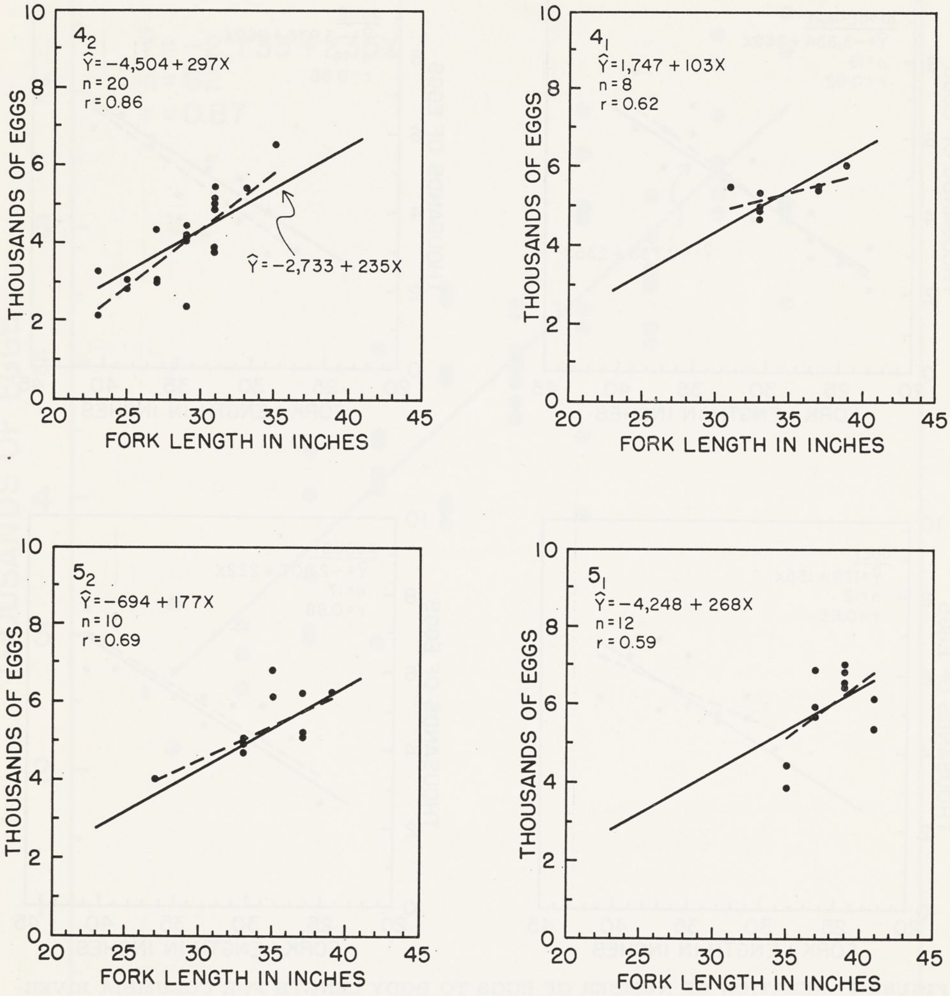

FIGURE 3. RELATION OF NUMBER OF EGGS TO BODY LENGTH FOR COLUMBIA RIVER CHINOOK SALMON BY AGE. (SOLID LINE REPRESENTS COMBINED REGRESSION FOR ALL AGES AND DOTTED LINES THE INDIVIDUAL AGE REGRESSIONS.)

For the convenience of those who might have occasion to use these data to compute potential egg deposition, etc., Table 4 is given. This table shows the calculated average number of eggs for each inch interval of length.

TABLE 4. **CALCULATED FECUNDITY OF COLUMBIA RIVER CHINOOK SALMON BY LENGTH AND SEASON.**

Fork Length (Inches)	*Season*				*Combined Seasons*
	April-May	*June*	*July*	*August*	
24	2,800	2,300	3,875	3,125	2,850
25	3,050	2,575	4,050	3,350	3,100
26	3,325	2,825	4,200	3,575	3,350
27	3,600	3,100	4,325	3,800	3,550
28	3,850	3,350	4,500	4,025	3,800
29	4,125	3,600	4,650	4,250	4,050
30	4,400	3,875	4,800	4,475	4,300
31	4,650	4,125	4,950	4,700	4,500
32	4,925	4,375	5,125	4,925	4,750
33	5,200	4,650	5,275	5,150	5,000
34	5,475	4,900	5,425	5,350	5,250
35	5,750	5,175	5,575	5,575	5,450
36	6,000	5,425	5,725	5,800	5,700
37	6,275	5,700	5,900	6,025	5,950
38	6,550	5,950	6,050	6,250	6,150
39	6,825	6,200	6,200	6,475	6,400
40	7,025	6,475	6,350	6,700	6,650
41	7,350	6,725	6,500	6,925	6,900
42	7,625	7,000	6,650	7,125	7,100

SEPARATION OF POPULATIONS

McGregor (1922 and 1923a) assigned ocean-caught salmon to the Klamath and Sacramento rivers by use of egg counts irrespective of length. Galbreath (1961) further substantiated this method in a study of the egg content of troll-caught chinook off San Francisco, California. Of 100 sample ovaries taken, only 4 contained less than the egg range for the Sacramento River established by McGregor (4,795–11,012).

Data collected in our study of the Columbia River was compared with published data from the Klamath and Sacramento rivers (Figure 4). Columbia River samples had a fecundity range of 2,148 to 7,705 eggs and a mean egg content of 5,090. Egg counts for the Klamath River ranged from 1,718 to 8,406 with a mean of 3,760 and for the Sacramento River, 4,795 to 11,012 with a mean of 7,422. An analysis of covariance test indicated a significant difference between the slopes ($F_{.05} = 3.86$ with 2 and 212 degrees of freedom) and a highly significant difference between the adjusted means ($F_{.05} = 147.20$ with 2 and 214 degrees of freedom) of the length-fecundity regressions for the three streams (Tables 2 and 3). Differences in sampling techniques could account for some of the differences between the relationships and also reduce their significance somewhat. Egg count techniques differed in that actual egg counts were made in the Columbia River study, whereas McGregor calculated number of eggs by weighing the ovaries, determining the number of ova per 10 grams, and calculating total number of eggs. Calculated numbers, however, are considered accurate enough for all practical purposes. Hartman and Conkle (1960) and Galbreath (1961) showed deviation of about 2% from actual egg counts.

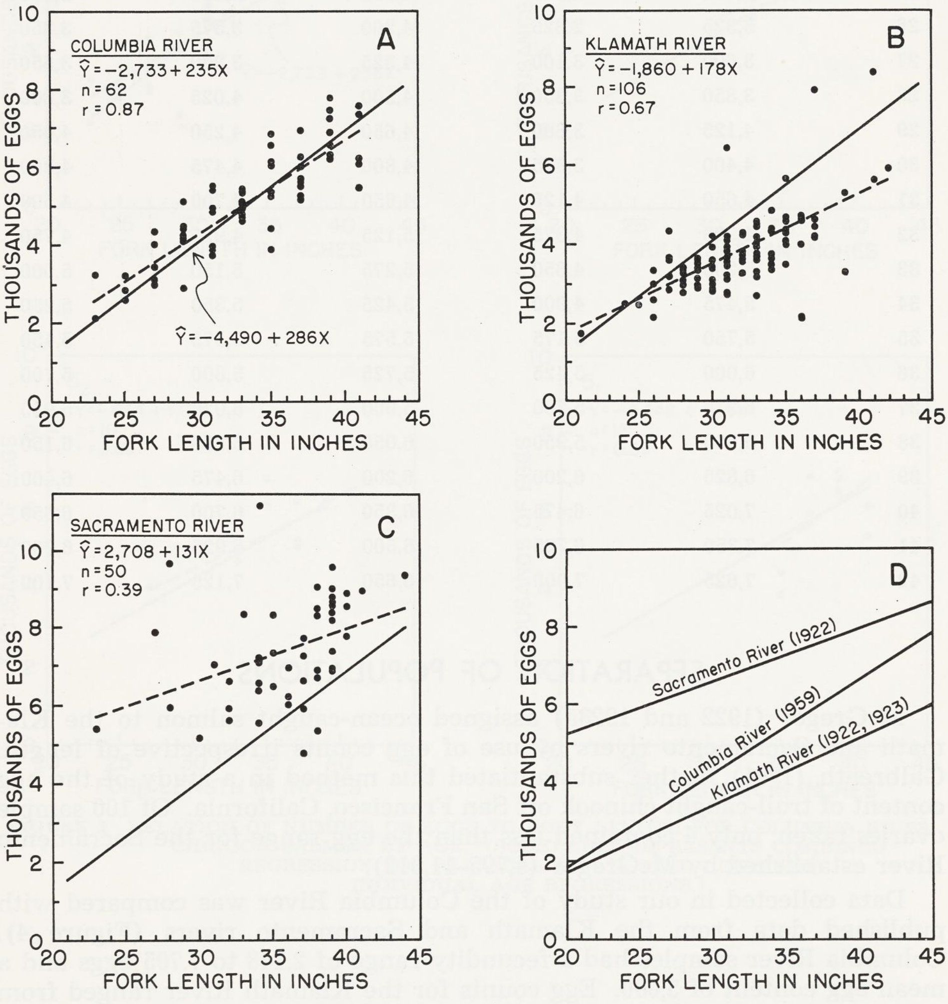

FIGURE 4. RELATION OF NUMBER OF EGGS TO BODY LENGTH FOR COLUMBIA, SACRAMENTO, AND KLAMATH RIVER CHINOOK SALMON. (SOLID LINE REPRESENTS THE COMBINED REGRESSION FOR THE THREE RIVERS AND DOTTED LINES THE INDIVIDUAL STREAM REGRESSIONS. GRAPH D SHOWS THE COMPARATIVE POSITIONS OF THE FECUNDITY REGRESSION LINES.)

It would appear that the significance of the differences between the length-fecundity regressions for these three rivers might permit assignment of some salmon in ocean catches south of the Columbia River to the proper stream of origin. However, because certain portions of the plotted data tend to overlap—smaller Columbia and Klamath river fish and larger Columbia and Sacramento river fish—assignment of the fish to the different rivers would be problematical. Also, the length-fecundity relationship of salmon from other streams is unknown and would confound the problem of separating salmon populations on this basis.

SUMMARY

Ovaries were collected from 62 female chinook salmon taken by commercial gill-net fishermen in the Columbia River including spring, summer, and fall runs. After preservation, the egg content of each ovary was determined by actual count. Analysis of the data involved the computation of an over-all length-fecundity regression line based on all samples, and investigation by analysis of covariance of the variability between seasons, age groups, and other river systems.

The number of eggs ranged from 2,148 for a 23-inch fish to 7,705 for a 41-inch fish with a mean of 5,090. The formula for the length-fecundity regression line was $\hat{Y} = -2{,}733 + 235X$, with a significant correlation coefficient of 0.87. This relationship did not deviate significantly from linearity, therefore it could be described as a straight-line relationship. Length-fecundity regressions from individual seasonal samples were computed as well as corresponding correlation coefficients, the values of which were all associated with significant probability levels. No significant differences were found between seasons.

Length-fecundity regressions were also computed for the four principal age groups in the sample. Tests indicated no significant differences between age groups. Since length is greatly influenced by time in the ocean, and fecundity is a function of length, fish of the same total age but with different periods of ocean life had different levels of fecundity.

A comparison was made between data collected in this study and data for the Klamath and Sacramento rivers. Klamath and Sacramento River samples had a fecundity range of 1,718–8,406 and 4,795–11,012, respectively, with means of 3,760 and 7,422. Analysis of covariance indicated a significant difference between the length-fecundity regressions for the three streams.

The length-fecundity relationship of Columbia River chinook was demonstrated to lie between that of the Klamath and Sacramento rivers. This suggested that some chinook races in the ocean catches could be separated in this manner. However, this method of racial identification cannot be considered reliable since overlapping in the length-fecundity relationship occurs, and does not consider other streams which have chinook populations.

ACKNOWLEDGMENTS

Thanks are due to George Hirschhorn, Wayne A. Burck, Robert B. Herrmann, Donald Amend, Bernie Carter, and Paul Knaupp, members of the research staff of the Oregon Fish Commission in 1959, who were involved in the collection of ovaries, compilation of data, and the tedium of egg counting.

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(Reprinted from Research Briefs, Fish Commission of Oregon, Volume 12, Number 1, April, 1966.)

Timing of Tributary Races of Chinook Salmon Through the Lower Columbia River Based on Analysis of Tag Recoveries

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INTRODUCTION

Since 1947, the Oregon Fish Commission and Washington Department of Fisheries have tagged anadromous salmonids in the Columbia River to obtain information for managing the fishery. This paper is primarily concerned with the timing of chinook salmon *(Oncorhynchus tshawytscha)* into tributaries based on the tagging data. Some of these individual tagging programs have been reported on by Schoning and Johnson (1956), Wendler (1959), Korn (1961), and Burck and Jones (1963).

General timing of the spring, summer, and fall runs of chinook into the lower Columbia River was established by early workers (Gilbert and Evermann, 1895; Rich and Holmes, 1928; and Craig and Hacker, 1940). Time of arrival of chinook into the Snake and Salmon river tributaries was determined from tagging programs conducted on the Snake River (Pirtle, 1956; and Thompson *et al.*, 1958). In this report, the general timing of the seasonal chinook runs was determined by counts at Bonneville Dam. Tag recoveries by date of tagging have been used to determine timing of the various tributary races through the lower Columbia River.

TAGGING AND RECOVERY METHODS

Tagging Methods

This paper is based on 25 tagging programs from 1947-65 in which Fish Commission of Oregon personnel participated and from which tags were recovered (Table 1). Fish were tagged at locations ranging from Sand Island, almost at the mouth of the Columbia River, to Bonneville Dam, a distance of about 145 miles (Figure 1).

The river is divided into statistical zones which facilitates analysis of catches. Boundaries of these areas correspond to State of Washington county boundaries, except for the upper limit of Zone 5. The present upstream deadline is 5 miles below Bonneville Dam. Commercial fishing, except by Indians, has not been allowed above Bonneville Dam since 1957.

Chinook were captured for tagging by diver and floater drift gill nets, set nets, commercial-type traps, and fish ladder and elevator traps (Table 1). Several types of tags were used during the various tagging programs: (1) Petersen discs; (2) spaghetti tags (plastic tubing); (3) streamers; (4) hog rings; and (5) nylon dart-type tags. Petersen disc tags were used predominantly in years prior to 1960 and were applied at the origin of the dorsal fin with nickel or stainless steel pins. Spaghetti tags were applied just below and slightly forward of the insertion of the dorsal

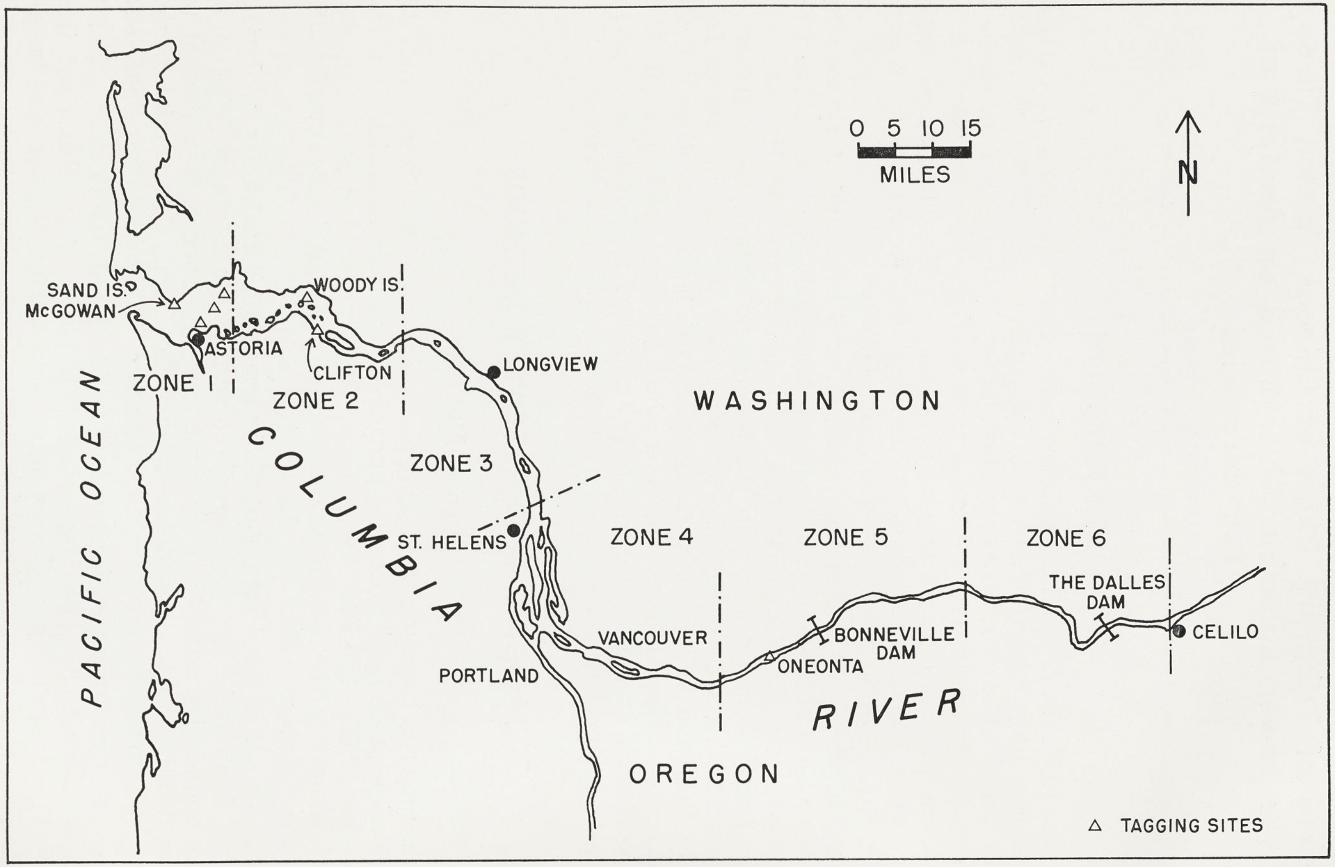

Figure 1—*Map of tagging sites and commercial fishery statistical zones in the lower Columbia River.*

Table 1—*Summary of Columbia River chinook tagging by zone and year, 1947-65.*

Zone and year	Tagging area	Tagging period	Number of tagging days	Number tagged	Gear used	Type of tag	Number of tag recoveries①	Per cent recovered
Zones 1 and 2								
1947	Sand Island	Aug. 18-Aug. 24	5	437	Comm. Trap	Petersen disc	5	1.1
	Woody Island	Aug. 28-Sept. 8	12	2,201	Comm. Trap	Petersen disc	41	1.9
1948	Sand Island	July 25-Sept. 10	7	410	Comm. Trap	Petersen disc	10	2.4
	Clifton	Mar. 31-Apr. 29	22	282	Gill net	Petersen disc	3	1.1
	Skamakawa-Clifton	Sept. 2-Sept. 7	4	518	Comm. Trap	Petersen disc	10	1.9
1949	Clifton	Mar. 10-Apr. 26	47	378	Gill net	Petersen disc and/or hog rings	16	4.2
1951	Sand Island	Aug. 12-Nov. 8	48	1,531	Comm. Trap	Petersen disc	143	9.3
1952	McGowan	May 11-Oct. 20	113	829	Comm. Trap	Petersen disc	55	6.6
1953	McGowan	Mar. 4-Oct. 16	148	746	Comm. Trap	Petersen disc	40	5.4
1954-55	Astoria-Altoona	Jan. 12-Apr. 25	47	1,486	Gill net	Petersen disc or spaghetti	48	3.2
1955-56	Woody Island	Dec. 2-Mar. 30	26	520	Gill net	Petersen disc or spaghetti	30	5.8
1960	Woody Island	Mar. 15-Apr. 28	23	827	Gill net	Nylon dart	31	3.7
1961	Woody Island	Mar. 11-Apr. 24	22	584	Gill net	Nylon dart	77	13.2
1962	Woody Island	Mar. 15-Apr. 24	21	686	Gill net	Nylon dart	51	7.4
1963	Woody Island	Mar. 15-Apr. 26	22	490	Gill net	Nylon dart	27	5.5
1964	Woody Island	Mar. 17-Apr. 26	22	346	Gill net	Nylon dart	34	9.8
1965	Woody Island	Mar. 15-Apr. 24	21	726	Gill net	Nylon dart	11	1.5
TOTAL ZONES 1 & 2				12,998			632	4.9

Table 1—*Summary of Columbia River chinook tagging by zone and year, 1947-65.—Continued*

Zone and year	*Tagging area*	*Tagging period*	*Number of tagging days*	*Number tagged*	*Gear used*	*Type of tag*	*Number of tag recoveries*①	*Per cent recovered*
Zone 5								
1948	Oneonta	Aug. 22-Sept. 7	6	646	Comm. Trap	Petersen disc	181	28.0
	Bonneville Dam	May 11-Sept. 16	31	1,467	Fishway Trap	Petersen disc	37	2.5
1949	Bonneville Dam	June 20-Sept. 15	34	871	Elevator	Petersen disc and/ or hog ring	32	3.7
1950	Bonneville Dam	Aug. 16-Sept. 27	23	1,425	Elevator and floating trap	Petersen disc and/ or streamer	64	4.5
1951	Bonneville Dam	Apr. 30-Aug. 8	26	592	Floating Trap	Petersen disc	13	2.2
1954	St. Helens-Oneonta	June 15-June 23	8	125	Comm. Trap	Petersen disc	4	3.2
1956	Bonneville Dam	May 9-Sept. 27	43	4,383	Floating Trap	Petersen disc	726	16.6
1957	Bonneville Dam	June 3-Sept. 20	89	6,020	Floating Trap	Petersen disc	335	5.6
TOTAL ZONE 5				15,529			1,388	8.9
GRAND TOTAL				28,527			2,020	7.1

① Commercial fishery recoveries not included.

fin. The spaghetti tag was applied with a long, straight aluminum needle and a simple overhand knot was used to tie the ends. During three experiments a few streamers and hog rings were used in conjunction with Petersen discs to determine retention of different types of tags. During 1960-65 test fishing operations, dart-type plastic tags were used. These tags consisted of a vinyl dart attached to a 3-inch length of spaghetti vinyl which in turn was glued to a numbered vinyl "flag." These tags were placed in the flesh of the fish near the insertion of the dorsal fin and lodged between the interspinous bones to help prevent tag loss. Approximately 46% (12,988 fish) of the fish were tagged in the Columbia River in Zones 1 and 2 from Sand Island near the mouth to Clifton, a distance of 33 miles. The remaining 54% (15,529 fish) were tagged at or near Bonneville Dam in Zone 5. In one experiment 94 fish were tagged in Zone 4, but because of the nearness to Bonneville Dam and for ease of data tabulation, these fish were included in Zone 5. To avoid repetition of the zonal designation when referring to tagging sites, the terms "lower river" for Zones 1 and 2 and "Bonneville area" for Zone 5 are also used.

Tagging programs by time period are indicated in Table 1. In many cases, tagging was conducted only during one seasonal run. However, fish were tagged during the McGowan experiments in 1952 and 1953, and at Bonneville in 1948, 1949, 1956, and 1957 throughout most of the spring, summer, and fall seasons.

Recovery Methods

The sources of tag recoveries used in this paper were: (1) sport fishery; (2) hatcheries; (3) Indian fishery; (4) spawning ground surveys; and (5) other, which includes fish taken at fishways and found dead in areas other than spawning grounds. Commercial fishery recoveries were not used, nor were recoveries of any kind in the main Columbia River or main Snake River below Brownlee Dam. A recovery of only one tag in a tributary for all seasons was not used.

The Columbia River drainage was divided into four geographical categories progressing upstream: (1) the lower Columbia River section—from the mouth upstream 125 miles through Zone 4; (2) middle Columbia River tributaries from Zone 5 upstream to the Snake River; (3) Snake River and tributaries; and (4) upper Columbia River and tributaries. Recoveries were tabulated by tagging area and recovery area for 2,020 tags recovered from 1947-65.

DESIGNATION OF MAJOR RUNS

Bonneville Dam Counts

Designation of the major runs of chinook in the Columbia River—spring, summer, and fall—are made according to time of passage over Bonneville Dam as recorded by the U. S. Army Corps of Engineers.[1] Daily

[1] Annual Fish Passage Report, Bonneville, The Dalles, McNary, and Ice Harbor Dams. Prepared by U. S. Army Engineer Districts, Portland and Walla Walla, Corps of Engineers.

counts of chinook over Bonneville Dam for 1964 illustrate division of seasonal groups by time of migration (Figure 2). Spring chinook pass the dam from March 1 to May 31; summer chinook from June 1 to July 31; and fall chinook from August 1 to November 30. This division is arbitrary as there is overlap and variation between years, however, based on past information, these dates appear to be satisfactory for a general division of chinook runs and are used by the fisheries agencies in management compilations.

Seasonal Date of Tagging

Although gross migrational seasons can be established by Bonneville counts, a different time period must be used for fish tagged below Bonneville Dam. The following criteria were used to allow for the mileage differences between Zones 1 and 2 and Bonneville Dam:

Spring—tagged before May 17
Summer—tagged from May 18 to July 16
Fall—tagged July 17 or later

RESULTS AND DISCUSSION

Each tributary race is discussed by seasonal group and location in the Columbia River system, pointing out time of passage through the tagging area. A map of the Columbia River basin is presented in Figure 3 locating various tributaries where tagged chinook were recovered.

The major problems which prohibit a more detailed analysis of tagging data are as follows:

1. Tagging intensity was not always proportional to the run.

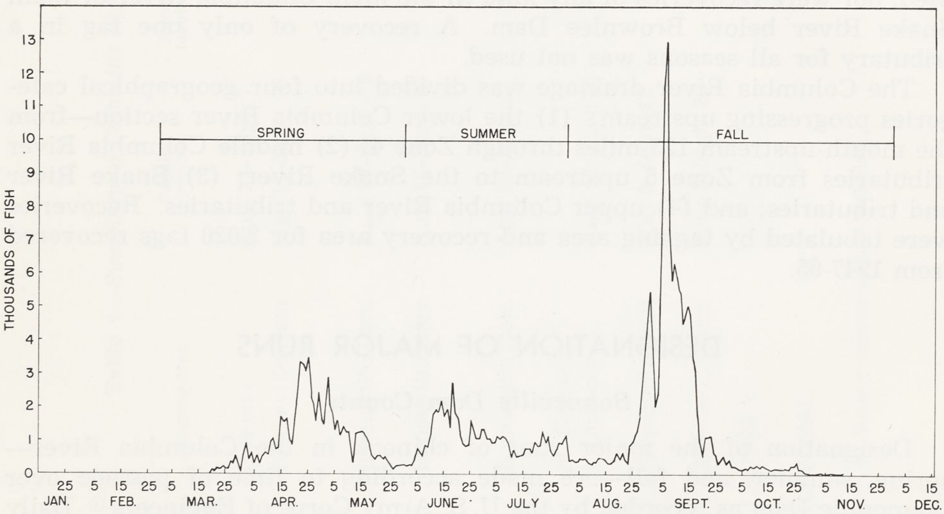

Figure 2—*Daily counts of chinook salmon over Bonneville Dam for 1964, indicating division of runs by time of migration.*

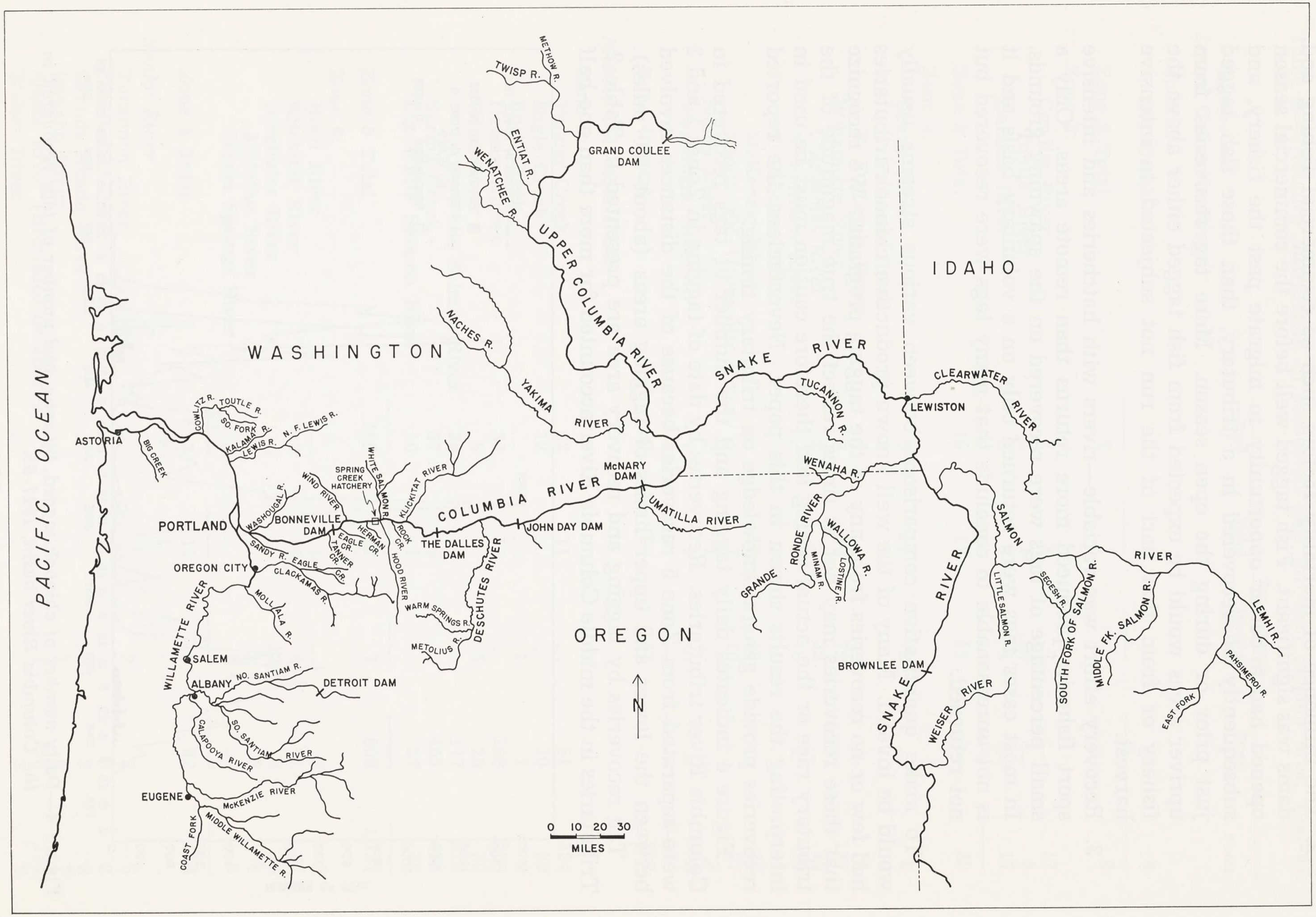

Figure 3—*Map of the Columbia River system.*

2. The influence of mortality factors such as commercial fishing and dams was significant. Fish tagged well before the commercial season opened had a better opportunity to migrate past the fishery, and subsequently be recovered in a tributary, than those fish tagged just prior or during the open season. More tag recoveries from upriver areas would be expected from fish tagged either above the fishery or from that part of the run not subjected to intensive harvest.
3. Recovery effort was variable—rivers with hatcheries and intensive sport fisheries produced more returns than remote areas. Only a small percentage of tags were recovered on the spawning grounds. In most cases tags were returned only on a voluntary basis and it is not unreasonable to conclude that many tags were recovered but not returned.

To make quantitative comparisons between various streams usually would be invalid. Many of the well known productive chinook tributaries had few or no recoveries from any of the tagging programs. We recognize that these recoveries may not at times reflect the true magnitude of the tributary race or the actual timing and therefore caution must be used in interpreting the results shown in this paper. Nevertheless, the reported recoveries provide general knowledge on tributary timing.

Figure 4 indicates daily tagging and the number of tags recovered in Columbia River tributaries. Recoveries by date of tagging in Zones 1 and 2 were separated from Zone 5 recoveries because of the distances involved between the lower and upper limits of tagging areas (about 150 miles).

Tag recoveries by tagging and recovery area are presented in Table 2. Tributaries in the middle Columbia River accounted for more than one-half

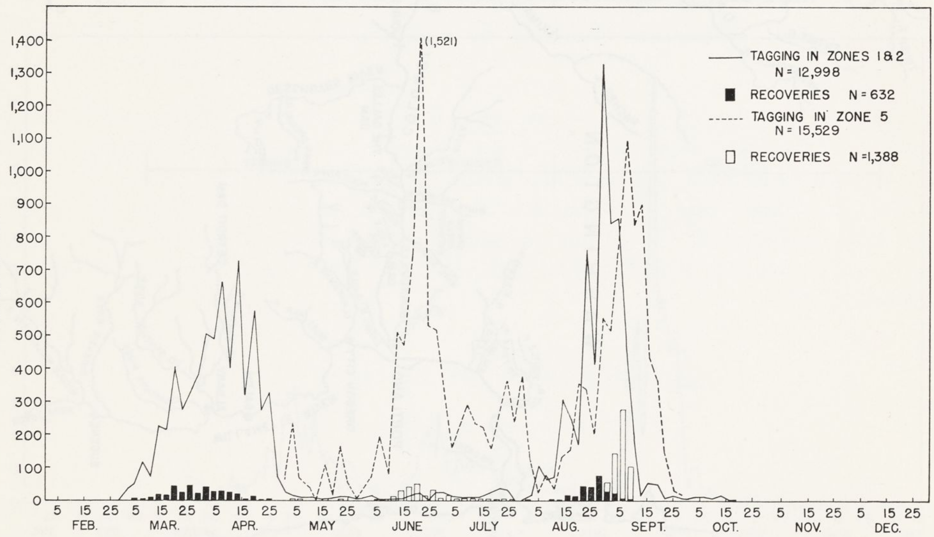

Figure 4—*Daily number of chinook tagged, by zone, and number of tags recovered in the Columbia River basin, 1947-65.*

Table 2—*Tributary distribution of recovered tags for each tagging area, 1947-65.*

Recovery area	*Zone 1*	*Zone 2*	*Woody Island*(1)	*Zone 5*	*Total*
	Tagging area				
Lower Columbia River					
Zone 2:					
Big Creek	7	1	....	....	8
Zone 2 Total	7	1	....	....	8
Zone 3:					
Cowlitz River	7	3	7	....	17
Toutle River	4	1	....	....	5
Kalama River	5	8	4	....	17
Zone 3 Total	16	12	11	....	39
Zone 4:					
Lewis River	5	1	2	....	8
N. F. Lewis River	4	5	....	....	9
E. F. Lewis River	4	....	....	....	4
Willamette River	8	57	72	....	137
Clackamas River	2	2	22	....	26
N. Santiam River	....	3	16	....	19
S. Santiam River	....	3	1	....	4
McKenzie River	....	10	18	....	28
Middle Fk. Willamette River	4	7	16	....	27
Sandy River	2	1	....	....	3
Washougal River	1	1	....	....	2
Zone 4 Total	30	90	147	....	267
Middle Columbia River					
Zone 5:					
Tanner Creek	62	11	....	51	124
Eagle Creek	12	....	....	10	22
Rock Creek	....	....	1	1	2
Herman Creek	39	12	....	158	209
Wind River	5	....	5	20	30
Little White Salmon River	34	4	1	177	216
Spring Creek	37	4	....	455	496
Big White Salmon River	10	1	....	27	38
Zone 5 Total	199	32	7	899	1,137
Zone 6:					
Hood River	....	1	....	2	3
Klickitat River	2	10	4	71	87
Deschutes River	....	....	12	6	18
Metolius River	....	....	1	3	4
Warm Springs River	....	....	2	....	2
Zone 6 Total	2	11	19	82	114
Snake River					
Tucannon River	....	....	2	3	5
Clearwater River	....	....	....	2	2
Grande Ronde River	....	....	....	3	3
Imnaha River	....	....	1	6	7
Snake River (Brownlee or above)	....	....	1	153	154
Weiser River	....	....	....	2	2

Table 2—*Tributary distribution of recovered tags for each tagging area, 1947–65.—Continued*

Recovery area	*Zone 1*	*Zone 2*	*Woody Island*①	*Zone 5*	*Total*
Salmon River					
Lower Main Stem②	....	....	....	6	6
Little Salmon River	....	....	....	4	4
South Fork Salmon River	....	....	....	54	54
Secesh River	....	....	....	6	6
East Fork of S. F. Salmon River	....	....	....	15	15
Middle Fork Salmon River	....	....	15	23	38
Upper Main Stem	1	1	8	69	79
E. Fork Salmon River	....	....	1	1	2
Pahsimeroi River	....	....	....	2	2
Lemhi River	....	....	5	....	5
Upper Columbia River					
Yakima River	....	....	8	3	11
Naches River	....	....	1	2	3
Wenatchee River	2	....	....	38	40
Entiat River	....	....	....	13	13
Methow River	....	....	....	4	4
Total Lower Columbia River	53	103	158	....	314
Total Middle Columbia River	201	43	26	981	1,251
Total Snake River	1	1	33	349	384
Total Upper Columbia River	2		9	60	71
Grand Total	257	147	226	1,390	2,020

① Test fishing at Woody Island (Zone 2).
② Below the Middle Fork Salmon River.

of the total tag recoveries; many of these streams have hatcheries located on them. Spring chinook enter some of these streams, however they are principally known for their fall chinook runs.

Table 3 records the method of tag recovery by area. Hatchery returns were the primary method of recovery, at least in Zones 5 and 6, while sport and Indian fishing accounted for most of the recoveries in the other zones and in the area above the Klickitat River.

Histograms indicating tag recoveries by date of tagging are presented for spring, summer, and fall runs, and listed by the four major geographical segments of the Columbia River drainage. Recoveries are also separated by zone of tagging (Figures 5-7).

Spring Chinook

Lower Columbia River

Two hundred and fifty-eight recoveries were made from tagging in Zones 1 and 2 (Figure 5). The Cowlitz and Willamette rivers are the only two tributaries downstream from Bonneville Dam considered to have substantial runs of spring chinook (Wendler, 1959). The Cowlitz River and its major tributary, the Toutle River, provided 11 recoveries ranging in date of tagging from March 17 to April 18.

Table 3—*Tributary distribution of recovered tags by method of recovery, 1947-65.*

Recovery area	Sport	Hatchery	Indian	Spawning grounds	Other①	Total
	Method of recovery					
Lower Columbia River						
Zone 2:						
Big Creek	....	1	....	....	7	8
Zone 2 Total	....	1	....	....	7	8
Zone 3:						
Cowlitz River	14	....	....	2	1	17
Toutle River	4	....	....	....	1	5
Kalama River	9	3	....	2	3	17
Zone 3 Total	27	3	....	4	5	39
Zone 4:						
Lewis River	4	....	....	....	4	8
N. F. Lewis River	4	....	....	....	5	9
E. F. Lewis River	2	....	....	....	2	4
Willamette River	134	....	....	....	3	137
Clackamas River	7	14	....	....	5	26
N. Santiam River	2	17	....	....	....	19
S. Santiam River	1	....	....	....	3	4
McKenzie River	11	....	....	1	16	28
Middle Fork Willamette River	11	12	....	....	4	27
Sandy River	1	....	....	....	2	3
Washougal River	1	1	....	....	....	2
Zone 4 Total	178	44	....	1	44	267
Middle Columbia River						
Zone 5:						
Tanner Creek	....	114	....	....	10	124
Eagle Creek	5	13	....	....	4	22
Rock Creek	....	....	1	....	1	2
Herman Creek	....	193	....	....	16	209
Wind River	3	21	....	1	5	30
Little White Salmon River	5	180	....	....	31	216
Spring Creek	....	496	....	....	....	496
Big White Salmon River	....	28	....	....	10	38
Zone 5 Total	13	1,045	1	1	77	1,137
Zone 6:						
Hood River	2	....	....	....	1	3
Klickitat River	4	58	14	....	11	87
Deschutes River	14	....	....	....	4	18
Metolius River	1	3	....	....	....	4
Warm Springs	....	....	1	1	....	2
Zone 6 Total	21	61	15	1	16	114

Table 3—*Tributary distribution of recovered tags by method of recovery, 1947-65.—Continued*

Recovery area	*Sport*	*Hatchery*	*Indian*	*Spawning grounds*	*Other*①	*Total*
	Method of recovery					
Snake River						
Tucannon River	5	....	....	....	....	5
Clearwater River	....	....	....	....	2	2
Grande Ronde River	1	....	....	1	1	3
Imnaha River	3	....	....	2	2	7
Snake River (Brownlee or above)	7	144	....	3	....	154
Weiser River	2	....	....	....	....	2
Salmon River						
Lower Main Stem②	6	....	....	....	....	6
Little Salmon River	4	....	....	....	....	4
S. F. Salmon River	52	....	....	....	2	54
Secesh River	6	....	....	....	....	6
E. F. of S. F. Salmon River	15	....	....	....	....	15
Middle Fork Salmon River	29	....	....	2	7	38
Upper Main Stem	78	....	....	....	1	79
E. F. Salmon River	2	....	....	....	....	2
Pahsimeroi River	2	....	....	....	....	2
Lemhi River	3	....	....	1	1	5
Upper Columbia River						
Yakima River	6	....	5	....	....	11
Naches River	....	....	....	1	2	3
Wenatchee River	2	....	2	....	36	40
Entiat River	....	13	....	....	....	13
Methow River	....	1	....	1	2	4
Total Lower Columbia River	205	48	....	5	56	314
Total Middle Columbia River	34	1,106	16	2	93	1,251
Total Snake River	215	144	....	9	16	384
Total Upper Columbia River	8	14	7	2	40	71
Grand Total	462	1,312	23	18	205	2,020

① Includes fish taken in experimental traps, found dead on banks, trapped or found in fish ladders, or taken at counting weirs.
② Below the Middle Fork Salmon River.

Four recoveries were made in the Kalama River of fish tagged from March 25 to April 18, and two recoveries were reported in the Lewis River of fish tagged on March 23 and 25. These two tributaries have spring-run fish, but are considered to be of more importance as fall chinook streams. The fact that only two recoveries of fish tagged after mid-April were made in these tributaries probably results from catch of fish by the commercial fishery. But, it also suggests that the peak passage period may occur before mid-April since substantial numbers of fish were tagged after that time.

Galbreath (1965) used Willamette River chinook tag recoveries and other data to point out timing of Willamette spring chinook. Indications were that the majority of Willamette spring chinook migrate through the lower Columbia during late March and early April and show peak abundance in the lower Willamette in April.

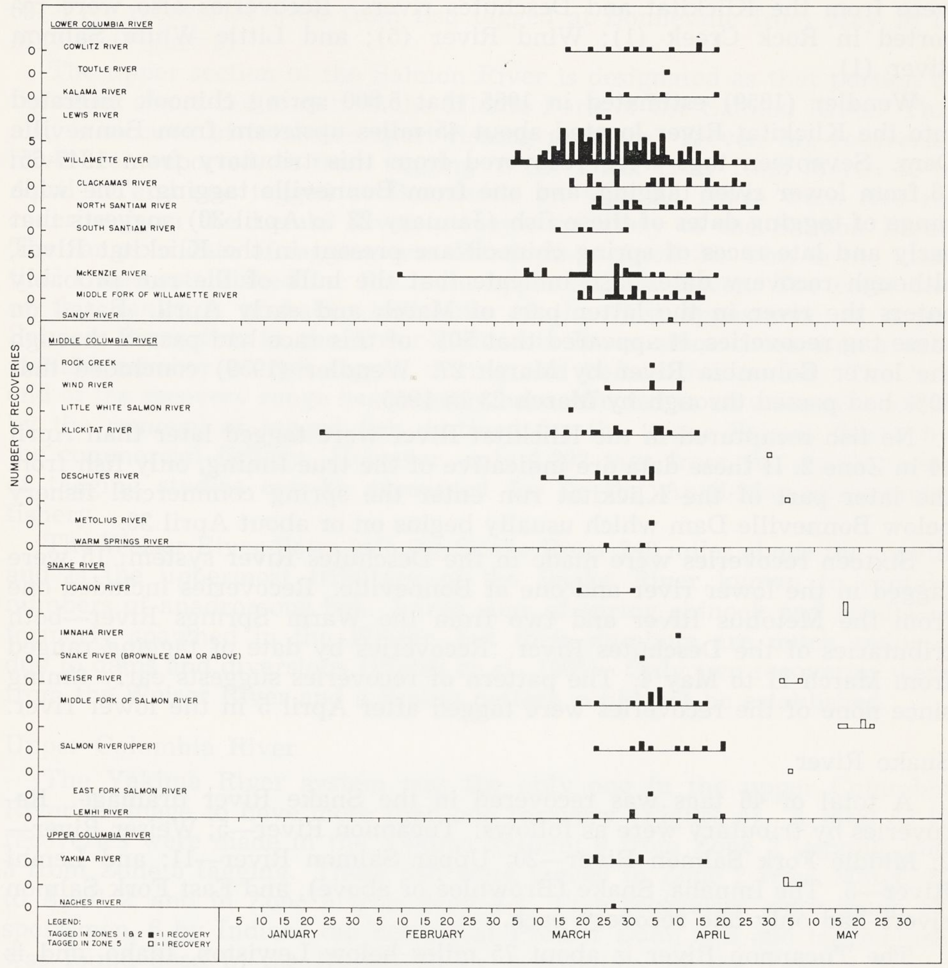

Figure 5—*Recoveries of tagged spring chinook salmon in tributaries of the Columbia River by date of tagging, January-May 1947-65.*

The range in dates of tagging for the main Willamette River chinook recoveries approximates that of the five spawning tributaries of consequence: Clackamas River (25 recoveries); North Santiam River (19); South Santiam River (4); McKenzie River (28); and Middle Fork Willamette River (27). Chinook entering the McKenzie River—the most important natural spawning tributary of the Willamette—have the greatest distance to travel and, based on tag recoveries, appear to enter the Columbia River slightly earlier than those fish destined for other tributaries of the Willamette River. Only one recovery was made in the Sandy River and of course could not indicate timing in this stream.

Middle Columbia River

Forty spring chinook tag recoveries were made from tributaries in the middle Columbia River area (Figure 5). Thirty-three of these recoveries were from the Klickitat and Deschutes rivers. Recoveries also were reported in Rock Creek (1); Wind River (5); and Little White Salmon River (1).

Wendler (1959) estimated in 1955 that 5,800 spring chinook migrated into the Klickitat River located about 45 miles upstream from Bonneville Dam. Seventeen tags were recovered from this tributary from 1947-65: 16 from lower river tagging, and one from Bonneville tagging. The wide range of tagging dates of these fish (January 23 to April 30) suggests that early and late races of spring chinook are present in the Klickitat River, although recovery dates also indicate that the bulk of the run probably enters the river in the latter part of March and early April. Based on these tag recoveries, it appeared that 50% of this race had passed through the lower Columbia River by March 27. Wendler (1959) concluded that 50% had passed through by March 23 in 1955.

No fish recaptured in the Klickitat River were tagged later than April 14 in Zone 2. If these data are indicative of the true timing, only fish from the later part of the Klickitat run enter the spring commercial fishery below Bonneville Dam which usually begins on or about April 30.

Sixteen recoveries were made in the Deschutes River system; 15 were tagged in the lower river and one at Bonneville. Recoveries included one from the Metolius River and two from the Warm Springs River—both tributaries of the Deschutes River. Recoveries by date of tagging ranged from March 11 to May 4. The pattern of recoveries suggests early timing since none of the recoveries were tagged after April 5 in the lower river.

Snake River

A total of 46 tags was recovered in the Snake River drainage. Recoveries by tributary were as follows: Tucannon River—5; Weiser River—2; Middle Fork Salmon River—20; Upper Salmon River—11; and Lemhi River—5. The Imnaha, Snake (Brownlee or above), and East Fork Salmon rivers had only one recovery each.

The Tucannon River is about 75 miles below Lewiston, Idaho, and is the only tributary of consequence in the lower Snake River between the mouth and Lewiston. A total of five recoveries were made in the Tucannon River; two from lower river tagging on March 19 and 31, and three from Zone 5 tagging on May 17 (Figure 5). The latter would be comparable to passage near the mouth of the Columbia River in late April or early May; thus a considerable range in timing is evident for this group of fish. All of these recoveries were made by sport fishing. It is interesting to note that three of the five recoveries had been tagged on one day in 1956. Although only one recovery was made in the Imnaha River (tagged April 10 in Zone 2) this river is considered to have a good run of spring chinook (Thompson *et al.*, 1958).

The Middle Fork Salmon River is one of the principal spawning tributaries for spring chinook above Bonneville Dam. There is also an intensive sport fishery in this river. Of fifteen recoveries made of fish tagged in the lower river from March 19 to April 14, 85% were on sport gear. These recoveries were from fish tagged during test fishing operations from 1961-

65. Five recoveries were from fish tagged at Bonneville from May 16 to May 23 (Figure 5).

The upper section of the Salmon River is designated as that portion of the river above the mouth of the Middle Fork of the Salmon River. This also is an area of intensive sport fishing pressure. Eleven tag recoveries have been reported, 10 from tagging in the lower river from March 23 to April 20 and one tagged at Bonneville on May 4. There were five recoveries from the Lemhi River, a major tributary of the Salmon River. The range in date of tagging was March 23 to April 20. This is the identical range established for the main upper Salmon River. The early end of this range is probably indicative of the first appearance of upper Salmon River fish in the lower Columbia River since there was a substantial number of fish tagged during and before this period. The late end of the recovery range has possibly been affected to an unknown extent by the removal of tagged fish destined for the upper Salmon River by the commercial fishery. However, only 1,202 tags from the entire series of tagging studies can be accounted for in the April-May commercial fishery.

The Weiser River flows into the Snake River 348 miles above the mouth and is the uppermost tributary of the Snake River known to contain numbers of anadromous fish. Large runs of spring chinook and steelhead formerly spawned in the Weiser, but their numbers are much reduced due to dams and diversions (Welsh *et al.*, 1965). Only two recoveries were from the Weiser River and a timing pattern could not be established.

Upper Columbia River

The Yakima River system was the only one in the upper Columbia River drainage to have more than one recovery (Figure 5). A total of 12 recoveries were made in the Yakima system; 9 from Zone 2 tagging, and 3 from Zone 5 tagging. These fish were tagged in Zone 2 from March 21 to April 2, and in Zone 5 from May 4-7. Five recoveries were made by sportsmen, 6 by Indians dip netting at Prosser Dam, and one tagged fish was found dead in the Naches River, a tributary of the Yakima River. The Zone 5 tagging dates suggest that a segment of the Yakima run is exposed to commercial fishing below Bonneville Dam after April 30.

Summer Chinook

Lower Columbia River

Only one recovery was made of a possible summer run chinook in lower river tributaries during the 13 years of tagging (Figure 6). This recovery was from the Clackamas River and was tagged on June 8. Because summer chinook are separated from spring chinook by a fixed date, this recovery is considered as a summer run chinook. However, most chinook migrating to the Clackamas River are considered as belonging to the spring run.

Middle Columbia River

The Deschutes River and a tributary, the Metolius River, were the major Middle Columbia River streams in which tagged summer chinook were recovered. Five recoveries in the Deschutes River had been tagged between June 13 and July 15. The three recoveries in the Metolius River had been tagged during July 1 to July 22. These fish were all tagged at Bonneville.

One fish tagged in Zone 1 on July 3 and captured at Oxbow Hatchery on Herman Creek was the only recovery from lower Columbia River tagging taken in the Middle Columbia River area. One recovery each was made in the Wind, Little White Salmon, Hood, and Klickitat rivers from tagging in Zone 5. Tagging dates of these recoveries were from June 4 to July 23. It is likely that these were strays or late spring or early fall run fish since these streams are not considered to contain summer-run stocks.

Snake River

The Snake River and its tributaries contributed 188 recoveries as follows: Clearwater River—2; Grande Ronde River—3; Imnaha River—6; Snake River (Brownlee or above)—3; Salmon River (lower)—6; Little Salmon River—4; South Fork Salmon River—54; Secesh River—6; East Fork of South Fork Salmon River—15; Middle Fork Salmon River—18; Salmon River (upper)—68; East Fork Salmon River—1; and Pahsimeroi River—2.

The two recoveries made on the Clearwater River, which flows into the Snake River at Lewiston, Idaho, were tagged at Bonneville between June 12-16. These recoveries are considered unusual since the chinook run in the Clearwater River was almost exterminated by a dam many years ago and only a token remnant run remains. The total chinook count at the Lewiston Dam in 1957, the year the recoveries were made, was only 152 fish.

No recoveries were made in the main Grande Ronde River, but one recovery was recorded in each of three of its tributaries—the Wenaha, Wallowa, and Minam rivers. The three fish were tagged at Bonneville from June 18 to June 22. Although only summer chinook tag recoveries were made in the Grande Ronde River system, annual spawning grounds surveys and recoveries from tagging at Lewiston on the Snake River in 1954-56 indicated that the Grande Ronde River system is also well utilized by spring chinook (Thompson *et al.*, 1958).

Six fish tagged at Bonneville were recovered in the Imnaha River. These fish were tagged from June 14 to July 8. Although field observations made during spawning ground surveys have failed to verify the presence of two distinct chinook spawning populations in the Imnaha River, these fish must be considered summer fish, at least by the method used to separate runs in this report. Spawning ground records over a period of 12 years indicate that the Imnaha River is probably the most consistently productive chinook salmon tributary for its size in eastern Oregon.

Three recoveries were made on the main Snake River of fish tagged at Bonneville from June 12 to July 23. All recoveries were made from the trap at Brownlee Dam.

Most of the recoveries in the Salmon River and its tributaries were from fish tagged at Bonneville. Dates of tagging were June 2-20 for lower

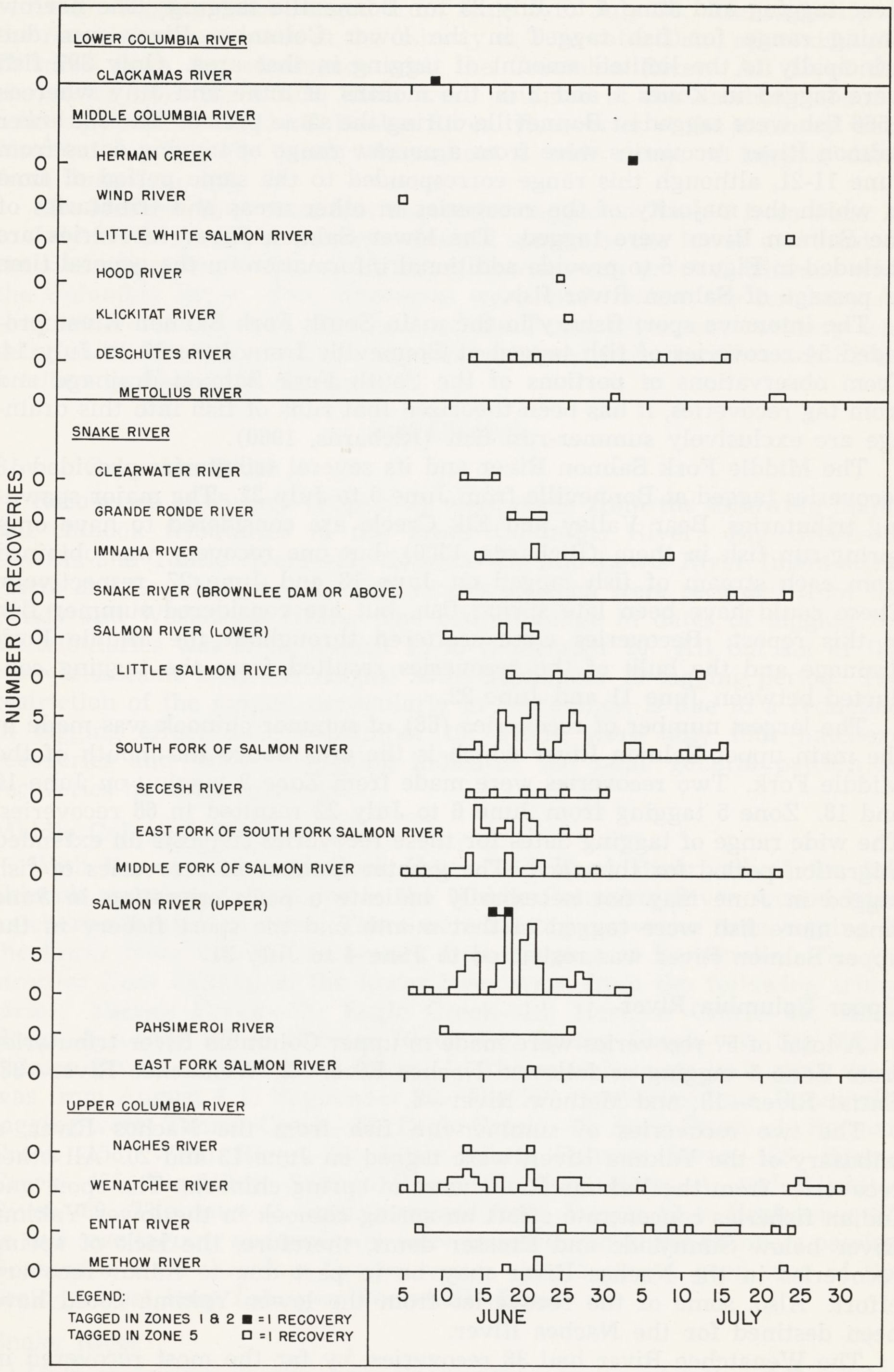

Figure 6—*Recoveries of tagged summer chinook in tributaries of the Columbia River by date of tagging, June-July 1947-65.*

river tagging and June 4 to July 23 for Bonneville tagging. The narrow timing range for fish tagged in the lower Columbia River was due principally to the limited amount of tagging in that area. Only 397 fish were tagged in Zones 1 and 2 in the months of June and July whereas 7,566 fish were tagged at Bonneville during the same period. The six lower Salmon River recoveries were from a narrow range of tagging dates from June 11-21, although this range corresponded to the same period of time in which the majority of the recoveries in other areas and tributaries of the Salmon River were tagged. The lower Salmon River recoveries are included in Figure 6 to provide additional information on the general time of passage of Salmon River fish.

The intensive sport fishery in the main South Fork Salmon River provided 54 recoveries of fish tagged at Bonneville from June 12 to July 14. From observations of portions of the South Fork Salmon drainage and from tag recoveries, it has been theorized that runs of fish into this drainage are exclusively summer-run fish (Richards, 1960).

The Middle Fork Salmon River and its several tributaries provided 18 recoveries tagged at Bonneville from June 5 to July 22. The major spawning tributaries, Bear Valley and Elk Creek, are considered to have only spring-run fish in them (Richards, 1960), but one recovery was obtained from each stream of fish tagged on June 13 and June 27, respectively. These could have been late spring fish, but are considered summer fish in this report. Recoveries were scattered throughout the Middle Fork drainage and the bulk of the recoveries resulted from the tagging conducted between June 11 and June 22.

The largest number of recoveries (68) of summer chinook was made in the main upper Salmon River which is the area above the mouth of the Middle Fork. Two recoveries were made from Zone 2 tagging on June 16 and 18. Zone 5 tagging from June 6 to July 22 resulted in 66 recoveries. The wide range of tagging dates for these recoveries suggests an extended migration period for this race. The greater number of recoveries of fish tagged in June may not necessarily indicate a peak migration in June since more fish were tagged in that month and the sport fishery in the upper Salmon River was restricted to June 4 to July 31.

Upper Columbia River

A total of 57 recoveries were made in upper Columbia River tributaries from Zone 5 tagging as follows: Naches River—2; Wenatchee River—38; Entiat River—13; and Methow River—4.

The two recoveries of summer-run fish from the Naches River, a tributary of the Yakima River, were tagged on June 13 and 20. All other recoveries from the Yakima River were of spring chinook. The sport and Indian fisheries concentrate effort on spring chinook in the lower Yakima River below Sunnyside and Prosser dams, therefore, the lack of spring recoveries in the Naches River may be in part due to minor recovery effort. Also, some of the recoveries from the lower Yakima could have been destined for the Naches River.

The Wenatchee River had 38 recoveries, by far the most recovered in the upper Columbia River system. Most of these fish were tagged in June although tagging dates ranged from June 5 to July 30. The majority of the recoveries were made at the fishway at Tumwater Dam, approximately 28 miles from the confluence with the Columbia River. All 13 of the recoveries from the Entiat River were obtained at the hatchery about 3 miles upstream from the Columbia River. Recoveries at the hatchery were distributed relatively evenly throughout a wide range of tagging dates from June 7 to July 24.

The Methow River had four recoveries tagged in Zone 5 from June 18 to July 23. Most of the summer chinook spawn in the lower one-third of the river from the Winthrop Hatchery downstream to its confluence with the Columbia River. Two recoveries were made below the hatchery on the main river and near the mouth of the Twisp River, one recovery was taken at the hatchery, and one tag was recovered from the Chewack River, a tributary above the hatchery.

Fall Chinook

Lower Columbia River

Recoveries of 55 tags (Figure 7) were made from the following major fall chinook tributaries in the lower Columbia River: Big Creek—8; Cowlitz and Toutle rivers—11; Kalama—13; and Lewis River (main stem, North and East Forks)—19. Two recoveries each were recorded from the Sandy and Washougal rivers. The overall range in dates of tagging for all tributaries was from August 15 to September 20. All but six of the recoveries came from the August 20 to September 10 tagging period. The restriction of the ranges, particularly in September, is due to a reduction in tagging effort after September 10. There were only four hatchery recoveries and dates of tagging indicated the same general pattern as recoveries by other methods.

Middle Columbia River

With the exception of Rock Creek and Hood River, all of the fall chinook spawning tributaries in the Middle Columbia River section have hatcheries located on them. There were 231 tag recoveries from tagging in the lower river and 967 recoveries from tagging at Bonneville. The recoveries from tagging in the lower river were from the following tributaries: Tanner Creek—73; Eagle Creek—12; Herman Creek—50; Wind River—5; Little White Salmon River—38; Spring Creek—41; Big White Salmon River—11; and Hood River—1. The overall range in tagging dates was from August 4 to September 20. The 967 recoveries from Bonneville tagging were: Tanner Creek—51; Eagle Creek—10; Rock Creek—1; Herman Creek—158; Wind River—19; Little White Salmon River—176; Spring Creek—455; Big White Salmon River—27; Hood River—1; and Klickitat River—69. The dates of tagging ranged from August 12 to September 27. In this case tagging and recovery were proportional to the numbers passing Bonneville Dam therefore the recoveries should give a good idea of the timing of hatchery fish over Bonneville Dam.

Snake River

Only recoveries on the main Snake River in the vicinity of Brownlee Dam or above were used. Recoveries were made from fish tagged in

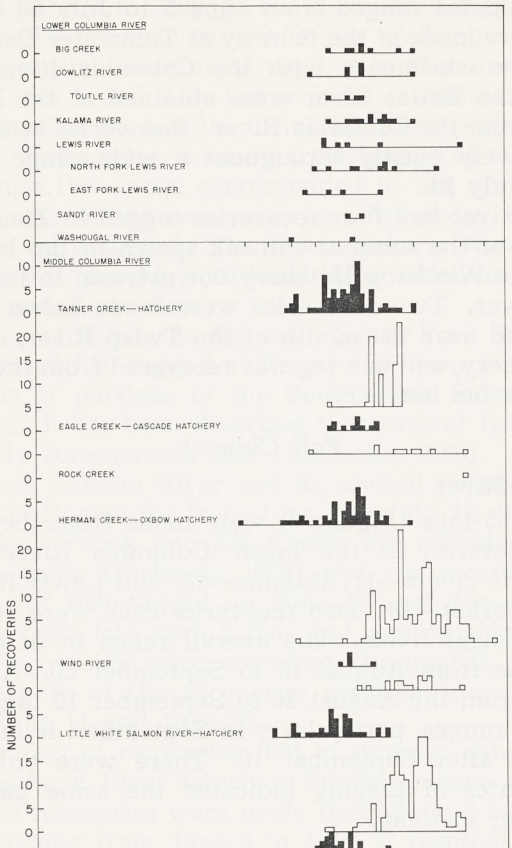

Figure 7—*Recoveries of tagged fall chinook in the Columbia River by tributary and date of tagging, August-September 1947-65.*

Zone 5 (Figure 7). Most of the recoveries came from the trap at Brownlee Dam, and unfortunately were all from one tagging experiment at Bonneville in 1957. Tagging dates of recoveries ranged from August 12 to September 18. Chinook are known to spawn in the main Snake River below Brownlee Dam, but no means of tag recovery exists in this area.

Upper Columbia River

The Wenatchee River was the only upper Columbia River tributary from which tag recoveries were reported. Two recoveries were made with Indian dip nets at Tumwater Dam. These fish had been tagged in Zone 1 on August 19 and September 1.

No fall chinook have been counted over Roza Dam on the Yakima River although they are present in the lower river. Aerial redd counts are made each year, but no redds have been observed above Union Gap near Yakima, Washington.[1]

Although there was a lack of recoveries in the upper Columbia River basin, annual fish counts at McNary and Priest Rapids dams indicate that about 10% of the fall chinook passing Bonneville Dam reach the upper Columbia River drainage (Pirtle, 1957). Very important main-stem spawning areas are present in the Columbia River above McNary Pool, but water depth and visibility precluded tag recovery.

SUMMARY

The Fish Commission of Oregon and the Washington Department of Fisheries conducted extensive cooperative chinook salmon tagging programs in the Columbia River from 1947 to 1965. In 25 experiments a total of 28,527 chinook was tagged. Approximately 46% (12,998 fish) were tagged in Zones 1 and 2 from Sand Island to Clifton, a distance of about 33 miles, and 54% (15,529) were tagged in the vicinity of Bonneville Dam.

The objective of this report is to utilize tag recoveries by date of tagging to determine the time of passage of various tributary races of chinook through the lower Columbia River. The Columbia River was divided into four geographical categories for classification of recoveries: (1) lower Columbia River; (2) middle Columbia River; (3) Snake River; and (4) upper Columbia River. Seasonal designation of the three major runs of chinook was defined by daily fish passage counts at Bonneville Dam as follows: (1) spring—March 1 to May 31; (2) summer—June 1 to July 31; and (3) fall—August 1 to November 30.

Two thousand and twenty recoveries were obtained from the following sources: (1) sport fishing—464; (2) hatcheries—1,312; (3) Indian fishery—23; (4) spawning ground surveys—16; and (5) other—205 (fishways at dams, found dead on banks, traps, etc.). Tags were returned primarily on a voluntary basis, and probably many more tags were recovered but not returned. Problems encountered which precluded detailed analysis of tag recoveries were: (1) tagging and recovery intensity was not constant during a specific run and (2) differential mortality rates existed such as that caused by commercial fishing and dams. Information showing the

[1] Personal communication from Thomas Meekin, Washington Department of Fisheries, 1963.

general timing of chinook through the lower Columbia River was illustrated by plotting tributary tag recoveries by date of tagging.

Recoveries of 356 spring chinook ranged in date tagged from February 9 to April 27 for fish tagged in the lower river and March 11 to May 23 for tagging at Bonneville. The bulk of the recoveries were from tagging in the lower Columbia River test fishing and were recovered in lower river tributaries, particularly the Willamette River system, by the intensive Willamette sport fishery. Chinook destined for upriver tributaries appear to peak later in the lower Columbia than do fish destined for lower river tributaries.

Recoveries of 259 summer chinook ranged in date tagged from June 8 to July 3 for lower river tagging and June 4 to July 30 for tagging at Bonneville. Most recoveries were from Bonneville tagging and Snake and upper Columbia River tributaries all showed approximately the same time of migration through the Columbia River.

Only 55 recoveries of tagged fall chinook were made in lower Columbia River tributaries. Recoveries indicated essentially the same tagging date range for all tributaries—August 14 to September 20. The majority of the 1,350 recoveries upstream (excluding the Snake River) were of hatchery origin and ranged from August 4 to September 20 for tagging in the lower river and August 16 to September 27 for tagging at Bonneville. Recoveries from all hatcheries exhibited similar timing through the Columbia River with the peak migration period the last week of August for fish tagged in the lower river and about one week later for fish tagged at Bonneville. Snake River fall chinook exhibited the same approximate migrational timing at Bonneville as did hatchery fish passing upstream to the mid-Columbia hatcheries.

It is evident from a general analysis of the tagging data that the different tributary races of Columbia River chinook salmon within the spring, summer, and fall runs are intermingled in their migration through the lower river. For example, fall chinook destined for any particular tributary are not a separate entity or discrete population distinguishable by different timing through the fishery. Royal (1953) has shown the opposite to be true for different races of sockeye salmon *(Oncorhynchus nerka)* in the Fraser River. The fact that tributary races within a run of chinook salmon are intermixed when passing through the lower river fishery has significance from a management standpoint. It would be difficult to afford additional protection to chinook from any particular tributary race because of overlap in timing through the fishery.

ACKNOWLEDGMENTS

The fact that these tagging experiments cover a period of 19 years makes it impractical to name the many members of the Fish Commission of Oregon and Washington Department of Fisheries that shared in the planning, tagging, and recovery phases of these programs. The author wishes to express his appreciation to the entire group for their part in the eventual formulation of this paper.

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