EGG-TO-MIGRANT SURVIVAL OF SPRING CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) IN THE YAKIMA RIVER, WASHINGTON

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ABSTRACT

Egg-to-migrant survival for the 1957–61 broods ranged from 5.4 to 16.4 percent—the first estimates of survival of chinook salmon in a large river system.

Spring chinook salmon spawn in the American, Bumping, and Naches Rivers and Rattlesnake Creek—tributaries of the Yakima River—and in the upper stretch of Yakima River proper. For both sexes, spawning fish in the upper Yakima River are smaller than those in the other areas. Mean lengths (mideye to end of hypural plate) were 45.5 and 57.3 cm. for the males and females in the upper Yakima River and 65.4 and 71 cm. for the males and females in the other areas.

Spring chinook salmon migrate to sea in their second year. Larger fish migrate earlier in the season than do smaller fish. Seaward migration reaches a peak at Prosser, Wash., on the lower Yakima River between April 14 and May 19. Movement tends to be nocturnal.

Knowledge about the life history of a species of fish is fundamental to its effective management. For Pacific salmon (*Oncorhynchus* spp.), some conception is required of survival from the egg to the seaward migrant stage. Survival from egg to migrant has been measured for four of the five species that spawn in North America—sockeye, pink, chum, and coho salmon (*O. nerka, O. gorbuscha, O. keta,* and *O. kisutch*)—but comparable information is almost completely lacking for chinook salmon (*O. tshawytscha*). For the race of chinook salmon known as spring chinook, survival has never been measured mainly because this race spawns in large river systems where sampling is difficult.[1]

The Columbia River, although its runs have been reduced to a fraction of their former size, continues to be a major producer of spring chinook salmon. To estimate the egg-to-migrant survival of a population of spring chinook salmon, the Bureau of Commercial Fisheries began a study in 1957 on the Yakima River, a tributary of the Columbia River in south-central Washington (fig. 1). The Yakima River was chosen because a trap in a diversion canal at Prosser, Wash., on the lower river provided a unique opportunity to sample the seaward migration. The trap allowed us to estimate the number of seaward migrants each year. Comparison of the number of migrants with the number of eggs deposited by the female spawners in the appropriate brood year yielded an estimate of survival to the seaward migrant stage. This paper is a summary of our work on the Yakima River from 1957 to 1963.

SPAWNING OF SPRING CHINOOK SALMON

The aim of our studies of adult spring chinook salmon was to estimate the number of eggs deposited. We had to determine (1) the distribution and abundance of redds, (2) the size, age, and fecundity of the spawners, and (3) the number of eggs retained by female spawners.

DISTRIBUTION AND ABUNDANCE OF REDDS

The spawning grounds of spring chinook salmon in the Columbia River system were originally delineated in the 1930's (Bryant and Parkhurst, 1950). For the Yakima River system, the following

[1] Seasonal races of chinook salmon in the Columbia River system are classified as spring, summer, or fall chinook depending on the time of year that the adults enter the river to spawn. In tributaries that contain more than one seasonal race, the spawning of spring chinook salmon is separated in time and space from the spawning of the other races.

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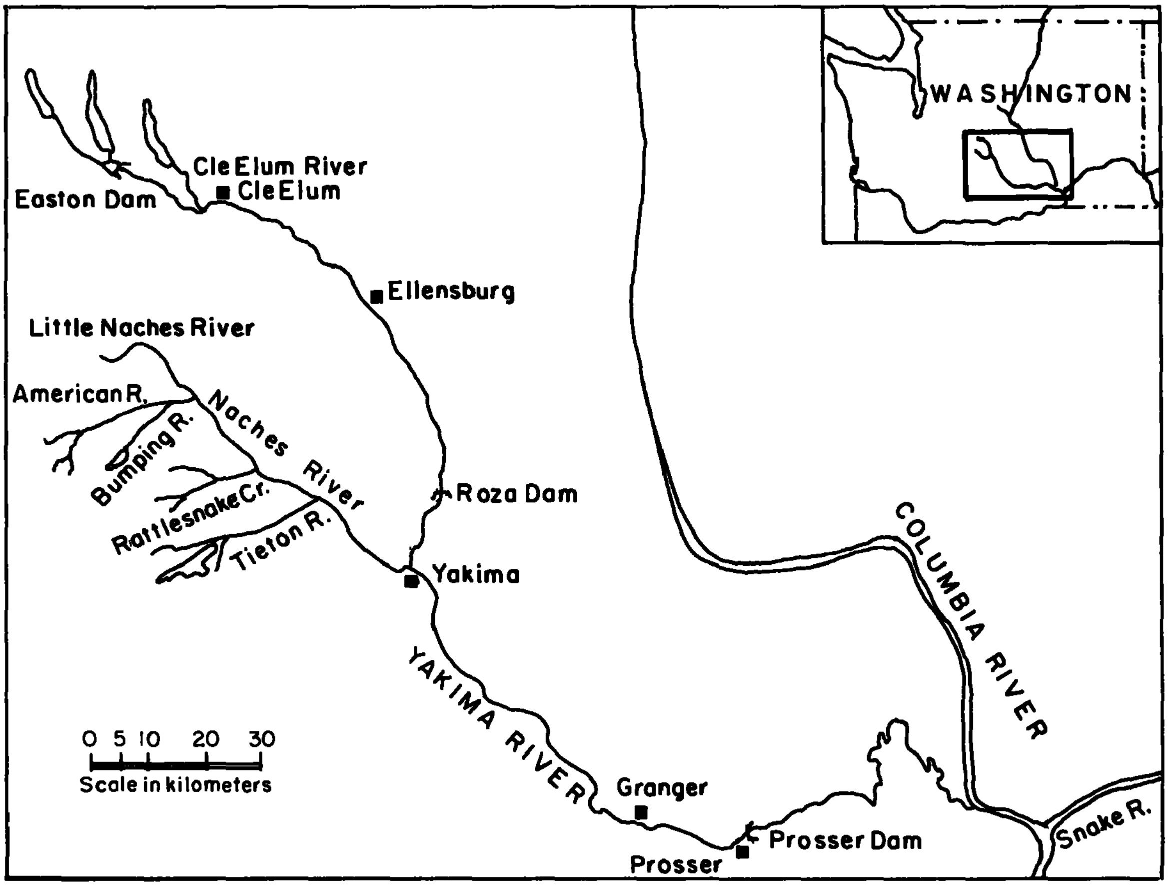

FIGURE 1.—Yakima River system and locations important to present study.

areas were listed: Yakima River from Easton Dam to Ellensburg, Naches River from the confluence of the Little Naches and Bumping Rivers to the confluence with the Tieton River, and Little Naches, Bumping, and American Rivers and Rattlesnake Creek. We surveyed these and other likely areas in 1957 but found that, except for a few scattered redds in the Cle Elum River, spawning was still confined to the areas reported by Bryant and Parkhurst (1950). We surveyed only the latter areas and the Cle Elum River in 1958–61.

Surveys were made in a standard manner. Working in pairs or alone, depending on the width of the stream, we counted the redds and the live fish as we waded downstream or floated downstream in rubber boats (table 1). If necessary, the surveys were repeated weekly until no unspawned fish were sighted. This precaution minimized the possibility that we might overlook redds made by females that were late arrivals.

Distribution of redds (fig. 2) varied little from year to year and agreed closely with Bryant and Parkhurst (1950).

TABLE 1.—*Number of spawning redds of spring chinook salmon in the Yakima River system, 1957–61*

Stream	Spawning redds				
	1957	1958	1959	1960	1961
	Number	*Number*	*Number*	*Number*	*Number*
Naches River and tributaries:					
American River	479	137	100	27	23
Bumping River	41	67	55	31	30
Little Naches River	106	16	22	3	2
Naches River	94	34	108	57	103
Rattlesnake Creek	44	30	21	8	8
Subtotal	764	284	306	126	166
Upper Yakima River: (Yakima River from Easton Dam to Ellensburg and the Cle Elum River)	1,216	531	255	184	175
Total	1,980	815	561	310	341

Spawning was distributed over a 6-week period. Peak of spawning was usually within the following dates:

American River, Aug. 8 to 12.
Bumping River, Sept. 5 to 10.
Little Naches River, Sept. 1 to 5.
Naches River, Sept. 1 to 5.
Rattlesnake Creek, Aug. 28 to Sept. 2.
Upper Yakima River, Sept. 17 to 22.

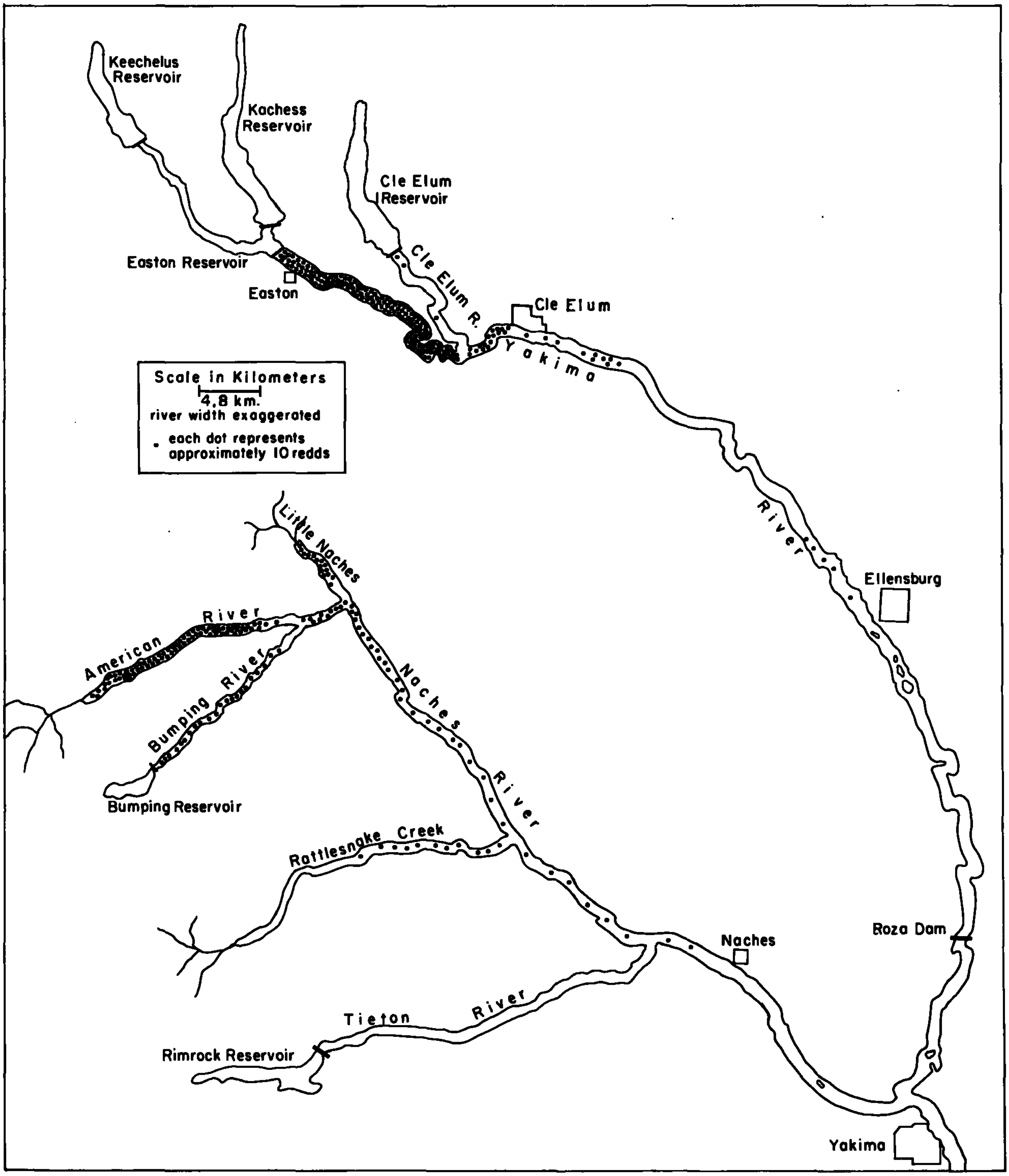

FIGURE 2.—Distribution of spawning redds of spring chinook salmon in the Yakima River system, 1957–61.

SIZE, AGE, AND FECUNDITY OF THE SPAWNERS

All of the spawned-out carcasses that could be retrieved were measured. Two measurements were obtained for each fish: fork length and mid-eye to posterior end of the hypural plate. The latter measurement excludes the snout and tail—appendages that are usually distorted on spawning salmon. The snout becomes elongated, particularly in the male, and the tail of the female is damaged in digging the redd.

Length-frequency curves by sex for the upper Yakima River and Naches River subareas (fig. 3) show that fish of both sexes are longer in the Naches River subarea than in the upper Yakima River subarea.[2] Mean lengths are 45.5 and 65.4 cm. for the males and 57.3 and 71 cm. for the females in the respective areas. The frequency distribution of length of males from the Naches River subarea is trimodal with peaks at 40, 61, and 79 cm. These modes correspond to those in samples of spring chinook salmon that are captured in the gill net fishery at the mouth of the Columbia River—fish that belong to age groups 1.1, 1.2, and 1.3, respectively.[3] Only two modes—at 40 and 55 cm.—appear in the length-frequency curve of males from the spawning area in the upper Yakima River subarea. These modes are comparable to the modes of the 1.1 and 1.2 age groups in the fishery. Females from the Naches River subarea have a single mode at 73 cm., which corresponds to the mode of females of the 1.3 age group in the fishery. Females from the upper Yakima River subarea have a single mode at 57 cm., which corresponds to the mode of the 1.2 age group in the fishery. We were unable to verify these gross length-age relations with scale data; the scales from spawned-out fish were so deteriorated that ocean ages were undeterminable.

NUMBER OF EGGS RETAINED BY FEMALE SPAWNERS

In 1960 and 1961, 82 females were examined for the number of eggs retained after spawning. Results were: 0 eggs—47 fish; 1 to 10 eggs—22 fish; 11 to 100 eggs—10 fish; and over 100 eggs—3 fish. The number of eggs retained by the spawning females does not appear to have any great effect on estimates of egg deposition.

ESTIMATED NUMBER OF EGGS DEPOSITED

Number of eggs deposited, $\hat{Y}$, was estimated by the formula

$$\hat{Y}=\sum_{i=1}^{6}n_i\hat{Y}_i$$

where n_i is the number of redds in stream (i), and $\hat{Y}_i$ is the estimated mean fecundity of the female spawners in stream (i). Here, in turn, $\hat{Y}_i = -3{,}634+105.51\ X_i$ where X_i is the mean fork length in cm. of female spawners in stream (i). The values −3,634 and 105.5 were reported by Galbreath and Ridenhour (1964), who investigated the fork length-fecundity relation of chinook salmon in the Columbia River. We used the dual measurements taken on the spawning grounds to convert to fork lengths the mideye to hypural plate measurements. These fork lengths are subject to error introduced by the elongation of the snout in the male and the wearing away of the caudal fin rays of the female in redd building. Although we were unable to measure this error, we believe it to be small.

The number of eggs deposited in the Yakima River system as a whole and that of each subarea declined markedly between 1957 and 1961 (table 2).

SEAWARD MIGRATION AND SURVIVAL OF PROGENY

We designed our studies with young salmon to estimate the number of fish that migrated seaward each spring. To make this estimate, we trapped and counted a sample of migrating fish each day during the 1959–63 migrations and from these partial counts made daily and seasonal estimates.

Sampling was at Prosser, Wash., on the lower Yakima River where a 3-m.-high dam creates a pool from which a canal transports water to a power plant 25 km. downstream. A battery of electrically powered rotary screens, 1.6 km. downstream from the entrance of the canal, diverts fish into an underground conduit which returns fish to the river. Just before it reenters the river, the conduit is equipped with a trapping system which, when activated, captures all fish that are being returned to the river (fig. 4). An aerial photograph of the area was the basis for a

[2] The upper Yakima River subarea, by our definition, includes that part of the Yakima River and its tributaries that lies above the confluence of the Yakima and Naches Rivers; the Naches River subarea includes the Naches River and its tributaries; and the main Yakima River is that part of the river that lies downstream from the confluence of the Naches and Yakima Rivers.

[3] The method of designating age follows the scale formulas of Koo (1962). The number of winters at sea is shown by an Arabic numeral preceded by a dot; similarly, the number of winters that the salmon spent in fresh water (not counting the winter the egg was in gravel) is shown by an Arabic numeral preceding a dot. Both are shown by two Arabic numerals separated by a dot. A salmon of age 1.2 spent 1 winter in fresh water and 2 winters in the ocean; the fish is 3 years old and in its fourth year of life.

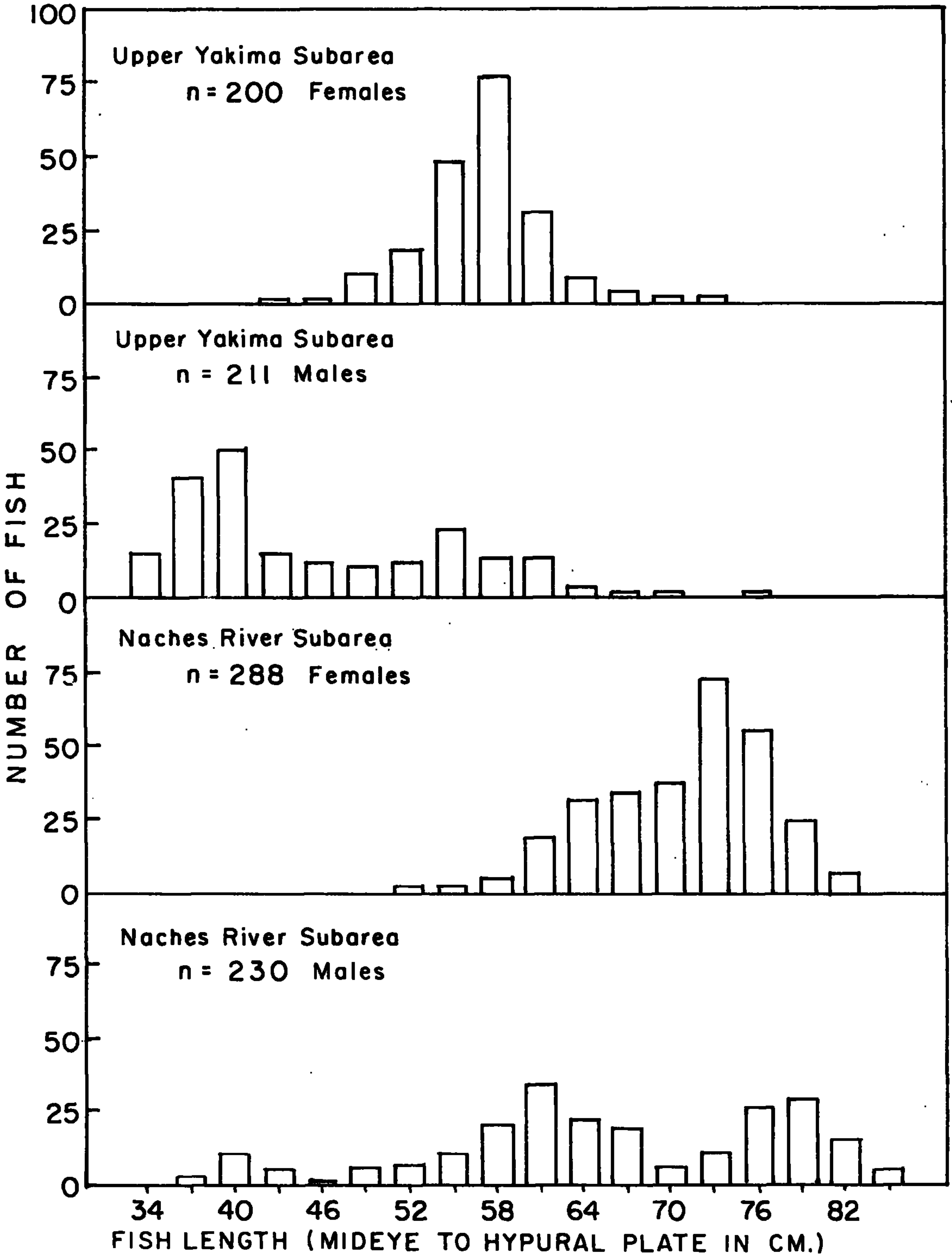

FIGURE 3.—Length-frequency distribution of adult spring chinook salmon in the Yakima River system, 1957–61.

TABLE 2.—*Estimates of number of eggs deposited by spring chinook salmon in the Yakima River system, 1957–61*

Year, subarea, and stream	Redds counted	Mean fork length of female spawner	Mean fecundity	Eggs deposited
	Number	*Centimeters*	*Number of eggs*	*Millions*
1957:				
Naches subarea:				
American River	479	86 1.	5,446	2.609
Bumping River	41	87.1	5,553	.228
Little Naches River	106	80.7	4,877	.517
Naches River	94	85.2	5,354	.503
Rattlesnake Creek	44	80.2	4,832	.213
Subtotal	764			4.070
Upper Yakima subarea	1,216	70.3	3,784	4.600
Total	1,980			8.670
1958:				
Naches subarea:				
American River	137	86.1	5,448	.747
Bumping River	67	80.8	4,888	.328
Little Naches River	16	84.0	5,231	.084
Naches River	34	84.3	5,255	.179
Rattlesnake Creek	30	81.1	4,926	.148
Subtotal	284			1.486
Upper Yakima subarea	531	66.1	3,342	1.774
Total	815			3.260
1959:				
Naches subarea:				
American River	100	89.7	5,831	.583
Bumping River	55	81.5	4,961	.273
Little Naches River	22	84.7	5,304	.117
Naches River	108	86.0	5,443	.588
Rattlesnake Creek	21	78.4	4,639	.097
Subtotal	306			1.658
Upper Yakima subarea	255	68.2	3,565	.910
Total	561			2.568
1960:				
Naches subarea:				
American River	27	84.2	5,250	.142
Bumping River	31	81.7	5,003	.155
Little Naches River	3	82.6	5,081	.015
Naches River	57	79.5	4,754	.271
Rattlesnake Creek	8	80.2	4,832	.039
Subtotal	126			.622
Upper Yakima subarea	184	66.3	3,358	.618
Total	310			1.240
1961:				
Naches subarea:				
American River	23	86.2	5,459	.126
Bumping River	30	80.1	4,816	.144
Little Naches River	2	82.6	5,081	.010
Naches River	103	86.2	5,464	.563
Rattlesnake Creek	8	80.6	4,867	.039
Subtotal	166			.882
Upper Yakima subarea	175	68.2	3,564	.624
Total	341			1.506

sketch to describe the function of the canal-conduit system. The trapping system is shown diagrammatically in figure 5.

Procedures for studying seaward migration were similar for all years. Trapping began about April 1 when young salmon were not yet abundant and continued until they became scarce—sometime in June. Fish were removed from the trap with dip nets at 8 a.m., 12 noon, 4 p.m., and 12 midnight. The trapping "day" used here extended from 8 a.m. of the calendar day indicated to 8 a.m. of the following day. Fish other than salmon were counted and released. Young salmon were transferred into tubs for closer inspection before they were counted and released.

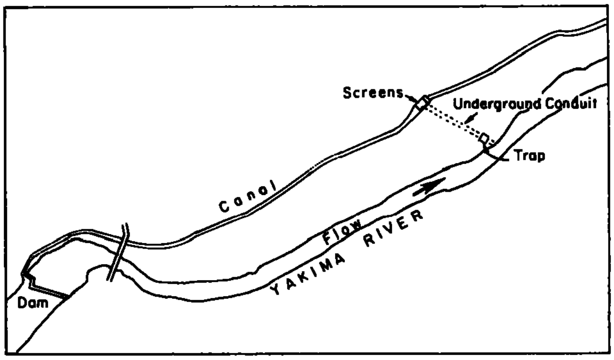

FIGURE 4.—Diagrammatic sketch of the system for sampling the seaward migration at Prosser. Low dam diverts water into the canal; screens divert fish into an underground conduit that carries them to the traps and eventually to the river.

Once a week a sample of young chinook salmon was anesthetized in a 1:20,000 solution of MS 222. Fork length to the nearest millimeter was recorded from each fish. Weight to the nearest gram was recorded from a randomly selected subsample of about 50 fish per week. Scales, selected from a stratified subsample, were placed between pairs of glass slides and later examined with a microscope to determine the age of the fish.

AGE AND SIZE OF SEAWARD MIGRANTS

Scales from 1,458 young chinook salmon captured at Prosser from 1959–63 revealed that fish were either in their first or second year of life. Certain differences between the age groups are noteworthy. First, the two age groups do not appear at Prosser at the same time; fish that are in their second year appear in early April, but fish that are in their first year do not appear until June. Second, when samples that contain fish of both age groups are viewed in tubs, the first-year fish (even the few that are as long as the fish in their second year) are readily distinguishable by their stouter bodies.

We reasoned that the stouter, first-year migrants were not spring chinook salmon but rather fall chinook salmon—progeny of adult fall chinook salmon that spawn near Granger, 40 km. upstream from Prosser. If they were spring chinook salmon migrating downstream from the upriver spawning areas, they would have had to move through the midriver areas in the winter or spring. But this movement did not take place. We sampled the Yakima River system extensively with electro-

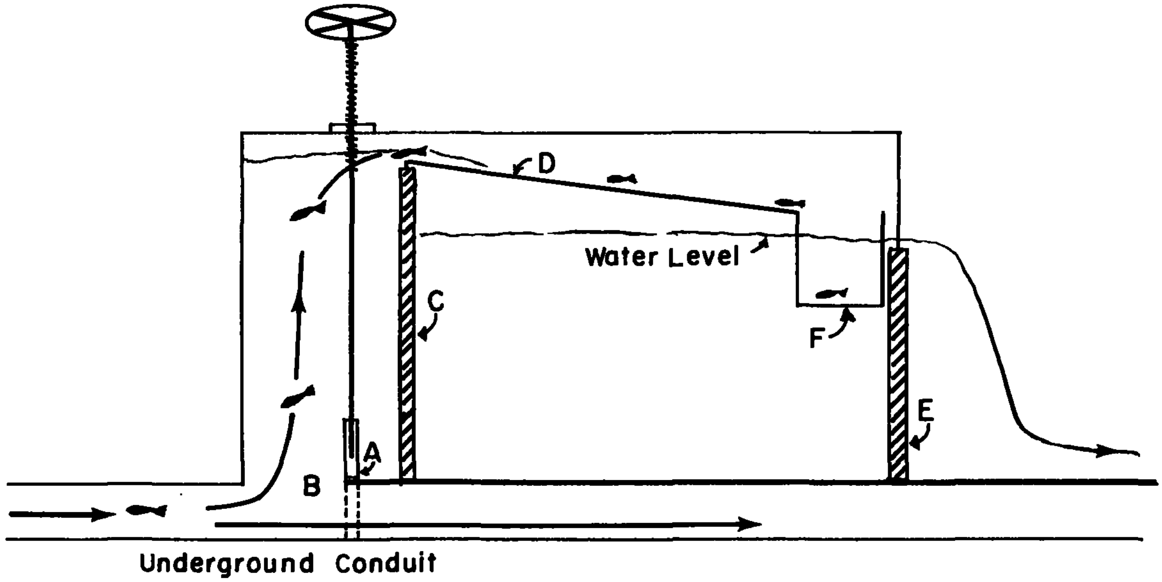

FIGURE 5.—Diagrammatic sketch of trapping system on bypass conduit on the Yakima River at Prosser. When valve (A) is open, fish pass directly to the Yakima River. To activate the trap, the valve is closed forcing the water and fish upward through a hole in the top of the conduit (B). Water flows over the top of the interior wall (C), through inclined plane screen (D), over a second interior wall (E), and on to the Yakima River. Fish and some water continue into trap (F).

fishing equipment in the winter and spring of 1958–63 but found no first-year fish in the mid-river stretches. Furthermore, no first-year fish migrated seaward past Roza Dam, 19 km. above the confluence of the Yakima and Naches Rivers, in either 1961 or 1962 (according to Donald Greenland).[4] Data presented here pertain only to spring chinook salmon, or fish that migrate seaward in their second year.

Length-frequency polygons of downstream-migrating spring chinook salmon (fig. 6) show that the modal length increased from 120 mm. in 1959 and 1960 to 125 mm. in 1961, 130 mm. in 1962, and 135 mm. in 1963. Present data are inadequate to explain the reason for the increase in modal length. Possible explanations include the availability of more food per young fish and differential growth and abundance of the several tributary subpopulations believed to be present.

Analysis of the length and weight data (table 3 and figure 7) clearly shows that the larger fish tend to migrate early in the season. The condition factor tends to increase—that is, the fish become heavier per unit length as the season progresses. This change is explained, at least in part, by the extended sojourn of the later migrating fish in water where the temperature is rising and food is becoming more abundant, and where their feeding becomes more intensive.

[4] Donald Greenland, Fishery Biologist, Bur. Commer. Fish., Columbia River Program Office, Portland, Oreg. Personal communication.

TIMING OF SEAWARD MIGRATION

The daily timing of the downstream migrations in 1959–63 was similar for all years (fig. 8). Generally the catches remained relatively stable between periods ending at noon, 4 p.m., and 8 p.m. and increased in the period ending at midnight. The hourly distribution of the catch between midnight and 8 a.m. is unknown, but the number of chinook salmon captured during the 8-hour period approximated the number taken from 8 p.m. to midnight. Thus, migration tended to be at night.

The week or weeks of heaviest seaward migration of spring chinook salmon at Prosser varied in 1959–63, but always fell between April 14 and May 19 (fig. 9).

SURVIVAL TO SEAWARD MIGRATION

We estimated the number of seaward migrants from the formula:

$$\hat{N}=\sum_{i=1}^{n}\hat{N}_i=\sum_{i=1}^{n}Ci(32.5/f_i)$$

where $\hat{N}$ is the estimated number of spring chinook salmon migrating seaward, $\hat{N}_i$ is the estimated

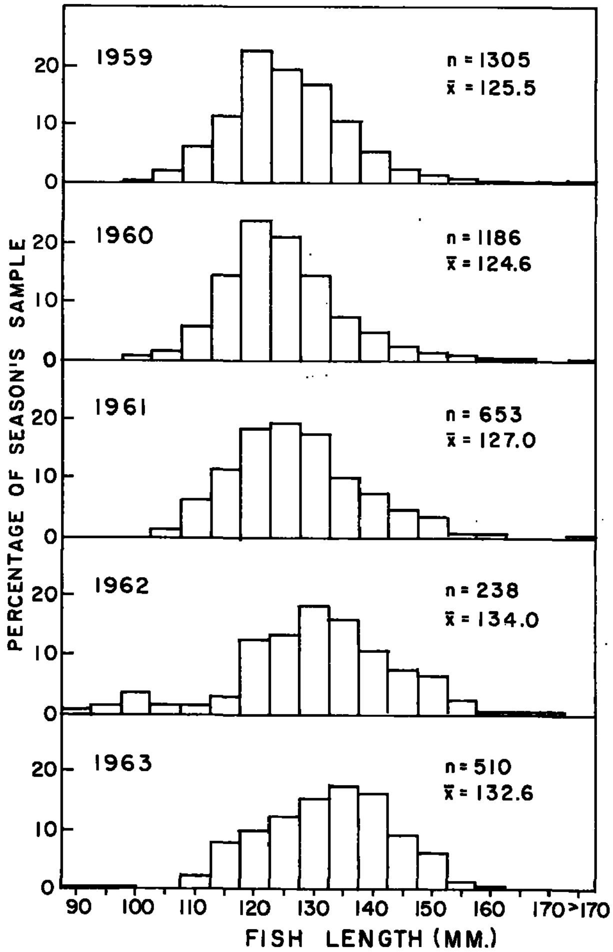

FIGURE 6.—Length-frequency distribution of Yakima River spring chinook salmon captured during their seaward migration at Prosser, 1959–63.

number migrating on day (i), Ci is the number captured in the trap on day (i), and f_i is the estimated flow in cubic meters per second of the Yakima River at Prosser on day (i) (U.S. Geological Survey, 1961–65). Canal flow is constant at 32.5 m.^{3} per second. This method requires the assumptions that the number of fish per volume of water is the same in the canal as in the river and that the mortality in the canal is the same as that in the adjacent stretch of river. The number of migrants that were caught in the trap and the total number that we estimated to have migrated seaward at Prosser are shown in figure 10 by day and year.

Estimates of the number of seaward migrants, estimates of the number of eggs deposited in the appropriate brood year, and the percentage survival are shown in table 4 and figure 11. Survival ranged from 5.4 to 16.4 percent; the average was 10.7 percent. The low survival of the 1957 brood was caused—to a great extent—by an unnatural condition that did not recur in the other years. In 1957 an estimated 30 to 50 percent of the eggs deposited in the upper Yakima River subarea succumbed to exposure when, in October and November, the water level was artificially lowered and maintained 2 feet below what it had

TABLE 3.—*Mean length, mean weight, condition factor, and size of samples of spring chinook salmon taken at Prosser, 1959–63*

Date (week ending)	Fish	Mean fork length	Mean weight	Condition factor
	Number	*Millimeters*	*Grams*	
1959:				
April 14	50	128.4	23.8	1.13
21	50	129.6	24.4	1.12
28	49	127.7	23.2	1.12
May 5	50	121.8	20.7	1.15
12	50	122.9	20.1	1.08
19	48	120.0	20.0	1.16
26	50	124.0	21.9	1.15
June 2	29	125.3	22.8	1.16
9	15	119.5	20.0	1.17
After June 9	23	117.6	19.5	1.20
1960:				
April 7	28	130.5	24.1	1.09
14	50	125.3	20.7	1.06
21	50	132.7	25.8	1.08
28	53	127.7	21.9	1.05
May 5	102	123.8	20.0	1.06
12	50	125.8	21.8	1.10
19	49	119.2	19.1	1.13
26	50	123.8	20.7	1.09
June 2	50	121.4	20.3	1.13
9	50	120.4	20.7	1.19
After June 9	51	121.8	21.8	1.21
1961:				
April 7	52	132.3	25.2	1.09
14	50	136.0	26.9	1.07
21	50	124.7	21.0	1.08
28	50	130.2	23.2	1.05
May 12	104	123.6	20.8	1.10
19	48	120.4	19.2	1.10
June 9	19	118.3	18.7	1.13
1962:				
April 14	50	137.7	28.7	1.10
21	50	139.4	29.6	1.09
28	50	130.3	23.7	1.07
May 19	33	125.7	21.7	1.09
June 2	37	129.5	24.5	1.13
After June 9	18	127.9	25.0	1.19
1963:				
April 7	30	143.9	31.6	1.06
14	33	138.2	29.6	1.12
21	38	141.4	29.7	1.05
28	45	138.6	28.4	1.07
May 5	110	133.5	26.7	1.12
12	40	136.3	27.3	1.08
19	37	131.8	24.2	1.06
26	42	130.7	23.8	1.07
June 2	32	127.8	21.7	1.04
9	60	120.1	19.0	1.10
After June 9	42	121.4	20.7	1.16

TABLE 4.—*Egg-to-migrant survival of young spring chinook salmon in the Yakima River (brood years 1957–61)*

Brood year	Egg deposited	Seaward migration	Survival
	Millions	*Thousands*	*Percent*
1957	8.670	464	5.4
1958	3.260	319	9.8
1959	2.568	194	7.6
1960	1.240	177	14.3
1961	1.505	246	16.4

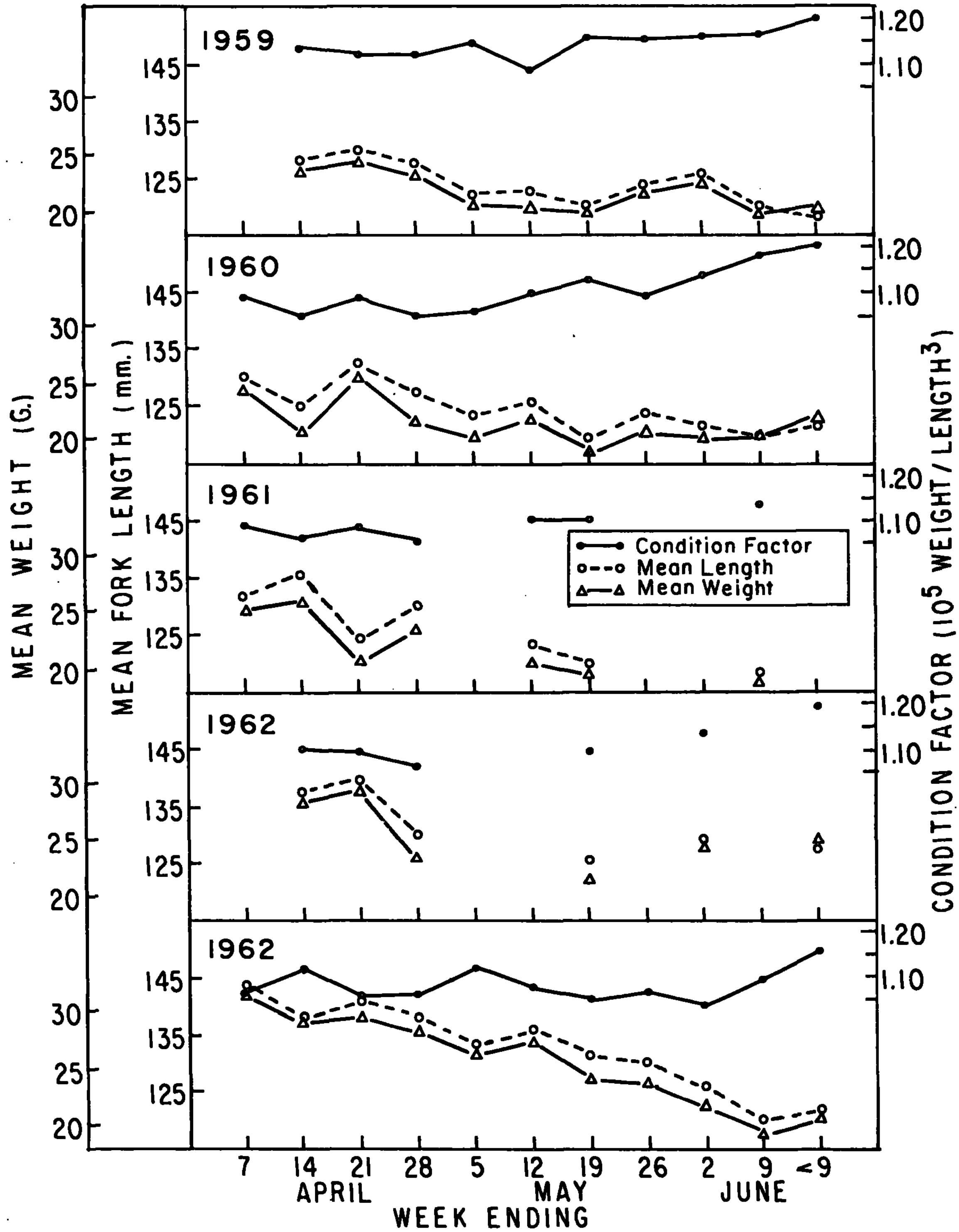

FIGURE 7.—Mean length, mean weight, and condition factor of Yakima River spring chinook salmon captured during their seaward migration at Prosser, 1959–63.

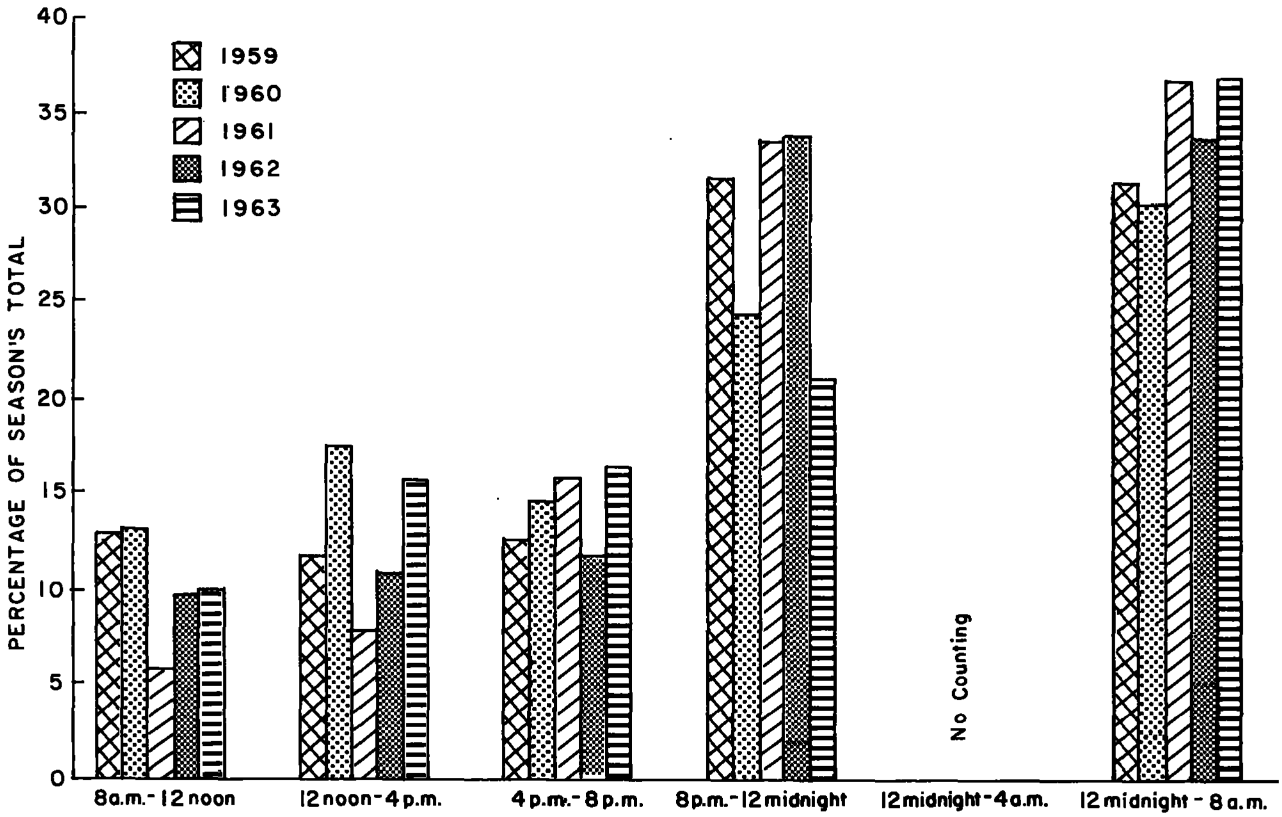

FIGURE 8.—Daily distribution of Yakima River spring chinook salmon captured during their seaward migration at Prosser, 1959–63.

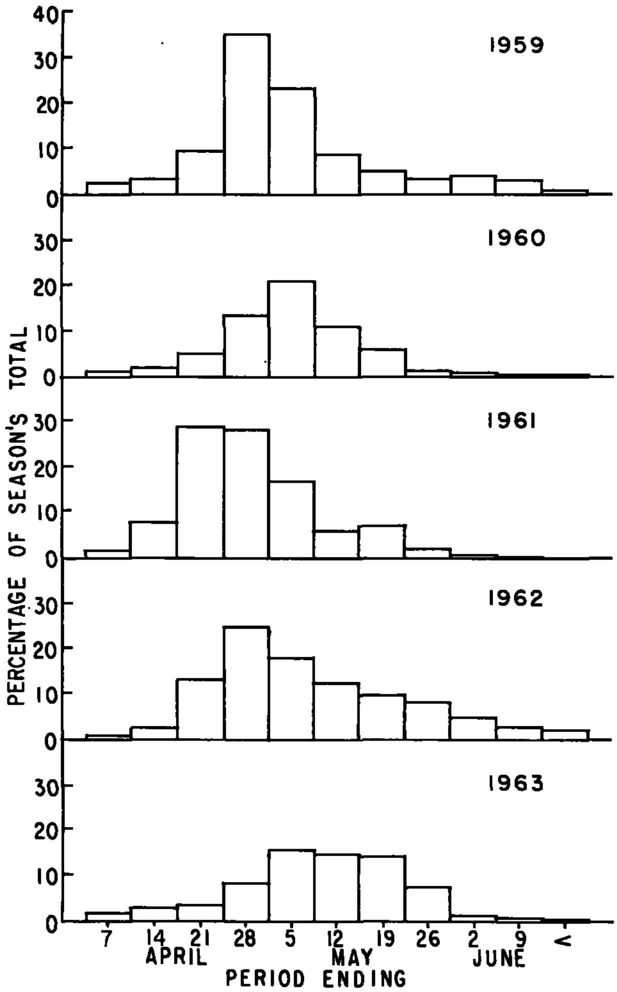

FIGURE 9.—Seasonal distribution of Yakima River spring chinook salmon captured during their seaward migration at Prosser, 1959–63.

been when the fish spawned in late September (Quentin Edson).[5] In subsequent years, per an agreement between the State of Washington Department of Fisheries and the U.S. Bureau of Reclamation—the agency controlling the flow of water over Easton Dam, a relatively uniform minimum flow was maintained from September until February when the young fish emerge from the gravel.

Estimates of survival from the egg to the seaward migrant stage for Pacific salmon are summarized in table 5. Prior to the present study, survival of chinook salmon had been estimated

[5] Quentin Edson, Fishery Biologist, City of Tacoma, Department of Public Utilities, Tacoma, Washington. Personal communication.

TABLE 5.—*Survival from egg to seaward migrant for five species of Pacific salmon*

Species and location	Survival, egg to seaward migrant		Period	Source of information
	Range	Average		
	Percent	*Percent*	*Years*	
Sockeye salmon:				
Cultus Lake, B.C	1.01– 3.22	1.87	4	Ricker, 1966.
Babine Lake, B.C	1.34– 5.18	3.77	5	Do.
Lakelse Lake, B.C	.60– 5.05	1.86	7	Do.
Port John Lake, B.C		3.00	(1)	Do.
Chilko Lake, B.C		8.00	(1)	Do.
Dalnee Lake, U.S.S.R	.005– 1.05	.28	10	Hanamura, 1966.
Pink salmon:				
McClinton Creek, B.C	6.90–23.80	(1)	6	Neave, 1966a.
Morrison Creek, B.C	4.70– 6.70	(1)	2	Do.
Hooknose Creek, B.C	.90–37.20	(1)	13	Do.
Lakelse River, B.C	18.00	(1)	1	Do.
Kispiox River, B.C	23.00	(1)	1	Do.
Kitwanga River, B.C	15.00	(1)	1	Do.
Wahleach Creek, B.C	37.00	(1)	1	Do.
Sashin Creek, Alaska	.10–21.80	6.33	22	McNeil, 1966.
Karymai Spring, U.S.S.R.	.02– 5.70	1.96	6	Semko, 1954.
Chum salmon:				
Nile Creek, B.C	.08–13.60	(1)	8	Neave, 1966b.
Hooknose Creek, B.C	.96–22.00	0	13	Do.
Karymai Spring, U.S.S.R.	.68– 4.20	2.16	7	Semko, 1954.
Coho salmon:				
Nile Creek, B.C	.76– 2.10	1.27	4	Godfrey, 1965.
Hooknose Creek, B.C	.70– 3.96	1.30	10	Do.
Minter Creek, Wash	.70– 9.65	1.71	11	Do.
Waddel Creek, Calif	1.16– 1.56	1.43	4	Do.
Chinook salmon:				
Fall Creek, Calif	7.00–32.00	14.50	4	Wales and Coots, 1955.
Yakima River, Wash	5.35–16.35	10.70	5	Present study.

[1] Not reported.

only in Fall Creek, Calif., and the usefulness of these values is limited. Fall Creek is a small atypical spawning stream and the progeny of the Fall Creek chinook salmon population migrate to sea in their first year of life (a characteristic of fall chinook, pink, and chum salmon, but not of spring or summer chinook salmon; the latter races, like sockeye and coho salmon, usually spend 1 year or more in fresh water before migrating to sea).

Relative to all other species, the limits within which the percentage survival of spring chinook salmon in the Yakima River fluctuates are neither wide nor narrow but reasonably moderate. Egg-to-migrant survival of spring chinook salmon in the Yakima River is generally higher than that for sockeye salmon and coho salmon—other species whose young spend 1 year or more in fresh water. The results of the various studies are not strictly comparable, however, because migrants are trapped at varying and sometimes unspecified points in time and distance from the nursery areas and the sea. Young spring chinook salmon trapped at Prosser must yet migrate 600 km. to the sea.

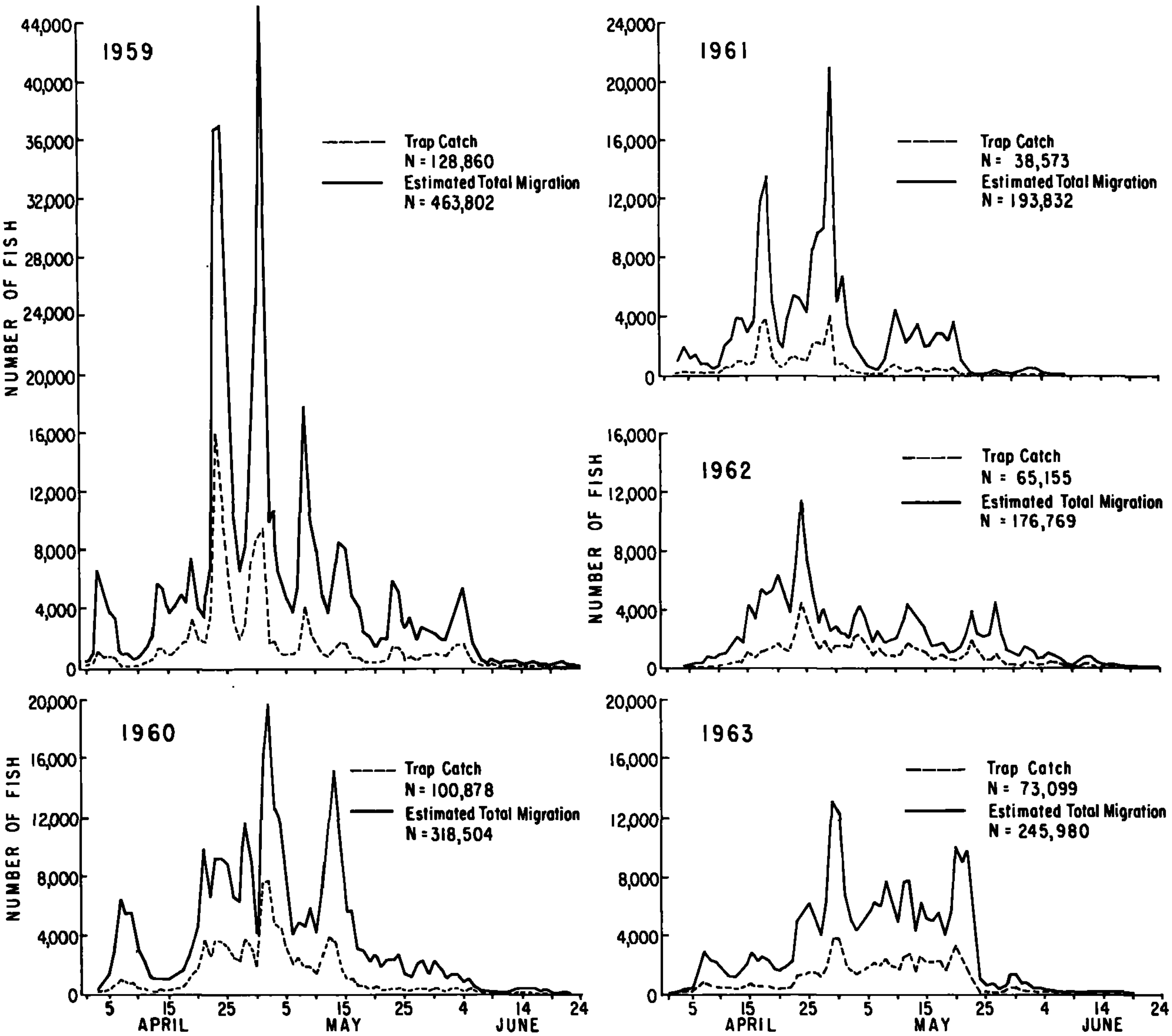

FIGURE 10.—Seaward migration of Yakima River spring chinook salmon at Prosser, 1959–63. Number captured in the trap are shown by broken lines. Solid lines indicate the calculated totals for the entire river (trap and remainder of the river).

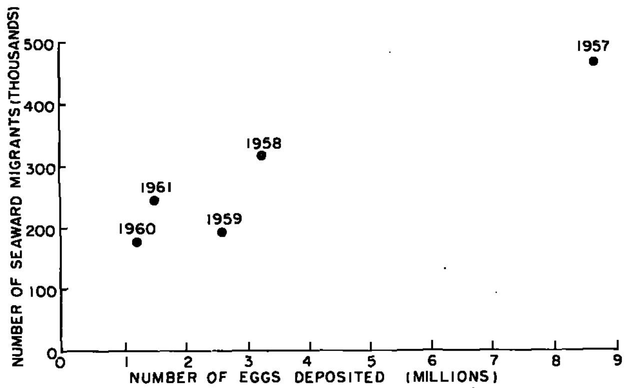

FIGURE 11.—Estimated number of seaward migrants and estimated number of eggs deposited, Yakima River spring chinook salmon, brood years 1957–61.

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