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ABUNDANCE AND AGE OF KVICHAK RIVER RED SALMON SMOLTS

BY ORRA E. KERNS, JR.

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ABSTRACT

Standardized methods are described for use of an index fyke net to determine annually the abundance of smolt migrations from the Kvichak River system, Bristol Bay, Alaska. Details of the fyke-net construction are presented. The fyke-netting procedure and the fishing season are discussed as well as some of the more important river conditions for an effective fyke-net site: water velocity and depth, channel changes, and debris. Annual indices of smolt abundance for the years 1955 through 1959 are presented. Comparisons in the timing of migration between years are included. Results of tests to determine the variation between sizes of catch and age composition of fish taken in nets fished side by side and up and down river are described. Information is presented showing that large parent escapements produced large smolt migrations and small escapements produced small smolt migrations.

A sampling program of fyke-net catches to determine age composition is described. Age composition has been based on length-frequency and scale studies. Age composition for each year is presented. Smolt age composition has been compared with fresh-water age composition of returning adults.

ABUNDANCE AND AGE OF KVICHAK RIVER RED SALMON SMOLTS

By Orra E. Kerns, Jr., *Senior Fisheries Biologist*
University of Washington

Two essentials to managing a fishery for red salmon, *Oncorhynchus nerka* (Walbaum), are knowledge of the abundance and of the ages of the smolts as they leave a river system on their way to the sea. When the abundance and ages of the smolts are related for a number of years to the number and ages of the returning adults, predictions can be made of the size of subsequent adult returns. These data are particularly important in the Kvichak River, since it is the largest red salmon producing system in Alaska.

Specific objectives of red salmon smolt studies in the Kvichak River system were (1) an index of the abundance, and (2) the age composition of the entire migration.

Our method of assessing smolt abundance is based on the catch of a single fyke net. Gear and fishing effort expended are kept constant, but the fishing site is changed slightly to provide uniform water depth and velocity. Combined daily fyke-net catches for the season provide an index of total smolt migration (Burgner, 1958).

An index of abundance is not as desirable as an enumeration of the total migration, which has been explained by Foerster (1929), Krogius and Krokhin (1948), and the International Pacific Salmon Fisheries Commission (1955), but a total enumeration in the Kvichak River system has not been practical. Suitable gear has not been developed to cope with the width, depth, and velocity of the river. Therefore, we have located and operated the fyke net in such a manner that we think it reasonable to assume a constant (but unknown) ratio of the fyke-net catch to the total migration.

Samples for the determination of age composition of the smolt migrations were taken from the fyke-net catches. Age composition has been based on smolt length-frequency and scale studies.

The Kvichak River drainage basin covers nearly 8,000 square miles. Included are two major lakes, Iliamna Lake, which is 80 miles long, 20 miles wide, and 1,115 square miles in area; and Lake Clark, which is 50 miles long, 4 miles wide, and 143 square miles in area (fig. 1). Iliamna Lake is about 50 feet above sea level and Lake Clark is about 220 feet above sea level (U.S. Army Corps of Engineers, 1957).

From 1947 through 1954 studies of age composition and sex ratio of the Naknek-Kvichak commercial catch and spawning-ground escapements were conducted annually by staff members of the Fisheries Research Institute, University of Washington. In the spring of 1955, at the request of Alaska Salmon Industry, Inc., systematic observations of red salmon runs in the Kvichak River system were initiated by the Institute under contract with the U.S. Bureau of Commercial Fisheries. Expanded investigations since 1955 were designed to measure mortalities at various points in the red salmon life history (Thompson, 1953).

The Kvichak River program began under the general direction of Dr. W. F. Thompson; project leader since 1956 has been H. D. Smith. The smolt enumeration program was supervised in 1955 by Dr. R. L. Burgner, in 1956 and 1957 by D. W. Linn, and in 1958 and 1959 by the author. Records and preliminary unpublished

Note.—The author is presently with the Fisheries Research Institute, College of Fisheries, University of Washington, Seattle 5, Washington.

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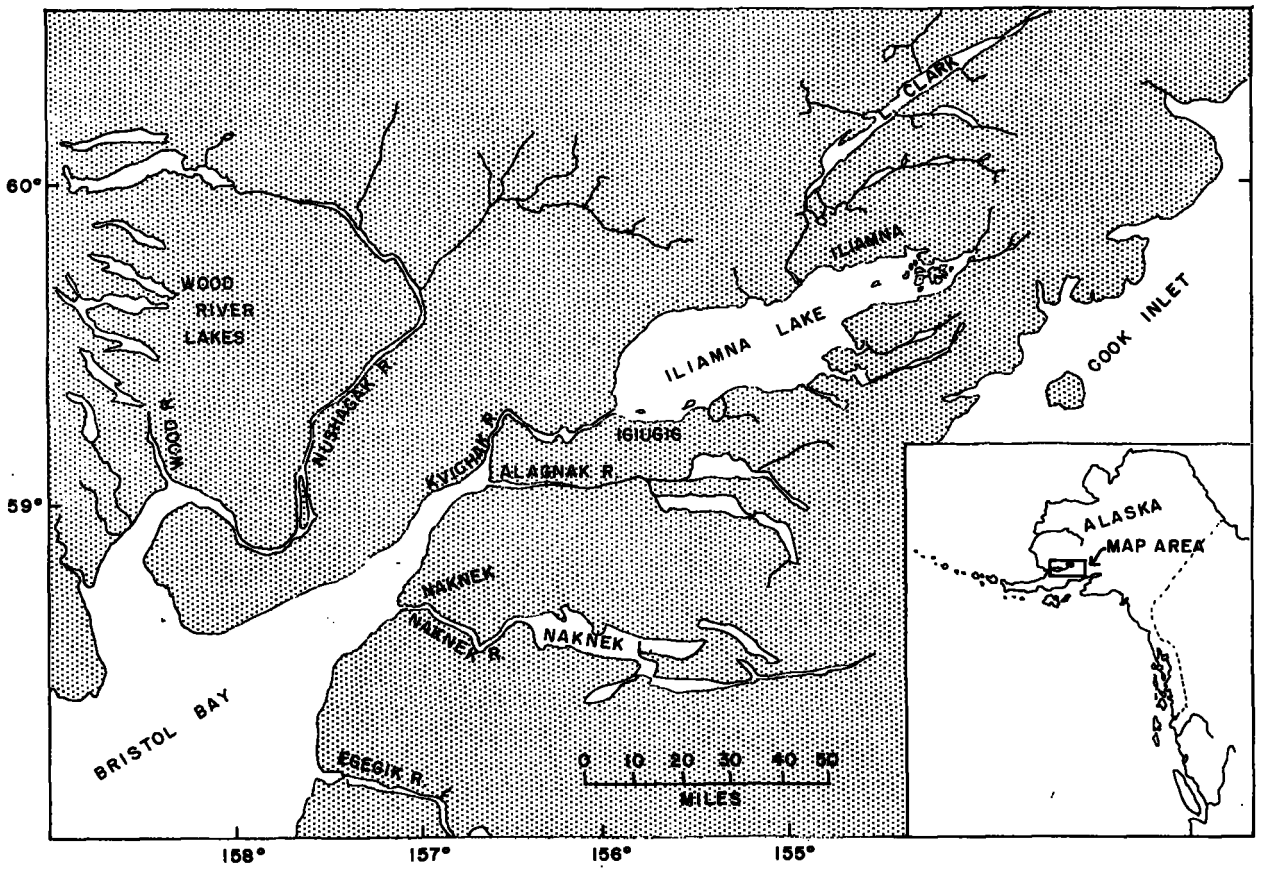

FIGURE 1.—Kvichak River system, Bristol Bay, Alaska.

reports of the Kvichak smolt studies are on file at the Fisheries Research Institute.

Credit for the development of most of the gear and methods used in this study is due Drs. W. F. Thompson, R. L. Burgner, and Ted S. Y. Koo, of the Fisheries Research Institute. The developmental work was conducted before 1951 at Mosquito Point, on the Nushagak River system, and was financed by Alaska Salmon Industry, Inc.

Unpublished reports were written by Dr. R. L. Burgner and D. W. Linn for the Kvichak smolt studies of 1955 and 1956, and the author has used freely and without reference the information from these reports.

Dr. O. A. Mathisen critically reviewed this paper and made helpful comments on the presentation of the data. The manuscript was edited by Drs. W. F. Royce, Ted S. Y. Koo, R. L. Burgner, and J. P. Harville, and H. D. Smith and J. F. Roos.

Appreciation is extended to all Fisheries Research Institute staff members, past and present, permanent and temporary, who were involved in collection of data.

DETERMINING RELATIVE SMOLT ABUNDANCE

Fyke-Net Design

The rigid frame of the fyke net used in this study measured 4 feet by 4 feet. The body of the net tapered from the frame to a single rectangular funnel 2 inches by 10 inches at the throat (fig. 2). A second funnel of the same dimensions was located in a detachable cod-end section, which facilitated emptying the catch. The net had two wings, each 10 feet long and 4 feet deep, with appropriate cork and lead lines. The two wings were held open by the force of the river current and two connecting spacer lines allowed the net to fish a consistent 9-foot wide section of the river. The net was made of

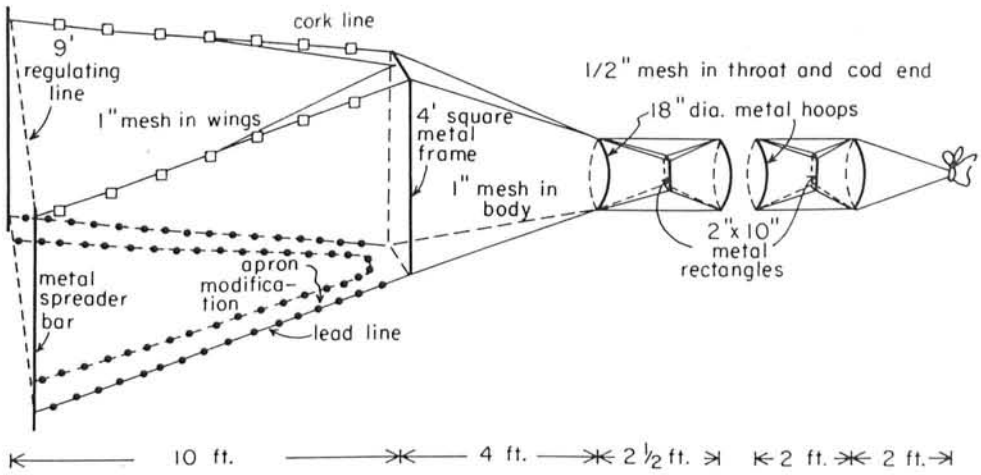

FIGURE 2.—Fyke net used in Kvichak River for assessing red salmon smolt abundance, 1955 through 1959.

knotted cotton webbing; the wings and body of 1-inch mesh (stretched measure) and the remainder of the net of ½-inch mesh. The fyke net is shown anchored in place in the river in figure 3.

Fyke-Net Site

Smolts contributed by both Iliamna Lake and Lake Clark must descend the Kvichak River on their way to the sea. The upper 4 miles of river from Iliamna Lake to Kaskanak Flats offer the

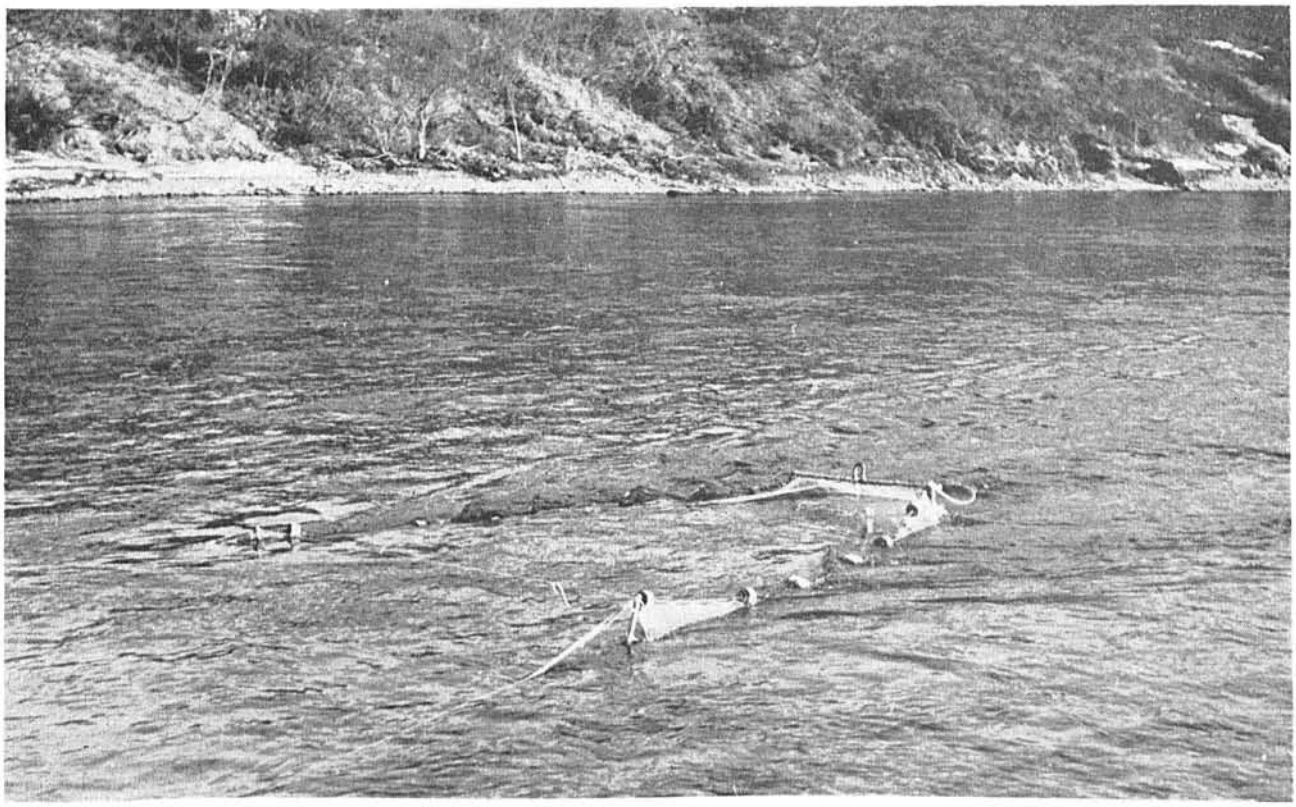

FIGURE 3.—Fyke net anchored in fishing position in the Kvichak River. (Photo by C. D. Becker.)

best fyke-netting sites. Here the river varies in width from about 400 feet to 1,000 feet, with depths to more than 15 feet and surface water velocities to at least 8 feet per second. The bottom consists mostly of gravel less than 4 inches in diameter. The riverbanks are steep because of the erosion that occurs nearly every year during high water. The river downstream from the Kaskanak Flats is affected by tides, causing variable water velocities unfavorable for fyke netting.

The index site (site B) used for smolt enumeration was approximately 4 miles downstream from the outlet of Iliamna Lake. Two other sites designated A and C were ½ mile and 2 miles downstream from the outlet (fig. 4). At the index site the river forms two channels, 570 feet wide and 225 feet wide. The fyke net was set on a submerged, slightly sloping gravel bar near the center of the main channel. This gravel bar extends at the same depth for at least 100 yards above and below the index site.

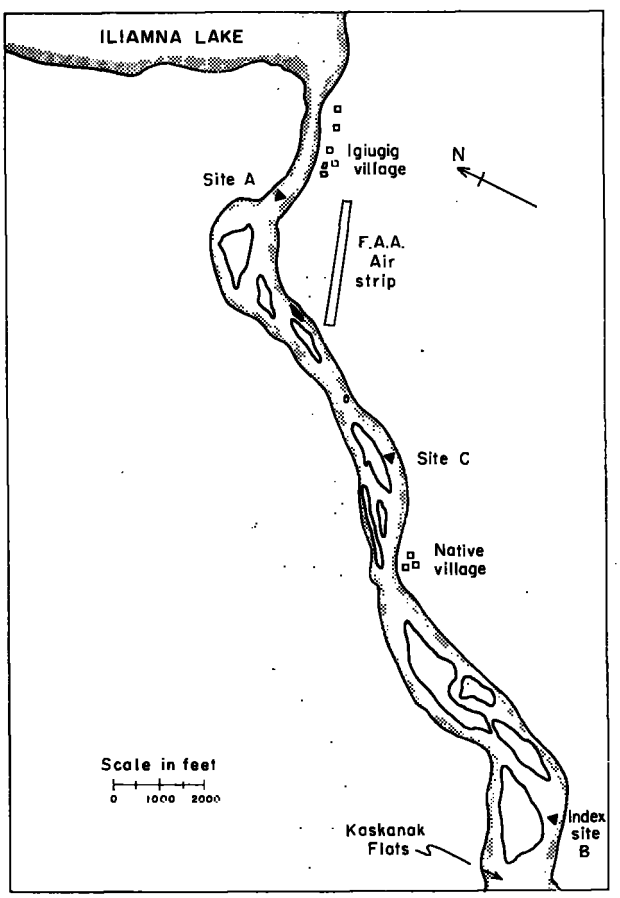

FIGURE 4.—Fyke-net sites A, B (index), and C, Kvichak River. (Map by D. W. Linn.)

Fyke-Netting Procedure

The fyke net was set before 2200 hours each night and tended from a 20-foot skiff by two or more men. To check the net, the cod end was first raised out of the water by one man. In this position the throat of the net was closed to the passage of fish. The cod end with the catch was detached by removing a single locking pin and an empty cod end immediately put in place and lowered into the water to continue fishing.

The second man pulled the release cord or zipper on the cod end and spilled the catch into a large weighing basket that was immersed in a tub of water. This weighing basket was then removed from the tub and hung on a spring balance of 40-pound capacity, suspended from a weighing stand in the skiff. The weighing basket was allowed to drain about 10 seconds before the weight of the fish and the time of catch were recorded. During peak migration the fish weighed about 20 pounds at a net check. Immediately after being weighed, the fish were returned to the river. Elapsed time for a net check was less than 30 seconds. The number of fish in a 1-pound sample was usually counted four times an hour and the number was used for conversion of total weight of fish to total number.

To avoid excessive mortality during periods of heavy migration, the net was checked as the fish accumulated. In an extreme instance in 1958 it was necessary to check the index fyke net nearly twice a minute. When the migration was very light, the net was checked every hour.

Fishing Season

The experimental fishing season during this study began in the spring before any smolt migration takes place and continued until only a few fish were caught each day. The smolt migration started after ice breakup (fig. 5) and following a rapid rise in water temperatures in Iliamna Lake.

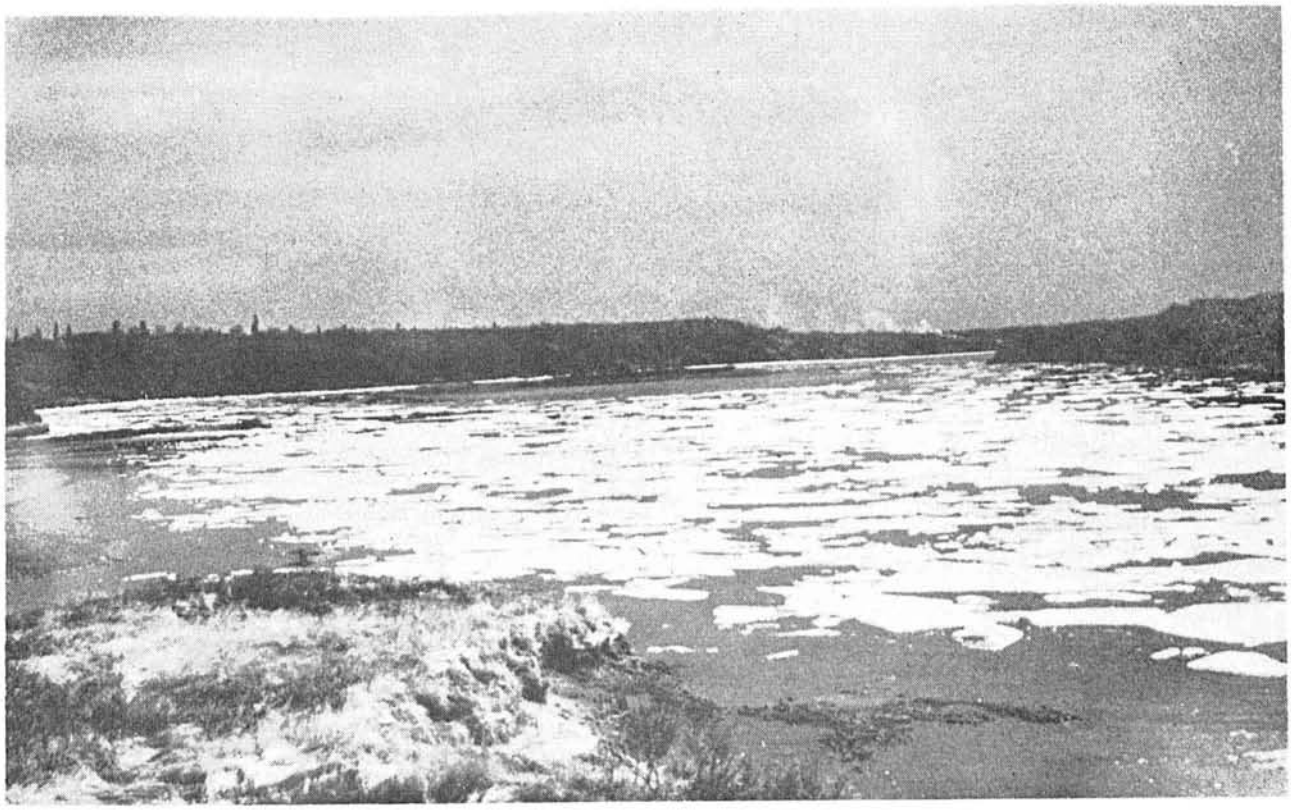

FIGURE 5.—Ice floes in the Kvichak River. (Photo by C. D. Becker.)

Daily Fishing Period

The smolt index was based on the total catch of the fyke net from 2200 to 0100 hours. This 3-hour period was selected on the basis of experience in the Nushagak system, where most of the smolts leave the lake during the darkest hours. The same nightly concentration of migration was found in the Kvichak River during 24-hour periods of fishing, as shown later.

River Conditions and Fyke-Net Efficiency

Water velocity.—Desirable surface-water velocity for fyke netting in the Kvichak River is 3 feet per second or more. This velocity is presumed necessary to prevent size selectivity, or larger fish evading the net. Net selectivity influenced by water velocity in the Kvichak River during 1955 was illustrated by two nets fished side by side at site A. The net in faster water, 3.1 feet per second, caught a greater poundage and larger-sized fish than the net in water of 2.4 feet per second velocity (fig. 6). A second test for size selectivity caused by similar water velocity was also made at the index site in 1955. The length frequencies of smolts taken during this test, in which two nets were fished side by side, are shown in figure 7. Both nets, fished in a current velocity of approximately 3.5 feet per

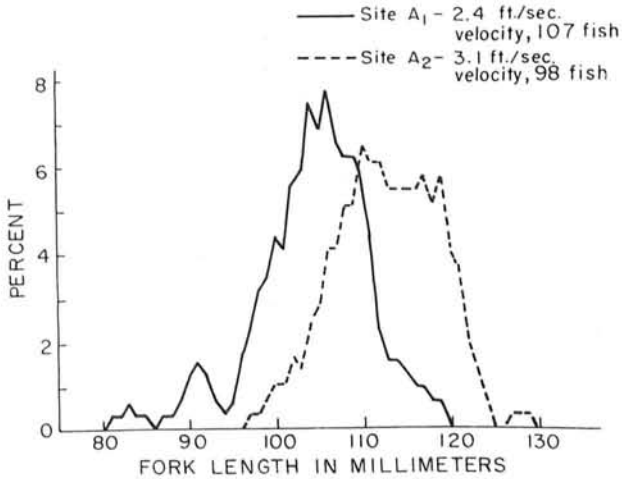

FIGURE 6.—Length frequencies of smolts captured in high and low velocity waters near site A from 2150 to 2210 hours, June 2, 1955. (Frequencies are smoothed by moving averages of threes.)

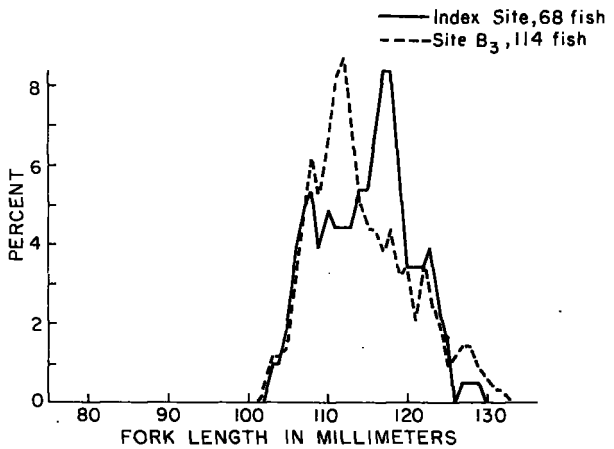

FIGURE 7.—Length frequencies of smolts captured in waters of similar velocity (approximately 3.5 feet per second) near index site from 2200 to 2212 hours, June 4, 1955. (Frequencies are smoothed by moving averages of threes.)

second, captured fish of comparable size. Water velocities at the index site were measured carefully with a Gurley current meter at least once each year during this study and varied little (table 1).

TABLE 1.—*Middepth water velocities at the index fyke-net site on Kvichak River*

Year	Date	Velocity (ft./sec.)
1956	June 21	3.5
1957	June 21	3.6
1958	May 17	3.5
1959	May 29	3.4

Channel changes.—Changes in river depth or width in the vicinity of the index fyke-net site could radically affect the migration path of smolts and thus influence fyke-net catches. However, no appreciable changes in the contour of the river bottom at the index site have been detected on maps prepared each year by the method of plane table mapping and sounding (fig. 8).

Water depth.—Water depth for effective fyke netting in the Kvichak River is fixed at from 3.5 to 4 feet. At a greater depth some fish escape over the wings and center of the net, since the net must rest on the river bottom at all times to prevent fish passing beneath it.

Changes in water depth of the Kvichak River have followed the same pattern each year of this study. Water depth is at a minimum in spring and reaches a maximum in late summer or early autumn. Increased water discharge results from melting snow and glaciers or from rainfall. The annual range and increase in water depth as measured at the Igiugig gaging station during the period of fyke netting are shown in table 2. Fluctuations in water depth have been proportionate between the gaging and fyke-netting sites each year. Changes in water depths necessitate shifting the fyke net periodically to optimum depth during the smolt migration.

TABLE 2.—*Annual water-depth ranges and increases in the upper Kvichak River*

Year	Observation dates	Comparative range (in inches)	Increase (in inches)
1955	May 29 to June 30	11 to 24	13
1956	May 18 to June 30	13 to 26	13
1957	May 8 to June 30	0 to 26	26
1958	May 4 to June 30	7 to 37	30
1959	May 23 to June 30	0 to 14	14

NOTE.—All water depths are based relatively on the lowest recording (in 1957), which is assigned the value of 0. The permanent water level gage is about 1 mile downstream from the outlet of Iliamna Lake.

Debris.—Net-clogging debris in a river can be a variable factor in operation of fyke nets. Efficiency of clogged nets was tested by Dr. Koo and the author in the Ugashik River system of Bristol Bay in 1956 (table 3). On even-numbered nights one net was used during the entire fishing period, and on odd-numbered nights a clean net was substituted midway in the fishing period at 2000 hours. Tests on nights when the net was not replaced indicated

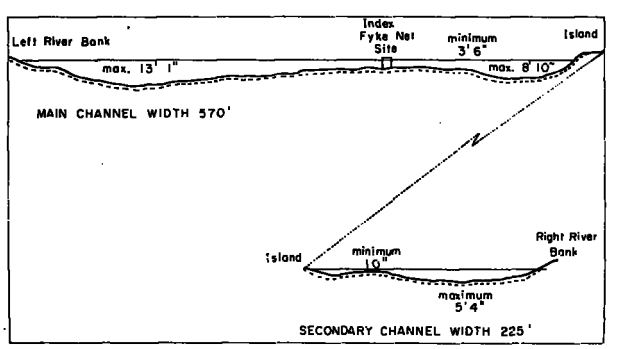

FIGURE 8.—Typical river bottom contour at index site, Kvichak River, June 23, 1958. (Water-gage reading, 32 inches; ratio of depth to width is drawn as 2 to 1.)

TABLE 3.—*Comparison of hourly fyke-net catches of smolts on one-net days (severe clogging) and two-net days (reduced clogging), Ugashik River, 1956*

Date	Hourly catch										
	1500–1600	1600–1700	1700–1800	1800–1900	1900–2000	2000–2100	2100–2200	2200–2300	2300–2400	2400–0100	Total
Two-net days: [1]											
June 1	0	2,000	2,858	409	280	1,376	18	208	132	495	7,776
3	.....	9	2	123	10	0	158	4,576	1,056	.....	5,934
5	.....	0	45	0	0	0	0	17	3	.....	65
7	.....	361	16	7	0	168	249	137	567	.....	1,505
9	20	21	101	1	150	0	0	1	139	43	476
13	17	131	9	0	0	1	1	24	38	84	305
15	0	0	31	120	1	8	0	0	23	70	253
17	0	0	0	0	0	0	0	121	89	3	213
Total	37	2,522	3,062	660	441	1,553	426	5,084	2,047	695	16,527
Percent	0.2	15.3	18.5	4.0	2.7	9.4	2.6	30.8	12.4	4.2	100.1
One-net days:											
May 31	.....	624	1,656	1,200	3,096	63	909	23	155	.....	7,726
June 2	.....	1,281	656	390	1,722	492	.....	.....	.....	.....	4,541
4	.....	13	2,005	0	0	1,417	5	12	8	.....	3,460
6	.....	0	0	1	0	8	0	1	.....	.....	10
8	.....	384	1	0	86	0	2	0	49	.....	522
10	.....	160	540	38	140	5	3	2	7	.....	895
12	.....	0	4	3	5	2	1	37	18	.....	70
14	.....	1	221	206	199	720	58	68	19	.....	1,492
16	.....	0	0	0	1	357	25	1	5	.....	389
18	.....	0	0	0	0	15	0	6	16	.....	37
Total	.....	2,463	5,083	1,838	5,249	3,079	1,003	150	277	.....	19,142
Percent	.....	12.3	26.6	9.6	27.4	16.1	5.2	0.8	1.4	.....	100.00

[1] Net change occurred at 2000 hours.

that the fyke-net catch decreased gradually with clogging for a period of 5 hours, after which few fish were caught. On nights when the clogged net was replaced with a clean net, the greater efficiency showed in an increased catch.

The most troublesome form of debris in the Kvichak River was a colonial diatom (*Gomphonema* sp.) which drifted in ribbonlike streams from Iliamna Lake whenever a moderate to strong wind prevailed down the lake. Debris of terrestrial origin, grass and leaves, became an occasional nuisance late in the season with the higher water levels. During periods of abundant debris it was necessary to change the nets frequently or to clean them while in fishing position.

DETERMINING SMOLT AGE

Sampling Procedure

From 1955 through 1957, representative 2-pound samples of smolts were taken from the fyke-net catches in approximate proportion to the size of the migration. On nights of heavy migration several samples were taken, and on nights of light migration one or no sample was taken. In 1958, 2-pound samples, taken in ½-pound lots each 15 minutes, were collected during each hour, provided adequate numbers of fish were available. The sampling procedure in 1959 was similar to that of 1958 except that 1-pound samples rather than 2-pound samples were taken. The fish included in all samples were taken randomly from the weighing basket to prevent size selection resulting from possible stratification. The samples of live fish were transferred to separate containers, which were 10-gallon milk cans or boxes placed along the riverbank in slow-moving water. The milk cans were partly screened on the sides and the boxes were made of ⅛-inch saran screen.

During the first 3 years of the investigations, samples were processed each morning; during 1958 and 1959, within 5 hours of capture. The change was made in 1958 to prevent mortalities that occurred in the earlier years from holding the fish overnight.

Length-Frequency Samples

The two important age groups of smolts in the Kvichak River, those spending one or two winters in fresh water, can nearly always be separated by length alone. Therefore, all fish in each sample were measured and the length-frequency method of age determination was employed.

Fish in groups of 10 to 15 were anesthetized in urethane [1] or chlorotone, measured from the tip of the snout to the fork of the tail, and returned to a container of fresh water to revive. Each length was tallied together with information identifying the sample. At a later date all length-frequency tabulations for 1 day were weighted according to the magnitude of the fyke-net catches during the daily 3-hour index period and combined in a composite season sample.

Scale Samples

Ages determined from length frequencies were verified from scale samples. Scale samples were taken from fish used in the length-frequency measurements, and the fish selected for scale samples were immediately preserved in 5-percent formalin. Several weeks after preservation, the fish were remeasured and the scale samples removed. Shrinkage of preserved specimens was adjusted by a shrinkage factor determined by measuring individual fish before and after their preservation. Shrinkage from live length varied from 3 to 7 percent, depending on the length of the fish, or about 4 millimeters. Four to eight scales were taken from each fish from immediately above or below the lateral line and between the dorsal and adipose fins. These scales were mounted in a spread pattern on a 1- by 3-inch glass slide. Scales from eight fish were mounted on a slide, with the length of each fish recorded on the slide label. The scales were covered with a second glass slide and the two slides taped together.

All scales were studied to determine number of annuli and amount of spring growth since formation of the last winter annulus. Spring growth does not appear on the scales of smolts that migrate soon after lake ice breakup, but it becomes apparent about midway through the migration season and the growth increases during the summer.

ABUNDANCE OF SMOLTS

The annual Kvichak River smolt index was based on the number of fish captured in a single fyke net fished each year of the study under similar fishing conditions and for the duration of the migration. This method was designed to detect fluctuations in the number of smolts from year to year. The number of smolts and calculated index values for the 5 years of the study are presented in table 4. The daily smolt catches each year are shown in appendix tables 1 through 5.

TABLE 4.—*Indices of smolt abundance in the Kvichak River*

Year	Number of smolts	Index value [1]
1955	214,000	11.2
1956	64,000	3.3
1957	25,000	1.3
1958	1,913,000	100.0
1959	1,643,000	85.9

[1] The total number of smolts caught in 1958 has been arbitrarily assigned the base value of 100.0.

Some adjustments of each year's total catch have been necessary. For the first 3 years of the study, some smolt catches from secondary net sites A and C were included to obtain the index value. The use of these sites was necessary because ice in the river prevented fishing at the index site early in the season and because the biologists who did the counting were involved with other duties late in the season. During 1955 and 1957, the catches from net-sites A and C were included when the two nets were contributing less than 7 percent of the season's catch. During the period of the ice flow in 1956 a substantial migration was detected at site A; and, consequently, an evaluation of these catches in terms of principal index-site catches was necessary. This evaluation was made on the basis of simultaneous fishing at the index site and site A for 4 days, from June 7 through June 10 (table 5). The ratio of catches of site A to those of the index site for the 4 days was

TABLE 5.—*Simultaneous smolt catches at site A and at the index site, 1956*

Date	Catch at—	
	Site A	Index site
June 7	874	9,449
June 8	16	4,127
June 9	8	1,851
June 10	0	115
Total	898	15,542

[1] Urethane has not been used extensively since reports of its carcinogenic effects were published.

0.06:1.00, and this ratio was applied to the catches obtained at site A before June 7 to estimate the index catches for this early period. The estimated index catches for 1956 are shown in appendix table 2.

During each year's smolt migration some hours and days of fishing were missed because of ice in the river or failure of the fyke-net anchors. Estimates of the number of fish passing the net site during hours not fished have been calculated on the basis of the average catch of the preceding and following hours. Estimates for days missed have been made by averaging the catches of the preceding and following days. Estimates for fishing hours missed have never exceeded 8 percent of the season's catch, and estimates for days missed have never exceeded 2.5 percent of the season's catch. The maximum estimate of hours missed was for the 1955 run and the maximum estimate of days missed was for the 1957 run.

During the peak of the 1959 migration, the cod end was placed on the net for 5 minutes of each 15 minutes fished and occasionally 5 minutes of each 30 minutes fished. The catches were multiplied by 3 or 6, as appropriate, for estimates of the 15- and 30-minute periods. This subsampling reduced handling of the fish and consequent injury to them. The estimates from the intermittent fishing in 1959 are considered reliable because of the homogeneity of catches noted in 1958 during periods of continuous net checking at the peak of migration. To test this homogeneity for 1958, all combinations of every third 5-minute catch (for the estimate of the 15-minute periods of fishing in 1958) were compared with the total of all consecutive 5-minute catches (total of 98), and the maximum error was found to be about ±0.5 percent. When each combination of every sixth 5-minute catch (for the estimate of the 30 minute periods) was related to the total catch, the maximum error was less than ±4.0 percent.

Timing of Migration

The timing of the Kvichak River smolt migrations is depicted by the annual cumulative catch curves (fig. 9). Each spring the migration started near the final day of ice flow in the Kvichak River (table 6) and continued through June or early July. The 1958 smolt migration is the earliest on record and corresponds to the early breakup of lake ice for that year.

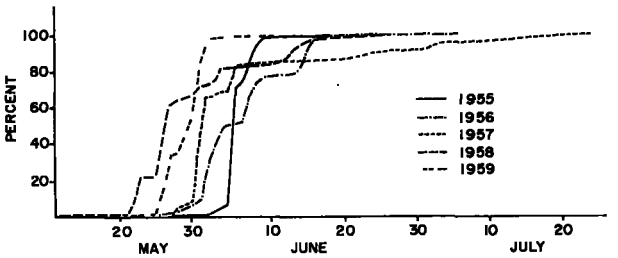

FIGURE 9.—Cumulative daily smolt catches at the index site in the Kvichak River, 1955 through 1959.

TABLE 6.—*Final day of ice flow in the Kvichak River*

Year	Date
1955	June 3
1956	June 6
1957	May 27
1958	May 9
1959	May 27

Each year the peak period of smolt abundance has been less than 2 weeks in duration (table 7). In the future this short period of major abundance can probably be used to reduce the effort previously necessary for smolt enumeration. Fyke netting can be started near the time of ice breakup and be continued only through the peak period of migration.

TABLE 7.—*Periods of peak catches of smolts in the Kvichak River*

Year	Total sampling period		Period of peak catches		
	Date	Number of days	Date	Number of days	Percent of season's catch
1955	May 28 – June 27.	31	June 4 – 9	6	94
1956	May 24 – July 4.	42	June 1 – 9, 14 – 16.	12	88
1957	May 28 – July 24.	38	May 28 – June 6.	10	84
1958	May 10 – July 5.	56	May 22 – June 3.	13	80
1959	May 23 – June 28.	36	May 26 – June 2.	8	98

Hourly Index Catches

The hours of largest smolt catch for each year are shown graphically in figure 10. In 1955 and 1956, the catches were largest from 2300 hours to midnight; during 1957 and 1958

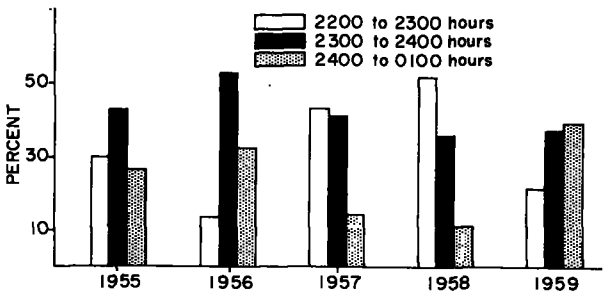

FIGURE 10.—Annual smolt catches, by hour, at the index site, 1955 through 1959.

they were largest from 2200 to 2300 hours; during 1959 they were largest from midnight to 0100 hours. The change in the hour of peak catches probably was related to the onset of darkness, which seems to promote smolt migration (Hoar, 1954). Darkness in the Kvichak system in May normally occurs about 2200 hours and in June about 2300 hours. During 1957 and 1958 the migration took place primarily in May, and therefore the early hour of peak migration. The 1959 migration also occurred in May but during this year the May nights were exceptionally clear and light. The 1955 and 1956 migrations occurred primarily in June which accounted for the later hour of peak migration than in 1957 or 1958. Extended fishing in 1958 and 1959 from 2100 to 0200 hours for most of the season established one index hour for each of these 2 years as the hour of greatest abundance (table 8).

TABLE 8.—*Hourly smolt catches at index site, May 10 to July 5, 1958, and May 27 to June 2, 1959*

Item	2100–2200	2200–2300	2300–2400	2400–0100	0100–0200	Total
1958:						
Catch	715,990	997,855	700,966	213,946	146,331	2,772,088
Percent	26	36	25	8	5	100
1959:						
Catch	76,071	293,069	503,532	578,690	461,214	1,912,576
Percent	4	15	26	31	24	100

24-Hour Fishing

Operation of the fyke net in several 24-hour periods was carried out only during 1957 and 1958 and only during a few of the peak days of migration (fig. 11; appendix tables 6 and 7). For purposes of analysis, the 24-hour periods were divided into six 4-hour intervals. In 1957, the year of smallest migration, more than 91 percent of the fish caught during the 12 days of round-the-clock fishing were taken from 2200 to 0200 hours (see fig. 11; appendix table 6). In 1958, the year of largest migration, only 62 percent of the catch was taken during this same 4-hour period in 9 days of 24-hour fishing (appendix table 7).

During 1959, many visual observations on a 24-hour basis revealed considerable migration outside the 3-hour period (2200–0100 hours). The cumulative number of fish migrating at a time other than the index period creates an underestimate of smolt abundance based on the index fishing period alone. No adjustment for daylight migration has been made for 1958 and 1959. Index fyke netting on a 24-hour basis, especially during years of large migration, is desirable in the Kvichak River system. Perhaps an automatic electronic counter can be used to reduce the cost of operation for this extended fishing.

Smolt Catches at Adjacent Net Sites

In 1955, two fyke nets were fished side by side, 50 feet apart, in the immediate index area for 4 days near the period of peak migration to obtain information on the variation that might be expected in catches from nets fished in the general area of the index site. The hourly catches (table 9) showed some variation, which

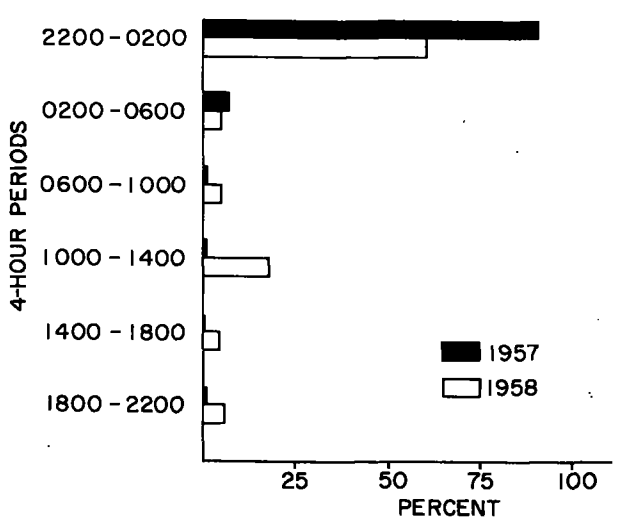

FIGURE 11.—Smolt catches on days of 24-hour fishing at the index site, 1957 and 1958.

TABLE 9.—*Comparative hourly catches of smolts at index site and at site B_4, June 7–10, 1955*

Date and site	2200–2300	2300–2400	2400–0100	Total
June 7:				
Index	1,824	20,482	2,020	24,326
B_4	1,577	11,926	2,100	15,603
June 8:				
Index	5,327	7,973	3,440	16,740
B_4	7,492	8,792	2,815	19,099
June 9:				
Index	2,295	3,005	2,984	8,284
B_4	2,600	9,978	3,686	16,264
June 10:				
Index	0	45	0	45
B_4	0	0	3	3
Total:				
Index	9,446	31,505	8,444	49,395
B_4	11,669	30,696	8,604	50,969

tends to average out over a period of time, indicating that nets fished in the general index area should sample effectively.

Smolt Catches at Distant Net Sites

In 1957 and 1958, efforts were made during most of the season to estimate the variability in smolt catches by fishing the index site simultaneously with site C, which is located 2 miles upstream (fig. 12). The daily smolt catches of the two nets for 1957 were similar, as were the total catches. The total catch at the index site was 23,000 fish and at site C, 19,000 fish (appendix table 13). These comparable catches suggest that both nets were fishing the same population at about the same rate during this year of relatively small abundance. In 1958, a year of much greater smolt abundance, the daily catches of the same two nets simultaneously reflected the fluctuations in the smolt migration but with less fidelity than in 1957 (fig. 12; appendix table 14). The total catch at site C in 1958 was only 40 percent as large as the catch at the index site. The difference in total numbers was due to much greater catches at the index site on the 5 days of heaviest migration. Visual observations and actual catches during these 5 days indicated that a large proportion of the smolt migration passed the upriver site C before the net-setting time.

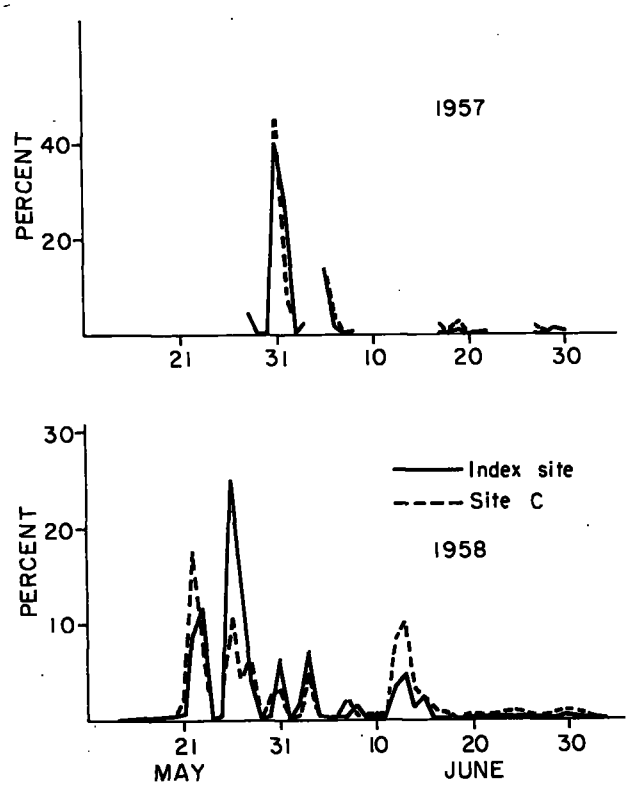

FIGURE 12.—Comparative smolt catches at index site and site C, Kvichak River, 1957 and 1958.

AGE COMPOSITION OF SMOLTS

For simplicity of analysis, samples used in smolt age determinations were restricted to those collected on days of major catches. The percentage of each year's smolt catch represented by the samples is shown in table 10.

Age analysis has been directed toward identification of two smolt groups only: fish which have spent one winter in fresh water, and fish which have spent two winters in fresh water. According to scale samples collected since 1955, smolts that have spent three winters in fresh water and fry (nō winters) have been rare. Their rarity has been further verified by analysis of about 6,500 adult red salmon scales that were taken from escapement samplings at the outlet of Iliamna Lake from 1955 to 1959.

TABLE 10.—*Smolt age-determination samples from the Kvichak River*

Year	Number of days of sampling	Fish caught during days of sampling	
		Number	Percent
1955	7	210,000	98
1956	15	[1] 31,000	96
1957	9	21,000	84
1958	13	1,794,000	94
1959	8	1,608,000	98

[1] The samples were taken at both site A and the index site; therefore, the actual catches of these two sites, during nights of sampling, were added to obtain the 31,000.

Analysis of these adult scales by Dr. Koo indicated that all smolts migrated before they had spent three winters in fresh water. In 1955 only 0.2 percent migrated from the lake as fry; in other years, no fry migrated.

The proportions of Kvichak River smolts in the two age groups during the 5 years of study are illustrated in the length-frequency curves of figure 13. The tabulated information regarding the daily sample size, the proportion of fish having spent one winter in fresh water, and the weighting values are shown in appendix tables 8 through 12.

Two relationships are apparent from these data. First, a definite trend is present in 1955 through 1958 from fish that spent two winters in fresh water to an increasingly dominant proportion of fish that spent one winter in fresh water. Then a complete reversal occurs in 1959 with dominance of the older fish. Additional years of data are necessary to establish the presence or absence of cyclic changes. Second, the modal length of the fish is related to population density in the lake system before migration. In 1958, the year of greatest abundance in Iliamna Lake, the mode of the fish that spent one winter in fresh water was about 1 centimeter less than that of the one-winter fish of other years. The same has been true of the fish in the older age group in 1955 and 1959, the next years of greater smolt abundance. The length modes of both age groups in 1956 and 1957, years of low abundance, have been larger or have been shifted to the right of the modes of 1955, 1958, and 1959. This same relationship has been reported in the Lake Dalnee red salmon smolts by Krogius and Krokhin (1948).

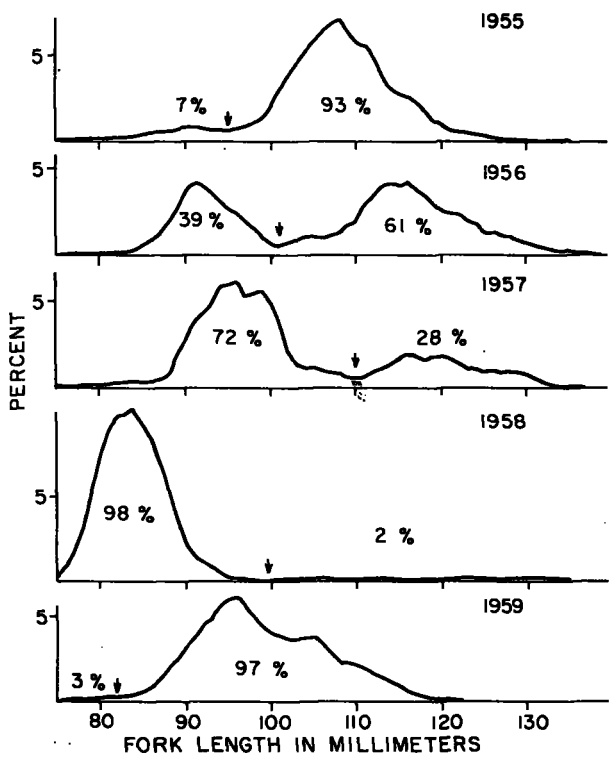

FIGURE 13.—Composite length frequencies of smolts, 1955 through 1959. (Each daily sample is weighted by magnitude of the fyke-net catches for that day. Total frequency for each year is smoothed by moving averages of threes. The arrows indicate the division point between age groups, as verified by scale samples.)

The relation between the smolt index catch by age groups and the magnitude of the parent escapement for each year of observation is shown in table 11. It is concluded from the data that large escapements have produced large smolt migrations, and small escapements have produced small smolt migrations.

Smolt Sizes at Adjacent Net Sites

In 1955 a comparison of smolt sizes was made in the simultaneous catches of two nets set side by side, 50 feet apart, at the index site. The

TABLE 11.—*Kvichak River parent escapements and resulting smolt catches*

Year	Number of fish in parent escapement [1]	Smolt catch		
		Age group [2]	Year	Number of smolts
1952	5,970,000	1	1954	No data.
		2	1955	195,000
1953	321,000	1	1955	19,000
		2	1956	39,000
1954	241,000	1	1956	25,000
		2	1957	7,000
1955	251,000	1	1957	18,000
		2	1958	39,000
1956	9,443,000	1	1958	1,874,000
		2	1959	1,591,000
1957	2,843,000	1	1959	47,000
		2	1960	432,000

[1] 1952-1954 escapements estimated from spawning-ground surveys by J. R. Gilbert and H. D. Smith. Since 1955, escapements estimated by daily tower counts at Igiugig.
[2] Number of winters the smolts spent in fresh water.

results are shown as length-frequency curves in figure 14. The similarity between the two nets in sizes of fish caught indicate that nets fished in the area bordered by the index and B_4 sites should sample reliably. The length-frequency curves presented in figure 7 also show similarity in the sizes of fish taken by two nets fished side by side.

Smolt Sizes at Distant Net Sites

Smolt samples taken in 1957 and 1958 during the simultaneous fishing of two nets, one 2 miles upstream from the other (fig. 15; appendix tables 10, 11, 15, and 16), show similarity of length frequencies and age composition and indicate that the nets were intercepting the same smolt population.

Verification of Fresh-Water Age

It is reasonable to assume that if the age composition of the smolts is reliable, then the fresh-water age composition of the adults that return after two or three winters in the ocean should be similar to that of the smolts. This comparison is made on the assumption that the marine survival rate is relatively constant for one-winter and two-winter fish. Only the adult samples taken at the Igiugig tower sites were used in this comparison, because samples from the commercial catch include fish bound for adjacent rivers in the Naknek and Egegik districts as well as the Kvichak River. The percentages of the two age groups of smolts in the 1955, 1956, and 1957 migrations, and the percentages of the various age groups of adults that returned from these smolt migrations are shown in table 12. This good relationship of smolt age to adult fresh-water age indicates the method for smolt age determination is valid.

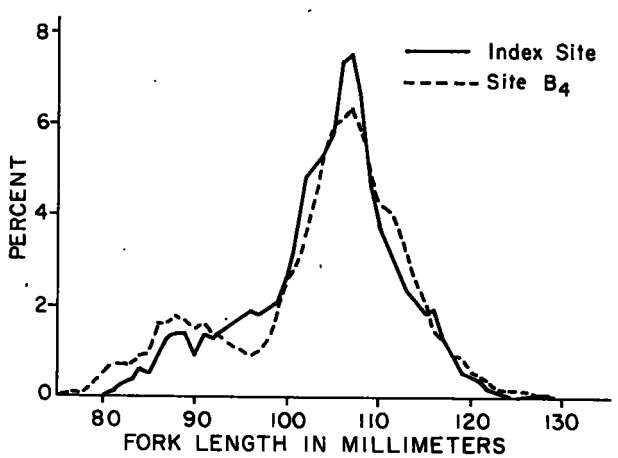

FIGURE 14.—Length frequencies of smolts captured at the index site and site B_4 between 2200 and 0100 hours, June 7 and 8, 1955. (Frequencies are smoothed by moving averages of threes.)

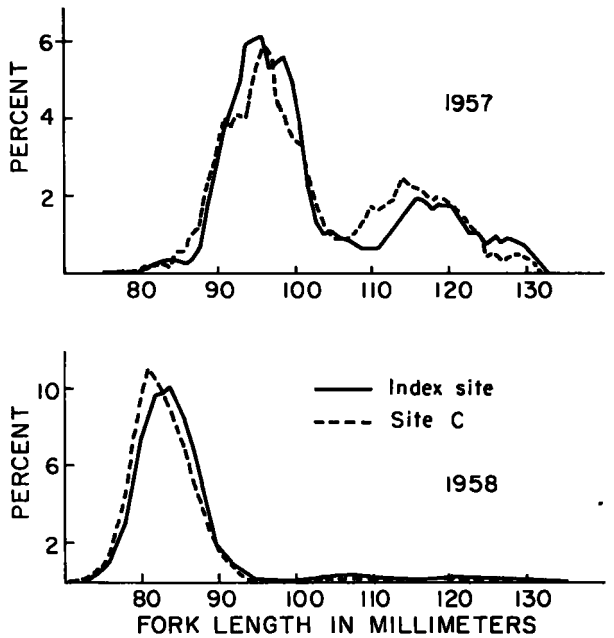

FIGURE 15.—Comparative smolt length frequencies, index site and site C, 1957 and 1958. (Each daily sample was weighted by the magnitude of the smolt catch for that day. Frequency for each year is smoothed by moving averages of threes.)

TABLE 12.—*Age groups (in percent) of smolts in migrations of 1955, 1956, and 1957 and of adults returning 2 and 3 years later*

Smolt migration [1]	Percent of sample	Adult returns			
		2 years later		3 years later	
		Age group [2]	Percent	Age group [2]	Percent
1955:					
Age-group 1..	9	4_2	3	5_2	8
Age-group 2..	91	5_3	97	6_3	92
1956:					
Age-group 1..	37	4_2	24	5_2	31
Age-group 2..	63	5_3	76	6_3	69
1957:					
Age-group 1..	72	4_2	25	5_2	100
Age-group 2..	28	5_3	75	6_3	0

[1] Age groups of smolts refer to number of winters the smolts spent in fresh water.

[2] Adult age determinations from escapement scale samples analyzed by Dr. Koo. Arabic figure refers to year in which fish returned as adults, and subscript figure refers to year in which fish migrated to sea.

The slightly increased percentage return of smolts that had spent two winters in fresh water probably could be expected because of their larger size and better chance of survival in the sea. This conclusion follows that of Foerster (1954), who showed a direct relation between marine survival and size of smolts. The discrepancy in age composition between the 1957 smolts and the adults returning in 1959 after two winters in the ocean could be due to inaccurate smolt sampling or to good survival conditions in the ocean. Good survival of fish spending two winters in the ocean was evident in nearly all districts of Bristol Bay in 1959.

DISCUSSION

The methods used in this study do not lead to a finite evaluation of smolt abundance and age composition. However, their reliability has been supported by most tests conducted during the past 5 years. The tests involved the simultaneous fishing of two nets side by side and two nets 2 miles apart up and down the Kvichak River, and the relating the age of the smolts to the fresh-water age of returning adults. It is important to note that the great differences in index values from year to year permit a large error in the accuracy of the method but the index method still enables detection of important changes in smolt abundance. Tremendous differences in abundance from year to year do occur, as is evident from the striking changes in the size of the adult population of Kvichak River red salmon (table 11). The large adult escapements have produced large smolt migrations and small adult escapements have produced small smolt migrations. Two extremes in the smolt index values are apparent for the past 5 years, the minimum represented by 1956 and 1957, and the maximum represented by 1958 and 1959 (table 4). The index of 1955 is nearly four times larger than the next smaller value (1956) but eight times smaller than the next higher value (1959).

The methods described in this paper have been shown to be reasonably accurate to date. Final evaluation of these methods, however, must wait until data are available on the return of adult salmon from a longer series of smolt migrations. Only after such an evaluation period can the estimation of the population variables and the prediction of subsequent adult returns be achieved with accuracy.

SUMMARY

The purpose of the smolt study, conducted from 1955 through 1959, was to provide an annual index of abundance and to determine the age and size composition of Kvichak River red salmon.

The relative index method used to assess smolt abundance was based on the season-long catch of a single fyke net set at the index site throughout the same daily fishing period (2200 to 0100 hours) and under similar river conditions each year. It was designed to determine major fluctuations in smolt abundance from year to year.

The annual indices of Kvichak smolt abundance were for 1955, 11.2; 1956, 3.3; 1957, 1.3; 1958, 100.00; 1959, 85.9. These index values are relative to the combined smolt catches of 1958, which were assigned a value of 100.0. The tremendous differences in smolt index values permit a large error in the accuracy of the method, but the index method enables the detection of important changes in abundance.

Large parent escapements have produced large smolt migrations and small parent escapements have produced small smolt migrations.

Weighted length-frequency samples, verified by scale samples, were used in age determination. Two predominant age groups of smolts occur in Kvichak River: those that have spent one winter in fresh water and those that have spent two winters in fresh water.

The smolt age composition for the 5 years indicated a trend toward cyclic variation and a relation of size to population density, smaller fish occurring during years of large abundance. The similarity of smolt ages with the fresh-water ages of returning adults supports the methods and results of age determination.

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APPENDIX

APPENDIX TABLE 1.—*Kvichak River smolt catches, by site, day, and hour, 1955*

Site and date	2200–2300	2300–2400	2400–0100	Total [1]	Percent
Site A:					
May 28				36	0.02
29				18	0.01
30				114	0.05
31				91	0.04
June 1				12	0.01
2				8,148	3.81
3				450	0.21
Index site:					
June 4				8,106	3.79
5	40,573	54,422	39,084	134,079	62.75
6	5,590	938	1,661	8,189	3.83
7	1,824	20,482	2,020	24,326	11.38
8	5,327	7,973	3,440	16,740	7.83
9	3,952	3,005	2,984	9,941	4.65
10	0	45	0	45	0.02
11				10	0.01
12	30	0	1	31	0.02
13	0	277	329	606	0.28
14	27	2	3	32	0.02
15	4	32	4	40	0.02
16	0	5	3	8	0.00
17				376	0.18
18	118	183	180	481	0.23
19	5	36	28	69	0.03
20				45	0.02
21	0	5	5	10	0.01
22	54	45	2	101	0.05
Site C:					
June 23	214	121	100	435	0.20
24	477	217	224	918	0.43
25	48	84	69	201	0.09
26	6	16	2	24	0.01
27	0	0	2	2	0.00
Total	58,249	87,888	50,141	213,684	100.00

[1] For days where no hourly catches are given, the totals, in part, are based on fyke-net catches before or after the index hours during the same day.

APPENDIX TABLE 2.—*Kvichak River smolt catches, by site, day, and hour, 1956*

Site and date	2200–2300	2300–2400	2400–0100	Total [1]	Percent
Index site:					
May 24				0	0.00
25				155	0.24
26				1,019	1.59
27				328	0.51
28				803	1.26
29				1,278	2.00
30				499	0.78
31				1,261	1.97
June 1				11,779	18.44
2				6,632	10.38
3				6,632	10.38
4				1,485	2.32
5				933	1.46
6				449	0.70
7	1,113	3,556	4,780	9,449	14.79
8	325	1,126	2,676	4,127	6.46
9	498	1,093	260	1,851	2.90
10	0	0	115	115	0.18
11	103	35	0	138	0.22
12	9	5	3	17	0.03
13	32	26	25	83	0.13
14	1,692	789	610	3,091	4.84
15	731	4,804	1,391	6,926	10.84
16	1,512	620	586	2,718	4.25
17	78	27	0	105	0.16
18	0	29	36	65	0.10
19	694	269	44	1,007	1.58
20	18	0	406	424	0.66
21	3	0	0	3	0.01
22	70	0	219	289	0.45
23	30	1	2	33	0.05
24	2	0	17	19	0.03
25	0	3	3	6	0.01
26	38	40	0	78	0.12
27	12	12	1	25	0.04
28	0	2	1	3	0.01
Site C:					
June 29	0	2	3	5	0.01
30	3	7	7	17	0.03
July 1	10	10	10	30	0.05
2	0	0	3	3	0.01
3	2	2	2	0	0.01
4	0	0	0	0	0.00
Total	6,975	12,458	11,200	63,886	100.00

[1] For days where no hourly catches are given, the totals are estimated catches based on 4 days' simultaneous fishing at site A and index site.

APPENDIX TABLE 3.—*Kvichak River smolt catches, by site, day, and hour, 1957*

Site and date	2200–2300	2300–2400	2400–0100	Total [1]	Percent
Index site:					
May 28	628	454	2	1,084	4.26
29	1	8	87	96	0.38
30				69	0.27
31				9,274	36.48
June 1	2,124	3,640	344	6,108	24.02
2				178	0.70
3	175	179	245	599	2.36
4	2	0	0	2	0.01
5	991	1,447	998	3,426	13.47
6	166	303	4	473	1.86
7	0	3	0	3	0.01
8	90	0	1	91	0.36
9	0	4	0	4	0.02
10	0	1	1	2	0.01
11	229	0	2	231	0.91
12	1	0	0	1	0.00
13	1	0	1	2	0.01
14	0	0	0	0	0.00
15	0	0	1	1	0.00
16				[2] 33	0.13
17	0	60	5	65	0.26
18				73	0.29
19				292	1.15
20				49	0.19
21				186	0.73
22				216	0.85
23				[2] 140	0.55
24				[2] 140	0.55
25				[2] 140	0.55
26				[2] 140	0.55
27	0	0	65	65	0.26
28				22	0.09
29				321	1.26
30				144	0.57
Site C:					
July 1				112	0.44
2				56	0.22
3				159	0.63
4				291	1.14
5				66	0.26
6				120	0.47
7				29	0.11
8				15	0.06
9				45	0.18
10				0	0.00
11				30	0.12
12				59	0.23
13				165	0.65
14				31	0.12
15				156	0.61
16				16	0.06
17				26	0.10
18				45	0.18
19				92	0.36
20				43	0.17
21				6	0.02
22				12	0.05
23				130	0.51
24				50	0.20
Total	4,408	6,099	1,746	25,424	100.00

[1] For days where no hourly catches are given, the net was not checked at the end of each index hour.
[2] The index net was not fished; the "total" was estimated as the average of the catches on the preceding and following days.

APPENDIX TABLE 4.—*Kvichak River smolt catches at index site, by day and hour, 1958*

Date	2200–2300	2300–2400	2400–0100	Total	Percent
May 10	7	11	14	32	0.00
11	19	48	102	169	0.01
12	676	523	522	1,721	0.09
13	71	87	101	259	0.01
14	21	37	43	101	0.01
15	72	176	58	306	0.02
16	25	183	155	363	0.02
17	2	112	280	394	0.02
18	430	95	392	917	0.05
19	304	668	386	1,358	0.07
20	[1] 540	885	[1] 1,248	2,673	0.14
21	7,000	6,000	1,864	14,864	0.78
22	131,250	[1] 45,763	1,621	178,634	9.34
23	137,418	[1] 81,793	5,313	224,524	11.74
24	10	3	0	13	0.00
25	177	93	429	699	0.04
26	[1] 326,972	[1] 131,643	20,238	478,853	25.03
27	166,796	99,099	8,554	274,449	14.35
28	20,254	47,565	7,356	75,175	3.93
29	360	38	6	404	0.02
30	4,620	846	1,566	7,032	0.37
31	15,096	75,276	31,191	121,563	6.36
June 1	90	38	4	132	0.01
2	2,809	20,885	6,664	30,358	1.59
3	37,851	60,375	43,491	141,717	7.41
4	1,110	3,627	986	5,723	0.30
5	165	44	46	255	0.01
6	1,900	464	870	3,234	0.17
7	2,756	2,438	2,120	7,314	0.38
8	6,225	11,556	12,285	30,066	1.57
9	1,876	252	97	2,225	0.12
10	216	197	291	704	0.04
11	2,808	489	2,235	5,532	0.29
12	23,678	16,585	28,928	69,191	3.62
13	[1] 51,176	[1] 42,375	1,890	95,441	4.99
14	13,700	[1] 14,729	1,590	30,019	1.57
15	18,408	17,384	8,692	44,484	2.32
16	979	2,086	1,916	4,981	0.26
17	357	842	2,052	3,251	0.17
18	2,450	3,200	965	6,615	0.35
19	51	7	0	58	0.00
20	4,183	2,068	612	6,863	0.36
21	780	154	59	993	0.05
22	1,674	920	1,001	3,595	0.19
23	2,430	878	255	3,563	0.18
24	176	926	1,316	2,418	0.12
25	1,523	499	1,395	3,417	0.18
26	139	563	523	1,225	0.06
27	645	1,246	2,871	4,762	0.25
28	225	168	11	404	0.02
29	726	841	1,849	3,416	0.18
30	3,276	2,624	4,980	10,880	0.57
July 1	740	1,386	1,848	3,974	0.21
2	415	82	546	1,043	0.05
3	27	31	8	66	0.00
4	30	50	54	134	0.01
5	141	13	57	211	0.01
Total	997,855	700,966	213,946	1,912,767	100.01

[1] Partly a visual estimate of the fish passing through the net with the cod end removed.

APPENDIX TABLE 5.—*Kvichak River smolt catches at index site, by day and hour, 1959*

Date	2200–2300	2300–2400	2400–0100	Total	Percent
May 23	81	270	946	1,297	0.08
24	48	2	60	110	0.01
25	208	2,592	1,188	3,988	0.24
26	67,701	97,470	68,000	233,171	14.19
27	83,148	96,774	135,846	315,768	19.22
28	21,154	1,905	1,028	24,087	1.47
29	1,100	34,385	122,396	157,881	9.61
30	29,736	93,840	109,121	232,697	14.16
31	107,396	166,842	150,248	424,486	25.83
June 1	49,529	104,900	17,378	171,807	10.46
2	1,006	4,886	42,673	48,565	2.96
3	143	19	3	165	0.01
4	73	132	254	459	0.03
5	340	742	585	1,667	0.10
6	815	200	10	1,025	0.06
7	4,118	6,918	2,663	13,699	0.83
8	138	257	158	553	0.03
9	0	220	180	400	0.02
10	140	0	2	142	0.01
11	0	0	0	[1] 74	0.00
12	0	0	5	5	0.00
13	0	0	0	[1] 83	0.01
14	23	128	10	161	0.01
15	0	0	0	[1] 952	0.06
16	924	507	312	1,743	0.11
17	0	0	0	[1] 1,027	0.06
18	306	3	2	311	0.02
19	0	0	0	[1] 1,444	0.09
20	472	1,121	983	2,576	0.16
21	0	0	0	[1] 1,325	0.08
22	0	4	69	73	0.00
23	0	0	0	[1] 94	0.01
24	108	5	2	115	0.01
25	0	0	0	[1] 70	0.00
26	12	2	10	24	0.00
27	0	0	0	[1] 351	0.02
28	187	438	53	678	0.04
Total	368,906	614,562	654,185	1,643,073	100.00

[1] The index net was not fished; the total was estimated as the average of the catches of the preceding and following days.

APPENDIX TABLE 6.—*Kvichak River smolt catches for 12 days of 24-hour fishing, at index site, 1957*

Date	2200–0200	0200–0600	0600–1000	1000–1400	1400–1800	1800–2200	Total
May 30	103	675	[1] 35	[1] 35	4	[1] 23	875
June 1	7,056	171	0	3	0	0	7,230
3	787	99	0	0	0	0	886
5	3,477	1	0	0	0	0	3,478
6	496	[1] 20	[1] 18	0	0	0	534
7	3	0	0	0	0	0	3
12	1	0	0	0	0	5	6
13	2	0	0	0	0	0	2
14	0	0	0	0	0	1	1
22	217	3	0	0	0	0	220
29	[1] 331	[1] 19	[1] 10	[1] 10	1	31	402
July 20	24	[1] 2	[1] 1	0	0	1	28
Total	12,497	990	64	48	5	61	13,665
Percent	91.45	7.24	0.47	0.35	0.04	0.45	100.00

[1] This figure is partly an estimate made necessary because the nets were not checked exactly at 4-hour intervals.

APPENDIX TABLE 7.—*Kvichak River smolt catches for 9 days of 24-hour fishing, at index site, 1958*

Date	2200–0200	0200–0600	0600–1000	1000–1400	1400–1800	1800–2200	Total
May 13	473	796	3	1	1	0	1,274
24	15	3	107	280	179	63	647
28	78,669	10,812	2,499	510	867	322	93,679
30	9,188	4,806	4,592	105,392	15,565	16,747	156,380
31	129,429	6,235	311	415	174	316	136,880
June 1	149	11	6	1,367	493	520	2,546
2	33,084	1,642	1,071	718	4,098	15,784	56,397
3	151,356	7,797	24,200	10,467	2,490	5,493	201,803
4	5,897	1,030	469	250	3,182	2,937	13,765
Total	408,260	33,222	33,258	119,400	27,049	42,182	663,371
Percent	61.54	5.01	5.01	18.00	4.08	6.36	100.00

APPENDIX TABLE 8.—*Weighted age composition of Kvichak River salmon, at index site, 1955*

Date	Number of samples	Number of fish	Age 1	
			Percentage in samples [1]	Index catch
June 2	2	191	4.2	342
4	4	377	0.3	24
5	4	690	2.9	3,888
6	2	306	10.8	884
7	5	644	16.6	4,038
8	6	789	18.0	3,013
9	3	437	35.5	3,529
Total	26	3,434	.....	15,718 (or 7.3%)

[1] Determined from daily unweighted length frequencies and scale samples.

APPENDIX TABLE 9.—*Weighted age composition of Kvichak River salmon, at index site, 1956*

Date [1]	Number of samples	Number of fish	Age 1	
			Percentage in samples [2]	Index catch
May 26	1	58	12.1	7
29	1	73	5.5	4
June 1	2	106	13.2	90
5	1	54	72.2	39
7	3	250	34.0	3,213
8	3	240	41.7	1,721
9	2	163	30.7	568
10	1	115	34.8	40
11	1	103	50.5	70
14	2	169	36.7	1,134
15	3	341	38.7	2,680
16	2	179	52.5	1,427
19	1	112	75.0	755
22	1	119	94.1	272
26	1	65	13.9	11
Total	25	2,147	.....	12,031 (or 39.2%)

[1] Samples and catches from May 26 through June 5 from site A.
[2] Determined from daily unweighted length frequencies and scale samples.

APPENDIX TABLE 10.—*Weighted age composition of Kvichak River salmon, at index site, 1957*

Date	Number of samples	Number of fish	Age 1	
			Percentage in samples [1]	Index catch
May 28	1	86	54.7	593
29	1	87	37.9	36
30	2	235	92.8	64
31	3	318	83.0	7,697
June 1	2	164	48.2	2,944
2	1	90	56.7	101
3	3	268	74.6	447
5	3	377	97.6	3,344
6	1	81	38.3	181
Total	17	1,706	.....	15,407 (or 72.3%)

[1] Determined from daily unweighted length frequencies and scale samples.

APPENDIX TABLE 11.—*Weighted age composition of Kvichak River salmon, at index site, 1958*

Date	Number of samples	Number of fish	Age 1	
			Percentage in samples [1]	Index catch
May 22	3	459	94.1	168,095
23	3	535	97.9	219,806
26	3	546	96.7	463,051
27	3	535	98.3	269,783
28	3	628	99.7	74,949
31	3	659	100.0	121,563
June 2	3	683	99.4	30,176
3	3	668	99.9	141,575
8	3	624	99.5	29,916
12	3	622	99.5	68,845
13	3	652	99.9	95,346
14	3	623	99.8	29,959
15	3	630	100.0	44,484
Total	39	7,864	.....	1,757,548 (or 97.9%)

[1] Determined from daily unweighted length frequencies and scale samples.

APPENDIX TABLE 12.—*Weighted age composition of Kvichak River salmon, at index site, 1959*

Date	Number of samples	Number of fish	Age 1	
			Percentage in samples [1]	Index catch
May 26	3	156	1.3	3,031
27	3	166	3.0	9,473
28	1	47	2.1	506
29	3	167	4.8	7,578
30	3	182	3.3	7,679
31	3	201	1.0	4,245
June 1	3	164	5.5	9,449
2	2	121	8.3	4,031
Total	21	1,204	.....	45,992 (or 2.9%)

[1] Determined from daily unweighted length frequencies and scale samples.

APPENDIX TABLE 13.—*Comparison of Kvichak River smolt catches, at index site and site C, 1957*

Date	Index site		Site C	
	Catch	Percent	Catch	Percent
May 28	1,084	4.75	1,160	6.08
29	96	0.42	595	3.12
30	69	0.30	79	0.41
31	9,274	40.62	8,646	45.35
June 1	6,108	26.75	1,889	9.91
2	178	0.78	111	0.58
3	599	2.62	404	2.12
5	3,426	15.00	2,705	14.19
6	473	2.07	1,061	5.57
7	3	0.01	16	0.08
8	91	0.40	156	0.82
17	65	0.28	425	2.23
18	73	0.32	183	0.96
19	292	1.28	524	2.75
20	49	0.21	92	0.48
21	186	0.81	84	0.44
22	216	0.95	60	0.31
27	65	0.28	312	1.64
28	22	0.10	124	0.65
29	321	1.41	296	1.55
30	144	0.63	142	0.74
Total and percent	22,834	99.99	19,064	99.98

APPENDIX TABLE 14.—*Comparison of Kvichak River smolt catches, at index site and site C, 1958*

Date	Index site		Site C	
	Catch	Percent	Catch	Percent
May 10	32	0.00	92	0.01
11	169	0.01	135	0.02
12	1,721	0.09	755	0.10
13	259	0.01	121	0.02
14	101	0.01	194	0.03
15	306	0.02	472	0.06
16	363	0.02	345	0.04
17	394	0.02	571	0.07
18	917	0.05	500	0.07
19	1,358	0.07	888	0.12
20	2,673	0.14	2,510	0.33
21	14,864	0.78	14,335	1.87
22	178,634	9.34	134,189	17.48
23	224,524	11.74	69,183	9.01
24	13	0.00	5	0.00
25	699	0.04	1,347	0.18
26	478,853	25.03	82,585	10.76
27	274,449	14.35	35,208	4.59
28	75,175	3.93	51,174	6.67
29	404	0.02	228	0.03
30	7,032	0.37	19,894	2.59
31	121,563	6.34	24,005	3.13
June 1	132	0.01	261	0.03
2	30,358	1.59	3,526	0.46
3	141,717	7.41	38,501	5.02
4	5,723	0.30	3,916	0.51
5	255	0.01	287	0.04
6	3,234	0.17	3,901	0.51
7	7,314	0.38	17,706	2.31
8	30,066	1.57	4,341	0.57
9	2,225	0.12	2,961	0.39
10	704	0.04	1,587	0.21
11	5,532	0.29	3,672	0.48
12	69,191	3.62	62,654	8.16
13	95,441	4.99	79,377	10.34
14	30,019	1.57	25,729	3.35
15	44,484	2.32	16,457	2.14
16	4,981	0.26	7,954	1.04
17	3,251	0.17	3,115	0.41
18	6,615	0.35	4,480	0.58
19	58	0.00	500	0.07
20	6,863	0.36	3,954	0.52
21	993	0.05	758	0.10
22	3,595	0.19	4,650	0.61
23	3,563	0.18	4,738	0.62
24	2,418	0.12	3,424	0.45
25	3,417	0.18	5,550	0.72
26	1,225	0.06	2,116	0.28
27	4,762	0.25	2,159	0.28
28	404	0.02	861	0.11
29	3,416	0.18	3,294	0.43
30	10,880	0.57	7,711	1.00
July 1	3,974	0.21	5,006	0.65
2	1,043	0.05	2,556	0.33
3	66	0.00	309	0.04
4	134	0.01	438	0.06
5	211	0.01	136	0.02
Total and percent	1,912,767	99.99	767,321	100.02

APPENDIX TABLE 15.—*Weighted age composition of Kvichak River salmon, at site C, 1957*

Date	Number of samples	Number of fish	Age 1	
			Percentage in samples [1]	Site C catch
May 28	1	94	74.5	864
29	1	74	36.5	217
30	1	85	57.6	46
31	2	164	56.1	4,850
June 1	3	294	69.0	1,303
2	None	None	[2] 75.4	84
3	1	121	81.8	330
5	2	223	96.9	2,621
6	1	161	88.8	942
Total	12	1,216		11,257 (or 67.6%)

[1] Determined from daily unweighted length frequencies and scale samples.
[2] Calculated as the average of June 1 and 3.

APPENDIX TABLE 16.—*Weighted age composition of Kvichak River salmon, at site C, 1958*

Date	Number of samples	Number of fish	Age 1	
			Percentage in samples [1]	Site C catch
May 22	2	310	96.1	128,956
23	3	462	99.1	68,560
26	2	392	99.0	81,759
27	2	362	99.2	31,950
28	3	623	99.7	51,020
31	3	624	99.8	23,957
June 2	3	677	100.0	3,526
3	3	684	99.9	38,462
8	3	636	99.5	4,319
12	3	619	99.8	62,529
13	3	634	99.8	79,218
14	3	627	99.8	25,678
15	3	607	100.0	16,457
Total	36	7,257		616,391 (or 98.3%)

[1] Determined from daily unweighted length frequencies and scale samples.

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