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MAIN-STEM AND TRIBUTARY SAMPLING OF RED SALMON SCALES FOR POPULATION STUDIES

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by

Ted S. Y. Koo, Research Assistant Professor
and
Howard D. Smith, Senior Research Biologist
Fisheries Research Institute
College of Fisheries, University of Washington
Seattle, Washington

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ABSTRACT

Comparison of freshwater age composition by scale studies was made on red salmon sampled at two locations: (1) in the Kvichak River before fish dispersed into the lake system, and (2) on spawning grounds after fish had spawned. Kvichak River samples in 1956 and 1957 had higher percentages of 1-winter-in-lake fish than did spawning ground samples. The discrepancy was believed to be due to difficulties in obtaining representative samples and proper weighting from spawning grounds. The 1958 samples from both locations were comparable, probably as a mere coincidence.

It is concluded that although spawning ground sampling is essential to studies of population density, distribution, and subpopulations in a lake system, it is difficult, if not impossible, to obtain and weight the samples so that they are representative of the whole escapement. The proper place to sample the entire escapement is in a trunk river, such as the Kvichak River in the Kvichak system.

INTRODUCTION

Age and size composition of red salmon *(Oncorhynchus nerka)* runs of Bristol Bay, Alaska may be determined only if both catch and escapement are sampled, because the commercial gear, restricted by regulation to gill nets of 5 1/2-inch mesh or larger, is highly selective on size, and therefore on age and sex of the fish. In the average runs, the commercial gear takes a higher proportion of the larger fish which have spent 3 years in the ocean, whereas more of the small fish escape. Catch is usually sampled at a cannery where fish are landed; escapement may be sampled at two places--first in the main river before dispersing to the spawning grounds, and second on the spawning grounds after fish have spawned.

The purpose of this paper is to determine whether or not spawning ground sampling can represent the entire escapement. If the objective is to study population density, time and geographical distribution, and subpopulations, spawning grounds are the place to sample. If it is to study sex ratio, age composition, and other characteristics of the population as a whole, the logical place to sample is in the trunk river or main stem where the entire escapement ascends within a relatively short period and can be adequately sampled.

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[1]Contribution No. 58, College of Fisheries, University of Washington.

This paper compares scale samples collected both in the trunk river and on spawning grounds in the Kvichak River system during the 1956 to 1958 field seasons. Because resorption erodes much of the peripheral part of scales of fish on the spawning ground, leaving only the central portion legible, comparison is confined to freshwater age composition.

SAMPLING AREAS

Kvichak River

The trunk river of the Kvichak system is the Kvichak River. In their upstream migration, red salmon follow the banks of this river and pass steadily into the lake along both sides of the outlet. They seldom use the deep midstream section as a migratory route. Escapement can therefore be sampled from either shore in the river or at the lower end of Lake Iliamna (fig. 1).

Samples of Kvichak River escapement were taken at Igiugig (1),[2] which is situated on the upper reaches of the river. Owing to the topography of the bottom and wave action caused by a prevailing wind, most sampling took place on the left or southeastern shore in Lake Iliamna immediately above the outlet.

Spawning Grounds

There are three principal types of spawning habitat in the Iliamna-Clark system. First in importance are the tributary streams and rivers, which support about 70 percent of the visible spawning population. Next in importance are the beaches on Lakes Iliamna and Clark and on the accessory lakes tributary to them. Last are the spring-fed ponds, such as Hudson Ponds (6), in which only a few salmon spawn.

All fish do not appear on the various spawning grounds at the same time nor within a short period of time. Although the entire escapement has passed through Igiugig and entered Lake Iliamna by the end of July, some populations do not appear on the spawning grounds until October or later. While attempts were made to obtain measurements and scale samples from all known important spawning areas in the system, it was indeed a formidable task to effect such a comprehensive coverage over a wide area and for an extended period of spawning.

[2] The Arabic figure in parenthesis immediately following the locality is the number used in figure 1.

SAMPLING METHODS

Kvichak River Sampling

The escapement on the Kvichak River was sampled with a beach seine of cotton webbing with 3-inch mesh (stretch measure). The net was 200 feet long and 12 feet deep and was set with a skiff powered by an outboard motor and hauled in manually.

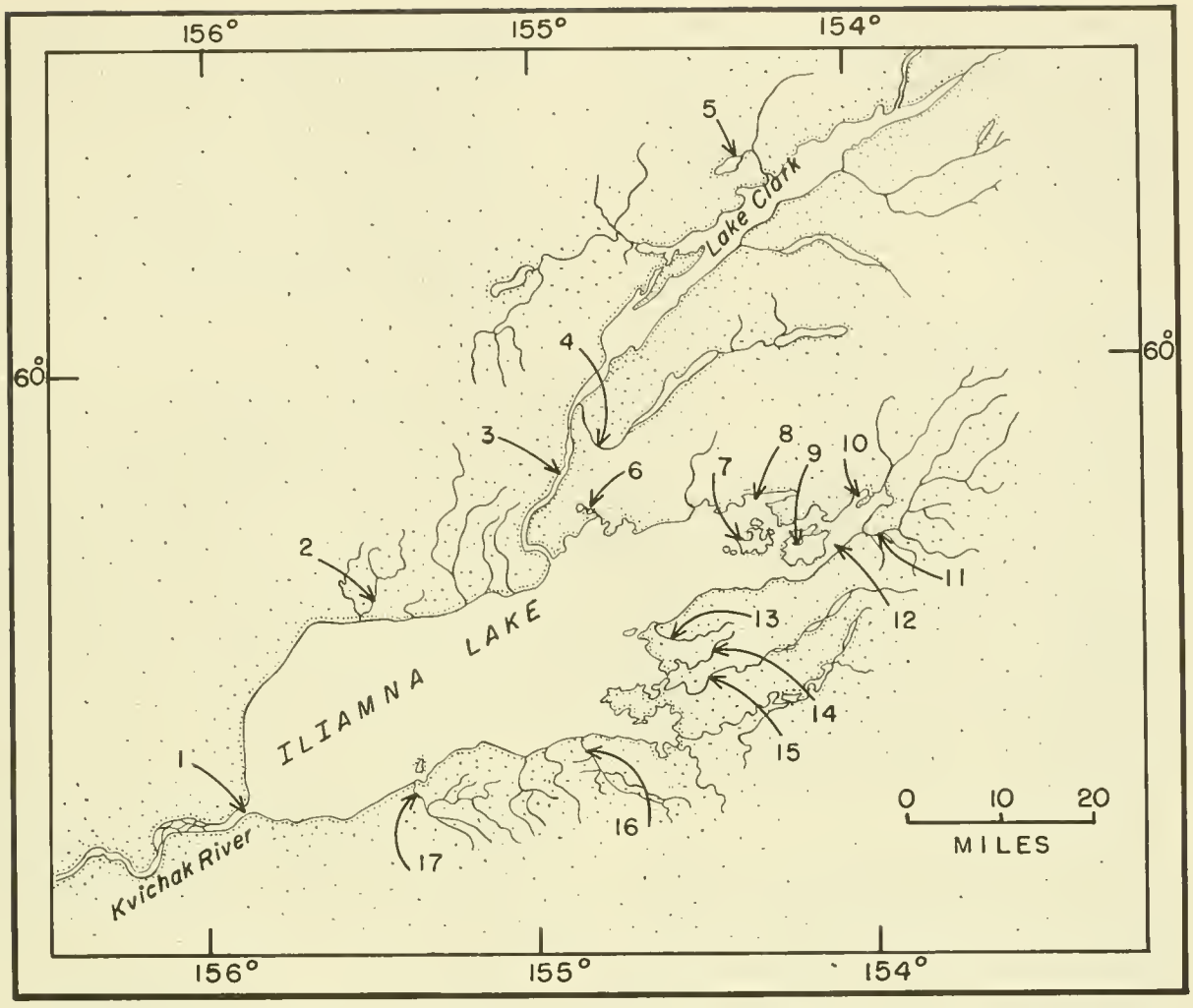
The escapement past Igiugig usually extends over the month of July. Except for the first and last few days of the migration, when only a few fish were running, fish were sampled daily. Each day 3 or 4 hauls were made, which normally took 4 to 6 hours. Fish were measured and tagged, and a scale was removed from each fish before it was released. When possible, 40 or more scale samples, about half of them from each sex, were collected each day.

Seining was carried on during a period of about 3 weeks each season. During this period, 87 to 99 percent of the escapement made its way into the lake, as revealed by daily counts (table 1).

Spawning Ground Sampling

Individual spawning grounds were surveyed by air, whenever possible, at a time when the greatest number of fish was present. A visual estimate of the population was taken then, but the actual sampling was deferred until later when enough dead fish for an adequate sample were available along the banks. At that time, a ground survey was made to take the sample.

The total spawning population seen during our aerial surveys constitutes only a fraction of the population counted at Igiugig. In the 3 years, 1956 to 1958, this fraction ranged from 10 to 18 percent. This relatively low estimate of the spawning population is partly due to the numbers of fish seen represent only the



(1) Igiugig
(2) Lower Talarik
(3) Newhalen River
(4) Tazimina River
(5) Kijik Lake
(6) Hudson Ponds
(7) Flat Islands
(8) Knutson Bay
(9) Surprise Creek
(10) Lonesome Bay
(11) Iliamna River
(12) Finger Beaches
(13) Tommy River
(14) Nick G. Creek
(15) Copper River
(16) Kokhanok Creek
(17) Belinda Creek

Figure 1.--Iliamna - Clark system, showing the sampling locations.

Table 1.--Samples of adult red salmon from the Kvichak River escapement, 1956-58

Year	Total escapement enumerated at Igiugig	Percent of escapement during sampling period	Scale sample	
			Number of scales collected	Percent of total escapement
1956	9,443,000	95.9	1,673	0.018
1957	2,965,000	99.1	1,742	0.059
1958	535,000	87.1	720	0.135

peak counts and partly due to the incomplete coverage of spawning grounds because of certain conditions. For instance, Lake Clark and many of its tributaries, important as they are as spawning areas, were not surveyed because of their turbid glacial water. Comparative sampling data on the spawning grounds are shown in table 2.

Only the more important spawning areas were sampled each year. An area important as spawning grounds in one year may not be so in another. Also, owing to weather or other difficulties, even localities that were important as spawning grounds were not visited in some years. Therefore, not all localities sampled in the first year were sampled in succeeding years. Of the 16 localities sampled in the 3 years, only 3 were sampled consistently in all 3 years; 6 in 2 years, and 7 in 1 year (table 3). The names and locations of the sampling areas are shown in figure 1. In 1956, the summed peak count of the scale sampling areas (marked by x in table 3) was about 81 percent of the total from all localities; in 1957, 56 percent; and in 1958, 73 percent.

General Methods

All scales were removed from a specified area on the body about midway between the dorsal and adipose fins and within 5 scale rows above or below the lateral line. They were mounted on gummed cards, and impressions were made on cellulose acetate for examination under the microscope and projector after the method described by Koo (1955).[3] Scales with regenerated nuclear areas were discarded. Those collected from the Kvichak River were read by one author and those from spawning grounds by the other. A certain portion of the samples were read by both authors to determine whether the two authors agreed, in general, in their interpretation of scale marks. The validity of scale markings read as annuli is not discussed here because it is not important to this study. Table 4 shows the percentage of agreement in the two readings.

Only freshwater age was determined, and only two age groups were involved, either one annulus (designated here as 1.), or two annuli (designated here as 2.). Two types of errors resulted in disagreement between readers: (1) Scales read as 1. by the first reader and 2. by the second, and (2) scales read as 2. by the first reader and 1. by the second. For the 23 disagreements encountered over the 3-year period (table 4), 12 were errors of the first type, and 11 were errors of the second type. Disagreements between readers thus tended to average out.

Comparative readings by the two authors indicate a high degree of agreement. Therefore, any major difference in age composition between Kvichak River and spawning ground samples cannot be attributed to difference in interpretation of scale marks.

FRESHWATER AGE COMPOSITION OF KVICHAK RIVER AND SPAWNING GROUND SAMPLES

In Kvichak River samples, percentages of age groups 1. and 2. were calculated for each day a sample was taken. They were then weighted according to the daily

[3]Biology of the red salmon, *Oncorhynchus nerka* (Walbaum) of Bristol Bay, Alaska, as revealed by a study of their scales. Ph.D. Thesis. University of Washington, Seattle. 164 pp. (Available on interlibrary loan or by microfilm service.)

Table 2.--Samples of adult red salmon from the Kvichak spawning grounds, 1956-58

Year	Peak population estimate from aerial surveys	Scale sample: Number of scales collected	Scale sample: Percent of total escapement
1956	1,440,000	1,050	0.011
1957	301,000	910	0.031
1958	96,000	848	0.159

Table 3.--Peak population counts on various Kvichak spawning grounds, 1956-58

[(x) indicates scale sample taken; --- indicates no survey made]

Locality	Number of fish, peak counts		
	1956	1957	1958
Copper River (15)[1]	450,000 (x)	70,000 (x)	20,000 (x)
Nick G. Creek (14)	5,000 (x)	3,000 (x)	1,200 (x)
Knutson Bay (8)	155,000 (x)	23,500 (x)	14,000 (x)
Belinda Creek (17)	6,000 (x)	2,000 (x)	---
Finger Beaches (12)	10,000 (x)	6,000 (x)	2,700
Tazimina River (4)	32,500 (x)	10,000 (x)	650
Kijik Lake (5)	86,000 (x)	27,000 (x)	6,000
Kokhanok Creek (16)	190,000 (x)	30,000	2,800 (x)
Lower Talarik Creek (2)	32,000 (x)	9,500	250
Iliamna River (11)	200,000 (x)	26,500	10,000
Newhalen River (3)	23,000	25,000 (x)	30,000 (x)
Tommy River (13)	12,000	2,100 (x)	2,050
Hudson Ponds (6)	3,000	500 (x)	0
Flat Islands (7)	41,000	3,700	1,200 (x)
Surprise Creek (9)	---	---	135 (x)
Lonesome Bay (10)	---	---	500 (x)
Miscellaneous	194,500	62,200	4,515
Total	1,440,000	301,000	96,000

[1] Number refers to location in figure 1.

Table 4.--Scale reading agreement by the two authors

Year material collected	Source of material	Number of scales read by both	Scales read as belonging to same age	
			Number	Percent
1956	Kvichak River	196	189	96.4
1956	Spawning grounds	117	109	93.2
1957	Spawning grounds	207	199	96.1

escapement counted from the towers erected in the stream at Igiugig. Finally, the total percentages of the two age groups for the entire season were calculated (table 5).

In spawning ground samples, percentages of the two age groups were calculated for each locality. These were weighted according to estimated population size for each locality, and the totals for all spawning ground samples were obtained. These are compared in table 5 with those from Kvichak River samples.

In 1956 and 1957, there was a marked difference in age composition between samples from the Kvichak River and from the spawning grounds, but in 1958, the age composition was practically identical. The differences in the first 2 years are consistent in that there is a higher proportion of 1. fish in Kvichak River samples than in spawning ground samples. In other words, proportionately more 2. fish were found on the spawning grounds than were first sampled in the Kvichak River. This is especially pronounced in 1956.

DISCUSSION OF RESULTS

Scale samples from both the Kvichak River and the spawning grounds naturally came from the same population. If they were representative of each place and were properly weighted, there should be no difference in the freshwater age composition between the two samples. The discrepancy revealed in 1956 and 1957 samples is obviously due to sampling difficulties, which may have occurred at either or both places. Let us examine each sampling closely.

Kvichak River Sampling

Theoretically, several factors here may cause nonrepresentative sampling of the population.

1. The sampling period: The run lasts about a month. Our sampling covered only about 3 weeks. The early and tail ends of the run were not sampled. However, most of the migration took place during the 3-week sampling period; in both 1956 and 1957, more than 95 percent of the run occurred within this period (table 1). This coverage can certainly be considered adequate.

2. The weighting: The percentages of the two age groups as determined from each day's samples were weighted according to the number of fish counted from towers in the Kvichak River. Tower enumeration of the adult run has been proved an accurate method of assessing the number of fish by this Institute's work on the Wood River and by the Fish and Wildlife Service's work on the Egegik

Table 5.--Freshwater age composition between Kvichak River and spawning ground samples of adult red salmon, 1956-58

Year	Locality	Age groups, in percent	
		1.	2.
1956	Kvichak River	83.6	16.4
	Spawning grounds	53.6	46.4
1957	Kvichak River	57.4	42.6
	Spawning grounds	44.1	55.9
1958	Kvichak River	11.6	88.4
	Spawning grounds	11.2	88.8

River.[4] Therefore, weighting by the daily counts should be reliable.

3. The sampling locality: Ideally fish should be seined from both shores in any day of sampling in order to avoid any possible selection of segregated groups of fish. Seining on both shores with equal effort was not achieved because of the difficulties mentioned earlier, and therefore may be a source of error. However, from tagging studies, the junior author (unpublished study) found that there was no evidence of stratification of fish on the spawning grounds, and at the same time individual areas contained tagged fish from each shore about in proportion to the numbers tagged there.

4. The sampling gear: Is it possible that the beach seine might be selective so that more 2. fish avoid the net and appear on the spawning grounds? This might happen if 2. fish were larger than 1. fish, either by their original difference in size or by their differential association with marine age, namely 6_3 and 4_2. The original difference in length, which amounts to about 20 percent during smolt stage, diminishes rapidly in the adults because of the overwhelming marine growth. Therefore, it is improbable that net selection could result on that account. The possibility of differential association of marine and freshwater ages can be ruled out since in 1956 the escapement was composed almost entirely (99 percent of 3_1 fish.

From the above considerations, we conclude that sampling in the Kvichak River was probably adequate, and the discrepancy in age composition between Kvichak River and spawning ground samples must be traced to the latter.

Spawning Ground Sampling

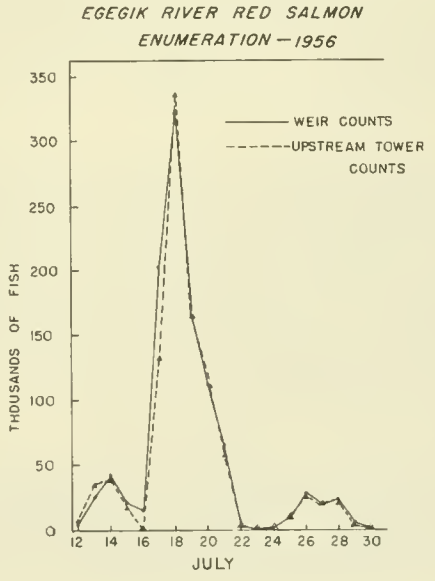
Possible sources of sampling error are as follows:

1. Although the sampling crew had tried to cover most major spawning areas, a number of places were left unsurveyed, either because of time and personnel limitations or because of practical difficulties. In 1957, for instance, sampling areas accounted for only 56 percent of the peak population estimated from aerial surveys.

2. Only a small portion (10 to 18 percent, table 2) of the actual escapement could be accounted for by spawning ground estimates. The weighting of age groups by localities was done according to relative population estimates, the accuracy of which could not be measured.

[4] The following is quoted from "Progress Report and Recommendations for 1957" by Administration of Alaska Fisheries, Juneau, Alaska, November 1956, p. 19:

> "2. Evaluation of Towers for Counting Adult Migrant Red Salmon in Bristol Bay.
>
> "A critical comparison of weir and tower counts was made on the Egegik River during the period July 12 to July 30 when somewhat more than a million adult fish migrated upstream (Figure 34).
>
> "After finding out the habits of the fish and locating towers in the proper places, a completely satisfactory count of the migrants was obtained. On two days during the early part of the run, fish by-passed the towers which were not located properly. During the balance of the migration, estimates of the total run from tower averaged only 1.6 percent lower than estimates made at the weir."



3. The important spawning streams are quite long, often 10 to 20 miles, and have fish distributed over the entire length. Ground surveys and sampling could normally cover only relatively short sections. If distribution of age groups was uneven over the whole length of the river, then sampling one or two sections could lead to biased results.

4. In some areas spawning took place over a long period of time, and there were instances of early and late populations. Owing to practical difficulties, repeated visits to a spawning ground were not made, and therefore the data used may be representative of one population but not the other.

5. The two age groups were not evenly distributed over all spawning grounds. While 1. fish predominated in one locality, 2. fish predominated in another (table 6).

The variable ratios of the two age groups on the spawning grounds occur in each of the 3 years and are occasionally extreme. This fact, coupled with the uneven distribution of population size on the various spawning grounds, makes proper sampling and weighting extremely difficult, if not impossible.

The above are general considerations of some theoretical factors that may cause spawning ground sampling to be nonrepresentative of the escapement population. Let us now examine each year individually.

1956 Samples.--Samples from only one spawning ground area, Tazimina River, has a higher percentage of 1. fish than samples from the Kvichak River (table 6), but Tazimina River was relatively unimportant as a spawning area (table 3). Therefore, weighting cannot be considered here as the main cause of the discrepancy between spawning ground and Kvichak River sampling.

Other factors that could have caused the discrepancy are: (1) Localities not sampled for scales had large populations with higher than 84 percent 1. fish. (2) The samples obtained from localities listed were not representative of the population; they could have been selective in favor of 2. fish because of timing, selection of a certain section of a stream, or other reasons.

1957 Samples.--Samples from only two spawning ground areas, Nick G. Creek and Belinda Creek, had significantly higher percentages of 1. fish than samples from the Kvichak River (table 6), but both these localities are insignificant spawning creeks (table 3). Unless the population in these creeks had been grossly underestimated, which is improbable, weighting cannot be a main cause for the discrepancy here.

The two factors that caused nonrepresentative samples in 1956 might also have caused them in 1957. Kokhanok Creek and Iliamna River, for instance, while both important as spawning areas, were not sampled.

1958 Samples.--Age composition of spawning ground samples agreed with that of Kvichak River samples. While in 2 previous years most spawning localities had higher percentage of 2. fish than Kvichak River samples, in 1958 most spawning localities had higher percentages of 1. fish (table 6). In fact, the unweighted mean is 21 percent for 1. fish in 1958, compared with the weighted mean of 11. Obviously then, weighting here has played a big role in bringing about the agreement between spawning ground and Kvichak River samples. This can be noted especially in the case of Newhalen River (table 3).

Only 8 locations were sampled in 1958 compared with 10 in either 1956 or 1957, and the sampling areas in 1958 were, in general, quite different from those of the other 2 years (table 3). Three new areas, Flat Islands, Surprise Creek, and Lonesome Bay, which were insignificant producers, were added in 1958, while some of the more important areas, Iliamna River, Kijik Lake, and Finger Beaches, were not sampled. Therefore, the excellent agreement between Kvichak River and spawning ground samples in 1958 is probably a fortuitous occurrence rather than a result of more representative sampling.

Table 6.--Number (n) of scales read and percentage (%) of 1. adult red salmon from various Kvichak spawning grounds, 1956-58

Locality	1956		1957		1958	
	n	%	n	%	n	%
Copper River (15)[1]	156	35.3	188	44.2	133	9.0
Nick G. Creek (14)	51	64.7	59	72.9	31	22.6
Knutson Bay (8)	53	81.1	24	54.2	84	31.0
Belinda Creek (17)	49	79.6	52	78.9	---	---
Finger Beaches (12)	24	62.5	26	26.9	---	---
Tazimina River (4)	48	89.6	41	41.6	---	---
Kijik Lake (5)	47	48.9	38	44.7	---	---
Kokhanok Creek (16)	125	76.8	---	---	82	7.3
Lower Talarik Creek (2)	40	62.5	---	---	---	---
Iliamna River (11)	39	48.7	---	---	---	---
Newhalen River (3)	---	---	53	34.0	127	1.6
Tommy River (13)	---	---	52	28.9	---	---
Hudson Ponds (6)	---	---	45	57.8	---	---
Flat Islands (7)	---	---	---	---	126	16.7
Surprise Creek (9)	---	---	---	---	29	20.7
Lonesome Bay (10)	---	---	---	---	24	58.3
All spawning ground samples, weighted:		53.6		44.1		11.2
Kvichak River samples, weighted:		83.6		57.4		11.6

[1] Number refers to location in figure 1.

CONCLUSIONS

The difference in freshwater age composition between Kvichak River and spawning ground samples is due to difficulties in obtaining representative samples and in proper weighting from the spawning grounds. Of the total escapement counted in the Kvichak River, only about one-fourth of it could be seen on the spawning grounds. Most of the population was therefore not available to sampling on the spawning grounds. It is not known whether the missing fish were near lake shores, in deep-water spawning areas, or hidden behind glacial water or other natural protection. Then, too, a large portion of the population seen was not sampled because extensive areas and lengthy spawning periods were involved.

Further, it is widely recognized that there are subpopulations of red salmon within one lake system, and that these subpopulations segregate on the spawning grounds. The fact that various localities in the Iliamna-Clark system showed different age composition is clear evidence

of such segregation. Sampling the segregated subpopulations to represent the whole population cannot be achieved without prohibitive increases in cost and effort.

We conclude, therefore, that to determine the sex ratio and the size and age composition of the escapement of red salmon into a lake system, the proper place to sample is in the trunk river, such as the Kvichak River in the Kvichak system, while the fish are migrating upstream before dispersing to the spawning grounds. This cannot adequately be replaced with spawning ground sampling. It must be added that trunk river sampling cannot replace spawning ground sampling either, if the objective is to study subpopulations in a lake system.

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