INVESTIGATIONS CONCERNING THE RED-SALMON RUNS TO THE KARLUK RIVER, ALASKA

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INTRODUCTION

The history of the Alaska salmon industry, until within the last few years, has been one of consistently increasing exploitation without regard to its effect on existing salmon supplies. In every district, as salmon stocks dwindled under this régime, the intensity of fishing effort was redoubled, and the amount of fishing gear in operation was increased by leaps and bounds in the attempt to maintain unimpaired, or to increase if possible, the size of the commercial pack. The necessity of making provision for future runs was ignored. No attention was given to the number of spawning fish that succeeded in escaping the nets. No one concerned himself with the size of the spawning reserves or their adequacy to maintain the runs. The congressional regulations in effect were hopelessly inadequate and the Bureau of Fisheries was without power to act.

Such a system could have only one result—the eventual depletion of the salmon supplies and the final extinction of the industry. This result was clearly foreshadowed in the years succeeding the close of the Great War and had been hastened, doubtless, by the extraordinary efforts during the course of the war to increase the salmon pack to the utmost, as a patriotic duty. Be that as it may, the conviction became universal, in the years following the armistice, that the salmon industry, by the methods then employed, was courting complete disaster and could be saved only by being subjected to close supervision under well-devised regulations.

To meet this emergency, Congress in 1924 enacted a law for the protection of the fisheries of Alaska, in which very wide regulatory powers were conferred on the Secretary of Commerce for the purpose of preventing further depletion of the salmon runs and of restoring them as nearly as possible to their former condition of abundance. Under his direction the Bureau of Fisheries has grappled with this problem.

Fortunately, considerable progress had been made prior to 1924 in ascertaining important facts in the life histories of our salmon. It was known that there are

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five distinct species of wide distribution throughout Alaska, and that each of these species has an independent, self-perpetuating colony in each of the streams that it inhabits. Each colony forms a self-contained unit, the members of which consistently interbreed, their progeny returning to their native stream at sexual maturity. Such a colony secures no recruits from adjacent streams; its maintenance at a high stage of abundance depends on there being provided each year, from its own members, an adequate spawning reserve, which shall successfully deposit their eggs in the river gravels. This necessity defines in large measure the regulatory duties of the Bureau of Fisheries. It must counteract the destructive agency of an unrestricted fishery by adopting and enforcing such regulations, locally applicable to the different fishing districts, as will insure year after year adequate spawning in each of the multitudinous streams throughout the vast extent of Alaska. The magnitude of this problem becomes at once apparent, but its almost incredible difficulties are known only to those intrusted with the administration of these fisheries.

In the first place it must be ascertained whether depletion of a given salmon run has occurred, and if so, to what extent. With adequate and reliable statistics, extending over a sufficient period of time, this can be done. Annual fluctuations in the magnitude of the runs, due to natural causes, can be recognized and evaluated and a trend established that will measure the declining supply. Usually the salmon statistics of the past have been inadequate and more or less untrustworthy, but such as they are they form our only basis for establishing the fact of depletion and its extent. In cases of pronounced depletion, however, such as unfortunately exists in many localities, even the rudest statistics are sufficient to demonstrate its existence.

It remains, then, to apply the remedy, and the question at once has arisen of how extensive a spawning reserve must be provided to check depletion and increase the size of the colony. In all fishery investigations in which conservation of a threatened supply has been the principal aim, the ideal has been properly emphasized to spare for commercial use all fish not needed to maintain the fish population at a high level of abundance. It is a generally accepted motto that we limit our spawning reserves to the lowest numbers consistent with safety, sparing every fish that can be spared for the world markets and for human consumption. But at the time the responsibility for the salmon fisheries of Alaska devolved on the Secretary of Commerce and the Bureau of Fisheries, we were without definite information concerning the number of spawning salmon necessary to produce a run of a given size. It was not even known, with regard to any stream, what proportion of its run had constituted its actual spawning reserve in any year, whether adequate or inadequate. Such statistics as we had dealt invariably with the portion of the run that had been captured for commercial purposes, never with that moiety that had escaped the fishermen and formed the basis for expectation of future runs.

In default of this essential knowledge, which it requires years of investigation to obtain, it may be asked what in the meantime has formed the basis of the bureau's activities in protecting the various runs. The answer is, the method of trial and error. When it is believed that a given district is threatened with overfishing, regulations are enforced which will diminish the commercial take of fish and increase the size of the spawning reserve, and the severity of the restrictions is planned to bear a direct relation to the seriousness of the depletion. In such cases it is not known what

had been the size of the spawning escapement previous to imposing the restrictions. It was known merely that it was inadequate and that the situation would be improved by such increase as the restrictions would provide. Future observations would reveal whether the regulations adopted would prove adequate, or should be strengthened to permit an even larger spawning reserve. In the present state of our knowledge, it is by this method that the majority of the fishing districts in Alaska must of necessity be administered.

It had been realized, however, even prior to the enactment of the Alaska fishery law of 1924, that our ignorance concerning the size of an optimum spawning reserve constituted a serious handicap in the administration of the salmon runs, and a program of investigation had been adopted in 1921 with the purpose of obtaining the desired knowledge. Such an investigation must of necessity concern itself with the independent colonies of one or more individual streams, and these streams must be carefully selected with certain requirements in view. As the essential part of the problem is to ascertain the complete returns from spawning colonies of known size, the streams selected for investigation must be so situated and of such character that both that portion of the run taken for commercial purposes and the portion that escapes to the spawning grounds can be accurately enumerated year after year. None of the streams in southeastern Alaska fulfill these requirements, as their colonies on their spawning migrations traverse long waterways behind the islands, where they mingle with other colonies bound for different streams and in common with them are there subject to capture. The spawning reserve in each of these streams could be enumerated, but the commercial take belonging to any stream is hopelessly commingled with the product of other rivers. For the same reason, none of the highly important salmon streams in Bristol Bay lends itself to this investigation. The commercial takes of the various streams can not be segregated. For similar reasons, the streams that enter Prince William Sound and Cook Inlet are not eligible.

It had been decided to inaugurate the experiment with the red or sockeye salmon (*Oncorhynchus nerka*), partly because this species is the best known in its life history and partly because, as the most valuable species in Alaska and the most sought after, it is subject to a very intensive fishery and is in special need of protection. Two of the best-known red-salmon streams in Alaska are the Karluk River, on Kodiak Island, and the Chignik River, which empties on the southern shore of the Alaska Peninsula, near its base. Each of these streams has supported an intensively conducted fishery over a long term of years, and each of them still maintains a red-salmon run of importance, however it may be diminished from its primitive abundance. Both the Karluk and the Chignik Rivers are of such size and character as to permit the installation of counting weirs for enumeration of the spawning escapement; and, what is equally important, their runs are nowhere subject to any considerable commercial capture except in the vicinity of their respective mouths. Except for an insignificant number of stragglers, the Chignik red salmon are not subject to capture beyond the confines of Chignik Bay, while the Karluk fish are captured only on the beaches between Karluk Head and Uyak Bay, with a limited number in Uyak Bay itself. Both of these streams answer admirably the requirements essential for these investigations—their commercial take can be

completely enumerated, free from admixture with the output of other rivers, and their spawning escapements can be led through the gates of counting weirs and the numbers accurately ascertained. For this reason they have been selected for this experiment. A counting weir was first installed in the Karluk River in 1921 and in the Chignik River in 1922, and they have been maintained in each subsequent year. The present report deals with the results thus far obtained in the Karluk River, leaving for later consideration the parallel series of determinations in the Chignik watershed.

KARLUK RIVER WATERSHED

Karluk River and the lakes from which it takes its source are located in the western part of Kodiak Island, approximately 154° west longitude and between 57° and 58° north latitude. The outlet of the river, which is approximately 30 miles long, is into Shelikof Strait, a short distance east of Karluk Head, one of the most distinctive and conspicuous landmarks of the Alaska coast.

The lakes are situated about 350 feet above sea level, as determined by an aneroid barometer, and are three in number. The largest lake, Karluk Lake proper, is 12 miles long by 2 miles in width at the widest place, and the area is approximately 14.6 square miles. It extends almost due north and south, with the outlet at the northern end. There are two smaller lakes (Thumb Lake and O'Malley Lake [1]) above the main lake. The accompanying map (fig. 1) shows these lakes, the main tributary streams, and the depth contours, as determined by a reconnaissance survey made by sextant and plane table during the summer of 1926. The lake is surrounded by mountains that rise abruptly to a height of about 2,500 feet above the level of the lake, and most of the tributary streams drop down abruptly from these mountains, tumbling over bowldery beds, which appear to be anything but favorable spawning grounds. From a few hundred yards to a mile or so of the lower courses of these streams is accessible to the spawning salmon, but their ascent usually is stopped abruptly by insurmountable falls.

Upper Thumb River (above Thumb Lake), Canyon Creek, and Falls Creek are the largest streams of the system. They meander for some distance through comparatively wide valleys and offer apparently by far the best spawning conditions. The underlying rocks are almost entirely shales, with an occasional small ledge of quartz. In the absence of any calcareous rocks, the water is extremely soft (a sample analyzed through the kindness of Dr. E. A. Birge, of the University of Wisconsin, indicated only about 4.5 cubic centimeters of fixed carbon dioxide per liter). The basin is evidently of recent glacial origin, as is indicated by the numerous cirques to be seen on the mountains, by the distinctly U-shaped contours of the valleys, including the bottom of the lake, and by numerous fine examples of glacial erosion to be seen on the exposed bedrock along the streams. Karluk Lake proper evidently was made by the formation of a large terminal moraine at what is now the foot of the lake.

The lake is of such recent origin that the shores have been very little modified by the action of the streams that enter the lakes. In only a few places has the shore line been built out by the deposit of silt and bowlders from the mountain sides,

[1] Named in honor of the present Commissioner of Fisheries, who has done so much to further the study and scientific care of the salmon fisheries of Alaska.

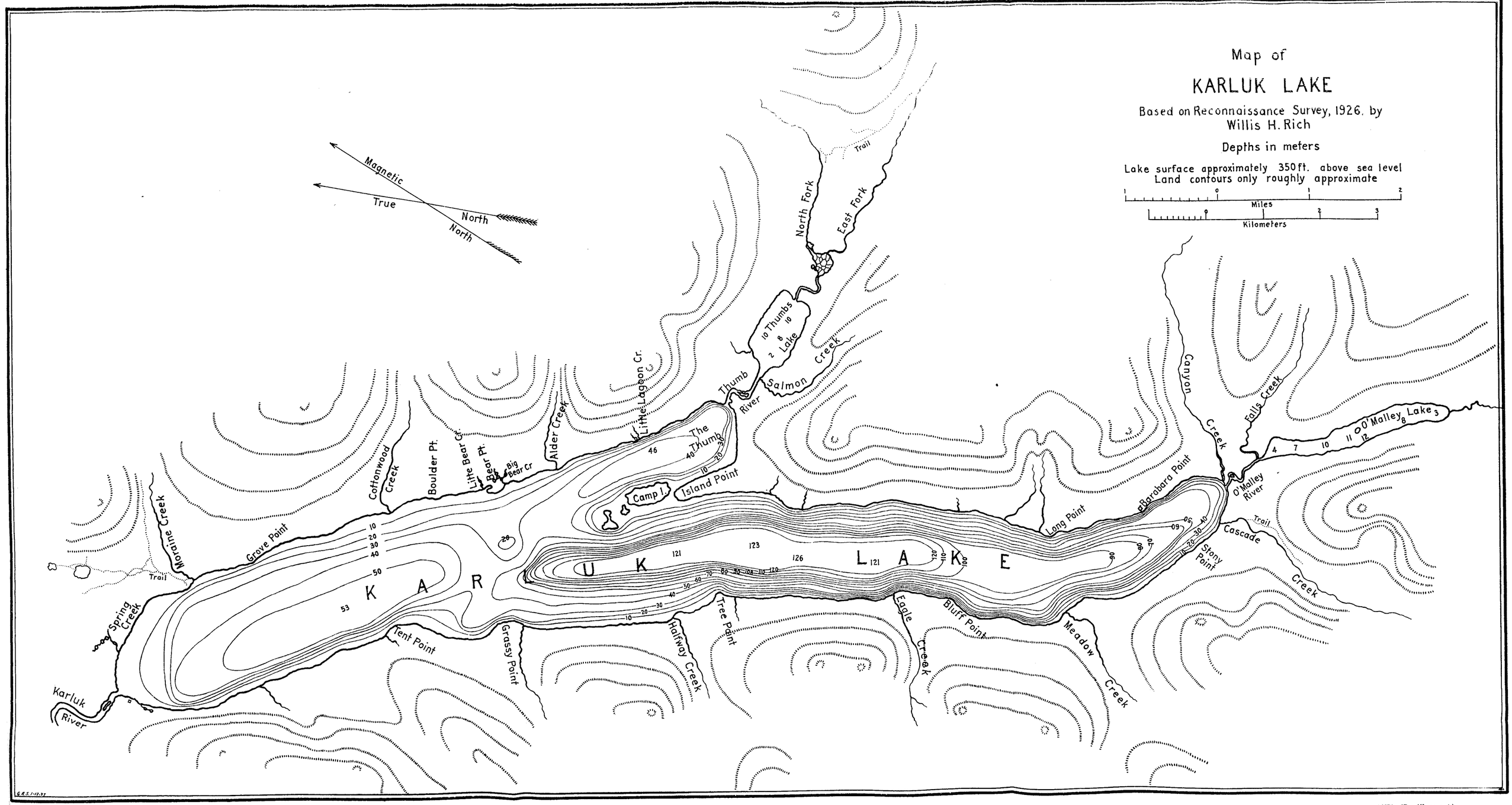

FIG. 1.—Map of Karluk Lake, Alaska

and in consequence the shore bench is very narrow and the bottom slopes steeply away from the shores. In general, the narrow beaches are composed of gravel and bowlders of varying size. Along the head of the lake, the head of the Thumb, the foot of the lake, and at a few other scattered places, the beaches slope somewhat more gradually than elsewhere and the gravel is of a size that makes these beaches suitable for spawning. In reality the lake consists of three distinct basins—one including the lower 3 miles, another including the Thumb, and the third and largest basin including the main upper arm. It seems probable that the main arm and the Thumb were formed by two glaciers which met and united just below where the islands now are situated. Apparently a small terminal moraine, which does not now rise to the present surface of the lake, forms the slight elevation that separates the lower basin from the two upper ones. The greatest depths of the lake are found in the lower part of the main arm, immediately above its junction with the Thumb, where a narrow, deep trough, 2 miles long, slightly exceeds a depth of 120 meters.

From the lower end of the lake, Karluk River flows tortuously in a westerly direction for about 2 miles; then in a northerly direction, along the western side of the valley, for some 8 miles more. At this point it is within some 3 miles of the upper end of Larsen Bay, an arm of Uyak Bay, and here there is a portage trail connecting Larsen Bay with the river. It was at this point that the upper weir was built and maintained during the season of 1926, as mentioned hereafter in the section dealing with the enumeration of the spawning escapement. Thus far the river has followed the northward extension of the valley in which the lake is situated, but it now turns westward and cuts through the mountains of the western side of the valley, and thence flows through generally mountainous country to the coast.

The descent of the river during the first 10 miles below the lake is approximately 50 feet, and most of this drop occurs in the first 4 or 5 miles. Here the river is swift and shallow, but in the next 4 or 5 miles, just above the portage trail to Larsen Bay, the river is deeper, wider, and flows much more slowly. During the late summer and fall this comparatively quiet portion is so filled with a dense growth of aquatic plants, chiefly the water crowfoot, *Ranunculus aquaticus*, and two species of Potamogeton, that it is almost impossible to navigate either with motor or oars. Below the portage the descent of the river is more rapid, falling about 300 feet in the 15 or 20 miles between the portage and the mouth of the river. About 4 miles above the mouth, the river widens out into a broad lagoon or estuary, which is shut off from the ocean by a narrow spit only 100 yards or so in width. The mouth of the river is at the western end of this spit. On the ebb tide a strong current flows out through the mouth, but on the flood tide an almost equally strong flow of ocean water takes place into the lagoon. The lower end of the lagoon, therefore, is at times very brackish, but brackish water is seldom if ever noted near the upper end. The spit that separates the lagoon from the ocean is important, since a large part of the commercial fishery for salmon at Karluk is carried on along its outer beach.

There are no large tributaries to the river below the lake. A few small streams enter, mostly from the eastern side, and these are used as spawning streams by the silver and king salmon. There are, in addition, numerous very small streams, which enter the river all along its course and drain the tundra flats and the smaller valleys of the hills and mountains through which the river flows.

The aquatic vegetation of Karluk Lake is peculiar, in that the abrupt slope of the bottom away from the shores provides little opportunity for the growth of the larger aquatic plants. The small bay near Bear Point supports a dense growth of Potamogetons, and there is a scattering growth near the foot of the lake, off the mouth of Moraine Creek, and in the shallow channel between Camp Island and Island Point. The rocks and bowlders alongshore, and to a considerable depth, are covered with a dense growth of filamentous algae of several species, however. The smaller lakes (Thumb and O'Malley) are much shallower, and in spite of their small area each of them supports a much greater growth of the larger aquatic plants, Potamogeton and Elodea, than does Karluk Lake proper. The shores of the lakes, the valleys, flats, and the lower slopes of the surrounding hills are well covered with groves of cottonwoods, alders, birches, and willows, and a variety of shrubs. By midsummer the narrow flats along the lakes and in the valleys and the more gentle slopes of the mountains are covered thickly with fireweed (*Epilobium angustifolium*) and tall grass, which make travel exceedingly difficult.

The climate of Kodiak Island is temperate. For 10 years the average temperature for the month of July (the warmest month) was 55.22° F., and for January (the coldest month) 28.92° F.[2] Karluk Lake usually freezes over in winter. According to information secured from reliable natives, who frequent the lake during the winter for hunting and trapping, it is usually frozen in by Christmas and opens again some time in April. Occasionally, however, during a very mild winter, such as was experienced in 1925–26, the lake does not freeze, but this is reported to happen only about once in 20 or 25 years. The surface temperature of the lake in summer is between 13° and 15.5° C. (55° to 60° F.). During the warm summer of 1926 the temperature for several weeks in July and August was close to 15° C., and Chamberlain reports that early in September, 1903, the surface temperature was 44° F. (6.7° C.), but that it had "fallen about 10 degrees in as many days." This would make the temperature at about August 23 of that year 54° F. (12.2° C.), and no doubt it had been higher earlier in the season.

STATISTICAL HISTORY OF THE FISHERY

Table 1 gives the yearly catch of red salmon at Karluk from the beginning of the commercial fishery in 1882 up to and including the season of 1926. The data are presented graphically in Figure 6.

The catch of 1882 contained less than 60,000 red salmon, but this increased rapidly until by 1888 the annual catch was greater than 2,000,000 fish. A high level of productivity was maintained, with only occasional poor catches, for about 20 years. During this period, from 1888 to 1907, the catch fell below 1,000,000 fish only once, and the average yearly yield was 2,304,803 fish. Since 1907, however, the catch has been appreciably less. In this period of 19 years there have been seven in which the catch fell below 1,000,000 fish, and the average yield for the entire period was only 1,306,152. It is apparent from the graph, furthermore, that it is not only the average yield that is reduced in the later years, but that both the maximum and the minimum yields are getting smaller. In other words, the good years have been getting poor and

[2] Geological and Mineral Resources of Kenai Peninsula, Alaska. By G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin, vol. 587, United States Geological Survey, 1915. Washington.

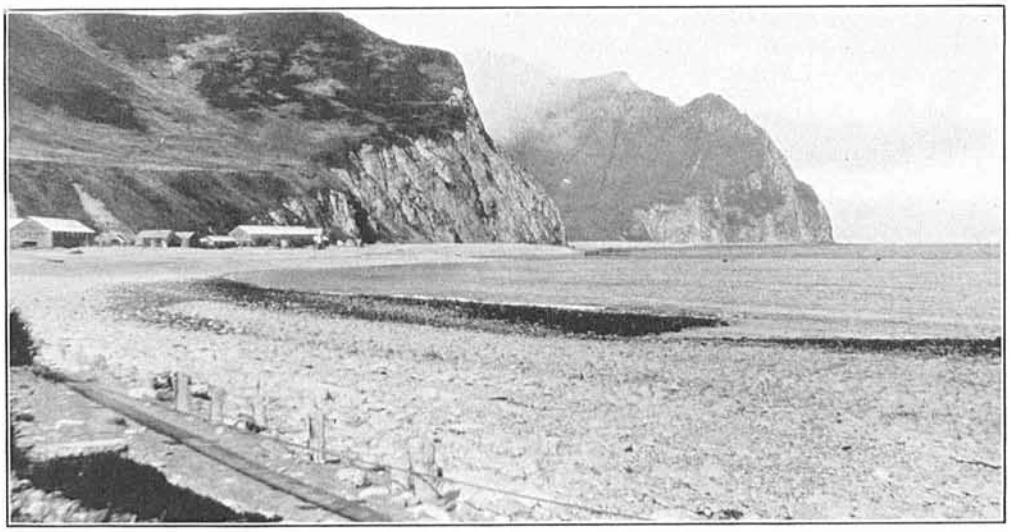

FIG. 2.—Seining beach at Karluk Spit, Karluk Head in background

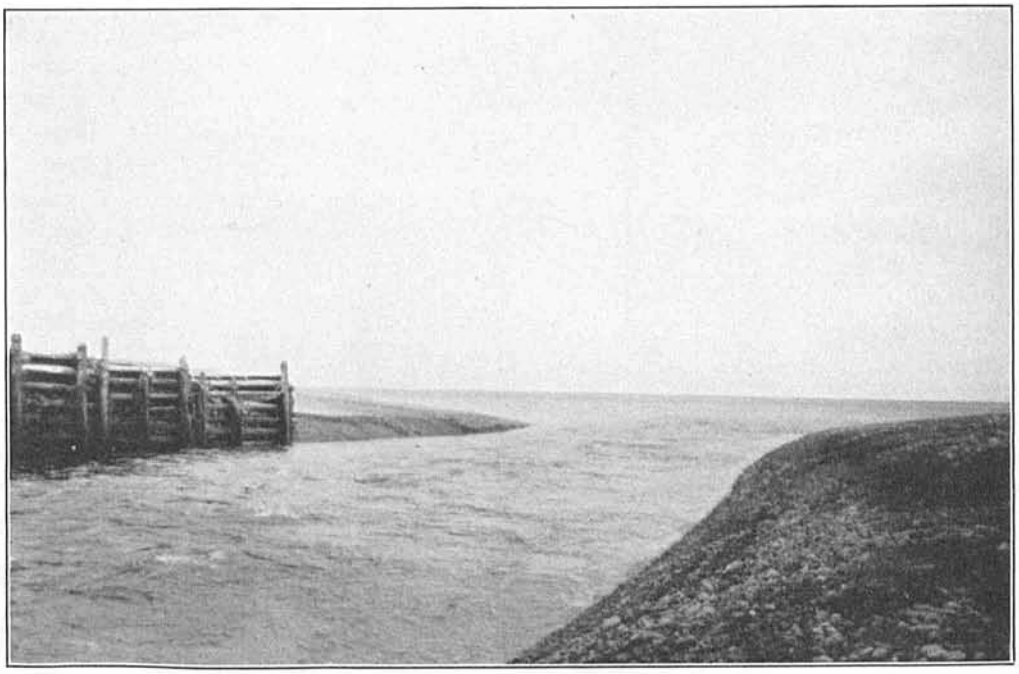

FIG. 3.—Mouth of Karluk River

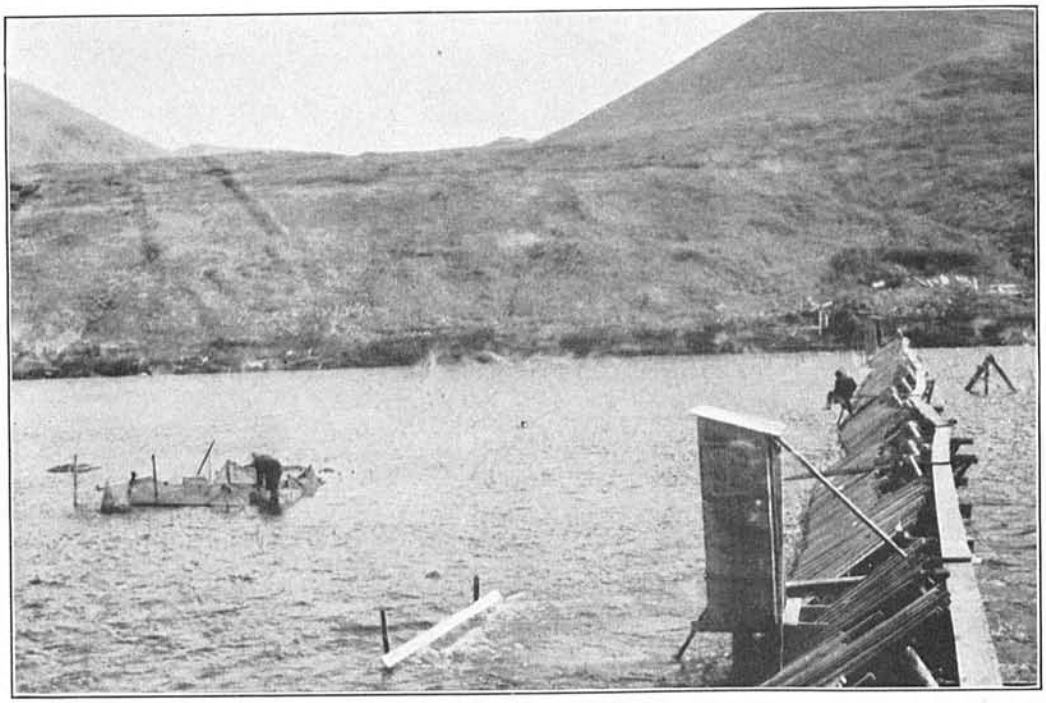

FIG. 4.—The counting weir situated just above the estuary

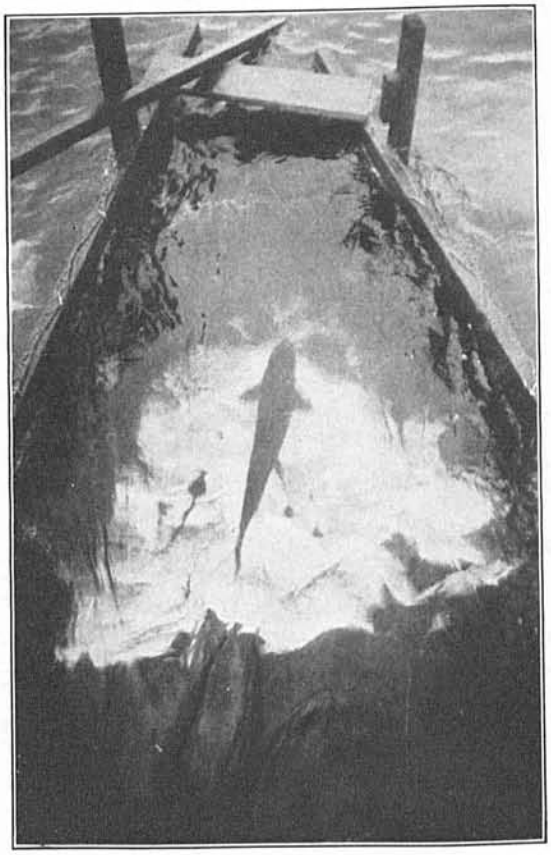

FIG. 5.—Salmon passing through one of the gates oi the tounting weir. Note the white-painted canvas fastened to the bottom, which improves the visibility, and the wire leads, which require the salmon to pass over the canvas

the poor years have been getting poorer. There is clear evidence here of depletion, although, fortunately, it has not become as serious as in some other localities. With the present requirement of a minimum escapement of 1,000,000 fish, which has been in force since 1925, it is hoped that the level of productivity may once again be raised, but it will not be until the season of 1930 that the catch will be affected by this regulation.

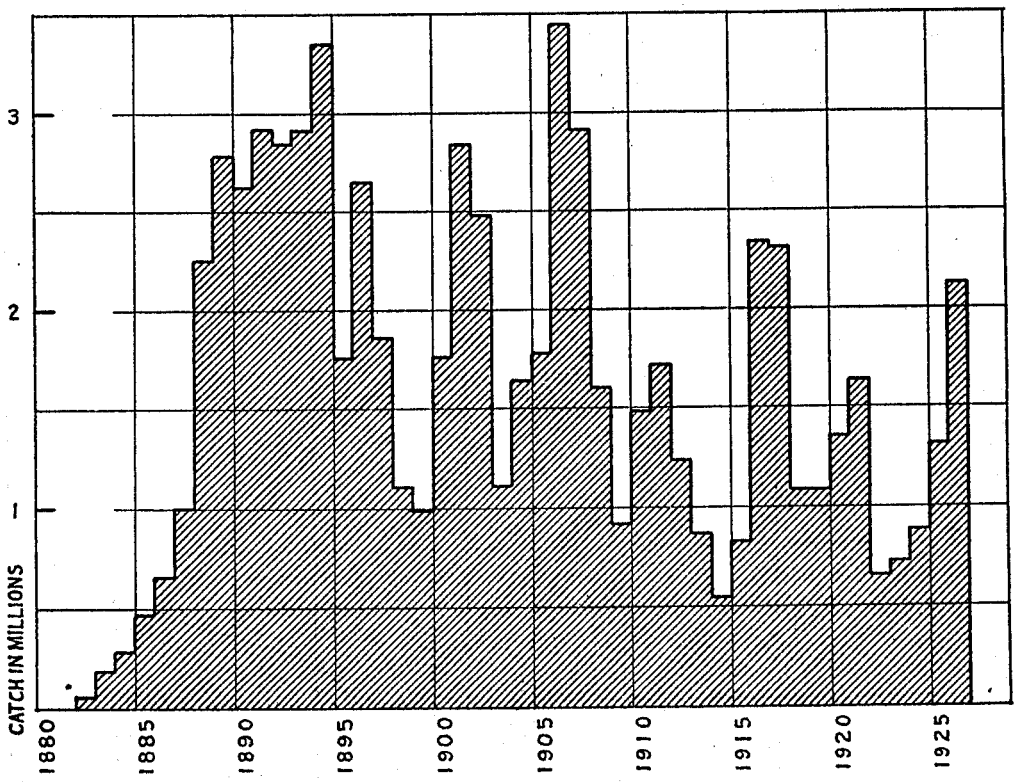

FIG. 6.—Yearly catch of red salmon at Karluk since the beginning of the fishery in 1882 to 1926

TABLE 1.—*Catch of red salmon at Karluk and immediate vicinity from beginning of canning industry in 1882*

[For the period from 1882 to 1894, inclusive, the figures herewith are based on an estimate of 14 red salmon per case]

Year	Number of canneries	Number of fish	Year	Number of canneries	Number of fish	Year	Number of canneries	Number of fish	Year	Number of canneries	Number of fish
1882	1	58,000	1894	4	3,349,976	1906	2	3,453,113	1918	3	1,092,775
1883	1	188,706	1895	4	1,762,000	1907	2	2,929,886	1919	2	1,089,809
1884	1	282,184	1896	3	2,650,000	1908	2	1,608,418	1920	2	1,368,526
1885	1	468,580	1897	3	1,865,731	1909	2	923,501	1921	4	1,641,758
1886	1	646,100	1898	3	1,102,957	1910	2	1,492,544	1922	5	658,159
1887	1	1,004,500	1899	3	991,848	1911	2	1,723,132	1923	3	727,730
1888	3	2,256,100	1900	2	1,767,671	1912	2	1,245,275	1924	4	890,752
1889	5	2,792,930	1901	2	2,841,247	1913	2	868,422	1925	4	1,317,993
1890	5	2,622,396	1902	2	2,485,112	1914	2	540,455	1926	4	2,131,616
1891	5	2,926,588	1903	2	1,109,975	1915	2	828,429			
1892	3	2,852,458	1904	2	1,638,949	1916	[1] 2	2,343,104	Total		73,561,823
1893	5	2,909,508	1905	2	1,787,618	1917	2	2,324,492			

[1] Part of these fish were transferred to canneries of the Alaska Packers Association at Alitak, Chignik, and Kasilof.

Figure 7 shows graphically the annual catches from 1896 to 1926, both inclusive, broken up into five-year cycles, of which there are six complete cycles and a seventh just beginning with 1926. No attempt was made to include the data for the years previous to 1896, as these data obviously are not comparable with those since that date. During the first few years (from 1882 to 1888) the industry was growing rapidly, and during the years from 1888 to 1895 it profited from the intensive exploitation of a practically virgin field. Since then the annual runs have presented a more or less regular sequence of events.

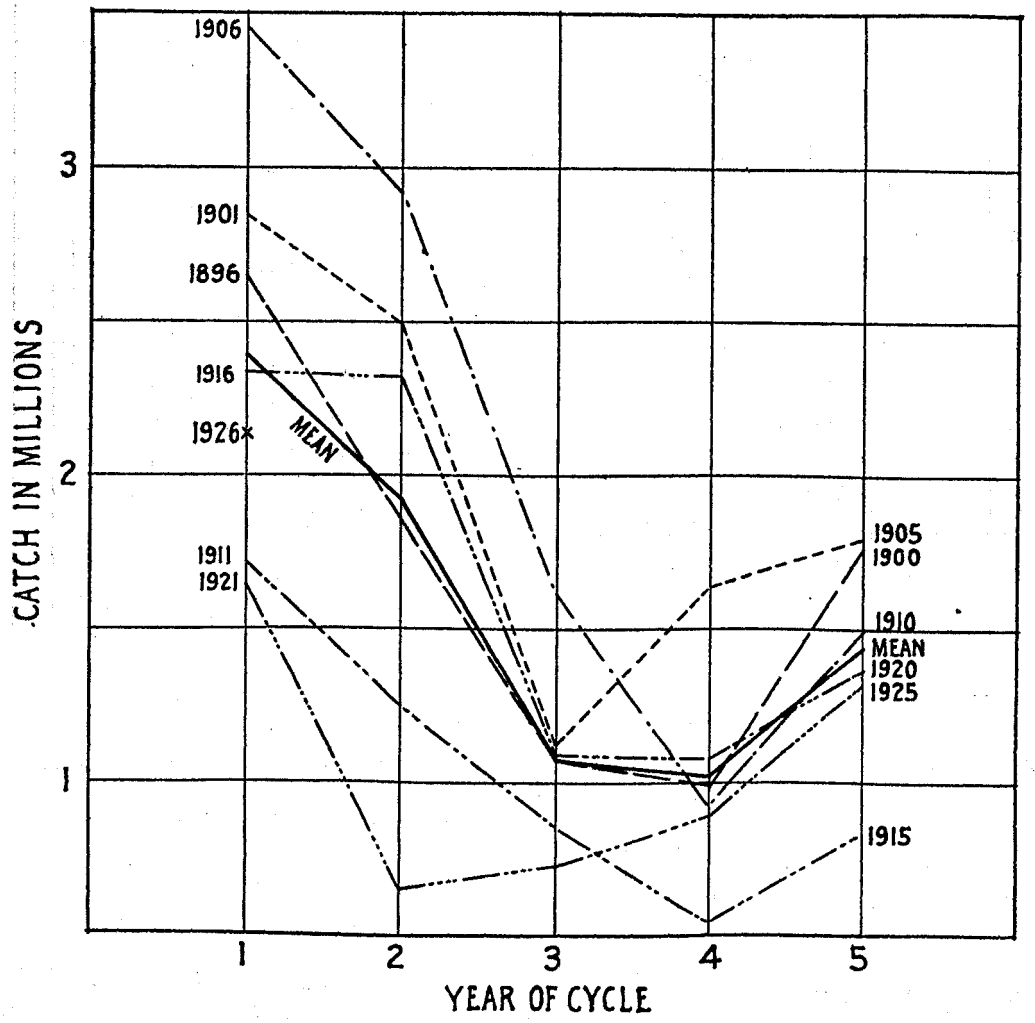

FIG. 7.—Catch of red salmon at Karluk in 5-year cycles, from 1896 to 1926

The graph shows clearly the cyclic character of the runs of red salmon in the Karluk River. Since the Karluk salmon are predominantly five-year fish, we anticipate a correlation between the run of any year and that of the fifth year preceding, the fifth year following, etc. With the exception of one of the six cycles, it is apparent from the graph that the Karluk runs consist of two good years followed

by three poor years—the good years are those ending in the figures 1, 2, 6, and 7, and the poor years end in the figures 3, 4, 5, 8, 9, and 0. This is well shown by the line of the mean, which is also shown on the graph.

The last cycle, that involving the years 1921–1925, differs from the others in that the second year is conspicuously the poorest one of the series. The other four years of the cycle, however, do conform very well with the corresponding years of the other recent cycles. Something obviously happened to reduce the yield of 1922 below that of the corresponding years of previous cycles.

No one can examine such a series of data without being impressed by the conspicuous correlation between the size of the catch in the corresponding years of the several cycles. There is a remarkably uniform tendency in each cycle, as shown on the graph, for the catch of the second year to be smaller than that of the first, for that of the third to be smaller than that of the second, for the catch of the fourth year to be about the same as that of the third, and for that of the fifth year to be greater than that of the fourth. If it can safely be assumed that spawning escapements are in the main roughly proportional to the catch, it becomes apparent that they are the predominating factor in determining the size of the runs.

That other factors may intervene is shown by the sudden drop in the catch from 1917 to 1922. The catch in 1917 was 2,324,492, while that in 1922 was only 658,159—one of the poorest on record since the fishery became well established. This is discussed in detail hereafter in the section entitled "Analyses of recent runs."

OBSERVATIONS ON THE SPAWNING GROUNDS

For its size, the Karluk River probably supports the most magnificent run of red salmon of any known stream—at least, of any stream on the American side of the north Pacific—and it has maintained this run in fair measure in spite of the very intensive fishery which has been conducted at the mouth of the river for more than 40 years. From time to time representatives of the Bureau of Fisheries have visited the lake and recorded something of the conditions found there during the spawning season. The earlier observations were only occasional and largely of the nature of general surveys. Eight years ago, however, the senior author of this paper undertook a more detailed and intensive study of the Karluk red salmon, and, as a part of this, regular yearly surveys of the spawning grounds have been made. At first these were intended to supply some measure of the extent of the spawning escapement, but a much more accurate measure of the escapement (by means of weirs, through which the fish are counted) was later adopted and has been in use since 1921. The observations on the spawning grounds are of great value, however, in showing the conditions under which the spawning takes place, and will help materially to determine the relative success that may be anticipated from the successive spawnings.

There are only two published accounts of observations of the spawning in Karluk Lake—those of Bean [3] and Chamberlain.[4]

[3] Report on the salmon and salmon rivers of Alaska, with notes on the conditions, methods, and needs of the salmon fisheries. By Tarleton H. Bean. Bulletin, United States Fish Commission, Vol. IX, 1889 (1891), pp. 165-208, Pls. XLV-LII. Washington.

[4] Some observations on salmon and trout in Alaska. By F. M. Chamberlain. Report, United States Commissioner of Fisheries for 1906 (1908). Bureau of Fisheries Document No. 627, 112 pp., illus. Washington.

Bean, with a small party, spent about four days at the lake—from August 17 to 21, 1889. A fairly good map of the lake was made and is published in the report, which contains an interesting and accurate description of the lake and river and of the fishery as then conducted at the mouth of the river. Regarding the spawning, Bean says:

Karluk Lake receives the waters of numerous small streams, in which salmon and trout are found whenever they are not prevented from entering them by an abruptness of the ascent. Each of the arms of Karluk Lake is connected by a short, rapid, and crooked river with smaller tributary lakes. The lake tributary to the east arm is about four-fifths of a mile in length, and the one connecting with the west arm is about 1½ miles long. In the small tributaries of Karluk Lake the rivers connecting its arms with their principal lakes and at various places around the shores of the principal lake—particularly at its southern end, between the mouths of rivers—we found nests of the red salmon. * * * The small rivers connecting Karluk Lake with its tributary lakes contain no obstructions to the passage of the salmon. These lakes freeze over in winter, and the natives travel over them to attend to their traps. They claim that they can obtain salmon at any time during the winter through the ice.

On the basis of observation made by Cloudsley Rutter during the summer of 1903, Chamberlain gives only a meager description of the lake and its tributaries and of the extent to which the various tributaries were used by the spawning fish. The following quotations from his report contain most of his remarks on the spawning of 1903:

There are numerous small streams entering the main lake, some of which, as the outlets of the tributary lakes, are of considerable length and suitable for spawning ground, while others are swift mountain torrents with rough beds, which offer but small areas for the fish. The shores of the lakes also are utilized for spawning.

The early arrivals of salmon spend some time in the region of the spawning beds before depositing any spawn. In the Naha the first sockeyes reach the lakes in June, but none spawn earlier than about the middle of August—after a lake residence of about six weeks. In the Karluk, in 1903, the first sockeyes entered the lake about the middle of June; they continued to arrive in numbers until the latter part of July. They spawned during August. The first arrivals, as in the Naha, thus spent about six weeks in the lake, and all remained at least four weeks before spawning. In the Fraser basin, in 1905, the first fish reached Seton Lake the latter part of July, the run continuing until the latter part of September. The first eggs were spawned the first week of September, and spawning continued until late in October. This was approximately the same length of residence before spawning as in the Naha and the Karluk.

During the residence in the lakes it is improbable that the fish occupy the greater depths, since it has been shown that these are not suitable for fish life. In the evenings salmon may often be seen in numbers "finning"—i. e., swimming leisurely at the surface in such manner as to expose the dorsal fin. The sockeye seldom jumps in lakes until about to approach the spawning bed, when there may be a slight demonstration of that habit. Ordinarily a lake may be filled with adult fish and no evidence of their presence noted by an observer.

Karluk Lake has many tributary creeks that are used by spawning fish, but the total area seems scarcely commensurate with the enormous productiveness.

In 1903 a careful count was kept of the sockeyes spawning in one stream of Karluk Lake, the second from the outlet on the right or east side.[5] This is a small creek, averaging some 10 feet in width, about 1 mile of which is used for spawning beds. From August 5 to September 5 of that year 21,756 spawned fish were examined in this creek, presumably the total number spawning there in that time, and practically the total for the season. Of these, males were in excess by about 3 per cent, the number being 10,723 females and 11,033 males. But one unspawned female was found dead. Dead unspawned males are more common. Of 636 females opened, about 80 per cent

[5] This is, without much doubt, the creek to which we have given the name "Moraine Creek."

were entirely spawned out; i. e., with no loose eggs in the abdominal cavity; the remaining 20 per cent had an average of 97 eggs unspawned, with the most in any instance noted 1,246. The sockeye carries between 2,500 and 4,000 eggs, an average, perhaps, of about 3,500. This remnant, then, amounts to about one-half of 1 per cent of the total number of eggs matured. The product of this one stream, on the same basis of estimate, is 37,000,000 eggs. It is believed that less than one-tenth of the number of fish entering the lake spawned in the above-mentioned creek. Thus, approximately 400,000,000 sockeye eggs were spawned in Karluk Lake basin in 1903. Sockeyes are reported by natives to spawn late in the winter, even under the ice, but it is doubtful whether it is usual for any noteworthy number to occur as a fall run, as with other species and in more southerly streams.

In 1903 the spawning season was practically over early in September. Since the fishing continues ordinarily into that month, the spawning should last much later. The double operation of cannery and hatchery, perhaps, accounts for its early close.

On Karluk Lake in 1903, in the creek on which the spawners were counted, these beds were examined by digging in the gravel to find the condition of the deposited eggs. Between August 5 and September 2, 58 "nests" were examined. In these were found 4,005 good eggs and 2,022 dead ones, or, in other words, about two-thirds of the buried eggs were found to be in good condition. On the latter date 587 eyed eggs were found under about 10 inches of gravel, with only 13 dead ones. This demonstrates that eggs will live and develop under proper conditions when deeply buried. In another stream, in the center of a nest, under 6 inches of gravel, only 29 of 620 eggs recovered were living. In a third bed, of 1,140 eggs taken from the lower half of the nest, in a light current and from under 7 inches of gravel, only 28 were dead. In general, the observer records few eggs from locations in strong current; this was possibly in part from failure to find the eggs as well as from their scarcity. Most beds show a decided balance in favor of the good eggs. In two examinations of the connecting stream from one of the tributary lakes less than 4 per cent of the eggs were dead.

Our observations, particularly those made in 1926, do not support the idea advanced by Chamberlain that the early arrivals that reach the lake about the middle of June remain in the lake until August before spawning. In 1926 the very heavy early run was spawning abundantly by the 10th of July, and apparently had completed spawning entirely before the 1st of August. In 1926 Moraine Creek was well seeded by this early run and was also used extensively by the later runs—those that spawned in the early part of August, at the same time Rutter's observations were made. Unless conditions were very different in the two years, then, it is difficult to believe that the 21,756 spawning fish counted in 1903 represent the total for that season, although no doubt it is a close approximation to the number in the creek during August. It is quite probable that conditions were vastly different in 1903 than in 1926, and that the early escapement was very much smaller. Certainly, if Moraine Creek in 1903 had received anything like the early spawning run it had in 1926 the remains of dead fish would have attracted the attention of a well-trained observer such as Mr. Rutter.

In 1911 a brief visit was made to Karluk Lake by Ward T. Bower and party. Unfortunately, it has been impossible to find the detailed notes made at the time, so that the only available information is contained in the following quotations from a section of an administrative report: [6]

An exploration was made of Karluk Lake the latter part of July primarily for the purpose of locating a hatchery site. A tributary stream near the lower end of the lake appears to be suitable

[6] Fish Culture in Alaska. By Ward T. Bower. *In* Alaska Fisheries and Fur Industries in 1911, by Barton Warren Evermann. Report, United States Commissioner of Fisheries, 1911 (1913). Bureau of Fisheries Document No. 766, pp. 66-88. Washington.

for this purpose. The lake is about 8 miles long and averages 1 mile in width, but the quite precipitous mountains which almost surround it leave remarkably few tributary streams accessible to the salmon for spawning purposes. The result is that many salmon spawn in the lake along the gravelly beaches. On August 1 the lake contained a large number. Two small lakes drain into Karluk Lake, the outlet of which is Karluk River, a stream shown by compass survey some years ago to be approximately 15 miles long. * * *

Of 200 [dead] females selected at random September 12 at Karluk Lake, it was found that 197 had spawned clean, 1 contained about 1,000 eggs, while the other 2 had about 150 eggs, which had died with the fish.

The stream mentioned as being suitable for hatchery purposes is presumably the same one in which Rutter's observations were made and which we have called Moraine Creek. Bower's observations during a very short visit to the lake, and his notes on the extent of available spawning streams, are in error, as our later and more extensive observations show. His notes on the completeness of spawning are important, however, as they check with those of Chamberlain, and both are at variance with the observations made by us during the very heavy spawning of 1926.

The next examination of Karluk Lake was made in the fall of 1917 by E. M. Ball. The following extracts from his report deal with the spawning of that year:

September 12.—This part of the river (the upper two miles) formed the spawning ground of a large number of red salmon, the river bottom being a mass of spawning beds. No trout were observed in this part of the river. Camp was made at the lower end of the lake.

September 13.—Left camp at 6 a. m. and proceeded along the southern [western] shore of the lake, making an examination of all streams as they were passed. Six streams of fair size enter the lake from the south [west]. All of them were occupied by spawning salmon, and around the mouth of each was a bank of dead fish that had spawned and drifted down the stream to the quiet waters of the lake. Piles of salmon had also accumulated at several points along the stream where brush and rocks had caused them to lodge. The shore of the lake was the resting place of thousands of skeletons of salmon. At the head of the lake are two much larger streams, one of which is the outlet of another lake, whose length is approximately 3 miles. The connecting stream is probably half a mile long and has an average width of 70 feet. The valley between the two lakes is simply a network of streams, all of which have gravel bottoms affording perfect grounds for the deposit of spawn. Thousands of salmon were then spawning, and yet other thousands had spawned and died. Trout were rather abundant also. Several streams enter the lake from the north [east]. Each of them seemed to have its share of salmon. We had intended to camp for the night on an island about the center of the lake, but threatening weather conditions caused us to return to the camp at the end of the lake, which we reached about 9 p. m. From sundown, until darkness prevented further observation, the lake was alive with feeding fingerlings.

It would be a difficult matter to estimate the number of salmon that had reached the lake. The run was still on, and those in the lake had not all approached the streams. A fair estimate of the number that had spawned, as indicated by the quantity of skeletons and dead fish observed in the streams and lake, together with those then spawning, would exceed 200,000 salmon.

In the late summer of 1919 Henry O'Malley, the present Commissioner of Fisheries, and the senior author made a very brief examination of the spawning in Karluk Lake. Unavoidable circumstances prevented the complete survey that had been planned. Observations were made on Cottonwood, Moraine, and Spring Creeks and along the foot of the lake. The same party again visited the lake in August, 1921, and their observations are recorded in the following notes taken from the diary of the senior author. Since these notes contain references to the observations of 1919, it has not seemed desirable to quote separately the notes made during the first brief visit.

August 8.—On upper 2 miles of river saw very many king salmon, often milling around in pairs. At foot of lake saw *no* large school of red salmon, such as was strikingly in evidence two years ago.

August 9.—Red salmon jumping all night outside Tent Point. Several dead males had drifted up on the shore, and a few were constantly swimming up and down along the beach. A creek enters at head of the bay on the northwest side of the point,[7] and many gulls were congregated at its mouth. The point has coarse, gravelly shores and bottom. The gravel is displaced in spots, but no definite nests have been observed.

The morning is fine; sky hazy; a few fog wreaths across face of mountains. No wind. Air 57°, water 54°, at 8 a. m. Creek near point 48°.

Visited creek above camp. About 2 or 3 feet wide and a mere trickle of water. Several hundred salmon densely crowded off mouth. Occasionally one or two scuttled up the beach through the trickle, the entire head and body exposed. The creek meanders through the low ground; bottom small bowlders and cobbles; no good spawning beds. Last evening a flock of gulls camped continuously on beach at mouth of creek, as though interested in eggs floating down.

Photos taken of fish off mouth and of fish partly eaten by bears a short distance upstream, where grass was trampled and evidence unmistakable of their presence last night or yesterday. Spawning had been in progress *along beach* and off mouth of creek.

Fitted Evinrude to boat and left for head of lake 9 a. m. Went directly out from Tent Point to middle of lake and sounded with a depth of 181 feet. [Approximately 54 meters, agreeing with our later measurements.][8]

After sounding, started up at 9.30, following west shore to examine creeks. About half way on west side is a creek (Grassy Point Creek) about 6 feet wide and now 6 inches deep, thickly beset with dead and living fish. Temperature 46°. In the lowest 1,000 feet (paced) we counted 1,400 dead salmon, and estimated that side branches contained as many more (4,800 in all), and that there are fully as many live salmon as dead ones. It is safe to say, counting those now preparing to enter the mouth, that there are 10,000 fish spawning in the lower 1,000 feet of the stream. Apparently about 1 mile of stream with spawning in progress, and probably 50,000 fish in all.

Gulls were thick at mouth of creek and some were encountered higher up. They were feeding on drifting eggs, which could be seen in every eddy. Creek bottom of coarse cobbles and gravel, very hard, apparently not dug up. Seems impossible eggs could be buried, and loss must be enormous.

Halfway Creek is larger than Grassy Point Creek, 15 to 20 feet wide in places, steeper, with swifter current, temperature 46°. Contains not half as many salmon, dead or alive. Bowlders larger. Floating eggs numerous; a flock of gulls at mouth. Went upstream to falls, perhaps one-fourth mile from mouth. These are impassable—may be 2,000 or 3,000 fish below them. Fewer dead fish, proportionately, than in Grassy Point Creek.

Sounded in middle of lake, opposite Tree Point, obtaining depth of *405 feet* [121 meters, agreeing exactly with later measurements].

At 2.40 p. m. reached a stream entering from southwest [Meadow Creek], at projecting point in south arm near head. Stream 10 to 15 feet wide, full of live and dead fish, containing probably more salmon than any other stream seen to-day. Gentle ascent, temperature 47°. The creek was explored for over half a mile and found fish thick all the way. Found no falls.

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[7] This is a small creek, shown on the map, but has been given no name. It may be called Tent Point Creek.

[8] The method by which these soundings were made is thought worthy of record. A number of spools of stout linen thread were provided, each marked as containing 100 yards. This measurement, on test, was found to be quite accurate. A number of small lead weights, weighing about one-half pound each, also were on hand. When a sounding was to be made, a weight was tied to the thread of one of the spools and let down to the bottom, while the boat was kept in position so that the thread led down vertically. The unreeling of the thread was made easy by inserting a heavy wire nail through the spool and allowing the spool to turn freely on the nail. When the weight had reached bottom the thread was broken off at the water line, the spool marked so that it could be later identified, and the thread left on the spool measured. The difference between this amount and 100 yards gave the depth at the point where the sounding was made. In cases where the depth was greater than 100 yards a second spool was used and the thread tied to the end of the thread of the first spool. The amount left on the second spool subtracted from 200 yards gave the required depth. The results obtained by this method have checked so consistently with those secured in 1926 through the use of a regulation fathom wheel that it is safe to say that the accuracy of the method here described compares very favorably with the customary methods of sounding.

August 10.—Air 56°, lake 53°. Tree Point projects far into lake—low, with row of cottonwoods. Is beyond entrance to Thumb Bay. Looking north from Tree Point, farthest point is Tent Point, Halfway Point being indistinguishable, as it does not project far and is evenly rounded. South from Tree Point one or more gently rounded projections, not worthy of name, then a conspicuous point completely hiding the shore beyond. This point is fairly bold, the crest of the descending ridge with dense growth cottonwoods. This we call *Eagle Point*, and there is no stream of importance between it and Tree Point.

On reaching Eagle Point found it to be a broad projection, one-eighth mile across, with wavy outline, and a southern low sandy point not worth designating. Beyond that the shore recedes in a convex curve to a rather deep bay, across which the triangular green slope of Meadow Point is seen, bounding the south side of the bay and with a row of trees beyond (i. e., across) the green. A fairly definite, steep, green point bounds the north end of the deep bay (Bluff Point), from which, looking north, only Eagle Point can be seen. One hundred yards outside Bluff Point, Eagle Point and Tree Point are in line. From Meadow Point north Eagle Point projects beyond the rest of the shore line.

A mile above Meadow Point fish are spawning along shores, with dead fish at bottom, showing this has been going on all season, but total number is inconsiderable. This spawning beach runs along a steep mountain side. A small creek, about 3 feet wide, enters middle of beach, and seepages undoubtedly exist. Arrive creek 11.45 a. m., about 1⅛ miles above Meadow Point Creek. About 500 live fish in lake at mouth. No fish to speak of upstream, although accessible and better bottom than usual. No dead fish in stream. Apparently late run. Eggs in better shape. Temperature 49°.

Off at 12 m. Around first point above creek, several hundred fish spawning along beach. In bay above, perhaps 200.

Cascade Creek. Next creek 12.10, one of three at head of south arm. Largest creek yet seen, 10 feet wide, with finer gravels. Fish spawned early, many dead and living. Temperature 50°. Contains about 1½ miles of spawning stretch and is better adopted to spawning than any other stream thus far seen. Materials finer and current less boisterous. Eddies contain many eggs, not one in five alive. Compared with other creeks visited, there are fewer dead salmon. Looks as though run might be relatively late.

Off at 1.25 p. m. Salmon spawning heavily in fine materials of beach for 200 yards above Cascade Creek and at intervals all the way to O'Malley River. Temperature upper lake 59°.

O'Malley River is about half a mile long, meandering in an almost level broad valley. Has fine gravels, excellent for spawning; yet, compared with other streams below, it has few fish. The upper lake, seen at first only from the lower end, was apparently 2 miles long.

A stream [Falls Creek] enters O'Malley River shortly below the lake, with temperature 54°. It carries about as much water as comes out of the lake. Fish running up this stream from O'Malley River, but comparatively few. In 200 yards of this stream counted 677 recognizable dead salmon. Where this stream joins O'Malley River a tally for a brief period showed an average of 3 passing up O'Malley River into the upper lake and 16 passing into the colder stream, Falls Creek.

Came back down old channel, with many times more dead and living fish. Temperature 55°.

Dragged boat up the river to O'Malley Lake, and started to head of lake. Stopped at a small creek coming in on west side, half way up lake; temperature 48°. About 200 fish spawning in fine gravel off mouth, but apparently none entering, although stream more favorable in appearance than many we have seen occupied. Many soundings were taken in O'Malley Lake below the island, where greatest depth was 35 feet, about 10 meters, and this was several times repeated. Above island, in middle of lake, depth was 10 feet.

The inlet at the head of the lake is a small sluggish creek, perhaps 12 feet wide and 6 to 12 inches deep, meandering through a nearly level bottom. It is only a short distance to impassable falls. Saw very few fish, no dead ones, except along the banks, fragments partly devoured by bears. Temperature 50°. Probably not more than 100 or 200 salmon in this stream. The whole lake seems useless as spawning ground.

Returned to shore of Karluk Lake at 5.35 p. m. Temperature of O'Malley River near mouth 54°. Another stream (Canyon Creek) enters Karluk Lake within 100 yards of O'Malley River. Same character—wide, gently flowing over fine gravels—an ideal spawning stream. Temperature

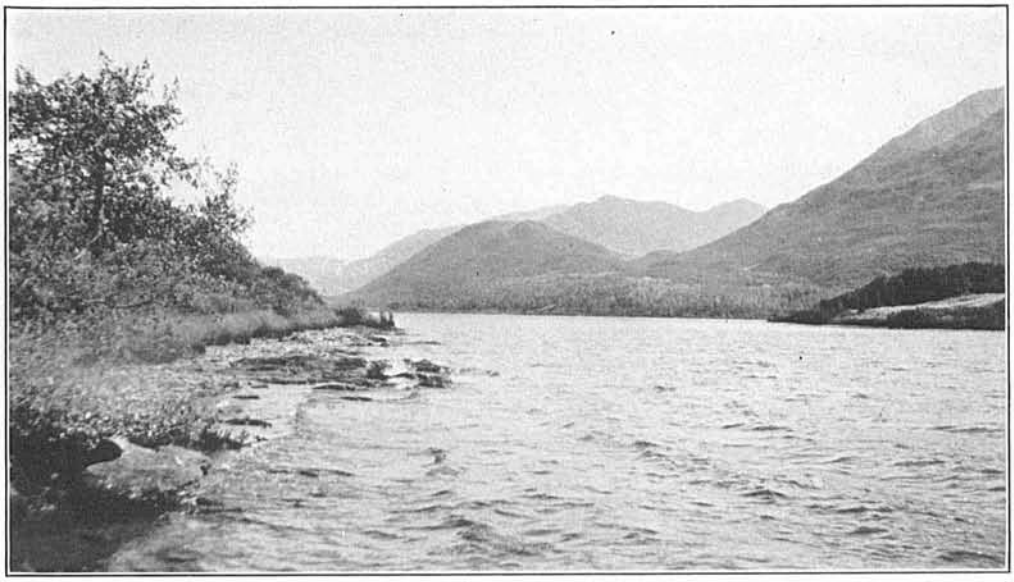


Fig. 8.—The Thumb, Karluk Lake, from Camp Island

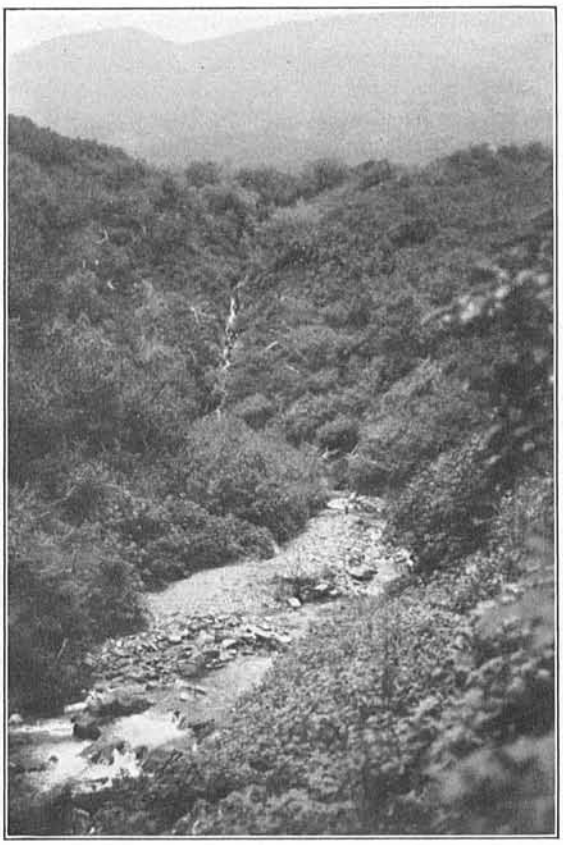


Fig. 9.—Salmon Creek, near the falls

FIG. 10.—Salmon Creek, near its mouth, at the height of the spawning in July, 1926

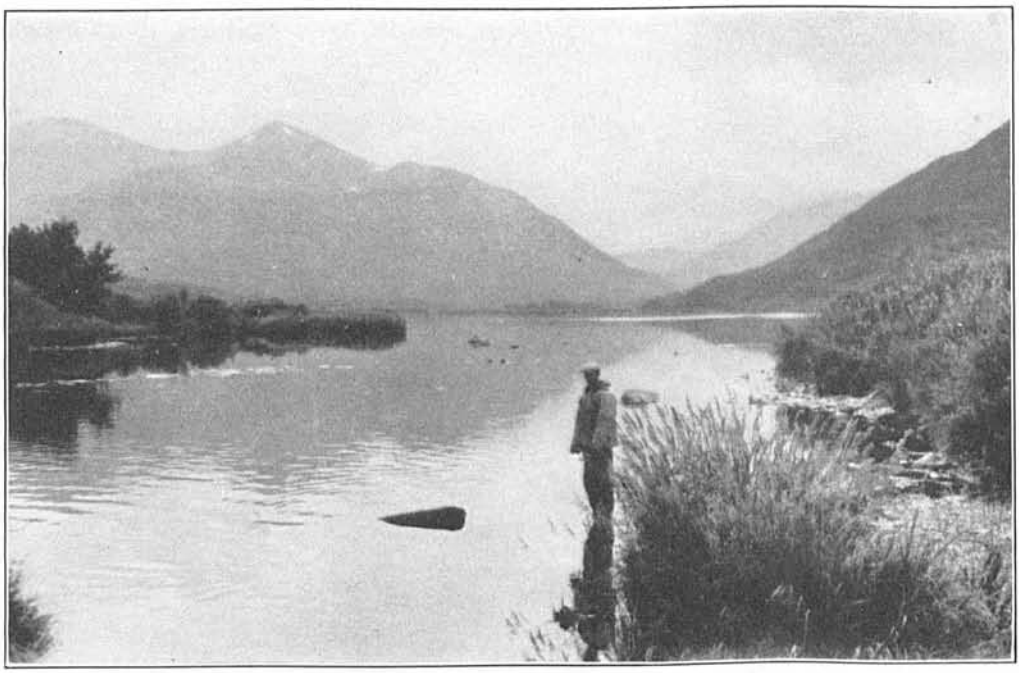


FIG. 11.—Thumb Lake, from its lower end

50°. Lower course with many dead and far more numerous living fish, which are in fine shape. This is equally important with O'Malley River. Length unknown to us. It is reported to be only a mile to impassable falls.

Walked around head of bay and down north shore to Barabara Point. The head of bay, beyond Canyon Creek, fronting low land, was one mass of spawning fish for 20 or 30 feet off shore. Camped at Barabara Point.

August 11.—Water of lake colder, 50° at 7.50 a. m.

Below Barabara Point, perhaps 300 yards, a small creek with perhaps 100 salmon around mouth. Earlier a few ran up and perished. Stream now 2 feet wide.

Took a sounding in middle of lake near entrance to South Arm, depth 235 feet (70 meters). Another off Long Point (east shore), depth 305 feet (91 meters).

Running down middle of lake to sound against stiff breeze. Opposite Bluff Point at 10.25 Reached sounding station opposite Eagle Point, in middle of lake, 10.35. Depth 405 feet (121 meters); same depth as off Tree Point.

Reached head Thumb Bay at 12.20. Temperature of bay 56°; of Thumb Lake 54°; of Thumb River 52°. Found dead on bank of Thumb River a red salmon 8 inches long, testes mature, had black spots on back but none on tail. Examined gill rakers, found to be characteristic.

Thumb Lake is shallow throughout, strewn with glacial bowlders near lower end. Soundings 20 and 33 feet (about 10 meters). Thumb River at mouth very wide and shallow, with two openings. Salmon constantly entering and floundering up the shallows, with backs exposed. They are numerous, but not crowded, all the way up to Thumb Lake, where most of them pass into a small stream, which enters from the left bank (looking downstream), immediately at foot of lake (Salmon Creek). A constant procession enters this tributary, said to be about 1 mile long. After witnessing intensity of spawning in Grassy Point and Meadow Creeks am impressed by fact that the apparently more favorable creeks are not crowded.

Upper Thumb River is full of "dollies." One examined (15 inches) had not been feeding and had testes white, though no liquid milt was present. Watching the "dollies" in creek, a number were seen turning on sides and rubbing against bottom as though spawning, but could not be sure that spawning was in progress. Contains few salmon, dead or alive. Said to be 1½ miles to impassable falls.

Leaving Thumb Bay for the foot of the lake we passed two or three very small creeks, all with a few salmon off mouth and entering. At 5 p. m., having made about 4 miles, we reached Cottonwood Point and camped at mouth of Cottonwood Creek, 10 to 15 feet wide, descending by gentle grade. Bowlders of large size are present, but finer materials make spawning possible, with covered eggs. Perhaps a hundred fish were thickly clustered off mouth, and were entering at intervals through water so shallow that the whole back and head were bare. Above, the stream is *thickly crowded* with spawning fish, which are almost as numerous as in Meadow Creek, in proportion to size of stream, and far more numerous than in O'Malley River. Temperature 53° at 5.30 p. m.

August 12.—Temperature, Cottonwood Creek, 49°, lake 50°, at 7.45 a. m. Salmon entering freely.

Reached Moraine Creek, at 9.45 a. m. Temperature 49°. This is one of the principal spawning streams, to be compared with Cottonwood Creek. Perhaps averages 15 to 20 feet wide, 6 to 8 inches deep, rapid current, but suited for spawning, except for too coarse materials. This creek was examined by O'Malley and me in 1919; apparently fewer fish this year. O'Malley thinks one-third less. The stream is well stocked, however, and may well be called crowded. Hundreds of fish are spawning along the beaches, for 100 yards or more north of the mouth. Rough estimate 20,000 salmon, many more alive than dead. Rutter visited this creek in 1903, walked down from falls (1½ miles) to mouth, and estimated 30,000 dead and alive.

Water 200 feet to north of mouth of Moraine Creek was 49½°, that of creek 49°; general surface temperature of lake, away from any stream, at 10 a. m. 50°.

Spring Creek at 10.20. Temperature 44°. First pond 49°, fed by stream 47°. Upper pond 46½°. More than twice as many fish this year as in 1919, but none too many. Upper pond perhaps 150 feet long by 60 feet wide. Fish spawn all through the small creeks which connect the ponds, and in the ponds, the creeks often not more than 2 feet wide. Counted 200 dead in upper pond. A third pond, still larger, was full of dead and living fish. Is fed by springs and has no inlet. About

250 feet long by 100 feet wide, depth 1 foot. Temperature 45½°. It has a little offset at bay at upper end, not included in estimate of size. Following measurements taken of dead fish in pond:

Males:	Females:
25½ inches.	25 inches.
24½ inches.	22½ inches.
25 inches.	23 inches.
24 inches.	21½ inches.
26 inches.	21½ inches.
23½ inches.	22 inches.
26 inches.	21 inches.
24 inches.	23½ inches.
24 inches.	24 inches.
22 inches.	23 inches.
25 inches.	23½ inches.
21 inches.	22 inches.
24 inches.	21 inches.
23 inches.	23 inches.
	23½ inches.
	23 inches.
24. 1 inches (average).	22. 7 inches (average).

Outlet of lower pond at mouth, 49°. Where Cold Creek (a small branch of Spring Creek, not named on the map) flows past outlet of lower pond, 39½°. Saw salmon leaving main stream (temperature 40°) and entering warmer water of pond outlet, and this must have been true during most of spawning season. Cold Creek has but few fish in it and practically no dead fish. It is less than 100 yards long above junction with Pond Creek and originates in springs.

Opinion of O'Malley and myself, four or five times as many salmon in Spring Creek as in 1919. This year it is a highly valuable spawning stream. It averages deeper than other tributaries to Karluk Lake, has fine gravel beds, and is able to care for a good run, probably even more than it had this year. It is a short stream, probably half a mile long.

Left at 11.40 a. m. for foot of lake, about one-fourth to three-eighths mile distant. The great school of salmon at foot of lake in 1919, estimated as containing 10,000 fish, was not present this year. Temperature of river, 60°.

The two authors of this report visited Karluk Lake together in 1922, accompanied by W. P. Studdert and Fred Lucas. At this time the junior author made a preliminary survey of the lake and tributary streams, while the senior author was concerned primarily with observations on the spawning grounds. The following notes are taken from the diary kept by the senior author:

August 18.—The river in the shallows below the portage was alive with king salmon, milling around, splashing, finning, and spawning. A few humps were with them in the shallows, but a very large number were resting quietly among the waterweeds, closely packed, side by side, their white bellies very conspicuous. These had probably reached this stretch of the river before becoming ripe, and were awaiting that event before going out on the spawning beds. The bottom of the stream where they lay was not suitable for spawning purposes. They are marked not only by the conspicuous white belly, but by the light or orange front and upper margin of the dorsal fin (an upper anterior margin) and by the bright reddish orange gill membrane.

Looking upstream from portage, few fish were seen. The character of the stream for two or three miles (or more) is not favorable. In this quiet, weed-grown (*Ranunculus aquatilis* and others) portion of the river, with slack current, few salmon remain.

Before entirely passing the mountain on our right, along the base of which the river runs for several miles, the current becomes more swift, the depth less, and the bottom most uneven, due to the gravel heaps made by spawning salmon. Humpbacks and kings were spawning on all suitable shallows and riffles from here to the lake, the humpies much the more numerous.

August 19.—On our way up the river we had seen scattering red salmon, but never in any numbers. It was not until we reached the final shoals below the lake that red salmon became a feature. In this short section, of perhaps a quarter mile, there were more reds than humps, and also a good sprinkling of kings. The reds were not moving up into the lake, as far as we could observe, but were acting in all respects like the kings and humps spawning along the river. Many pairs were seen; they were milling around and finning and fighting, for all the world like those seen later along the lake shores. Some males were frayed. They were undoubtedly spawning.

As regards the number of humpbacks found along the river, it can be said they were abundant in all shallow gravelly stretches with good current. The gravels were not fully occupied; there was easily room for twice the number, but the impression was strong that they were numerous, perhaps sufficiently so.

Kings were not seen by us between the portage and the last stretch of river before reaching the lake, although it is reported that the deep hole 2 or 3 miles below the lake is a favorite spot for them to lie in and then spawn near at hand. We saw many king salmon in this hole two years ago. This year they were numerous immediately below the lake. They were even spawning in the foot of the lake itself, in the channel at one side of the sand island that lies where the river current begins; but not a single king was seen last year or this beyond that point. The lake shores and tributaries were free from kings.

Thumb River. The lowest stretch (perhaps one-eighth mile) of this short stream pursues a westerly course and is very wide and shallow, much like the main Karluk River immediately below Karluk Lake. Sand bars and islands at the mouth divide the current this year in three channels, the southwest channel the largest. This section of Thumb River is a favorite spawning ground and was thickly beset with spawning fish. At first sight it seemed to reproduce the conditions of last year. Spawners were everywhere in considerable numbers, and more were entering constantly; but inspection showed that here, as in the main river, humpbacks far predominated over the reds. I estimated conservatively 1 red to 5 humps; Lucas, 1 to 20.

At the upper end of this lower east-west portion of the river it turns abruptly south, and then swings back in a wide curve to the foot of the lake, which has the same axial line as Thumb Bay. The river is less than half a mile long and was beset with humps for its entire length. Where the outlet leaves Thumb Lake, a tributary of some size comes brawling in at a sharp angle, from south or southwest, and is a favorite spawning ground for red salmon. Far more spawn in this stream than in Thumb Lake or in all of its other tributaries. A bar or flat at the mouth of this tributary was deep in dead red salmon last year, whereas this year comparatively few were present. We enumerated 625 dead salmon at this point, including all that could be seen lying in deeper water immediately off the mouth. Lucas and Studdert went up this stream the following day about three-fourths mile to a fall, which blocked further progress. Studdert counted 251 live fish, and is certain he did not miss more than 25. The dead fish along the stream were not counted. No humpbacks were seen among the dead at the mouth of the stream; one live one was seen by me and three by others, in the creek itself. All other salmon seen were reds.

Returned to shore of Karluk Lake; inspected the beach line to the north of Thumb Creek. For 500 yards the salmon were scattered along the beach, spawning in the gravels. These were all red salmon. We waded among them and examined carefully and could not discover a single humpback.

August 20.—At the head of Thumb Lake, at mouth of inlet, 75 or 100 red salmon were schooled off the two entrances (a long sand island between) and were entering at intervals during our stay of two hours. In the creek itself very few salmon were seen, either dead or alive, and the dead fish were all old, as though no spawning had been in progress since the early part of the season. Lucas walked up the stream for about 3½ miles and came to falls, at the foot of which a small number of reds were gathered, making futile efforts to jump them. None were seen by him above the falls. During the walk he saw few dead fish. This must be considered a relatively unimportant spawning stream, yet it appears to have ideal spawning gravels and a good flow of water. The gravels continued, according to Lucas, for 2 miles or more, and for that distance a few reds were seen alive in the stream and dead along the banks. But above, the character of the stream changed. It became rapid and turbulent, and the bed consisted of rock slabs, with only occasional limited patches of gravel. Along this stretch saw no dead fish, and none living, until the falls were reached.

A tributary comes out of a side valley (to the left, looking upstream) and joins the main stream near its mouth. Almost no live fish were seen in this creek, and no dead ones, although the gravels seemed favorable. On the flats above the junction of the two streams are a number of bayous with excellent spawning gravels, but these were mostly untouched.

No other important tributaries enter Thumb Lake. A small creek enters in the northwest corner, building out a delta of coarse stones, which projects to form a slightly prominent point of the shore line.

A limited amount of spawning was in progress off the mouth of this creek and for perhaps 100 yards above. Then the stream becomes very rapid, descending in short steps over coarse rocks and bowlders, in a little ravine. Apparently no salmon ascend beyond this point. As so frequently with these short and otherwise favorable streams, the greater number of the spawners must fall a prey to the bears. Well-beaten bear trails were everywhere, and wallows where they lie and devour the fish they have thrown out on the bank. Fragments of freshly eaten salmon nearly always testify to the presence of these bears immediately before (or at the time of) our visit.

The humpbacks were not found in Thumb Lake or tributaries, save for an occasional straggler. For the total population of the Thumb Lake, Thumb Creek, and tributaries, one red to five humps would be an approximation to the condition this year.

August 21.—Took dory up O'Malley River into the lake; surveyed the latter while Lucas and Studdert ascended the inlet as far as spawning fish were found. The inlet is a considerable stream with apparently favorable gravels. We observed a few reds off its mouth and in the creek, perhaps 50 to 75 in all, but the stream soon becomes unfavorable, traversing a hilly district with swift current and coarse slabs of rock. The watershed is short, an extensive valley to be seen beyond the near ridge that bounds its upper end evidently draining to the south. The part of the stream suitable for spawning probably is limited to the lower 200 or 300 yards. There were two mouths to the stream at the time of our visit, one on each side of a sandy bar thrown up by stream and lake. The eastern mouth was much larger, but red salmon were entering through each of them.

No other tributary of any importance enters O'Malley Lake, but the most valuable spawning stream of this watershed enters the outlet of the lake immediately below its emergence. It comes out of a valley to the east, enters O'Malley River from the left (looking upstream), and is the creek into which the majority of the fish were observed to enter last year, when we stood at the junction and tallied those coming up the river. A few continued into the O'Malley Lake, but the majority went into Falls Creek, as we have designated this stream. On inspection by Lucas, it was ascertained that the lower mile of this creek runs through the bottom lands and is well stocked with spawning fish, but beyond this the hilly country is reached, the stream grows boisterous, with a bottom of slaty rock, and practically no more fish were found. This continues for another mile, to a vertical fall of 20 feet, wholly insurmountable. Below the falls evidence of fish were found where bears had fed, and a few were seen all the way to the falls, but they were widely scattered.

In addition to O'Malley River, there enters at the head of the lake (i. e., Karluk Lake) a stream we call Canyon Creek, of real value. It comes out of an extensive valley to the left (facing head of lake) of the valley containing Falls Creek, and descends into the same, flat, swampy meadow land through which O'Malley River and the lower course of its affluent, Falls Creek, flow. Looking toward the head of the lake we see three valleys, occupying deep convergent clefts in the mountains. The right-hand one is occupied by O'Malley Lake and its main inlet, the middle one by Falls Creek, and the left-hand one by Canyon Creek. The latter enters Karluk Lake only 400 feet to the left of the mouth of O'Malley River, and is a beautiful, clear, cold stream in its lower course, with ideal spawning gravels. It was examined by Studdert, who reported that in its lower course, for about three-fourths mile, it meanders through a flat overgrown with tall, coarse grass, and the bottom is ideal for spawning. Then it enters hilly country, has a swift current and rocky floor, and carries but few fish. Along with Falls Creek it forms the principal spawning area of the head of the lake.

August 22.—Two short creeks (Grassy Point Creek and Halfway Creek), entering the west side of lake, were explored by Lucas and Studdert. Both are brawling streams, with coarse bowlder beds and only occasional very limited patches of gravel. They are only 10 to 15 feet across, but in spite of their small size and unfavorable character they carry more red salmon in proportion to

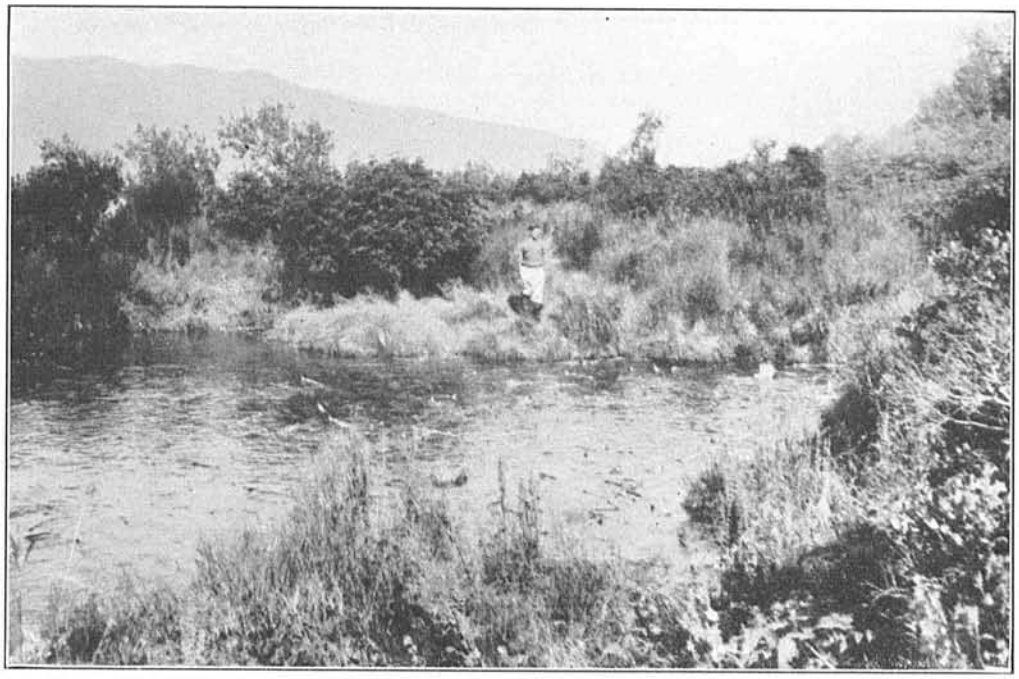


FIG. 12.—Lagoon at Little Lagoon Creek in July, 1926

FIG. 13.—Salmon densely massed in one corner of the lagoon at Little Lagoon Creek in July, 1926. These fish were congregated at the point where one of the small streams enters

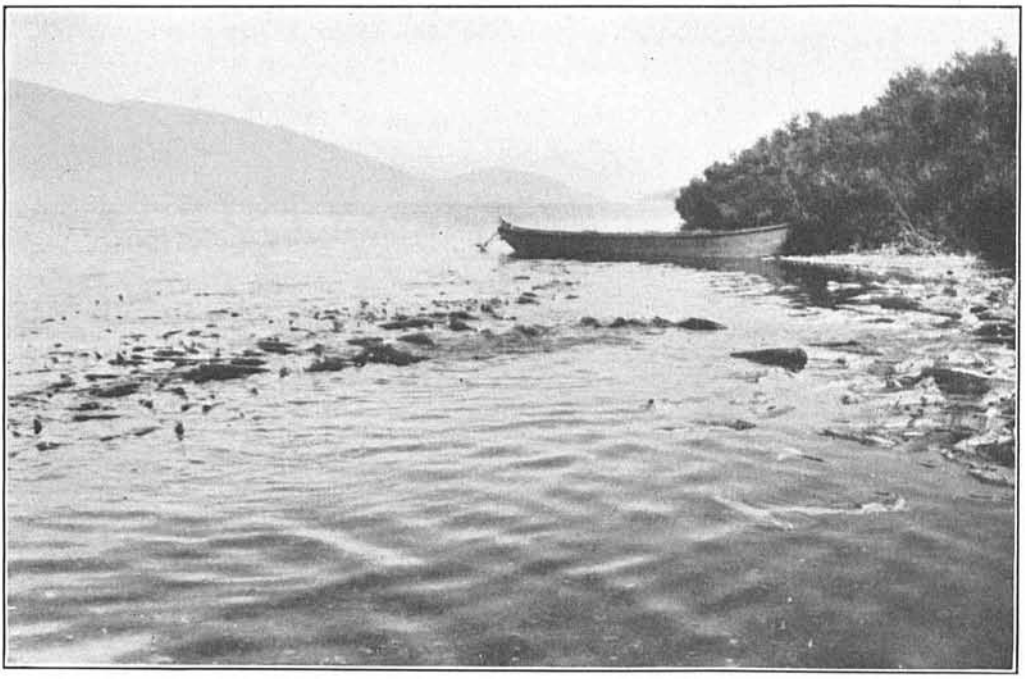


FIG. 14.—School of salmon off the mouth of Little Lagoon Creek, 1926

FIG. 15.—Dead salmon in the lagoon at Little Lagoon Creek in August, 1926

their size than do the more suitable spawning streams of the Thumb and Head of Lake. Only about a mile of their course is suitable for spawning, sometimes even less. No humpbacks were seen in any of the short creeks on the west coast.

August 23.—Ran to head of lake. Lucas and Studdert examined Cascade Creek and Meadow Creek. At the latter fish were congregated off the mouth, entering at intervals. Perhaps 100 there, all told. Comparatively few dead fish. The stream was reported favorable for one-half mile, then rapid and bowldery, and fish dropped off, although no falls were encountered. The stream became so rough that in less than 2 miles the fish had disappeared.

As regards numbers of fish at head of lake, it seemed that, as nearly as we could estimate, the scarcity of red salmon this year is nearly equally distributed over all parts of the lake. Compared with 1921, the dead fish and the living were lacking in what appeared equal proportions. The rivers at the head of the lake were signally deficient, the sloughs in which last year the dead salmon had so greatly become aggregated were relatively poorly covered.

The shore spawning grounds about Cascade Creek, O'Malley River, and Canyon Creek were less populated, proportionally, than were the streams themselves. Along that stretch of beach to the left of O'Malley River, extending for a quarter of a mile, where last year a continuous band of spawners was closely crowded, contained this year only a few straggling pairs. But on the whole the situation seemed in harmony with our expectation, from the counting at the weir, that on the average there were only one-fifth the fish this year that we found last year.

A very few scattering humpbacks find their way to head of lake and enter streams. Probably less than a dozen, all told, were seen in O'Malley River and Falls Creek. None were observed spawning in the lake gravels.

August 24.—Ran down east shore, examining all streams below Thumb Bay. Cottonwood Creek had a few fish off mouth; occasionally one was seen to enter. Contrasts strikingly with last year, when there was a constant procession of salmon scurrying over the shallow beach. Perhaps 100 live fish in the first one-fourth mile of stream and comparatively few dead ones. Lucas and Studdert ascended stream into the canyon. Available spawning grounds in lower one-half mile only; above that no falls found, but rapid and impracticable.

Temperature at mouth Alder Creek 45° at 9.55 a. m., when lake temperature was 47° and air 54°.

The eastern shore of lake north of Thumb contains many shallow stretches of good gravels, in which spawning red salmon are working. The total number is small this year, but they are widely distributed. No live humps observed anywhere among beach spawners, but two dead ones seen on beach between Alder Creek and the Thumb. None were seen in short rocky streams on either side of the lake.

Spring Creek was again examined. *Very* deficient, compared with last year. Only some half a dozen live fish and practically no dead ones seen below ponds, and in the ponds themselves certainly not one-tenth as many, living or dead. *None* seen in the right-hand fork above junction with outlet of ponds.

Mouth of Spring Creek 41° at 12.45. Right-hand fork above junction 38°. Left-hand fork above junction 43°. All fish were in warmer left-hand fork. Last year we saw an occasional one ascending right-hand fork, but this year none were there. Temperature at upper end of upper pond, where water seems to enter at base of abrupt bluff, 40°.

Latter part of afternoon with Lucas, ran to head of lake and returned by way of Meadow and Tree Points. Temperature of Canyon Creek at mouth, 46°. O'Malley River at mouth 48°. Spawning gravels at upper end of lake 46°. Temperature of lake just outside entering current of O'Malley River 47°.

It will be seen that fish entering O'Malley River leave a temperature of 47° to enter one of 48°.

Fred R. Lucas, who had accompanied the writers on their visit to the lake in 1922, again examined the spawning grounds in 1924, and the following extracts are taken from his report:

Karluk.—The large humpback run in Karluk River did considerable damage to to the red-salmon spawn. On August 21 hundreds of thousands of fish died in the 20 miles of river between the weir and the still water at the Larsens Bay portage. The mortality included adult red salmon,

humpbacks, and trout, as well as young fish. The cause is unknown, unless it was due to overcrowding of humpbacks, with a possible fall of the water level in the river. Mr. Wood states that a few days later the river was still packed with live fish. It is estimated there were over 4,000,000 humpbacks passed through the weir this season.

Three men made a trip to Karluk Lake from September 16 to 24, inclusive. No unusual number of dead salmon containing spawn were seen above Larsen Bay portage, except in two creeks in the lake, as noted later.

Red salmon in considerable numbers had spawned and were spawning in the river from one-half to three-quarters of a mile below the lake, beginning at a point where the river makes a right-angled turn around the shoulder of a mountain.

It is believed, after viewing the river, lake, and spawning creeks, that only one-fourth to one-third of the humpbacks reached the lake. In the river the dead spawned-out humpbacks were piled in windrow after windrow, parallel with the stream, for its entire course.

Each creek is mentioned below in geographical order, starting at the outlet of the lake and going up the west side and returning on the east side.

Grassy Point Creek.—The first creek, going up the west side of the lake, just beyond Grassy Point. This creek did show unmistakable signs of some catastrophe to adult fish, similar to the lower river. Numbers of dead red and humpback salmon, that had not spawned, were seen in an advanced state of decay, yet not so far advanced as the ones in lower river. A few reds were spawning in the upper part of the stream; and some humpbacks were still alive in lower part, but spawned out. Judging from the distribution of dead fish and eggs adrift, most of the humpbacks stayed in lower part of stream, where is the best spawning gravel, and here is where the dead, unspawned fish were seen.

Halfway Creek.—Indications of a considerable number of humpbacks previously in this stream. No dead unspawned fish of either species. Several hundred reds spawning. Piles of dead eggs were in the creek. About two-thirds were humpback eggs. Red eggs were observed, that had been killed about the time they were to come out of the tender stage. Several dozen red eggs were noticed containing live fish past the tender stage. Quite a number of trout were in evidence. School of 200 reds was seen through the wall of breakers at the mouth of creek.

Meadow Creek.—This creek was well populated with spawning reds for about one mile. Judging from the dead fish, the creek was full of humpbacks a short time before. More than a dozen dead reds, full of eggs, were noticed, but no dead humpbacks. The reds were in a better state of preservation than the humpbacks in lower river. One thing noticeable in the piles of dead fish washed against rocks in the stream was that there would be two or three reds against the rock and then seven or eight humpbacks on top of them. These reds were spawned out.

Cascade Creek.—Very few fish of any kind have used this stream. Some dead humpbacks were seen one-fourth to one-half mile from the lake, and a few reds were spawning.

Beach at head of lake.—Large numbers of humpbacks have spawned here on top of a good many reds. Some other reds were spawning.

O'Malley River.—Red salmon were spawning in this stream in larger numbers than ever noticed before by the writer. Believe it would average a pair to each square yard, except in the so-called "pothole," where they had spawned earlier. Two visits in August in previous years disclosed comparatively few fish in this stream. Apparently the red spawning here is at its height in September. Thousands of humpbacks had spawned here and some red eggs had been dug out. The reds were now digging out the humpback eggs. Behind every rock and in every eddy piles of humpback eggs lay. Within 22 steps the writer counted 12 piles that would average 5 gallons to a pile; and behind a small island about 6 feet in diameter there were more than a 50-gallon barrel full of humpback eggs. These eggs were all dead; had been dug out and drifted around before passing the tender stage. A small percentage of red eggs was among them. In fact, more or less red eggs were noticed adrift in every stream where humpbacks had spawned. Upon examining the live red eggs, including those partly white, there were about the following proportions: Fifty per cent were well eyed, 25 per cent were fertile but in tender stage (most of them beginning to show white spots); and 25 per cent were not yet to the tender stage. The dead red eggs—that is, eggs that had turned entirely white—were more numerous than the live ones. All of these live eggs will probably be picked up by the birds and trout before they hatch and after the dead eggs decompose.

Falls Creek.—Stream coming in on left below O'Malley Lake. This stream was visited by walking over the ridge from O'Malley Lake to the falls. Did not see a live or dead red salmon in this stream during the upper two-thirds of the distance from falls, but humpback carcasses were thick almost to the falls. A comparatively small number of reds was spawning over the humpbacks in the lower part of the stream. Some reds had spawned here before the humpbacks, but the entire stream was, in the main, given over to the latter.

Small stream at head of O'Malley Lake.—A few humpbacks have spawned here but no reds were seen.

Canyon Creek.—This is the best red stream on the lake this year. Some dead humpbacks were at the lower end, but live and dead reds were thick all the way to the falls. Some of the early red eggs are being dug out by present spawners.

The Thumb.—Beach at head of thumb. Reds and humpbacks have spawned here in about equal proportions. Some reds are still spawning.

Thumb River.—More reds spawning here than in previous years. Conditions very similar to the similar stream at the head of the lake. Great numbers of humpbacks have spawned here and the reds are now busily working over the same ground. Humpback eggs, with some red eggs, were piled in heaps in eddies and shallows on the right-hand side. Apparently the humpbacks had dug up the early red nests, and what eggs were past the tender stage were still alive but drifting around.

Salmon Creek.—Found this stream well populated with reds. It had been even better populated with humpbacks and some reds earlier in the season, as indicated by eyed red eggs drifting around. One very small red was observed. A considerable portion of the live red salmon were small fish.

Upper Thumb River.—Both of these creeks had been seeded early by reds. Only bones were left in the water, but carcasses thrown out by the bears were thoroughly dried. A few live ones were still to be seen, especially in the left-hand or smaller branch. A considerable number of humpbacks had spawned. Trout were plentiful. Not many eggs were adrift.

First creek below Thumb on north side (either Alder or Cottonwood Creek).—Had more dead humpbacks than reds, with a few reds spawning now; also the usual number of humpback and red eggs on top of gravel. Humpback eggs in larger quantities and all dead; some red eggs eyed and alive.

Second creek from the Thumb (either Cottonwood or Moraine Creek).—This creek had at least six times more humpbacks than reds, with a few reds spawning now.

Spring Creek.—Evidently the humpbacks spawned mostly in creek below potholes. Red carcasses in potholes were not as numerous as two years ago. Digging in the gravel, discovered humpback eggs exclusively, up to the potholes; but in little lakes, especially the upper one, more red eggs than humpbacks. Very few live reds anywhere in this creek.

There were spawned-out humpbacks at every place where we landed around the lake. We were delayed two days on the lake by a strong wind and provisions were exhausted. Each creek was ascended as far as the fish could go, with two exceptions—the largest creek at the head of Thumb Lake and the second creek from lower end of Karluk Lake on the north [east] side.

The most extensive observations of the spawning in Karluk Lake were made during the season of 1926 by the junior author and a small field party. The greater part of the months of July and August were spent on the lake, which was carefully mapped and sounded. Some preliminary observations on the limnology of the lake were made, including both surface and deep temperatures on the lakes, temperatures of the tributary streams, and some few qualitative plankton collections were made. Other data bearing on the history of the eggs and of young salmon during their life in the lake were secured. Particular attention was given to the spawning of the adult fish, which was made especially interesting and important by the remarkably fine run and escapement of 1926. The spawning escapement was the best in many years, and in all probability was the best that has ever been observed by the few white men who have visited the lake. The notes made are too extensive to quote in full,

but the following abstract has been prepared, giving the observations bearing especially on the spawning:

July 12.—Very few fish in the river below the lake. About 100 spawning in a very small spring-fed stream that enters the lake from the west side, about 300 yards above the outlet. Temperature of this creek 39.5° F.; of the lake surface 52° F.

July 14.—Salmon spawning abundantly at the head of the Thumb, in Thumb River, and in Salmon Creek, which was explored up to the first impassable falls. Apparently every available spawning space was occupied in the river and in the creek. * * * At the head of the Thumb, near the mouth of Thumb River, and in the lower part of Thumb River the nests were as thickly placed as possible—one nest touching the next. Just below the mouth of Salmon Creek the salmon were collected in a dense school—they were packed in vertically, and the whole pool showed only a mass of noses sticking up above the surface. In the creek itself both live and dead salmon were numerous—estimated 1,000 to each 25 yards in the lower part of the stream. The dead salmon were apparently not long dead, as decay was not far advanced. About three-quarters of a mile of this creek is available for spawning. Estimated at least 15,000 fish in the creek, not counting those in the river outside. Estimated 5,000 in Thumb River and about its mouth.

July 15.—Halfway Creek. Two to three thousand fish spawning in the first two to three hundred yards. A dense school just off the mouth. Several hundred spawning on the beach, both north and south of the creek. Two or three hundred on a stretch of fine beach about 300 yards south of the mouth of the creek.

At the head of the lake estimated 4,000 salmon spawning alongshore, especially between the mouths of Cascade Creek and O'Malley River. Except in a few places, all available space seemed to be well covered. Dead fish were very numerous and had apparently spawned earlier than in Salmon Creek, as they were in a more advanced stage of decay. Many of the earlier spawning beds had been exposed by the receding of the water (a condition frequently noted throughout the season), and it was judged that spawning had taken place about two weeks before—i. e., about July 1.

O'Malley River and the lower parts of Falls Creek and Canyon Creek appeared to be populated to capacity, and there were dense schools just outside their mouths. * * * In O'Malley Lake, however, only very few salmon were to be seen. There were a few near the outlet and near the inlet, but there were not more than a few hundred in the entire lake.

July 16.—Little Canyon Creek. Although very small in area, the place was one of the most remarkable and interesting of any visited. A small pond or lagoon had been formed just back of the beach by two small streams that drain from the mountain side. The stream connecting the lagoon with the lake is not more than 25 or 30 feet long, and the lagoon is only 50 or 60 feet in width. The water was very cold, 45° F. in the outlet from the lagoon and 39° F. at the inlets, while the surface temperature of the lake was 59° F. The concentration of spawning salmon here was so great that it could hardly have been exceeded. Estimated 1,500 salmon in the lagoon, 2,000 just outside, and about 800 (counted roughly) dead on the beach just outside. They were spawning thickly in the lagoon, and equally on the beach, and for about 200 yards below Little Lagoon Creek, especially at places where there were small trickles of water entering the lake from the mountain side.

Estimated 2,000 salmon spawning in Big Bear Creek and on the beach south of Bear Point. Salmon spawning alongshore on both sides of Boulder Point.

Cottonwood Creek was examined hastily. Salmon were spawning in the creek and were thickly bunched off the mouth of the stream, so that the surface of the water was a mass of fins and noses.

Moraine Creek: Estimated 1,500 to 2,000 spawning fish in the first 100 yards; 1,000 to 1,500 were just outside the mouth, thickly schooled, as has been so often observed. Spawning was in progress for 300 to 400 yards along the shore of the lake below Moraine Creek, and it was estimated that there were about 500 salmon for each 100 yards. The water along this beach was somewhat cooler than the lake surface offshore, probably caused by seepage.

Spring Creek: Probably no salmon schooled about the mouth of Spring Creek, though there was a fair number spawning all along the creek and in the holes. Estimated 1,200 to 1,500 in all.

July 17.—Grassy Point Creek was examined for about 300 yards, and it was estimated that there were about 3,500 salmon in this distance. A large school was waiting just outside the mouth,

FIG. 16.—Dead salmon on the beach, early in August, 1926

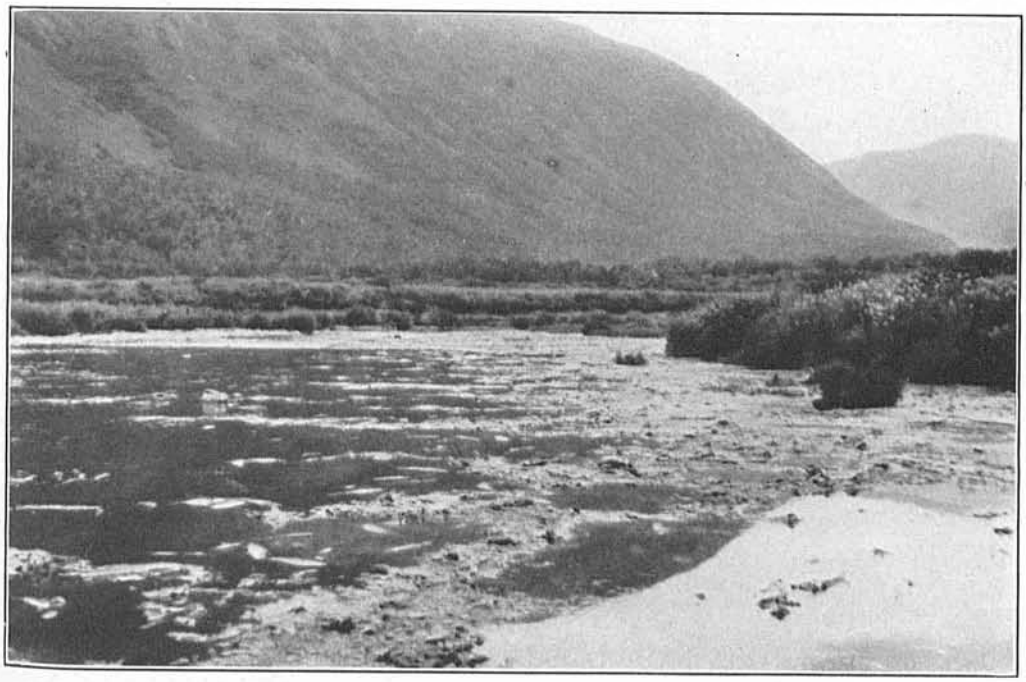


FIG. 17.—Lower Thumb River in August, 1926. Note the great numbers of dead salmon and the spawning beds exposed by low water

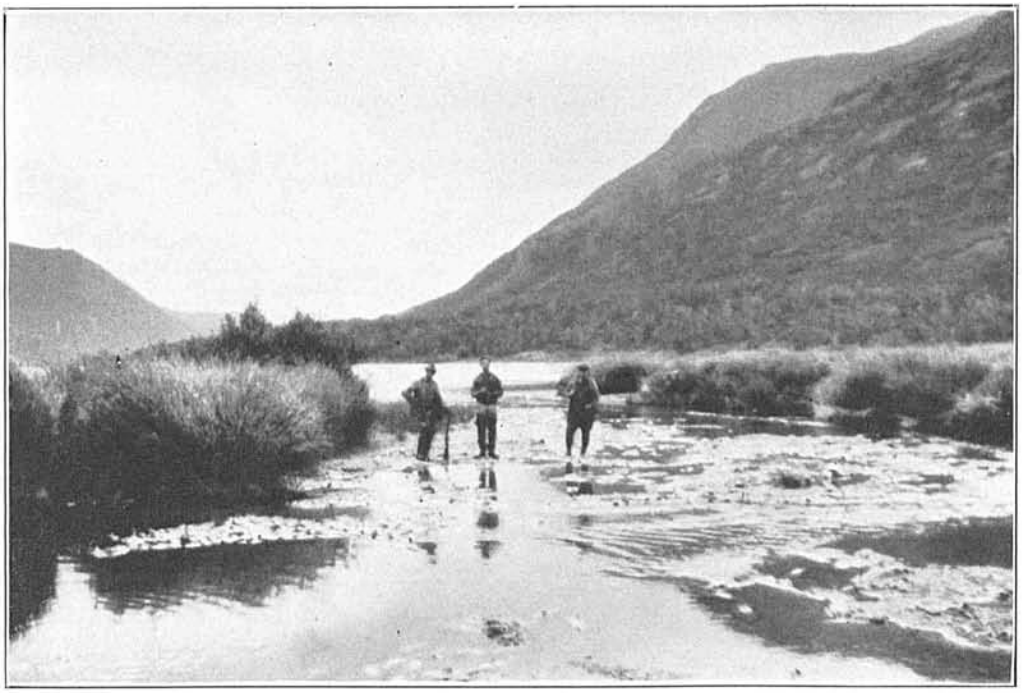


FIG. 18.—Lower end of Canyon Creek, August, 1926

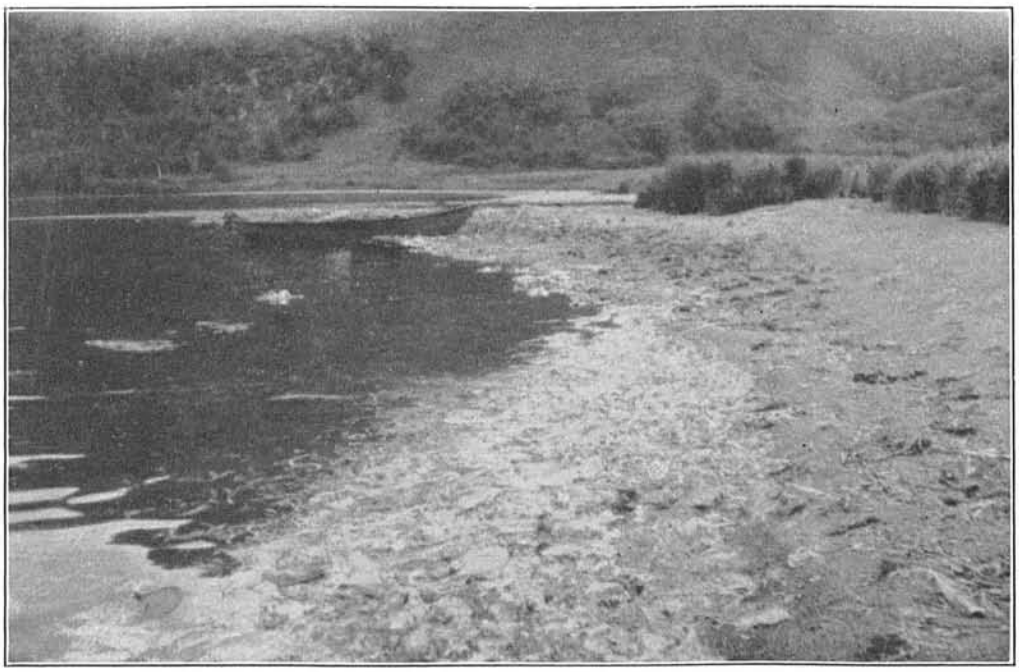


FIG. 19.—The beach at the head of the Thumb, late in August, 1926. The dried skin and bones of dead salmon left by the blowfly larvæ may be seen above the water line. The white streak, 6 or 8 feet wide, along the edge of the water is composed of the disintegrated bodies of dead salmon

and fish were spawning for about 150 yards north and 100 yards south. About 1,500 fish in all in the lake around the mouth of this creek. Very similar conditions were noted along the beach near Halfway Creek and at Meadow Creek. In Meadow Creek we estimated that 3,000 to 3,500 fish, spawning or dead, were contained in the lower 200 to 300 yards. Another thousand or 1,500 were schooled off the mouth or spawning along the beaches on each side of the stream.

July 18.—Spawning salmon were noted, though they were not numerous, along the south side of Grassy Point, the south side of Tent Point, and about the mouth of a small creek that enters the lake about 400 yards north of Tent Point. Others were noted along the shores near two small creeks that enter from the west side about one-half and 1 mile above the foot of the lake.

In Thumb Lake several thousand salmon were seen schooled in the lower end, where it narrows to the outlet, and all along the lower end to the north of the outlet. Thumb River, above the lake, was prospected for about 2 miles. The river branches about one-half mile above the lake. One branch (the main one) goes on in the same general direction as the part below the forks (i. e., toward the east), while the other branch comes from a valley to the north. At the junction, the north branch breaks up into several mouths, forming numerous small islands and deltas. This whole system of the upper Thumb River was crowded to its apparent capacity with spawning salmon. The gravel of the river bed was everywhere covered with spawning beds; apparently there was not a square yard of the whole river bed, wherever there was suitable gravel, that did not contain a spawning bed.

Toward the upper part of the south branch fish were not quite so numerous, but spawning conditions were not so favorable here, as the fall was becoming more rapid, with cascades and big slate bowlders common. Similar conditions were observed in the north branch, which is not quite as large as the south branch. All of the channels in the delta region were densely populated with spawning fish. If anything, the north branch was more densely populated than the south branch, though on account of the greater size of the latter it evidently contained more fish. Almost everywhere in both branches the live salmon were in rank after rank across the streams—one rank right behind another. There were tens of thousands of dead salmon strewing the banks and gravel bars. Any estimate of the number of spawning fish was difficult but it was thought that certainly not less than 300,000 fish, and probably about half a million, had entered Upper Thumb River up to this time. This year (1926) there was no single spawning area as important as this one. It accommodated about half of the heavy early escapement, as well as a fair proportion of the later runs.

The small creek entering Thumb Lake near the northwest corner was examined for a few hundred yards, as far as salmon can ascend. There were 700 to 800 fish in the creek, about 500 dead along the shores of the lake, and some 1,500 massed in a typical dense school off the mouth of the stream and spawning along the foot of the lake on both sides.

July 19.—A few spawning fish were seen at the first point above Island Point on the east side of the lake. There is no creek here, but the topography indicates that there may be some drainage seeping through the gravel. A few were seen at scattered points along this shore, up to the head of the lake, but the total number was inconsiderable—probably not more than a few hundred.

Canyon Creek was examined for about 2 miles. Great numbers of fish were spawning here, though apparently they were not quite as numerous as in Upper Thumb River, nor was there quite as large a spawning district. At one place there was a fine large hole in the river, approximately 6 feet deep, 30 feet wide, and 60 feet long, which was filled with salmon. Estimated 4,000 to 5,000 in this one spot, and between 100,000 and 150,000 in the whole stream. At the upper limit of the part explored the creek goes through a rugged, steep-walled canyon, in which is a fall that is almost but not quite insurmountable for salmon. We watched many fish trying to get up over the fall, but saw none succeed, although a few were seen above. This is doubtless practically the upper limit of the spawning area in this stream.

Falls Creek was explored for about 1½ miles. No insurmountable falls were reached, although the upper quarter of a mile was a series of cascades, and here fish were relatively scarce. Estimated 20,000 to 25,000 fish in the entire stream, which is considerably smaller than Canyon Creek.

There are a number of small spring branches to O'Malley River, which enter between Falls Creek and Karluk Lake and which provided spawning areas for a large number of salmon. One, alone, had about 5,000 fish, both dead and alive, and it was estimated that in all there must have been twice that number.

August 1.—At Halfway Creek only a very few hundred salmon were to be seen. These were about the two mouths of the stream and spawning along the beach for about 100 yards on each side. There were many dead fish in the creek and along the beach, far advanced in decomposition—much further decomposed than on our previous visit. * * * There appeared to be comparatively few fish in the creek above the mouth.

August 3.—Thumb River, where it enters the Thumb, is quite a different looking stream now as compared with two weeks ago. Comparatively few fish were to be seen, though the shore on each side of the mouth of the river was covered with carcasses in advanced stages of decay. * * * Many dead salmon are to be seen all along the shores of the lake, even where, for a mile or so, no spawning had been in progress.

August 4.—In the streams at the head of the lake comparatively few live salmon were to be seen, even in Cascade Creek, O'Malley River, and Falls Creek; but dead carcasses lined the shore at the head of the lake, though in places remote from any spawning areas. Along the shores of Camp Island there were dead salmon, averaging about one every 10 feet, and at places more abundant than that.

August 5.—On a visit to the foot of the lake it was noted that live salmon were scarce, as usual, but there were many dead ones. The shore all along the foot of the lake, from Spring Creek to the outlet, was thickly covered with decayed remains of spawned-out salmon and with the skins and bones left after the myriads of blowflies had done their work.

August 6.—There were only about 100 fish spawning in Little Lagoon Creek, although the lagoon was literally choked with dead salmon.

August 7.—Moraine Creek was explored for about 1 mile. There were lots of dead salmon as far as we went, but very few live fish—probably not more than 1,500 to 2,000 in the whole creek. There were salmon still above the highest point we reached, but the creek became much steeper within the next few hundred yards. We estimated that 10,000 to 15,000 fish had spawned here up to this date.

August 8.—A new run of fish was noted in O'Malley River. These were clean and bright, and many had not yet acquired the bright red spawning dress. Only a few of the earlier run remained alive, * * * the vast majority of the tremendous numbers we saw three weeks ago were dead and their carcasses rapidly disintegrating. There were several thousand of these fresh-run salmon along the foot of O'Malley Lake. They were in shallow water but were not spawning. A few dead females observed in O'Malley River and along the foot of O'Malley Lake were quite green, and it was evident that the new run was not yet ready for spawning.

About 1,000 fish were schooled in Karluk Lake, just outside the mouth of O'Malley River. About the same number were schooled off the mouth of Canyon Creek, and a few were in the creek itself. The same conditions were noted in Falls Creek, Cascade Creek, and Meadow Creek, which contained a few live fish, apparently mainly of a fresh run, and multitudes of dead salmon piled up in great masses against the larger bowlders, lining the banks, and rapidly disintegrating under the influence of decay and blowflies. Fish were spawning along the beach at the head of the lake.

This fresh run of fish was apparently the beginning of the second heavy run into the Karluk River. This run begins late in July, and in one day some 37,000 had been counted through the upper weir, located at the Larsen Bay portage, just a few days before these were seen at the lake. During the last few days of June and most of July the average daily escapement had been less than 10,000. Confirming this interpretation is the fact that the new run, wherever noticed, was composed of fish that were distinctly larger than the fish that entered Karluk River in June and spawned during July. The careful measurements made of daily samples of fish taken at the mouth of the river show clearly this increase in size. (See the section entitled "Analyses of Recent Runs.")

August 9.—In Thumb River there were only a few thousand live fish left in the whole system. * * * A few fish, apparently of the new run, were to be seen about the mouth of the river, in Thumb Lake, and in the stream itself, but there was no great showing of live fish anywhere. Only at one place in the upper river, where a short stream entered from a large spring, were the fish at all thickly schooled, but even here there were only a few hundred.

August 14.—About 100 fish, apparently newly arrived, were seen off the mouth of Moraine Creek.

August 16.—Several hundred fish were schooled off the mouth of O'Malley River, and about 2,000 were spawning in the river. Some of the fish observed on the eighth, at the foot of O'Malley Lake, were spawning, but the majority were still waiting and were massed in close schools in shallow water, close to shore where drainage from springs cooled the water. * * * About 1,000 were dead along shore. Between 1,000 and 1,500 fish were seen in the creek that enters at the upper end of O'Malley Lake. Most of these were dead, though there were a few hundred live ones in the creek and in the lake about its mouth.

August 22.—Comparatively few live salmon were found in Upper Thumb River—estimated 10,000 to 20,000. There were a few hundred about the mouth of the upper river. In the river below Thumb Lake, however, salmon were more numerous than they had been since the heavy spawning in July. The number here was estimated at between 1,000 and 1,500. A few were schooled off the mouth of Salmon Creek, but no such number as in early July.

August 23.—Halfway Creek was explored as far as the first falls that are impassable for salmon The available portion of the creek is only about a quarter of a mile in length. About 1,200 to 1,500 fish were spawning here, and it was estimated that not less than 5,000 had previously spawned and died.

Grassy Point Creek was less well populated, although about ½ mile is available for spawning. Estimated only 300 live salmon here, largely confined to the lower two-thirds of the stream. Estimated that between 5,000 and 10,000 had spawned here during the early run.

Spring Creek contained very few fish. A dozen or so were seen off its mouth, and about 75 in the stream and the spring pools. Moraine Creek was examined for only a few hundred yards and contained virtually no spawning fish. Only 7 live salmon were seen in the creek, and a dozen or so were in the lake about the mouth.

Cottonwood Creek was explored to the first impassable falls—about a half mile. Estimated that 5,000 to 10,000 salmon had spawned here earlier in the season, although on this date there were only some 500 live fish in the stream and about 200 schooled in the lake near its mouth.

Little Bear Creek is a small, spring-fed stream of much the same character as Spring Creek. It rises in several shallow pools, averaging 25 to 30 feet across, which are used to a limited extent by the spawning salmon. It was estimated that several hundred salmon had spawned here, but no live ones were seen. A few dozen were in the lake just outside.

August 24.—A few dozen fish were seen off the mouth of Salmon Creek, but there were very few fish in the creek itself. Only about 50 were counted in the first 200 yards.

Thumb River, below Thumb Lake, contained a number of salmon, estimated at between 1,500 and 2,000. They were spawning there and not passing on up the river. About 800 salmon were spawning along the shore at the head of the Thumb on each side of the mouth of the river.

Big Bear Creek: This is similar in character to Spring Creek and Little Bear Creek, but is larger than either, containing two or three times as much spawning area. It was estimated that about 1,000 salmon of the early run had spawned here, but there were only a few dozen live fish on this date.

Willow Creek is another steep, bowldery stream, similar to Cottonwood, Grassy Point, Halfway, and Meadow Creeks. Quite a number of fish were schooled off the mouth and some were spawning along the beach, the total number being estimated at 200. This stream is passable to salmon for about a quarter of a mile. There were about 400 live fish in the creek, and it was estimated that 4,000 to 5,000 had spawned here previously.

O'Malley River: Five hundred to 1,000 fish were schooled off the mouth, and about 1,000 were spawning in the river between Karluk and O'Malley Lakes. The fish previously noted were spawning all along the shore at the foot of O'Malley Lake.

Falls Creek: The scene here was typical of most of the streams at this time—many dead fish almost completely decomposed, the water foul with refuse from the carcasses, and comparatively few were congregated in the holes.

Canyon Creek: One thousand two hundred to 1,500 live fish were observed in the lower half mile, and a dense school containing several hundred was off the mouth of this stream.

Salmon were spawning all along the beach, from a little distance east of the mouth of Canyon Creek to Cascade Creek. They did not appear to be very abundant, however. * * * Estimated about 1,000 in all.

Cascade Creek: This was relatively more densely populated than most of the other streams. The stream was explored for about three-quarters of a mile. Above the first quarter mile the stream rises rapidly, flowing through a precipitously walled canyon. Spawning fish were seen as far as we went, but there the bed of the stream became still steeper and it is doubtful that many fish were above. It was estimated that there were 2,000 to 2,500 fish in the stream.

Meadow Creek: This stream was explored for about 500 yards. Only about 500 live fish were seen and about ten times as many dead ones.

This completed the observations on the lake spawning grounds for 1926. It is apparent from the notes that the spawning during the latter part of August was remarkably light, especially in view of the fact that there was a heavy escapement through the weir during the month. The following note made on August 24 bears on this:

Many salmon have been seen during the past few days, jumping and "porpoising" in the lake tself—alongshore and out over the deeper water. It seems probable that these are waiting in the lake to ripen before seeking the mouths of the streams. Certainly we have seen no such numbers in the streams as have been counted through the weirs during the past month.

However, during the trip down to the portage, on August 27, great numbers of salmon were also seen in the river below the lake. Evidently, many of the fish that entered the river during August had remained in the river. The river was examined on August 10 and was found to contain only a few fish, but on the 27th "we saw fish everywhere in the river. * * * In the first 2 miles below the lake they were very numerous, and many of them were spawning. However, this was by no means true of all the fish in the river, as we noted fish entering the lake at the outlet, and there were many quite obviously passing upstream below the region where the fish were spawning. Under these circumstances it was difficult to estimate the number of fish actually spawning in the upper 2 miles of the river, but I believe there were between 50,000 and 100,000. In addition, there were as many more, approximately, in the river passing up, either to spawn in the upper reaches of the river or to go on into the lake."

The summer of 1926 was exceptionally dry throughout most of Alaska. This was not only a matter of common observation but is shown in the records of the Weather Bureau. Throughout the Karluk System the streams were very low, probably lower than they had been for many years. The lake, too, was noticeably lower, the level late in August being about 1 foot below what appeared to be the normal level, judging by the grass and other vegetation alongshore. Just what effect this will have on the success of the spawning is problematical; it may be slight or it may be great enough to offset in considerable measure the effect of the fine spawning escapement. On August 9 the following notes were made:

In Thumb River, where the spawning had been heaviest, many of the nests were exposed by the lowering of the water. We dug in some of them and found mainly dead eggs, although a very few live ones were found.

Similar conditions were noted in all of the larger streams—O'Malley River, Falls Creek, and Canyon Creek. All of these flow for a considerable portion of their lower courses through flats, where the stream beds are relatively wide. All of the other streams, except those small ones of the character of Spring Creek, drop down much more abruptly from the mountains, and the beds are more closely confined. These, therefore, were not as much affected by the dry season.

Perhaps associated with the dry season, there was a noticeably heavy mortality among the unspawned fish in 1926. This was observed throughout the season and in all the spawning streams. On July 18, in Spring Creek, "it was very noticeable that many of the females were not completely spawned out; 6 of 12 examined had eggs apparently still in good condition. Most of these were apparently not spawned at all, although ripe." On the same date, in upper Thumb River "we saw many dead females, ripe but unspawned, and many others that were not completely spawned out. Causes of death quite unknown, as most of them appeared to be in fine condition." On August 16, at the foot of O'Malley Lake, there were "about a thousand dead [salmon] alongshore and * * * all the dead females had apparently died without spawning and before the eggs had ripened; roe still solid." These, of course, were the late run mentioned above. Similar observations were made frequently during the summer, and the general impression given was that about 25 per cent of the females that reached the lake died only partially spawned out. This is strikingly different from the conditions observed by both Rutter and Bower, mentioned above, both of whom reported nearly all of the females as spawning completely. In 1924 Mr. Lucas noted the death of large numbers of unspawned salmon in Grassy Point Creek, but specifically states in his notes that dead unspawned fish were *not* found in several of the other streams. It is apparent that the death of unspawned fish in 1926 was quite unusual. This may have been due to low water, the crowded conditions on the spawning beds, a combination of these two, or to some other cause.

LIFE HISTORY OF KARLUK RED SALMON

The run of red salmon to the Karluk River extends over a period of about five months, beginning in May and ending in October. The commercial fishing season for the years 1916 to 1926 is given in Table 2.

TABLE 2.—*Fishing season at Karluk, Alaska, from 1916 to 1926*

Year	Began fishing	Stopped fishing	Year	Began fishing	Stopped fishing
1916	June 3	Oct. 2	1922	June 5	Sept. 19
1917	June 4	Sept. 27	1923	June 8	Sept. 15
1918	June 10	Sept. 28	1924	June 1	Sept. 30
1919	June 6	Sept. 25	1925	June 15	Sept. 10
1920	May 26	Sept. 27	1926	do	Sept. 15
1921	June 15	Sept. 24			

The first fish to appear are, in general, well advanced toward spawning and certainly do not linger long in the lake before seeking the spawning gravels. The earliest spawning has not been observed, but it is believed to take place not later than the middle of June. From that time until late in the fall uninterrupted spawning is in progress in suitable gravels about the shores of the lake and in all favorable tributaries.

The spawning grounds have been visited frequently in the middle of the season, when, in favorable years, the tributaries are thickly lined with dead and dying fish, many of the dead even then in the last stages of decay. At the same time, spawning is actively in progress, and a constant procession of new arrivals from the lake is prepared to work again every available stretch of gravels. Undoubtedly the late

comers dig up many of the nests of those that came earlier, and destroy a regrettably large number of eggs; but they replace those they destroy with fresh lots of their own eggs, and many of the earlier eggs must escape destruction. Even in years of very heavy runs, when waste of eggs is excessive, the net result is probably a more complete seeding of all available gravels than occurs during runs of more moderate dimensions. It may well be that a spawning escapement beyond a certain size entails an economic loss. The increase in numbers of progeny produced by such overplus of spawners may not compensate for surrendering the economic value of the parents; but we have no evidence that "overseeding" of the beds ever occurs, with a diminished run in consequence. That the reverse is the case, we have a certain amount of evidence, and need only refer to the quadrennial run on the Fraser River, which persisted throughout historic times despite almost incredible crowding of the spawning grounds during the "big years." The more moderate spawning of the intermediate years produced only the limited runs of those years; and when finally the spawning escapement of a big year, because of a catastrophe, was during one season reduced to a fraction of its usual size, the big run disappeared completely and has never been restored.

As bearing on this point, we have in evidence also the large and small runs of pink salmon (*Oncorhynchus gorbuscha*), which occur in alternate years in virtually every portion of its range. The pink salmon matures invariably in the second year of its age. All the members of any run have developed from eggs laid down during the second year previous. Every big year, then, produces a big year, although with this species especially, the streams are crowded to capacity and beyond during years of heavy run. The waste here again is enormous, and the economic phases of the question may well be taken into consideration; but it is well to keep in mind that the net results of such excessive crowding of the streams are in the way of increased runs. To those, therefore, whose duties lie in the examination of spawning grounds, we recommended a certain hesitancy in certifying that the beds are "fully occupied" by spawners or are "overseeded."

During the summer of 1926 the ovaries from a number of females were preserved and the eggs counted to determine the number produced by each female, and from this the number that may be deposited on the spawning beds. The ovaries from 40 females were thus studied, the work being done by S. P. Smith, temporary scientific assistant. From each of the two ovaries found in each female a portion weighing 5 grams was taken and the eggs counted. Then the entire ovary was weighed and the number of eggs calculated. The results are given in Table 3 and are shown graphically in Figure 20.

TABLE 3.—*Number of eggs in Karluk River red salmon taken September 15, 1926*

Average length, centimeters	Number of individuals	Left ovary	Right ovary	Total	Average length, centimeters	Number of individuals	Left ovary	Right ovary	Total
53	1	1,320	1,510	2,830	61	10	1,884	1,917	3,801
54					62	8	2,039	2,018	4,058
55	1	1,645	1,310	2,955	63	4	1,828	1,915	3,744
56					64	1	2,085	2,750	4,835
57	2	1,600	1,682	3,282	65	2	1,975	2,019	3,994
58	1	1,328	1,030	2,358	66	1	1,735	2,509	4,244
59	3	1,818	1,837	3,655					
60	6	1,748	1,739	3,487	Average				3,728

It is apparent that the larger females have the greater number of eggs, the relationship being such that a difference of 1 centimeter in the length of the fish is accompanied, on the average, by a difference of 150 in the total number of eggs. The average of 3,728 is considerably higher than the number of eggs taken from red salmon as reported by fish culturists. The average number of eggs per female, as reported in the records of the hatchery formerly operated by the Alaska Packers Association on the Karluk River, is approximately 2,900. This discrepancy is doubtless due to the failure, in routine hatchery operations, to secure all of the eggs

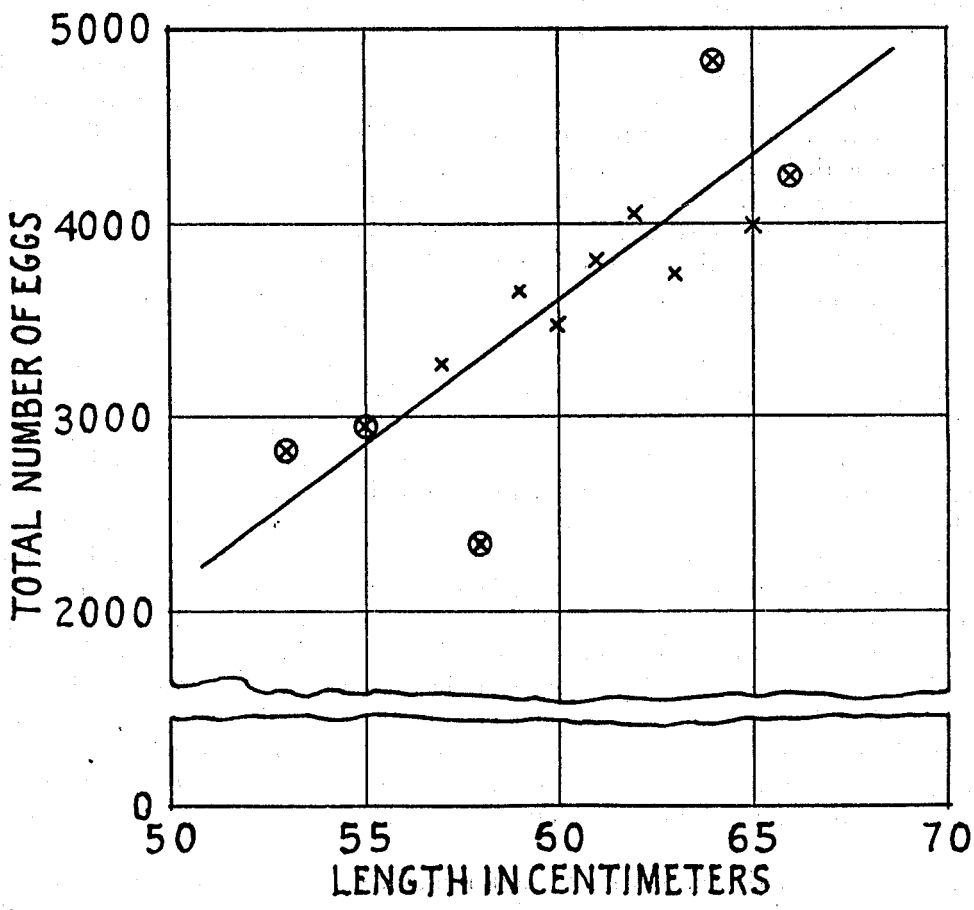


FIG. 20.—Number of eggs in Karluk River red salmon taken on September 15, 1926. ⊗, data from single individual.

produced by each female. Some may be lost before the artificial spawning takes place, and others may be left in the body of the female, especially if she is not perfectly ripe. The data secured by Chamberlain[9] indicate in the Karluk race an average number of eggs per female of 3,500—approximately the same as our figures.

These figures are especially interesting as indicative of the enormous number of eggs deposited on the spawning beds of Karluk Lake in a favorable year. It is probable that more than 1,000,000 females entered Karluk Lake to spawn

[9] See footnote 4, p. 9

during the season of 1926. This would represent over 3,000,000,000 eggs. Many of the females, however, died after entering the lake but before spawning, and many others died before depositing all of their eggs. It seems safe to say, however, that well over 1,000,000,000 eggs were deposited in the gravels of the lake and of the streams tributary to the lake. Of this tremendous number comparatively few survive even to make the seaward migration. The fate of those that do not survive, and the factors that affect, favorably or otherwise, the survival of the eggs and young fish during their life in fresh water, are questions that can not be answered now and are to be considered in the future study of the Karluk salmon.

The period of the hatching of the eggs and the time of emergence of the fry from the gravels is another subject that awaits investigation in the Karluk. That these are virtually controlled by the temperature of the water is well known; and from such data as we possess it is considered highly probable that the first fry to emerge make their appearance not earlier than the following spring and consist largely of those that, as eggs, were deposited earliest in the preceding summer. Following these there may well be a continuous emergence of fry during all the summer months, maintaining an order in their appearance corresponding roughly with that in which the eggs were laid down during the previous season. It has been observed elsewhere in western Alaska that fry of the previous season's spawning, with yolk sac still attached, could be found at the very end of the season. These were doubtless derived from the latest eggs to be laid the preceding fall.

The young remain in Karluk Lake for a comparatively long period and during this time make a sturdy growth. So far as known to us, none leave the lake on their seaward migration before the spring of their second year, and even these are few in number and form a negligible proportion of any brood. The great majority pass down the river and out to sea in the spring of their third year, while a smaller number remains in the lake until the spring of their fourth year, and an occasional individual until the spring of its fifth year. Random samples were collected in the spring of 1926 on five different days, extending from May 30 until June 12, comprising in all 619 individuals. Of these, 1.6 per cent were in their second year (see fig. 21), 74 per cent in their third year (fig. 22), 24 per cent in their fourth year (fig. 23), and 0.4 per cent in their fifth year (fig. 24). The youngest group averaged 96 millimeters in length, the 3-year group 135 millimeters, the 4-year group 144 millimeters, and the 5-year group 169 millimeters long. Of the total number, 314 were males and 305 females.

In addition to the classes above enumerated, which comprise the regular seaward migration of fingerlings, there are found in the river in spring and early summer a limited number of fry in their first year, which are believed to straggle out to sea during the early part of the season. Apparently they are not moving downward with the regular seaward migration of lake fish, but are observed even after the fingerling migration is past, in the eddies along the banks of the river and among the water weeds along the shore where the current is slack; but they seem to have disappeared before midsummer, and have doubtless gone to sea. The origin of these fry has not been traced, and it is not known positively that none of them have come out of the lake at this early age; but as considerable numbers of adult salmon are known to spawn in the river gravels below the lake it is considered probable that

the fry in question have had this origin and that they occur numerously. If this is true, their mortality in the sea must be extraordinarily great, for there are relatively few mature fish returning to spawn that have had this early history. In the 1926 run of mature fish only six-tenths of 1 per cent belonged to this group, which passes out to sea in the early fry stage before the formation of the scales, and the adult scales of which do not, therefore, record any growth in fresh water.

The seaward migration of Karluk fingerlings is a notable sight. At the mouth of the river they are first observed late in May, the wave of migration reaching its height and commencing to recede during the first two weeks of June. Where they first encounter brackish water (in the lagoon at the mouth) they are seen on every side leaping high in the air, with flashes of silver, rehearsing in miniature the leaping habit of the adults when they first taste fresh water on their return from sea at time of spawning.

At the time of their downward migration the Karluk fingerlings are unusually large and form a sturdy stock. They can well be expected to give a good account of themselves during their life at sea and should escape their enemies in larger measure than do the smaller fingerlings of many other streams. Their large size is partly due to their long residence in Karluk Lake, partly, no doubt, to the unusually favorable conditions for growth which they find in this watershed, and partly, perhaps, to a racial habit of vigorous growth, which they may possess independent of external conditions. In so far as their large size and consequent high survival value is determined by length of residence in fresh water, these desirable qualities may have been dearly bought, for it is an open question whether the serious reduction in numbers that must accompany an additional year or two of residence in fresh water may not outweigh the advantages that the survivors experience through increase in size. Those who have seen the hordes of trout and other predatory forms that infest river and lake and daily take their tremendous toll of young salmon during the entire period of their life in fresh water find it difficult to believe that mortality during this period is less than it would have been if spent in the sea. Sea life certainly has the advantage of inducing more rapid growth, with the result that the relatively defenseless stages are passed through more rapidly. We can be sure that a racial habit of migrating seaward predominately in the spring of the second year instead of during the third and fourth years, as at present, would produce vastly larger schools, consisting of migrants of smaller size. What the net results would be, compared with the present procedure, we have no facts to determine, but we look hopefully to the results of further investigations along the lines now planned. The Chignik fingerlings are much smaller when they seek the sea than are those of the Karluk race. If we can succeed in estimating the numbers of downstream migrants in the Karluk and Chignik Rivers over a term of years and can establish the average proportion of each that returns at maturity, we shall have important evidence bearing on this problem.

The problem itself is of more than academic interest, and in a modified form possesses great practical importance. More and more, in recent years, the salmon hatcheries have employed their funds in increasing their pond capacity and in feeding and rearing the young to larger sizes before liberation. It is a moot question whether funds thus employed produce larger net results than they would produce if used to

liberate larger numbers of young at a smaller size. In this, also, we are without facts to determine the problem. In one important respect the advantage would seem to lie with hatchery practice, for in pond life the young are protected from predaceous enemies and would appear thus to enjoy a signal advantage over wild stock spending an equal time in fresh water; but this is not the whole story, for the pond-reared fish are in turn exposed to certain dangers, due to crowding in limited quarters and to prolonged artificial feeding, from which the wild stock are exempt. No reliable statistics are available concerning the mortality incident to pond culture. When these have been secured we shall have made a beginning toward the solution of this most important problem in fish propagation.

As is true generally with the young of the red salmon, those of the Karluk race disappear on reaching salt water and roam the seas without detection until, after having spent varying periods in the ocean, they seek the river once more at spawning time. As will appear below, they mature at various ages ranging from 3 to 8 years, spawn but the once, and then perish. The list of the various age groups follows, considered in connection with the classes of fingerlings from which they develop.

These classes are five in number, as has appeared from the above sketch of their history, and are based on age at time of migration. They will be numbered from 1 to 5, the No. 1 group comprising the migrant fry in their first year, and the groups numbered from 2 to 5 representing those that migrated in their second third, fourth, and fifth years, respectively. This division will reappear in our analysis of adult runs and will form the basis of primary groups founded on length of residence in fresh water before migrating to sea. The secondary divisions are based on the number of years spent in the sea before maturing, and this varies in each primary group. Thus, the members of group 1, both males and females, mature and return to the river either in their third year of sea feeding or in their fourth. As they entered the sea during their first year after hatching, they are in their third or their fourth year at time of maturing. We designate these two age groups by the symbols 3_1 and 4_1, the first figure in each case representing the age at maturity, and the second the year of its life in which it migrated from fresh water.

The members of group 2 likewise mature in their second, third, or fourth year in the sea, and are therefore in their third, fourth, or fifth year of age at maturity. They are here designated as the 3_2, 4_2, and the 5_2 age groups (figs. 31 and 32).

Group 3 comprises the great majority of the youthful migrants, and furnishes the largest age groups among the adult fish. A rare individual of this group, always a male fish, is known to mature during its first season at sea while still in its third year, having spent but a few months on the sea feeding grounds. These diminutive "grilse" range from 30 to 40 centimeters long; and as they readily pass through the meshes of the seine used in the capture of the commercially valuable part of the run, they easily escape notice. (See fig. 25.) A larger size of grilse, belonging to group 3, is one year older than those above mentioned and returns in its second season in the sea as 4-year fish. These are still largely, but not exclusively, males, and are undersized fish of little value. The members of group 3 do not attain their full size and become commercially valuable until their third year in the sea, when they are in their fifth year. (Fig. 28.) The great majority of them always mature at this age, and they constitute always the great bulk of the commercially valuable run. A

smaller proportion remains at sea for one additional year, returning in their sixth year. (Fig. 30.) Group 3 gives rise, therefore, to four age groups, which we will designate as the 3_3, 4_3, 5_3, and 6_3 groups, the first figure in each designation giving the age at maturity and the second figure the number of years' residence in fresh water.

Group 4 is the second in point of abundance among the migrating fingerlings and furnishes correspondingly abundant classes in the mature run. Here, again, as in Group 3, a certain small proportion matures precociously and the fish are undersized and of little or no value, to which the name grilse is applied. Two age groups are present among these grilse, corresponding to the two described above in Group 3. The first of these matures during the first season in the sea and the members of it are exclusively male fish under 40 centimeters in length and wholly valueless, although in the fourth year of their age. (Fig. 26.) The second group is one year older, as the fish mature during their second season in the sea, when in their fifth year. In this group, also, the males greatly outnumber the females, but in less degree than in the corresponding class of grilse in Group 3. The most valuable contribution that Group 4 makes to the mature run is the fish that return in their third year of sea life, at the age of 6. (Fig. 29.) Although much less numerous than the 5_3's, they form a material part of the commercial run. Relatively few members of Group 4 remain at sea an additional year and return as 7-year fish, and we have encountered but one individual captured in the fifth year of sea feeding at the age of 8. Group 4 gives rise to five age groups, which we designate as the 4_4, 5_4, 6_4, 7_4, and 8_4 groups. Only the 6_4's have any considerable value.

Group 5 is the least numerous of all and is encountered only rarely among fingerling migrants or in the adult runs. Their greater age on reaching the sea seems to predetermine them to earlier maturing after a shorter period of sea feeding. A few diminutive male grilse that return after a few months in the ocean have come to our attention. (Fig. 27.) These were exclusively males, as in the corresponding classes of grilse in Groups 3 and 4. We have also encountered a few others (also males) that matured in their second sea year at the age of 6, and a small number of full-sized fish in their third sea year, at the age of 7. The 12 individuals of the 7-year group comprised 3 males and 9 females. If further experience with this group shall demonstrate an equally high percentage of females, this will furnish an interesting commentary on the high percentage of the males in Group 5 that mature precociously. This group gives rise to but three age groups, which we here designate the 5_5, 6_5, and 7_5 groups, all of which are without commercial importance.

From the above sketch it is apparent that while the length of the period that the young spend in fresh water has a certain influence on the age at which maturity is attained, the most important factor governing growth is the length of time spent in the sea. Full-sized adults, with females as numerously represented as the males, are produced in the Karluk race not before the third year of sea feeding, whatever the age or size of the fingerlings at the time of the seaward migration. Many individuals mature and return to spawn and die having had less than three seasons in the sea, but these are always markedly undersized, conspicuously deficient in color of flesh and amount of oil, and they develop in minor degree the secondary sexual characters that mark the species. They are largely male fish and are known as grilse.

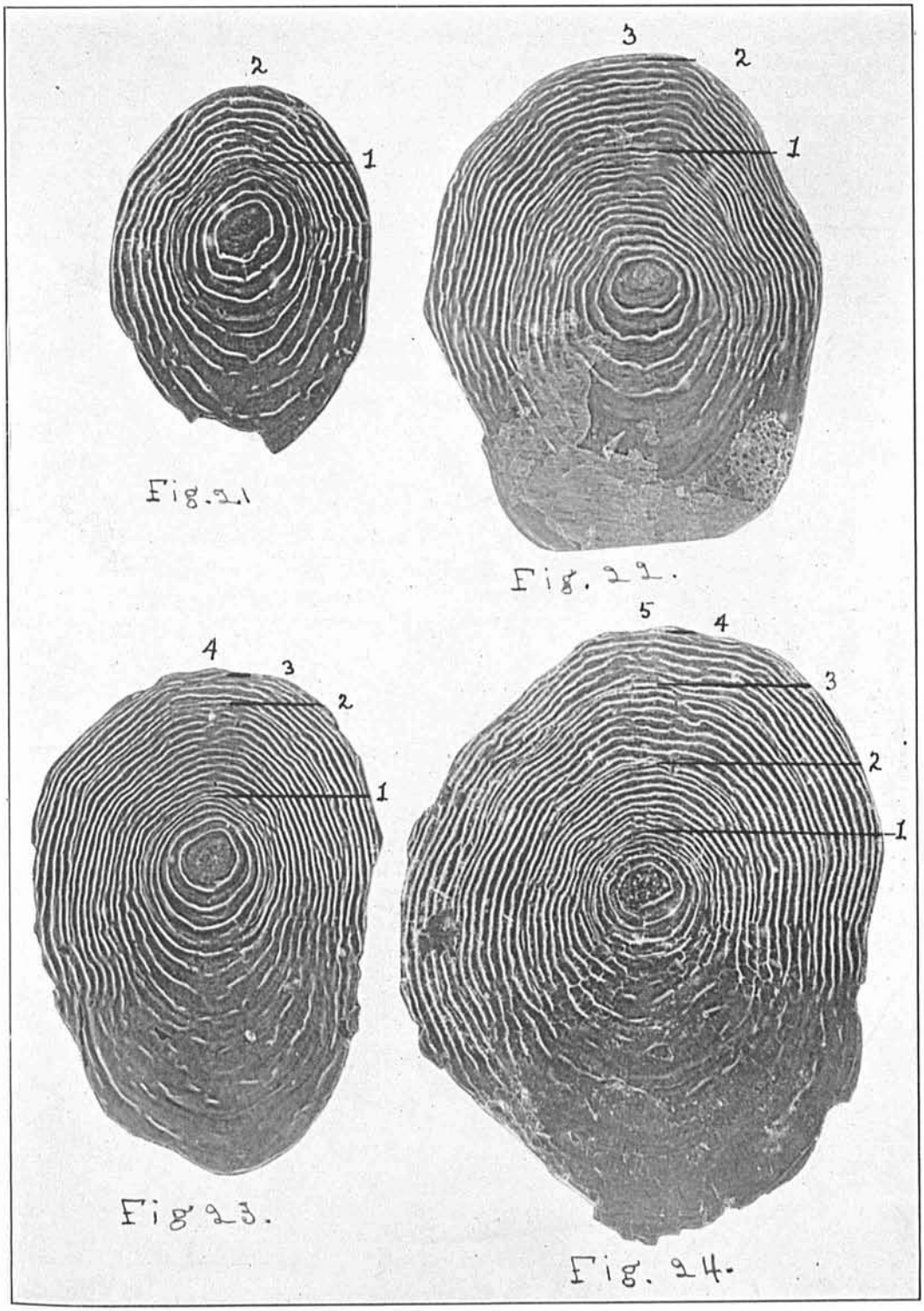
The effect of age on such precocious maturing is shown by the fact that none of the individuals that belong to the two youngest groups of seaward migrants—those in their first and those in their second years—mature thus precociously, and they do not appear in the run until their third year in the sea. It is demonstrated further by the fact that the 3-year migrants rarely mature during their first sea year. For although the 3-year migrants greatly outnumber those that seek the sea in their fourth year, the latter group produces over 90 per cent of the No. 1 grilse. It would seem that in this case age alone must be the determining factor, for although the 4-year migrants average a little larger than do those in their third year, the amount of overlap is so great as virtually to eliminate size as a factor of any considerable importance.

The two factors that by their interaction seem largely to control the phenomena of early maturing in the sea life of the fish are age and sex. The effect of the two working concurrently is shown in illuminating fashion in the history of the No. 2 grilse, which mature during their second year in the sea. Descending the river as fingerlings the previous year, they had spent the summer and winter, and more or less of the second season, feeding vigorously in the sea. A few of them appear in the early portion of the run with the first fish to enter in May, and there are some stragglers that accompany the run into late June or early July. Then comes an interval of several weeks in which no grilse appear, to be followed late in the season by a period in which they occur in much greater numbers than at any previous time. In certain seasons they constitute, numerically, a very considerable proportion (as much as 30 per cent) of the fish that form the latter part of the run. They are still obviously undersized fish, and although the larger individuals overlap in size the smallest of the next older group, the greater part of them are easily segregated by their small size and general appearance.

Two separate year classes are represented among these No. 2 grilse—those in their fourth and those in their fifth year. They were fellow migrants from lake to sea during the same spring, when one class was in its third year and the other in its fourth. They have spent the same length of time in the sea, where their principal growth has been made, and they differ but little in average size. The reaction of these two classes to the influences that cause early maturity is most instructive. In both classes the early part of the run, during spring and early summer, is composed exclusively of male fish. In the latter part of August and in September mature females appear in both classes, but in widely different proportions, the 5-year class containing a much larger relative number of females than does the 4-year group. This becomes obvious in the following table, which gives separately for 1924, 1925, and 1926 the numbers of the sexes in No. 2 grilse taken by random sampling early in September.

TABLE 4.—*Sex distribution in grilse*

Year	Four-year grilse			Five-year grilse		
	Males	Females	Per cent females	Males	Females	Per cent females
1924	325	43	12	229	174	43
1925	190	35	16	90	56	38
1926	41	7	15	92	38	29



SEAWARD MIGRANT RED-SALMON FINGERLINGS, 1926

FIG. 21.—Female in second year, 94 millimeters long, June, 10, 1926
FIG. 22.—Male in third year, 144 millimeters long, May 30, 1926
FIG. 23.—Male in fourth year, 145 millimeters long, May 30, 1926
FIG. 24.—Male in fifth year, 175 millimeters long, June 10, 1926

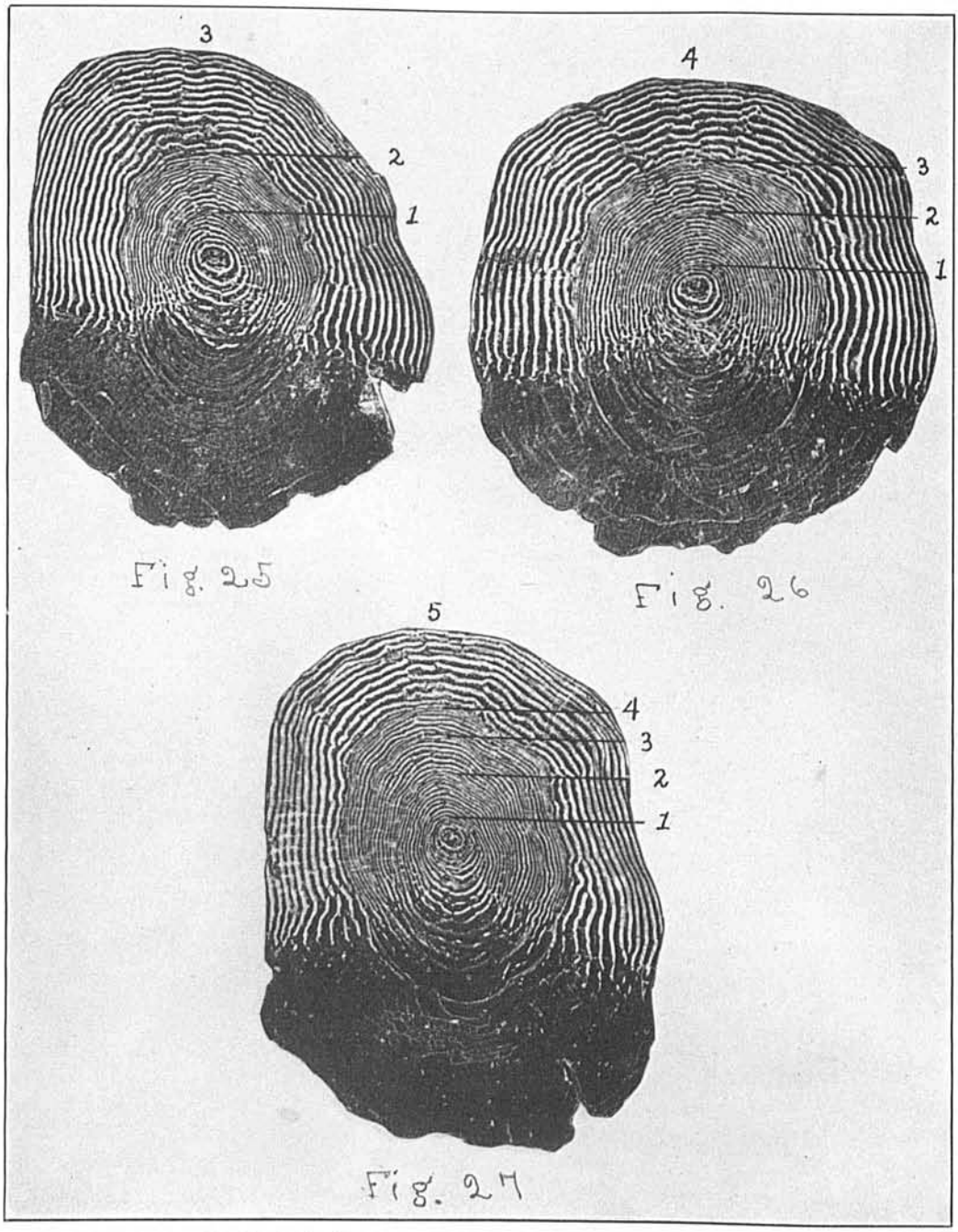


FIG. 25.—Male of 3_3 age group, 33 centimeters long, September 12, 1924
FIG. 26.—Male of 4_4 age group, 34 centimeters long, September 9, 1924
FIG. 27.—Male of 5_5 age group, 33 centimeters long, September 9, 1924

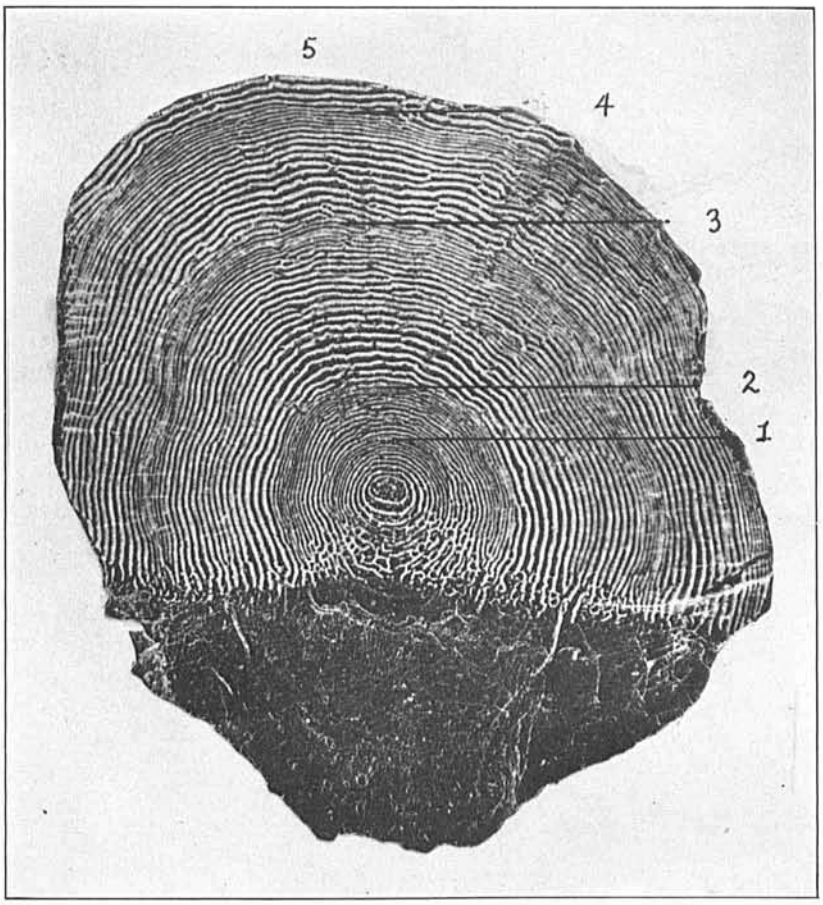


FIG. 28.—Male of 5_3 age group, 61 centimeters long, June 9, 1924

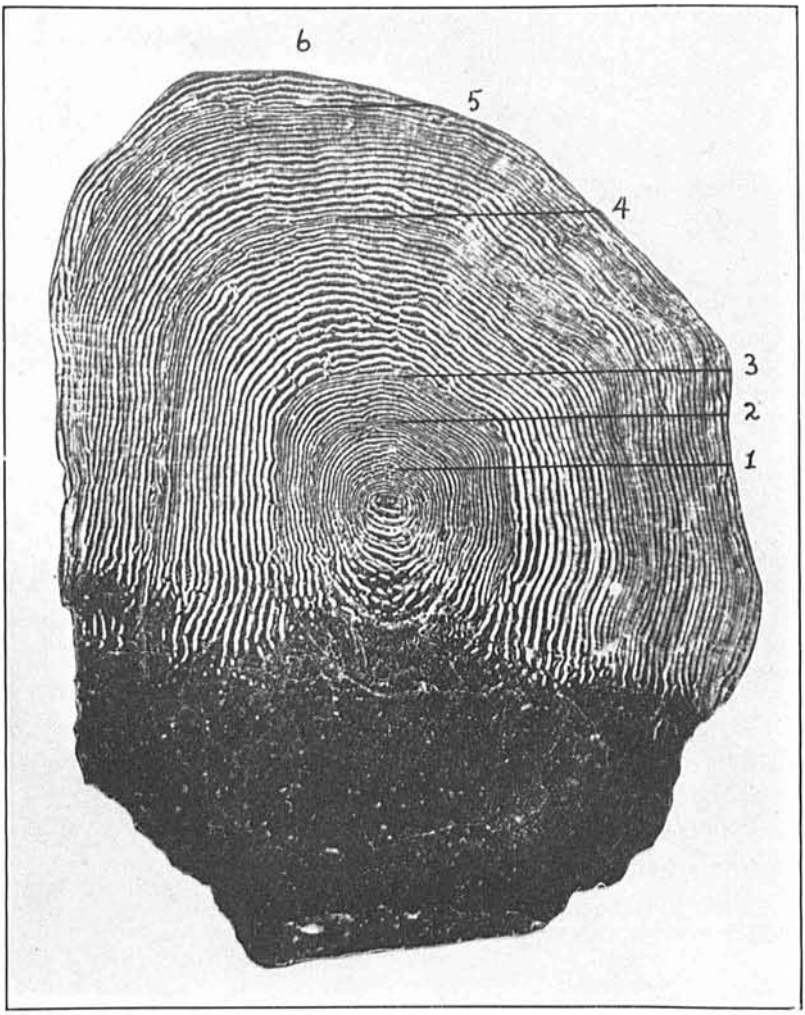


Fig. 29.—Female of 6_4 age group, 55 centimeters long, June 9, 1924

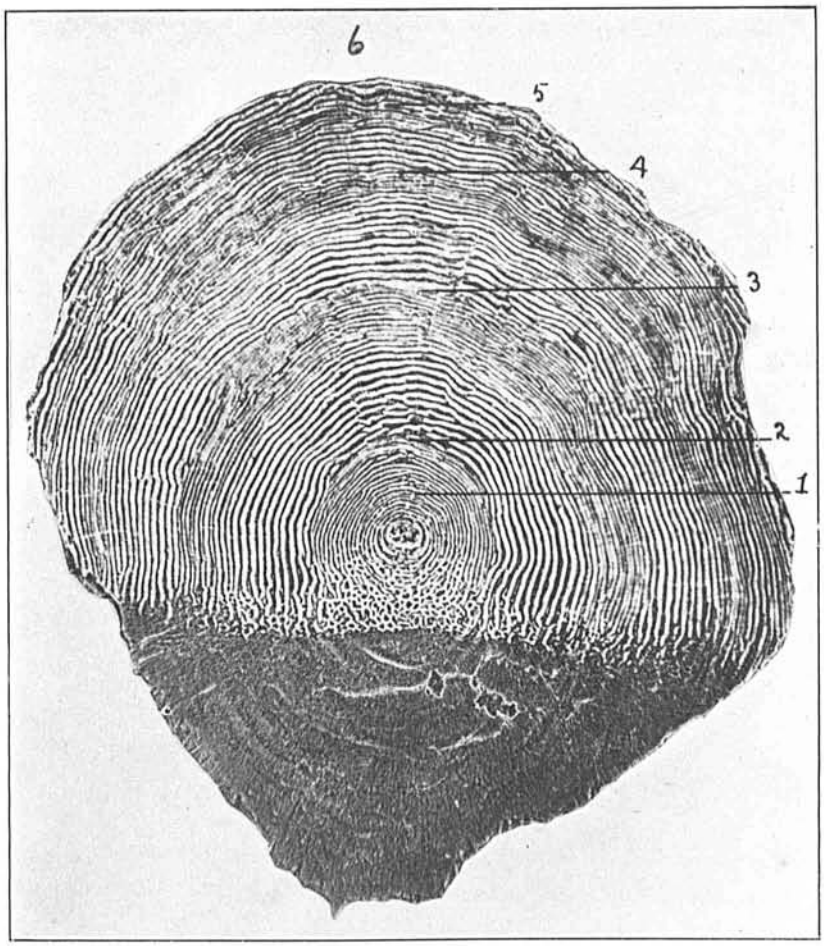


FIG. 30.—Male of 6_3 age group, 68 centimeters long, June 9, 1924

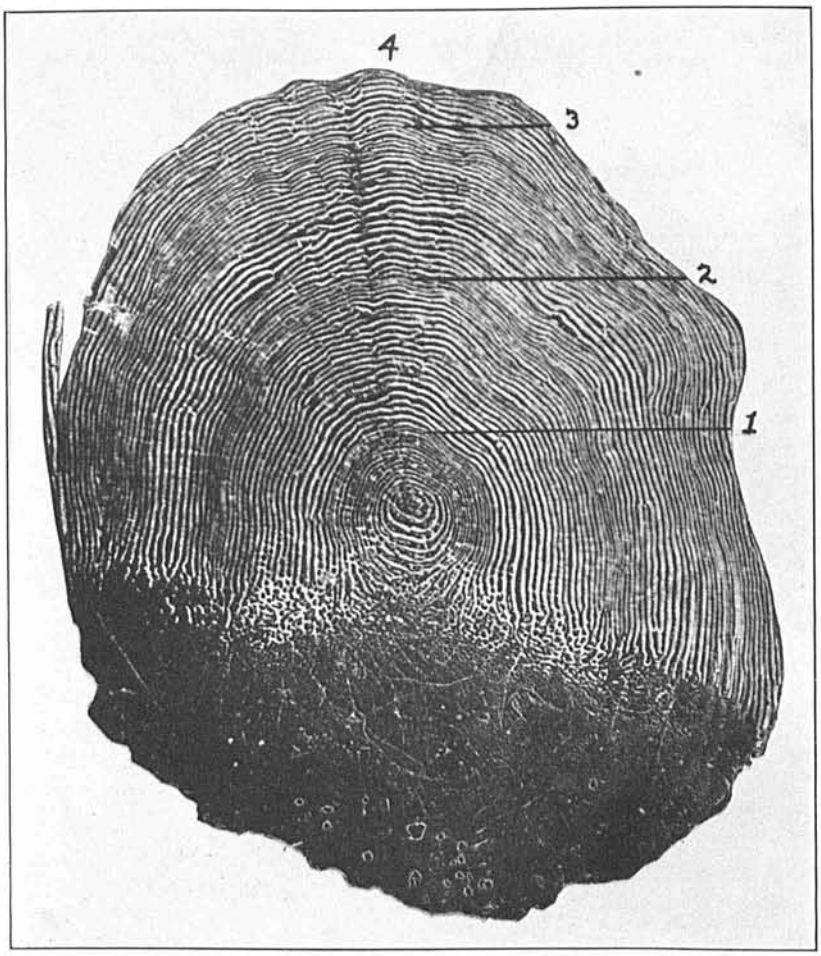


FIG. 31.—Female of 4_2 age group, 57 centimeters long, June 25, 1924

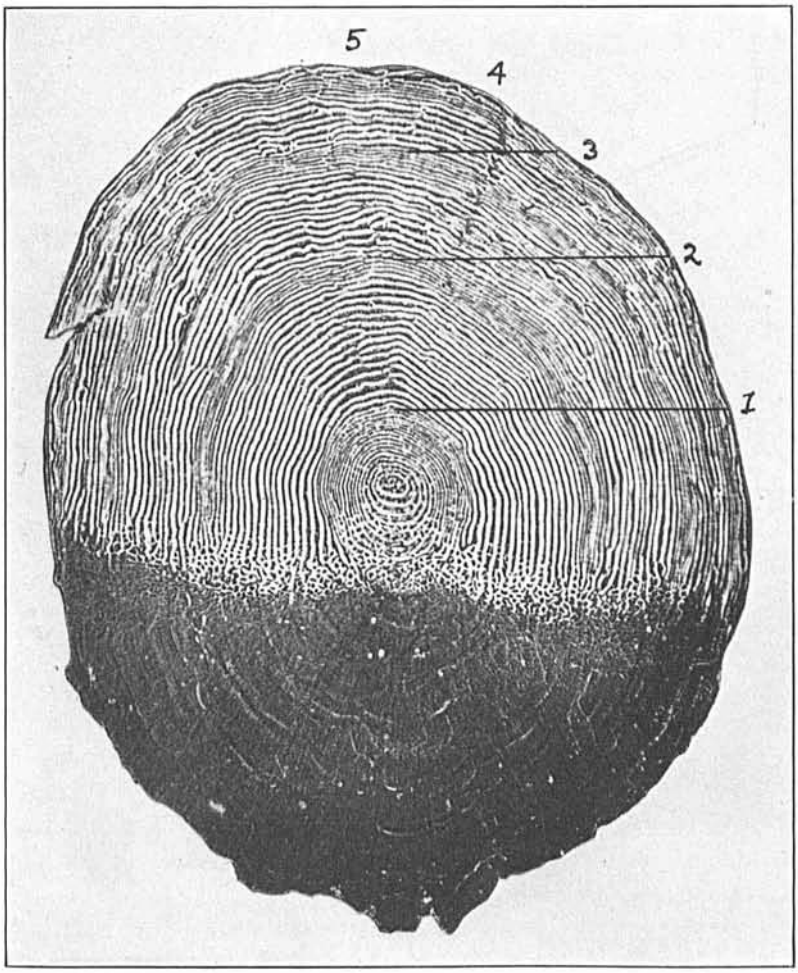


Fig. 32.—Female of 5_2 age group, 57 centimeters long, June 16, 1924

As we have previously stated, the Karluk grilse have little commercial value. Their flesh is conspicuously deficient in color and oil and their size is so small they can not be handled economically. As they are so largely males, they could have biological significance, it would seem, only in case there were a marked deficiency of males among the older fish that make up the main body of the run. A deficiency of males does exist, in fact, and this appears to be a constant feature of the Karluk race. Excluding from consideration the grilse, our random sampling of adults throughout the season of 1924 (4,776 individuals) gave 46 per cent males and 54 per cent females. In 1925, with 5,214 individuals, there were 44 per cent males and 56 per cent females. In 1926, with 8,114 individuals, there were 43 per cent males and 57 per cent females. This is an unusual condition among red-salmon races and appears the more remarkable from the fact that, aside from the grilse, every important year class shows a deficiency of males. Whether in natural spawning, with a deficiency of males, a single male will serve more than one female is a question to which we have no answer as yet. If they will not do so, the unusual development of grilse in the Karluk race may have a useful purpose.

To recapitulate: No. 1 grilse spend a single summer in sea feeding, are exclusively males, and become mature near the close of the same season in which they migrate seaward from the lake. They are drawn almost exclusively from migrating fingerlings in their fourth and fifth years. The much larger group of 3-year fingerlings contributes very few individuals that mature during their first summer in the sea.

No. 2 grilse mature during their second summer in the sea and in greatest numbers toward the close of the summer, when females appear in limited numbers with the greatly preponderating males.

The great majority of the Karluk red salmon, those that constitute the backbone of the run, mature during their third summer in the sea, when they are in their fifth or sixth year. Of these two, the 5-year class is by far the most important, for it develops from the 3-year fingerlings, which constitute the great majority of the downstream migrants. The 4-year fingerlings also develop principally during their third summer at sea and form the sixth year class above mentioned. It constitutes the second most important group in the run. In 1926, the 5-year class here considered comprised about 80 per cent of the run and the 6-year class about 10 per cent.

We can state, therefore, that despite the very wide diversity in life history found among the Karluk red salmon, there is one prevailing mode to which the majority conform. These migrate seaward as fingerlings in their third year and mature in their fifth year, during their third summer at sea. In case the fingerlings have lingered one year longer in fresh water, they still largely conform to the racial habit of maturing in their third sea summer and are then in their sixth year.

ANALYSES OF RECENT RUNS

As previously stated, the primary object of our investigation is to ascertain the natural yield from a spawning colony of known size—to determine the ratio between the number of parents spawning in any given year and the number of the resulting progeny, when the latter shall return at maturity. Will a single pair of spawners produce, on the average, 1 pair of mature salmon, or 2 pairs, or 5 pairs, or 10 pairs?

The secondary object is to conduct these investigations over a sufficient period of time that we may determine to what extent results will vary in different years, due to natural influences, favorable or unfavorable, which shift in effectiveness from year to year. This will constitute a quantitative study of fluctuations in abundance due to natural causes.

The varying productivity from year to year in a given salmon fishery is due to the interaction of the two factors that we here propose as objects of our investigation. An unusually small run of salmon in any river in a given year may be due to insufficient spawning in the corresponding year of the preceding cycle, or it may be due to unusually unfavorable conditions that have increased mortality among the members of the brood beyond the ordinary, or it may be due to a combination of the two factors. We have at present no means of making a direct study of fluctuations in abundance due to natural causes. Many of these are unknown to us, and with regard to the rest their effect can in no instance be quantitatively determined; but when we shall have eliminated from our problem variations in yield due to differing intensities of spawning, as we hope to do in the prosecution of these investigations, all fluctuations that can not be accounted for by this primary cause must be referred to the total effect of shifting natural conditions. The relative importance of the two can then be determined, and we can ascertain how high a degree of correlation exists between the intensity of spawning and the productivity of the fishery. If normally a high degree of correlation exists, the problem of an effective administration of the salmon fisheries will be greatly simplified. To produce consistently large runs, it will be necessary only to provide spawning reserves of sufficient size, which it will be within our ability to determine. If, on the other hand, it shall prove that fluctuations due to causes beyond our control are of preponderating influence and largely mask the effects of variable spawning, a successful administration of the fisheries will be rendered more difficult and uncertain. A larger safety factor would then be called for. Larger spawning reserves would have to be provided in order that their more numerous progeny can neutralize in some measure the disastrous effects of unfavorable years. It is not necessary to point out that predictions of the size of future runs, based on the size of spawning colonies year by year, will have value in such degree only as we establish correlation between numbers of spawning fish and the number of their progeny that attain maturity and enter the runs. Such predictions will be unreliable in such degree as fluctuations due to natural causes interfere with the expected results.

Our primary line of investigation calls first for an accurate determination each year of the total returns of red salmon to the Karluk River and the division of these between commercial catch and spawning escapement. The commercial catch is obtained directly from the companies that operate in the Karluk district, and the spawning escapement is obtained at a counting weir operated by the Bureau of Fisheries near the mouth of the river. Returns from these two sources are now available for each year from 1921 to 1926, inclusive.

Having, then, the complete census of each annual run, as well as the number of salmon that each year comprise the spawning reserve, it remains only to recognize and enumerate the progeny of the various spawnings as they return at maturity, in order to establish the ratio of increase for which we are seeking. This could be

done easily if all the progeny of a given spawning matured at the same age and thus constituted the run of a given year; but, as we have seen, maturity in the Karluk race is attained at any age from 3 to 8 years. The returns from the 1921 spawning, for instance, are distributed throughout the runs from 1924 to 1929, and those of 1922 from 1925 to 1930. If our aim is to be accomplished, each year's run must be analyzed into its various age components, and each of these must be determined quantitatively. By this method we can be prepared to add together the 3-year fish of 1924, the 4-year contingent of 1925, the 5-year quota of 1926, the 6-year group of 1927, the 7-year group of 1928, and the rare 8-year individuals of 1929, and obtain a total that will represent the complete returns of the 1921 spawning; and so on, by the same method, for each succeeding year.

This analysis of the runs is conducted by the customary method of random sampling. A certain number of individuals are taken at random, without selection, to form what is considered an adequate sample of the commercial catch on a given day. The sample must be large enough to furnish reliable data concerning the constitution of the run on the day on which it is taken, and successive samples must be obtained at close enough intervals to present a record of such changes in the constitution of the run as may develop from time to time throughout the season. Believing it wiser to err on the safe side of unnecessarily extensive sampling, rather than the reverse, we are attempting in each sample to secure data from 100 or more individuals taken by the random method. With regard to each individual, we obtain length, weight, sex, and a specimen of scales for the determination of age. The results have been such as to assure us of the adequacy of our method and the sufficiency of our sampling to present a reliable cross section of the entire run.

Although no returns from the 1921 spawning—the first for which we had numerical data—could be looked for until 1924, we undertook an analysis of the run of 1922, to survey the field and secure a background for the determinations of future years. The characteristics of the Karluk race were not wholly unknown to us at that time, for as a part of our general investigation of red-salmon races we had previously examined limited samples of the runs of 1916, 1917, 1919, and 1921. For each of these years, except, perhaps, 1917, the samples were too small to permit generalizations as to the characteristics of the entire run, being confined to one or two days of the season only. We have material gathered on seven different days in July and August in 1917. We include returns from each of these years for such value as they may have for purposes of comparison.

Having established our base line in 1922, our series of complete consecutive analyses begins in 1924 and should continue without interruption as long as the investigation is in progress. The results obtained are not to be confined to the segregation and enumeration of age groups, although this is our prime object. Many other important facts in the life history of the Karluk salmon will emerge, it is hoped, from the data obtained. These should include, among others, unexplored phenomena in the growth of the salmon and in the quantitative relations of the various age groups that develop in the broods of successive years. The latter is a most important subject, from the practical standpoint, and is one concerning which no information has been obtainable hitherto. In the line of our present experiment, we shall ascertain the numbers of each age group that develop from the eggs of a given brood and,

accordingly, the proportions in which each age group is present among the progeny of a certain spawning. By comparison of similar figures from successive spawnings, we shall be prepared to develop the amount of variation that is found in this relation. If, for instance, among the progeny of the 1921 spawning we find that the 6-year age group comprises 20 per cent of the whole, how will this compare with the 6-year group that develops from the 1922 spawning, and this with the results of successive years? Will they also be present in approximately 20 per cent of the whole, or will the relation be a widely varying one in successive broods? If in the relative numbers of each age group a fair degree of uniformity is found to develop from different lots of eggs, the number of individuals found in the younger age groups of any brood, which are the first to make their appearance in the runs, will serve as a reliable basis for prophecy concerning the size of successive age groups that develop from this same lot of eggs. From the size of these early samples of the brood we should be able to compute with a fair approach to accuracy the sum total of all the progeny of this spawning and would find ourselves in possession of that great desideratum—a reliable basis for prophecy concerning the size of future runs. If, however, the relative number in various broods that develop at the same age is highly variable, the size of the younger age groups, as they successively appear, would present but indifferent evidence concerning the size of the older age groups, some of which may well constitute the dominant group or groups in future runs. If such wide variation exists, we can only seek for causative factors and may succeed in correlating a tendency in a certain brood toward early or late maturing with a certain set of external conditions.

For convenience of reference in connection with the following discussion of dominant and other age groups and the brood years to which they are referred, we present below the records of Karluk red-salmon packs, in even thousands of cases (48 one-pound cans to the case), from 1910 to 1920. We have no evidence concerning the size of the spawning escapements for these years.

We present below our analyses of the runs of the various years for which we have data, taking them in chronological order.

	Cases		Cases
1910	107, 000	1916	167, 000
1911	124, 000	1917	166, 000
1912	89, 000	1918	78, 000
1913	62, 000	1919	78, 000
1914	39, 000	1920	98, 000
1915	59, 000		

RUNS OF 1916 AND 1917

For a period of four years immediately preceding 1916 the Karluk pack of red salmon had been very poor, ranging from 39,000 cases in 1914 to 89,000 cases in 1912. In 1916 and 1917, however, the pack suddenly increased to over 165,000 cases in each of those years. It becomes of interest to ascertain the prevailing age of the 1916 and 1917 fish and to discover which brood years had been mainly responsible for the sudden increase in the runs of those two years.

Our samples of the 1916 fish are but two in number—one of 116 fish taken on July 19, the other of 266 fish obtained August 24. An analysis of these is given in

Table 5, from which it appears that the predominating age group is the 5_3's—fish that migrated seaward as fingerlings in their third year and matured and entered the run in their fifth year. Eighty-five per cent of our material belongs to this group and must therefore have developed from eggs laid down in 1911, when the Karluk red-salmon pack amounted to 124,000 cases. The only other age groups represented in significant numbers are the 6_3's and 6_4's, and as both of these matured in their sixth year, they developed from the brood year 1910. Together, they comprise 13 per cent of the samples obtained, a not unusual proportion of 6-year fish in runs of other years. The pack of red salmon in 1910 amounted to 107,000 cases, and while the 6-year progeny of that year appear in normal numbers in the run of 1916, the 5-year group, which probably was largely responsible for the run of 1915, was very limited, if we judge from the 1915 pack, which was of only 59,000 cases.

TABLE 5.—*Random samples of the Karluk red-salmon run of 1916, distributed by age groups, sex, and length*

[M=male; F=female]

Length in inches	Age group and sex											Total
	4_2	4_3		5_3		5_4		6_3		6_4		
	F	M	F	M	F	M	F	M	F	M	F	
18												
18½			1				1					
19												
19½		1										
20	1											
20½												
21					4							
21½				1	5	1	1					
22					19							
22½				1	27						3	
23				7	41	1		1	1		10	
23½				8	39					2	3	
24				20	45				1	5	4	
24½				19	14					3	2	
25				29	6			1	1	6		
25½				25	1			1	3	1		
26				9					1			
26½				4				1				
27				1								
Total	1	1	1	124	201	2	2	4	7	17	22	382

The 1917 run is represented in our material by the following samples:

	Individuals
July 10	249
Aug. 18	100
Aug. 23	99
Aug. 25	210
Aug. 26	100
Total	758

As indicated in Table 6, the proportions of the principal age groups in 1917 are very similar to those obtaining in our samples for 1916. The 5_3 group is again dominant and comprises 88 per cent of the whole, while the two 6-year groups (6_3 and 6_4) together amount to 10.4 per cent. An unusually large proportion of the 1917 run is thus seen to be derived from the spawning of 1912, a year in which the commercial take was rather poor (89,000 cases). Whether the spawning escapement

of that year was disproportionately heavy, as compared with the commercial catch, or whether the natural conditions were unusually favorable for the 1912 brood, with the mortality factor greatly reduced, is a question concerning which we have no information for this year. Whether such lack of correlation as frequently exists between commerical catches of the corresponding years of successive cycles is due to discrepancies between the commercial catches and the spawning escapements, or to the disturbing influence of the variable natural factors (aside from spawning intensity) that control abundance, is the principal problem we hope to solve by means of the present series of experiments.

TABLE 6.—*Random samples of the Karluk red-salmon run of 1917, distributed by age groups, sex, and length*

[M=male; F=female]

Length, in inches	Age groups and sex																	Total
	3_1		3_2	4_1		4_2		5_2		5_3		5_4	6_3		6_4		7_4	
	M	F	M	M	F	M	F	M	F	M	F	M	M	F	M	F	M	
16			1															
19												1						
19½																		
20																		
20½											1							
21											2							
21½										2	2					1		
22										3	9	1				1		
22½										3	11					2		
23	1	1		1			1		1	17	38		1	1		4		
23½					1					16	51			1		3		
24						1			1	26	69			7	3	7		
24½								1	1	32	64			4	3	6		
25				1						58	63			6	4	6		
25½								1		54	15		5	2	12	4		
26								1		57	4		3	4	10	1		
26½										21			2		3			
27										8			2		2		1	
27½								1		2			2					
Total	1	1	1	2	1	1	1	4	3	299	329	2	15	25	37	35	1	758

RUNS OF 1919 AND 1921

For the year 1919 we have but a single sample, obtained on July 26 and consisting of 103 individuals. This doubtless gives reliable indication of the constitution of the run on that date but takes no account of the changing elements of the run as these appear during the course of the season. In Table 7 we enumerate the individuals in our sample and refer them to their appropriate age groups, sex, and length groupings. From this it appears that the 5_3 group continues to be dominant, constituting 81 per cent of the sample, but represents a somewhat smaller proportion of the run than in any other year we have considered. The pack of red salmon in 1919 was small, amounting to only 78,000 cases, and it is of interest to ascertain that the principal element present in the run was derived from the year 1914, which furnished the smallest pack known in the history of the river (39,000 cases).

TABLE 7.—*Random samples of the Karluk red-salmon run of 1919, distributed by age groups, sex, and length*

Length, in inches	Age groups and sex										Total
	4_2	4_3	5_2		5_3		6_3		6_4		
	M	M	M	F	M	F	M	F	M	F	
21	1										
21½						1					
22		1				3					
22½		1				2					
23						10					
23½						7				3	
24					2	11				1	
24½					2	8		2			
25					6	2		3			
25½					7	2		1	1		
26				1	7			1	1		
26½					5						
27					1		1				
27½					1						
28											
28½			1								
Total	1	2	1	1	38	46	1	7	2	4	103

The run of 1921 was more generous than those that immediately preceded it, being responsible for a pack of 119,000 cases, or approximately 1,670,000 fish. For the first time in that year we are in a position to state the size of the spawning escapement, which closely approximated the number of fish that entered the commercial catch. The total run to the river in that year, then, amounted to somewhat more than 3,000,000 salmon. Our samples are again very limited, consisting of two lots, the first taken on August 7, consisting of 106 individuals, and the second obtained August 16, with 105 specimens. In Table 8 we group these according to age, sex, length, and the length of residence in fresh water. Not only are the 5_3's again dominant, but they are present in larger proportion than in any other run thus far reported. Eighty-eight per cent of the samples are of this group and are derived from the brood year 1916, which was signalized by a pack of over 167,000 cases. No 4-year fish were present in our samples, although the year from which they would have been derived (1917) produced a pack almost as large as that of 1916. It is to be noted, however, that 1917 gave no indication, in any subsequent year, of having been a successful brood year. There can be no reasonable doubt that the great majority of its progeny would return to the river in 1922 as 5-year fish, but the pack of that year was only 46,000 cases.

TABLE 8.—*Random samples of the Karluk red-salmon run of 1921, distributed by age groups, sex, and length*

[M=male; F=female]

Length, in inches	Age groups and sex									Total
	5₂		5₃		6₂		6₄		7₄	
	M	F	M	F	M	F	M	F	F	
21				1						
21½			1							
22				5						
22½				6						
23			2	25				1		
23½			5	19		1	1	2		
24			8	20		2	2	1		
24½			9	14	1			1		
25	1	1	12	9	2	1	1		1	
25½			15	3	1					
26			17	2	3					
26½			2				1			
27			8				1			
27½			2							
28			1							
Total	1	1	82	104	7	4	6	5	1	211

KARLUK RED-SALMON RUN OF 1922

During the season of 1922 for the first time a fairly satisfactory series of samplings was attempted, although these were smaller and less frequent than in subsequent years. Two samplings per week were planned, of 75 individuals each, the first taken June 5 and the last September 18. There were 33 samples in all, evenly distributed, 3 or 4 days apart, between the above-mentioned dates. The tota number of individuals examined and included in this report is 2,469.

The year 1922 offers one of the conspicuous failures in correlation between the packs of a brood year and the year in which the progeny of the brood year largely return. As we have already seen, the Karluk red salmon mature principally at the age of 5 years, and the race has established, therefore, a well-marked 5-year cycle. The only other age that participates to any considerable degree in the run is six, the five and six year fish together constituting usually over 95 per cent of the run. This being the case, the brood years for the 1922 run were 1916 and 1917, in each of which over 165,000 cases of red salmon were packed. Using size of pack as a basis for prediction, it would have seemed highly probable that the year 1922 would produce one of the largest packs of recent years, for it could be expected to include the 5-year fish from 1917 and the 6-year fish from 1916—two outstanding years, each of which had produced a pack larger than that of any of the intervening years between 1916 and 1907. The results in 1922, however, were not at all in accord with such a prophecy, for the red-salmon pack of that year amounted only to 46,000 cases.

The analysis of our samplings of the run, presented in Table 9, shows beyond question that the failure in this instance was caused by the very meager returns from the brood year 1917. Not only was the total pack of 1922 very small, but the proportion of this poor pack produced by the progeny of 1917 was extrordinarily low, consisting of only 63 per cent, whereas in normal years the 5-year fish comprise 80 per cent or more of the total run. If it had not been for the unusually large proportional contribution to the run made by the other brood year (1916), the results would have been even more serious. For, whereas the 6-year fish in normal years make only 10 to 15 per cent of the run, in 1922 these constituted 36 per cent. From

these facts it is apparent that the year 1916 produced a normal brood and contributed its due quota to the run of 1922, while the year 1917, with a pack practically equal to 1916, had been largely a failure. The cause of this failure is again beyond our knowledge. Weather conditions may have favored more than usually intensive fishing, and the commercial catch may have been large at the expense of the spawning escapement. In that case, the pack of 166,000 cases in 1917 may have included the greater part of the run of that year, with the escapement so reduced below a safe minimum that no favorable results were possible. The only other alternative would be a spawning escapement perhaps equally as large as was that of 1916, the disparity in the results of the two years being due to unfavorable natural conditions that decimated the 1917 brood. This question has always recurred in every discussion of brood years and the runs for which they are responsible, and has always been left without answer. Only when we shall deal with years in which the size of spawning escapement is known, can we hope for a solution.

TABLE 9.—*Random samplings of the Karluk red-salmon run of 1922, distributed by age groups, sex, and length*

Length, in centimeters	Age groups and sex																				Total
	4_1	4_2		4_3		4_4	5_2		5_3		5_4		5_5	6_3		6_4		6_5	7_4		
	M	M	F	M	F	M	M	F	M	F	M	F	M	M	F	M	F	M	M	F	
30						1															1
31						1															1
32																					
33						1															1
34													1								1
35																					
36																					
37																					
38																					
39																					
40				1																	1
41											1										1
42																					
43									1												1
44											1										1
45				2							1										3
46				1																	1
47			1							1	1										3
48										4		2									6
49			1						3	8	1										13
50				4					3	7	4					1	2				21
51				1					3	14	1				2	2	1				24
52			1	1					5	22	2	1		2	2	1	1				38
53				1	1				17	31	4			2	7		3	1			67
54			1	1				1	25	48	1			4	13	3	3			1	101
55		1		3				2	35	33	1			6	19	3	3		1		107
56		1		1					30	50	1	1		10	27		5				126
57				1	1		1		37	49	2			4	37	5	2				139
58			3						50	80	1			18	43	6	7				208
59			1						62	105				18	63	2	6				257
60								2	51	82	1			27	68	6	7				244
61									48	89				31	62	9	9				248
62		1	4				1		70	70				32	42	9	4			1	234
63			1				1		72	46				35	24	11	5				195
64	3								72	23				31	10	5					144
65									46	11				37	6	8	1			1	110
66							1		43	5				20	2	4					75
67									28	2				13	1	2					46
68									17					7		1					25
69									9					7		1					17
70									4					5							9
Total	3	3	13	17	2	3	4	5	731	780	23	4	1	309	428	79	59	1	1	3	2,469

The frequency of sampling necessary to give an adequate account of the constitution of the run during the entire season depends, of course, on the degree of uniformity or the lack of uniformity in the run itself from day to day and from week to week. As appears in Table 10, which follows, 12 different age groups were represented in the

run of 1922, three of which (5_3, 6_3, and 6_4) comprised nearly 97 per cent of the run. Had these been present in fairly uniform relative abundance throughout the season, very few samplings would have answered our purpose; but such was by no means the case. The two major groups, especially (5_3 and 6_3), varied widely in this respect, the 5_3 group being present in largest relative numbers during the latter portion of the season, when the 6_3's were least abundant, the two varying fairly uniformly in opposite directions, until in August and September the 6_3's had almost disppeared from the run. In Table 10, we give, for each of the days throughout the season in which samples were taken, the percentage in which each age group was present. The marked trend toward increasing percentages in the 5_3's and diminishing percentages in the 6_3's as the season advances is clearly apparent. A similar phenomenon is also obvious in other age groups. In the next most important group, the 6_4's, there is a less marked but still evident tendency in the same direction as in the 5_3's toward relative increase in the latter part of the season. This is also unmistakable in the groups 4_2, 4_3, 4_4, 5_4, and 5_5, while in 4_1 and 5_2 the reverse again is the case, these two groups agreeing with 6_3 in running predominantly or altogether in the early part of the run. The constitution of the run is therefore a constantly changing one, with certain groups increasing as the season progresses or making their appearance only toward its latter end, while other groups are either confined to the first few weeks or appear in largest relative numbers at that time.

The early running groups (4_1, 5_2, and 6_3), we note with interest, differ widely in age but agree in the length of time they spent in the sea, which is one year in excess of the period spent by the late-running groups above enumerated. A comparison with similar data for subsequent years will be of value.

TABLE 10.—*Percentage of all classes, Karluk run of 1922, in random samplings taken on a series of dates*

Date	4_1	4_2	4_3	4_4	5_2	5_3	5_4	5_5	6_3	6_4	6_5	7_4
June 5	1.5				1.5	31			66			
June 7					1	31			68			
June 10					1	28			68	3		
June 13	1	1			3	42			53			
June 16	1					28	1		69	1		
June 19		1			1	46	1		48	3		
June 22						28	1		66	5		
June 24			4		1	36	1		57	1		
June 27			3		3	33			58	3		
July 1						37			56	7		
July 5		1				38	1		56	4		
July 8						36	5		48	11		
July 12						36			55	9		
July 14						59	1		27	13		
July 17		1	1			66			27	4		1
July 20		1				68			26	4		1
July 24						84	1		11	4		
July 27						72			20	8		
July 31						67			23	8	1	1
Aug. 3						73			19	8		
Aug. 7		1	3			71			15	9		1
Aug. 10			1			81			15	3		
Aug. 14		1				94	1		3	1		
Aug. 17		1				84	1		7	7		
Aug. 21		1				87			7	5		
Aug. 24		1				83	1		3	12		
Aug. 28		1	1			72	3		3	20		
Aug. 31		1				75	4		1	19		
Sept. 4			1	1		86	3		3	4		
Sept. 8			4			89	3		1	3		
Sept. 11		1	1			94	1		1	2		
Sept. 14		1	3	3		87		1	1	4		
Sept. 18		3	3			89	4		1			

Another series of changes that progressively follow the course of the run are the increases in length and weight in both sexes of all the age groups. As an example of the increase in length, we give in Table 11 the average lengths, in centimeters, for males and females of the 5_3 group, separately for each date on which samples were taken, the series being smoothed twice by threes.

It will be apparent from this series that while the upward trend in length is unmistakable for the entire season, it does not progress uniformly. In fact, throughout the month of June the lengths in both males and females decrease fairly uniformly with each succeeding sample, the increase beginning with the sample of July 1 in the males and in the sample of June 27 in the case of females. This increase is of short duration, however, for on July 14, in both males and females, another decrease sets in, which reaches its culmination in both sexes on July 20. A more rapid increase is then registered, which continues without interruption to the close of the season in the case of males, with a slight recession in the mid-September samples in the females.

Other age groups give evidence of similar increase in size during the season, but the number of individuals present in each sample is so small that a reliable series of averages can not be secured.

TABLE 11.—*Karluk red-salmon run, 1922*

[Average lengths, in centimeters, of age group 5_3 on a series of dates]

Date	Males	Females	Date	Males	Females	Date	Males	Females
June 5	58.8	57.0	July 12	58.9	56.8	Aug. 21	63.6	60.7
June 7	58.6	56.9	July 14	58.5	56.0	Aug. 24	63.8	60.7
June 10	58.5	56.5	July 17	57.3	54.6	Aug. 28	63.8	60.7
June 13	58.3	56.2	July 20	56.6	53.5	Aug. 31	63.9	60.8
June 16	57.8	55.9	July 24	57.0	53.7	Sept. 4	64.1	60.9
June 19	57.6	55.5	July 27	58.5	55.2	Sept. 8	64.1	60.9
June 22	57.5	55.4	July 31	60.4	57.3	Sept. 11	64.1	60.8
June 24	57.2	55.3	Aug. 3	61.5	58.7	Sept. 14	64.3	60.5
June 27	56.8	55.4	Aug. 7	62.1	59.4	Sept. 18	64.3	60.3
July 1	57.1	55.5	Aug. 10	62.3	59.8			
July 5	57.7	56.0	Aug. 14	62.7	60.3	Mean	60.3	57.7
July 8	58.7	56.6	Aug. 17	63.2	59.8			

KARLUK RED-SALMON RUN OF 1924

The two years mainly responsible for the run of 1924 were 1918 and 1919, each of which had furnished a small or moderate pack of approximately 78,000 cases. The 5-year and 6-year fish derived from these two brood years were in normal relative numbers, the 5-year fish constituting 79 per cent of the run, the 6-year fish 17 per cent. The remaining 4 per cent were largely 4-year fish of the 4_3 group. These were grilse, largely males, which migrated seaward as fingerlings in the spring of 1923 and matured precociously as undersized fish of little value.

The random sampling of this year was on a larger scale than heretofore, material being obtained whenever possible on each day during the fishing season. The total number of individuals thus obtained was 5,132, and these are distributed by age group, sex, and length in Table 12, which follows. The age groups represented in the run are essentially the same as those that appeared in 1922. A single group, 3_3, lacking in 1922, was represented in our 1924 samplings by a single specimen; while two groups, 5_5 and 6_5, each represented by a single individual in our 1922 material, were not present in 1924. The groups 5_3, 6_3, and 6_4 again exceeded in numbers any of the other groups present, and together constituted 92 per cent of the run.

TABLE 12.—*Random samplings of the Karluk red-salmon run of 1924, distributed by age groups, sex, and length*

Length, in centimeters	Age groups and sex																			Total
	3_3	4_1	4_2		4_3		4_4	5_2		5_3		5_4		6_3		6_4		7_4		
	M	M	M	F	M	F	M	M	F	M	F	M	F	M	F	M	F	M	F	
30	1						2													3
31							2													2
32							8													8
33							1													1
34							5													5
35																				
36																				
37																				
38					2															2
39					5															5
40					4															4
41					3							1								4
42					4							1								5
43					6	1						2								9
44					6															6
45					4							3								7
46					7					1		3								11
47					5					6		2								14
48					7	1				3		2				1				14
49			1		10	1				1		1		1		2				21
50				1	8	2				3			1			1				17
51				1	13	2				7		6	5			1				39
52					14					20		5	6				4			52
53					16					29		12	5							72
54				3	19					54		11	13			2				128
55					12	1				76		13	13		1		7			152
56				1	8			1	1	119		19	7	1			11			204
57			1	1					2	193		18	2		1	6	16			293
58				2					1	236		13	2		7	7	29			366
59			1	2					1	277		6		1	9	13	43		2	438
60				1					1	259		2		5	24	11	54			404
61								1	1	267				6	17	14	57		4	508
62			1							220				11	22	28	51			522
63								1	1	146	2			11	18	39	32			458
64				1				1	2	78				9	11	53	19	2	2	432
65								1		38				18	8	45	12	2		318
66									1	15				10	3	38	5	1	1	246
67								1		1				8		31		2		163
68										1				7		11		1		75
69										1				6		3	1	1		43
70		1								1				1		3				14
71														1		1				5
72								1												2
Total	1	1	4	13	153	8	18	7	11	1,793	2,052	122	54	96	121	309	351	9	9	5,132
Average length	30.0	70.0	56.75	56.5	49.5	49.6	32.3	64.0	60.5	62.7	59.1	54.2	54.1	64.4	61.5	63.7	60.3	66.1	61.8	

In Table 13 we give the percentages of each age group in the series of random samplings throughout the season. The results are very similar to those we obtained in the run of 1922. Certain groups are most abundantly represented in the early part of the run or are entirely confined to it, while other groups are the reverse of this and either grow more numerous in the latter part of the run or else are found in this part only. In our discussion of the run of 1922, we stated that the data we had for that year indicated that the early running groups had spent the longest time in the sea before maturing, while the groups that showed a distinct tendency to mature and enter the run in the latter part of the season were those whose sojourn in the sea had been of shorter duration. We will now pass the different groups of the 1924 run in review to ascertain what degree of correspondence is found in the two years.

The two groups that spent the least time in the sea are the 3_3 and the 4_4 groups. Each of these matured and entered the run during the same season in which it descended to the sea as a fingerling. As shown in Table 13, the few individuals of

these groups that we secured in our random sampling were taken only in the latter part of the summer.

Those next in succession are the 4_3 and the 5_4 groups, which matured during their second season in the sea, remaining one year longer than the 3_3 and the 4_4 groups. In the 4_3 and 5_4 groups an interesting anomaly is found in the presence of two distinct maxima in their runs. As shown in Table 13, a portion of them enter early with the first part of the run, are found each day consistently in our samples, and then, for a period of a month or more, almost wholly disappear, to be followed in August and September with a second run of greater proportions than the first. The early running fish of these two groups agree in being exclusively males, while in the fall a sprinkling of females appear, the majority of which belong to the 5_4 group. We have no explanation to offer for this peculiar feature of their run. In Table 10, for the year 1922, the same bimodal tendency is shown in these two groups; less marked than in 1924, because the representatives of the groups in 1922 were comparatively few in number.

TABLE 13.—*Karluk red-salmon run of 1924. Percentages of each age group in random samplings throughout season*

Date	3_3	4_1	4_2	4_3	4_4	5_2	5_3	5_4	6_3	6_4	7_4
June 9 and 10				5		1	72		18	2	2
June 11 and 12			1	2		1	83	1	8	3	1
June 13 and 14				1		1	81		10	7	
June 16 and 17			1	2		2	78	1	10	6	
June 18 and 19			1	2			84	1	4	8	
June 20 and 21				2		1	82	2	4	8	1
June 23				1			86	1	4	7	1
June 25 and 26			1	2			80	1	10	5	1
June 27				4		1	84		6	5	
June 30 to July 1				4		1	80	1	6	8	
July 3				6		1	72	2	7	11	1
July 6			1	2		1	72	2	7	15	
July 7						3	72		11	13	1
July 8 and 9		1				1	81		2	15	
July 10 and 11						1	76		4	19	
July 12 and 14			2			1	72		8	17	
July 15 and 16							73		3	22	2
July 19 and 20							69		4	24	3
July 22 and 23			2	1			66		8	23	
July 24 and 25							80		4	15	1
July 26 and 28							79	1	2	18	
July 29 and 30							75		5	20	
July 31 and Aug. 1			1	1			81		2	14	1
Aug. 2 and 4				2			72		5	21	
Aug. 5 and 6				3			75		2	20	
Aug. 7 and 8						1	61	1	2	35	
Aug. 9 and 16				1			81		1	17	
Aug. 18 and 19				4			79	3		14	
Aug. 20 and 21			1	5			69	7		18	
Aug. 22 and 23				3			79	5		13	
Aug. 25 and 26				3			81	1		15	
Aug. 27 and 28				2	1		76	2	2	17	
Aug. 30 and Sept. 1	1			4	2		73	6		14	
Sept. 2 and 4				15			64	23		9	
Sept. 6 and 8				3			73	9		15	
Sept. 9 and 10				9	8		61	12		10	
Sept. 11 and 12				7			71	13		9	
Sept. 13 and 15				8	2		59	18	1	12	
Sept. 16 and 18				10	3		68	8	1	10	

The next series, selected on the basis of length of residence in the sea, are the 4_2, 5_3, and 6_4 groups. In each of these maturity was reached in their third season in the sea. In a measure they seem to present a transition between the early-running and late-running series. In 1922 the 4_2 group appeared to belong with the latter, as the majority of the individuals occurred in the samples taken in August and September; but in the 1924 run no such tendency is shown, as virtually all the samples ob-

tained were taken in June and July. This group is sparsely represented in the run at all times, and an examination of its participation in future runs will be necessary to decide whether it shows any distinct tendency to appear in one part of the run rather than in another. At first sight, a discrepancy seems to exist also with the 5_3 group, as between 1922 and 1924; for in 1922 the relative numbers of this group entering the daily run were lowest early in the season and increased with fair regularity until August and September. Nothing of this appears in the run of 1924. On the contrary the list of percentages shows a slight but unmistakable decrease throughout the season, the change being of such small magnitude as to suggest a balanced run in the 5_3 group, the decreasing percentages being occasioned by the increase in the 6_4 group, which is marked and fairly uniform throughout the season. In 1922 the 6_4 group was present in very small numbers and had no appreciable effect on the percentages of 5_3's, although the same tendency existed toward heavier representation in the latter part of the season; but in that year the 6_3's were present in larger numbers than in any other year within our knowledge. During the whole month of June and the first week of July this group comprised more than half of the run, and then rapidly dwindled, until in August and September it had almost disappeared. It is doubtless the association of a reduced number of the 5_3 group with an unusually strong representation of 6_3's that gives the former an appearance during 1922 of being a late-running group. In 1924 the 6_3 group was sparsely represented, being far less numerous than the 6_4's. The latter show a distinct tendency to run strongest late in the season.

The fourth series, which matured during its fourth season of sea feeding, includes the 4_1, 5_2, 6_3, and 7_4 groups. All of these show, in the 1924 run, an unmistakable tendency to strong representation early in the run. In fact, three of these groups were wholly confined to the first half of the season.

The increase in size throughout the season is as well marked in 1924 as in 1922, as is shown by comparison of Table 11 with Table 14, these giving the average lengths of the representatives of age group 5_3 in all samples taken in their respective seasons. Certain differences between the two seasons are at once apparent, the most conspicuous being the larger sizes throughout the season in 1924, as well marked in the females as in the males. The mean length, obtained from the daily averages of males in 1922, is 60.3 centimeters, while in 1924 the mean length of the males is 63.1 centimeters. The mean length of the females, obtained in the same manner, is 57.7 centimeters for 1922 and 59.6 for 1924. These differences are apparent at the beginning of the two seasons and are maintained throughout.

In addition to the greater average lengths observed in 1924, there is a certain difference in the sequences, passing down the series of lengths. In 1924 the increase in both males and females is more regular, with no periods of recession, as seen in 1922. A slight increase is apparent during June in both males and females, while in 1922 a well-marked decrease in both sexes was evident. There are other irregularities present in 1922, also, which are not registered in 1924. Due to these, perhaps, the mean length was not reached in 1922 until the first of August, while in 1924 it appeared in both sexes on July 22 and 23.

In Table 14 the series of lengths have been smoothed twice by threes.

TABLE 14.—*Karluk red-salmon run of 1924*

[Average lengths, in centimeters, of age group 5_3 on a series of dates]

Date	Males	Females	Date	Males	Females
June 9 and 10	60.0	57.2	July 29 and 30	63.5	59.5
June 11 and 12	59.9	57.1	July 31 to Aug. 1	63.6	59.6
June 13 and 14	60.0	57.3	Aug. 2 and 4	63.6	59.6
June 16 and 17	60.1	57.6	Aug. 5 and 6	63.6	59.6
June 18 and 19	60.3	57.8	Aug. 7 and 8	63.8	60.0
June 20 and 21	60.5	57.7	Aug. 9 and 16	64.1	60.8
June 23	60.6	57.7	Aug. 18 and 19	64.7	61.5
June 25 and 26	60.5	57.6	Aug. 20 and 21	65.0	61.8
June 27	60.2	57.5	Aug. 22 and 23	65.1	61.9
June 30 to July 1	60.3	57.5	Aug. 25 and 26	65.1	61.9
July 3	60.9	57.6	Aug. 27 and 28	65.1	61.7
July 5	61.6	57.8	Aug. 30 to Sept. 1	65.2	61.4
July 7	62.4	58.2	Sept. 2 and 4	65.3	61.2
July 8 and 9	62.6	58.6	Sept. 6 and 8	65.5	61.5
July 10 and 11	63.0	59.0	Sept. 9 and 10	65.7	62.0
July 12 and 14	63.2	59.3	Sept. 11 and 12	65.9	62.1
July 15 and 16	63.6	59.7	Sept. 13 and 15	65.7	61.8
July 17 and 18	63.5	59.9	Sept. 16 and 18	65.4	61.0
July 19 and 20	63.3	59.9	Sept. 22	65.1	61.1
July 22 and 23	63.1	59.6			
July 24 and 25	63.1	59.5	Mean	63.1	59.6
July 26 and 28	63.3	59.4			

KARLUK RED-SALMON RUN OF 1925

The most important brood years for 1925 were 1919 and 1920, the former furnishing the 6-year fish, which constituted 21 per cent of the run; the latter the 5-year fish, with 72 per cent. Taken together, the product of the two years comprised 93 per cent of the run, to be compared with the 96 per cent in 1924. The remaining 7 per cent in 1925 were largely 4-year fish, of which the 4_3 group (largely of male grilse) was again in greatest numbers. It will be noted that the 5-year fish in 1925 were relatively less numerous than in 1924 (72 per cent instead of 79 per cent) and the 6-year fish more numerous (21 per cent instead of 17 per cent).

The random sampling for the season was on the same scale as in 1924, with daily takes whenever possible throughout the fishing season. Unfortunately, the first half of June is almost wholly unrepresented. Eleven age groups were present at some time during the season, including the 3_1 group, which previously had been observed only in 1917, when two specimens were included in our few samples for that year. Thirty individuals appeared in our 1925 material, with the males twice as numerous as the females. The 3_1 group consists of individuals that proceeded to sea in the fry stage during the season in which they hatched and matured in their third season. The fry migrants in the Karluk usually spend an additional year in the sea, returning as members of the 4_1 group, but in 1925 the latter group contains less than half as many members as the former.

The total number of individuals obtained by random sampling in 1925 was 5,513, which are grouped by age, sex, and length in Table 15. The age groups 5_3, 6_4, and 6_3 are here stated in the order of their importance in the run, their relation represented, respectively, by the percentages 78, 18, and 4. Corresponding figures for 1924 are 81, 14, and 5, and in the abnormal year 1922, 63, 6, and 31.

TABLE 15.—*Random samplings of the Karluk red-salmon run of 1925, distributed by age groups, sex, and length*

Lengths, in centimeters	Age groups and sex																				Total
	3_1		4_1		4_2		4_3		5_2		5_3		5_4		6_2		6_4		6_5	7_4	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	F	M	F	
43							3						1									4
44							6					1						1				8
45							3					1										4
46							10										1	1				12
47							8				1	1	2				1					13
48					1		4				2	2	3				1	1				14
49						1	4				1	4	1					1				12
50						1	11	1			1	2	1	1		1		5				24
51						1	8				2	7	1				2	1				22
52	1				1	1	18	3			7	13	2	1		1	1	3				52
53						5	30	2			7	17	7	1		1		8				78
54		1			1	10	26	3			17	60	7	1		1	2	6				135
55	3	1		1	4	4	38	2			31	75	12	4		3	1	10	1			190
56	1	3	1		3	13	17	1			33	97	11	1		1	5	18				205
57		1		2	8	7	18			1	35	149	2	1	1	4	4	28				261
58	2	1			3	3	7		1		56	220	5		3	7	4	44				356
59	2	1			6	5	4				77	284	4	1	3	15	9	50			1	462
60	6	1			6	3	1				92	300			7	20	21	66		1	2	526
61	3	1		3	3	2					135	284	1		8	22	26	77			2	567
62	1		2	1	8	2				2	177	245			11	23	40	59			4	575
63	1				2				1	3	194	198			14	16	56	63			3	551
64					1					3	234	126			22	12	56	36			2	492
65					1	1					195	71			6	3	50	28		2	1	358
66			2		1				1		184	22			8	3	39	15		2		277
67					1				1		127	5			7		41	2		1		185
68											48	1			3		17					69
69					1						28				1		13			1		44
70											6						5			1		12
71											2						2					4
72									1													1
Total	20	10	5	7	51	59	216	12	5	9	1,692	2,185	60	11	94	133	397	523	1	8	15	5,513

The appearance of each age group in the run of 1925, and its relative importance throughout the season, is shown in Table 16. From this it is again apparent that in general such groups as have spent the longest time in the sea before maturing enter at the very beginning of the run and develop their greatest strength before the middle of the season, while the reverse is the case with the groups that have spent the shortest period in the sea. The most marked example of this is in the case of the 6_3 and the 6_4 groups. Although they belong to the same brood year and are of the same age, they exhibit opposite tendencies as regards time of running. The 6_3 group runs strongest in June and virtually disappears by the first of August. The 6_4 group, on the contrary, is sparsely represented in the June run and develops its greatest numbers from the middle of July to the close of the season. As the greater part of the growth and development of the fish occurs in the sea, it is not strange that length of residence there, rather than total age, should determine this matter.

The 5_3 group, which stands midway between the two series as regards length of life in the sea, develops no obvious tendency in either direction in the run of 1925.

TABLE 16.—*Karluk red-salmon run of 1925. Percentages of each age group in random samplings taken throughout the season*

Date	Age groups										
	3_1	4_2	4_3	4_1	5_2	5_3	5_4	6_3	6_4	6_5	7_4
June 1		1.0	1.0			69.0		27.0	2.0		
June 18		1.0			1.0	79.0		16.0	2.0		1.0
June 20		1.0	6.0			63.0		21.0	9.0		
June 22		7.0	1.0			73.0		12.0	7.0		
June 23		9.0			1.0	66.0		13.0	11.0		
June 24 and 27		6.0	4.0			68.0	0.5	15.0	6.0		.5
June 26 and 29		5.0	3.0	0.5		71.0		12.0	8.0		.5
June 30 and July 1		4.0	6.0			71.0	1.0	9.0	8.0		1.0
July 13 and 14	1.0	6.0	1.0			73.0	1.0	5.0	12.0		1.0
July 15 and 16		3.0	.5		.5	65.0	.5	3.0	27.0		.5
July 17 and 18		3.0	2.0	.5	3.0	70.0		3.0	18.0		.5
July 20, 22, and 23		1.6	.7	1.1		73.0		2.0	21.0		.7
July 24 and 25		2.0	1.0	1.0		65.0	.5	1.0	30.0		
July 27 and 28	5.0	2.0	.5			68.0	.5		24.0		
July 29 and 30	1.7	1.3	2.0		.5	73.0		1.3	20.0		
July 31 and Aug. 1		2.0	1.3	.4		77.0		.9	18.0		.4
Aug. 3 and 4			1.0			86.0	1.0	1.5	10.0		.5
Aug. 5 and 6		1.7	.8		.4	66.0	.8	3.0	27.0		.4
Aug. 8 and 10	1.3	1.7	1.7		.8	77.0	.8	.4	15.0		1.3
Aug. 11 and 12	4.0	2.6	3.5	.4		74.0	1.8	.9	11.0		1.8
Aug. 13 and 14		1.0	5.0	.5	.5	78.0		.5	14.0		.5
Aug. 15 and 17		.5	9.0			75.0	1.5	.5	13.0		
Aug. 18 and 19		.5	10.0		.5	68.0	2.0	1.0	18.0		
Aug. 20 and 21	.8	.4	8.0			74.0	.4	.4	16.0		.4
Aug. 22 and 24	.5	.5	8.0	1.0		72.0	2.0		16.0		
Aug. 25 and 26			11.0		.5	68.0	3.0		18.0		
Sept. 7			9.1			58.2	8.2		24.5		
Sept. 7			17.2			52.5	4.0		26.3		
Sept. 8			10.8			50.0	8.3		30.0	0.8	
Sept. 8			5.3			47.4	9.5		37.9		

The age group 5_3, which at all times constitutes the majority of the run, affords a striking example of the increase in length and weight that occurs among its members during the season. The first individuals to appear in the run have registered no growth of the current year on the margins of their scales, which are occupied by the terminal check of the preceding fall and winter. Among later arrivals, the new growth of the year begins to appear in the form of one or two strong, widely separated circuli, which contrast strongly with the fine crowded lines of the winter check, which they surround. These broadly spaced summer rings increase in number among the individuals of the run as the season advances, until at the close of the summer all scales are marked by a well-defined marginal band of broadly spaced rings. Still later, in the fall, these may, in turn, become margined by a few narrowly spaced rings, the beginning of the fall-winter check of the current year.

This regular growth during the season is well shown in Table 17, which gives for the principal age group (5_3) the average lengths and weights of males and females throughout our series of samples. In the series of June averages (as was the case in 1922, but not obviously in 1924) can be noted a slight progressive decrease in both males and females, registered in both lengths and weights. The increase begins with the first of July and proceeds without interruption until September. The question of the adequacy of our samples receives favorable testimony in the close correspondence of males and females throughout the series of their fluctuations, and also in the strict parallelism in average lengths and weights when even minor changes are in question. Each of the four series in Table 17 has been smoothed once by threes.

TABLE 17.—*Karluk red-salmon run of 1925. Average lengths and weights of age group 5_3 throughout season*

Date	Centimeters		Hectograms		Date	Centimeters		Hectograms	
	Males	Females	Males	Females		Males	Females	Males	Females
June 18	59.8	57.1	23.8	20.7	Aug. 5 and 6	63.7	60.7	29.4	25.4
June 20	59.7	57.0	23.8	20.7	Aug. 8 and 10	64.0	60.8	29.8	25.6
June 22	59.4	57.1	23.2	20.6	Aug. 11 and 12	64.2	61.1	30.1	25.7
June 23	59.3	57.0	22.9	20.5	Aug. 13 and 14	64.5	61.3	30.4	26.0
June 24 and 27	58.9	56.7	22.2	20.2	Aug. 15 and 17	64.4	61.5	30.2	26.4
June 26 and 29	59.1	56.7	22.4	19.8	Aug. 18 and 19	64.6	61.7	30.6	26.6
June 30 and July 1	59.3	57.3	23.2	20.8	Aug. 20 and 21	64.7	61.9	30.7	26.7
July 13 and 14	60.7	58.1	25.5	21.9	Aug. 22 and 24	65.2	62.0	31.4	26.7
July 15 and 16	61.8	58.8	27.3	23.2	Aug. 25 and 26	65.2	61.9	31.4	26.8
July 17 and 18	62.4	59.1	28.1	23.6	Sept. 7	65.1	61.9	31.8	26.6
July 20, 22 and 23	62.5	59.4	28.1	24.0	Sept. 7 [1]	65.4	61.9	31.8	26.6
July 24 and 25	62.6	59.9	28.3	24.4	Sept. 8	65.4	61.8	31.8	26.5
July 27 and 28	62.9	60.1	28.8	24.7	Sept. 9	65.3	61.8	31.7	26.6
July 29 and 30	63.3	60.3	29.3	25.1					
July 31 and Aug. 1	63.7	60.4	29.5	25.2	Means	62.8	59.9	28.2	24.2
Aug. 3 and 4	63.9	60.5	29.6	25.4					

[1] Second sample.

KARLUK RED-SALMON RUN OF 1926

The 1926 run has been investigated on the basis of daily sampling, in so far as this proved practicable. Little or no material could be obtained during periods closed to commercial fishing, so the record is incomplete prior to June 15, as well as during week ends throughout the season. The earliest example is dated May 24 and the latest September 14. There are 66 samples, taken on different days, and these contain records of 8,172 individuals. Of these, 78.6 per cent belong to the 5_3 group, 9.1 per cent to the 6_4 group, and 5.8 per cent to the 6_3 group. By age, irrespective of group, our samples contain 81 per cent in their fifth year, 15 per cent in their sixth, 3 per cent in their fourth, and 1 per cent in their seventh year.

The principal brood years for this run, therefore, were 1920 and 1921, the progeny of these two years forming 96 per cent of the run. Concerning 1920, we have little information beyond the size of the commercial catch, which was approximately 100,000 cases. In 1921 there were approximately 1,500,000 spawners. The very large run of 1926, when commercial catch and spawning escapement together aggregated some 4,500,000 red salmon, can properly be attributed to the fact that it had for its two principal brood years 1920 and 1921, with their large spawning reserves. The crowded condition of the spawning beds in 1921 was notable; but in spite of the destruction of eggs, when nests were dug up by a succession of spawners, the resulting brood brought to maturity in 1926 some 3,500,000 5-year fish. When this sum shall have been augmented by the number of 6-year fish that will presently appear in the run of 1927, the showing should be a very favorable one.

In Table 18 we present an analysis of the run based on our series of samplings. Representatives of 14 age groups were present, including several 6_5's and 7_5's, which had not appeared in previous years. We note also that the 4_2's and 5_2's, which develop from fingerlings (usually not numerous) that migrate seaward in their second year, were present in disproportionately large numbers.

TABLE 18.—*Random samplings, Karluk red-salmon run, 1926, distributed by age groups, sex, and length*

Length, in centimeters	Age group and sex																							Total
	3_1		4_1		4_2		4_3	4_4	5_2		5_3		5_4	6_3		6_4		6_5	7_4		7_5		8_4	
	M	F	M	F	M	F	M	M	M	F	M	F	M	M	F	M	F	M	M	F	M	F	M	
31								1																1
39							1																	1
40							1																	1
41																								2
42							2																	4
43							4																	7
44							7																	1
45												1												2
46							2																	2
47							2																	4
48							2						1			1								5
49							1				4													13
50						2	1				3	5	1				1							13
51					1		2				3	6	1											27
52					1		2				5	16	1			1	1							40
53					4	3					7	23	1			1				1				55
54		1			1		4				21	24	2			1	1							113
55		1			4	12	1		1		27	54	2		3	2	6							181
56	2				9	8	3			2	44	99	3		1	4	5	1						307
57		2			7	13			1	2	68	186	2	1	10	6	7	1		1				424
58		2		1	4	17				3	106	244	1	2	13	7	23	1						521
59	3	2		3	9	14			1	12	113	303		2	18	6	30			5				669
60	2		1		8	20			1	19	142	382		6	34	9	38		1	3		3		832
61	2		1	2	10	11			2	12	152	493		14	49	13	62			8		1		972
62	2		1	6	11	7			2	14	205	551		12	47	31	68		2	12		1		968
63				9	9	1			5	13	275	494		19	46	30	61		1	4		1		980
64			2	6	9	2			6	10	375	396		27	42	40	55		5	5				730
65			1	1	7				4	2	373	224		19	21	54	17		3	1	2		1	528
66						1			5	2	321	97		16	17	44	17		2	5		1		389
67					2				7	1	257	36		20	7	52	6			1				182
68									5		137	8		5	1	25			1					121
69			1						5		92	3		9	1	7			3					60
70									3		41			6		7			3					14
71									1		8			1		4								3
72											2			1										
Total	11	8	7	28	96	111	35	1	49	92	2,777	3,649	15	160	310	345	398	3	21	46	2	7	1	8,172

Reviewing the eight years for which we have here presented records variously complete or incomplete, we find that the Karluk race is most diversified in its lines of development, apparently more so than is the case with any other race we have examined. Seventeen distinct age groups have been represented in one or more of these runs, all but three of them being detected in the run of 1926. The complete list is as follows, the principal figure representing the year of its age in which the fish matured and the smaller figure the year of its age in which it migrated seawards: 3_1, 3_2, 3_3, 4_1, 4_2, 4_3, 4_4, 5_2, 5_3, 5_4, 5_5, 6_3, 6_4, 6_5, 7_4, 7_5, 8_4.

For comparison with previous years, we present Table 19, giving the age-group composition of the run, as evidenced by our daily samplings. The dominant group, 5_3, does not vary widely during the season but is relatively most numerous in the spring and late summer, with an intervening period in July when it is obviously less abundantly represented. The next two groups, in order of importance, are 6_3 and 6_4, which follow their usual procedure, the former increasing in abundance as the season progresses, while the 6_3 group is in relatively greater number early in the spring and almost wholly disappears before fall.

The minor groups, in general, make their entrances and exits and are present most abundantly during the periods already indicated for previous runs. The 3^8 and 4_1 groups vary in 1926 from what we have previously observed, inasmuch as they

appear here as late-running fish. The 4_2 and 5_2 groups agree this year in showing no distinct culmination in their run, but in August and September they largely disappear from the run.

TABLE 19.—*Karluk red-salmon run of 1926. Percentages of each age group in random samplings throughout season*

Date	Age groups													
	3_1	4_1	4_2	4_3	4_4	5_2	5_3	5_4	6_2	6_3	6_4	6_5	7_4	7_5	8_4
May 24			5	1		4	80		7		2		1		
May 27			3				82		10		4		1		
May 30			1	1		2	83		10		2		1		
May 31			6	1		2	75		15		1				
June 2			1				89		9		1				
June 7			7	1		1	78		9		4				
June 15			4			3	79		14						
June 16			8	1			79		10		2				
June 17			4			1	82		11		2				
June 18			3			5	75		16		1				
June 19			2			2	80		14		2				
June 21			4			2	77		16		1				
June 22			6	3		3	72		13		2		1		
June 23			4	1		2	80		8		5				
June 24			4	3		1	80		10		2				
June 25			5			1	78		13		2		1		
June 26			7	2		3	72		13		3				
June 29			7			5	68		14		6				
July 1			6			3	74		9		7		1		
July 3		2	6			2	74		6		10				
July 6			4	1		1	78		13		2		1		
July 7			5	1		2	81		6		5				
July 8			3			2	73		7		12		2		1
July 10			9			5	67		13		3		3		
July 12		1	8			1	78		7		5				
July 13	1	2	4			7	69		12		5				
July 14			4			8	72		7		8		1		
July 15	1	1	4			4	71		7		12				
July 16		1	6			13	62		5		8		5		
July 17		1				9	71		9		9		1		
July 19			4			4	70		11		8		3		
July 20	2	1	2			4	74		6		8		3		
July 21	3	2	1			3	78		6		7				
July 22		3	3			3	79		3		9				
July 23		1	6				70		4		15		4		
July 24	1		1				74		6		16		1	1	
July 26		1				1	75		2		17		3	1	
July 27			2				85		6		7				
July 28	1					2	83		4		9		1		
July 29	2	1	1			1	83		1		10		1		
July 30							80		8		12				
July 31		2				1	80		3		12		2		
Aug. 2		1		1			81		2		14		1		
Aug. 3		1	1				75		5		17		1		
Aug. 4		1					88		1		9		1		
Aug. 5						1	75		8		18		3		
Aug. 6			1				90		2		7				
Aug. 10							80	1	5		11		2	1	
Aug. 11			1				85		2		10		1	1	
Aug. 12	1	1					85		3		9		1		
Aug. 14	1	4		1		2	79	1			8		3	1	
Aug. 16			1	2		1	78	1	4		11		2		
Aug. 17		1	1	1			81		2	1	12		1		
Aug. 18	1	2					83		3		10		1		
Aug. 19		1					92	1			5		1		
Aug. 20		2	1				86	1			10				
Aug. 21					1		88		1		10				
Aug. 25	1	1	1				84		1		10		2		
Aug. 26				1			84	1	1		13				
Aug. 27	1			1			89				9				
Aug. 28			2				79	1	1		17				
Sept. 1	1	1					82				16				
Sept. 3				1			83	1			15				
Sept. 4							83		1		16				
Sept. 6	1						88				11				
Sept. 7							86				13			1	
Sept. 8			1	1			75		1		21		1		
Sept. 9							81	2		1	16				
Sept. 10							79	1			20				
Sept. 11		1					79		1		19				
Sept. 13							72	2			26				
Sept. 14			2	1			79			1	17				

Careful examination of the sizes attained by the principal age groups in different years may yield data of interest and importance. How slight the differences are from year to year within the limits of the same age group is not generally appreciated. Years are cited in which the fish are said to average very large, as well as other years in which the reverse condition appears; but invariably, when such is the case, an examination of the runs demonstrates that the fish run small in years when a younger age group dominates, and average large when an older and larger group prevails.

If the groups are segregated, however, and their average lengths and weights carefully ascertained, the conviction is quickly formed that we are dealing with a highly standardized race characteristic. From year to year the same group presents average sizes that differ by very small amounts. Usually, however, when the data have been gathered by the same observer, it will be found that the lengths of males and females in the same year vary from the norm in the same direction, and can be checked by parallel differences in the weights. In such cases, where the sampling has been adequate, the differences between one year and the next, however small these may be, are genuine phenomena and in need of explanation.

The dominant 5_3 group of the Karluk run offers abundant material for such investigations; but the data at present available are not adequate. For the early years here reported on we have only limited samples covering only a few days of the runs. Furthermore, the measurements were made by different observers, who had little or no training. However, we shall give a list of the average lengths (Table 20) thus ascertained for the 5_3 group in different years, for such information as, under the circumstances, it can be expected to furnish concerning the extremes of variation to which these average lengths are subject.

TABLE 20.—*Average lengths, in centimeters, of males and females of the 5_3 group in a series of years*

Year	Males	Females	Year	Males	Females
1916	63.0	59.3	1924	62.7	59.1
1917	63.5	61.0	1925	62.9	59.9
1919	64.5	60.3	1926	63.5	61.1
1921	64.4	60.3			
1922	60.9	58.4	General average	63.2	59.9

The only considerable variation from the general average is found in the year 1922, which is noted as having had the poorest run in the history of the Karluk River. Apart from the record of that year, the extremes of variation are only 1.8 centimeters in the case of males and 2 centimeters in the case of the females. With regard to the abnormally small sizes shown for the year 1922, the question arises whether there is any direct connection between the failure of the run of that year and the small size of the fish. Was there a scarcity, during the growth of this brood, in the pelagic organisms on which the red salmon almost exclusively feeds, a scarcity that caused extensive mortality among the colony and stunted the growth of those that survived? A reliable series of measurements, extended over a term of years, may throw light on this important question.

The average lengths and weights of the 5_3 group during each of the days in 1926 on which we secured samples are given in Table 21.

TABLE 21.—*Karluk red-salmon run of 1926. Average lengths and weights of age group 5_3 throughout the season*

Date	Centimeters		Hectograms		Date	Centimeters		Hectograms	
	Males	Females	Males	Females		Males	Females	Males	Females
June 15	61.6	59.2	24.7	22.0	July 30	64.7	62.4	29.4	26.7
June 16	61.4	58.9	24.5	21.8	July 31	65.0	62.4	29.9	27.0
June 17	61.2	59.0	24.4	22.0	Aug. 2	65.5	62.8	30.7	27.5
June 18	60.7	58.8	24.2	21.9	Aug. 3	65.7	62.8	31.1	28.0
June 19	60.8	58.9	24.1	22.0	Aug. 4	65.7	63.0	31.1	28.1
June 21	61.0	58.8	24.2	21.9	Aug. 5	66.0	62.9	31.6	28.0
June 22	60.6	59.4	23.8	21.8	Aug. 6	65.8	63.0	30.8	27.8
June 23	60.6	58.9	23.9	21.8	Aug. 10	65.6	62.9	30.8	27.5
June 24	60.2	58.8	23.6	21.8	Aug. 11	65.1	62.6	29.8	27.0
June 25	60.7	58.8	24.0	21.8	Aug. 12	65.4	62.7	30.5	27.0
June 26	61.1	58.7	24.4	21.9	Aug. 14	65.6	62.9	30.3	27.1
June 29	61.3	58.7	24.7	22.0	Aug. 16	65.8	63.0	30.5	27.0
July 1	61.6	59.1	24.9	22.1	Aug. 17	65.8	63.0	30.5	27.4
July 3	61.6	58.9	24.9	22.3	Aug. 18	65.7	62.8	30.5	27.1
July 6	61.7	59.2	25.1	22.5	Aug. 19	65.8	62.9	30.8	27.1
July 7	61.8	59.8	25.5	23.3	Aug. 20	65.4	62.6	30.4	26.7
July 8	61.8	59.9	25.6	23.4	Aug. 21	65.4	62.5	30.5	26.6
July 10	62.3	60.3	26.2	24.2	Aug. 25	65.3	62.4	30.2	26.3
July 12	63.0	60.8	27.2	24.8	Aug. 26	65.4	62.8	30.3	26.6
July 13	63.1	61.4	27.5	25.6	Aug. 27	65.3	62.6	30.2	26.3
July 14	63.4	61.7	28.0	25.8	Aug. 28	65.4	62.5	30.0	25.9
July 15	63.3	61.6	27.8	25.8	Sept. 1	65.5	62.4	29.1	25.5
July 16	63.7	61.5	28.4	25.9	Sept. 3	65.6	62.4	29.7	25.7
July 17	63.7	61.4	28.3	25.5	Sept. 4	65.4	62.4	29.9	25.8
July 19	64.0	61.3	28.4	25.2	Sept. 6	65.3	62.1	29.2	25.6
July 20	64.1	61.4	28.3	25.3	Sept. 7	65.1	61.9	28.9	25.3
July 21	64.4	61.9	28.5	26.0	Sept. 8	64.9	61.8	28.7	25.2
July 22	64.6	62.4	29.1	26.9	Sept. 9	65.1	61.9	29.2	25.0
July 23	64.8	62.4	29.7	26.9	Sept. 10	64.9	61.6	29.1	24.9
July 24	65.0	62.6	29.9	27.1	Sept. 11	65.0	61.5	29.0	24.8
July 26	64.6	62.3	29.4	26.6	Sept. 13	64.8	61.4	28.5	24.6
July 27	64.6	62.6	29.2	27.0	Sept. 14	65.0	61.5	28.5	24.6
July 28	64.5	62.3	29.4	26.6					
July 29	64.4	62.4	28.9	26.8	Mean	63.9	62.0	28.2	25.2

Again, there is a slight recession in size during the latter half of June, to be followed by a recovery in early July, and this by a rapid increase from the 10th of July on through the remainder of that month and into early August. During the first two weeks of September there is the usual decline in size, registered in males and females alike and in both length and weight. Careful inspection of the table shows clearly that we are dealing in this series with something more than simple growth phenomena during a period of vigorous feeding. A regular succession of events is indicated in this and similar tables for previous years contained in this report. A distinct tendency toward increase or decrease in size, shared by both males and females, is shown for the same period in each year, indicating that in different phases of the run we are dealing with heterogeneous material with different growth histories. For comparison with the succession of sizes that accompany the course of the season in the case of the 5_3 group, we give, in Table 22, the average lengths and weights of the 6_3 and the 6_4 groups for certain periods throughout the season.

TABLE 22.—*Karluk red-salmon run of 1926. Average lengths and weights of age groups 6_3 and 6_4 throughout the season*

	Age group 6_3				Age group 6_4			
	Centimeters		Hectograms		Centimeters		Hectograms	
	Males	Females	Males	Females	Males	Females	Males	Females
June 15-29	63.7	61.7	27.1	24.9	60.3	58.5	23.5	21.5
July 1-31	64.9	62.2	28.7	25.5	63.1	61.3	28.3	25.7
Aug. 2-28	67.0	62.8	31.6	26.0	65.2	62.4	29.6	26.4
Sept. 1-14					65.6	62.1	29.8	26.0

Among the adult salmon that return to the Karluk River to spawn there is always found a larger number of females than males. The proportions differ somewhat in different years, partly due to the number of grilse that enter the run. For the grilse, alone, of all the age groups, show a marked preponderance of male fish. In Table 23 the proportions of the sexes are given for different sections of the run of 1926. It will be noted that during the second half of June and from the middle of July to the end of August the relative numbers of males and females are virtually identical, varying less than 1 per cent during this most important part of the run. During the earlier part of the run, prior to the middle of June, the males show greater abundance, about equaling the females in number. During the latter part of the run, especially in September, the males show a marked increase, slightly exceeding the females for the average of this period. This reversal near the end of the season is not wholly due to the increase in numbers of grilse running at this time, for if we take into consideration only the 5_3 and the 6_3 groups, we find in them also a slight excess of males.

TABLE 23.—*Karluk red-salmon run of 1926. Percentages of males and females in samples during different portions of run*

Date	Males	Females	Date	Males	Females
May 24 to June 18	49.1	50.9	Aug. 14 to Aug. 27	39.8	60.2
June 19 to July 3	39.0	61.0	Aug. 28 to Sept. 11	53.1	46.9
July 6 to July 17	42.1	57.9	Total	43.0	57.0
July 19 to July 29	39.4	60.6			
July 30 to Aug. 12	39.9	60.1			

In Table 24 we give, for purposes of comparison, the proportions of males and females in the three principal age groups during four recent years. We give also the relative proportions of the males and females in the total samples of all age groups taken during those years. It will be noted that the excess of females is greatest in age group 6_3 for each of the four years presented, a condition that may well stand related to the fact that the 6_3 group has spent one more year at sea than have the other two groups and is thus potentially older. Inasmuch as the males show a constant tendency to mature at an earlier age than do the females, it results that early-maturing age groups very generally show a heavier percentage of males than do the older groups.

TABLE 24.—*Percentages of males and females in principal age groups in a series of years*

Year	Sex	Age groups			Total samples
		5_3	6_3	6_4	
1922	Males	48.4	42.0	57.3	47.6
	Females	51.6	58.0	42.7	52.4
1924	Males	46.6	44.3	46.8	49.0
	Females	53.4	55.7	53.2	51.0
1925	Males	43.7	41.4	43.2	46.2
	Females	56.3	58.6	56.8	53.8
1926	Males	43.2	34.0	46.4	43.2
	Females	56.8	66.0	53.6	56.8

In the face of this constant inequality of the sexes in mature salmon of the Karluk race stands the fact that among the fingerlings on their seaward migration males and females are in equal numbers, or, if there be a slight inequality, it is in favor of the males. Among 619 fingerlings taken at random in the spring of 1926, 315 were males and 304 females. Among 450 random selections of the spring of 1925, 227 were males and 223 females. Only two alternatives seem to confront us by way of explanation. Beginning their sea life in equal numbers, the males and females may have a different survival value, with a selective mortality acting in favor of the females; or there may be a very considerable precocious development of the males, which may elude us largely because of their small size, and with these eliminated from the commercially valuable fish the preponderance of females would be assured.

ESCAPEMENTS AND TOTAL RUNS, 1921 TO 1926

The weekly escapements during the five years in which the weir has been maintained are given in Table 25. In Table 26 we present data of the runs for these same years. The runs represent the commercial catch plus the escapement. The data for the catch were secured from the three canneries that draw mainly from the Karluk run—the Alaska Packers Association, the Northwestern Fisheries Co., and the Robinson Packing Corporation. The data are complete except for 1921, in which no figures are available for the Robinson Packing Corporation. Their pack for that year is known to have been comparatively small, and it is believed that no great error is brought in by taking the catch of the two other canneries as the total.

TABLE 25.—*Escapement of Karluk red salmon by weeks, 1921 to 1926*

	1921	1922	1923	1924	1925	1926
May 11–17				1		
		60	141	301	19	577
	5,894	418	1,102	4,149	30,249	80,704
June 1–7	16,254	9,921	71,724	86,111	32,733	479,455
	155,097	8,355	28,843	148,417	20,440	437,051
	137,334	57,739	42,169	127,645	263,029	127,537
	195,151	29,897	62,954	64,913	211,021	45,520
June 29–July 5	74,291	46,770	35,647	57,674	34,289	41,516
	72,556	24,366	9,274	39,837	39,927	43,339
	28,668	19,660	3,497	10,882	25,447	34,277
	19,737	6,877	31,491	25,659	24,482	30,300
July 27–Aug. 2	70,954	8,035	24,091	[1] 57,894	64,752	77,956
	96,677	19,403	66,404	[1] 36,281	110,570	101,703
	114,102	7,919	13,036	[1] 61,502	95,862	80,647
	58,867	5,595	48,610	[1] 54,357	19,705	104,139
	79,316	[1] 2,500	38,467		33,797	224,592
Aug. 31–Sept. 6	42,974	[1] 2,500	27,919		200,247	230,498
	143,022	24,343	61,389		74,730	91,136
	14,760	35,618	43,217		100,431	176,939
		61	10,570		51,815	49,609
Sept. 28–Oct. 4		15,721	62,641		182,763	9,448
		29,116	9,110		4,619	43,314
		34,336	1,683			23,145
		236				
Total	1,325,654	384,684	694,579	775,705	1,020,927	2,533,402

[1] Estimated; see text.

TABLE 26.—*Accumulated totals of the runs of Karluk red salmon for each week, from 1921 to 1926, and percentage of the total run for the season that had accumulated to the end of each week*

Date	1921		1922		1923	
	Number of fish, thousands	Per cent of total run	Number of fish, thousands	Per cent of total run	Number of fish, thousands	Per cent of total run
May 4–10	5					
May 18–24	5	0.2		0.05	1	0.08
May 25–31	22	.7	10	1.1	73	5.1
June 1–7	177	6.0	23	2.5	102	7.2
June 8–14	315	10.7	94	10.0	211	14.9
June 15–21	544	18.6	139	14.8	347	24.5
June 22–28	765	26.2	216	23.1	422	29.7
June 29–July 5	875	29.9	246	26.2	447	31.5
July 6–12	968	33.9	281	30.0	489	34.4
July 13–19	1,123	38.3	318	34.0	552	38.9
July 20–26	1,379	47.1	362	36.8	659	46.4
July 27–Aug. 2	1,617	55.2	411	43.8	788	55.5
Aug. 3–9	1,848	62.9	453	48.3	851	60.0
Aug. 10–16	2,040	69.4	501	53.5	957	67.5
Aug. 17–23	2,311	79.0	561	59.9	1,050	74.0
Aug. 24–30	2,495	85.0	610	65.0	1,101	77.5
Aug. 31–Sept. 6	2,771	94.6	727	77.6	1,255	88.5
Sept. 7–13	2,872	98.0	838	89.3	1,326	93.5
Sept. 14–20	2,915	99.5	858	91.4	1,346	94.8
Sept. 21–27	2,926	100.0	873	93.0	1,408	99.2
Sept. 28–Oct. 4			902	96.2	1,418	99.9
Oct. 5–11			937	99.9	1,419	100.0
Oct. 12–18			937	100.0		

Date	1924		1925		1926		Average per cent, 1924, omitted
	Number of fish, thousands	Per cent of total run [1]	Number of fish, thousands	Per cent of total run	Number of fish, thousands	Per cent of total run	
May 18–24	4	0.2	30	1.0	81	1.7	0.6
May 25–31	90	4.5	63	2.2	560	12.1	4.2
June 1–7	256	12.8	83	2.9	997	21.6	8.0
June 8–14	426	21.3	346	11.9	1,125	24.3	14.4
June 15–21	545	27.2	598	20.5	1,377	29.7	21.6
June 22–28	634	31.7	710	24.4	1,517	32.6	27.2
June 29–July 5	699	34.9	785	27.0	1,573	34.1	29.7
July 6–12	768	38.4	820	28.2	1,662	36.0	32.3
July 13–19	857	42.8	871	29.9	1,803	39.0	36.0
July 20–26	949	47.5	1,001	34.4	2,012	43.6	41.7
July 27–Aug. 2	1,020	51.0	1,379	47.4	2,300	49.9	50.4
Aug. 3–9	1,115	55.7	1,644	56.4	2,606	56.5	56.8
Aug. 10–16	1,203	60.2	1,809	62.1	2,844	61.5	62.8
Aug. 17–23	[2] 1,410	70.5	1,987	68.0	3,316	71.7	70.5
Aug. 24–30	1,545	77.3	2,266	77.7	3,751	81.3	77.3
Aug. 31–Sept. 6	1,718	85.9	2,342	80.4	4,072	88.3	85.9
Sept. 7–13	1,878	93.9	2,674	91.6	4,474	97.0	93.9
Sept. 14–20	1,910	95.5	2,726	93.4	4,534	98.2	95.5
Sept. 21–27	1,960	98.1	2,909	99.9	4,543	98.5	98.1
Sept. 28–Oct. 4	1,980	99.1	2,913	100.0	4,587	99.5	99.1
Oct. 5–11	1,999	100.0			4,610	100.0	100.0
Oct. 12–18	2,000	100.0					100.0

[1] The percentages here based on an assumed total run of 2,000,000, as explained in the text.
[2] The figures from here to the end of the season were calculated, as explained in the text.

The escapement records are accurate, except for 1922 and 1924. In 1922 the weir was opened for about two weeks—from August 20 to September 5. This was caused by the drifting down on the rack of great numbers of dead pink salmon, which had spawned in the river. Their number was so great that the weir was blocked and washed out, and it was impossible to maintain it. The available records for 1922 have been examined carefully, however, and it is estimated that the escapement during the two weeks could not have been more than about 5,000 red salmon. The last days before the weir was opened the escapement was only a few hundred per day, and the same was true for the week or more after the weir was again in place.

In 1924 the weir was not operated after August 21. Another heavy run of pink mon entered the Karluk River that year, and the weir was washed out as it had been in 1922. The records for 1924, furthermore, are made less reliable than those of the other years as the result of a system of estimating which, through a misunderstanding, was put into practice for a part of the time that the weir was in operation. The following notes were made by the senior author at the time:

> Reds were actually counted through the weir up to and including July 26. From that time until the 21st of August the number was estimated as follows: There were six gates, all of which were opened when the run was so heavy that they were all necessary, or if the run slacked a little, two of the six were closed and fish permitted to pass through the other four. If the numbers were still further reduced, for a time only two were open. The counting was done at two gates only, and the number of red salmon that passed through was multiplied by 3, if six gates were open, or by 2 if four gates were open. The gates at which the counting was done were changed so that any inequality was thus taken care of. The water was clear and there was no difficulty in distinguishing the reds and counting them. Any inaccuracy in this method was due to unequal numbers passing the different gates and not to difficulty in distinguishing reds and counting them. When the run was heavy enough to make it necessary to open other gates than those at which counting was in progress, they ran about equally at all the gates, in the opinion of Mr. Wood.

On account of the lack of complete escapement records for 1924 it has been impossible, of course, to get directly the total run; but for purposes of comparison it is important that we know approximately what this was. The following procedure, therefore, was adopted: In the last column of Table 26 are given the average percentages of the total runs that had accumulated up to the given dates. These averages have been based on the records for the years 1921, 1922, 1923, 1925, and 1926 only. If we assume that the accumulated total for the run up to July 16 (the last date on which the weir was operated) was, in 1924, approximately the same percentage of the total run as in the other years, and from these data calculate the total run, this proves to be very close to 2,000,000 fish. The accumulated total to August 16, 1924, was 1,203,000, and the average percentage of the total runs that had accumulated to that date in the other years was 62.8. Dividing this accumulated total by 0.628 gives us 1,920,000 as the total run. Similar calculations, based on the accumulated totals up to August 9 and 2, give the total run as 1,965,000 and 2,020,000, respectively. We believe, therefore, that the total run in 1924 was, for all practical purposes, close to 2,000,000, and have used this figure in calculating the number of fish in the run subsequent to August 16 and in calculating the accumulated percentages during the part of the season previous to August 16. On account of our method of calculation, the percentages after that date are the same as those in the last column of the table—the average percentages based on the five years for which we have reliable data.

The "run," as we have used the word here, is the catch plus the escapement. In the natural course of events the fish first approach the beach at Karluk Spit, where the commercial fishery is carried on. Those that escape the seines enter the river and may remain in the estuary or passing back and forth between the estuary and the ocean for some time before passing on up to the lake. The weir is situated just above the estuary, and the fish do not pass the weir until they are definitely starting their migration to the lake; and once they have started they do not turn

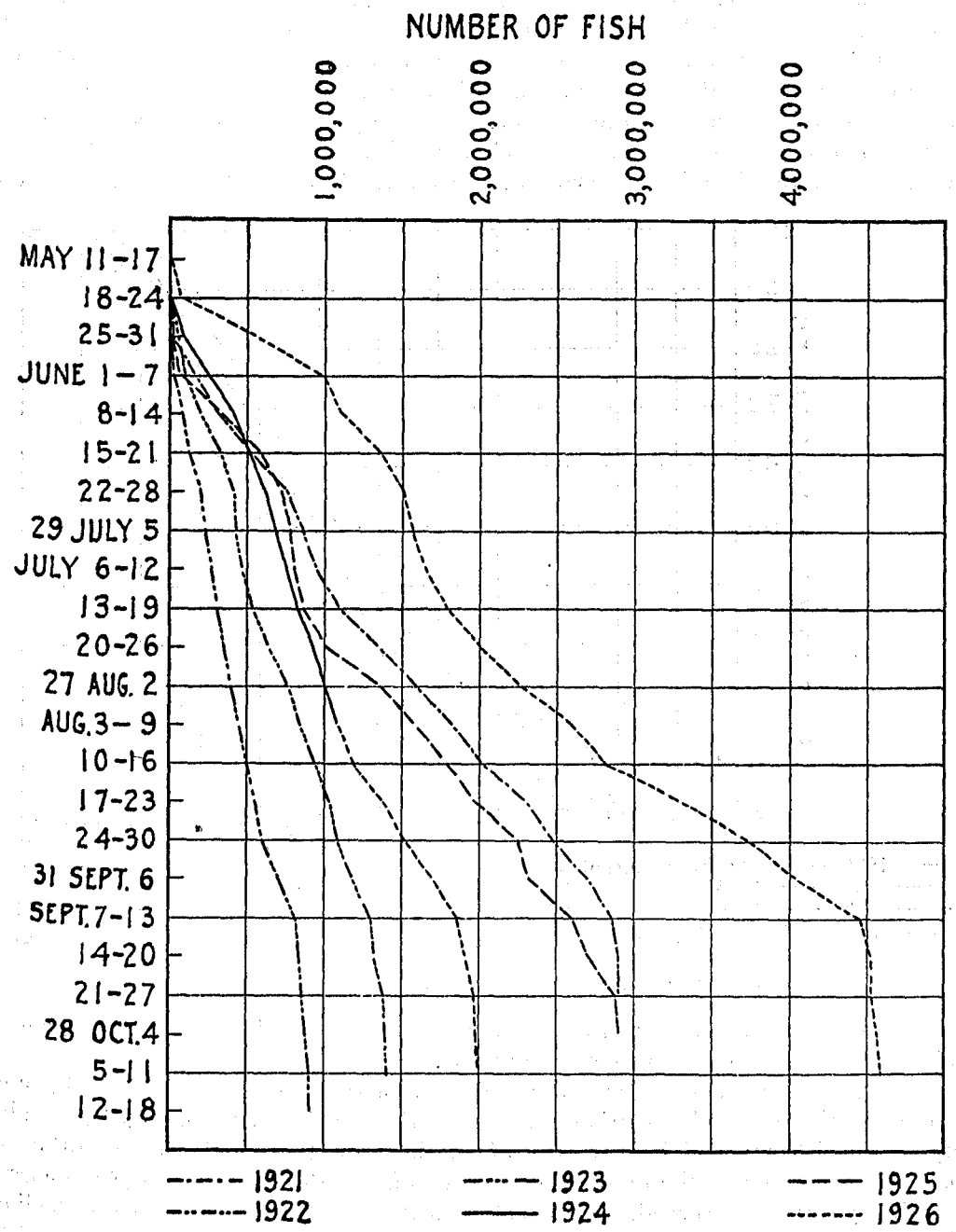


FIG. 33.—Accumulated total number of fish in the run for each week, 1921 to 1926. The dotted portion of the line for 1924 indicates an estimation

back.[10] On account of the time spent in passing through the estuary, between the time the fish first reach the beach and the time they pass the weir, we are not justified in adding the catch and the escapement of the same dates and calling the result the "run" for those dates. Several systems have been tried, and the best evidence we have indicates that an average time of approximately one week elapses while the fish are passing through the estuary. For the purpose of securing the "run," therefore, we have added the catch for each week with the escapement for the following week. The dates given in Table 26 are those on which the catches were made. We

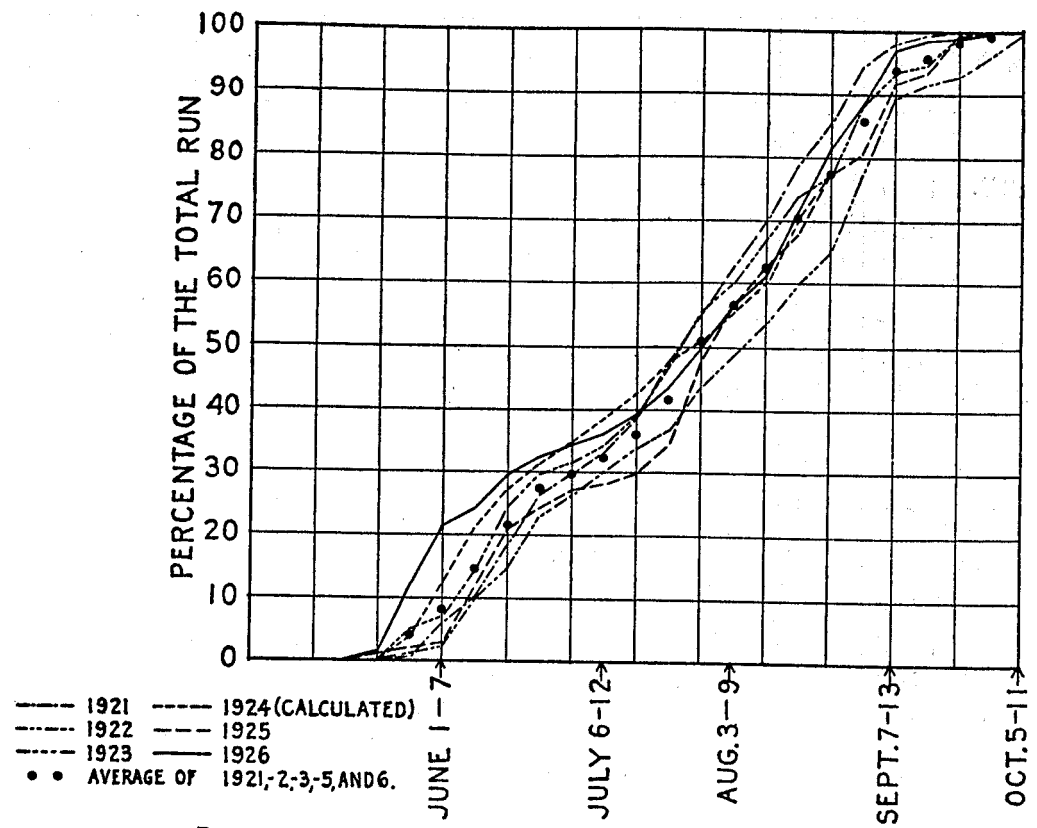


FIG. 34.—Accumulated percentages of the total run for each week, 1921 to 1926

have found that our data, when aggregated into weekly totals, serve every purpose, and we have adopted this system throughout.

The years for which we have detailed data on the runs (1921 to 1926) include completely the last cycle mentioned in the section dealing with the statistical history of the fishery; and it is worthy of special note that, with the exception of 1922, this cycle follows the previous cycles in so far as the relative size of the corresponding years is concerned. This fact indicates to us that here we are dealing with a series of years that, in all probability, are typical of the years of the other

[10] Marking experiments conducted during the summer of 1926 showed that the time required for the migration between the lower weir and the upper weir, situated at the Larsen Bay portage, was only four or five days. It is believed that the entire journey to the lake requires only about a week.

five cycles that have passed since the runs became stabilized following the establishment of the fishery.

Figures 33 and 34 show graphically the data presented in Table 26. Figure 33 gives the number of fish in the accumulated totals for each week for each of the years. Figure 34 gives for each year the weekly accumulated percentage of the total run for that year. In spite of the great differences in the actual size of the runs, there is a remarkable uniformity in the various years in the progress and development of the runs. The curves are invariably steep during June and August, indicating heavy runs during those months. The tendency for the curves to flatten out during July is well marked and clearly reflects the usual poor run of that month. Up to the 13th of September, in most years, the run continues to be good, but it falls off rapidly after that date.

This uniformity in the development of the runs, if supported by a similar study of the runs in future years, will be of very great practical value. From these data it will be possible to tell, comparatively early in the season, just how large the run is likely to be. With this information at hand the regulations can be so adjusted as to provide an adequate spawning escapement, well distributed over the season. At the same time it will be possible for the commercial fishery to plan its season's work to the best advantage and to know approximately, long before the end of the season, what the total pack will be. Even with the few data at hand it seems probable that the total run can be prophesied with some degree of accuracy at least by the end of June. The importance of doing this, from the viewpoint of the fishery administrator and of the commercial fisherman, is so great that it can not be overestimated.

BASES FOR PREDICTION OF FUTURE RUNS

Whatever may be the cause of the extensive fluctuations that occur in the size of consecutive salmon runs, there can be no question that they are responsible, during many seasons, for very serious economic loss. The salmon industry is dependent on supplies of raw material that are available during short periods of the year, varying in different districts from a few weeks to a very few months. The Bristol Bay District furnishes an example of an extremely short fishing season of four weeks, while the Karluk region stands near the opposite extreme with a season of three months; but in all regions, long or short, complete preparations for the season's operations have to be made months in advance. Funds must be secured, labor contracted for, boats, fishing gear, and supplies of every description must be obtained on a scale large enough to permit a maximum pack if the season proves favorable in its supplies of salmon. If, for any reason, only a meager run develops, the losses may well mount into the millions of dollars. Much of this loss could be avoided if the unfavorable character of the season could be foretold. Operations could be conducted on a reduced scale, or, in extreme cases, they could be temporarily discontinued.

The direct economic saving that would result from reliable predictions of the runs would be even less important than the indirect results along the line of conservation. Whatever the immediate cause of a failure in the run, this disastrous condition will be perpetuated and intensified if during that season fishing opera-

tions are conducted with their usual intensity, accompanied by the customary feverish raking and scraping to secure the largest pack possible under unfavorable circumstances. If the nature of the season could be predicted with a fair degree of certainty, it would be possible to avoid immediate serious operating losses and at the same time aid in standardizing the runs by securing a more nearly adequate spawning escapement even in a poor year.

One of the foremost among the objects to be sought in a fisheries conservation program, therefore, is a reliable basis for prediction concerning the magnitude of future fish supplies. This need is appreciated in all fishery investigations, whether of salmon or herring, halibut, cod, or mackerel. The significance of the intensive studies of dominant year groups, of which we hear so much, lies here. In the case of the salmon, in comparison with other marine fisheries, we enjoy certain obvious advantages in developing a technique of prediction, together with certain disadvantages equally obvious. Among the advantages we find the salmon segregated in relatively small, geographically limited, self-perpetuating races, the entire spawning colonies of which annually may be passed in review, and permit detailed quantitative and qualitative determinations impossible in the case of species that spawn in the sea. Among the disadvantages stands prominently the fact that the salmon are relatively short-lived, and, after the young enter the sea, are for the most part wholly inaccessible until the year in which they reach maturity, seek their spawning beds, and invariably die. We are largely deprived, therefore, of the important aid to prediction that can be obtained by the investigation of dominant or defective year classes, which can be seen to pass through the herring or other fisheries over a term of years. With the salmon these are available only in a very minor way, which will be discussed later in these pages in connection with the possible significance of grilse runs of different magnitude.

The great advantage to be found in the use of year classes for purposes of prediction, whether abnormally large or small, lies in the fact that by the time these are sufficiently defined the major part of the hazards that confront every brood are already past, and we have to do with the survivors of a long series of attacks to which the brood has been subject in every stage from the egg to the mature fish. Every hazard means also an uncertainty, and with the passing of the hazards the uncertainties grow less and less. The most reliable evidence concerning the final condition of the brood is that obtained from the years immediately preceding maturity, while the earlier years give progressively less that is authoritative. Still less significant than the fry is the number of eggs produced during the season responsible for the brood; and of still less value, the number of spawning pairs. We believe, however, that all of these, when quantitatively known, have significance and value, though in varying degree, and it is this that justifies us in undertaking investigations concerning the relation that will be found to exist between the number of spawning parents, at one end of the chain, and the final number of their mature progeny, at the other. We consider it probable that we shall discover a significant correlation.

We have no doubt, however, that if we could substitute for the number of spawning fish the number of resulting fry emerging from the gravels, or, of still higher value, the number of fingerlings of the brood that accomplish their seaward migration, we would be in possession of data of far greater predictive value. We have

focused our attention, first, on number of parents, because of the immediate practical value of the results to be obtained on pressing problems of conservation. The Bureau of Fisheries is empowered to secure an adequate escapement of spawning fish and can find means for attaining this end; but it has no influence over the seasonal conditions that favor or are detrimental to egg-laying, incubation, and hatching, or to the incidence of disease, the attacks of parasites, or the depredations of predatory forms, all of which exact a heavy toll during life in fresh water.

Although the first duty of the bureau is to assure adequate spawning reserves, we shall not neglect other data that can be obtained in the prosecution of our investigations, nor the testing of these as to their predictive value. Annually we shall secure the census of fish that ascend the river to spawn. This does not furnish the actual number of spawning fish, inasmuch as many die without spawning on reaching the lake or its tributaries; but it is believed closely to approximate the number of actual spawners and represents the closest determination of their number of which we are capable. As to the subsequent history of the brood, we entertain no hope of being able to estimate the numbers of fry emerging from the gravels, nor of the numbers of fry and fingerlings during their residence in the lake. Attempts to estimate the proportions of the downstream migration appear more promising, although the difficulties in the way seem formidable. After the fingerlings have reached the sea, the only clues that can be obtained as to the size of the growing colonies are such as are furnished by the precociously maturing grilse. The No. 1 grilse—those that mature during the same season in which they reach the sea (figs. 25, 26, and 27)—have little or no value for this purpose. They are recruited almost exclusively from a small group of fingerlings, which migrate seaward in their fourth year, and such predictions as could be based on the numbers in which they appear from year to year would furnish evidence concerning only the 6_4 and 7_4 groups, which furnish relatively unimportant constituents of the run. To be of any considerable value, predictions must deal with the probable size of the 5_3 group, which normally comprises about 80 per cent of the run. This group is largely withdrawn from observation from the time when it descends the river to the sea, in its third year, until it returns as 5-year fish. Only a small percentage of it matures precociously one year earlier and returns to form the 4_3 group.

This group varies greatly in size with different years, and the question for us to solve is whether the magnitude of its occurrence in any year gives reliable evidence of the size of the brood to which it belongs, which will largely mature the following year as group 5_3 and will form the bulk of that year's run. If approximately the same percentage of each brood matures precociously as 4_3 fish, the numbers of the latter will have predictive value; but if the percentage varies widely in response to external conditions that differ from year to year and affect the age of maturing, the number of 4_3 grilse can not be relied on as an indicator of the size of the next year's run. This important question can be answered only after observations extending over a term of years.

A good example of the manner in which we seek to make use of the lines of evidence above described is found in our attempts to predict the probable size of the 1927 Karluk run. As we have already indicated, these lines of evidence are at present to be considered as on trial. They are subjects for investigation and are

chosen as the most promising fields for predictive research. Not until they have been subjected individually to the crucial test of extended experimentation shall we be in a position to indicate the degree of dependence that can safely be placed in them. At the present stage of progress they form the only basis we have for prophecy and can be used tentatively and with caution for such value as they will be found to possess.

The 5-year fish, members of the 5_3 group, that can confidently be expected to constitute the great majority of the 1927 run developed from eggs laid down during the summer and fall of 1922. They hatched during the season of 1923 and remained in residence in Karluk Lake until the spring of 1925, when, in company with other groups of fingerlings, both younger and older, they descended the river to the sea in a pronounced wave of migration. Nothing further was seen of these 3-year fingerlings until the appearance in the run of 1926 of a certain number of individuals that had separated themselves from their companions and had matured at the early age of 4 years (the 4_3 group), while the great majority of their fellows remained behind in the sea for further growth and development.

We have available, then, as indicators for the run of 1927, (1) the number of spawning fish counted through the weir in 1922; (2) the size of the downstream migration, as observed (but in no way quantitatively determined) in 1925; and (3) the abundance of 4_3 grilse in the run of 1926. We shall consider these in their order.

1. The red-salmon run of 1922 to the Karluk River was one of the poorest of which we have any record. For only one other year since the industry was firmly established (that of 1914) has there been an equally poor commercial yield. More important than the commercial take is the spawning escapement, which in 1922 amounted to 383,684 fish. This count, however, did not include the escapement during a period from August 20 to September 4, during which the counting weir was unable to operate because it was blocked by dead humpback salmon that had spawned above the weir and drifted down upon it. Judging from the condition of the run prior to August 21 and subsequent to September 4, a liberal estimate of the fish that ascended the river during the 15 days in which the weir did not function would give a sufficient number to raise the total spawning escapement for the season to 400,000 fish. This is to be compared with the escapement in 1921, which totaled approximately 1,500,000 fish. The returns of the 1921 spawning thus far obtained indicate a probable rate of increase of three to one. If this ratio should hold with some degree of approximation for the spawning of 1922, the total yield of that brood would be 1,200,000 fish. Should 80 per cent of these run as 5-year fish in 1927, according to expectation, they would total 960,000, and the 4 and 6 year fish that would accompany them from other spawnings might be expected to raise the total run to a figure not exceeding 1,500,000. It will be noted that this estimate is based on the assumption—which our present experience is too limited to justify—that the ratio of increase in the Karluk, from spawning colony to mature progeny, will, with each year, approximate three to one. The experience of 1927 will be most valuable as throwing light on the extent to which this ratio fluctuates in different years.

2. No attempt was made in the spring of 1925 to estimate the number of downstream migrants, which were largely derived from the 1922 spawning. They could

be observed about the weir, through which they had no difficulty in passing, and were especially conspicuous in the brackish lagoon below the weir, where they seemed to linger a brief while, accustoming themselves to the denser medium. In the lagoon the red-salmon fingerlings have the habit of leaping freely into the air, thus giving some clue to the distribution of schools within the lagoon and to the density of the population. The general belief of all observers in 1925 was that the fingerling migration compared well with previous years and may have been larger than was observed in 1924; but the basis for this judgment obviously was inadequate, and little dependence can be placed on it. If we were dealing with well-ascertained data, which indicated a fingerling migration in 1925 equal or superior to that of 1924 (the foundation of the run of 1926), we could ignore the dismal predictions based on the very limited spawning reserve of 1922 and could look forward confidently to a successful run in 1927. In that case we should be forced to conclude that the relatively few spawners of 1922 had encountered extraordinarily favorable conditions and had produced a colony of fingerlings far beyond the ordinary. The possibility of such an occurrence emphasizes the high value of a fingerling estimate, even if this be only roughly approximate; but the general impressions concerning the fingerlings of 1925 are not of sufficient validity to do more than inject a certain element of doubt into the situation beyond that which was already present.

3. There remains to consider the evidence obtainable from the size of the 4_3 grilse group present in the 1926 run. As we have shown elsewhere, these grilse appear in limited numbers in the early part of each run, then dwindle in numbers or wholly disappear during the middle of the season, and reappear in a run of considerable proportions late in August and during the first half of September. Our observations cover the years 1924, 1925, and 1926, and are derived in part from random sampling throughout the season, but chiefly from special studies of their relative abundance carried on late in the season. These studies were also based on the method of random sampling, but on a much larger scale than was found adequate for other purposes. We shall confine our attention here to the special examination of the catch made during certain days in September of each of the three years, the fish being taken at random from the fish bins at Larsen Bay or Uyak.

In 1924, on September 8, 300 fish were taken at random from the bins at Larsen Bay, 44 of which (14.7 per cent) were of the 4_3 group. On September 9, 300 more were examined, of which 45 (15 per cent) were 4_3's. A third sample, of 300, was taken on September 11, which proved to contain 32 of the 4_3 group (11 per cent), and a fourth sample, on September 12, of 200 fish, contained 25 (12.5 per cent). Of the above 1,100 fish examined from September 8 to 12, there were 146 4_3's, amounting in all to 13.4 per cent; 90 per cent of these were males and 10 per cent females.

In 1925, similar series of determinations were made on September 8, 9, and 11. Five hundred were examined on each of the first two dates and 300 on the last, and the percentages of the 4_3 group ran, respectively, 11, 25, and 15. In view of the wide disparity of the three dates, it would have been desirable to extend our series in both directions from the dates selected; but limitations placed on the fishing season that year made further experiments along this line impossible. We are left in doubt, therefore, whether the 25 per cent observed on September 9 or the 11 and

15 per cents of September 8 and 11 stand closer to the general average of this group during that portion of the run. The general average for the 1,300 individuals that we examined in 1925 is 17.3 per cent of 4_3's. Had we attempted an estimate of the 1926 run, based on the relative number of 4_3 grilse present in 1924 and 1925 and the ascertained run of 1925, the above figures would have warranted us in predicting a somewhat larger run in 1926 than we had in 1925, but not as large as the 1926 run actually proved to be. If the 1925 percentage of grilse had been 22 instead of 17.3, this would have furnished us a basis for a fairly accurate forecast of the 1926 run. However, admitting the incompleteness of our data for both 1924 and 1925 and the improbability that even with adequate determinations of the numbers of grilse we should have a basis for any closely accurate predictions, our experience with the 4_3 grilse counts in 1924 and 1925 and the corresponding 5_3 returns in 1925 and 1926 is favorable to the theory that a fairly definite relation exists between the number of younger fish occurring in the run of one year and the size of the run of the following year. The experience of only two years, however, is insufficient foundation for any high degree of confidence, and we must look to the results in 1927 and susequent years either to confirm or to refute the theory we tentatively entertain.

The run in 1927 will offer crucial evidence in this direction. As we have seen, the spawning reserve of its principal brood year, 1922, was very limited and apparently inadequate to produce a normal run. On the other hand, such superficial observations of the fingerling migration of 1925 as were made gave favorable indications, although these were not of such character as to inspire confidence. We have now to consider the 4_3 grilse run of 1926 as our third basis for prediction, and it may be stated at the outset that it was almost nonexistent. Appreciating the significance of these data, a much more extensive series of determinations was made in 1926 than in either of the two previous years. The run was sampled on September 1, 3, 4, 6, 8, 9, 10, 11, and 15, one thousand individuals being examined on each of those dates, except the 3d, the 11th, and the 15th. Five hundred, each, were examined on the 3d and 11th, and 700 on the 15th. The total number included in this test, therefore, was 8,700. It is believed this sampling was entirely adequate, especially in view of the comparatively little variation in the results from day to day. On only one day (the 15th) was the number of the 4_3 group present as high as 1 per cent of the sample taken. On the other 9 days the percentages varied from three-tenths to nine-tenths of 1 per cent, with no obvious trend. The total number observed was 48, of which 41 were males and 7 females. The average percentage of the 4_3 group present in the run during the first half of September was thus only fifty-five one-hundreths of 1 per cent. When these figures are compared with the 13.4 per cent in 1924 and the 17.3 per cent in 1925 it is seen that the grilse of 1926 corroborate the evidence derived from the limited spawning of 1922 and give no grounds for hope of a normal return of 5_3's in 1927.

As we have stated above, such hope as exists must be based on the general impression of an extensive fingerling migration in 1925. These fingerlings were largely the progeny of the scanty 1922 spawning, and we have no knowledge of any physical or other conditions in 1922 that could be considered extraordinarily favorable for the production of a large crop of fingerlings from a strictly limited number of eggs. Nevertheless, such conditions may have existed.

As having a possible bearing on this subject, we may recall that 1922 was one of the big cycle years for the pink or humpback salmon. The run of that year was extensive, and spawning occurred not only along the river but on virtually all the important red-salmon beds of the lake system, where they outnumbered the red salmon at least 5 to 1. The progeny of the 1922 pink run comprised the banner run of that species to the Karluk River in 1924, when they were vastly more numerous, even, than in 1922. Obviously, then, the conditions for the successful spawning of pinks in 1922 were extraordinarily favorable and the yield disproportionally large, yet their eggs were laid down in the same gravels with the red salmon and at the same time. It becomes a most interesting question whether conditions favorable to one species under such circumstances would be equally favorable to the other. If a red-salmon run of normal proportions should, after all, develop in the Karluk in 1927, that would go far toward answering this question in the affirmative. Such an answer would lead us to entertain grave apprehensions for the Karluk red-salmon run in 1929, for the pink salmon spawning of 1924, in spite of its almost unparalleled intensity, was a complete failure. No pink run whatever resulted in 1926. If a similar fate befell the 1924 red-salmon eggs, we shall have an extremely limited fingerling migration in 1927 and a failure of the run of 1929. We have as yet, however, no observational basis for anticipating in these two species corresponding success or failure in any given year, even when they share the same spawning beds.

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ERRATA

Figure 5: In the legend "oi" should be "of" and "tounting" should be "counting."
Page 12, line 16: "observtaions" should be "observations."
Page 22, 9th line from bottom of page: "Morain Creek" should be "Moraine Creek."
Page 28, table 3: In the box head over the reading column the word "cubic" should not occur.
Page 52, table 17: "Decigrams" in the box heads should be "Hectograms."
Page 56, table 21: "Decigrams" in the box heads should be "Hectograms."
Page 309, last line: "on" should be "no."
Page 353, line 13 from the bottom: "athoms" should be "fathoms."
Page 409, first line of last paragraph: "severa" should be "several."
Page 473, last line of text: "orm" should be "form."
Page 495, line 4: "in" should be "is."
Page 540, line 3: "noe" should be "none."
Page 579: Below table 24 there should be a footnote, as follows: "See footnote 3, table 20, page 575."