SALMON OF THE NORTH PACIFIC OCEAN—PART IV SPAWNING POPULATIONS OF NORTH PACIFIC SALMON

1. SOCKEYE SALMON IN THE FAR EAST

by
N. Hanamura
Hokkaido Regional Fisheries Research Laboratory
Hakodate, Japan, August 1964

INTRODUCTION

Not many studies have been made regarding the distribution of spawning grounds of sockeye salmon (*Oncorhynchus nerka*) in streams and lakes of the Far East and the conditions which affect their reproduction. This report is largely a synthesis of information reported by Soviet researchers studying salmon of the Kamchatka Peninsula.

CHARACTERISTICS OF SPAWNING GROUNDS

As is the case with other species of salmon, sockeye salmon spawn on gravel bottoms of streams and springs, but they also spawn on gravel bottoms along lake shores. The spawning grounds of sockeye salmon are characterized by the presence of ground water. Ground water in their spawning beds is usually not high in oxygen content (5–6 mg/L), relatively high in free carbonate content (0.8–22 mg/L), and fairly high in *p*H (6.3–8.2) (Krogius and Krokhin, 1948). Also, the temperature of the ground water is relatively low and its variation is far smaller than that of stream water.

In Karymai Spring, which is a typical sockeye spawning area in the Bolshaia system, stream water temperature ranges from 1°C in winter to 10°C in summer. The temperature of ground water running through spawning beds averages 5–7°C during August and September, 3–4.5°C during October through January (the critical period for egg development), 2–4°C during January through April (alevin stage), and 3–6°C during May through July (period of downstream migration). (Semko, 1954.) This temperature range is surprisingly small.

The most important and most typical sockeye spawning grounds in West Kamchatka are found in the Ozernaia River system. The water temperature in Lake Kuril, which feeds the Ozernaia River, is 5–9°C in August and September, 1.3–6°C in October through January, 0.5–1.3°C during January through April, 2.6–4.7°C during May through July ; its range is far smaller than that of stream water (Egorova, 1960, unpublished).

In Lake Dalnee, water temperature in the spawning grounds is 6–7°C during the summer, when water temperature is 13–14°C in areas other than the spawning grounds (Krogius and Krokhin, 1956). In an experiment conducted in Lake Dalnee, mature sockeye salmon kept in captivity in a shore area of the lake where there was no ground water died without depositing their eggs (Krogius and Krokhin, 1948).

Sockeye of individual local populations return to the same spawning grounds year after year. Changes in water level or abundance of fish may make their upstream migration difficult and affect the amount of energy spent in reaching the spawning grounds and securing spawning beds ; difficulties in upstream migration may sometimes cause changes in the muscle colour of spawners. Even under such circumstances, however, the same spawning grounds seem to be used by succeeding generations of the local stock.

DISTRIBUTION OF SPAWNING GROUNDS

No details are available regarding the distribution of sockeye spawning grounds over the entire Far Eastern region. Figure 1 shows the location of those spawning areas which are mentioned in this report.

Most of the fish entering the Ozernaia River, which is the greatest sockeye producer in the Far East, spawn along the shores of Lake Kuril in areas of gravel bottom adjacent to the mouths of small streams flowing into the lake, where there is abundant ground water. Some spawn in the upper reaches of the Ozernaia River, in the outlet of the lake and in tributaries flowing into the lake. (Egorova, 1960, unpublished.)

Received for publication August 1964. Original, Japanese.
Source : Joint reporting team, Committee on Biology and Research. INPFC Document No. 701.
Bull. 23, Int. North Pac. Fish. Comm., 1967.

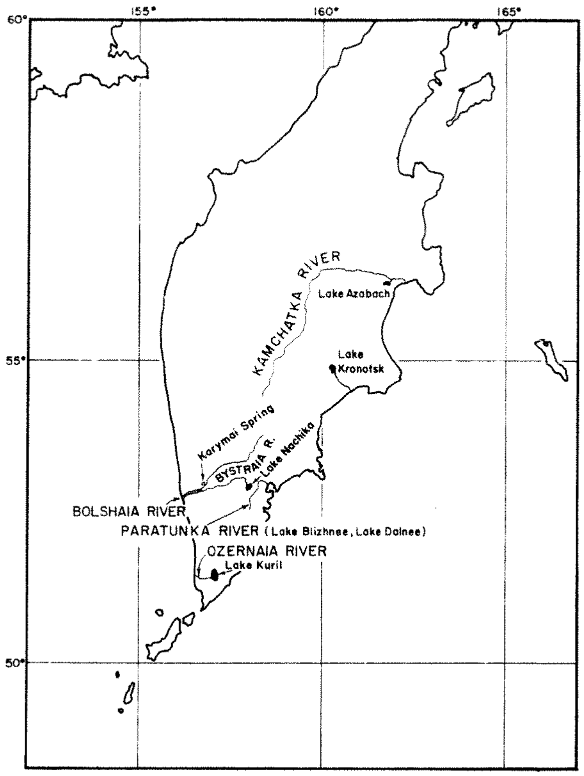

FIGURE 1. Sketch of the Kamchatka Peninsula showing location of sockeye salmon spawning areas mentioned in the text.

The geographical distribution of the main spawning grounds of Kamchatka River sockeye, which are next to Ozernaia sockeye in abundance, is not known to us. Only the locations of some of the typical spawning grounds in this system have been reported. It is reported that in Lake Dalnee approximately 5% (or 60,000 m²) of the lake area is suitable for sockeye spawning (Krogius and Krokhin, 1948) and that spawning grounds are located on all but the northeast shores of the lake (Krokhin, 1960). Krokhin (1960) also states that sockeye spawning grounds in Lake Blizhnee are concentrated along the shore of the western half of the lake, that the sockeye of Lake Kronotsk (a lake-resident form) spawn in the lake itself as well as in tributaries flowing into the lake, and that sockeye of Lake Azabach spawn mostly along the west and northwest shores and partly in tributaries flowing into the lake.

No information is available on the geographical distribution of Bolshaia River sockeye salmon spawning grounds.

TIMING AND GEOGRAPHICAL CHARACTERISTICS OF UPSTREAM MIGRATION AND SPAWNING

The timing of upstream migration and spawning is known reasonably well only for the following populations of Far Eastern sockeye salmon.

OZERNAIA RIVER POPULATIONS (Egorova, 1960, unpublished)

Upstream migration occurs from June to September, with peak runs from the end of July to the end of August. The main spawning grounds are along the shore of Lake Kuril, which is more than 60 km above the river mouth. Fish arrive at the spawning grounds one to two months after their entrance into the river. Hence, spawning occurs from the end of August to October. In exceptional cases, some fish spawn during the winter. A counting fence is located at a point 55 km from the river mouth and approximately 5 km downstream from the outlet of Lake Kuril, and the enumeration of sockeye salmon migrating into Lake Kuril for spawning is carried out on a daily basis (by counting fish during certain hours of the day) during the entire period of migration. Sockeye salmon pass the counting station during the period from mid-July to early September, as shown in Figure 2. The peak period seems to be from early August to late August. The annual total numbers of fish are shown in Table 1.

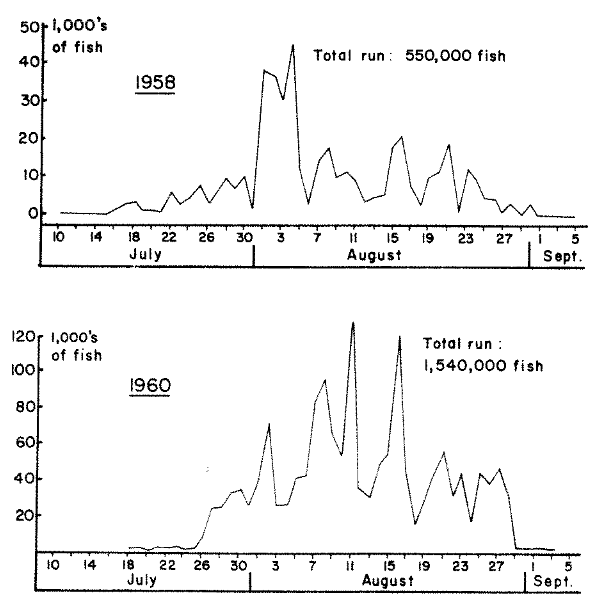

FIGURE 2. Upstream migration of Ozernaia River sockeye in 1958 and 1960 (Egorova, 1960, unpublished).

TABLE 1. Spawning run of the Ozernaia River system, by year and by age (Egorova, 1960 unpublished).[1]

Year	Age						
	4_3	5_3	6_3	6_4	7_3	7_4	Total
1940		2.08 (35.0)	3.87 (65.0)	+ +	+ +	+ +	5.95 (100)
1941		1.57 (40.0)	2.37 (60.0)	+ +	+ +	+ +	3.94 (100)
1942		1.17 (25.0)	3.53 (75.0)	+ +	+ +	+ +	4.70 (100)
1943		1.30 (16.0)	6.87 (84.0)	+ +	+ +	+ +	8.17 (100)
1944		0.82 (20.0)	3.30 (80.0)	+ +	+ +	+ +	4.12 (100)
1945		0.85 (13.5)	2.05 (32.7)	2.85 (45.5)	+ +	0.52 (8.3)	6.27 (100)
1946		1.58 (39.5)	1.28 (32.0)	0.12 (3.0)	+ +	1.02 (25.5)	4.00 (100)
1947		2.46 (51.0)	2.25 (47.0)	0.03 (0.7)	+ +	0.06 (1.3)	4.80 (100)
1948		0.77 (28.3)	1.87 (68.3)		0.04 (1.2)	0.07 (2.2)	2.75 (100)
1949		0.59 (7.7)	6.39 (84.1)	0.54 (7.1)	0.08 (1.1)	+ +	7.60 (100)
1950	0.07 (1.8)	0.92 (23.6)	2.62 (67.4)	0.17 (4.3)	0.05 (1.3)	0.16 (1.6)	3.89 (100)
1951	0.02 (0.3)	1.43 (21.3)	4.13 (61.7)	0.78 (11.6)	0.15 (2.3)	0.19 (2.8)	6.70 (100)
1952	0.02 (0.3)	1.99 (29.6)	4.15 (61.6)	0.06 (0.8)	0.14 (2.0)	0.38 (5.7)	6.74 (100)
1953	0.03 (0.6)	0.97 (19.0)	3.44 (67.0)	0.43 (8.3)	0.10 (1.9)	0.17 (3.2)	5.16 (100)
1954	0.03 (0.5)	1.87 (38.0)	2.02 (41.0)	0.42 (8.7)	0.12 (2.4)	0.46 (9.4)	4.92 (100)
1955	0.13 (0.9)	0.98 (14.0)	4.77 (68.1)	0.66 (9.4)	0.14 (2.0)	0.32 (4.6)	7.00 (100)
Average	0.05 (0.8)	1.33 (24.5)	3.43 (63.4)	0.35 (6.7)	0.05 (0.9)	0.20 (3.7)	5.41 (100)

[1] Upper numerals—millions of fish; lower numerals (in parentheses)—percentages.

KAMCHATKA RIVER POPULATIONS (Krogius and Krokhin, 1956)

The principal run of early sockeye in the Kamchatka River takes place during June; the late run occurs prior to the end of August. Spawning is most active during the period from late July to mid-August.

LAKE DALNEE POPULATIONS (Krogius and Krokhin, 1948)

There are two runs of sockeye salmon to this lake. The earlier spawners enter the lake during the period from the end of May to the end of June and spawn during the period from the end of July or early August to mid-August in relatively deep waters; their numbers are small. The bulk of the spawning population enters the lake from early or mid-July to the end of August and spawns during the period from the end of August to the end of October in shallow waters along the lake shore. The annual total numbers of fish entering Lake Dalnee and Lake Blizhnee are shown in Table 2; data on chronological changes in their arrival are not available.

BOLSHAIA RIVER POPULATIONS (Semko, 1954)

There are spring sockeye runs in the Bolshaia River, although the numbers of fish involved are small. The upstream migration occurs from late May to mid-June, with the peak in early June. They spawn only in certain tributaries flowing into Lake Nachika during the period from late July to the end of August. The major Bolshaia River sockeye populations spawn in spring-fed streams and lakes, and their upstream migration occurs during the period from late July to mid-August, with peak runs in late July and early August. Chronological changes in the number of spawners entering the spawning grounds are known only for Karymai Spring, which is a tributary located approximately 70 km above the river mouth; these data are

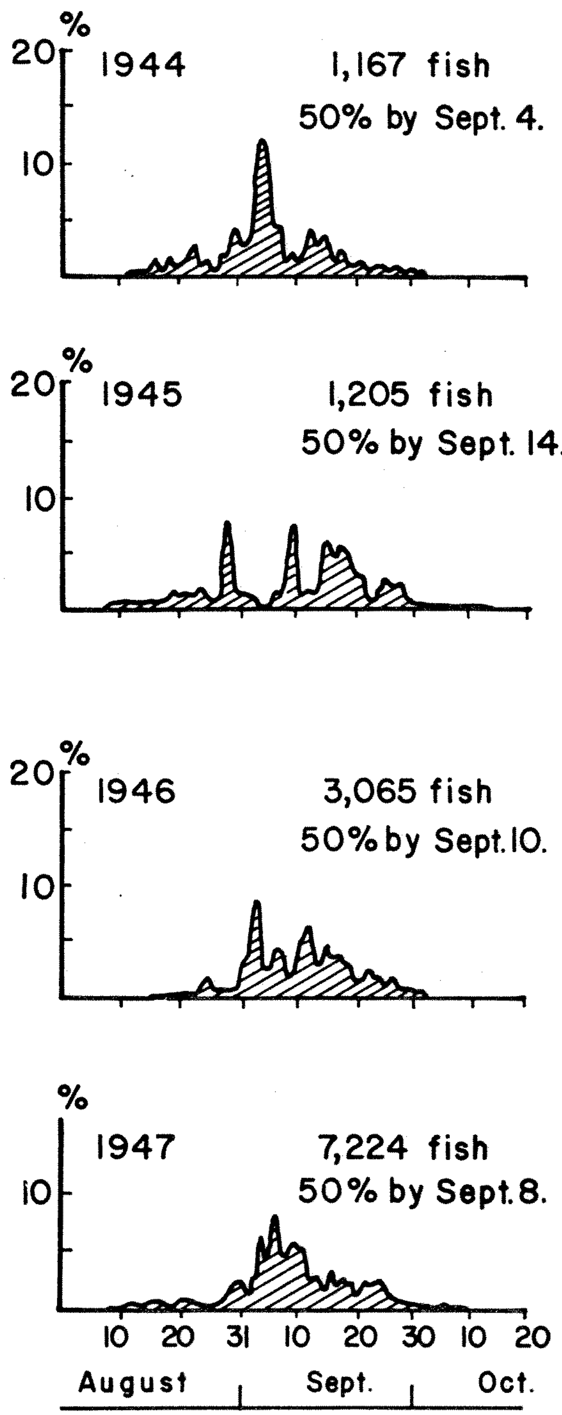

FIGURE 3. Number of sockeye spawners entering Karymai Spring (Bolshaia River), 1944–47 (Semko, 1954).

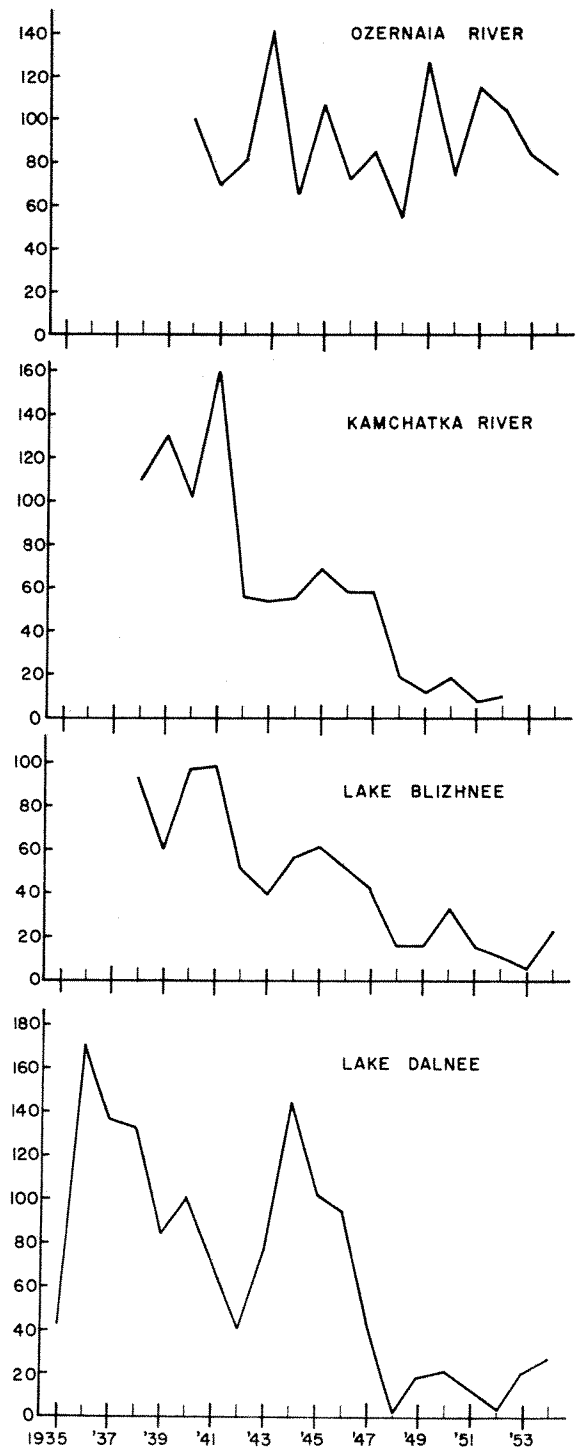

FIGURE 4. Fluctuations in numbers of spawners in the sockeye runs to various systems from 1935 to 1954, as percentages of the run of 1940 (Krogius and Krokhin, 1956).

Table 2. Catch and escapement of sockeye salmon spawning in the Paratunka River system, in number of fish (Krogius and Krokhin, 1948).

Year	Lake Dalnee			Lake Blizhnee		
	Catch	Escapement	Total	Catch	Escapement	Total
1935	9,500	26,500	36,000	—	—	—
1936	8,550	141,950	150,500	—	—	—
1937	18,200	100,000	118,200	—	—	—
1938	24,250	84,950	108,200	17,650	82,750	100,400
1939	21,850	48,650	70,500	26,850	43,550	70,400
1940	16,450	70,750	87,200	43,900	70,500	114,400
1941	21,600	36,800	58,400	27,800	82,900	110,700
1942	13,700	20,300	34,000	35,500	18,500	54,000
1943	36,500	27,000	63,500	20,500	18,500	39,000

shown in Figure 3. According to this figure, the timing of arrival at the spawning grounds varies somewhat from year to year, but is, in general, from about August 10 to about October 20. The period from late August to late September is considered to be the peak.

GENERAL CONDITIONS OF STOCKS

Trends of Fluctuations in Abundance

Year-to-year changes in the escapements to various sockeye streams in the Far East are shown in Figure 4. A declining trend is noted for the Kamchatka River, Lake Dalnee and Lake Blizhnee. Such a trend is not noticeable for the Ozernaia River. With the expansion of offshore fishing from 1953–54, it became more and more difficult to know the fluctuations in abundance of stocks, even roughly, from coastal data alone. Recent data on catch and escapement of sockeye are shown in Table 3.

The general distribution and migration of Kamchatka River and Ozernaia River sockeye in the ocean have been investigated. From the offshore catches in the respective areas of distribution of these two stocks, the quantities of presumably immature fish have been subtracted and the remainder is considered to be the catches of mature sockeye from these stocks. Combining these catches with the coastal catches and escapements (or trends in escapement), it is indicated that no trends of decline have been noticeable for the Ozernaia River stock and that even some increase has

Table 3. Catch of sockeye salmon and escapement to various rivers in Kamchatka, 1950–63 (data from the Japan-Soviet Fisheries Commission).

Year	West Kamchatka			East Kamchatka			High seas fisheries catch (1,000's of metric tons)
	Coastal catch (1,000's of metric tons)	Estimated escapement (millions of fish)		Coastal catch (1,000's of metric tons)	Estimated escapement (millions of fish)		
		Ozernaia	Bolshaia		Kamchatka	Apuka[1]	
1950	8.2	1.0	—	1.1	—	—	—
1951	7.0	2.4	—	0.7	—	—	—
1952	8.9	2.4	—	0.3	—	—	1.5
1953	5.0	1.2	—	0.1	—	—	3.2
1954	3.6	0.3	—	0.4	—	—	7.8
1955	2.4	0.5	—	0.7	—	—	26.6
1956	4.3	1.2	—	1.4	—	—	20.3
1957	3.0	1.4	0.1	0.6	0.8	0.1	43.3
1958	0.6	0.6	0.1	0.4	0.6	0.1	25.6
1959	2.5	2.1	0.2	1.5	2.0	0.2	19.7
1960	2.2	1.5	0.3	1.8	1.5	0.1	30.6
1961	6.8	2.5	0.2	1.0	1.5	0.1	36.7
1962	4.1	0.8	0.1	0.6	1.0	+	24.8
1963	2.5	0.5	0.2	0.9	0.5	+	19.1

[1]Oliutorskii district; not shown in Figure 1.

been noted for the Kamchatka River stock since 1953–54. For Ozernaia River sockeye the catch and escapement have been studied systematically since 1940; the total coastal return has ranged from 3–8 million, of which 300,000 to 4,200,000 escaped to the spawning grounds. (Egorova, 1960, unpublished.)

Krogius and Krokhin (1956) believed that it was desirable to have 2–3.5 million spawners in the Ozernaia system, that under conditions favourable for reproduction a satisfactory return could be expected from 1.2 million spawners, and that an escapement of 300,000 as observed in 1954 was very insufficient. It has been revealed, however, that the return from 1954 spawning was at an average level (see Table 3).

The sockeye stock of the Kamchatka River was at a high level of abundance during 1937–39, but the return decreased during 1942–47, and a sharp decline took place from 1948 on. At that time, both offshore and coastal catches were small; the same trend was also observed in the Paratunka system. The catching of sockeye in the Kamchatka River area has been prohibited since 1951, except for fishing by several experimental traps used for determining the size of the run (Krogius and Krokhin, 1956). Considering the offshore catches of mature sockeye in the area of distribution and during the period of migration of Kamchatka River fish, and the conditions of coastal runs, it is indicated that the stock has recovered considerably after the period of 1948–53. As a result, the fishing closure in this coastal area has been released since 1962.

For Paratunka River sockeye (Lake Dalnee and Lake Blizhnee stocks), some indication of increase is recognizable since 1953–54, but data for the most recent years are not available as yet.

For Bolshaia River sockeye, only the coastal catch statistics and data on the escapement to the Karymai Spring are available to us. There is some indication that the Bolshaia run has been at a low level in recent years.

Characteristics of Fluctuations in Abundance

Among Far Eastern salmon, the sockeye salmon has the most specialized requirements for spawning grounds. They spawn only in areas supplied with ground water, and their spawning streams have lakes at present or used to have lakes in the past. The reproduction of sockeye is subject to very restricted conditions as early as the spawning process, the degree of success of which is the first factor, chronologically, to affect the abundance of progeny. For this reason, the probabilities for favourable sockeye spawning greatly decrease when spawning grounds are overcrowded. Thus, overcrowding of spawning grounds tends to have a greater effect on the abundance of progeny (through lower survival rates of eggs) than in other species of salmon. Also, fry and juvenile sockeye spend one to four years in fresh water before they go downsteam. They are subject to losses from various causes during this part of their life cycle. Consequently, the significance of survival in fresh water as a factor causing fluctuations in abundance is greatest for sockeye salmon. (Krogius, 1951.)

The growth rate of sockeye salmon is subject to considerable fluctuation, but does not show such apparent inverse correlations with abundance as are observed in pink salmon. However, there are obvious correlations between the rate of growth and that of maturation. The rates of growth and maturation seem to be affected by changes in abundance in the case of Ozernaia sockeye but not in the case of Kamchatka River sockeye. (Krogius, 1951.)

In general, sockeye salmon show smaller differences in the rates of growth and maturation in the ocean than do other species of salmon. This indicates that the abundance of sockeye salmon is more strongly affected by conditions in fresh water (particularly those associated with spawning, egg development and the survival of young) than by conditions in the ocean. Certain phenomena contrary to this general tendency have been reported, however. For example, the sockeye salmon born in streams of East and West Kamchatka during 1938–42, which entered the sea during 1941–44, showed a gradual increase in the proportion of early-maturing fish. The abundance of sockeye during this period was even greater than that of previous years. The North Pacific Ocean generally became warmer during the period of oceanic residence for these year classes. In other words, the speed of maturation seems to have increased not from a decrease in abundance of fish but from an increase in the rate of metabolism resulting from warming of the ocean. (Krogius, 1951.)

Over a number of years the rate of return from seaward migrants of Lake Dalnee sockeye ranged from 21% to 48%, with an average of 33%, but decreased greatly (to 5–20%) for the brood years 1943–45. Also, the growth of the 1944 year class in the ocean was very poor. The number of downstream migrants from this year class was very low and also the abundance of fish of the year classes prior to 1944, which spent part of their oceanic period of life with fish of the year class 1944, was not particularly high. It is, therefore, indicated that the ocean conditions during 1946–48 were not favourable for the life of sockeye salmon. It should be noted that the abundance of the year classes 1943–45 was small not only for Lake Dalnee sockeye, but also for the sockeye salmon of the

Kamchatka River and various other streams flowing into the northwest Pacific. (Krogius, 1951.)

REFERENCES

EGOROVA, T. V. 1960, unpublished. Biostatistical data and biological information on sockeye salmon obtained at the Ozernaia Laboratory by a Japanese scientific group which visited there in 1960.

KROGIUS, F. V. 1951. On the dynamics of abundance of the sockeye salmon (*Oncorhynchus nerka* (Walbaum)). *Izvestiia Tikhookeanskogo Nauchno-Issledovatelskogo Instituta Rybnogo Khoziaistva i Okeanografii* (Izv. TINRO), Vol. 35, pp. 1–16.

KROGIUS, F. V., and E. M. KROKHIN. 1948. On the production of young sockeye salmon (*Oncorhynchus nerka* (Walbaum)). *Izv. TINRO*, Vol. 28, pp. 3–27.

KROGIUS, F. V., and E. M. KROKHIN. 1956. Results of a study of the biology of sockeye salmon, the conditions of the stocks and the fluctuations in numbers in Kamchatka waters. *Voprosy Ikhtiologii*, No. 7, pp. 3–20.

KROKHIN, E. M. 1960. Spawning grounds of sockeye salmon (*Oncorhynchus nerka* (Walbaum))—a review of their geomorphology, temperature conditions and hydrochemistry. *Voprosy Ikhtiologii*, No. 16, pp. 89–110.

SEMKO, R. S. 1954. The stocks of West Kamchatka salmon and their commercial utilization. *Izv. TINRO*, Vol. 41, pp. 3–109.