FISHERIES AND MARINE SERVICE

Translation Series No. 3160

The Amur pink salmon (Oncorhynchus gorbuscha) : a commercial and biological survey

by R.I. Enyutina

Original title: Amurskaya gorbusha (Promyslovo-biologicheskii ocherk)

From: Izvestiya Tikhookeanskogo Nauchno-Issledovatel'skogo Instituta Rybnogo Khozyaistva i Okeanografii (TINRO) (Proceedings of the Pacific Scientific Research Institute of Marine Fisheries and Oceanography), 77 : 3-126, 1972

Translated by the Translation Bureau(BH/PJH)
Multilingual Services Division
Department of the Secretary of State of Canada

Department of the Environment
Fisheries and Marine Service
Pacific Biological Station, Nanaimo, B.C.
Arctic Biological Station, Ste. Anne de Bellevue, P.Q.

1974

214 pages typescript

DEPARTMENT OF THE SECRETARY OF STATE
TRANSLATION BUREAU

MULTILINGUAL SERVICES DIVISION

CANADA

SECRÉTARIAT D'ÉTAT
BUREAU DES TRADUCTIONS

DIVISION DES SERVICES MULTILINGUES

FoM 3160

TRANSLATED FROM — TRADUCTION DE: Russian

INTO — EN: English

AUTHOR — AUTEUR: Enyutina, R.I

TITLE IN ENGLISH — TITRE ANGLAIS:

The Amur pink salmon (Oncorhynchus gorbuscha): a commercial and biological survey

TITLE IN FOREIGN LANGUAGE (TRANSLITERATE FOREIGN CHARACTERS)
TITRE EN LANGUE ÉTRANGÈRE (TRANSCRIRE EN CARACTÈRES ROMAINS)

Amurskaya gorbusha (Promyslovo-biologicheskii ocherk)

REFERENCE IN FOREIGN LANGUAGE (NAME OF BOOK OR PUBLICATION) IN FULL. TRANSLITERATE FOREIGN CHARACTERS.
RÉFÉRENCE EN LANGUE ÉTRANGÈRE (NOM DU LIVRE OU PUBLICATION), AU COMPLET, TRANSCRIRE EN CARACTÈRES ROMAINS.

As above

REFERENCE IN ENGLISH — RÉFÉRENCE EN ANGLAIS

As above

PUBLISHER — ÉDITEUR	DATE OF PUBLICATION / DATE DE PUBLICATION			PAGE NUMBERS IN ORIGINAL / NUMÉROS DES PAGES DANS L'ORIGINAL
Pacific Research Institute of Fisheries and Oceanography(TINRO)	YEAR / ANNÉE	VOLUME	ISSUE NO. / NUMÉRO	3 - 126
PLACE OF PUBLICATION / LIEU DE PUBLICATION				NUMBER OF TYPED PAGES / NOMBRE DE PAGES DACTYLOGRAPHIÉES
Moscow, USSR	1972	77	-	214

REQUESTING DEPARTMENT / MINISTÈRE-CLIENT: Environment

TRANSLATION BUREAU NO. / NOTRE DOSSIER Nº: 784488

BRANCH OR DIVISION / DIRECTION OU DIVISION: Fisheries Service

TRANSLATOR (INITIALS) / TRADUCTEUR (INITIALES): BH/PJH

PERSON REQUESTING / DEMANDÉ PAR: Mr. H.D. Smith

YOUR NUMBER / VOTRE DOSSIER Nº: 769 - 18 - 14

DATE OF REQUEST / DATE DE LA DEMANDE: 27 December 1973

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

SOS-200-10-6 (REV. 2/68)
7530-21-029-5333

DEPARTMENT OF THE SECRETARY OF STATE
TRANSLATION BUREAU

MULTILINGUAL SERVICES DIVISION

CANADA

SECRÉTARIAT D'ÉTAT
BUREAU DES TRADUCTIONS

DIVISION DES SERVICES MULTILINGUES

CLIENT'S NO. N° DU CLIENT	DEPARTMENT MINISTERE	DIVISION/BRANCH DIVISION/DIRECTION	CITY VILLE
	Environment	Fisheries Service, Office of the Editor	Ottawa
BUREAU NO. N° DU BUREAU	LANGUAGE LANGUE	TRANSLATOR (INITIALS) TRADUCTEUR (INITIALES)	
784488	Russian	BH/PJH	AUG 2 4 1974

Tikhookeanskii nauchno-issledovatel'skii institut rybnogo khozyaistva i okeanografii (TINRO)

(Pacific Research Institute of Fisheries and Oceanography)

1972

THE AMUR PINK SALMON (<u>Oncorhynchus gorbuscha</u>): A COMMERCIAL AND BIOLOGICAL SURVEY

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

R. I. Enyutina

*Numbers in right margin indicate corresponding page numbers in original text.

SOS-200-10-31

INTRODUCTION /3/

In the past the pink salmon of the Amur basin occupied an important place in the salmon fishing industry of the Soviet Far East. By 1941 the mean catch in even years was 110 000-120 000 centners, out of a population of over 20 million fish, which was about 10% of the total pink salmon catch of Kamchatka, Sakhalin, the Okhotsk Fishing District and Primor'e (the Maritime Province).

The period of high pink salmon numbers was followed after 1941 by a considerable decline, the number falling gradually to reach in 1952 the lowest level recorded in the history of the industry: the catch fell to 9 000 centners out of a total population of 1 million fish.

Since 1953 the commercial exploitation of the pink salmon in the Amur basin has been under severe restriction: catches of Amur pink salmon now do not exceed 2 % of the far-eastern catches of this species and only in particularly plentiful years (1958), recurring in 10-yearly cycles, have they reached almost 25 %. The efforts of fisheries research scientists have therefore been directed primarily toward the development of measures to help to restore the pink salmon population. Many scientific papers and notes on the biology and exploitation of the Amur pink salmon have been published, but still more information of different sorts still remains stored in the archives of the Pacific Research Institute of Fisheries and Oceanography (TINRO) and its Amur branch. The absence of any general treatise on the pink salmon of the Amur basin, similar to those written by R.S. Semko for the Kamchatka pink salmon and by P.A. Dvinin for the pink salmon of Southern Sakhalin, combined with the considerable economic importance of this fish, led the writer to attempt to compile a general survey of the available scientific material in order to present as complete a picture as possible of the present level of our knowledge in this field.

This book consists of 10 sections dealing with such problems as the commercial exploitation, the state of the stocks and the biology of the Amur pink salmon, predicted catches of this fish and measures aimed at maintaining and increasing the stocks. A map of the spawning area and the approximate distribution of local salmon populations are given.

The material on which this book is based covers the period from 1900 to 1965. Besides published sources the following materials also have been used: statistics of catches of the Nizhne-Amurskii (Lower Amur) and Severo-Sakhalinskii (Northern Sakhalin) State Fishing Trusts; data collected at the Dal'ryba /4/ control stations from 1925 to 1941 and the fishery improvement stations of the Amurrybvod organization from 1949 to 1965 as regards the times of the spawning run, quantitative and qualitative estimates of spawning stocks of the pink salmon and of downstream-migrant young fish in inspected rivers, and data obtained by the headquarters of the Hydrometeorological Service of the Far East for levels, water and air temperatures, thickness of the snow, direction and force of the wind and fluctuations in tides. Biological information on the pink salmon of the Amur basin and adjacent regions is based on the results of research conducted by the Amur branch of TINRO, in which the author has participated for many years.

1. COMMERCIAL EXPLOITATION /5/

The same type of fishing equipment is used to catch the various forms of Pacific salmon in the Amur basin -- the pink salmon (Oncorhynchus gorbuscha), the summer chum (O. keta keta) and the autumn chum (O. keta autumnalis). The development of pink salmon fishing is therefore a part of the development of salmon fishing in the Amur basin in general. The catch is of course the principal element characterising the exploitation of any fish.

Catches of the pink salmon in the Amur basin will be examined for the sake of convenience for separate periods: from 1902 to 1940 they are taken from the works of B.A. Geineman (1911) and M.S. Aleksin (1923), the statistics of the Dal'rybvod organization and data of the Lower Amur and Northern Sakhalin Fisheries Trusts. Like all statistics they are not irreproachable. The figures for catches in 1902-1940 were probably not obtained with sufficient care for them to be taken as complete, for they did not account for salmon caught throughout the whole of its distribution area in this basin and the figures for the catch are not related to abundance of fish in the fisheries. However, for all their deficiencies, these figures to which I shall frequently refer have the great advantage that as a rule they were collected within the confines of virtually the same fishing district, although at one time it was called Nikolaevsk (until 1935)[1], but later the Lower Amur District[2]. Even allowing

---

[1]This included (Tikhenko, 1915) all the lower course of the River Amur from the village of Tsimmermanovka to its mouth, the lower course of the River Amgun' for a distance of 300 versts (321 km), the continental and Sakhalin shores of Amurskii Liman (Amur Sound) and the south-western coast of the Sea of Okhotsk to the west of the Straits within the boundaries of Udskii uezd (Uda County).

[2]This district included the lower course of the River Amur from the village of Kiselevo to its mouth, the continental shore of the Sound from Baidukov Island to Cape Lazarev, the shore of the Tatarskii Proliv (Tatar Straits) with De-Kastri Bay and the south-western coast of the Sea of Okhotsk from Baidukov Island to the River Kol'.

for some inaccuracies they nevertheless demonstrate the intensity of pink salmon fishing in past years and they give a clear idea of the state of the stocks of this fish in the various stages of development of the fishing industry.

Detailed information on the pre-Revolutionary period of the salmon fishing industry is given by Kramarenko (1898), Alekseev (1905), Geineman (1911), Trautshol'd (1912), Tikhenko (1915) and Lebedev (1916a, 1916b); their observations are described briefly in this section.

1. THE PRE-REVOLUTIONARY PERIOD AND PERIOD OF THE CIVIL WAR /6/

A. The Period Before the First World War (1902-1913)

Salmon fishing in the Amur basin was carried out originally for the personal needs of the local peasant and indigenous population. It was a purely local consumer activity for the lack of a railway prevented fish from the Amur from being sent to the central districts of Russia. Not until 1870 was the first catch of Amur salmon exported to certain neighbouring districts of Priamur'e

An impetus to the more rapid development of salmon fishing was given when, after 1892, fish could be sold to the owners of Japanese fishing vessels entering the lower reaches of the Amur River. At that time most fish was caught in Nikolaevsk District. Usually the Japanese bought the salmon from the local population, processed it by the use of their own labour, and then transported the finished salted product to Japan.

The importation of Amur fish into Japan increased from year to year. This can be judged from the number of Japanese sailing vessels carrying salmon from Nikolaevsk District: there were only two in 1892, but in each subsequent year including 1900 the numbers were four, six, eight, 18, 32, 24, 34 and 64 (Taguchi, 1963). In 1897 the Japanese not only purchased fish but also obtained the right to fish for salmon in areas reserved for their own use by means of trap nets in Amur Sound.

This fishing by the Japanese, processing their own fish, brought no profit to Russia. This fact compelled the Priamur'e Department of National Resources to issue regulations according to which salmon fishing by foreign ships was prohibited from 1899 in Nikolaevsk District. They were permitted only to purchase fish from the local population and to process it for preserving at special fish-processing stations leased by the Treasury. From that time the fishing industry in Nikolaevsk District started on a new phase of development: the whole of the local indigenous and peasant population took an active part in fishing; Russian entrepreneurs soon followed suit, and eventually the fishing industry became capitalist-owned.

After the signing of the Russo-Japanese Fisheries Convention for 12 years in 1907 the Japanese obtained the right to fish for salmon in Amur Sound, but only with the use of Russian labour. Because they were prohibited from using their own labour the Japanese found the fishing in that region less profitable and for that reason only seven curing stations were hired by the Japanese firm in those years; most were in the hands of Russian entrepreneurs.

Despite certain limitations applied to the Japanese, the scale of fishing for the Amur pink salmon increased year by year (Table 1) and on the average for even years (in the period 1908-1912) 5 million fish or 50 000 centners were exported to Japan.

By 1909, according to Tikhenko (1915), no fewer than 28 operating fish barriers of the Japanese type, 380 barriers of peasant type and 700 drag seines were counted in the lower reaches of the River Amur and Amur Sound.

Not satisfied with selling fresh fish at low prices to Japanese curers, Russian fishery owners began to seek an outlet for finished products in the markets of Western Siberia, European Russia, and even abroad. The demand for Amur fish increased progressively. This compelled the capitalist fishery owners to increase their output of fish products, and the peasants and local /7/ indigenous population changed from being catchers of fish to curers of fish, sometimes employed by an entrepreneur.

TABLE 1. Number of Pink Salmon Caught in Amur Sound and Exported to Japan from 1902 to 1914, in Millions of Fish (after Heineman, 1912; Pushkov, 1914; Lebedev, 1916)

Годы 1	Добыто в лимане 2	Вывезено в Японию 3	Годы 1	Добыто в лимане 2	Вывезено в Японию 3
1902	4,80	0,36	1909	2,95	2,21
1903	2,13	0,32	1910	7,70	4,50
1906	5,64	0,07	1911	3,86	2,55
1907	1,42	1,48	1912	7,53	5,00
1908	4,60	5,57[1]	1913	7,47	1,32
			1914	14,53	3,28

[1] These figures evidently include catches of pink salmon in fishery districts adjacent to the Sound.

KEY: (1) Years; (2) Taken in the Sound; (3) Exported to Japan.

The number of fishery enterprises under capitalist control increased rapidly. In the lower reaches of the River Amur and Amur Sound, according to Navozov-Lavrov (1927), their number varied in different years before the Revolution from 40 to 92. The peasant industry played an important role in salmon fishing. It yielded on the average 35 % of the total catch (Kuznetsov, 1923).

The revival of commercial activity in the period 1907-1914 led to an increase in the population in the lower Amur valley. For instance, according to figures given by Rusanov (1924a) the population of the town of Nikolaevsk increased from 5,700 in 1898 to 15,000 in 1914, while the peasant population of Nikolaevsk District increased from 2,200 to 4,100 from 1907 to 1914.

Many new villages appeared in the lower part of the Amur valley. They numbered 29 at the beginning of the First World War and three years later another five had been added (Dobrovol'skii, 1923). As the population increased so also did the scale of subsistence salmon fishing.

Before the war in Nikolaevsk District 74 fish-processing and 52 fish-catching sectors were being let out to tenant fishery entrepreneurs; barriers of Russo-Japanese type were used at 24 of these sectors, barriers of Gilyak type at three, and drag seines at 25 sectors (Rusanov, 1924b). The local population fished for salmon with 292 barriers of Gilyak type and 645 seines (Smetanin, 1929). As determined by Smetanin, in the period from 1907 to 1915 the average daily catch of Amur pink salmon was 6.9 million fish (83 000 centners), of which 5.4 million fish were accounted for by commercial fisheries and 1.5 million fish by the local population.

In 1910-1911 the Japanese harvests of salmon in Amur Sound fell sharply for the fortunes of the market turned in favour of Russian capital. In 1913 most of the fishing sectors in Nikolaevsk District were in the hands of Russian entrepreneurs, who processed chiefly pink salmon for the Japanese market. The scale of this processing had fallen considerably by 1914, whereas salmon processing for the Russian market had increased (Table 2). An important contributory factor to this result was the construction of the Trans-Siberian Railway connecting the Far East with Central Russia. /8/

With the development of Japanese fisheries in the Russian coastal and sea waters (especially in Kamchatka), Japanese purchases of fish caught in Nikolaevsk District also began to fall after 1913. According to Lebedev (1916a), for instance, purchases of pink salmon in the Amur in 1912 amounted to 4.9 million fish, but to only 1 million fish in 1913.

Exploitation of Amur salmon, which began by subsistence fishing, was thus converted with the passage of time into a major commercial enterprise. The pre-war period was characterized by a decrease in Japanese purchases and the completion of the victory of Russian entrepreneurs with the nationalization of the fishing industry. The period from 1909 to 1914 was one of established commercial fishing on the Amur. Of the total number of Amur salmon caught in 1902-1913, the pink salmon accounted for about 22 % and, as Table 3 shows, the actual catches were comparatively high, reaching on the average 5.6 million fish (about 60 000 centners) in even years and 3.4 million fish (about 50 000 centners) in odd years[1].

TABLE 2. Relative Quantities of Pink Salmon Prepared for the Home and Export Markets (after Tikhenko, 1915)

Годы 1	Всего заготовлено, тыс. шт. 2	3 В том числе, %	
		на русский рынок 4	на японский рынок 5
1910	316	39	61
1911	87	31	69
1912	718	57	43
1913	1039	57	43
1914	1812	82	18

KEY: (1) Years (2) Total number of fish processed, in thousands (3) Comprising, per cent (4) For the Russian market (5) For the Japanese market

B. The War Period and the Years of Japanese Intervention (1914-1922)

Genuine interest was not shown in the pink salmon as an object of commerce until the period of the First World War, when the demand for prepared fish products increased enormously. The catch of this fish in Nikolaevsk District in 1914-1918 reached 13 million fish or 140 000 centners in the even years (Table 3).

---

[1] The mean weight of a pink salmon here and later in Table 3 is taken as 1.1 kg in even years and 1.4 kg in odd years.

The Japanese contribution to the fishing industry in Nikolaevsk District continued to diminish. In 1914 the Japanese had only seven curing stations on the Sakhalin shore of Amur Sound, where they both caught and processed the pink salmon (Tikhenko, 1915), and one sea-fishing sector leased for a three-year period (1914-1916). The Japanese purchased Amur pink salmon from 28 sectors in Nikolaevsk District (Lebedev, 1916b).

After 19 09 direct correlation could no longer be found between the quantity of fishing gear and the size of the catch of pink salmon, for the size of the catches decreased faster than the contraction of the industry (Smirnov, 1947). The figures for the catches of pink salmon in Amur Sound after 1908 are therefore also pointers to the state of its stocks.

After 1914 poor catches of pink salmon in odd years became particularly /9/ conspicuous. Catches of the odd year-classes in this period on the average did not exceed 750 000 fish per annum, equivalent to a weight of approximately 10 000 centners.

However, despite these sharp fluctuations in the pink salmon catches, the period 1915-1917 was comparatively favourable for the development of the Russian fishing industry on the Amur (Smetanin, 1929). By 1915 the Japanese market had taken second place to the increased home market, and by the end of 1917 the fishing industry of Nikolaevsk District was completely independent /10/ of the low prices of the Japanese market and the entire production of fish from this district was disposed of in Russia.

The Russian fishing industry began to undergo modification also in its organization. In 1916 the Zakupsbyt Cooperative Organization and the Tsentrosoyuz * Office first appeared; through their agents these organizations processed Amur salmon for sale in the Far East and Siberia. According to the bulletin of the Board of Control of Fisheries and the State Fishing Industry

* Central Union of Consumers' Societies - Transl.

TABLE 3. Catches of Pink Salmon in the Amur Basin in the Period 1902-1940[1]

Годы	Амурские промыслы		Сахалинские промыслы		Всего	
	млн. шт.	тыс. ц	млн. шт.	тыс. ц	млн. шт.	тыс. ц
1902	Combined catches / Уловы объединены				4,80	52,8
1903					2,13	29,8
1904					3,46	38,1
1905					2,34	32,8
1906					5,61	62,0
1907	1,35	18,9	0,07	1,0	1,42	19,9
1908	4,57	50,3	0,03	0,3	4,60	50,6
1909	2,55	35,8	0.40	5,5	2,95	41,3
1910	7,50	82,7	0,20	2,0	7,70	84,7
1911	3,52	49,4	0,34	4,6	3,86	54,0
1912	6,71	73,9	0,82	8,9	7,53	82,8
1913	7,21	101,6	0,26	3,0	7,47	104,6
1914	14,40	158,3	0,13	1,6	14,53	159,9
1915	0,86	12,0	0,13	1,8	0,99	13,8
1916	8,22	90,7	1,02	10,9	9,24	101,6
1917	0,52	7,3	0,04	0,5	0,56	7,8
1918	13,30	146,0	1,58	17,7	14,88	163.7
1919	0.39	5,5	0.03	0,4	0,42	5,9
1920	11,90	131,0	0,10	1,0	12,00	132,0
1921	0.19	2,6	0.01	0,2	0,20	2,8
1922	8.88	97,8	0.12	1,2	9,00	99,0
1923	0,13	1,8	0,01	0,1	0,14	1,9
1924	10,95	120,6	1,97	21,5	12,92	142,1
1925	—	—	—	—	—	—
1926	14.64	161.3	2,51	27,3	17,15	188.6
1927	0.19	2.7	—	—	0,19	2.7
1928	11,62	128,1	6,22	68,1	17,84	196,2
1929	—	—	—	—	—	—
1930	8.15	89,3	1.51	17,0	9.66	106.3
1931	0.34	4.8	0,01	0.1	0.35	4.9
1932	8.21	90,2	1,87	20.7	10.08	110.9
1933	0.11	1.5	0.42	5.9	0.53	7.4
1934	5.75	63.3	3,61	39,7	9,36	103.0
1935	0.28	3.9	0.31	4.3	0.59	8.2
1936	2.73	30.1	2,33	25.5	5,06	55,6
1937	0.45	6.3	1,19	16,7	1.64	23.0
1938	6.36	70.0	5.42	59,6	11,78	129,6
1939	3.07	43.0	2.53	35.4	5,60	78.4
1940	3,32	36,5	0,50	5,5	3,82	42,0

[1] Catches from 1902 to 1906 taken from Geineman (1911), from 1907 to 1922 from Aleksin (1923), from 1923 to 1933 from the statistics of Dal'rybvod, from 1934 to 1940 from the statistics of the Lower Amur and North Sakhalin Fisheries Trusts (from 1902 to 1933 for the Nikolaevsk Commercial District, from 1934 to 1939 catches at the De-Kastri, Ayana, Kol' and Cape Petrovskaya fisheries and the Chkalov fish factory are excluded). The catches of the Sakhalin fisheries from 1933 to 1940 include catches of the south-west and east coasts of Sakhalin.

KEY; (1) Years (2) Amur fisheries (3) Millions of fish (4) Thousands of centners (5) Sakhalin fisheries (6) Total

(1923, No. 9), by 1918 in the region of Nikolaevsk and above the use of barriers was replaced almost everywhere by seining, and in the Sound only eight of the original 16 barriers still remained. The intensive development of seining in the lower reaches of the River Amur and in Amur Sound led to the establishment of fisheries there by Russian capitalists.

The Japanese intervention caused much damage to the Russian fishing industry. In the course of three years (1920-1922) nearly all the best equipped and most soundly organized fisheries located below Nikolaevsk were burned or razed to the ground (Navozov-Lavrov, 1927). The Ozerpakha Fish Preserving Factory was completely destroyed (Il'in, 1927) and many of the villages with all their fishing equipment were burned.

Having obtained from Kolchak's government in Omsk an extension to the convention in 1919 the Japanese continued to exploit the fishery sectors although they no longer paid for their hire (Kosakov, 1924). In 1922 in Nikolaevsk District they occupied 85 of the 101 fishery sectors still working (Gruzdovskii, 1925). In 1920-1922 the Nikolaevsk District once again was working almost entirely for the Japanese market: 91.2 % of the salmon catch was exported to Japan leaving only 8.8 % for the Russian market (Kozakov, 1923).

Pink salmon fishing by the Japanese continued no less intensively than before: the number of barriers was increased by the occupying Japanese to 31 (Ekonom. Zhizn' Dal'nego Vostoka, 1924, No. 1/15). The pink salmon catches, which remained extremely small in 1919 and 1921 (on the average 300 000 fish, or 4 000 centners, were caught annually), were high in the even years -- not less than 10 million fish or about 115 000 centners per annum (Table 3).

The years of the First World War and Civil War were thus characterized by the high intensification of pink salmon fishing on the Amur. During this period, in the even years, the catches of pink salmon averaged about 45 % of the catches of the summer and autumn chum, i.e., they were almost twice as high as in the pre-war years. As a result of the sharp and considerable fluctuations in the numbers of spawning stocks of pink salmon during these years the mean catch of this fish in the even years was 11.9 million (about 130 000 centners) but only 0.5 million fish (about 7 000 centners) in odd years.

2. THE SOVIET PERIOD

A. The Period Before the Second World War (1923-1940)

With the establishment of Soviet rule in the Far Eastern Territory the fishing industry was not nationalized. Only the waters themselves were taken over by the State. The fishery buildings, the equipment and the fishing fleet remained in private hands as before.

On the Amur 1923 was the year of rebirth of the Russian fisheries. In /11/
the lower Amur fishing district only 41 peasant and 28 capitalist fisheries were working (Navozov-Lavrov, 1927). Temporary makeshift buildings were put up quickly for processing the fish. The Japanese entrepreneurs had lost their access to commercial salmon fishing on the Amur. At the beginning of 1923 the first state-owned fishing enterprise (Dal'gosrybprom) was established. For the State to exert its influence on the fishing industry and also in order to obtain funds, a joint-stock company was established by Dal'gosrybprom in conjunction with the "Lyuri" Trading Company in four sectors of the lower reaches of the River Amur (Andrianov, 1924).

In 1929 in Nikolaevsk District there were only 18 fishery sectors including those in Amur Sound part of Sakhalin; the largest salmon fisheries in this region were entirely in the hands of State and cooperative organizations.

Most of the salmon was salted for the Russian market but some was exported in the fresh-frozen form abroad (Red'ko, 1929).

Industrialization of the Far Eastern Territory, which began in 1929, brought a new influx of population into the Amur valley. According to figures obtained by the Khabarovsk Provincial statistical department the population of the largest industrial centre on the Amur, the town of Komsomol'sk, was 70 800 in 1939, i.e. seven years after the town started to be built. The population of Nikolaevsk-on-Amur increased from 5 100 in 1923 (Lagutin, 1926) to 17 000 in 1939.

The Lower Amur State Fisheries Trust, with a system of fish factories and depots, located chiefly along the continental shore of Amur Sound and in the main channel of the Amur River, was created in 1932. Together with the creation of fishery collectives, this event led to a further influx of the rural population. From 1926 to 1939, according to figures of the statistical department, it increased in the Lower Amur District by three times, in Ul'chskoi District by 4.6 times, and in the P. Osipenko District by 4.8 times. The increase in population naturally meant an increase in salmon fishing for local consumption, with a consequent and considerable intensification of the industry.

The Soviet pre-war period of the pink salmon fishing industry was similar in character to the preceding period (1914-1922), i.e., it was marked by high catches of year-classes in even years and extremely low catches of year-classes in odd years, except in 1939. The pink salmon stocks of odd year-classes in 1923-1937 were so exhausted that after 1925 commercial pink salmon fishing in the Amur basin in odd years was prohibited for a period of eight years. Only the local indigenous population (Arctic peoples) had the right to fish and only on a scale necessary for their personal requirements and for feeding their haulage dogs. Catches of pink salmon of odd year-classes with this limitation on the industry, averaged only 0.3 million fish (about 4 000 centners).

Pink salmon fishing in this period was based on year-classes of even years. In the lower reaches of the River Amur and in Amur Sound, together with the north-west coast of Sakhalin, the mean annual catch of pink salmon in even years was 13.5 million fish (about 148 000 centners). The commercial importance of the pink salmon, compared with the Amur summer and autumn chum, as before was considerable: the mean annual catches in even years were (by weight) about 38 % in the period 1923-1932, i.e., more than one-third[1].

B. The Period of the Second World War (1941-1945) /12/

The Second World War presented the fishing industry of the Amur basin with an extremely important task: despite the difficulties of wartime, to increase the catch of fish in every possible way. From the second half of 1941 until the end of the war the whole activity of the fishing industry was reorganized to suit the conditions and requirements of wartime.

Salmon fishing was carried out not only by the State (Goslov) and collective (Kolkhoz) sectors. Because of the economic difficulties, the system of "fishing by auxiliary suppliers" -- various institutions and organizations -- achieved considerable popularity. It was carried out chiefly in the main channel of the Amur, where it was almost the only method used, accounting for 95 % of the total catch of pink salmon in odd years, i.e., years of poor catches. The catches of pink salmon of odd year-classes were at least as high as in the 1920s-1930s, with a mean annual value of 1.2 million fish (or 16 000 centners) (Table 4). The catches of even year-classes of pink salmon, however, were

[1]From 1933 to 1939, because of the absence of appropriate figures, the pink salmon catch on the south-west and east coasts of Sakhalin was included in that for Rybnovsk District.

only half the pre-war level, averaging about 6 million fish per annum (or 69 000 centners) for the Amur basin together with the north-west coast of Sakhalin.

The figures given in Table 5 demonstrate the decrease in pink salmon yields during wartime years (with an increase in the quantity of fishing equipment).

Despite intensification of the industry, the pink salmon catches thus showed no increase in wartime.

C. The Post-War Period (1946-1965)

The post-war period in the pink salmon fishing industry on the Amur can be divided into two stages. The first stage (1946-1952) is marked by high catches with all forms of equipment which could be got ready for fishing, although numerically speaking the amount of equipment was less than in 1941-1944[1]. The second stage, starting in 1953, is one of prohibition or limitation of pink salmon fishing in odd years and also, as a rule, some limitation of the catch in even years. During years of prohibition of the industry usually barriers, sometimes trap nets, were used in Amur Sound as a device for monitoring the catch. On the right coast of the Sound, starting in 1957 test fishing has been carried out by the Aleevskii barrier situated 6 km to the south-west of Cape Pronge; on the left coast of Amur Sound, near Cape Tabakh, the Chardbakhskii test barrier has been in operation. Test pink salmon fishing has also been carried out in one of the spawning rivers of the Amur basin -- the River Amgun'; a drag seine was in operation there from 1948 to 1955 and a drift net from 1961 to 1967.

---

[1]In 1946, 1948 and 1950 the number of barriers in waters of the Lower Amur Trust was 43-61, together with 25-29 trap nets and 72-81 drag seines.

TABLE 4. Catches of Pink Salmon in the Amur Basin in the Period 1941-1965[1] /13/

(1) Годы	(2) Предприятия Нижне-Амурского рыбтреста						(6) Северо-западное побережье Сахалина		Total Всего	
	(3) Материковое побережье и низовья Амура		(4) Русло Амура выше г. Николаевска		(5) Всего по Амуру					
	(7) тыс. ц	%	(7) тыс. ц	%	(7) тыс. ц	%	(8) млн. шт.	(7) тыс. ц	(8) млн. шт.	(7) тыс. ц
1941	12,8	99,2	0,1	0,8	1,00	12,9	0,51	6,6	1,51	19,5
1942	59,4	77,5	17,2	22,5	6,96	76,6	1,13	12,4	8,09	89,0
1943	11,7	73,6	4,2	26,4	1,14	15,9	0,24	3,3	1,38	19,2
1944	35,4	74,8	11,9	25,2	3,64	47,3	0,71	7,7	4,35	55,0
1945	4,5	52,9	4,0	47,1	0,71	8,5	0,08	1.0	0,79	9,5
1946	39,2	69,3	17,4	30,7	5.09	56,6	0,49	5,4	5,58	62,0
1947	4,5	52,3	4,1	47,7	0.61	8,6	0,13	1,8	0,74	10,4
1948	93,6	80,7	22,4	19,3	9,67	116,0	1,14	12,5	10,81	128,5
1949	4,3	63,3	2.5	36,7	0,57	6.8	0,74	8,9	1,31	15,7
1950	8,0	69,0	3,6	31,0	0,83	11,6	0,06	0,9	0,89	12,5
1951	6.7	48,8	7.0	51,2	1,05	13,7	0,71	9,3	1,76	23,0
1952	6,7	93,0	0,5	7,0	0,48	7,2	0,13	1,9	0,61	9,1
1953	7,6	93,7	0,1	1,3	0,59	7,7	0,07	0,9	0,66	8,6
1954	1,1	91,7	0,1	8,3	0,09	1,2	0,15	2,3	0,24	3,5
1955	3.3	100,0	—	—	0,21	3,3	0.05	0,7	0,26	4,0
1956	9,0	100,0	—	—	0,64	9,0	1.43	20.0	2,07	29,0
1957	4,4	100,0	—	—	0,29	4,4	0,04	0,6	0,33	5,0
1958	60,0	85,7	10,0	14,3	7,00	70,0	2,00	20,0	9,00	90,0
1959	5.7	100,0	—	—	0,36	5,7	0,14	2,3	0,50	8,0
1960	22,8	71,5	9,1	28,5	2,45	31,9	0.14	1,7	2,59	33,6
1961	0,7	87,5	0,1	12,5	0,05	0,8	0,08	1,4	0,13	2,2
1962	4,1	78,8	1,1	21,2	0,29	5,2	0,02	0,3	0,31	5,5
1963	6,6	95,6	0,3	4,4	0,35	6,9	0,09	1,6	0,47	8,5
1964	5,6[3]	97,5	0,1[2]	2,5	0,22[3]	5,7[2]	0,03[3]	0,5[3]	0,35[3]	6,2[3]
1965	4,2[2]	95,5	0,2[2]	4.5	0,26[2]	4,4[2]	0,24[3]	2,5[3]	0,50[3]	6,9[3]

KEY: (1) Years (2) Enterprises of the Lower Amur Fisheries Trust (3) Continental shore and lower reaches of the Amur (4) Main channel of the Amur above Nikolaevsk (5) Total for the Amur (6) North-west coast of Sakhalin (7) Thousands of centners (8) Millions of fish

---

[1]Before 1948 catches were converted from weight to numbers as in Table 3, but from 1948 to 1965 the conversion was done allowing for the mean weight of a pink salmon for each year separately.

The following enterprises are engaged in fishing on the continental shore of Amur Sound and lower reaches of the Amur: Baidakov Island, Puir, Ozerpakh, Tneivakh, Chnyrrakh, N. Pronge, Dzhaore, and Cape Lazarev. Fish in the main channel of the Amur are caught by employees of four fish factories situated in Orel'-Chlya, Tyr', Solontsy and Marinsk. The north-west coast of Sakhalin includes catches obtained in Amur Sound and landed at the fisheries of the Rybnovsk Fisheries Combine and further south (in Tangi), and also the Lyugi fishery situated to the north of Amur Sound, in the Gulf of Sakhalin.

[2]Fishing prohibited (catches by test fishing equipment only).

[3]Fishing restricted.

TABLE 5. Quantity of Salmon Fishing Equipment and Catch of Pink Salmon by the Lower Amur Trust in 1941-1944

Орудия лова 1	1941	1942	1943	1944
Невода ставные 2	44	101	136	102
» закидные 3	308	358	438	395
Заездки 4	50	45	55	117
Вылов, тыс. ц 5	18,1	74,3	18,9	48,4

KEY: (1) Fishing equipment (2) Trap nets (3) Drag seines (4) Barriers (5) Catch, thousands of centners

Before the introduction of prohibition, i.e., in the period from 1946 to 1952, the mean catch of pink salmon in the Amur basin, together with the northwest coast of Sakhalin, averaged 16 000 centners or about 1.2 million fish in odd years and 52 300 centners, or about 4.4 million fish, in even years. The comparatively high mean catch of pink salmon in the even years of this period was due entirely to the large year-class of upstream migrants in 1948.

The removal of relatively large numbers of fish from the reduced pink salmon stocks of the odd year-classes along the migration routes from year to year diminished the size of these stocks still further and did not leave a /14/ spawning ground for a sufficiently large number of brood stock to replenish the reserves. Since 1953 fishing for Amur pink salmon of odd year-classes has therefore been prohibited.

After 1952 Japanese sea fishing for salmon began to develop intensively. Pink salmon of the Amur basin was being caught in the southern part of the general area of distribution of these fish, to the south of latitude 40°N, and pressure on the industry was particularly strong before 1958 (Kotov, 1957); later, however, it was limited by the Fishing Convention which is now in force. In 1953-1964 the mean catches of even year-classes of pink salmon were about 28 000 centners or 2.4 million fish per annum. However, remembering that catches of the pink salmon were limited in 1954, 1956, 1958 and 1964, this figure as a reflection of the level of the pink salmon stocks must be regarded as rather on the low side.

In the post-war period the mean annual catch of even year-classes of pink salmon, despite considerable fluctuations in individual years (from 3 500 to 120 800 centners), has thus been about 38 000 centners or 3.2 million fish.

II. POPULATION DYNAMICS

As with other Pacific salmon the pink salmon population is not constant. It varies both from year to year and also over longer periods.

At the beginning of the 20th century, when commercial exploitation of the pink salmon stocks of the Amur was only just beginning, marked fluctuations or, to use the modern term, periodicity, was found in the catches: in even years more pink salmon were caught than in odd years (see Tables 1 and 3). Alternation of weak and strong year-classes is also observed in the pink salmon in other fishing districts than the Amur basin: Primor'e, Sakhalin, the west and east coasts of Kamchatka, the continental shore of the Sea of Okhotsk, and also the north-eastern part of the Pacific Ocean.

Most investigators have explained the fluctuations in the pink salmon population in even and odd years by its two-year life cycle and have linked it with the effects of environmental conditions in the river. Tikhii (1926), Pritchard (1938) and Pravdin (1940), for example, considered that these cyclic changes were caused by some sort of "catastrophe," causing death of one year-class; besides this same cause, Soldatov (1938) also suggested overfishing of one year-class. Davidson (1934) and Semko (1939) attributed these fluctuations on the one hand to environmental conditions affecting one year-class unfavourably, and on the other hand to the effects of fishing. Derzhavin (1930) and Kaganovskii (1949) rejected any effect of commercial fishing and regarded the cause of periodic fluctuations in the pink salmon population as environmental conditions not yet explained. Nikol'skii (1952) suggested that sea and freshwater conditions have some effect on the occurrence of this biannual population cycle. He considered that the "biannual cycle of the pink salmon population is an adaptation connected with the specific pattern of food relationships in the two successive year-classes in the sea" and that "this type of population dynamics could be formed only as an adaptation to stable conditions of reproduction (spawning in areas of the channel with the fastest rates of flow and with minimal deposition of silt), always ensuring a guaranteed minimum of replenishment."

Birman and Levanidov (1953) also supported the theory of a biannual life cycle of the pink salmon and explained this cycle by contradictions between successive year-classes in the sea based on food supply, which "do not permit the existence for any length of time in nature of the two successive pink salmon populations in equal or approximately equal numbers," on account of which one /16/ year-class directly or indirectly limits the population of the other. This theory was later confirmed by Birman (1954).

Semko (1954) analysed the available facts and reached the opposite conclusion, to the effect that the pink salmon population as a rule is not limited by the food reserves in its feeding ground. Abramov (1954) likewise finds no contradiction between the fish population and the food supply available in the sea and postulates that the most important factor in this case is the abiotic conditions in the spawning grounds and biotic conditions (predators and competitors) in the rivers and sea. More recently Birman (1966), recognising a strictly biannual life cycle of the pink salmon on the basis of investigations of the sea, has explained this biannual cycle of strong and weak year-classes also on account of biannual periods of fluctuations of the Kuroshio, although he recognised that this periodicity is not entirely the result of the unilateral action of climatic conditions, but that it is also an inherent property of the pink salmon as a rule governing the dynamics of its stock.

Another group of investigators does not consider that the age of the pink salmon is two years and consequently does not link the fluctuation in numbers of this species in even and odd years with this factor. Monastyrskii (1952), for example, who accepts the heterogeneous nature of individual year-classes of the pink salmon, considers that this cycle results from the alternation of abundant and sparse year-classes depending chiefly on the conditions of reproduction. Vedenskii (1954) explained the existence of the biannual cycle on the grounds that the age of the pink salmon is four years and that the food supply in the sea is inadequate, whereas Lapin (1963) regards the segregation of the single stock in time, because of differences in the time of maturing of individual fish, as the cause of the appearance and disappearance of the two-year cycle.

A characteristic feature of the two-year cycle is an increase in the amplitude of the fluctuations in catches during periods of most intensive fishing activity. On the Amur this was observed in the period from 1914 to 1935. In consecutive years the amplitude of these fluctuations amounted to 1: 64 (for 1922-1923).

Besides the two-year cycle, Kuznetsov (1923), Smirnov (1947) and others have described alternation of pink salmon catches in four-year periods, although they do not discuss the reasons for this phenomenon. Nikol'skii (1954) also notes a less clearly defined ten-year cycle for the pink salmon. In the Amur basin the largest spawning migrations of the pink salmon were observed in 1928, 1938 and 1948, and Birman (1955) attributes this phenomenon to the influence of maxima of solar activity. Particularly abundant pink salmon migrations also were repeated in 1958.

The pink salmon population also varies over longer periods, which Kaganovskii (1949) explains by climatic factors: by cooling or warming of the waters in the northern part of the Pacific Ocean. Besides the fluctuations in the pink salmon population annually and over longer periods already mentioned, cases have been reportedwhere the salmon migrations in consecutive years were about equal in number. This happened on the Amur in 1912-1913, in 1939-1940, for the five years from 1949 to 1953, in 1959-1960 and in 1961-1962. The fluctuations in the pink salmon population are thus varied in character and sometimes they may be absent.

The most typical of all the examples given are the biannual fluctuations /17/ in the pink salmon population. The "catastrophe" theory does not satisfactorily explain their appearance, for it is unlikely that such catastrophes would take place in all areas where the pink salmon is found. The theory that commercial fishing is solely responsible, by depleting the stocks of one year-class, likewise cannot be justified for fluctuations in the pink salmon population in even and odd years occurred before the beginning of industrial exploitation. The biannual cycle likewise cannot be explained by the conditions of breeding of the pink salmon, for in different years they may be sometimes favourable, sometimes unfavourable, yet as a rule the dominance of one year-class remains constant.

If neither commercial fishing nor the conditions under which the pink salmon spends the river period of its life are responsible for the biannual fluctuations in its population, the explanation can only be sought in the conditions of life of the fish during its period in the sea. Two possible lines of research have so far been followed:

a) the study of conflict between consecutive (non-mixing) year-classes the basis of food supply;

b) the study of the age structure of the stock and acceptance of the segregation of individual spawning populations on account of differences in the time when individual fish mature.

Which of these two explanations will provide a true and complete answer to the biannual cycle of the pink salmon, or whether some completely different explanation will be required, only time will show. At present, however, all that is known for certain is that this phenomenon, as Kaganovskii (1949) rightly stated, is a rule characteristic of the pink salmon as a species, and an adaptive property responsible for rapidity of maturing, the rapid rate of renewal of the spawning stocks, and its numerical predominance over other species of the genus Oncorhynchus (Birman and Levanidov, 1953).

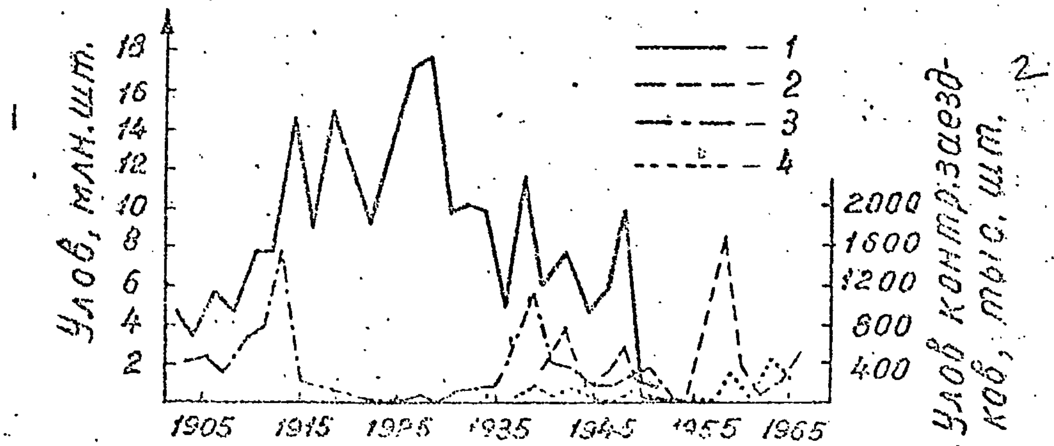

Fig. 1. Dynamics of the pink salmon catch in the Amur basin. Catches in even years: 1) commercial, 2) with test barriers; catches in odd years: 3) commercial, 4) with test barriers.

Key: (1) catch, millions of fish (2) catch with test barriers, thousands of fish

Catches of pink salmon of even year-classes (Fig. 1), despite the sharp and considerable fluctuations over a period of 64 years and the depression in 1950-1954, have always exceeded in size the catches of pink salmon of odd year-classesexcept in 1963, as will be specially discussed below. For the Amur pink salmon, unlike this species in other commercial fishing districts of the Far East, a constant biannual cycle with no deviation from the alternations of abundance of spawning migrations in even and odd years, is thus a characteristic feature.

/18/

III. THE SPAWNING STOCK

1. The Spawning Area

As a result of many years of research I.I. Kuznetsov defined the extent and the state of the spawning grounds of the pink salmon in the Amur basin and added to the earlier information given by Brazhnikov (1900) and Soldatov (1912) on the upper limit of its spawning area. This information was augmented and some of its details filled in as a result of later work by expeditions of the Amurrybvod organization and of the Amgun' station of the Amur Division of TINRO.

The spawning area of the pink salmon (Fig. 2) occupies the basin of the Lower Amur and Amur Sound. It includes 39 rivers, 24 of them tributaries of the Amur itself, eight feeding lakes communicating with the main channel, and seven entering Amur Sound.

Before 1910-1912 the pink salmon settled in large numbers in many of the rivers of the Amur basin. It was found in all rivers of Amur Sound and travelled upstream from the mouth for a distance of 700 km, reaching the River Khungari, a tributary of the Amur on its right bank, regarded as the upper limit of its spawning area. After 1912 the density of occupation of the spawning area gradually diminished. Poor catches of pink salmon were first observed in the highest spawning tributaries of the Amur -- the Rivers Pisui, Machtovaya and Gorin. After 1918 migration of the pink salmon into the Rivers Gorin, Khal'bao and Yai almost completely ceased, and only a few pink salmon frequented the River Beshenaya. By 1921 comparatively small migrations of pink salmon were also observed in the Rivers Yai, Machtovaya and Salasu, tributaries of Lake Udyl', and in the River Khilka. At the present time the pink salmon is almost completely absent from the region of the uppermost spawning grounds of the Amur -- in the Rivers Khungari, Gorin, Khal'bao and Machtovaya. The upper limit of the present spawning area of the pink salmon has now descended along the Amur for almost 200 km and large numbers of pink salmon no longer ascend above the River Salasu.

The contraction of the spawning area of the pink salmon in the Amur basin has taken place on account of a general decrease in the stock of the Amur pink salmon due primarily to climatic causes (low winter snowfall). Another contributory factor has been the rendering of certain spawning rivers useless for this purpose because of human activity (settlement in certain districts). Many rivers lost their spawning importance because of a fall in the water table as long ago as in the 1920s. For this reason the pink salmon has ceased or almost ceased to visit small streams in the lower reaches of the Amur, the estuary and Amur Sound: the Aksha, Kamora, Charrakh, Naleo and Lyangrovaya.

The general diminution in the stock of the Amur pink salmon caused by /19/
unfavourable climatic conditions and the consequent unusability of a certain part of the spawning area has thus led to a contraction of the spawning stock and to a narrowing of the spawning area of this species.

The sharp rise in the pink salmon population in certain years led to a wider distribution of the fish in the main channel and the spawning tributaries. In 1914, for instance, when the fish migrated in large numbers, good catches were obtained above the village of Bogorodskii (240 km from the mouth), whereas in 1913, when there were very few pink salmon, hardly any were caught higher than 150 km from the mouth (Tikhenko, 1915). In 1958, another year of particularly abundant migration, pink salmon ascended the Amur, as the statistics

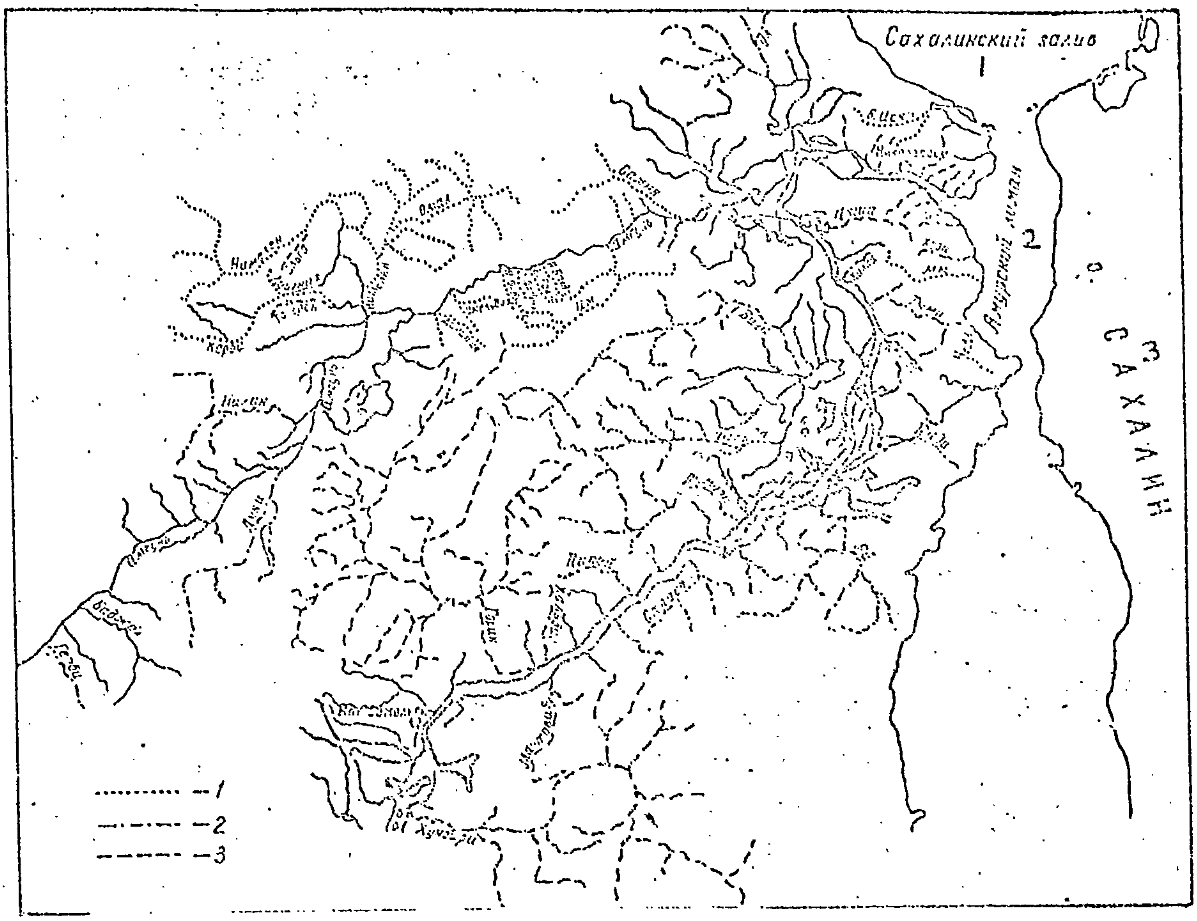

Fig. 2. Spawning area of the pink salmon of the Amur basin: 1) densely populated spawning grounds, 2) thinly populated, 3) spawning grounds visited by the pink salmon in the past.

Key: (1) Gulf of Sakhalin (2) Amur Sound (3) Sakhalin Island.

---

of Amurrybvod show, even beyond the River Khungari to reach the River Anyui 810 km from the mouth. In 1958 the pink salmon ascended the main channel of /20/ the River Amgun' for a distance of nearly 550 km, i.e., more than 100 km higher than usually; the fish spawned in the tributaries Usman, Merek and Guginka, in which nobody had previously seen it. However, this did not happen everywhere. In 1948, for example, despite an exceptionally abundant migration of the pink salmon the region of its spread was restricted to the lower reaches of the Amur: fish with sex products almost ripe in the Amur

Sound could not ascend further along the Amur River because the high temperatures stimulated their development, so that they were distributed among the lower tributaries, chiefly the Amgun'. The distribution of the pink salmon in the Amur basin, as these examples show, is not determined strictly by instinct for its natal river. Occupation of the spawning area is thus an active method whereby the pink salmon adapts itself to the conditions of reproduction, depending on its numbers, the state of the spawning grounds and the physiological state of the migrating fish.

2. Importance of Individual Rivers and Districts in Reproduction

The relative importance of individual river systems in the natural reproduction of the pink salmon of the Amur basin will be examined with special reference to four districts:

1. Rivers of the continental shore of Amur Sound (from north to south) -- the Lyangrovaya, Charrakh, Khuzy, My, Uarke, Tymi and Chomi.

2. The rivers of the Amur estuary (from below upward) along the right bank: Naleo, Tarakanovka and Zubarevka, and along the left bank: Chardbakh, Vakkar, Praure, and Malaya and Bol'shaya Patkha.

3. Tributaries of the Amur (except the River Amgun') -- left bank: the Rivers Kamora and Lichi (near Nikolaevsk) and the River Ul, flowing into Lake Orel', connected with the Amur by a channel; next, the Rivers Bichi, Bitki and Pil'da in the basin of Lake Udyl', connected with the Amur by the Ukhtinskaya channel, into which flows the River Uta, and much higher still, the Rivers Limuri, Pisui, Khal'bao and Gorin; tributaries on the right bank: the Rivers Aksha[1], Khilka, Gera, and Krivaya and Pryamaya Kenzha, Uki[1], Ai[2], Bystraya,

---

[1]Flows into the Lake of the corresponding name.
2Flows into Lake Kizi.

Beshenaya, Salasu, Ul'chi, Tuchanka (Kurgu vtoraya), Machtovaya (Tudur) and Khungari.

4. The basin of the River Amgun', which occupies a particularly important place in the system of the spawning rivers. The River Amgun' flows into the Amur on the left bank 145 km from its mouth. In the lower course of the Amur it is the largest tributary, more than 900 km in length, and the main spawning ground for the pink salmon and the summer chum. It receives several major tributaries, essentially large rivers, reaching 150-300 km or more in length. The total length of all the spawning channels exceeds 2 000 km. From below upward they are arranged in the following order: Samnya, Nizhnyaya Uda, Verkhnyaya Uda, Lyusa, Nizhnyaya Bal'za, Verkhnyaya Bal'za, Im, Nizhnyaya Balda, Verkhnyaya Balda, Nizhnii Gorbylyak, Verkhnii Gorbylyak, Omel'din, Dimitin, Nimelen, Nilan, Duki, Egogna and Gerbi. The River Gerbi joins the Amgun' approximately 900 km from its mouth. Consequently, the pink salmon ascends further along the Amgun' than along the Amur.

Statistics obtained by the observer check points of Dal'ryba and the fisheries improvement stations of Amurrybvod furnish the basis for determination of the relative importance of individual rivers and districts in the /21/ reproduction of the pink salmon. The former, 13 in number, functioned in the pre-war period from 1925 to 1941; the latter, numbering six, have functioned since 1949. Since counting the number of salmon in the spawning rivers was interrupted during the years of the Second World War and since the post-war period differed from the pre-war period in the considerable contraction of the pink salmon stock, I decided to examine this problem for two distinct periods of time: pre-war (1925-1941) and post-war (1949-1965).

One of the disadvantages of statistics for the number of pink salmon entering the spawning rivers is the fact that more or less regular observations have been made only in a few rivers (Khuzy, My, Chomi, Naleo, Ul, Beshenaya, Samnya and Im), and elsewhere only fragmentary information is available for the other rivers covering from one to five seasons. Another disadvantage of these statistics is that there is no indication of how complete was the counting of the spawners the work could have been late starting or could have finished before the end of the spawning migration; the counting fence could have been temporarily out of action because of damage by the high flood water).

These disadvantages are counterbalanced, however, by the fact that comparatively regular observations were made on the principal spawning rivers of the pink salmon and, knowing the approximate ratio between the pink salmon numbers in adjacent rivers in the same year, it was easy to detect any underestimate of the number of spawners.

Since Levanidov (1964a) did not give the calculations by which he obtained the numbers of pink salmon in the rivers of Amur Sound, I shall discuss this problem in more detail as original material for the other districts also. The starting point for my calculations for the rivers of Amur Sound was the determination of the ratio between the numbers of pink salmon visiting all the test rivers in the same year. For even year-classes this was 1938, when 1 661 000 fish visited the principal rivers of Amur Sound (excluding the Charrakh, where no observations were made, and the Uarke, which according to I.I. Kuznetsov, has always been visited by only a few pink salmon). Taking this figure as 100 % I obtained the ratio between the numbers of the pink salmon stocks for the Rivers Lyangrovaya, Khuzy, My, Tymi and Chomi (in %), of 10, 30, 39, 4 and 17 respectively (Table 6). Subsequently these percentages were converted only for years with a corresponding abundance of pink salmon migrating into the spawning rivers (in this case a check was provided by the statistics for catches, see Table 3) and the numbers of the pink salmon stocks were determined in those rivers where no counting was carried out (given separately in the table).

For the much lower numbers of the pink salmon in the year-classes of the even years (1934 and 1936) the ratio between the numbers of the stocks in the rivers of Amur Sound was rather different: 7, 21, 51, 4 and 17; towards the left shore of Amur Sound (River Lyangrovaya) and into the right-bank river closest to the mouth of the Amur (River Khuzy) relatively fewer pink salmon penetrated because of increased migrations of the species into the River My.

For the odd years in the period 1925-1935 the number of pink salmon of these year-classes was very low, much higher in 1937, and in 1939 and 1941 unusually high for odd year-classes As in the previous example, so also in this case the relative importance of the individual rivers was determined initially for two periods, 1937 being classed as a year with a low number of this fish. The figures for the number of pink salmon migrating into the rivers of Amur Sound in 1925 were taken as the starting point for this period, making appropriate corrections for incomplete counting depending on the mean for several years. The ratio between the numbers of the pink salmon stocks for the same rivers in years of low numbers was 2, 25, 51, 4 and 18, but in 1939 and 1941 the number of pink salmon migrating into the Rivers Lyangrovaya and Tymi were taken as 14 %, just as with the abundant year-classes of even years (see Table 6). It will be clear from the figures given in this table that the most important of the spawning rivers of the continental shore of Amur Sound for reproduction of the pink salmon stocks were the Khuzy, My and Chomi; moreover, the River My accounted on the average for about 35 % of the spawning stocks of the pink salmon of Amur Sound. The contribution /22/

of the other rivers was comparatively small, only 12-15 % of the total number of pink salmon entering the rivers of this region.

The relative numbers of pink salmon entering the rivers of Amur Sound differed from year to year. The role of the River My in reproduction of the pink salmon was inversely proportional to the abundance of the spawning stock entering the Sound; in odd years, especially years when the odd year-classes were present in very large numbers, the importance of the southernmost river entering the Sound -- the Chomi -- in pink salmon reproduction increased; this can be explained by the approach to this neighbourhood of pink salmon belonging to the maritime stock, with a cycle opposite to that of the Amur pink salmon; the contribution of the left-shore tributaries of Amur Sound (the Lyangrovaya and also, evidently, the Charrakh) reached 8-10 % only in years of the largest spawning migrations and the figure fell to 2 % when the spawning migrations were small.

The mean numbers of the spawning stocks of pink salmon in the rivers of the continental shore of Amur Sound in even years was 1 500 000 and in odd years 350 000 fish with fluctuations in years of low and high stocks between 16 000 and 2 606 000 fish. /23/

In the past the pink salmon entered all rivers of the Amur Estuary to spawn. The importance of the rivers of the Estuary in the reproduction of the Amur pink salmon was small compared with the rivers of the Sound. The population of the spawning stocks of pink salmon in the largest river flowing into the Estuary -- the Naleo, -- as the data in Table 7 show, averaged about 230 000 only until 1932 and later the number fell considerably. With this fact in mind it can be postulated that in even years the total number of pink salmon in all the rivers of the Amur Estuary averaged not more than 200 000 fish.

TABLE 6. Numbers of Spawning Stocks of Pink Salmon in the Principal Rivers of Amur Sound in 1925-1941 (thousands of fish)

Годы (1)	Реки (2)					
	Лянгровая (3)	Хузи (4)	Мы (5)	Тыми (6)	Чоми (7)	Сумма (8)
			Четные годы (9)			
1928	167	500	650	67	283	1667
1930	217	558	565	87	747	2174
1932	260	872	928	104	443	2606
1934	37	113	274	22	91	537
1936	9	42	50	5	19	125
1938	170	498	642	74	277	1661
1940	38	239	691	56	408	1402
(11) Среднее	137	403	503	59	324	1453
%	9	28,4	36,4	4,0	22,2	100
			Нечетные годы (10)			
1925	0,3	4,0[1]	8,0	0,6	2,9[1]	15,8
1927	0,5	6,1	12	0,9	4,3	23,8
1929	1,2	8,3	38,2	2,5	11,0	61,2
1931	1,8	23,2	46[1]	3,6	16,4[1]	91,0
1933	1,1	17,4	22,7	2,1	9,5	52,8
1935	6,5	82,2	165[1]	13,0	58,5[1]	325,2
1937	5,5	61,5	147,5	11,0	51,0	276,5
1939	131	274,5	297,5	51	553	1307
1941	104	264,1	332,8	41	293,8	1036
(11) Среднее	28	82,4	118,9	14,1	111	354,4
%	7,9	23,2	33,6	4,0	31,3	100

[1] Увеличена с поправкой на недоучет (12)

KEY: (1) Years (2) Rivers (3) Lyangrovaya (4) Khuzi (5) My (6) Tymi (7) Chomi (8) Total (9) Even years (10) Odd years (11) Mean (12) Augmented by a correction for incomplete counting

TABLE 7. Numbers of Spawning Stocks of the Pink Salmon in the River Naleo in 1925-1937 (in thousands)

(1) Четные годы	1926	1928	1930	1932	1934	1936		Среднее (4)	%
(2) Количество	137	390	184	207	30	3		159	97
(3) Нечетные годы	1925	1927	1929	1931	1933	1935	1937	Среднее (4)	%
(2) Количество	1,5	1,0	1,5	5,4	1,0	21	2,7	4,9	3

KEY: (1) Even years (2) Number (3) Odd years (4) Mean

In a third district, the sector from the town of Nikolaevsk to the mouth of the Amgun', even fewer pink salmon reproduced. Most of them (80 %) entered the largest river, the Ul, where after 1932, as in the rivers of the Estuary, in even years there was a marked decrease in the number of fish entering for spawning (Table 8). The mean pink salmon population in this sector in even years can be given roughly as 15 000.

TABLE 8. Numbers of Spawning Stocks of Pink Salmon in the River Ul in 1930-1941 (in thousands of fish)

1 Четные годы	1930	1932	1934	1936	1938	1940	Среднее 4	%
2 Количество	13,1	39,3	0,9	3,9	12,1	1,3	11,7	92
3 Нечетные годы	1931	1933	1935	1937	1939	1941	Среднее 4	%
2 Количество	0,1	0,02	1,2	0,2	4,1	0,5	1,0	8

KEY: (1) Even years (2) Number (3) Odd years (4) Mean

The numbers of pink salmon entering the spawning rivers of this district were smallest in the sector above the mouth of the Amgun'. The pink salmon population here in odd years was negligible: the fish as a rule came only singly or at most a few dozen at a time. In the principal rivers of this sector in even years several thousand pink salmon were found, but after 1932 they were numbered only in hundreds (Table 9); the total number in all rivers was about 25 000 fish.

TABLE 9. Numbers of Spawning Stocks of Pink Salmon in the Rivers Beshenaya, Khilka and Kenzha in 1926-1940 (in thousands of fish)

Реки 1	1926	1928	1930	1932	1934	1936	1938	1940
Бешеная 2	8,1	2,9	11,7	0,4	0,4	0,03	3,3	0,33
Хилка 3	6,9	31,0	4,2	—	—	—	—	—
Кенжа 4	0,2	1,3	—	—	—	—	—	—

KEY: (1) Rivers (2) Beshenaya (3) Khilka (4) Kenzha

On the whole the mean pink salmon population in the rivers of the third district can be estimated roughly at 40 000 fish. /24/

In the Amgun' basin the Rivers Samnya and Im were the most important for reproduction of the pink salmon (Table 10). However, the ratio between the pink salmon populations in them was by no means always the same: on the average many more salmon entered the River Samnya than the River Im.

TABLE 10. Numbers of Spawning Stocks of the Pink Salmon in the Rivers Samnya and Im in 1925-1941 (in thousands of fish)

1 Реки	2 Четные годы								
	1926	1928	1930	1932	1934	1936	1938	1940	
Самня 3	—	—	—	—	—	16	365	341	
Им 4	20	87	91	151	6,3	2,2	35	86	
	5 Нечетные годы								
	1925	1927	1929	1931	1933	1935	1937	1939	1941
Самня 3	—	—	—	—	—	3,6	21	31	127
Им 4	0,3	—	0,03	—	—	—	4,6	17	—

KEY: (1) Rivers (2) Even years (3) Samnya (4) Im (5) Odd years

In years of high pink salmon stocks the mean population in the Rivers Samnya and Im was 400 000, while in years of small numbers of even year-classes (1936) and in odd years it was about 20 000 fish. Considering the area of the spawning grounds of the remaining rivers, the contribution of these two rivers to the total population of pink salmon migrating into the River Amgun' in the first case can be taken as not less than 50 %, and in the second case as about 80 %. On this assumption, the mean size of the pink salmon stock in the River Amgun' in years of large spawning migrations was 800 000 fish and in years of small spawning migrations about 25 000 fish. If the pink salmon populations in the rivers of all spawning areas are compared the relative contribution of each of them to reproduction of the pink salmon in the Amur basin is obtained (in %): rivers of Amur Sound -- 59; rivers of the Amur Estuary -- eight; tributaries of the Amur -- 1.5; the basin of the River Amgun' -- 31.5. In the figures given it may be that the role of rivers of the Estuary and the Amgun' are a little on the low side. For rivers of the Estuary this could be due to the large numbers of salmon caught in the spawning rivers near the town of Nikolaevsk, the most densely populated sector of the spawning area of the pink salmon. The considerable exploitation of this fish on its migration pathways both in the Amur and in the Amgun', where the salmon fishing industry was not restricted until 1940, was undoubtedly reflected in the figures for pink salmon in the Amgun' basin. The role of the Amgun' in my calculations may also, perhaps, be exaggerated because of the incomplete counting of the brood stock in the Rivers Samnya and Im as a result of damage to the counting fences or delay in their installation because of severe floods which are a characteristic feature in the basin of this river.

Last but not least among the rivers for reproduction of the pink salmon is the Iski, flowing into Schast'ya Bay in the Sea of Okhotsk. Its basin borders on the Amur basin on the south and west and it shares the same climatic conditions. For this reason variations in the survival rate of the pink salmon in the River Iski were frequently identical with those of the Amur and it was considered formerly that the Iski pink salmon was part of the Amur stock. Without going into this question of the stock to which the Iski pink salmon belongs I shall nevertheless examine the importance of this river in a district where, /25/
as will be shown below, the territories of the pink salmon of the Amur and Sea of Okhotsk stocks are contiguous (Table 11).

TABLE 11. Numbers of Spawning Stocks of Pink Salmon in the River Iski in 1930-1941 (in thousands of fish)

Четные годы 1	1930	1932	1934	1936	1938	1940
Количество 2	967	511	86	117	1000	30
Нечетные годы 3	1931	1933	1935	1937	1939	1941
Количество 2	1,3	3,8	135	349	515	727

KEY: (1) Even years (2) Number (3) Odd years

The figures given in Table 11 do not illustrate the mean pink salmon population in the River Iski in even and odd years because until 1937 considerable migrations into this river were observed in even years, but after 1939 the migrations became larger in odd years (Table 15). However, in the 1930s the odd-year year-classes showed a steady increase, so that in the course of a decade the population increased by more than 500 times. If the River Iski is included in the Amur system, its contribution before the change in its cycle would be about 18 % of the migrating salmon population. The work of counting salmon migrating into the spawning rivers was resumed in 1949 but only in six of the principal rivers for pink salmon reproduction: My, Ul, Beshenaya, Samnya, Im and Iski.

Unstable climatic conditions have been a characteristic feature of the Amur basin in the post-war years, and this has led to sharp fluctuations in the pink salmon population. The general contraction of its stocks, which became evident as long ago as in 1932 and has become particularly pronounced in the post-war period, as well as the contraction of the useful spawning area in some rivers in the lower reaches of the Amur, has been reflected in the distribution of the salmon over the spawning area. For instance, in odd years the rivers of the Estuary have lost their importance in salmon reproduction, and in even years their contribution relative to the rivers of Amur Sound has fallen from 11 to 1-2 %; in even years the pink salmon population in the River Ul was at the same level as the odd year-classes the pre-war period, except for the particularly abundant stocks migrating in 1956 and 1958; the tributaries of the Amur above the mouth of the Amgun' have almost completely lost their importance for spawning in odd years; the ratio between the pink salmon populations in the principal rivers of the Amgun' basin has changed: the influx of the salmon into the River Samnya has decreased by several times compared with the River Im; the ratio between the spawning stocks of the pink salmon in the two principal regions -- the rivers of Amur Sound and the Amgun' basin -- has changed considerably.

It would be technically incorrect to determine the mean pink salmon population in even and odd years in the principal rivers of the Amur basin: the numbers of the spawning stocks of the pink salmon in the River Im, for example, in 1952 and 1958 were in the ratio of 1: 230, and in 1955 and 1963 in the ratio of 1: 2 500. In Tables 12 and 13, therefore, these figures are given relative to the level of the salmon stocks.

TABLE 12. Numbers of Spawning Stocks of the Pink Salmon of Even Year-Classes in 1950-1964 (in thousands of fish) /26/

Годы 1	Реки 2					Сумма 8
	Мы 3	Ул 4	Им 5	Самня 6	Бешеная 7	
			Низкая численность 9			
1950	158	0,6	26	24	0,1	208,7
1952	37	0,6	17	31	0,2	85,8
1954	268	1,3	163	78	5,4	515,7
1960	74	7,8	—	7,5[1]	4,2	93,5[1]
1962	50	0,3	0,1[1]	0,7[1]	0,3	51,4[1]
1964	12,3	0,02	12	15	0,4	39,7
Среднее 10	99,9	1,8	43,6[1]	26,0[1]	1,8	—
%	57,7	1,05	25,2[1]	15,0[1]	1.05	100
			Высокая численность 11			
1956	861	41	62[1]	2218	22	3204[1]
1958	812	69	3949	5370	12	10212
Среднее 10	836	55	2006[1]	3794	17	6703[1]
%	12,5	0,8	29,8[1]	56,6	0,3	100

KEY: (1) Years (2) Rivers (3) My (4) Ul (5) Im (6) Samnya (7) Beshenaya (8) Total (9) Small population (10) Mean (11) Large population

The data in Tables 12 and 13 show that in years of very great abundance of the spawning stocks (1956 and 1958) about 80 % of the pink salmon were distributed among the tributaries of the Amgun' and only about 20 % in the rivers of Amur Sound; at times of average stocks (1963) the Amgun' spawning grounds were less densely populated: their contribution was about 45 % of the

TABLE 13. Numbers of Spawning Stocks of the Pink Salmon of Odd Year-Classes in 1949-1965 (in thousands of fish)

Годы 1	Реки 2					Сумма 8
	Мы 3	Ул 4	Им 5	Самня 6	Бешеная 7	
			Низкая численность 9			
1949	651	2,0	65	18	0,9	736,9
1951	296	0,4	20	13	0,2	329,6
1953	91	0,02	14	2,4	0,03	107,4
1955	13	0,1	0,1	4,2[1]	0,03	17,4[1]
1957	17[1]	0,2[1]	0,03	3,7[1]	0,2	21,1[1]
1959	106	0,3	—	—	0,2	106,5[1]
1961	11	—	—	—	0,05	11,1[1]
1965	6,7	0,42	140	72	0,06	219,2
Среднее 10	149,0[1]	0,49[1]	39,9	18,9[1]	0,21	—
%	71,5[1]	0,2[1]	19,1	9,1[1]	0,1	100
			Высокая численность 11			
1963	336	0,06	250	190	0,25	776,3
%	43,3	0,0	32,2	24,5	0,0	100

[1] Учет неполный. 12

KEY: (1) Years (2) Rivers (3) My (4) Ul (5) Im (6) Samnya (7) Beshenaya (8) Total (9) Small population (10) Mean (11) Large population (12) Counting incomplete

pink salmon migrating into the Amur basin; in even years with small populations of pink salmon the contribution of the Amgun' spawning grounds was about 25 % of the stock, whereas in odd years it was about 20 %. These figures confirm once again that the distribution of the pink salmon over the spawning area in the Amur basin is directly dependent on the abundance of its year-classes. It would therefore be wrong to examine this problem with respect to even and odd year-classes of salmon as was done by Levanidov (1965), for the fluctuations in the numbers of salmon migrating into the Amur during the last 15 years have not been regular in character. According to the data in the tables given above and appropriate calculations[1], the relative importance of the individual spawning areas in reproduction of the pink salmon in the Amur basin in the post-war period can be represented as follows (Table 14):

[1]The contribution of the River My as a spawning ground in years of high abundance was 36 % of that of all rivers flowing into Amur Sound, in years of average abundance of the stocks it was 45 %, and in poor years 52 %; the contributions of the Rivers Samnya and Im compared with the total for the rivers of the Amgun' basin was 50, 65 and 80 % respectively.

TABLE 14. Distribution of the Pink Salmon Over the Spawning Area in the Amur Basin in the Period 1949-1965 (in %) /27/

Районы 1	5 Уровень запасов горбуши		
	высокий 6	средний 7	низкий 8
Реки лимана Амура 2	20	51	78
Реки эстуария и притоки Амура 3	5	4	2
Бассейн р. Амгунь 4	75	45	20

KEY: (1) Districts (2) Rivers of Amur Sound (3) Rivers of the Estuary and tributaries of the Amur (4) Basin of the River Amgun' (5) Level of the pink salmon stocks (6) High (7) Average (8) Low

If the sizes of the brood stocks migrating into the spawning rivers in odd years are compared the years 1949 and 1951 stand out as years in which 89 % of the pink salmon stock migrating into all rivers of the Amgun' basin entered the River My; in the subsequent period, in years of small and also of comparatively large populations, the number of pink salmon entering the River My averaged only 42 %. It is interesting to note that in the pre-war period the contribution of the River My as a spawning ground was 69 % of that of the Rivers Samnya and Im in odd years. This phenomenon is probably linked with the change in the cyclic fluctuations of the maritime pink salmon stocks in 1953-1954 (see Table 22), some of which migrate, as will be shown below, into the rivers of the south-western part of Amur Sound.

In the course of a few decades a redistribution of the pink salmon within the spawning area has thus taken place. Compared with the 1930s, as Levanidov (1962b) has also mentioned, this change has been expressed as a decrease in the relative importance of the southern tributaries of the Estuary and the small tributaries of the Amur from the mouth of the Amgun' to the upper limit of the spawning area, and as an increase in the relative importance of the Amgun' basin.

Just as in the pre-war period it is impossible to determine the mean pink salmon populations for even and odd years in the River Iski, because of the change in the cyclic variations of its numbers (Table 15).

TABLE 15. Mean Annual Catch of Pink Salmon on the North-West Coast of the Sea of Okhotsk and in the Amur Basin (in thousands of fish)

Места лова	Годы			
	1929—1936		1939—1951	
	четные	нечетные	четные	нечетные
Охотский рыбопромысловый район (улов на 1 невод)	30	11	12	26
Р. Иски (пропуск рыб через контрольно-учетное заграждение)	435	47	21	337
Бассейн Амура				
а) общий улов	8540	490	5466	1860
б) улов двух контрольных заездков в лимане			354	86

KEY: (1) Site of catch (2) Okhotsk Fisheries District (catch per seine) (3) River Iski (fish passing through counting fence) (4) Amur basin: a) total catch b) catch at two counting barriers in Amur Sound (5) Years (6) Even (7) Odd

Judging from the cycles of the catches (Table 15) in the period 1929-1951 most pink salmon in the River Iski were from the Sea of Okhotsk stock, but later (Table 16, Fig. 3) most were from the Amur stock.

The similarity between the climatic conditions of the Iski and Amur basins was evidently reflected in the abundance of the individual year-classes, variations in the size of which in the River Iski in the post-war period were similar to those of the pink salmon population in the rivers of the Amur basin.

TABLE 16. Numbers of Spawning Stocks of the Pink Salmon in the River Iski in 1949-1963 (in thousands of fish) /28/

Четные годы	1950	1952	1954	1956	1958	1960	1962	1964
Количество	26	78	338	1344[1]	1344	31	16	14
Нечетные годы	1949	1951	1953	1955	1957	1959	1961	1963
Количество	275	221	41	24	32	22[1]	23	259

[1] Учет неполный

KEY: (1) Even years (2) Number (3) Odd years (4) Counting incomplete

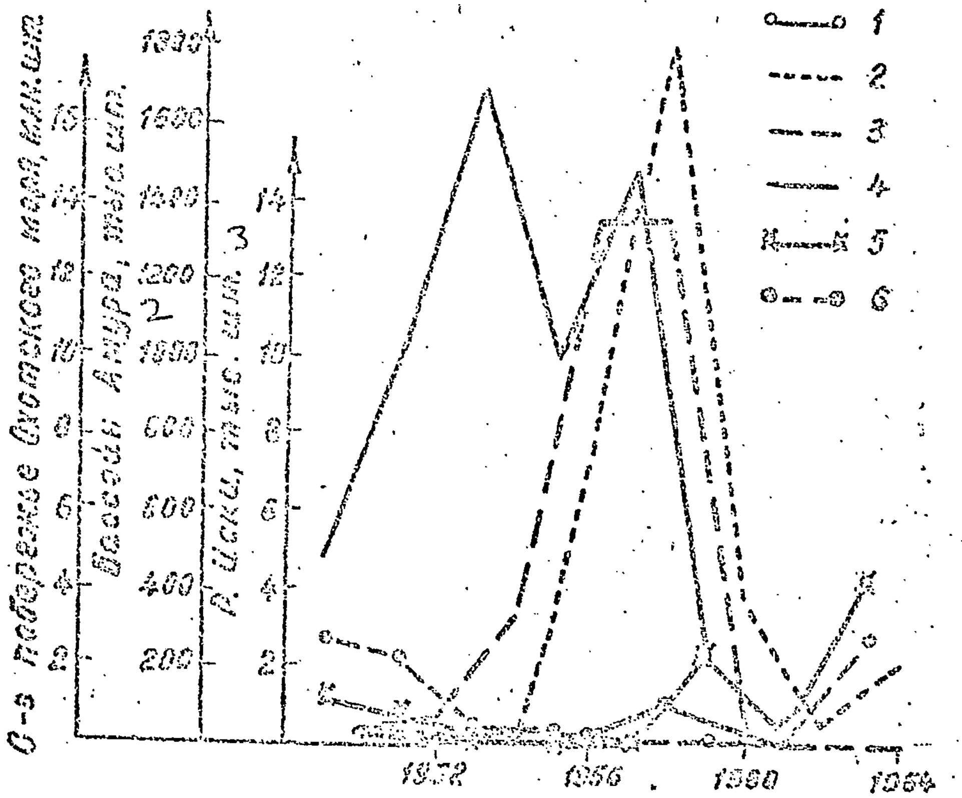

Fig. 3. Number of pink salmon migrating into the River Iski and fluctuations in its catches in the Amur and off the north-west coast of the Sea of Okhotsk: 1) Okhotsk, 2) Amur, 3) Iski -- even years; 4) Okhotsk, 5) Amur, 6) Iski -- odd years.

Key: (1) North-west coast of Sea of Okhotsk, millions of fish (2) Amur basin, thousands of fish (3) River Iski, thousands of fish

---

3. Utilization of the Spawning Stock

The general decline in the pink salmon stocks in the Amur basin which began in the 1940s is evidence that much of the spawning stock remained under-utilized for a quarter of a century. Failure of the fish to arrive year after year has resulted in the spoiling of many spawning grounds: they have become packed hard because of the deposition of small and very small particles of soil among the pebbles.

The long-debated question of whether the reconstruction of the redds in which the spawn is deposited by fish newly arrived at the spawning grounds is harmful or useful for the reproduction of salmon in years of abundance has /29/ been decided by Levanidov (1964c) in favour of the conclusion drawn earlier by Smirnov (1947). "The beneficial effect of a large number of breeding salmon in the spawning grounds and of the high density of spawning," -- observes Levanidov, -- "lies in the repeated turning over of the soil, the widening of the spawning places, and the increased biological productivity of spawning and breeding waters by 'fertilizing' of them with salmon dying after spawning." The improved soil structure in breeding grounds of the autumn chum, for example, after they have been dug over by salmon, persists for two or three years. As Levanidov emphasizes, overfilling the spawning grounds with brood stock does not lead to any decrease in the number of progeny (compared with other year-classes;it is not therefore a factor regularly causing fluctuations in the numbers of the population.

Later Levanidov introduces the concept of "optimal filling of the spawning grounds," when the largest catches and the maximal occupancy of the spawning grounds are attained with a constant level of salmon stocks. Optimal filling of the spawning grounds for pink salmon of the Amur basin has been determined as 18-20 million fish. Since the intensity of commercial exploitation of the Amur salmon in fresh waters, according to Levanidov (1964c), is about 50 % of the spawning stock, the other half must be made up of fish that have reached the spawning grounds. It must therefore be accepted that the present level of filling of the spawning grounds with pink salmon is much below the optimum.

/30/

IV. LOCAL STOCKS

1. History

The first indication that pink salmon belonging to different stocks were being caught off the continental shore of the Tatar Straits and Amur Sound was given by Rubin (1931). He considered that differences in the character of small and abundant year-classes and in the size and weight of the pink salmon in these regions are an indication of these differences in stocks.

The view expressed originally by Brazhnikov (1900) and supported by Soldatov (1912) and Pravdin (1932, 1940), that the pink salmon enters the Amur from the north, from the Sea of Okhotsk, most probably led many investigators to consider that the region of reproduction of the Amur pink salmon lies in Schast'ya Bay, to the north of Amur Sound, into which the River Iski flows.

In 1932, as a result of morphometric investigations of pink salmon caught in the lower reaches of the River Amur and in adjacent sectors of Amur Sound and of the open sea (the west coast of Sakhalin, the south-west part of Amur Sound near Cape Uarke, the Gulf of Sakhalin near Petrovskaya Spit, and Schast'ya Bay), I.F. Pravdin distinguished an Amur stock of pink salmon -- Oncorhynchus gorbuscha natio amurensis nova.

Thereafter the name Amur pink salmon was generally given not only to the fish migrating into the tributaries of the Amur to reproduce, but also to the salmon that reproduces in the rivers of Amur Sound and the River Iski. One result of this situation was the all-year investigations conducted in 1937-1941 by TINRO on the River Iski to study the causes of fluctuations in the stocks of Amur salmon.

When distinguishing between the stocks of Amur and West Kamchatka pink salmon I.F. Pravdin did not rule out the possibility of the existence of smaller, independent local stocks within each of these main forms. N.V. Milovidova-Dubrovskaya in 1933 compared the pink salmon of Primor'e (the Maritime Province; River Tumnin) and the Amur pink salmon (after Pravdin) caught in Amur Sound (Cape Lazarev, Rivers Chomi and My) and in the River Iski with respect to a number of biological features but found no significant biological differences between them. On the basis of having caught a pink salmon at the mouth of the River Somon (10 km to the south of De-Kastri), labelled on the coast of North Korea, A.M. Derzhavin (1933) suggested that pink salmon of the maritime stock can migrate along the continental shore of the Tatar Straits to the north as far as the region of De-Kastri Bay.

Intensive commercial exploitation and considerable cyclic and periodic /31/
fluctuations in the population with a decrease in the over-all level of the stocks of pink salmon in the Amur basin made it necessary to determine the boundaries of the spawning area of the Amur pink salmon and whether this species is attracted to particular spawning rivers within the limits of the Amur fisheries district. However, no special research in this direction was undertaken for 20 years although a number of hypotheses were put forward. According to the records of Amurrybvod, for instance, I.I. Kuznetsov regarded the pink salmon in the Rivers Iski and Chomi as belonging to different stocks,

unconnected with the Amur pink salmon stock, on the basis of the considerable distance of these rivers from the Amur, and on that basis he considered that the waters of the Amur, Amur Sound and Schast'ya Bay are frequented by different stocks of pink salmon.

According to statistics of the industry, I.B. Birman observed that the abundance of the pink salmon migrations off Cape Lazarev and in De-Kastri Bay alternates in even and odd years just as in Primor'e. He therefore suggested that the activities of the fishing enterprises of Cape Lazarev and De-Kastri are based largely on pink salmon of the Primor'e stock and that this fish frequents the rivers of the southern part of Amur Sound -- the Chomi and My.

The hypothesis that Primor'e salmon migrates into the southern part of Amur Sound, in the region of Cape Uarke, was also expressed by Kaganovskii (1949) on the basis of the catching of a pink salmon tagged on the east coast of Korea in this region and also of I.F. Pravdin's statement that in this region, unlike in the more northern fishing grounds, migrations of pink salmon in even years were smaller than in odd years. Toward the middle of the present century certain facts thus suggested that pink salmon of the Primor'e stock frequent the Amur basin.

I studied the composition of the pink salmon stocks of the Amur fisheries district in 1950-1954 by comparing the morphological, morpho-biological and other features of the pink salmon from its principal spawning river in the Amur basin (the Amgun') with the pink salmon from the south-western part of Amur Sound (River My, Capes Uarke and Lazarev), the Tatar Straits (De-Kastri Bay), Primor'e (Datta Creek), and Schast'ya Bay in the Sea of Okhotsk (River Iski); this section consists largely of a description of the findings.

2. Method

Pink salmon from the above-mentioned rivers and fishing districts were compared with respect to fish of the same size, 45-46 cm long and usually aged 1+. Since even in the absence of breeding colour considerable sexual dimorphism was found in the pink salmon, only silvery coloured females, found in the spawning rivers at the beginning of the spawning migration, were used. In this way it was possible to compare material caught at sea, in Amur Sound and in the rivers.

The morphometric analysis included 28 features, seven of them meristic. Features of the head, trunk and fins were studied; they were measured in the usual way. Ratios were calculated relative to the length of the body as the standard (using I.F. Pravdin's definition).

The rate of growth was determined from the scale, under a magnification of 7 x 5, using an ocular-micrometer. Lea's formula was used for the back calculations. The calculated length of the fish as far as the outer border of the zone of narrowed sclerites was taken as the length of yearlings.

The absolute fertility was calculated by a gravimetric method from samples of eggs weighing 20 g. /32/

The condition factor was determined by Fulton's formula, slightly modified: $K = \frac{(Q - q) \times 100}{l^3}$, where the weight of the gonads was excluded from the weight of the fish as being too variable. The distinguishing feature of the method, enabling definite similarity or difference to be discovered between the pink salmon of the named rivers and fishing districts, was the choice of a homogeneous material excluding the influence of variation due to sex, size, breeding activity, and age.

3. Factual Material

A. Morphometry

From material obtained from Datta Creek and De-Kastri Bay we know (Enyutina, 1955) that morphologically similar pink salmon reach these areas: the forms compared were identical with each other in 27 (of the 28) meristic and structural features, and a difference was found in only one feature (depth of the head), to which too much importance must not be attached because of the very wide limits of its variations. They are also morphologically similar to the pink salmon of the south-western part of Amur Sound caught in the neighbourhood of Capes Lazarev and Uarke and in the River My (Enyutina, 1954b).

Having pooled all the similar material I compared the pink salmon of the south-western part of Amur Sound with (a) the Primor'e pink salmon (from Datta Creek and De-Kastri Bay) and (b) with the Amur pink salmon proper, from its principal spawning tributary, the River Amgun'; this last was also compared with the pink salmon of the River Iski (Table 17).

The mean values of the meristic features of the pink salmon of these areas, as Table 17 shows, do not go outside the limits of the species characteristics and true differences are rare. When looking for local differences I disregarded these features, for they are known to vary considerably year by year even in fish from the same river (Pritchard, 1945; Enyutina, 1955).

The investigations showed (Table 17) that the pink salmon of the south-western part of Amur Sound and of Primor'e differ in only one feature -- the pectoventral distance (the anterior part of the abdomen), which is very variable within the limits of the species characteristic and can be disregarded; in all the other 20 structural features there was no difference.

The pink salmon of the River Amgun' has completely different morphological features from the pink salmon from the south-western part of Amur Sound.

TABLE 17. Comparative Characteristics of Morphological Features of Pink Salmon Caught in Different Places

Наименование признаков	Пределы эмпирических рядов				Средние величины признаков										
	Приморье	юго-западная часть Амурского лимана	р. Амгунь	р. Иски	Приморье		юго-западная часть Амурского лимана		р. Амгунь		р. Иски		$\frac{M_1-M_2}{\pm\sqrt{m_1^2+m_2^2}}$	$\frac{M_2-M_3}{\pm\sqrt{m_2^2+m_3^2}}$	$\frac{M_3-M_4}{\pm\sqrt{m_3^2+m_4^2}}$
					M_1	$\pm m_1$	M_2	$\pm m_2$	M_3	$\pm m_3$	M_4	$\pm m_4$			
Число чешуй в *ll*	150—185	157—198	156—196	164—192	171,25	0,85	172,75	1,02	176,75	1,01	180,60	1,47	1,13	2,77	2,15
Жаберных лучей	11—14	9—13	11—14	11—13	12,65	0,08	12,14	0,09	12,45	0,06	12,24	0,12	4,25	2,87	1,57
Жаберных тычинок на 1 дуге	27—35	27—33	27—33	28—32	30,69	0,17	30,08	0,16	30,23	0,15	29,80	0,27	2,62	0,68	1,39
Лучей в Д ветвистых	9—12	10—12	9—13	10—12	10,55	0,08	10,31	0,06	11,05	0.09	11,40	0,11	2,40	6,85	2,47
Лучей в А ветвистых	12—16	12—16	13—16	14—16	14,11	0,09	14,06	0,10	14,65	0,08	15,04	0,11	0,37	4,61	2,87
Позвонков	67—71	63—71	67—71	68—70	69,02	0,10	69,06	0,15	68,91	0,09	68,84	0,14	0,22	0,86	0,42
Пилорических придатков	70—160	103—151	113—193	98—167	118,90	2,14	124,90	1,60	133,80	2,29	136,80	3,26	2,25	3,19	0,76
Длина рыла	7—8	7—9	7—9	9—11	7,87	0,04	7,86	0,04	8,42	0,05	9,70	0,13	0.18	8,75	9,21
Заглазничный отдел головы	13—18	14—17	15—18	16—18	15,69	0,08	15,83	0,09	16,63	0,07	16,82	0,11	1,17	7,02	1,46
Длина головы	25—29	25—28	26—30	27—32	26,31	0,10	26,55	0,12	27,77	0,09	29,18	0,22	1,54	8,13	5,92
Длина верхнечелюстной кости	9—11	9—12	9—12	10—14	10,20	0.06	10,34	0,06	10,60	0,07	11,56	0,17	1,65	2,83	5,22
Ширина верхнечелюстной кости	1,9—2,7	2,0—2,7	1,9—2,9	2,1—3,2	2,18	0,02	2,27	0,02	2,36	0,02	2,59	0,05	3,21	3,22	4,26
Длина нижней челюсти	13—17	15—19	15—18	17—20	16,03	0,08	16,10	0,10	17,05	0,08	18,36	0,21	0,55	7,43	5,82
Высота головы через середину глаза	12—15	12—14	13—16	13—19	13,12	0,08	13,13	0,09	14,12	0,10	14,59	0,24	0,08	7,38	1,81

TABLE 17 (continued)

Наименование признаков (1)	Пределы эмпирических рядов (16)				Средние величины признаков (21)										
	Приморье (17)	юго-западная часть Амурского лимана (18)	р. Амгунь (19)	р. Иски (20)	Приморье (17)		юго-западная часть Амурского лимана (18)		р. Амгунь (19)		р. Иски (20)		$\frac{M_1-M_2}{\pm\sqrt{m_1^2+m_2^2}}$	$\frac{M_2-M_3}{\pm\sqrt{m_2^2+m_3^2}}$	$\frac{M_3-M_4}{\pm\sqrt{m_3^2+m_4^2}}$
					M_1	$\pm m_1$	M_2	$\pm m_2$	M_3	$\pm m_3$	M_4	$\pm m_4$			
Наибольшая высота тела (22)	28—34	29—36	30—37	28—34	31,68	0,14	31,87	0,17	32,80	0,18	30,71	0,31	0,59	3,77	5,81
Наименьшая высота тела (23)	8—10	8—10	9—10	9—10	8,88	0,06	9,00	0,06	9,92	0,03	9,41	0,12	1,50	13,73	4,12
Антедорсальное расстояние (24)	55—63	56—63	58—64	60—65	58,77	0,18	58,90	0,19	60,39	0,15	62,54	0,29	0,50	6,16	6,59
Постдорсальное расстояние (25)	50—58	49—57	50—58	51—58	52,61	0,15	52,58	0,20	53,92	0,16	53,55	0,35	0,12	5,23	0,96
Антевентральное расстояние (26)	61—68	63—68	59—71	67—73	64,93	0,19	65,73	0,18	67,08	0,20	68,59	0,32	3,05	5,02	4,01
Антеанальное расстояние (27)	87—94	86—95	85—95	88—96	90,07	0,21	91,13	0,19	89,90	0,22	90,87	0,35	3,75	4,23	2,35
Передняя часть брюха (28)	39—45	38—46	39—46	40—45	41,27	0,16	42,63	0,17	41,76	0,19	42,27	0,28	5,40	3,43	1,51
Задняя часть брюха (29)	21—26	21—26	22—27	22—26	23,37	0,15	23,50	0,14	23,94	0,13	23,72	0,20	0,63	2,30	0,92
Длина хвостового стебля (30)	21—25	21—24	22—25	22—25	22,77	0,11	22,86	0,10	23,57	0,11	23,32	0,16	0,67	4,80	1,29
Длина основания Д (31)	11—15	11—14	12—16	12—16	13,03	0,09	12,94	0,10	14,02	0,09	14,08	0,17	0,60	8,06	0,31
Длина основания А (32)	13—18	10—18	14—17	14—18	14,60	0,11	14,09	0,18	15,49	0,07	16,44	0,17	2,41	7,25	5,17
Высота А (33)	11—16	10—15	11—16	13—18	12,66	0,15	12,50	0,15	13,76	0,12	15,15	0,20	0,75	6,56	5,97
Длина верхней лопасти С (34)	17—22	17—22	18—24	18—22	19,18	0,11	18,98	0,14	20,30	0,12	19,96	0,20	1,12	7,17	1,46
Длина средних лучей С (35)	6—9	6—8	6—8	7—10	7,04	0,07	6,88	0,05	7,26	0,06	8,24	0,15	1,86	4,87	6,08
Количество исследованных особей (36)	65	65	75	25	65		65		75		25		—	—	—

KEY: (1) Name of feature (2) Number of scales in .... (3) Branchiostegal rays (4) Gill rakers on arch 1 (5) Branched rays in D (6) Branched rays in A (7) Vertebrae (8) Pyloric caeca (9) Length of snout (10) Retro-orbital part of head (11) Length of head (12) Length of maxillary bone (13) Width of maxillary bone (14) Length of lower jaw (15) Depth of head through middle of eye (16) Limits of empirical series (17) Primor'e (18) South-western part of Amur Sound (19) River Amgun' (20) River Iski (21) Mean values of features (22) Greatest depth of body (23) Least depth of body (24) Antedorsal distance (25) Post-dorsal distance (26) Anteventral distance (27) Anteanal distance (28) Anterior part of abdomen (29) Posterior part of abdomen (30) Length of caudal peduncle (31) Length of base of D (32) Length of base of A (33) Depth of A (34) Length of upper lobe of C (35) Length of middle rays of C (36) Number of individuals studied

Characteristically nearly all its structural features are relatively large. Real differences are found in the length of the snout and lower jaw, the retro-orbital part of the head, the length and depth of the head, the greatest and smallest depth of the body, the antedorsal, postdorsal, anteventral and anteanal distances, the length of the caudal peduncle, the upper lobe and the middle rays of the caudal fin, the depth of the anal fin and the length of the base of the dorsal and anal fins.

The pink salmon of the River Iski has a relatively longer head, upper and lower jaw and middle rays of the caudal peduncle than the Amgun' pink salmon. /35/ It has a wider upper jaw, a greater antedorsal distance, and its anal fin is higher and longer at the base. However, what really strikes the eye is the low depth/length ratio of the body of the Iski pink salmon, as shown by the much smaller height of the body and of the caudal peduncle than in the Amgun' pink salmon. The pink salmon of the south-western part of Amur Sound, although morphologically indistinguishable from that of the continental shore of the Tatar Straits, i.e., the Primor'e pink salmon, thus shows considerable differences in nearly all its features from the pink salmon migrating into the main channel of the Amur. In most of its structural features, however, the latter also differs significantly from the pink salmon of the River Iski.

In the light of these investigations it is clear why Milovidova-Dubrovskaya (1937) at that time found no significant differences between the pink salmon of Primor'e and of the south-western part of Amur Sound, for which the material was in fact homogeneous. It is also easy to understand why Pravdin (1932), when giving the morphometric characteristics of the Amur pink salmon and distinguishing it as natio amurensis, used mixed material, including the qualitatively different salmon from the south-western part of Amur Sound, the main channel of the River Amur and Schast'ya Bay.

Analysis of the morphological features of the pink salmon of the River Amgun', the south-western part of Amur Sound and the River Iski reveals clear differences in the following group of features: depth of the body (greatest and smallest), postdorsal distance, length of the caudal peduncle and length of the upper lobe of the caudal fin. The absolute and relative values of these features of the Amgun' pink salmon are much greater than those of the pink salmon from the south-western part of Amur Sound and River Iski. So far as the last two areas are concerned, local stocks of pink salmon either are completely indistinguishable in these features or they differ slightly. Like all features in general, those mentioned are of adaptive importance and they depend on the geomorphological indices and the hydrological conditions of the spawning rivers (Nikol'skii, 1955).

Unlike the Amgun' salmon, which ascends the river for a considerable distance and, consequently, utilises a large amount of energy in order to reach its spawning grounds, the pink salmon entering the rivers of the south-western part of Amur Sound and the River Iski travels only a short distance to its spawning grounds because of the shortness of its headwaters. Naturally, therefore, the more powerful caudal peduncle and caudal fin and, as will be shown below, the high level of nutrition of the Amgun' pink salmon are well coordinated with its longer spawning migrations in the river.

The high depth/length ratio of the body of the Amgun' pink salmon is evidently connected with the flat character of the river channel (the lower course of the Rivers Amur and Amgun'), for a considerable length of which the fish carries out its spawning migration. The mountainous character of the Rivers Iski and My and, consequently, the faster flow of the rivers, have led to different hydrodynamic qualities of the pink salmon in these rivers: the streamlined, cylindrical shape of the body. Despite the geographical separation of the pink salmon in the Rivers Iski and My, the similar conditions (the mountainous character of the rivers) in their spawning areas have led to the formation of similar morphological features in them. A similar phenomenon has also been observed with other fish (Frolov, 1950).

B. Biological Indices /36/

The sex ratio in the Amgun' pink salmon as a rule reflects some predominance of females (Table 18); in some years (1954) the number of females in the stock increased considerably, and this also was observed in pink salmon in two other rivers. However, the comparatively small material for the Rivers Iski and My for 1954 (125 and 150 fish respectively) cannot be regarded as sufficiently representative. The same can be said about the sex ratio of the pink salmon in the River Iski in 1950 (161 fish) and the River My in 1952 (139 fish); otherwise appreciable predominance of males in the stock was observed for the pink salmon of the Rivers Iski and My (Table 18).

TABLE 18. Size and Sex Ratio of Pink Salmon from Different Rivers

1 Годы	2 Пол	5 р Амгунь					9 р. Мы					10 р. Иски				
		длина, см 6		вес, 7 г	%	8 число рыб	длина, см 6		вес, 7 г	%	8 число рыб	длина, см 6		вес, 7 г	%	8 число рыб
		AC	Od				AC	Od				AC	Od			
1950	самцы 3	47,5	34,9	1473	52	1181	52,5	39,8	1844	58	179	50,7	—	1711	51	83
	самки 4	45,1	33,9	1207	48	1097	48,2	36,5	1429	42	129	47,5	—	1309	49	78
1951	самцы	45,5	33,6	1282	46	368	52,4	38,0	1714	51	127	50,1	35,6	1434	58	261
	самки	43,7	33,1	1119	54	433	49,2	36,8	1408	49	123	49,3	36,5	1364	42	188
1952	самцы	49,4	35,4	1838	46	629	54,2	39,0	1999	59	82	51,3	38,1	1866	53	256
	самки	45,9	34,0	1434	54	754	49,8	36,6	1504	41	57	47,6	36,3	1458	47	232
1953	самцы	48,7	34,7	1593	47	268	54,4	39,1	2028	57	208	51,9	36,6	1782	57	284
	самки	45,3	33,1	1239	53	309	50,6	37,1	1619	43	159	48,5	36,1	1455	43	215
1954	самцы	51,0	36,9	1806	43	768	54,3	38,8	1931	45	67	50,0	36,5	1680	39	49
	самки	48,1	35,7	1410	57	1028	49,9	37,0	1513	55	83	47,3	36,5	1413	61	76

KEY: (1) Years (2) Sex (3) Males (4) Females (5) River Amgun' (6) Length, cm (7) Weight, g (8) Number of fish (9) River My (10) River Iski

On the average, therefore, the ratio between the numbers of males to females for the Amgun' pink salmon was 47: 53, compared with 56: 44 and 55: 45

respectively for pink salmon from the Rivers Iski and My.

The material in Table 18 shows that as a rule smaller pink salmon migrate into the River Amgun' than into the Rivers My and Iski[1]. The smaller linear dimensions of the Amgun' pink salmon are not due to the sex ratio, as Zamakhaev (1959) considered, but to true differences in the size of pink salmon of the same sex from different rivers. Smaller in size than the salmon from the Rivers Iski and My, the pink salmon of the Amgun' was lighter in weight; however, for the same groups by size the Amur pink salmon always had the greatest weight (Fig. 4).

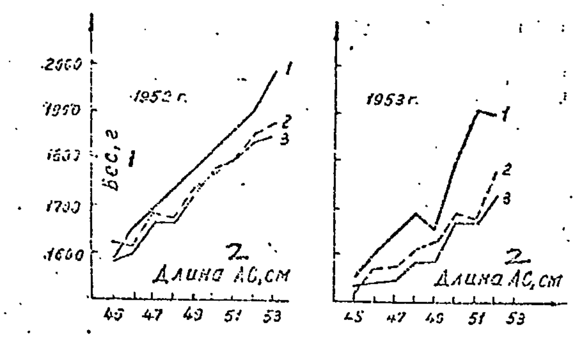

Fig. 4. Ratio between length and weight of pink salmon (excluding weight of gonads): 1) River Amgun', 2) River Iski, 3) River My.

Key: 1) Weight, g 2) Length AC, cm.

According to the figures for 1950-1953 the Iski salmon grew fastest in the first year of life (30.5 cm) and the Amgun' salmon (27.5 cm) the slowest. In the second year of life the Amgun' and Iski salmon grew almost equally, on the average by 19.0 cm, whereas the salmon from the River My outstripped them in growth, increasing in size on the average by 21.8 cm (Enyutina, 1955). This inequality in the growth of the salmon from the different rivers was

[1]As an exception, the salmon migrating into the River Iski were not larger than those migrating into the River Amgun' only in 1954.

clearly reflected in the scale structure: within the first check they have the same number of sclerites but the width is different; in the growth during the second year, on the other hand, although the width of the sclerites is comparatively uniform their number differs.

It might naturally be supposed that this last growth of the scale (growth in the second year of life) would be less in the salmon leaving the place of its growth sooner and, conversely, that growth in the second year of life must be linked to some degree with the beginning of the spawning migration. In /37/ fact, the opposite picture is observed: in the pink salmon of the River My the amount of growth of the scale in the second year of life as well as the number of sclerites during this period are much greater than in the salmon of the River Iski although the former enters the river a month sooner than the latter.

To ascertain the specific features of scale structure of the pink salmon from the fishing districts examined previously and from the area of Cape Dzhaore (on the right shore of Amur Sound 6 km to the north of the mouth of the River My) individuals of the same size were compared (Table 19).

The only real differences (expressed as M_{diff}) found between the pink salmon of the River Amgun', on the one hand, and that caught in the region of De-Kastri, Cape Lazarev and Cape Uarke and in the River My, on the other /38/ hand, are in the length of the fingerling and the winter growth and in the number of sclerites of the winter ring. The visible manifestation of these differences is that the Amgun' salmon has a smaller growth of the scale before the zone of narrowed sclerites than the salmon of the continental shore of the Tatar Straits and the south-western part of Amur Sound but a greater growth of the latter zone as a result of the larger number of sclerites forming it. The salmon caught near Cape Dzhaore occupy the special and, apparently, intermediate position for these features. To judge from M_{diff}, it is closer to the Amgun' form although there are almost no real differences between it and the salmon from the more southerly districts. In the structure of the scale, it bears a distinct resemblance to the salmon caught in the sector from De-Kastri Bay to the River My and it clearly differs in this feature from the salmon migrating into the River Amgun'.

TABLE 19. Differences in Growth and Scale Structure of Pink Salmon of the Same Size from Different Fishing Districts, 1952

Показатели	Де-Кастри		м. Лазарева		м. Уарке		р. Мы		м. Джаоре		р. Амгунь	
	M	±m	M	±m	M	±m	M	±m	M	±m	M	±m
Прирост, см[1]												
Сеголетка	24,69	0,41	24,70	0,35	24,65	0,42	24,70	0,36	23,25	0,35	22,94	0,34
Годовика	28,33	0,42	28,10	0,31	28,21	0,39	27,89	0,35	27,49	0,44	27,77	0,33
«Зимний»	3,37	0,19	3,40	0,19	3,37	0,22	3,05	0,19	4,25	0,31	4,65	0,26
Второго года	17,13	0,47	17,95	0,39	17,81	0,39	17,55	0,32	18,41	0,52	17,57	0,29
Число склеритов:												
в зоне первого года	18,72	0,40	18,15	0,35	17,60	0,33	17,35	0,23	18,20	0,33	18,36	0,34
в зоне «зимнего» роста	3,20	0,15	3,05	0,13	3,24	0,19	3,05	0,13	3,76	0,20	4,12	0,21
в зоне второго года	10,92	0,29	11,05	0,02	11,24	0,25	11,45	0,29	11,40	0,31	11,52	0,25
Число исследованных рыб	25		20		25		20		25		25	

KEY: (1) Indices (2) Growth, cm[1] (3) Fingerling (4) Yearling (5) Winter (6) Second year (7) Number of sclerites (8) In zone of first year (9) In zone of winter growth (10) In zone of second year (11) Number of fish studied (12) De-Kastri (13) Cape Lazarev (14) Cape Uarke (15) River My (16) Cape Dzhaore (17) River Amgun'

---

[1] The measurements in the line "Fingerling" show the calculated length of the body of the pink salmon before the beginning of the zone of narrowed sclerites; in the "Yearling" line they show the same as far as the end of this zone; the "Winter" growth represents the growth of the fish calculated for the zone of narrowed sclerites, and the "Second year growth" line gives the length of the body of the salmon calculated after the formation of the winter ring.

Later studies of scale structure (Enyutina, 1963) confirmed the similarity between the salmon on the west coast of Hokkaido, i.e., from the Sea of Japan, with that caught in Amur Sound, in the region of Cape Pronge.

The more homogeneous the material studied, the more reliable the comparison of the fertility of the pink salmon caught in different regions, for even within a group of salmon of the same size and the same weight considerable variations are found in the number of eggs. Comparison of individuals of the same size showed that the salmon of the River Amgun' is distinguished from the rest by its higher fertility and its better condition (Table 20).

TABLE 20. Fertility and Condition of Pink Salmon of the Same Size Caught in Different Regions

Районы 1	Плодовитость 9 M		±m	Коэффициент упитанности 10 M		±m	Число рыб 11
Бух. Датта 2	1350	1378	32,3	1,15	1,15	0,01	65
Зал. Де-Кастри 3	1423			1,15			
М. Лазарева 4	1453	1348	27,5	1,14	1,15	0,01	65
М. Уарке 5	1248			1,16			
Р. Мы 6	1357			1,16			
Р. Амгунь 7		1643	40,4		1,37	0,02	25
Р. Иски 8		1488	47,5		1,04	0,02	25

KEY: (1) Regions (2) Datta Creek (3) De-Kastri Bay (4) Cape Lazarev
(5) Cape Uarke (6) River My (7) River Amgun' (8) River Iski
(9) Fertility (10) Condition factor (11) Number of fish

Consequently, these biological features also reveal differences between the pink salmon of Schast'ya Bay, the main channel of the River Amur and the south-western part of Amur Sound and similarity between the last of these types and the Primor'e pink salmon.

The specific fecundity index $\frac{AC \times Q}{r}$ for 1950-1954, reflecting the reproductive capacity of the species, was much higher (42) on the average for the pink salmon from the River My than for that from the Amur (36).

C. Fluctuations of the Population

According to the statistics of Amurrybvod in odd years on the average $3\frac{1}{2}$ times more pink salmon penetrated into the River My than in even years. Near Cape Lazarev, as in De-Kastri Bay, larger catches also were observed in odd years. In other words, the character of alternation of the abundance of the spawning migrations of the pink salmon in the south-western part of Amur Sound is the same as in the waters of the Tatar Straits; the opposite /39/
picture was observed, however, in the Amur (Table 21).

TABLE 21. Mean Annual Catch of Pink Salmon in Adjacent Fishery Districts (thousands of fish)

Места лова 1	Период наблюдений 7	Годы 8	
		четные 9	нечетные 10
Бассейн Амура (без м. Лазарева) 2	1940—1953	4220	810
Северное Приморье 3	»	1014	2980
Де-Кастри 4	»	221	307
М. Лазарева 5	»	79	120
Р. Мы (пропуск через контрольно-учетное заграждение) 6	1949—1953	98	346

KEY: (1) Place of catch (2) Amur basin (without Cape Lazarev) (3) North Primor'e (4) De-Kastri (5) Cape Lazarev (6) River My (passing through counting fence) (7) Period of observations (8) Years (9) Even (10) odd

Very characteristically the largest pink salmon catches in the period 1945-1953 were observed in the Tatar Straits (near the west coast of Sakhalin, in Primor'e and in De-Kastri Bay) and also in the south-western part of Amur Sound in 1949 and the north-western part of the Sound and in the Amur in 1948. Table 22 and Fig. 5 also show the similarity between the fluctuations in catches of pink salmon in the Sea of Japan and fluctuations in its population in the River My.

TABLE 22. Catches of Pink Salmon in Primor'e and Number of Spawners Migrating into the River My

Районы (1)	Годы (5)											
	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Приморье (2) (тыс. тонн)	5,2	1,2	2,7	1,2	0,3	1,7	0,2	4,5	1,0	3,4	2,2	1,3
Р. Мы (тыс. шт.) (3)	651	158	296	37	91	268	13	851	17[1]	812[1]	106	74

[1] Учет неполный. (4)

KEY: (1) Districts (2) Primor'e (thousands of tons) (3) River My (thousands of fish) (4) Counting incomplete (5) Years

The dynamics of the catches shows that abundant migrations of pink salmon were observed in even years near the north-west coast of the Sea of Okhotsk and in the River Iski before 1937; after 1939 the cycle changed and the migrations became less abundant in odd years. At the same time, the catches of pink salmon in the Amur still remained high in even years and low in odd years (Table 15).

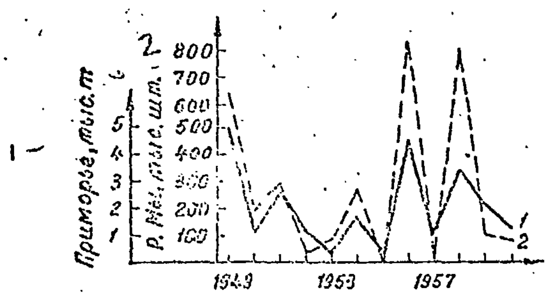

Fig. 5. Catches of pink salmon in Primor'e and Number of spawners migrating into the River My: 1) Primor'e, 2) River My.

Key: (1) Primor'e, thousands of tons (2) River My, thousands of fish

No direct investigations have been carried out to study the migration routes of the pink salmon in the region of Schast'ya Bay, bordering on the north-western part of Amur Sound. /40/

Mass migration of the pink salmon into the rivers of the north-western part of the Sea of Okhotsk and into the River Iski usually begins at the same time, as a rule in the second half of July and continuing until the middle of August; the last migrations into the River Iski usually take place before the end of August. It is interesting to note that there is no difference between the migration times of the Iski chum and the chum of the north-western rivers of the Sea of Okhotsk. In the subsequent years the character of fluctuations in the population of the Iski pink salmon changed in the opposite direction: in the period 1952-1964 the mean number of migrating salmon in even years was 452 000 fish, but only 76 000 in odd years.

A study of the causes of fluctuation in the Amur salmon stocks in 1937-1941 showed that the size of the salmon catch at installations on the left shore of Amur Sound depended directly on the number of fish entering the River Iski for spawning. It was therefore postulated that the spawning ground of the pink salmon of the Sea Okhotsk extends further south than the basin of the River Iski. In all probability, when numbers of the Amur pink salmon are high its spawning area also extends more widely into neighbouring districts, including, in particular, Schast'ya Bay. /41/

To determine to which stock the pink salmon of the north-western part of Amur Sound (Rybnovsk District) belongs, in 1959 I compared it with the pink salmon from the Nevel'sk Straits, i.e., the Primor'e stock (Enyutina, 1955). Comparison of individuals of the same size from the first migrations showed that the Rybnovsk pink salmon differs from the Primor'e only in the smaller depth of the caudal peduncle ($M_{diff} = 7.7$) and in the structure of the scale. The difference in scale structure was expressed as a much smaller number of sclerites in the "Fingerlings" of the Rybnovsk pink salmon (15.65 ± 0.17 compared with 17.12 ± 0.16), and a greater increase in length of the scale in the second year of life (20.34 ± 0.25 compared with 17.92 ± 0.21) than in the

Primor'e salmon. In other words, the Rybnovsk salmon, although attaining the same size as the Primor'e in the period of its spawning migration, lagged behind it in growth in the first year of life but grew more rapidly later.

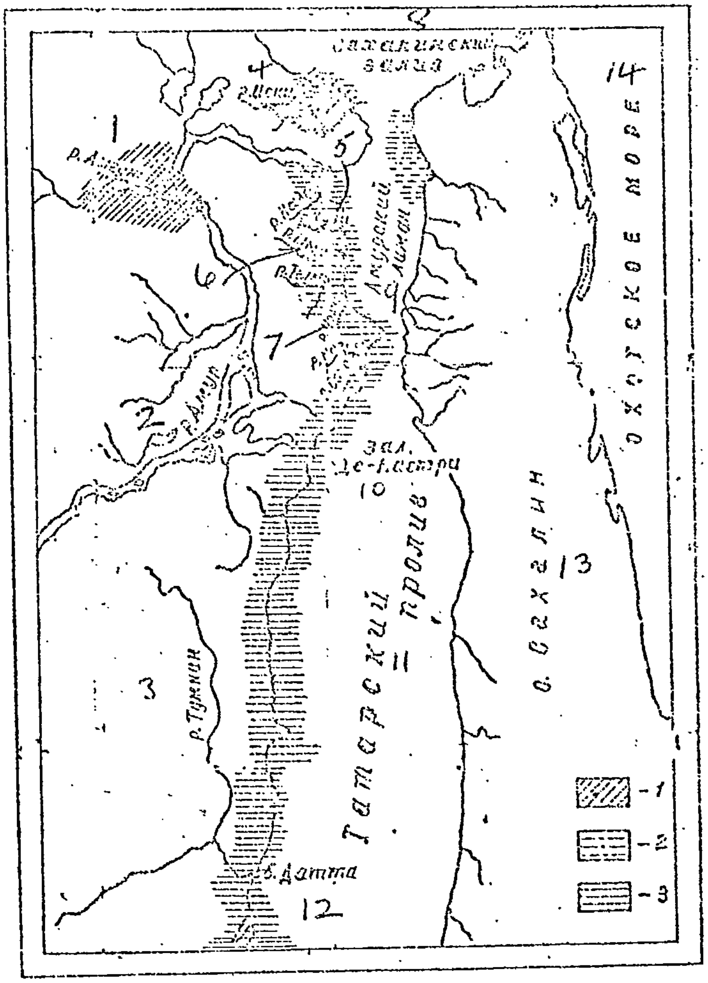

Fig. 6. Distribution of local pink salmon stocks in the lower reaches of the Amur and adjacent waters: 1) Amgun' stock, 2) Okhotsk stock, 3) Primor'e stock.

Key: (1) River Amgun' (2) River Amur (3) River Tumnin (4) River Iski (5) River Khuzi (6) River Ny (7) River Chomi (8) Gulf of Sakhalin (9) Amur Sound (10) De-Kastri Bay (11) Tatar Straits (12) Datta Creek (13) Sakhalin Island (14) Sea of Okhotsk

It can be stated on the basis of the facts described in this chapter that pink salmon of the Primor'e stock migrates into Amur Sound from the south, from the Sea of Japan, and is distributed among the spawning rivers of the south-western part of the Sound from Cape Lazarev to the River My, and some of these fish probably also enter the Amur, where they keep mainly to its right bank.

The basin of the River Iski, situated to the north-west of Amur Sound at the boundary between the areas of two pink salmon stocks, is frequented in different years preferentially by the Sea of Okhotsk stock or the Amur stock of pink salmon.

A local stock differing from the Primor'e and Iski (Sea of Okhotsk) stocks in a number of morphological features, sex ratio, size, weight, rate and character of growth, fecundity, condition, and character of alternation of abundant and sparse year-classes, is distributed in the largest of the spawning tributaries of the Amur basin -- the River Amgun'. The necessary information regarding the spawning routes of this stock has not yet been obtained.

At the beginning of the spawning run a certain proportion of the Primor'e stock of pink salmon, dispersed from it during the growing period, evidently migrates into the north-eastern part of Amur Sound (Fig. 6).

/42/

V. SPAWNING MIGRATIONS

1. Migration Routes

There are two different opinions regarding the migration routes of the pink salmon into Amur Sound: the first (Brazhnikov, 1900; Soldatov, 1912; Kaganovskii, 1949) assumes entry of the pink salmon from the north, from the Sea of Okhotsk; according to the second (Shmidt, 1905, 1950; Navozov-Lavrov, 1927; Derzhavin, 1933; Milovidova-Dubrovskaya, 1937; Sato, 1938; Dvinin, 1949), the pink salmon enters Amur Sound from the south, from the Sea of Japan. The first of these views is based on two facts: pink salmon are caught by the fisheries of the left shore of Amur Sound and the catches of this species follow the same cycle in the River Amur and along the north-west coast of Sakhalin; the second is based on tagging data, on the finding of pink salmon with Japanese hooks, and the fact that the fluctuations in its catches are the same on the continental shore of the Tatar Straits and in the south-western part of Amur Sound.

Pravdin (1932) occupied a special position in this matter. He did not consider that the problem of migrations of the Amur pink salmon has been completely solved and postulates that the stocks of the fish for commercial exploitation are formed in the south-western part of the Sea of Okhotsk, from which they migrate both towards the west of Sakhalin and the River Amur. However, Pravdin made one qualification: his hypotheses are in conflict with the facts that pink salmon with Japanese hooks are found in Amur Sound and in 1928 a pink salmon, tagged on the coast of Korea, was found in the same region, near Cape Uarke. Returning to the question of migrations of the Amur pink salmon later, Pravdin (1940) accepted that some of these fish may migrate into the Sound from the southern part of the Sea of Japan, near the coast of Korea.

Before 1961 the fisheries of De-Kastri and Cape Lazarev caught many pink salmon[1]. The small rivers Somon and Nigir', flowing into the Tatar Straits near these capes, could not provide sufficient spawning ground for the whole mass of pink salmon migrating into that region. There is no doubt that the salmon caught at De-Kastri and Cape Lazarev had mainly migrated into more northern regions, where such relatively large spawning rivers as the Chomi, Tymi and My were available.

In 1953 the Amur branch of TINRO (Birman and Enyutina) studied the migration routes of salmon into Amur Sound. Fish were caught in the Nevel'sk Straits in the region of the Chastye Islands and near the west coast of Amur Sound between Cape Dzhaore and Cape My, using drift nets and trap nets /43/ in the period from 2 to 9 July. In every case the salmon was running against the current. These investigations confirmed that a large proportion of the pink salmon (84 %) entering Amur Sound and the Rivers Chomi, Tymi and My came from the south, through the Nevel'sk Straits, and only 16 % came from the north, when the tide came in from the Sea of Japan. The possibility

[1]Since 1961 no fishing for pink salmon has been carried on in these regions.

cannot be ruled out that this small proportion of the fish had changed its principal direction of movement (from south to north) because of a change in the direction of the tide.

Migrations of the pink salmon along the continental shore from south to north are confirmed by the times of its appearance in the fishing grounds of Soviet Primor'e, the Tatar Straits and Amur Sound. According to the observations of Milovidova-Dubrovskaya (1937) and Pushkareva (1951), the pink salmon entered the River Tumnin on the last days of May or the first days of June; the statistics of the catches show that further north, in De-Kastri Bay, the first pink salmon were usually caught in the first 10 days of June, i.e., later than in regions further south but sooner than near Cape Lazarev[1].

A similar direction of migration of the pink salmon is observed along the Sakhalin shore of the Tatar Straits (Shmidt, 1905; Navozov-Lavrov, 1927). According to Dvinin (1952), the run of the pink salmon in the southern part of the west coast of Sakhalin in the region of Nevel'sk-Chekhov begins on 5-10 June, whereas further north the spawning migrations toward the coast are 10-15 days later. Comparison of all the facts (catching tagged fish, the identical cycles of catches of the pink salmon off the continental shore of the Tatar Straits and in the south-western part of Amur Sound, the high catches near Cape Lazarev, the times of the spawning migration, test fishing with nets and, finally, morphological and biological similarity) thus suggests that most of the pink salmon enter the waters of Amur Sound from the Tatar Straits through the Nevel'sk Straits.

Observations by Isida and Miyaguchi (1959) show that the pink salmon of

---

[1]The beginning of the run of the pink salmon was established at the fisheries of Datta Creek, De-Kastri and Cape Lazarev from the statistics of the industry. It is possible, therefore, that the true beginning of the run in these districts may have been earlier.

the Sea of Japan migrating to the north along the west coast of the islands of Honshu and Hokkaido has exhibited abundant migrations in even years since 1953. This corresponds clearly to the cycles of pink salmon catches in the south-western part of Amur Sound (Table 22). Similarity in scale structure of the pink salmon of the west coast of Hokkaido and the Amur pink salmon (Enyutina, 1963) confirms the previous hypothesis that the pink salmon of the Sea of Japan migrates into Amur Sound.

With the development of Soviet marine research Birman (1964, 1965) showed that the migration of the Amur pink salmon from the ocean through the Friza Straits is impossible because of the low water temperatures. The hydrometeorological features of Amur Sound and the growth patterns of the Amur and Primor'e stocks of pink salmon convinced Birman that the Amur pink salmon spends the winter and feeds in the Sea of Japan.

The northern part of Amur Sound has not yet been adequately studied as regards the migration routes of pink salmon. Huge shoals of the autumn chum come into this region and then enter the Amur. The autumn chum is therefore considered to reach the Amur from the north, from the side of the Gulf of Sakhalin. This cannot be said about the pink salmon, judging from its very small catches in the Puir fishery district (on the continental shore of the Sound) and from its almost complete absence in the region of Cape Men'shikov /44/ and Baidukov Island (the Chkalov Fish Factory), i.e., at its outlet into the Gulf of Sakhalin.

Migrations of pink salmon into the Rybnovsk district of Sakhalin, i.e., chiefly into the north-eastern part of Amur Sound, are always large. However, it is still difficult to say definitely from where the pink salmon comes into this region. This will be clear from the example of 1959 (Table 23).

TABLE 23. Distribution of Pink Salmon Catches in Different Parts of the Rybnovsk District as Percentages of the Total Catch for Five-Day Periods, 1959

1 Участки лова (с юга на север)	Июнь 9				Июль 11							
	IV[1]	V	VI	10 всего	I	II	III[2]	10 всего	IV	V[2]	VI	10 всего
2 Кривой рог	86,4	63,3	96,0	76,5	7,4	—	—	6,1	—	—	—	—
3 Рыбозаводы № 3, 40	—	28,2	—	16,3	81,0	75,8	54,6	78,6	34,7	100,0	64,9	46,9
4 Зотовская банка	13,6	8,5	4,0	7,2	5,6	4,8	—	5,3	26,5	—	7,8	19,1
5 Музьма	—	—	—	—	6,0	19,4	45,4	9,5	38,8	—	27,3	34,0
6 Всего выловлено, ц	22	234	148	404	838	145	44	1027	464	7	294	765

[1] Пятидневки. 7

[2] Лов горбуши почти не производился из-за сильных штормов. 8

KEY: (1) Place of catch (from south to north) (2) Krivoi Rog (3) Nos. 3 and 40 fish factories (4) Zotovskaya Banka (5) Muz'ma (6) Total catch, centners (7) Five-day periods (8) Hardly any pink salmon caught because of severe gales (9) June (10) Total (11) July

TABLE 24. Dynamics of Pink Salmon Catches in Rybnovsk District of Sakhalin and at the Aleevka Control Barrier in 1961 for Five-Day Periods as a Percentage of the Total Catch for the Fishing Season

1 Места лова	4 Июнь						Июль 5						Август 6			7 Всего
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	
Рыбновский район 2						1,6	0,7	6,8	9,7	1,4	8,1	12,6	2,1	56,9	0,1	1400 ц 8
с. Алеевка 3	0,1	1,6	2,1	17,7	37,6	25,1	4,6	4,3	0,9	2,1	2,5	0,8	0,4	0,2		40217 шт. 9

KEY: (1) Place of Catch (2) Rybnovsk District (3) Aleevka Village (4) June (5) July (6) August (7) Total (8) Centners (9) Fish

After the sharp decline in pink salmon catches in the period from 6 to 15 July taking place in all parts of Amur Sound, in Rybnovsk District unlike all the others a fresh and considerable increase was observed in the fourth five-day period, followed by a smaller increase in the sixth five-day period of July (Table 23). The increase in catches in the fourth five-day period /45/ of July took place on account of one day only -- 17 July -- because of the arrival of a large shoal of pink salmon. The catch on 17 July (399 centners) was not the largest daily catch in Rybnovsk District in that fishing season. It will be clear from Table 23 that most of the catch consisted of pink salmon from northern areas, and the contribution of Muz'ma, i.e., the most northerly fishing point, situated outside Amur Sound, was about 40 % of the total catch for the district.

The data in Table 23 illustrate clearly the movement of the pink salmon from south to north along the Sakhalin shore of Amur Sound. The appearance of the pink salmon at the end of the fishing season in the region of the Muz'ma fishery in comparatively large numbers coincided with a decrease in catches in the central part of Rybnovsk District (Nos. 3 and 40 fish factories) and the total cessation of catches in the southern part (Krivoi Rog). This relationship between pink salmon catches in different fishery areas of Rybnovsk District does not allow a definite answer to the question whether the pink salmon moves along the Sakhalin shore of Amur Sound from south to north, to enter the Gulf of Sakhalin of the Sea of Okhotsk (the point of view held by Sato, 1938), or whether some of the pink salmon stock approaches the north-west coast of Sakhalin at the end of July from the north, from the Sea of Okhotsk (the point of view of Birman, 1964). This second point of view is supported by the dynamics of the pink salmon catches in Rybnovsk District and in the Cape Pronge District (Table 24). Whereas most pink salmon pass near the right shoreof Amur Sound in June, only the first shoals of this salmon are appearing off the north-west coast of Sakhalin.

The data in Table 23 and 24 show that the pink salmon can also enter Amur Sound from the Gulf of Sakhalin, i.e., from the north, but much later than it enters from the Sea of Japan. The latter, continuing its migration in the main South Channel, near Cape Dzhaore reaches the continental shore and then moves along it toward the mouth of the shallow coastal channels, when it enters the Neronovsk Channel, also along the left shore of Amur Sound.

Year by year the spawning stocks of pink salmon migrating into the Amur are distributed unevenly between the fisheries of the right and left shores of the Sound. The pink salmon catch of the fisheries on the right shore is generally larger than that of the left shore. Only the years 1938 and 1948, i.e., years of particularly large salmon populations, were exceptions, as is clear from Table 25.

In 1934-1950 pink salmon catches on the right shore of Amur Sound were thus on the average 9.4 times greater than those on the left shore and only the particularly abundant salmon year-classes were equally distributed in Amur Sound during the spawning run, as earlier information confirms (Soldatov, 1912; Tikhenko, 1915).

With the typical distribution of the migrating pink salmon between the fisheries of the right and left shores of Amur Sound, i.e., with more of them near the right shore the ratio between the catches in individual years varies within wide limits. For instance, catches at the Chardbakh and Aleevka control barriers were in the ratio of 1: 2.3 in 1957, 1: 10 in 1961, and 1: 23 in 1959.

2. Time of the Run

According to the observations of TINRO the pink salmon began to enter the Amur at the end of May. Control nets set up in the period 1958-1965 off Cape Pronge almost immediately after passage of the ice, showed as a rule later periods (Table 26). These first fish, known as "messengers," are ignored by /46/

TABLE 25. Distribution of Pink Salmon Catches Among Fisheries of the Right and Left Shores of the Amur Sound in 1934-1950

Берег	Предприятия	Улов	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Правый	Де-Кастри[1] м. Лазарева Джаоре Н. Пронге	тыс. ц	22,4	5,5	21,4	2,7	27,7	10,2	26,7	12,3	51,8	13,6	28,5	6,8	28,6	5,7	49,8	4,0	6,5
		%	79,2	93,2	83,3	84,3	50,9	73,8	76,2	80,9	81,1	87,7	75,1	90,7	62,9	85,1	51,2	70,2	79,3
Левый	Пуир Озерпах Тнейвах Чныррах	тыс. ц	5.9	0,4	4,3	0,5	26,6	3,6	8,3	2,9	12,0	1,9	9,4	0,7	16,8	1,0	47,3	1,7	1,7
		%	20,8	6,8	16,7	15,7	49,1	26,2	23,8	19,1	18,9	12,3	24,9	9,3	37,1	14,9	48,8	29,8	20,7

KEY: (1) Shore (2) Right (3) Left (4) Fisheries (5) De-Kastri (6) Cape Lazarev (7) Cape Dzhaore (8) Cape Pronge (9) Puir (10) Ozerpakh (11) Tneivakh (12) Chnyrrakh (13) Catch (14) Thousands of centners

[1] The catches of this fishery are included in those of the right-shore fisheries of Amur Sound.

TABLE 26. Times of the Pink Salmon Run in the Region of Cape Pronge and Numbers of its Spawning Stocks

Год 1	Улов двух контрольных заездков, тыс. шт. 6	Дата появления первых особей (по данным контрольных сетей) 10	11 Дата, к которой было поймано рыбы в % от общего улова: начало хода 12		массовый ход 13			конец хода 14		Дата окончания хода 15	Продолжительность массового хода (в днях) 16
			1	10	25	50	75	90	99		
1957	20	5/VI	15/VI	17/VI	19/VI	22/VI	27/VI	17/VII	8/VIII	18/VIII	9
1958	1720[1]	14/VI	24/VI	29/VI	1/VII	6/VII	16/VII	22/VII	26/VII	11/VIII	16
1959	269	5/VI	12/VI	15/VI	19/VI	28/VI	3/VII	5/VII	8/VII	31/VII	15
1960	389	13/VI	24/VI	28/VI	1/VII	5/VII	9/VII	14/VII	24/VII	8/VIII	9
1961	44	30/V	9/VI	17/VI	21/VI	24/VI	28/VI	6/VII	24/VII	1/VIII	8
1962	72	7/VI	18/VI	20/VI	22/VI	28/VI	2/VII	5/VII	12/VII	20/VII	11
1963	437	5/VI	14/VI	17/VI	19/VI	23/VI	29/VI	4/VII	23/VII	9/VIII	10
1964	233	5/VI	16/VI	18/VI	20/VI	22/VI	25/VI	29/VI	6/VII	22/VII	5
1965	244	6/VI	16/VI	19/VI	21/VI	26/VI	30/VI	6/VII	26/VII	7/VIII	10
2 уровень запасов											
3 высокий	свыше 500 тыс. шт. 7	14/VI	24/VI	29/VI	1/VII	6/VII	16/VII	22/VII	26/VII	11/VIII	16
4 средний	от 100 до 500 тыс. шт. 8	7/VI	16/VI	19/VI	22/VI	27/VI	1/VII	6/VII	17/VII	3/VIII	10
5 низкий	до 100 тыс. шт. 9	4/VI	14/VI	18/VI	21/VI	25/VI	29/VI	9/VII	25/VII	3/VIII	9

KEY: (1) Year (2) Level of stocks (3) High (4) Average (5) Low (6) Catch of two control barriers, thousands of fish (7) Over 500 000 fish (8) From 100 000 to 500 000 fish (9) Under 100 000 fish (10) Date of appearance of first individuals (from data of control nets) (11) Date when fish were caught, in per cent of total catch (12) Beginning of run (13) Mass migration (14) end of run (15) Date of end of run (16) Duration of mass migration (in days)

[1]Data incomplete; with correction for restriction on catching they were about 2 million fish.

the fishermen for pink salmon in the Sound are usually caught with fences that are not completed until 10-15 June. Individuals of the last spawning migrations likewise are not caught because their exploitation is unprofitable. When speaking of the time of spawning migration of the pink salmon I thus mean the period of its commercial fishing, and by the beginning and end of the run I imply an intensity such that only single individuals are caught continuously during reassembly of the barrier. With this meaning of the term the end of the spawning migration of the pink salmon in Amur Sound can be timed as a rule to the first 10 days of August. The last single specimens found scattered at intervals can be caught at the end of August or even in September, along with the autumn chum.

Practical fishery experience shows that delay in the appearance of the "messenger" pink salmon announces the return of an abundant stock of that fish /47/ (Starovoitov, 1926). In the 1926 fishing season, for example, when the maximal number (161 000 centners) of pink salmon was caught by the Amur fisheries alone, the run was almost 10 days late (Vorotnikov, 1927). Davidson and Vaughan (1939), who observed this phenomenon in a study of the Alaskan pink salmon regarded it as a regular feature. Planned investigations of the Amur and Primor'e pink salmon confirmed the validity of these observations. From my own material (Table 26), in abundant years the pink salmon enters the Amur considerably later than in years of poor catches.

The changes in the times of migration of the pink salmon into Amur Sound can be seen more clearly still from the same statistics presented in Table 27.

Regular changes in the times of the run of the pink salmon for year-classes of high, average and low stocks is observed, as Table 26 shows, from the appearance of the first fish until the end of the mass migration, within the limits of which from 25 to 75 % of the total catch for the season may be found. However, a marked difference in the times of the spawning migration is observed /48/ for year-classes which differ sharply in their numbers. This difference, both in the times of appearance of the first runs and in the beginning and climax of the mass migration, averages 10 days and becomes greater still (up to 17 days) at the end of the mass migration. Whereas in small stocks of pink salmon the bulk of the fish enters the Sound in the last 10 days of June, in the case of abundant stocks it does so in the first half of July. The last migrations of pink salmon of spawning stocks of different sizes end at different times but, as a rule, they do so at the end of July or the beginning of August.

TABLE 27. Catches of Pink Salmon at the Aleevka Control Barrier in Ten-Day Periods in Per Cent of the Total Catch of this Salmon for the Season

Годы 1	Июнь 2			Июль 3			Август 4
	I	II	III	I	II	III	I
1957	—	60,2	31,2	8,0	0,5	—	—
1958	—	—	21,7	34,2	26,8	16,5	0,8
1959	—	29,1	34,2	34,2	2,3	0,2	—
1960	—	—	20,3	61,3	16,4	1,6	0,4
1961	1,7	19,8	62,6	8,9	3,0	3,4	0,6
1962	един. 5	10,3	45,0	42,3	2,4	—	—
1963	—	31,8	49,3	15,6	1,5	0,9	0,9
1964	0,1	31,6	63,6	3,9	0,8	един.	—
1965	един.	11,0	63,4	20,3	1,0	3,5	0,8

KEY: (1) Years (2) June (3) July (4) August (5) Single

The same rule was observed some years ago for the pink salmon of south-east Alaska (Davidson and Vaughan, 1939) and they explained it by the rate of growth of the salmon during its stay in the ocean: small stocks under favourable feeding conditions grow well, mature more rapidly, and start their spawning migration sooner; abundant stocks grow comparatively more slowly, remain at the feeding grounds as long as possible, and therefore start the spawning migration later. There is a basis for this explanation. However, outside this rule there are examples of late migrations of small populations of pink salmon, such as in 1947 and 1960, and of comparatively early migrations of an abundant stock of pink salmon, as in 1939. It will be clear from Table 26 that the duration of the mass migration of the pink salmon likewise is not connected with the size of the year-class: the main run may take place either in very short periods, ending in as little as five days (1964) or it may extend over three times as long for a stock of the same number (1959). Consequently, the time of the spawning migration of the pink salmon in fresh water is determined not only by the abundance of its year-classes. Not the least important role, as will be shown below, in this phenomenon is played by hydrometeorological conditions.

The time when the pink salmon enters the spawning rivers is independent of the time of its appearance in Amur Sound. Often the fish appears in many rivers quite considerable distances apart at almost the same time. This shows that the main mass of the fish moves initially upward along the Amur, filling the lower tributaries somewhat later. /49/

3. Hydro-Meteorological Conditions Accompanying the Spawning Migration

A. Temperature

It was hitherto considered that the opening of the ice in Amur Sound is one factor determining the times of migration of the pink salmon into fresh water (Table 28).

Although the data in this table apparently confirm the relationship between these two phenomena mentioned above, they cannot be regarded as sufficiently well established: instead of the beginning of the spawning migration of the pink salmon the beginning of its commercial fishing is given, and this date is linked with the time of readiness of the barriers for fishing, which in turn depends on the meteorological and economic conditions of the year.

TABLE 28. Time of Breaking of the Ice Around Baidukov Island and Beginning of Pink Salmon Fishing in Amur Sound

Показатели 1	Год 6			
	1939	1941	1942	1947
Дата вскрытия льда 2	30/V	25/V	4/VI	2/VI
Начало лова в районе: 3				
Пуир (левый берег) 4	15/VI	11/VI	18/VI	16/VI
Нижнее Пронге (правый берег) 5	13/VI	10/VI	20/VI	17/VI

KEY: (1) Events (2) Date of breaking of ice (3) Beginning of fishing in district: (4) Puir (left shore) (5) Nizhnee Pronge (right shore) (6) Year

More concrete statistics are given in Table 29. They show that:

The warming of the water in Amur Sound before the beginning of the spawning migration of the pink salmon does not depend on the time when the ice breaks in this region (1962 and 1965);

With comparatively late clearance of ice on Amur Sound, migrations of the pink salmon may be observed either early (1961 and 1965) or late (1958 and 1960), and they are unconnected with the general warming of the water.

The appearance of "messenger" pink salmon in Amur Sound is observed over a wide range of temperatures -- from 4 to 14°C, -- but usually at a mean water temperature of about 12°C. Individual small shoals are observed to come in at the same temperature, marking the beginning of the spawning migration of the pink salmon.

The main run of the pink salmon in Amur Sound usually takes place when the mean water temperature is 15-18°C, whereas on the west coast of Kamchatka, according to Susumo Sugano, the main run is observed at a temperature of 10-13°C. This difference points to the "thermophilia" of the Amur pink salmon.

It is impossible to correlate the whole spawning migration of the pink salmon with any particular mean water temperature. In Amur Sound the migrating pink salmon is exposed to the action of different temperatures, variation of which from the beginning to the end of the run is in the direction of an increase (Table 30).

The amplitude of fluctuations of the mean daily temperatures in the surface layer during the spawning migration of the pink salmon reached 13°C (Table 30); according to the observations of Birman it was almost the same (12.4°C) in 1948 also, near Cape Ozerpakh (the left shore of Amur Sound). The entry of the pink salmon into the spawning rivers of the Amur basin is not observed at water temperatures below 5.5°C. The other limiting temperature at which the pink salmon continued to move upstream to the spawning grounds was 22.1°C. /50/

The spawning migration of the pink salmon is naturally more prolonged over a wider temperature range. For the River Iski in 1953 this was from 6.8 to 22.1°C. In the rivers of the Amgun' basin, where the spawning migration of the pink salmon is usually short, the temperature limits are quite narrow: in the River Samnya in 1950 from 9.5 to 13.3°C. The amplitude of variations of /51/
the mean daily temperatures during the main run of the salmon in the Rivers Im (1950 and 1952) and My (1949, 1951 and 1952) reached 5-7°C, and in the River Iski (1951, 1952 and 1953) it reached 7-15°C. Of the waters examined the coldest for the pink salmon is the River My. During the main run of the pink salmon the water temperature in it remains on the average between 8 and 12°C, but in the Iski it is much higher (12-14°C) and in the River Im it is close

TABLE 29. Hydrological Conditions During Spawning Migration of the Pink Salmon in the Amur Sound (Cape Dzhaore District)

1 Годы	2 Дата очищения ото льда	3 Температура воды в период		6 Вылов в июне в % к общему улову горбуши за весь сезон	7 Температура воды во время массового хода горбуши (вылов 25—75% стада)
		4 от очищения льда до появления первых особей	5 от появления первых особей до начала нерестового хода (вылов 1% стада)		
8 Ранняя весна					
1959	22/V	5,9 (0,3—14,0)	14,4 (11,8—16,3)	63,3	14,8 (12,9—17,8)
1962	23/V	11,5 (8,8—14,4)	14,9 (10,4—17,0)	55,3	14,6 (13,3—15,8)
1963	23/V	6,5 (0,2—11,6)	11,3 (10,0—13,6)	81,1	16,5 (15,6—18,0)
1964	21/V	8,6 (2,8—13,4)	11,0 (8,9—14,4)	95,3	14,8 (14,0—15,5)
9 Поздняя весна					
1958	28/V	8,3 (0,1—13,2)	15,5 (13,2—18,4)	21,7	18,1 (16,2—20,4)
1960	30/V	7,9 (0,4—14,4)	9,4 (6,4—12,6)	20,3	15,0 (11,3—18,0)
1961	28/V	2,8 (0,4—14,2)	9,6 (4,2—13,4)	84,1	15,2 (11,8—17,6)
1965	2/VI	10,6 (9,3—11,8)	13,7 (11,7—15,3)	74,4	14,6 (13,3—16,4)

KEY: (1) Years (2) Date of clearing of the ice (3) Water temperature in the period (4) From clearing of the ice to appearance of the first salmon (5) From the appearance of the first salmon to the beginning of the spawning migration (catch 1 % of stock) (6) Catch in June in % of total catch of pink salmon for the season (7) Water temperature during mass migration of pink salmon (catch 25-75 % of the stock) (8) Early spring (9) Late spring

TABLE 30. Mean Water Temperature in Surface Layer of Amur Sound in Different Periods of the Spawning Migration of the Pink Salmon

Год и район наблюдений 1	Начало хода 4		Массовый ход 6		7 Конец хода	
	дата 5	t°	дата 5	t°	дата 5	t°
1958, м. Пронге 2	19/VI—1/VII	16,4(10—18)	2—16/VII	18,1(16—20)	17/VII—11/VIII	20,7(18—23)
1963, м. Джаоре 3	5—13/VI	11,9(11—13)	14/VI—2/VII	16,9(12—21)	3—31/VII	20,9(17—23)

KEY: (1) Year and district of observations (2) Cape Pronge (3) Cape Dzhaore (4) Beginning of run (5) Date (6) Main run (7) End of run to 15°C. The intensity of the spawning migration of the pink salmon varies appreciably in rivers if there is a sharp decrease or increase in the water temperature (Fig. 7).

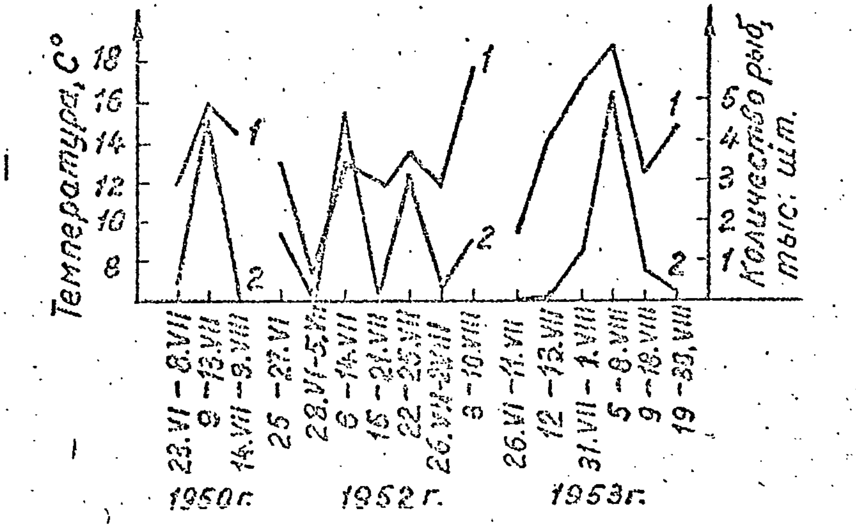

Fig. 7. Dynamics of migration of the pink salmon and fluctuations in water temperature in the River Iski: 1) temperature, 2) number of fish entering the river.

Key: (1) temperature, °C (2) number of fish, thousands.

B. Water Level

Migration of the salmon in Amur Sound is also affected by variations in the water level due to the risė and fall of the tides. Observations made in 1959 in the region of Cape Pronge showed that the pattern of fluctuations in the pink salmon catches depending on the character of variation of the water level[1] in the coastal zone is very complex. Increased runs of the pink salmon were observed at times:

Of high or almost high tide;

From low to high water, during a considerable rise in its level;

---

[1]Variations in level were taken every hour on the basis of tide gauge readings at the hydrological post of the Hydro-Meteorological Service at Cape Pronge.

From high to low tide, but with a comparatively large body of standing water;

Low tide, when the daily amplitude of variation between high and low water was small.

Pink salmon runs on the right shore of Amur Sound thus increased when the water level was relatively high and decreased as a rule when the water level fell. The same sort of relationship between size of spawning migrations and water level has also been observed in this region for the summer chum. /52/

The rise and fall of the tides, caused in this region by conditions in the Sea of Japan, are considerably influenced by the flow of water from the River Amur (Navigation on the East Coast of Siberia, 1932). The water of the Amur, directed to the south from its mouth, adds to the outgoing tidal current but delays the incoming tide. The slight flow at high water is a favourable time for movement of the pink salmon. This fish is known to follow the currents of calmest water close to the shore and for that reason it is caught in the greatest numbers at times of high, static water. At times when the June and July high tides in the region of Cape Pronge occur during daylight and low tide in the early evening or night, the spawning migration of the pink salmon at night almost ceases. With slight fluctuation in level during the 24 hours clear and regular variations in the pink salmon catch are hardly ever observed.

At fisheries on the left shore of Amur Sound the dynamics of the salmon run relative to the rise and fall of the tides is quite different. As Borisov (1925) observed, salmon were caught there only at low tide and during high tide they kept to the middle of the North Channel, avoiding the fences. The increase in the salmon catch by fisheries on the left bank at low tide was explained by Voskresenskii (1948) by the efforts of the fish, migrating close to the shore, where the current was slower[1], to save its strength for later in its journey.

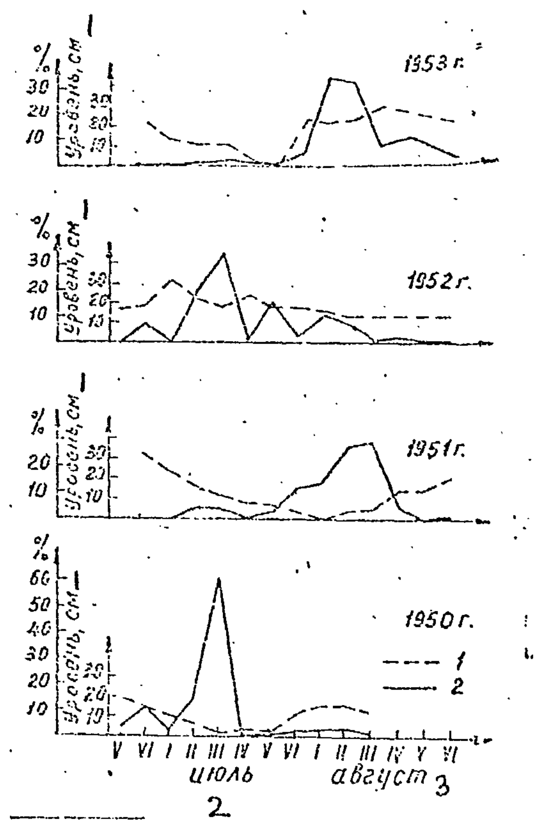

Fig. 8. Dynamics of pink salmon migration and variation in water level in the River Iski: 1) level, 2) number of fish entering the river (per cent) compared with total number of incoming brood stock.

Key: (1) level, cm (2) July (3) August

The pink salmon enters the spawning rivers when the water level is low (Strekalova, 1954) or high; the mass migration coincides with a comparatively high level, although in some rivers and in some years (River Iski, 1950, 1951) it may occur at the time of the greatest fall in the water level (Fig. 8). This fact could have a favourable effect on the choice of the place for /53/

[1]At low tide the velocity of the current in Nevel'sk Channel is very great in the region of the north-west end of Sakhalin Island because of the discharge of the main body of Amur water.

spawning, for an increased level of water immediately after mass migration of the pink salmon must help to bring about a more uniform distribution of brood stock already arrived in the rivers and, consequently, the more complete utilization of the useful spawning area by them.

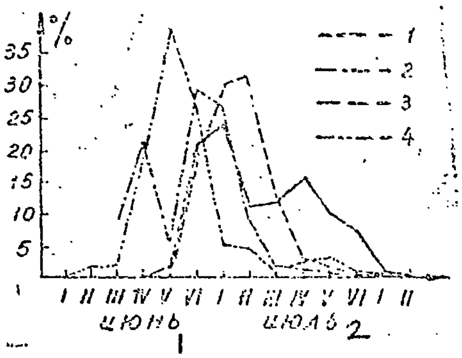

Fig. 9. Dynamics of pink salmon catches in Amur Sound near Cape Pronge during the spawning migration: 1) 1958, 2) 1959, 3) 1960, 4) 1961.

Key: (1) June (2) July.

C. Direction and Force of the Wind

The prevailing winds in Amur Sound in summer, during the spawning migration of the pink salmon, are south and south-east. Their mean velocity is 10-12 m/sec, but on some days it may reach 20 m/sec. With such a strong wind catches of pink salmon and summer chum by trap nets are very much reduced and almost down to zero. As soon as the weather becomes calm the catches suddenly increase considerably. Gale-force winds producing a rough sea set the whole mass of water in motion in areas near the coast where usually the fishing equipment is situated. So as not to exhaust itself during gales in the shallow waters the fish probably moves away from the shore into the main channel, and when the sea becomes calm again it returns to the quieter water in the coastal area, where it is caught by the fishing equipment.

On leaving the shore during severe gales for the main channel the pink salmon moves steadily toward the mouth of the Amur. Some years, in periods of approaching calm weather, it appears first in areas nearer to the mouth, but later in areas further away from it.

North and north-east winds are less common in Amur Sound. They have the opposite action on the run of the pink salmon by the right shore of the Sound than the south winds and they are accompanied by larger upstream migrations. In 1958, for instance, at the Aleevka control fence, on days of mass migration of the pink salmon (from 29 June to 26 July), when the winds were from the north and north-east, the mean daily catch of pink salmon was 1000 centners, but only half when the winds were in the south and south-east. North winds, coinciding in direction with the flow of water from the Amur entering the Tatar Straits, do not give rise to such strong agitation of the shallow water as is observed with south winds. This is evidently the reason why catches of pink salmon by fences on the right shore are higher. So far as the effect of winds on the pink salmon migration off the left shore of the Sound is concerned, a final explanation is still awaited.

As was demonstrated above, of all the factors examined above only the physiological is regularly reflected in the time of the pink salmon runs into Amur Sound, and its effect is manifested as delay in the run of comparatively small fish belonging to very abundant year-classes. However, the main run of the pink salmon in Amur Sound has a distinct temperature optimum of its own (15-19°C).

Data relevant to the elucidation of the dynamics of the spawning migration of the pink salmon relative to the rise and fall of the tides and to wind activity given in this section are extremely sketchy and by no means exhaustive, for the problem is complex and calls for special research.

4. Dynamics of the Run /54/

As was stated above, the fluctuations in the run of the pink salmon in Amur Sound during the 24 hours are due to fluctuations in level connected with the rise and fall of the tides. In the region of Cape Pronge in 1958, when high static waters in June and July occurred in daylight, maximal catches of the pink salmon were observed (Table 31).

TABLE 31. Dynamics of the Pink Salmon Run in Amur Sound During the 24 Hours (in per cent of total catch of the Aleevka barrier in 24 h)

Годы (1)	Часы суток (2)								Всего (3)
		3	6	9	12	15	18	21	
1957	—	11,0	23,0	32,1	11,2	13,2	8,5	1,0	100,0
1959	—	7,9	16,9	18,1	18,9	22,8	14,8	0,6	100,0

KEY: (1) Years (2) Time of day (3) Total

Commercial catches of the pink salmon in Amur Sound vary from day to day within wide limits. These variations in catch reflect the rhythm of the run of the pink salmon caused by a complex system of relations between the physiological state of the fish and the external environmental conditions examined above. The dynamics of catches of the pink salmon by the Aleevka control barrier for four of its year-classes (1958-1961), differing sharply in their abundance [1], is illustrated in Fig. 9. The number of fish caught at the barrier is aggregated here for five-day periods, smoothing out diurnal

[1] The pink salmon catch during the spawning migration was (in thousands of fish): 1583 in 1958, 258 in 1959, 323 in 1960, and 40 in 1961.

fluctuations in the catches and bringing to light the general character and intensity of migration of the pink salmon during the season. As is clear from Fig. 9 the pink salmon in Amur Sound may have one (as in 1960 and 1961) or two (as in 1958 and 1959) runs, unconnected with the size of the spawning stocks. A characteristic feature of the run is its rapid increase: from the appearance of the first fish to the beginning of the mass migration the time is usually from 10 to 15 days. The end of the run of the pink salmon is more gradual. It lasts from 15 to 40 days (or more). As Fig. 6 shows, its duration is inversely proportional to the size of the stock. The diurnal rhythm of the run of the pink salmon in different spawning rivers is in general of the same character: the run becomes swifter at dawn and continues until twilight, although at mid-day the intensity of the run is reduced (Table 32).

Meanwhile, as Table 32 shows, the dynamics of the pink salmon run in these rivers in the course of the 24 hours also has certain distinguishing features. In the rivers My and Iski, for instance, about 25 % of the fish pass through the control barrier before 7 a.m.; only about 5 % pass during the next 6-7 h; most of the fish, however, about 70 % of them, pass through after 1-2 p.m. In the River Samnya, a tributary of the second order of the River Amur, the pink salmon starts to rise later, but does so more intensively than in the rivers of the Sound and more than 60 % of the salmon rise before 10 a.m. The other periods of the run are shifted correspondingly. The period of a small run lasts from 10 a.m. to 4 p.m.: at this time about 10 % of the fish pass through; the second increase in the run is observed during the evening, after 4 p.m., accounting for about 30 % of the total number of fish passing through per day.

After observing the irregularity of the salmon run during the 24 hours /55/
in the rivers of Kamchatka and in the Amur Abramov (1953) concluded that the size of the run increases when the sunlight falls from the side or from behind

relative to the course of the fish, and it stops completely if bright sunlight shines directly against the direction of the run. This conclusion was confirmed by data obtained in 1951 for the River Im (a second-order tributary of the Amur, flowing from the south), when from 7 a.m. to 4 p.m. only about 2 % of the salmon of the total number counted during the 24 hours passed through the control fence. The fact that salmon do not move at night and that they move more or less uniformly on days of continuous cloud strengthened the view that the diurnal dynamics of the pink salmon run is the result of the reaction of the fish to light.

TABLE 32. Dynamics of the Run of the Pink Salmon in Spawning Rivers During the 24 Hours (in per cent of total number of fish passing through the barrier per day)

1 Реки, годы	5 Часы суток							6 Всего
	4 — 7 — 10 — 13 — 16 — 19 — 21							
2 Мы, 1962	24,9	3,5	0,8	26,6	44,2			100,0
1963	20,6	4,0	7,6	24,9	15,8	27,1		100,0
3 Самня, 1960		62,2	6,4	4,6	10,3	16,5		100,0
	4 — 6 — 8 — 14 — 18 — 20 — 21							
4 Иски, 1959	1,4	10,4	9,1	0,1	21,2	40,3	17,5	100,0
1960	13,5	16,0	10,3	5,2	18,0	20,0	17,0	100,0
1961	4,3	8,3	5,3	10,5	21,3	28,1	22,2	100,0
1962	10,9	9,6	3,2	2,2	20,9	26,2	27,0	100,0

KEY: (1) Rivers, years (2) My (3) Samnya (4) Iski (5) Time of day
(6) Total

In the basin of the River Iski the pink salmon and chum move slowly along the river, staying for a long time in the quiet, deep parts of its course. Sometimes the salmon also move downstream, but they then climb again, overcoming the current. The mean rate of movement of the pink salmon is 1.7 km per diem. Such slow progress of the fish is explained by the fact that most individuals are not ready for spawning when they enter the River Iski; they mature during their stay in the river.

The salmon react precisely to an increase in the level and to a resulting increase in the rate of flow. Up to certain limits the rate of rise of the fish increases with an increase in the rate of flow. They develop a particularly high speed when crossing bars in the river bed. By resting in places with a slow-moving current and by mounting rapidly through shallow areas with a fast current, the salmon thus expend their energy economically as they ascend the rivers. When the rise in water level is very great the pink salmon and chum cannot overcome the too rapid current and they therefore stop their run until the level has fallen suitably; in such cases an increase in the run is observed only at the beginning of the rise of the water. The principles governing the migration of the pink salmon in the rivers I have examined can undoubtedly be extended also to any other river. Movement of the pink salmon in the spawning rivers is thus determined by the physiological state of the fish and, in particular, by the degree of maturity of the sex products, and it is a complex adaptive reaction of the organism to light and to variation in the water level.

/56/

VI. QUALITATIVE COMPOSITION OF POPULATIONS AND THEIR BIOLOGICAL CHARACTERISTICS

1. The Sex Ratio

The sex ratio at certain periods of the spawning migration and for spawning stocks of pink salmon as a whole has been determined by analysis of the catches. This method is technically more correct for it takes into account the considerable fluctuations in catches in the course of migration, characteristic of the pink salmon[1].

Appreciable predominance of males is characteristic of the first runs of salmon migrating into Amur Sound, and it is also a feature of other salmon of the genus Oncorhynchus. In the data given in Table 33 this is evident for 1958, when the observations included the beginning of the spawning migration.

As a rule with time the relative number of males decreases and there is /57/
a corresponding increase in the number of females. However, in some years the males remain numerically predominant almost throughout the spawning migration. Judging from 1960, the relative number of males was greatest even when the spawning migration of the pink salmon was nearly at its end. Sometimes, for example in 1961, the sex ratio starts with predominance of males but subsequently follows no strict rule: sometimes it is equal, sometimes numerical predominance of females over males changes to the opposite ratio several times in succession.

---

[1]All other qualitative parameters of the pink salmon also were determined by analysis of catches.

TABLE 33. Sex Ratio of the Pink Salmon in Amur Sound During the Spawning Migration, N. Pronge

1. Месяц, пятидневка		1958 г.		1959 г.[2]		1960 г.		1961 г.[2]	
		самцы, самки 6	число рыб 7	самцы, самки 6	число рыб 7	самцы, самки 6	число рыб 7	самцы, самки 6	число рыб 7
2 Июнь,	III	—	—	1,4 : 1	200	—	—	1,5 : 1	396
	IV	2,9 : 1	157	1,1 : 1	200	—	—	1,2 : 1	1266
	V	2,8 : 1	1853	1,3 : 1	200	1 : 1,2	132	1,1 : 1	2495
	VI	1,7 : 1	1963	1,2 : 1	300	1,2 : 1	1263	1 : 1	2695
3 Июль,	I	1,5 : 1	2327	1 : 1	200	1,1 : 1	3089	1 : 1,2	3300
	II	1,7 : 1	1358	1 : 1,5	200	1,3 : 1	2108	1 : 1,2	1039
	III	1,3 : 1	2306	1 : 1,1	200	1,1 : 1	3025	1,2 : 1	158
	IV	1 : 1,1	2573	1 : 1,3	221	1,2 : 1	1911	1,4 : 1	40
	V	1 : 1,4	3089	1 : 1	197	1,4 : 1	1973	1 : 1	335
	VI	1 : 1,3	2164	1 : 1	80	1,3 : 1	301	1,2 : 1	383
4 Август,	I	1,1 : 1	1829	—	—	1,3 : 1	932	1 : 1,4	173
	II	1,1 : 1	445	—	—	1 : 1,3	243	—	—
5 Среднее за сезон		1,2 : 1	20449	1,1 : 1	1998	1,2 : 1	14709	1,1 : 1	11285

KEY: (1) Month, five-day period (2) June (3) July (4) August (5) Mean for the season (6) Males, females (7) Number of fish

The pattern of fluctuation in the sex ratio of the pink salmon during the run, as the figures given above show, is very complex. This is not due, as it is with the chum, for example, to the three clearly marked migrations which differ from each other in the length, weight, and age of the individuals. The dynamics of the pink salmon run, with more or less sharp fluctuations in catches from day to day, as was shown above has a unimodal or bimodal curve and it serves to distinguish clearly the main run of the fish as well as the beginning and end of the spawning migration. If the spawning migration of the pink salmon is examined from the point of view of these periods, the sex ratio in them for year-classesof 1958-1961 can be represented as follows (Table 34).

In most cases predominance of males is characteristic of the beginning

[1]The sex ratio was not studied at the beginning of the spawning migration.

TABLE 34. Sex Ratio of the Pink Salmon in Amur Sound for Various Periods of the Spawning Migration, N. Fronge

Год	Начало хода			Массовый ход			Конец хода		
	дата	самцы, самки	число рыб	дата	самцы, самки	число рыб	дата	самцы, самки	число рыб
1958	20—28/VI	2,3 : 1	2666	29/VI—26/VII	1,2 : 1	13942	27/VII—11/VIII	1 : 1,1	3811
1959	12—13/VI	1,4 : 1[1]	100	15/VI— 7/VII	1,1 : 1	1109	9—29/VII	1 : 1,4	798
1960	17—23/VI	1 : 1,2	132	27/VI—18/VII	1,2 : 1	10812	21/VII— 8/VIII	1,3 : 1	4008
1961	15/VI	1,5 : 1[1]	396	16/VI— 1/VII	1,1 : 1	8205	2/VII— 1/VIII	1 : 1,2	2684

KEY: (1) Year (2) Beginning of run (3) Date (4) Males, females (5) Number of fish (6) Main run (7) End of run

[1] The sex ratio was not fully investigated.

TABLE 35. Sex Ratio of the Pink Salmon in Spawning Grounds (data of Amurrybvod)

Река	Год	Количество рыб, %		Кратное соотношение полов	Количество исследованных рыб
		самцы	самки		
Мы	1925	46,6	53,4	1 : 1,1	159
Мы	1930	42,6	57,4	1 : 1,3	176
Мы	1932	47,7	52,3	1 : 1,1	411
Ул	1936	48,4	51,6	1 : 1,1	3870
Мы	1950	54,0	46,0	1,2 : 1	4396
Мы	1951	46,4	53,6	1 : 1,2	3456
Мы	1952	48,0	52,0	1 : 1,1	6227
Мы	1953	50,0	50,0	1 : 1	1564

KEY: (1) River (2) My (3) Ul (4) Year (5) Number of fish, per cent (6) Males (7) Females (8) Sex ratio (9) Number of fish studied of the spawning migration, as the results in Table 34 show; in 1959 and 1961 it would probably have appeared higher had the observations included fish from the first of the spawning runs, containing what are known as the "messengers". During the main run the sex ratio was almost equal, although males predominated slightly. At the end of the spawning migration as a rule females predominated somewhat, but sometimes, as in 1960, the sex ratio was reversed.

The sex ratio of the pink salmon during its main run was different in fish caught on the left shore of the Sound. For instance, in the district of the Ozerpakh Fishing Combine in 1951 the ratio of males to females was 1: 1.4 and in 1952 it was 1: 1.3. In 1956 and 1957, in the region of the Tneivakh fish factory the number of females also was higher than the number of males. It is difficult at present to say whether this difference in the sex ratio of the pink salmon caught by fisheries on the right and left shores of Amur Sound is accidental or not. However, it agrees sufficiently closely with the sex ratio for pink salmon from the Rivers My and Amgun' (Table 18) to suggest that migration of the Amgun' stock of pink salmon takes place along the left shore of the Amur Sound.

The mean sex ratio of the pink salmon for the whole of the spawning migration from 1958 to 1961 is given in Table 33. These figures agree completely with the sex ratio of the pink salmon determined during its main run in these same years (Table 34). The sex ratio in the stock is naturally determined by the sex ratio of the fish during the main run, for the relative number of pink salmon at the beginning and end of the spawning migration is small. These figures show that from year to year sometimes males and sometimes females predominate in the stocks of pink salmon from the Amur Sound, although the ratio between the two sexes remains close to 1: 1.

During spawning of the pink salmon the impression is obtained that males predominate considerably. In I.I. Kuznetsov's opinion this apparent predominance is explained by the earlier maturation of the males and their participation in spawning not with one, but with several females (Table 35). In fact, the sex ratio of the pink salmon in the spawning grounds as a rule shows some predominance of females. Probably the males die first in the spawning grounds. This could also be explained by their earlier readiness for spawning (Soldatov, 1912), a process accompanied, as will be shown below (Lysaya, 1951), by the accumulation of large quantities of toxic urea in the blood. However, the observed difference in the sex ratio of the pink salmon from Amur Sound and the spawning grounds cannot be taken as significant for in both cases the sex ratio still remains close to 1: 1.

It is difficult to say how this equal or almost equal sex ratio of the /59/
pink salmon is achieved. We know from the work of Persov (1965) that in pink salmon embryos and in larvae in the period of hatching and shortly afterwards (length 24-30 mm, weight 120-226 mg) the gonads of all individuals are ovaries. The testes form much later and their appearance is preceded by redifferentiation of the ovaries. In general the sex glands develop earlier in the pink salmon than in other salmon of the genus Oncorhynchus, and this is evidently related to the earlier onset of sexual maturity.

2. Dimensions and Weight

In the course of 16 years of investigation of the pink salmon (1950-1965) among sexually mature fish migrating into Amur Sound none was found with a length (AC) below 28 and above 66 cm or with a weight below 245 and above 3 800 g. Fish with these extremes of size and weight are very rarely found and all the subsequent argument is thus based entirely on average values characteristic of the stock as a whole.

Males of the pink salmon, as of other Pacific salmon, are usually somewhat larger than the females. An exception to this rule was the first spawning migrations of pink salmon in 1958 when the females were larger (Table 36).

The dimensions of the pink salmon vary differently from the beginning to the end of the migration in different years. Their variations can be studied more correctly in relation to body length (Od), which does not vary with the appearance of the breeding colour. The dimensions of the males in 1959-1961 and of the females in 1959 at first increased slightly in the course of the migration and then decreased (Table 36); only in 1958 did they increase steadily for the males. In females in 1960 and 1961 a decrease in size was observed toward the end of the run, and in 1958 their size sometimes decreased, sometimes increased from beginning to end of the run. Variations in size of the pink salmon in the course of the spawning migration in Amur Sound were not regular in character in earlier years either. This phenomenon is evidently due to a random combination of various fish differing in their rate of growth. This view is supported by the results of measurement of pink salmon at particular periods of the run (Table 37).

Wherever salmon fishing is undertaken commercially the size of the salmon varies in even and odd years. These variations are considered to be attributable to differences in the abundance of the odd and even year-classesof pink salmon. Usually the Amur pink salmon is larger in years when it migrates in smaller numbers, and conversely, it is smaller in years of more abundant migrations. The appearance of large fish in the first catches is regarded in the industry as an indication that the migration of the salmon will be small; conversely, if small fish are found it heralds an abundant run.

During the last 15 years there were two maxima in the pink salmon populations of the River Amur: in 1948 and 1958. The fish in these years were the

TABLE 36. Variations in Mean Size of Pink Salmon (in cm) in Amur Sound During the Spawning Migration, N. Pronge

Месяц, пятидневка (1)		1958 г.				1959 г.			
		AC		Od		AC		Od	
		самцы (6)	самки (7)	самцы (6)	самки (7)	самцы (6)	самки (7)	самцы (6)	самки (7)
Июнь, (2)	III	—	—	—	—	48,4	44,6	36,5	34,9
	IV	39,9	42,2	30,2	32,1	49,3	46,6	36,5	35,5
	V	39,3	42,2	29,5	32,1	47,5	46,4	35,2	35,0
	VI	42,4	41,9	31,2	31,5	49,6	46,6	36,6	35,4
Июль, (3)	I	42,4	41,4	30,8	30,5	50,6	48,8	37,0	35,7
	II	43,1	42,0	31,4	31,9	51,8	48,5	37,7	36,4
	III	43,8	41,8	32,0	31,4	52,1	48,7	37,8	36,5
	IV	43,8	42,0	32,2	31,4	50,9	49,2	36,9	36,6
	V	44,1	41,5	32,5	29,1	50,2	47,7	36,4	35,6
	VI	44,8	41,7	31,1	30,3	50,4	47,6	36,1	35,7
Август, (4)	I	45,5	42,8	32,9	31,8	—	—	—	—
	II	45,5	43,5	33,2	32,4	—	—	—	—
Количество исследованных рыб (5)		2600				1998			

Месяц, пятидневка (1)		1960 г.				1961 г.			
		AC		Od		AC		Od	
		самцы (6)	самки (7)	самцы (6)	самки (7)	самцы (6)	самки (7)	самцы (6)	самки (7)
Июнь, (2)	III	—	—	—	—	—	—	—	—
	IV	40,6	45,7	35,0	34,6	47,9	46,7	35,8	35,2
	V	45,4	44,3	33,7	33,4	52,6	48,0	38,5	36,2
	VI	47,3	45,1	35,5	34,0	50,7	48,1	36,9	36,1
Июль, (3)	I	47,3	44,7	35,2	33,9	54,2	48,4	39,6	36,3
	II	47,9	45,4	35,7	34,5	51,1	48,4	37,5	35,8
	III	49,5	45,7	36,6	34,3	50,8	46,7	37,0	35,9
	IV	48,7	45,5	36,2	34,5	46,5	45,2	33,8	33,6
	V	49,3	45,5	36,1	34,3	45,8	45,9	33,9	33,8
	VI	44,6	42,7	32,6	32,1	48,7	46,1	34,7	34,0
Август, (4)	I	44,1	42,8	32,5	30,1	48,5	46,6	34,5	34,2
	II	43,6	43,1	32,6	31,8	—	—	—	—
Количество исследованных рыб (5)		1652				1350			

KEY: (1) Month, five-day period (2) June (3) July (4) August (5) Number of fish examined
(6) Males (7) Females

/60,61/

TABLE 37. Variations in Mean Size of Pink Salmon (in cm) in Amur Sound at Different Periods of the Spawning Migration, N. Pronge

Период хода 1	1958 г. AC самцы 6	1958 г. AC самки 7	1958 г. Od самцы 6	1958 г. Od самки 7	1959 г. AC самцы 6	1959 г. AC самки 7	1959 г. Od самцы 6	1959 г. Od самки 7	1960 г. AC самцы 6	1960 г. AC самки 7	1960 г. Od самцы 6	1960 г. Od самки 7	1961 г. AC самцы 6	1961 г. AC самки 7	1961 г. Od самцы 6	1961 г. Od самки 7
Начало 2	39,7	42,0	30,4	31,7	47,1	45,5	35,3	35,2	45,3	44,2	33,8	33,4			—	—
Массовый 3	43,2	41,6	31,6	30,8	49,6	47,1	36,6	35,5	47,9	45,2	35,0	34,2	50,8	47,8	37,3	36,0
Конец 4	44,4	42,6	33,1	31,8	51,3	48,5	37,2	36,2	47,2	44,3	34,7	32,8	50,8	47,7	37,0	35,4
Среднее за сезон 5	43,0	41,7	31,5	30,8	49,6	47,1	36,6	35,5	47,9	45,2	34,7	34,1	50,8	47,8	37,3	35,9

KEY: (1) Period of migration (2) Beginning (3) Main run (4) End (5) Mean for the season
(6) Males (7) Females

TABLE 38. Variations in Scale of Spawning Migrations and Mean Size of Pink Salmon in Amur Sound in Different Years

Показатели 1		1948	1950	1951	1952	1953	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Улов двух контрольных заездков, 2 тыс. шт.		576	58	66	36	19	775[1]	19	2000	269	389	44	72	370	233	243
Длина АС, 3 см	правый берег 4	—	—	—	—	—	—	47,2	42,5	48,8	45,7	49,3	50,3	49,8	48,8	49,2
	левый берег 5	44,0	47,8	46,8	48,2	47,4	47,1	—	—	—	—	—	—	—	—	—

KEY: (1) Parameters (2) Catch at two control barriers, thousands of fish (3) Length AC, cm
(4) Right shore (5) Left shore

---

[1] Incomplete data.

smallest in size. The pink salmon was also very small in 1926 and in 1928 (Vorotnikov, 1927; Pravdin, 1932), when the level of the stock was exceptionally high. After 1948 the numbers of even year-classes of the pink salmon have reduced sharply and in subsequent cyclic year-classes the fish have been even larger than in odd years. Migration of large fish in spawning stocks of even year-classes continued until 1958 when, just as in 1948, an abundant year-class of pink salmon consisting of small fish returned to the Amur (Table 38).

Differences in the size of the pink salmon in even and odd years are /60/
explained by Birman on the grounds of differences in the ecological conditions of the maritime period of their life and differences in the duration and frequency of feeding migrations; According to Kaganovskii (1949) they are due to differences in the adequacy of the food supply for the pink salmon stocks (the effect of competition for food is ruled out in this case). This would be an indisputable argument were it not for one fact. The pattern of variation in the number and size of the pink salmon is not regular, for the size of the fish is almost identical in year-classes differing in their abundance
For example, the year-class of pink salmon returning to the Amur in 1957 was /61/
very small in number compared with the year-class taking part in migrations in 1956, but the size and weight indices were essentially the same: the difference in size was only 0.7 cm and the difference in weight 189 g, well within the limit of accuracy of measurement. There was likewise virtually no difference in the size and weight of the pink salmon of the migrations in 1953 and 1956 and in those of 1961-1963, despite equally large differences in their numbers.

This phenomenon is not confined to the pink salmon of the Amur basin. /62/
In the River Iski, for example, which belongs to the basin of the Sea of Okhotsk, there was a relatively abundant stock of pink salmon in 1951 but the

length of the fish taking part in it was just the same as in the much smaller year-classes before and after. In Primor'e in 1948 and 1949, according to the observations of TINRO, the pink salmon migration into the River Tumnin was on a much larger scale than in previous years, but the length and weight of the fish remained almost the same. This problem has so far received little study and it may be that variations in the quantity of food available for the pink salmon in the sea play an important role. Be that as it may, not all changes in the pink salmon population are reflected in its qualitative indices. Accordingly the view formerly held that a small stock of pink salmon consists of relatively larger fish, and a large stock of smaller fish, is highly oversimplified.

I shall not make a closer analysis of this problem here because it would need to be supported by concrete facts concerning the feeding conditions of the pink salmon in the maritime period of its life which I do not possess. I shall simply state that if there is no constant and definite correlation between the size of the stock and the size of the fish, this means that the feeding conditions are not constant.

Since the weight of the pink salmon correlates with its body length, it is subject to the same variations during the spawning migration and from year to year as the linear dimensions and there is therefore no need to dwell in detail on this matter. I shall simply state that variations in the weight of individuals of the same population and between individuals of different year-classes can be very considerable (Table 39).

3. Scale Structure and Rate of Growth

Variations in the size of the pink salmon are due to inequality in the rate of growth of the fish. Some idea of the character of growth of the individual pink salmon and of its populations as a whole is given by the scales. An investigation of the character of growth of the scale (Enyutina, 1963) gave the following results:

a) In males and females of the same size differences in the mean length of the scale and the mean number of sclerites do not exist or, in other words, the character of growth of the scale is independent of the sex of the pink salmon;

b) With an increase in size of the fish the number of sclerites in the first year's growth changes on the average very little, but the increase in the number of sclerites in the second year's growth is very considerable;

c) Although differences in the time of the downstream migration and individual differences in the growth of the fish together determine the existence of small and large individuals during the first year of life, it is ultimately the rapid growth of some fish and the extremely slow growth of others in the second year of life that is responsible for the considerable difference found between the size of adult individuals;

d) Scales in the second year's growth of the pink salmon of the last spawning migrations have more widely spaced sclerites, their number is directly dependent on the size of the fish, but it is usually smaller than for fish of first upstream migrations;

e) In fish of the same spawning area the scale structure does not /63/ stay the same in different years: the number of sclerites varies in the fingerling, in the check, and in the second year's growth, and the sclerites are sometimes more closely packed, sometimes more widely separated.

In contrast to the ordinary type of scales, with only one zone of narrowed sclerites or "check," scales with an additional ring of narrowed sclerites in the nuclear part are sometimes found in the pink salmon, and the epithet "fingerling" has been applied to it any investigators have observed it. This ring is supposed to be formed by delayed growth of the fish and it is laid down (Vedenskii, 1954) at a time when the young pink salmon is leaving the coastal waters for the open sea.

In different parts of the Amur basin and neighbouring districts (Schast'ya Bay, the continental shore of the Tatar Straits, North Primor'e) in some years pink salmon with additional rings on the scale are found in large or small numbers simultaneously (from 0.1 to 35.2 %), but in other years they are nowhere to be found. The results of observations to study the frequency of the fingerling ring in the pink salmon in open waters of the Sea of Japan, in the rivers of Primor'e and the Amur basin, as Miyaguchi (1959) points out, are clearly in agreement. The character of variation in the incidence of additional rings on the pink salmon in 1955-1958 was similar for the Amur basin and the basin of the Sea of Japan (Enyutina, 1962).

In the pink salmon in neighbouring spawning areas (the Rivers Iski, Amgun', My) in some years the additional ring is laid down at the same time but the frequency with which it is found is not always clearly connected with the abundance of the pink salmon population in each river. On the whole, for the pink salmon migrating into the Amur basin Lapin (1963) found the additional ring much more often in small populations. Given identical hydrological conditions (water level) this can evidently be explained by the earlier downstream migration and the longer stay of the young fish in the coastal zone, on account of its delayed departure from the coast in search of food.

The calculated body length, the scale length and the number of sclerites in the period of formation of the second zone of narrowed sclerites in fish with type 1 (1) +[1] scales are on the average almost the same as in yearlings

[1] The conventional way of describing a scale with an additional ring.

with the typical 1 + scale structure. Consequently the formation of the additional ring on the scale does not reflect delayed growth of the fish.

It can be concluded from the structure of the scale, from back-calculations of the length, and from Birman's data (1960) for the maritime period of life of the pink salmon that the additional ring in the nuclear part of the scale is formed in the sea about in July-August, i.e., before the end of the summer feeding period.

Considerable variations in length (not exceeding 23 cm) are observed in individuals of the same population in both the first and the second year of /64/ life (Table 40).

Comparison of the changes in the mean values of the body length with changes in the numbers of the Amur pink salmon (Enyutina, 1955; Krykhtin and Smirnov, 1962) gave the following results:

a) With a considerable increase in the population of the spawning stock the dimensions of the fish (and also its weight and fecundity) diminish appreciably; conversely, with a marked reduction in the population they increase;

b) Indices of length (and weight) may be almost identical in spawning stocks of different numerical size;

c) If spawning stocks are numerically very small for a number of years, their quantitative indices will vary in different years.

Variations in body size in numerically different pink salmon stocks have been explained conjecturally by inequality in the available food supply per individual in years of poor catches and of abundance (Kaganovskii, 1949; Nikol'skii, 1950) and by differences in the time when the young fish reach the feeding grounds, which depend on the time of the downstream migration of the fry from the rivers (Krykhtin and Smirnov, 1962). In 1954-1962 as a result of investigations of the salmon at sea facts were obtained to show that in years of large salmon populations the food relations with the chum and sockeye become

TABLE 39. Variations in Weight of the Pink Salmon (in kg) Between Individuals of the Same and Different Year-Classes in Amur Sound, N. Fronge

Пол		1958	1959	1960	1961	1962	1963	1964	1965
Самцы	среднее	1,03	1,75	1,55	1,86	2,10	1,99	2,02	1,54
	колебания	0,47—2,32	0,59—3,63	0,50—2,91	0,53—3,71	0,40—3,20	0,53—3,18	0,75—3,61	0,75—3,8
Самки	среднее	0,93	1,50	1,21	1,52	1,60	1,58	1,54	1,57
	колебания	0,45—1,57	0,38—2,54	0,60—2,04	0,77—2,60	0,50—2,30	0,53—2,45	0,65—2,70	0,75—3,20

KEY: (1) Sex (2) Males (3) Females (4) Mean (5) Variations

TABLE 40. Growth, Scale Structure and Population of the Pink Salmon in the River My in the Period 1950-1959

Год	Длина АС, см	Численность, тыс. шт.[1]	Расчисленная длина, см: годовика — пределы колебаний	Расчисленная длина, см: годовика — среднее	Расчисленная длина, см: прироста 2 года — пределы колебаний	Расчисленная длина, см: прироста 2 года — среднее	Число склеритов: в приросте 1 года — пределы колебаний	Число склеритов: в приросте 1 года — среднее	Число склеритов: в приросте 2 года — пределы колебаний	Число склеритов: в приросте 2 года — среднее	Число рыб
1950	49,4	158	22,5—36,5	29,9	8,5—29,5	19,5	14—25	19,4	6—16	12,0	196
1951	50,7	296	21,5—38,5	27,8	10,5—33,5	22,9	14—25	19,5	10—20	13,2	200
1952	52,0	37	25,5—39,5	30,8	13,5—32,5	21,2	15—24	19,5	7—18	13,4	129
1953	52,8	91	19,5—40,5	29,0	13,0—32,4	23,8	14—23	19,6	5—20	14,2	200
1954	51,6	268	20,5—43,5	30,0	12,6—31,2	21,6	13—27	20,0	4—21	14,4	137
1955	53,0	13	26,0—43,0	32,7	8,5—30,5	20,3	15—25	20,7	6—17	12,7	80
1956	50,4	851	24,4—40,2	31,1	10,3—30,7	19,3	15—28	21,1	7—19	12,9	134
1957	52,1	17[2]	20,8—33,7	27,9	16,9—30,9	24,2	14—22	17,5	12—19	14,4	73
1958	42,7	812[2]	19,5—31,7	25,5	9,9—27,3	17,2	14—26	17,7	7—15	11,9	142
1959	51,9	106	22,2—37,2	30,4	15,4—35,0	21,5	16—28	22,3	9—20	13,7	116

KEY: (1) Year (2) Length AC, cm (3) Population, thousands of fish (4) Calculated length, cm (5) Of yearling (6) Limits of variations (7) Mean (8) Second year's growth (9) Number of sclerites (10) In first year's growth (11) In second year's growth (12) Number of fish

[1] Determined from brood stock entering the River My.

[2] Incomplete count.

acute; as a way out of this contradiction and as an adaptation to the new feeding conditions the pink salmon can broaden its food spectrum and change over partly or completely to forced feeding, with a resulting decrease in the rate of growth and of maturation of the fish (Andrievskaya, 1966). This explains the decrease in size of the pink salmon in years when the population of the stock is considerably increased. The data in Table 40 show, however, that in years of high salmon catches there is not necessarily any decrease in size of the fish, as will be clearly seen by the growth of the salmon born in 1954.

If the feeding grounds of the pink salmon and summer chum in the sea actually coincide, as Hirano (1951) asserts, growth of the pink salmon must be definitely related to the summer chum numbers. We should therefore be right to expect a decrease in size of the individual pink salmon in the spawning year-class of 1956, which fed simultaneously with the abundant year-class of summer chum born in 1954. However, the contradiction in this matter simply serves to emphasize the complexity of the growth pattern of the pink salmon /65/
in different year-classes.

A technical conclusion can be drawn from the facts described above: comparison of the pink salmon caught in different districts on the basis of its scales is possible only in the same year and in fish taken for analysis at the same periods of the spawning migration.

4. Weight and Ripeness of the Sex Products

The pink salmon reaches Amur Sound with sex products of different ripeness, ranging from stage II to stage V, using L.S. Berg's (1935) five-point scale, slightly modified by A.G. Smirnov, but in most cases in stages II-III, III-II and III. Ripening of the sex products in fresh water takes place, just as it does in other Pacific salmon, through the action of gonadotropic hormones in conjunction with increased activity of the thyroid gland (Hoar, 1953).

The weight of the sex products in male and female pink salmon differs and as a rule is directly dependent on the size of the fish. During the spawning migration in Amur Sound the absolute weight of the testes and ovaries increases; so also does the relative weight of the gonads (the weight of the gonads as a percentage of the body weight), reflecting the degree of their maturation (Tables 41 and 42).

The data in Table 42 show that the pink salmon migrates into Amur Sound at different degrees of maturity in different years; on the average, however, the relative weight of the gonads or coefficient of maturity (Nikol'skii, 1938) is 5.0 for the males and 7.5 for the females.

As the pink salmon ascends from Amur Sound into the spawning tributaries the gonads undergo further maturation (Table 43).

TABLE 41. Changes in Absolute Weight of Gonads (in g) of the Pink Salmon in Amur Sound at Different Stages of the Spawning Migration, N. Pronge /66/

Год 1	Период хода 2			Среднее за сезон 6
	начало 3	массовый 4	конец 5	
1958	51 (8—130) / 76 (27—127)	64 (15—162) / 79 (26—164)	74 (11—180) / 105 (48—223)	64 (8—180) / 80 (26—223)
1959	55 (5—125) / 75 (44—130)	87 (10—220) / 106 (19—250)	113 (2—224) / 147 (60—284)	86 (2—224) / 107 (19—284)
1960	54 (10—125) / 74 (30—132)	69 (13—205) / 89 (35—192)	91 (25—195) / 114 (40—210)	69 (10—205) / 89 (30—210)
1961	—	100 (9—230) / 110 (37—221)	123 (23—265) / 138 (22—360)	105 (9—265) / 117 (22—360)

Примечание. В числителе — самцы, в знаменателе — самки. 7

KEY: (1) Year (2) Period of migration (3) Beginning (4) Main run (5) End (6) Mean for the Season (7) Note. Males in numerator, females in denominator.

In the Amgun', where artificial pink salmon breeding has been begun, the use of brood stock for fish breeding purposes is adversely affected by the

TABLE 42. Changes in Relative Weight of Gonads (in per cent of body weight) of the Pink Salmon in Amur Sound at Various Stages of the Spawning Migration, N. Pronge

Период хода 1	1958 г.		1959 г.		1960 г.		1961 г.	
	самцы 6	самки 7	самцы 6	самки 7	самцы 6	самки 7	самцы 6	самки 7
Начало 2	5,7	7,8	3,7	5,2	3,8	6,4	—	—
Массовый 3	6,1	8,6	4,8	7,1	4,2	6,8	4,7	6,6
Конец 4	7,0	11,1	6,1	9,6	6,3	10,0	6,3	9,1
Среднее за сезон 5	6,2	8,7	4,8	7,1	4,2	6,8	5,1	7,2

KEY: (1) Period of migration (2) Beginning (3) Main run (4) End (5) Mean for the season (6) Males (7) Females

TABLE 43. Changes in Coefficient of Maturity of the Pink Salmon Between Amur Sound and Spawning River

Место лова 1	1950 г.		1951 г.		1952 г.		1953 г.	
	самцы 5	самки 6	самцы 5	самки 6	самцы 5	самки 6	самцы 5	самки 6
2 Лиман Амура, Озерпах	4,6	7,0	5,6	8,1	5,4	7,6	4,9	7,6
3 Р. Амгунь, село Сергие-Михайловское	6,1	7,8	7,2	9,8	6,4	9,0	6,8	9,3
4 Р. Им, село Красный Яр	7,2	10,1	8,1	13,4	7,3	14,3	8,1	12,6

KEY: (1) Place where caught (2) Amur Sound, Ozerpakh (3) River Amgun', Sergie-Mikhailovskoe village (4) River Im, Krasnyi Yar village (5) Males (6) Females

inadequate maturity of their sex products. In the sector of the Amgun' nearest to the Udinskii factory, near the village of Sergie-Mikhailovskoe, the coefficient of maturity (Table 43) was much lower than in the spawning river Im, although it varies from year to year depending on the state of maturity of pink salmon migrating into the Sound and on the water temperature during the spawning run.

The pink salmon takes on the average 10 days on its journey from Sergie-Mikhailovskoe village to the River Im. Consequently, to attain the degree of maturity of the gonads characteristic of fish in the spawning river, salmon of the main run would have to be kept in the tanks of the fish-breeding factory at least 10 days, and in order to obtain brood stock for the current year they would have to remain for much longer.

In spawning rivers where under natural conditions the final maturation of the fish takes place the sex products reach their maximum of development; the relative weight of the gonads in female pink salmon may reach 25 %, but in males, on the other hand, it decreases and this is accompanied by lique- /67/ faction of the sperm (Table 44).

TABLE 44. Changes in Coefficient of Maturity of the Pink Salmon at Different Periods of the Spawning Migration, River Im, 1951

Период хода 1	Самцы 4		Самки 7	
	колебания 5	среднее 6	колебания 5	среднее 6
Массовый 2	5,2—15,0	8,1	8,5—22,4	13,4
Конец 3	3,8—10,9	5,6	7,5—24,7	13,5

KEY: (1) Period of migration (2) Main run (3) End (4) Males (5) Variations (6) Mean (7) Females

In the pink salmon, as in other Pacific salmon, the development of the sex products during starvation at the time of the spawning migration takes place at the expense of nutrients stored in the body, with the result that the level of nutrition falls sharply (Table 45).

The state of maturity of the gonads is very dependent on the condition: for females of equal size and 42-43 cm in length in the River Amgun' the coefficient of correlation in 1948 was r = -0.84.

5. Breeding Colour

In the pink salmon, as in other salmon of the genus *Oncorhynchus*, during the spawning migration parallel with maturation of the gonads the breeding colour is formed. In the mouths of the rivers the first arrivals of the pink salmon as a rule consist of individuals with no visible external "nuptial" changes: the fish have silver scales and they appear well nourished. Somewhat later, with an increase in the scale of the run, fish begin to appear with slight evidence of a breeding colour, shown to begin with by the males. At the end of the spawning migration the number of spent fish increases considerably and the nuptial changes themselves become increasingly more marked: the scales lose their silver colour, dark pigments appear on the body and in the mouth, the body becomes appreciably flattened from the sides, and a hump appears on the back of the males.

TABLE 45. Changes in Weight of Gonads and in Condition of Female Pink Salmon During the Migration, River Amgun', 1948

Месяц, пятидневка (1)		Абсолютный вес гонад, г (4)		Относительный вес гонад, % (7)		Коэффициент упитанности (8)	Число рыб (9)
		колебания (5)	среднее (6)	колебания (5)	среднее (6)		
(2) Июль,	I	40—175	110	4,5—14,2	10,1	1,25	87
	II	45—190	110	5,7—18,4	10,6	1,19	145
	III	65—165	116	6,3—14,4	11,0	1,18	40
	IV	80—165	115	6,9—14,7	10,8	1,16	20
(3) Август,	I	100—250	151	7,3—22,5	17,3	0,97	95

KEY: (1) Month, five-day period (2) July (3) August (4) Absolute weight of gonads, g (5) Variations (6) Mean (7) Relative weight of gonads, per cent (8) Condition factor (9) Number of fish

Similar changes in the degree of breeding colour are shown by the fish during their ascent to the spawning areas. Whereas in Amur Sound most pink salmon have ill-defined nuptial changes, most of them in the spawning /68/ rivers and, in particular, at the spawning grounds have a well-defined breeding colour.

For convenience in describing the degree of nuptial changes in the pink salmon the following scheme is used by the Amur division of TINRO for biological analysis:

Stage 1. Features of external nuptial changes absent. Males difficult to distinguish from females by external appearance.

Stage 2. Slight curvature of the upper jaw of the males and appreciable increase in height of the spine. Readily distinguishable from females by these features. The fish at this stage have scales that are easily removed, an unchanged body colour, and a well-nourished appearance.

Stage 3. The jaws are appreciably lengthened and curved and possess well-developed teeth. The body is appreciably flattened from the sides and considerably enlarged in depth (in the males). The body colour is yellowish-grey, with prominent brownish-yellow spots. The scales are difficult to remove.

Stage 4. Snout beak-shaped. Body and head considerably flattened from the sides, well-developed hump, colour variegated. Brownish-purple hues are predominant, especially on the gill covers, fins, and on the body above the lateral line. Below the lateral line the colour is pale yellow, with a greenish hue. The scales cannot be removed. The fish has an extremely emaciated appearance.

Stage 5. Kelt.

Considerable changes take place in the pink salmon during the development of the breeding colour as a result of hyperplasia of the bone and cartilage tissues (Chernavin, 1918). The greatest changes affect the premaxillary bones (especially in males): on account of some lengthening and, chiefly, growth of the cartilage on the small, toothless ossicles, not reaching the end of the snout, very large bones with powerful teeth, covering the whole anterior border of the rostrum, are formed. The maxilla and mandible are also appreciably lengthened and large, curved teeth grow from the latter. On account of growth of the prenasal part the chondrocranium is greatly lengthened, while the cartilaginous rostrum grows appreciably in width also; parts of the skull not closed by bone lying posteriorly to the rostrum also become thicker. The formation of a hump in males is connected with lengthening of the bones of the spine, the lower ends of which fit between the spinous processes of the vertebrae.

Soldatov (1912) observed considerable variation in the degree of development of the sex products of female pink salmon in the absence of a breeding colour many years ago. The observations of Birman (Abramov, 1953) showed that of six male pink salmon with almost liquid testes, i.e., in stages IV-V of maturity, found in , Amur Sound in 1948 only two had a well-marked breeding colour, in two others the nuptial changes were hardly visible, and the other two males had a silvery colour. This suggested that the breeding colour of salmon is not the result of intensive development of the sex glands, as Kuznetsov (1937) postulated.

My own material, given in Tables 46 and 47, also shows that an equal degree of maturation of the gonads does not necessarily mean an equally well marked breeding colour, although a pink salmon in a distinct breeding colour as a rule has sufficiently well developed sex products.

TABLE 46. Degree of Manifestation of Breeding Colour by Pink Salmon with Gonads in Stage IV of Maturity, River Amgun' /69/

Год 1	2 Стадии брачного наряда			Число рыб 4
	2	3	4	
1949	80,2 / 97,4	19,8 / 2,1	0 / 0,5	395 / 678
1950	42,8 / 86,3	40,7 / 12,9	16,5 / 0,8	413 / 517

Примечание. В числителе — самцы, в знаменателе — самки. 5

KEY: (1) Year (2) Stage of breeding colour (4) Number of fish (5) Note. Males in numerator, females in denominator

TABLE 47. Stages of Maturity of Male Pink Salmon in Stage 4 of Breeding Colour, River Amgun', 1950

Количество[1]	Стадии зрелости гонад[2]				Число рыб[3]
	III	III-IV	IV	IV-V	
Штук[4]	8	69	67	1	145
%	5,5	47,6	46,2	0,7	100

KEY: (1) Number (2) Stages of maturity of gonads (3) Number of fish (4) Fish

This suggests that the development of the breeding colour is related not only to the maturation of the sex products; certain other factors are undoubtedly concerned. Abramov (1953) considers that it is preferable not to use the term "breeding colour" to apply to fresh-water features of adult salmon, and that since they appear in salmon as a result of morphological and physiological changes[1] with the participation of the organ of vision[2], they are protective at the spawning grounds and are developed in the course of evolution of the salmon as an adaptation to the environment. As the information in these tables shows, the absence of strict correlation between the state of the gonads and the degree of nuptial changes confirms Birman's view that "maturation of the gonads and development of the breeding colour are simply two processes that have undergone parallel development."

6. Fecundity

It will be clear from Table 48 that in 12 year-classes of the Amur pink salmon all parameters connected with fecundity are grouped together for even and odd years.

---

[1]The physiology of the process of their formation has not yet been explained.

[2]The pink salmon, when it can no longer see, still remains a smolt.

TABLE 48. Changes in Fecundity and other Qualitative Parameters of the Pink Salmon in Amur Sound in 1950-1963

Год (1)	Длина тела AC, см (2)		Вес тела, г (5)		Абсолютная плодовитость (6)		Коэффициент упитанности $\frac{(Q-q)\cdot 100}{l^3}$ (8)	Показатель индивидуальной плодовитости $\frac{l\,(Q-q)}{r}$ (9)	Относительная плодовитость (10)		Число рыб (11)
	колебания (3)	среднее (4)	колебания (3)	среднее (4)	колебания (3)	среднее (4)			$\frac{r}{AC}$	$\frac{r}{Q-q}$	
1950	38—55	46,6	600—2500	1276	600—3200	1473	1,18	375	31,6	1,24	221
1952	40—57	47,1	650—2170	1383	700—3150	1660	1,22	362	35,2	1,30	475
1956	37—56	45,4	850—2250	1278	626—2720	1390	1,23	377	30,6	1,21	744
1958	34—50	41,9	450—1570	932	456—1947	1141	1,15	310	27,2	1,35	1157
1960	37—52	44,5	600—2040	1212	672—2790	1459	1,26	339	32,8	1,31	817
1962	37—54	47,6	450—2250	1540	777—2996	1696	1,31	397	35,6	1,20	418
1951	39—53	46,5	750—2050	1295	835—2382	1592	1,19	346	34,2	1,34	457
1953	41—55	48,2	840—1950	1383	900—2700	1642	1,14	373	34,1	1,29	103
1957	38—54	46,9	750—2100	1464	519—2784	1604	1,29	390	34,2	1,23	396
1959	33—57	47,6	380—2540	1498	327—3178	1644	1,27	400	34,5	1,19	1015
1961	40—56	47,3	770—2600	1516	700—2858	1832	1,31	358	38,7	1,32	672
1963	35—55	47,6	530—2500	1547	675—3066	1669	1,35	424	35,1	1,12	499

KEY: (1) Year (2) Body length AC, cm (3) Variations (4) Mean (5) Body weight, g (6) Absolute fecundity (8) Condition factor (9) Index of individual fecundity (10) Relative fecundity (11) Number of fish

This Table shows that variations in individual fecundity of the pink salmon are very great. Its mean value also fluctuates considerably. In the years under consideration the differences in the mean fecundity of the pink salmon in even and odd year-classes have diminished appreciably: in even years the fecundity was 1470, but in odd years 1664 eggs, whereas in 1925-1934, according to Kuznetsov (1937), the corresponding figures were 1221 and 1717. The explanation of this fact may be as follows.

For the Amur pink salmon 1925-1934 was a period of sharp fluctuations in the numbers of consecutive year-classes (Table 3); the dimensions of the fish in even and odd years differed considerably at that time. Fecundity, however, directly dependent on the size of the fish, was on the average 500 eggs greater in odd years than in even. In the period 1950-1963 no regular variations in number were found in even and odd years. The pink salmon stocks of even year-classes were high only in 1956 and 1958, but in 1950, 1952 and 1962 they /71/ were depressed. Because of the larger size of the fish in 1950, 1952 and 1962, as the figures in Table 48 show, the fecundity was almost at the level of odd year-classes; for that reason the difference in fecundity of the pink salmon in even and odd years was on the average only 200 eggs in 1950-1963.

Correlation between the fecundity of the pink salmon and its linear dimensions is, however, not always observed (Semko, 1939; Dvinin, 1952; Enyutina, 1955). According to my observations the degree of correlation between fecundity and size is low: the coefficient of correlation for 1950 is +0.25.

The fecundity of the pink salmon varies regularly not only with the size of the fish. As Fig. 10 shows, in two consecutive year-classes with considerable differences in abundance size, fish with the same dimensions differed in fecundity. The increase in fecundity of the pink salmon in the year-classes of

1949 and 1959, which were of low abundance, could have taken place only because of a decrease in size of the eggs, and this is confirmed by the evidence in Table 49.

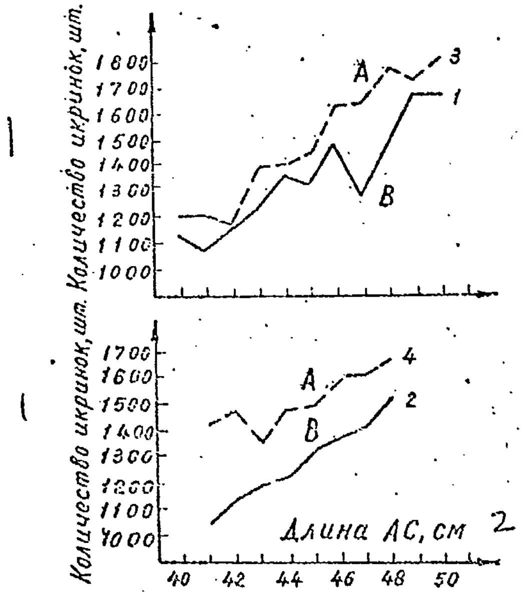

Fig. 10. Correlation between length and fecundity of the Amur pink salmon for year-classes of high and low abundance. B) large numbers; 1) 1948, 2) 1958; A) small numbers; 3) 1949, 4) 1959.

Key: (1) Number of eggs (2) Length AC, cm

TABLE 49. Size of Eggs in a Sample Weighing 20 g from Pink Salmon 43-45 cm in Length

1 Место сбора материала	Год 4	Стадия зрелости гонад 5	Среднее количество икринок 6	Число рыб 7
Р. Амгунь 2	1948	IV	155	58
	1949		258	38
Н. Пронге 3	1958	III	280	156
	1959		360	54

KEY: (1) Place where material collected (2) River Amgun' (3) N. Pronge (4) Year (5) Stage of maturity of gonads (6) Mean number of eggs (7) Number of fish

A decrease in size of the eggs of pink salmon belonging to stocks of low abundance is constantly observed. In the River Amgun', for example, the four year-classes of pink salmon after 1949 were represented by extremely small numbers and the number of eggs in a sample weighing 20 g from fish 43-45 cm long in Stage IV of maturity of the gonads was 284, 220, 257 and /72/ 270 after 1950.

The low level of correlation between the size of the fish and the size of the eggs at the same stage of maturity (the coefficient of correlation for 1950 and 1951 is -0.21 and -0.31 respectively) is the reason why the pink salmon can maintain its characteristic fecundity as a species even when the abundance of the stock decreases over a period of several years.

The fecundity of the pink salmon is more dependent on body weight than on body length; the coefficient of correlation for 1950 was +0.33. However, this degree of correlation is nevertheless very small, so that the weight of the pink salmon is not always clearly reflected in its fecundity (Table 48). In the 1961 and 1962 year-classes of pink salmon, for example, despite the same mean weight of the fish the difference in fecundity was 136 eggs. Characteristically no difference was observed in the size and condition of the fish forming these year-classes, but their numbers were equally very low.

The absence of high correlation between body weight and fecundity in year-classes of even and odd years, as with year-classes of high and low abundance is clearly reflected in the relative fecundity $(\frac{r}{Q - q})$[1]. Another index of relative fecundity, expressing the ratio between fecundity and body length $(\frac{r}{AC})$, is higher for the smaller year-classes of pink salmon (1952, 1961, (1962) and lower for abundant year-classes of pink salmon (1956, 1958).

These facts on relative fecundity are in agreement with the similar observations of Semko (Kaganovskii, 1949) on the Bol'sheretsk pink salmon which show that definite differences between even and odd year-classes of the

---

[1]The weight of the gonads, which increases considerably toward the end of the spawning migration (Table 41), is excluded from the body weight both here and in Loganzen's (1955) Index of Individual Fecundity.

pink salmon (i.e., yielding good or poor catches) are revealed by the ratio of fecundity, not to body weight, but to body length. For this reason the index of individual fecundity for the pink salmon does not show any regular correlation (Table 48). Fecundity is even less closely connected with the condition of the pink salmon. The condition factor for fish with approximately the same fecundity varied in 1952, 1953, 1957, 1959 and 1963, according to my observations, from 1.14 to 1.35, whereas in 1952, 1956, 1959 and 1960, fish of about equal condition had fecundity varying from 1390 to 1663 eggs.

As these observations showed, neither the length nor the weight of the pink salmon reflected any appreciable changes in its fecundity. The main parameter determining the fecundity of the pink salmon is the size of its eggs, and this depends not only on the size of the fish but also on the abundance of the spawning year-class of the species.

7. Changes in the Blood Picture

The investigations of Lysaya (1951) in 1948 and 1949 showed that the blood picture of the pink salmon varies considerably as the fish migrates from Amur Sound to the spawning grounds (Table 50).

The red cell count, haemoglobin concentration, and the concentrations of sugar and osmotically active substances (chlorides, calcium) are lower in the spawning grounds (the Rivers Samnya and Im) than in Amur Sound (Ozerpakh, N. Pronge) but the erythrocyte sedimentation rate (ESR) and the urea and total nonprotein nitrogen concentrations are higher.

Changes in the concentrations of the physiological and biochemical components of the blood were observed at the extreme points of the spawning migration of the pink salmon (from Amur Sound to spawning grounds) and they depended on the stage of sexual maturity of the fish. This provided the basis for the

TABLE 50. Physiological and Biochemical Changes in the Blood of the Pink Salmon in Connection with the Spawning Migration /73/

Компоненты и показатели (1)	Лиман Амура (11) 1948 г.	Лиман Амура (11) 1949 г.	Нерестилища (12) 1948 г.	Нерестилища (12) 1949 г.	Количество рыб (13)
Эритроциты, тыс. на мм³ (2)	1557[1] / 1925	1710 / 1480	1315 / 1020	1301 / 940	5 / 9
Гемоглобин, % (3)	— / —	58,0 / 48,4	— / —	50,8 / 33,0	5 / 9
РОЭ, мм в час (4)	2,3 / 2,3	2,9 / 2,4	4,8 / 4,6	8,0 / 15,0	5 / 9
Сахар, мг % (5)	98,4 / 67,8	85,6 / 56,7	30,4 / 23,2	39,8 / 24,6	40 / 45
Мочевина, мг % (6)	36,4 / 30,9	20,8 / 16,2	92,7 / 73,5	75,4 / 33,0	40 / 45
Остаточный азот, мг % (7)	— / —	84,2 / 64,6	— / —	97,6 / 94,6	21 / 21
Хлориды, мг % (8)	339 / 294	295 / 267	250 / 218	270 / 254	11 / 11
Кальций, мг % (9)	10,5 / 9,3	12,0 / 9,2	8,1 / 8,3	11,2 / 10,9	11 / 11

[1] В числителе — самцы, в знаменателе — самки (10)

KEY: (1) Components and indices (2) Red blood cells, thousands/mm³ (3) Haemoglobin, per cent (4) ESR, mm in 1 h (5) Sugar, mg % (6) Urea, mg % (7) Nonprotein nitrogen, mg % (8) Chlorides, mg % (9) Calcium, mg % (10) Males in numerator, females in denominator (11) Amur Sound (12) Spawning ground (13) Number of fish

conclusion that changes in the physiological state of the blood depend on ripening of the sex products. A sharp increase in the blood urea of salmon in the spawning grounds was attributed by Lysaya to the irregular protein breakdown taking place as a result of severe emaciation of the fish and the almost total loss of the tissue carbohydrates and lipids. The urea initially "retained" by the salmon for maintaining the osmotic pressure of the blood later exerts a toxic action, resulting in death of the salmon of the genus *Oncorhynchus* after spawning.

8. Death Before Spawning

Death of the pink salmon and summer chum before spawning is often observed in the spawning rivers of the Amur basin. According to figures obtained by Amurrybvod, in 1950, 1951 and 1953 the proportion of fish dying before spawning in the River My was between 1.2 and 2.8 %, whereas in 1952 it was almost 17 %. Among female pink salmon the mean mortality in 1960 and 1962 in the River Im was 1.6 %, in the River Beshenaya 6.1 %, and in the River Iski 10.0 %. In most cases the dying fish were completely healthy in appearance. They were either smolts or fish with a well-developed breeding colour. Less frequently larger fish were seen that had died before spawning. Usually their body (particularly the head and fins) was infected with Saprolegnia; sometimes deep bites on the body, caused by the teeth of marine mammals, also were infected with Saprolegnia.

Whether the infection with Saprolegnia was the cause of the disease and /74/ death or simply a complication of the main disease it is difficult to determine for no special investigations have been carried out in this direction.

Death of the salmon before spawning sometimes occurs on a massive scale and leads to considerable depletion of their stocks. In 1934, for example, in the River Bol'shaya on Kamchatka P.A. Dvinin and R.S. Semko observed massive mortality among the pink salmon soon after its arrival from the sea in the part of the river close to the mouth, as a result of the temporary development of an exceptionally rare oxygen deficiency.

In 1955 A.P. Makeeva (1956), working on the River My, discovered the cause of mass death of pink salmon when she found flagellates of the genus Trypanoplasma in the blood and coelomic fluid of fish that had died. The number of these parasites in the blood was 1.5 times greater than the number of red cells. Infection of the fish by the trypanoplasmid was shown to take place in the river through leeches Piscicola geometra, Hemiclepsis marginata, etc. The sick and dying fish looked quite healthy externally; at autopsy however, blood and a grossly enlarged, friable, chestnut-brown (instead of dark red) spleen were found in the body cavity.

The wide distribution and large numbers of these species of leeches in the Amur basin and the discovery of Piscicola in large numbers on the pink salmon (Lukin, 1955, 1962) lead to the appearance of epizootics in some years on such a large scale that they appreciably affect the numbers of Pacific salmon in the pre-spawning period.

/75/

VII. REPRODUCTION

1. Spawning Rivers and Distribution of Brood Stock in Them

The pink salmon of the Amur basin as a rule reproduces in comparatively short rivers in the foothills from 10 to 200 km in length. The spawning grounds in these rivers extend almost continuously along parts of the river bed composed of relatively loose material. In most cases this material consists of small pebbles or pebbles mixed with sand.

Spawning rivers are characterized by specific conditions of water level. It varies considerably during the year. It is noteworthy that the time of high water in the rivers of the Amur basin, unlike those of Kamchatka, usually does not coincide with the spawning period of the pink salmon and for that reason its reproduction is subject to much less wastage than on Kamchatka (Kuznetsov, 1928). The mean depth at the spawning grounds reaches 1.5 m. With a mean water level in the rivers the most typical depth at the spawning grounds of the pink salmon is 0.4-0.6 m. With a thickness of ice of 16-78 cm, the mean depth at the spawning grounds beneath the ice varies from 9 to 24 cm.

Spawning rivers for the pink salmon also have a characteristic temperature pattern, distinguished by relatively large changes in the course of the 24 hours (up to 5°C in the River My).

The rate of flow at the Amur spawning grounds of the pink salmon is greater than on Kamchatka and it averages 0.8 m/sec, with variation in certain years and in different rivers from 0.3 to 1.5 m/sec. However, as a rule the pink salmon will not spawn if the rate of flow is less than 0.7 m/sec (Soin, 1954).

The hydrochemical conditions of spawning rivers have been studied sufficiently completely by Vasil'ev (1959) and can be described as follows.

The oxygen concentration (in mg/litre) is 8-10 in summer, 11-12 in autumn, 7-8 in winter and 8-9 in spring; the free carbon dioxide concentration (in mg/litre) is the same (1-5) in summer, autumn and spring but rises to 20 (or perhaps even more) in winter. Diurnal changes in the gas concentrations are very small and are observed only in summer. The gas concentrations in different parts of the rivers are usually about the same.

Seasonal variations in pH in the spawning rivers are very slight, and the reaction is weakly acid, pH 6.1-7.3.

The mineral composition of the water varies greatly in different spawning rivers but all are of the hydrocarbonate type. Their salt content is usually below 50-60 mg/litre and their total hardness does not reach 2-3^{o}, i.e., the water is soft and has a low mineral content. The predominant mineral components are bicarbonates, the mean concentration of which exceeds 30 mg/litre.

The distribution of spawning stocks of pink salmon in the basin of a /76/
spawning river depends, as investigations carried out by TINRO in 1937-1941 showed, mainly on three principal factors: 1) the water level and flow rate, 2) the scale of the run, and 3) the degree of maturity of the individual fish.

If the water levels are very low the fish will select deep parts of the bed for spawning and will not enter the tributaries; higher levels lead to a wider distribution of the brood stock throughout the basin of the spawning river. Abundant year-classes also make maximum use of the whole spawning area of the river: the pink salmon in years of a large run will even enter some mountain streams. The first arrivals of fish usually ascend higher up the spawning rivers than the more mature individuals of subsequent runs. Having entered the spawning rivers with the gonads in stage V of maturity a pink salmon will not ascend higher but will spawn in the mouth or in the pro-estuarine spawning grounds. The brood stock go towards the spawning places in groups of several score of fish, stopping periodically to rest in quiet places. The early arrival of a large number of males at the spawning grounds may have the result, as Strekalova (1954) observed, that the same male may spawn with several females during the spawning period. However, such a situation must evidently entail the repeated utilization of the sex products of the males.

2. Spawning

Having reached the spawning grounds the brood stock usually stay for a few days in pits or holes, after which they break up into spawning groups (usually to each female there are 3-4 males, but sometimes as many as 9-10), after which the female begins to excavate the soil, choosing the main portions of the channel where the rate of flow is high and silting is minimal; at this stage the males keep behind her. According to Soin's (1954) observations in the River My, the excavation of mounds continues on the average for 6-7 days. One, two or three nests will be made in them, 40 cm or more apart. A description by Taranets (1939) of the process of preparation of spawning mounds and the laying of eggs by the pink salmon in the basin of the River Iski is given below:

"As the pink salmon digs a pit for the first nest, a wide ridge is formed behind it. When laying the first portion of eggs in the pit, on the floor of which a larger pebble is always placed, the female pink salmon sprinkles the place with earth and starts to dig the pit for the second nest a little higher upstream. In most cases the eggs are laid in two portions; sometimes, however, especially if the soil conditions are unsatisfactory, it is impossible to distinguish the two nests."

The shape and size of the mounds depend on the rate of flow, the relief of the river bed and banks, the character of the soil and the depth of water; the dimensions of the mounds evidently do not depend on the number of spawners (the population of the pink salmon stock in 1938 was high and in 1951 low; Table 51).

TABLE 51. Size of Spawning Mounds of the Pink Salmon in the Basin of the Rivers Iski (after Taranets, 1939), Im (after Abramov, 1953) and My (data of Moscow State University, 1952)

1 Река, год	5 Длина бугра, см		8 Ширина бугра, см		9 Число бугров
	6 колебания	7 среднее	6 колебания	7 среднее	
2 Иски, 1938	118—232	155	58—118	84	14
3 Им, 1951	35—80	56	25—60	36	26
4 Мы, 1951	115—190	156	90—150	121	9

KEY: (1) River, year (2) Iski (3) Im (4) My (5) Length of mound, cm (6) Variations (7) Mean (8) Width of mound, cm (9) Number of mounds

During spawning a female pink salmon with a mean weight of 1.3 kg performs a lot of work, digging and shifting about 0.33 m^3 of soil. The eggs are covered with soil to a mean depth of 20-30 cm (variations from 18 to 50 cm) and they are thus better protected against exposure to unfavourable factors: movement of the soil, freezing, drying, and silting.

In the rivers of the south-western part of Amur Sound, including the River My, spawning of the pink salmon usually begins in the second or at the beginning of the third ten-day period of July; the main run goes on for 10-15 days until the last 10 days of August, and spawning ends completely at the end of September. The total duration of the spawning period averages 60 days. /77/

A little later, in the first 10 days of August, the pink salmon starts to spawn in the River Iski, evidently because the spawning migrations to this river are later than those of the pink salmon to the River My; the climax of spawning occurs on 17-25 August and it ends in the middle of September. The mean duration of the spawning period of the pink salmon in the River Iski is 45 days.

The pink salmon usually starts to spawn in the basin of the River Amgun' in the last 10 days of July, the main run occurs from the end of July to the beginning of August, and spawning ends in the middle of August; this river has the shortest spawning period, lasting about one month.

The duration of the spawning period depends directly on the duration of the spawning migration. In fact, in the Rivers Samnya and Im, where the spawning migration of the pink salmon is only half as long as in the River My (mean duration for many years 35 days compared with 64 days) the spawning period is also half as long. In the River Iski, where the spawning migration is of the same duration as in the River My (mean 64 days) the spawning period is two weeks shorter. It ends in mid-September probably because the water temperature falls below the optimal limit for spawning.

The duration of the spawning season of the pink salmon is also connected with the abundance of the stock. Taranets, working on the River Iski in 1938-1941, observed that abundant year-classes had a longer spawning period and weak year-classes a shorter one. The increase in the spawning period for abundant year-classes of pink salmon, according to the statistics of Amurrybvod, is 10 days. As a rare exception the spawning period may also be considerably drawn out for weak year-classes of pink salmon (as in the River My in 1955), evidently because of the low density of the spawning migration.

The pink salmon spawns in both low and high water levels at depths of between 0.5 and 1.5 m. Sometimes it spawns in pits more than 2 metres deep. If the water level is moderate, the most typical depths at which spawning takes place are 0.6-1.0 m. The rate of flow at the spawning grounds is relatively high: 1.5 m/sec.

The water temperature during spawning of the Amur pink salmon is from 6.4 to 15.6°C, and according to I.I. Kuznetsov, spawning reaches a maximum at temperatures of 9.2 to 13.7°C.

In years of great abundance of the pink salmon such as, for example, in 1958 the spawning grounds in all spawning rivers of the Amur basin were overcrowded with brood stock. The pink salmon reproduced even in parts of rivers unsuitable for spawning: in stagnant water, at great depths, and in places with an unsuitable substratum. Everywhere substratum in which eggs had already been de- /78/
posited in mounds was being excavated again. In that year, as in 1938 and also, evidently, in 1948 many spawning areas that had become almost useless because of silting of the substratum, thanks to the repeated excavation, were improved by the fish.

The density of distribution of the spawning mounds depends on the abundance of the spawning stock. According to observations made in 1959-1962, when the spawning grounds were relatively crowded, there was one mound on the average to an area of 1 m^2, whereas when the spawning population was low there was one mound to a mean area of 10 m^2.

A high proportion of eggs laid by salmon brood stock is lost during the spawning period. According to Taranets (1939), 38.9 % of the eggs of the pink salmon in the River Iski were lost in 1938, compared with 15.4 % in 1939;

statistics of the fisheries improvement stations of Amurrybvod show that the loss in 1951 was 55.5 % in the River Iski, 59.7 % in the River My and 68.8 % in the River Im, whereas in 1953 the corresponding figures for these rivers were 57.4, 40.5 and 57.6 %; Strekalova (1954) estimated the loss of eggs of the pink salmon in the River My in 1952 at 43.5 %. The loss of eggs during spawning of the Amur pink salmon (mean 54.7 %, variations from 15 to 60 %) was thus much higher than that stated previously by Kuznetsov (1928) and Taranets (1939) and almost the same as that of the pink salmon of Primor'e, Sakhalin and Kamchatka (Semko, 1939; Dvinin, 1952; Vasilenko, 1959). This large loss of eggs is evidently explained by the spawning of this species in fast-flowing currents.

Of all the females which set out to spawn, usually some do not discharge all their eggs. The mean percentage of such females in 1960-1962 was 33.6 in the River Samnya, 48.8 in the Im, and 25.8 in the Iski, and the proportion of undischarged eggs in these fish varied from 1 to 18 % (in 1953 it reached 26 %).

3. Conditions of Development of the Eggs and Larvae in the Mounds

Observations by Strekalova (1954) show that the soil in the nests of the pink salmon consists two-thirds of pebbles and stones measuring from 1 to 10 cm and one third of sand and gravel.

The winter conditions of the rivers and the abiotic conditions in the spawning mounds of the pink salmon, studied in detail and described by Vasil'ev (1958, 1959) for the Amur spawning grounds, have the following characteristics.

In autumn the mean rate of filtration of the water in the redds of the pink salmon (the rate of the under-gravel current) is 3.69 m/h. In July-August the mean oxygen concentration in the redds is 8.08 mg/litre with variations from 6.24 to 10 mg/litre, and the mean carbon dioxide concentration is 2.8 mg/litre with variations from 1.2 to 5.6 mg/litre. Later, from the middle of September to the middle of November, because of a large increase in the oxygen concentration in the river water and a decrease in the water flow the oxygen and carbon dioxide concentrations in the soil in the redds increase and the pH lies between 6.2 and 6.5. The mean oxygen concentration reaches 9.94 mg/litre with variations from 6.85 to 11.57 mg/litre and the mean carbon dioxide concentration rises to 4.7 mg/litre with variations from 2 to 10.2 mg/litre.

The temperature conditions in the redds are characterized by great stability. The maximum diurnal variations in temperature do not exceed 1.5-2°C. The highest temperature recorded in the pink salmon redds is 12-13°C.

Despite the almost continuous ice cover, the intensity of aeration of the spawning rivers remains very high. If the winter level of the rivers is high and they do not freeze completely to the bottom, the oxygen concentration is /79/
approximately 7.5-10 mg/litre, the carbon dioxide concentration 8-20 mg/litre, and pH between 6.2 and 5.9. In winters of low water levels and little snow, when the rivers freeze completely to the bottom, their oxygen concentration may, however, fall almost to zero and their carbon dioxide concentration may rise to 40 mg/litre or more.

The water temperature in the channel of the spawning rivers in winter is approximately zero while the temperature in the redds is between 0.05 and 0.2°C.

In winter, if the rivers do not freeze completely, the mean oxygen concentration in the redds is 7.57 mg/litre, the mean carbon dioxide concentration 20.3 mg/litre, and pH 5.9. In winters with complete freezing of the rivers the gas concentrations in the redds are similar to those in the channels of the rivers.

The pink salmon egg has a diameter of 4-6 mm and weighs 118-198 mg (Smirnov, 1964). The comparatively thick membrane of the eggs makes them relatively inaccessible to predators inhabiting the redds such as planarians, amphipods, and insect larvae.

According to the observations made by the Moscow University expedition, in water at a temperature of 12-14°C gastrulation begins 6 days after fertilization and ends on the tenth day. The embryonic heart begins to pulsate after 12 days, and circulation of the blood can be seen on the fourteenth day. Dark pigment begins to appear in the eyes of the embryo 20-22 days after fertilization.

The incubation times of most of the eggs laid in the period of the main run in the rivers of the south-western part of Amur Sound are from 60 to 90 days. Depending on the incubation times, the times at which the larvae emerge from the redds are widely spread (from May to July). At the time when they leave the redds the pink salmon larvae are 28-32 mm long and they still have a large remnant of the yolk sac.

4. Downstream Migration of the Young Salmon

The downstream migration of young salmon in spawning rivers is counted by Amurrybvod by a sampling method using standard conical trap nets made of wire netting with a mesh of 3x3 mm, as used by Taranets (1939). The trap nets are set across the channel of the rivers close to the mouth at different levels: on the surface, at mid-depth, and near the bottom.

The efficiency of the downstream migration is judged by reference to the "downstream migration index" -- the ratio between the number of young downstream migrants and the fecundity of the spawning stock, expressed as a percentage. However, this index gives no idea of the abundance of the pink salmon in a particular year for the Amur basin as a whole, for the counting of the downstream migrants is carried out only in certain spawning rivers, admittedly the most important, and not in the main channel of the Amur. Only where a count is taken can it provide a sufficiently reliable basis for judging the abundance of the pink salmon in that particular region.

To obtain more precise information about the abundance of the pink salmon in the Amur basin year by year it is thus necessary to develop a more extensive network of observation points on other rivers.

A. Times and Duration of the Downstream Migration

The downstream migration of the young pink salmon in the rivers of the Amur basin usually begins in the first half of May. In some years the young fish begin to migrate downstream in the second half of April, when the spawning rivers are still covered with ice; sometimes the downstream migrants do not appear until the end of May. The main downstream migration of the pink /80/ salmon takes place as a rule over a period of one month, from the end of May to the end of June. The latest time of downstream migration of the pink salmon for the spawning rivers of the Amur basin is mid-August.

The true picture of the distribution of downstream migrants of the pink salmon in time does not fit exactly into the scheme just described. Observations made at the fisheries improvement stations of Amurrybvod in 1950-1963 have shown (Table 52) that the times of beginning of the downstream migration, its peak, and its end vary considerably in different rivers, and in the same river in different years the difference may amount to a month.

The duration of the downstream migration of the young pink salmon in the tributaries of the Amgun' -- the Rivers Samnya and Im -- is comparatively short, on the average 55 days, whereas in the Rivers Iski and My it is always 10-20 days longer. The longest downstream migration of the pink salmon is observed in the River My, and this agrees fully with the longest period of the spawning migration and of actual spawning of the pink salmon in that river. The same rule applies to the Rivers Samnya and Im, where the comparatively short spawning migration and period of spawning of the pink salmon are associated with more compressed periods of the downstream migration of the young fish.

TABLE 52. Times and Duration of Downstream Migration of Young Pink Salmon in 1950-1963

Характер наблюдений 1	Река 7			
	Самня 8	Им 9	Мы 10	Иски 11
2 Начало ската	4—17/V	4—23/V	21/IV—28/V	14/IV—30/V
3 Массовый скат	25/V—16/VI	16/V—16/VI	26/V—5/VII	28/V—25/VI
4 Конец ската	24/VI—20/VIII	15/VI—2/VIII	13/VII—11/VIII	26/VI—1/VIII
5 Продолжительность в днях[1]	46—64 (54)	39—91 (55)	44—102 (74)	42—101 (68)
6 Коэффициент ската, %	0,4—22,9	0,005—3,0	1,5—22,9	0,3—41,4

KEY: (1) Nature of observations (2) Beginning of migration (3) Main migration (4) End of migration (5) Duration in days (6) Downstream migration index, per cent (7) River (8) Samnya (9) Im (10) My (11) Iski

[1] Mean annual duration of the downstream migration given in parentheses.

The time of the downstream migration is thus determined largely by the duration of the spawning migration and the time of spawning; temperature conditions during development of the eggs and larvae, it must be assumed, also play a not insignificant role.

B. Hydrological Conditions Accompanying the Downstream Migration

The young pink salmon begin to leave the redds in March or April, underneath the ice. The beginning of the main downstream migration of the young salmon usually coincides with a comparatively high water level in the spawning river, resulting from melting of the snow and thawing of the ice. The first young salmon always migrate downstream under the ice. The water temperature at this time is close to 0°C.

Later the intensity of the downstream migration of the young pink salmon depends not so much on the level as on the temperature of the water. Up to a certain limit (which occurs at the end of June or beginning of July, when the great majority of young salmon have already migrated downstream and the water temperature in the river is rising steadily) an increase or decrease in the water temperature leads almost always to a corresponding increase or decrease in the number of migrants (Fig. 11).

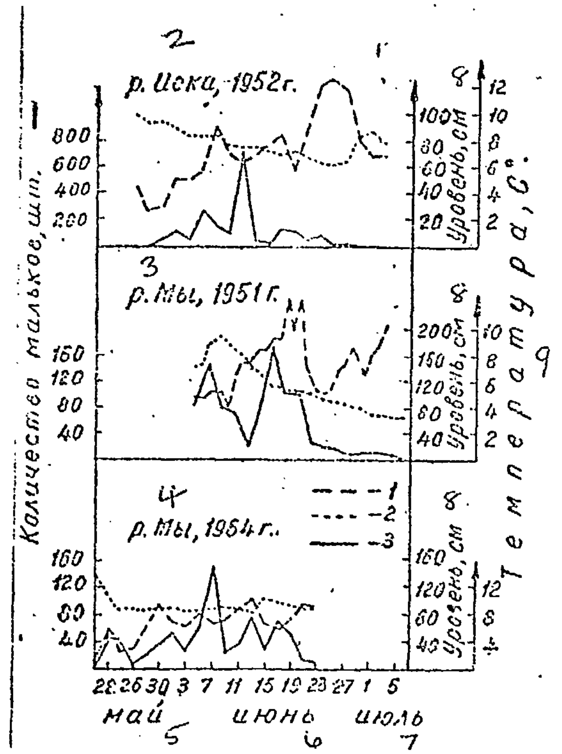

Fig. 11. Mean catch of young pink salmon per trap, water temperature and water level in the river: 1) temperature, 2) water level, 3) dynamics of downstream migration.

Key: (1) Number of fish (2) River Iski, 1952 (3) River My, 1951 (4) River My, 1964 (5) May (6) June (7) July (8) Level, cm (9) Temperature, °C.

The mass downstream migration of the young pink salmon in rivers of the Amur basin and in the River Iski begins when the water temperature is not below 4°C. The temperature difference in the period of the downstream migration varies from 5.3° (River Samnya, 1951) to 15.5° (River Beshenaya, 1963), /81/ with a mean level of about 10°. The highest water temperature at which young pink salmon were still caught in the counting nets was 18.6°C (River Samnya, 1951). Just as in Primor'e (Vasilenko, 1959) the intensity of the downstream migration of the young Amur pink salmon increases with an increase in the water temperature (Fig. 11). The water temperature at which downstream migration is observed in both the first and the second halves of the downstream migration period is the same -- from 6 to 9°. The rate of flow during downstream migration of the young salmon varies depending on the water level in the river from 0.25 to 2 m/sec. The largest number of young salmon migrates downstream when the rate of flow is 1-1.5 m/sec. The migration almost ceases if the water level falls considerably and, consequently, so also does the rate of flow.

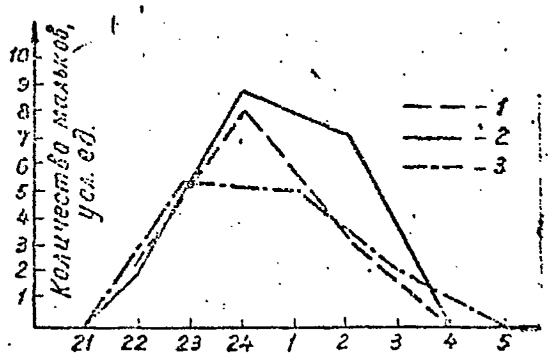

Fig. 12. Dynamics of downstream migration of young pink salmon with time of day: 1) River Ul, 1963; 2) River My, 1964; 3) River Im, 1963.

Key: (1) Number of fish, arbitrary units

The fact that the young pink salmon all accomplish their downstream migration at the same time, when the water level in the spawning river is comparatively high, evidently enables the fish to preserve the energy reserves which it needs for its subsequent catadromous migration.

C. Dynamics of the Downstream Migration

In the spawning rivers of the Amur basin and in the River Iski the downstream migration of the young pink salmon usually is observed in darkness, between 10 p.m. and 3 a.m. (Fig. 12). As a rare exception, the young salmon in the River My in 1953, in the River Iski in 1954, and in the River Im in 1959 migrated downstream in small numbers by day also, evidently on account of a sudden considerable rise of the water level and, consequently, an increase in the rate of flow. The highest catches of the young salmon in the traps are observed on dark, overcast nights.

During their downstream migration the young salmon are distributed in the depth of the water more or less uniformly (Fig. 13). Only in some years do the migrants tend to be found in somewhat larger numbers in the surface layer of the water, while in other years, on the other hand, they may prefer the water near the bottom.

/82/

D. Nutrition

The nutrition of the young pink salmon migrating downstream from the spawning rivers of the Amur basin (Samnya, Im and My) was studied by V.Ya. and I.M. Levanidov (1957) on the basis of observations in 1951 and 1952. It was concluded from their results that during the period of downstream migration the young pink salmon obtains little food (the number of young salmon with empty stomachs caught in the Rivers Samnya and My in 1951-1952 averaged 80 %), and it evidently feeds only in the first half of the day. The diet consists

/83/

basically of aquatic invertebrates (larvae of mosquitoes and midges and pupae, larvae of mayflies and stoneflies, water bugs); flying and crawling insects (beetles, ticks) play a secondary role although they occupy an important place in the dietary spectrum.

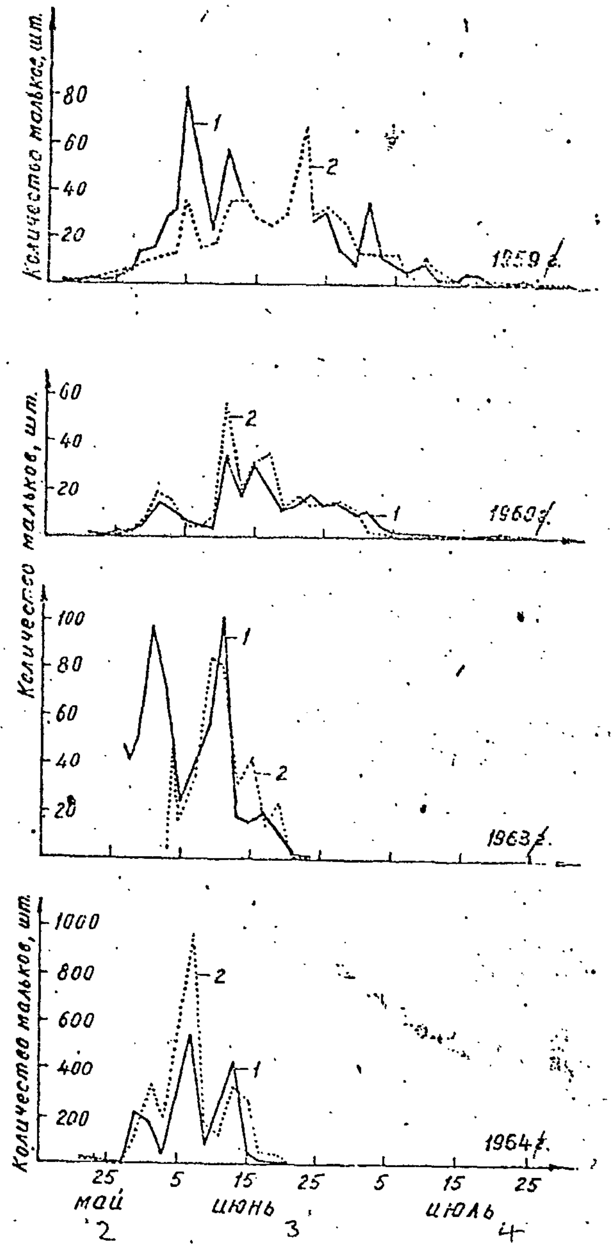

Fig. 13. Dynamics of downstream migration of young pink salmon in the River My at different depths: 1) in the surface layer, 2) near the bottom.

Key: (1) number of fish (2) May (3) June (4) July

Characteristically the intensity of feeding of young pink salmon migrating downstream from the tributaries of the Amgun' (the Rivers Im and Samnya) is much higher than for the fish from the River My, because of their longer migration path. During the downstream migration the intensity of feeding of the young salmon as a rule increases gradually (on account of an increase in the water temperature), although their mean size and weight remain almost unchanged.

Comparison of the dietary spectra of young pink salmon and summer chum reveals the possibility of competition for food in years when these fish are abundant. However, this possibility perhaps does not materialise, as Volovik (1964) suggests, if the feeding of the young pink salmon and chum is studied in conjunction with the ecology, distribution and behaviour of the young fish and the organisms which they use as food. On the whole Volovik considers that random catches of young pink salmon from different parts of the rivers (tributaries of the Amur) without any indication of the precise region of feeding can give only a qualitative picture of the nutrition of the young pink salmon.

E. Qualitative Composition

At all periods of the downstream migration from the rivers the young pink salmon are silvery in colour, with no pigmented spots or bands of colour on the sides and belly and with a dark olive green colour of the back. The investigations of Zueva (1965) showed that the body begins to turn silvery in colour (deposition of guanine in the skin) early and that, unlike the Kamchatka steelhead and the chum, the process of smoltification takes place with omission of the "parr" stage. Early silvering of the body stops the development of the pigment (melanin) cells located along the lateral line. The beginning of this process is accompanied by hyperfunction of the thyroid gland.

The young pink salmon are in general relatively uniform in size (31-35 mm) although variations in individuals may be very considerable: 27-42 mm. Characteristically changes in the body length (AC) of the young fish during the downstream migration are small and are not regular in character (Table 53).

The weight of the young fish is a more variable parameter. Its observed variations were between 80 and 500 mg. However, just as in the case of the condition factor (after Fulton), in this case also it is difficult to detect regular changes during the period of the downstream migration. At the beginning of the migration in the spawning rivers Im and My the young pink salmon more often grows in weight accompanied by an improvement in condition, than in length, as does the autumn chum (Levanidov, 1964b); meanwhile in the River Samnya, for example, the exterior of the fish remains almost unchanged throughout the downstream migration.

Variations in the condition factor of the young pink salmon during the downstream migration are evidently not the result of differences in the intensity of exogenous feeding. The fact that this index is higher for the young fish in the initial period of the downstream migration is evidence rather that the yolk sac has not yet been completely absorbed in individuals observed collectively at the beginning of migration when the water temperature is low.

The length and weight of the young fish likewise do not remain constant over the years. Particularly large variations were observed in the pink salmon of the River Iski in 1951 and 1954 (Table 54) and were probably due to differences in the water temperatures of the river in those years and to the different timing of the downstream migrations of the young fish.

Considerable variations in the condition factor of the young pink salmon in different rivers during downstream migration in the same year (Table 53)

TABLE 53. Changes in Qualitative Parameters of Young Pink Salmon from Different Rivers During the 1952 Downstream Migration

Период наблюдений 1	3 Длина тела, мм		5 Вес, мг	Коэффициент упитанности 6	Число рыб 7
	колебания 4	среднее 2	среднее 2		
			р. Самня 8		
8/V	32—39	33	206	0,57	89
4/VI.	32—37	34	215	0,55	100
8—10/VI	31—37	33	207	0,58	200
11—16/VI	32—37	33	218	0,61	200
17—22/VI	31—36	34	233	0,59	86
В среднем 2	31—39	33	216	0,60	675
			р. Им 9		
5/VI	28—35	31	214	0,71	100
7—10/VI	28—35	31	213	0,71	127
11—16/VI	28—34	31	207	0,69	199
18—20/VI	28—35	31	212	0,71	91
22—24/VI	28—35	31	190	0,64	66
25/VI—12/VII	30—39	32	194	0,59	28
В среднем 2	28—39	31	210	0,70	611
			р. Мы 10		
6—11/VI	31—36	33	207	0,58	28
16/VI	30—36	33	198	0,57	136
20—24/VI	30—37	33	206	0,57	179
30/VI—5/VII	27—42	32	151	0,46	112
6—11/VII	30—36	32	150	0,46	79
16—25/VII	32—35	33	166	0,46	19
В среднем 2	27—42	33	190	0,53	553

KEY: (1) Period of observation (2) Mean (3) Body length, mm (4) Variations (5) Weight, mg (6) Condition factor (7) Number of fish (8) River Samnya (9) River Im (10) River My

TABLE 54. Length and Weight of Young Pink Salmon in Downstream Migrations During 1951-1963

Год 1	р. Самня 2			5 р. Им			6 р. Мы			7 . Иски		
	AC, мм	вес, 3 мг	число 4 рыб	AC, мм	вес, 3 мг	число 4 рыб	AC, мм	вес, 3 мг	число 4 рыб	AC, мм	вес, 3 мг	число 4 рыб
1951	33,3	250	637	—	—	—	32,2	185	110	35,0	270	388
1952	33,5	220	700	31,1	210	1000	32,7	190	545	32,3	237	400
1953	33,7	260	397	33,1	230	630	32,8	222	585	32,9	236	300
1954	31,7	275	130	31,9	220	73	33,7	197	65	30,3	167	257
1955	32,0	230	72	34,2	250	255	32,7	228	230	33,6	278	414
1956	33,8	240	203	32,8	230	28	—	—	—	33,1	227	298
1958	32,6	230	105	32,4	211	120	32,5	275	90	31,6	222	287
1959	31,5	213	524	31,1	216	570	31,7	236	386	32,2	238	295
1960	32,3	238	351	31,8	237	201	32,6	264	349	32,8	246	393
1961	32,0	218	200	31,2	222	118	—	—	—	32,4	324	322
1962	32,4	219	300	31,8	235	300	—	—	—	32,9	237	244
1963	32,0	235	192	32,2	241	150	31,2	259	200	32,8	250	262

KEY: (1) Year (2) River Samnya (3) Weight, mg (4) Number of fish (5) River Im (6) River My (7) River Iski are possibly the result of differences in preparedness of the young fish for the next stage of the migration outside the spawning rivers. Young fish in the River My, which flows directly into the salty waters of Amur Sound, since they have a comparatively low condition factor (because of the more complete absorption of the yolk sac), are in fact more prepared than young fish from the Rivers Samnya and Im, which before they emerge into Amur Sound have to migrate first along the River Amgun' (80-120 km), and then along the main channel of the Amur (160 km). In some years, however, this relationship is not observed. In 1963, for example, young downstream migrants from the River My had a higher condition factor than those from the Rivers Samnya and Im; this happened most probably because of their early and very short downstream migration (28 May-23 June). /86/

In years of a prolonged downstream migration of the young fish, occupying the hottest time of the year (July and the first half of August) hardly any fish have an unabsorbed yolk sac, showing that they have gone over to exogenous feeding; in this case the exterior actually reflects the condition of the young fish. Its value for fish from different rivers is fairly constant on the average. In 1959, for example, variations in the condition factor of young fish from the Rivers Samnya, Im, My and Iski (Table 54) ranged from 0.68 to 0.73.

No special study has yet been made of the effects of individual environmental factors on the qualitative composition of the young pink salmon, but it would be very important in connection with the development of techniques for the artificial breeding of the pink salmon. Determination of the dominant environmental factor at a particular stage of development of the egg and young fish would help breeders to improve the qualitative composition of the young fish supplied from the factories and thus to improve its chances of survival.

In their qualitative indices the young downstream migrants from rivers of the Amur basin are indistinguishable from those of Kamchatka, and whereas the latter migrate in fresh water in April or May, with a water temperature not higher than 8°C (Baranenkova, 1934), the comparatively late downstream migration in warmer waters of the Amur pink salmon is an adaptation to the longer distance separating the Amur spawning rivers from the salt water.

The fate of the young Amur salmon after migrating downstream into the Sound still remains completely uninvestigated. Information on the feeding migration of fingerlings of this species in late autumn in the warm layers of the southern part of the Tatar Straits and the northern part of the Sea of Japan (Dvinin, 1949, 1952) suggests that some, if not all, the young Amur pink salmon stay there.

VIII. STATE OF THE STOCKS AND REASONS FOR THEIR FLUCTUATIONS

The state of the stocks of pink salmon in the Amur basin is usually estimated from catches of the fish obtained in the lower reaches of the river and Amur Sound, where 90 % of the commercial fishing of this salmon takes place, or in years when commercial fishing is prohibited or limited, it is estimated from catches obtained with counting equipment. With the organization of fisheries improvement stations in the Amur basin, since 1948 the statistics of the fishing industry have been supplemented by information on the number of brood stock filling the spawning rivers.

Let us examine how the level of the Amur pink salmon stocks has varied during the period of their commercial exploitation.

Stocks of pink salmon in the Amur basin remained at a comparatively stable and high level from the first time the catches were recorded until 1914: the mean annual catch for the even years was about 80 000 centners (7.3 million fish) and in odd years about 40 000 centners (2.9 million fish).

From 1914 to 1935, when the two-year cycle was particularly prominent, the bulk of the fish caught belonged to even numbered year-classes. Their mean catch was about 100 000 centners per annum (9.1 million fish), compared with only about 6 000 centners (0.4 million fish) of the odd year-classes.

After 1928 catches of pink salmon of the even year-classesin the Amur began to diminish gradually. This diminution characteristically was accompanied after 1937 by some increase in the numbers of the odd year-classes. However, despite this approximation of the abundance of the two successive year-classes after 1928 the total catch of pink salmon in even and odd years (as A.N. Derzhavin pointed out in his lecture to the Provincial Fisheries Conference in 1930 in Vladivostok) was relatively constant, averaging about 10 million fish, i.e., on the average 3.5 million fish smaller than before 1928; in other words, in the period from 1929 to 1935 there was a gradual decrease in the stocks of pink salmon in the Amur.

In the period from 1936 to 1948 the biennial cycle was less pronounced but the pink salmon stocks continued to diminish. Catches of this fish for even year-classes averaged about 60 000 centners per annum (6.0 million fish), except the particularly abundant year-classes of 1938, 1942 and 1948, when twice as many salmon were caught, whereas the average for odd year-classes was about 27 000 centners per annum (1.9 million fish).

After the particularly unfavourable winter of 1948/49 the abundance of the pink salmon year-classes even years fell catastrophically and remained depressed until 1956. Pink salmon catches in odd and even years during this /88/ period were equalized but their mean value was only about 14 000 centners or 1.1 million fish per annum. Such a prolonged depressed state of the pink salmon populations in two consecutive year-classeshad not previously been observed throughout the history of Amur salmon fishing. The stocks of this species were at too low a level to justify commercial exploitation.

The period immediately after 1955 was distinguished by instability of the pink salmon stocks. A marked increase in the population of the even year-classes took place in 1956 and, in particular, in 1958, when about 2 million fish were caught by two counting barriers on the right and left shores of Amur Sound. The salmon runs gradually decreased in the next two year-classes of 1960 and 1962, when they amounted to about 20 % of the numbers of the parental stocks, but in 1964 the catches at two counting barriers again increased to 233 000 fish (Table 56).

The pink salmon runs of the odd year-classesalso varied considerably in the period 1956-1965. The catches at the two control barriers varied in individual years from 19 000 to 437 000 fish.

Excluding the pink salmon runs of particularly abundant stocks in even (1956 and 1958) and odd (1963) year-classes, a characteristic feature of this last period (1956-1965) was recovery from the depression and some increase in the number of salmon. However, the stocks of this species in the Amur basin in this period were at the 1936-1948 level, i.e., in a very strained condition.

Since before 1937 no observations had been made on the conditions of development of the pink salmon in the bed the effect of hydrological and other factors on the abundance of the salmon in those years had to be estimated.

It was concluded by Smirnov (1947) from investigations conducted by TINRO in 1937-1941 that the main cause of the decrease in the Amur salmon stocks, including the pink salmon, was the freezing up of the spawning grounds. This had a particularly adverse effect in harsh winters with little snowfall, and the fall in the water level in the spawning tributaries contributed to the result. The considerable clearing of the snow by the wind from the surface of the ice on the river channel as a rule led to an increase in the thickness of the ice cover, increasing still further the freezing up of the spawning redds (Nikol'skii, 1952).

The way in which the return of the pink salmon progeny is influenced by the hydrometeorological conditions during incubation of the eggs was later investigated by Abramov (1954), using material of the Nikolaevsk-on-Amur Hydrometeorological Station, the area of operations of which is territorially close to the spawning ground of the pink salmon. Periods of a fall and rise in the numbers of the even year-classes of pink salmon, which he studied by reference to the catches in the period 1914-1920, 1926-1928 and 1946-1950, coincided with unfavourable (low air temperatures, low precipitation) and favourable conditions during development of the eggs. The exceptionally unfavourable conditions of the winter of 1913-1914 led Abramov to postulate a considerable decline in the stocks of pink salmon of the odd year-classes, a phenomenon first observed in the Amur basin in 1915.

The work of Vasil'ev (1959) also showed that death of the eggs and fry of the pink salmon and summer chum takes place because of a disturbance of the water supply of the redds as a result of freezing up of a few local areas of the rivers to the bottom.

The correctness of Smirnov's (1947) conclusion was later confirmed when the Amurrybvod organization in 1949 began its regular observations on the /89/ upstream and downstream migrations of salmon in the chief spawning rivers of the Amur basin. The state of the stocks of the Amur pink salmon and the causes of their fluctuations in the period 1948-1965, in the light of such factors as commercial catches, catches made with counting equipment, the number of spawners reaching the spawning rivers, the conditions of development of the eggs and larvae in the bed and the downstream migration of the young salmon, is described below.

In 1948 almost 128 000 centners of pink salmon, or about 11 million fish, were caught in the lower reaches of the Amur River and Amur Sound, including the waters off the north-west coast of Sakhalin. The occupation of the spawning rivers by the brood stock was extensive, However, because of freezing up of the spawning grounds in the winter of 1948/49, only a small stock of pink salmon returned to the Amur in 1950. Its commercial catch was only 12 500 centners, or about 0.9 million fish, i.e., only one-tenth of that in 1948.

The reserves of pink salmon in 1952 were at an even lower level. The catch was only about 600 000 fish. After the particularly bad year in 1948, the level of the pink salmon stocks of the even year-classes was thus only just over half its level for the poor year-classes of the odd years, i.e., the stocks were in a depressed state.

In 1954 and 1956 pink salmon catching by the Amur fishing industry was restricted. Meanwhile, since 1954 the numbers of pink salmon of even year-classes had begun to increase. As the data in Table 55 show, half a million pink salmon migrated in that year into the main spawning rivers: the My, Samnya, Im, Ul and Beshenaya.

The winter of 1954-55 in the region of distribution of the pink salmon was favourable for the development of the eggs and larvae. The spawning rivers were covered with a thick layer of snow early, which prevented the eggs from dying through freezing up and led to a comparatively abundant downstream migration of the young fish and the return of an even larger year-class of pink salmon in 1956: over 3 million pink salmon entered the rivers mentioned above, according to incomplete statistics, and only a little fewer than this number were caught in Amur Sound.

In the winter of 1956/1957 there was no freezing up of the spawning grounds in the Rivers Samnya and Im (the basin of the River Amgun'), the chief spawning rivers of the pink salmon in the Amur basin, with the result that the survival rate was high and the downstream migration of the young salmon took place in large numbers.

In 1958 this year-class returned to the Amur. According to incomplete data, the number migrating into the Rivers My, Samnya, Im, Ul and Beshenaya was more than 10 million fish, and almost the same number were caught in the lower reaches of the river and Amur Sound, together with off the north-west coast of Sakhalin.

The spawning and development of the pink salmon of this year-class took place under different hydrometeorological conditions in different districts. In the Rivers Beshenaya and Ul, which play only a secondary role in the reproduction of the Amur pink salmon, the conditions of development of the eggs and larvae were on the whole favourable. In the Im and Samnya the pink salmon spawned when the water level was very high. During the sudden fall in the water level after spawning the redds were exposed and enormous numbers of eggs deposited in them died with the first frosts. The lowest water level of the last 10 years in the River Amgun' in the winter of 1958/59 unquestionably favoured the freezing of large areas in the basin of this river down to the bottom, with a consequent massive mortality among the salmon eggs and fry. In the River My, because of the thin covering of snow, which hardly reached 20 cm, and the low air temperatures considerable freezing up of the spawning grounds also was observed.

As a result of the generally unfavourable conditions for the incubation and development of the pink salmon in the winter of 1958/59 its downstream migration in 1959 from the main spawning rivers was in very small numbers. Its abundance for all five rivers was almost nine times smaller than in 1957, so that there were no grounds for expecting a particularly heavy run of pink salmon in 1960. This prediction was confirmed by what actually happened. In the Amur basin, together with the Rybnovsk district of Sakhalin, in 1960 the catch of pink salmon was 33 600 centners or 2.6 million fish, from three to /91/

TABLE 55. Occupation of Spawning Rivers by Pink Salmon in Even Years (thousands of fish) and Downstream Migration of the Young Fish from these Year-Classes (millions of fish)

Год	Река				
	Самня	Им	Мы	Ул	Бешеная
1950 (нерест)	24,0	26,2	158	0,6	0,1
1951 (скат)	учета нет		9,8	учета нет	
1952 (нерест)	30,0	17,0	37,1	0,6	0,2
1953 (скат)	1,0	0,5	3,8[1]	учета нет	0,1
1954 (нерест)	78,1	163,1	268,0	1,0	5,4
1955 (скат)	учета нет	1,5	24,5[1]	учета нет	1,5
1956 (нерест)	2218[1]	61,5	861[1]	40,7	21,5
1957 (скат)	293,0	47,7	31,1	18,3	2,0[1]
1958 (нерест)	5370[1]	3249[1]	812[1]	69,0	12[1]
1959 (скат)	17,3	5,7	8,8	9,3	3,5
1960 (нерест)	учета нет		74,1	7,8	4,2
1961 (скат)	1,1	0,1	1,0	0,1	0,2
1962 (нерест)	0,7[1]	0,1[1]	50,0	0,3	0,3
1963 (скат)	7,9	3,1	10,2	0,8	0,1
1964 (нерест)	15,0	12,0	12,3	0,02	0,4
1965 (скат)	14,2	2,2	1,6	—	0,1

[1] Учет неполный

KEY: (1) Year (2) Spawning (3) Downstream migration (4) Counting incomplete (5) Rivers (6) Samnya (7) Im (8) My (9) Ul (10) Beshenaya (11) No figures available four times less than in 1958. Control counts confirmed the same relationship between the catches of pink salmon in 1958 and 1960 (Table 56).

TABLE 56. Relative Numbers of Individual Year-Classes of Pink Salmon in the Region of the Nevel'sk Straits and in Amur Sound

Год 1	Средний улов на 1 невод в проливе Невельского 2		Улов двух контрольных заездков на правом и левом берегу лимана 5	
	ц 3	тыс. шт. 4	ц 3	тыс. шт. 4
1957	127	8	288	19
1958	885	88	17202[1]	1720[1]
1959	337	21	4305	269
1960	308	24	5064	389
1961	—	—	659	44
1962	—	—	1224	87
1963	—	—	6600	370
1964	—	—	3961	233
1965	—	—	3424	243

[1] Горбуша второй половины массового хода и конца хода не вылавливалась. 6

KEY: (1) Year (2) Mean catch per seine in Nevel'sk Straits (3) Centners (4) Thousands of fish (5) Catch of two control barriers on the right and left shores of the Sound (6) Pink salmon of the second half of the main run and the end of the run were not caught.

Because of the high flood level which destroyed the counting barriers on the main spawning rivers, the brood stock in 1960 was counted only in the Rivers My, Ul and Beshenaya, into which 86 000 pink salmon migrated, 10 times less than into the same rivers in 1958 (Table 55).

The spawning year-class of the Amur pink salmon in 1960 was equal in abundance to the average for the even year-classes.

The winter of 1960/61 was very unfavourable for the development of this year-class. The very small quantity of precipitation in the lower reaches of the Amur and the low air temperature, reaching -42°C in December and January, led to considerable freezing up of the spawning grounds. The losses from freezing were 50-60 % in the River My, 51 % in the Samnya and 84 % in the Im. The downstream migration of the pink salmon from these rivers was negligibly small -- only a little more than 2 million young fish. As was expected the return of adult fish from this year-class in 1962 was small. Altogether 5 500 centners or 0.3 million fish were caught in the Amur basin together with the north-west coast of Sakhalin, i.e., one-eighth of the parental year-class. A very small stock returned to the Amur basin, amounting to about 51 000 fish in the Rivers My, Ul and Beshenaya.

As a result of the favourable conditions of incubation in the winter of 1962/63 a high proportion of the eggs and young fish from this small year-class survived, and the downstream migration amounted to 22 million fish. However, the return of adult fish from this progeny in 1964 was small: only about 40 000 fish migrated into all the rivers where counting was carried out, and of these only 12 000 entered the Rivers My, Ul and Beshenaya.

The abundance of the odd year-classes of pink salmon, which were in a depressed state from 1915 to 1935, suddenly rose considerably in 1939, judging from the catches, but later the numbers fell again and were sometimes average and sometimes at a low level.

The stocks of pink salmon in 1949 and 1951 were at a relatively low level. /92/ In these years the average catch was 19 300 centners or 1.5 million fish for the season. Because of freezing up of the spawning grounds in the winter of 1951/52 the approaches of the pink salmon in 1953 were very small compared with these years, and only 8 600 centners or 660 000 fish were caught in the Amur basin. The upstream migration of spawners into the main spawning rivers was just as sharply reduced (Table 57).

The freezing up of the spawning rivers was very severe in the winter of 1953/54 as a result of the early onset of frosts and the almost total absence of a snow cover, and this lowered the stocks of pink salmon in 1955 still further. The migration of the pink salmon into the River Amgun' was catastrophically small. Counting carried out by the Amur branch of TINRO in the

TABLE 57. Occupancy of Spawning Rivers by Pink Salmon in Odd Years (in thousands of fish) and Downstream Migration of Young Fish from these Year-Classes (in millions of fish)

Год 1	Река 5				
	Самия 6	Им 7	Мы 8	Ул 9	Бешеная 10
1949 (нерест) 2	17,6	64,6	650,7	2,0	0,9
1950 (скат) 3	учета нет				
1951 (нерест)	12,5	20,0	295,7	0,4	0,2
1952 (скат)	учета нет 11	0,5	10,7	—	0,01
1953 (нерест)	2,4	14,0	90,7	0,02	0,03
1954 (скат)	учета нет 11	0,06	1,1	—	—
1955 (нерест)	4,2[1]	учета нет 11	13,0	0,1	7,0
1956 (скат)	учета нет 11	0,2[1]	1,5	—	0,1[1]
1957 (нерест)	3,7[1]	0,03	16,3[1]	0,2[1]	0,2
1958 (скат)	0,4	0,2	5,5	0,02	—
1959 (нерест)	учета нет 11	учета нет 11	106,5	учета нет 11	
1960 (скат)	2,2	0,9	7,7	0,01	0,02
1961 (нерест)	учета нет 11		11,4	незначит. 12	0,1
1962 (скат)	4,1	3,6	4,5	0,02	0,01
1963 (нерест)	189,7	250,3	335,6	1,8	0,25
1964 (скат)	38,9	16,3	13,6	1,3	0,25
1965 (нерест)	72,0	140,0	6,7	0,4	0,06
1966 (скат)	17,0	27,7	3,1	—	0,01

[1] Учет неполный. 4

KEY: (1) Year (2) Spawning (3) Downstream migration (4) Count incomplete (5) River (6) Samnya (7) Im (8) My (9) Ul (10) Beshenaya (11) Not counted (12) Very small

River Amgun' gave a catch of only 83 fish from 133 hauls with a drag seine in the course of one month.

Since 1955 fishing for pink salmon in odd years has been prohibited in the Lower Amur District.

In 1957 the occupancy of the spawning rivers by brood stock improved slightly, or at least it was not reduced (Table 57), as a result of the very favourable conditions for development of the eggs in the winter of 1955/56.

In 1959 the spawning year-class of pink salmon was more numerous than in 1957: as regards numbers of fish, the mean catch per seine in the Nevel'sk Straits was more than 2.3 times higher than in 1957, off the north-west coast of Sakhalin it was 3.8 times higher, and at the counting barriers more than 14 times higher (Table 56); nearly 6 times more pink salmon migrated into the River My than in 1957.

The quite numerous spawning year-class of pink salmon in 1959 (according to figures given by Amurrybvod it was 12 % in the River Im and 30-35 % in the Rivers Samnya, My and Beshenaya), because of the considerable freezing up of the spawning grounds in the winter of 1959/60, yielded only 11 million young fish from the main spawning rivers. The return of the pink salmon in 1961 from this downstream migration was small. For example, 10 times fewer pink salmon migrated into the River My than in 1959 and the catches at two control barriers in Amur Sound were 6 times less than in 1959. Consequently, the reduction in the numbers of the spawning population in 1961 took place in the river period of life of the pink salmon. However, in 1960-1961 there was a decrease in the temperature of the southern part of the Tatar Straits (the inflow of heat-containing waters was below the annual normal, an event which regularly caused a reduction in the pink salmon catches off the south coast of Sakhalin (Shelegova and Lundberg, 1965; Lundberg and Shelegova, 1965).

Temperature conditions were probably responsible for the decrease in the total population of pink salmon in the Sea of Japan in 1961, as shown by the catches obtained by salmon drift nets (Darda, 1965).

In 1963 a large-scale migration of pink salmon took place into the Amur basin. The catch at two counting barriers in Amur Sound for odd year-classes during the period 1957-1965 was unprecedented: about 7 000 centners or about 400 000 fish, and pink salmon were caught in Rybnovsk District and in the main channel of the Amur. Despite considerable removal of pink salmon in the lower reaches of the river and in Amur Sound, more than 778 000 migrants were counted into monitored spawning rivers. The appearance of this abundant year-class of pink salmon in the Amur basin in 1963 did not tally with the size of the downstream migration of the young salmon, which hardly exceeded 12 million for the same rivers in 1962. Exceptionally large approaches of pink salmon were observed in 1963 on the west coast of Southern Sakhalin and, according to aerovisual observations by TINRO, into the rivers of Primor'e (the continental shore of the Tatar Straits). It is interesting to note that, contrary to the /94/ well-known rule, the spawning migrations of the pink salmon in 1963 were relatively early, possibly on account of the unusual hydrological conditions in the sea in 1963, which altered the times and direction of the spawning migrations of the pink salmon near the south-east coast of Sakhalin, the east coast of Hokkaido, and in Primor'e. A similar change in the regions of concentration and the paths of migration of the pink salmon and chum, on account of a redistribution of the water masses, was observed in 1961 by Frolov (1965).

In certain years with exceptional hydrometeorological conditions in the sea the usual direction of the spawning migrations of salmon can therefore be varied. In such cases the attachment of individual stocks to the natal basins is disturbed, as was probably observed in 1963.

At the same time it must be pointed out that in 1963 the number of Japanese salmon-fishing vessels in the Sea of Japan was reduced to 290 (by almost 50 %) and this could be a very significant factor in the increased return of the pink salmon.

The favourable winter of 1963/64 for the development of the eggs and larvae of the pink salmon resulted in an exceptionally high downstream migration of the young fish, amounting to 70 million fish for the Rivers Samnya, Im, Ul and My. However, despite this fact, the return of adult fish in 1965 was small. Only about 400 000 pink salmon migrated into rivers where counting was carried out. The sharp decrease in the number of the progeny did not take place, as these observations show, in fresh waters.

According to Birman (1965) the Amur, Primor'e and Western Sakhalin stocks of pink salmon, Eastern Sakhalin pink salmon of the early (summer) migration, and part of the Hokkaido stock are distributed in the Sea of Japan; of these, the Amur stock is the largest. It and the Primor'e stock of pink salmon share common wintering districts. For that reason, probably, their numbers are closely interconnected. In 1949 and 1951, for example, when the migration of pink salmon in Primor'e was abundant but in the Amur it was small, from 8 to 9 times more pink salmon migrated into the River My than into the Rivers Samnya and Im, but after the change in the cycle which occurred in Primor'e in 1952, when high catches were obtained from even year-classes, there was a marked decrease in the approaches of the pink salmon in the south-western part of Amur Sound in odd years and an increase in these migrations in even years (Table 22).

The spawning year-classes of pink salmon in 1958 and 1963 show particularly clearly that a high level of occupancy of the Amur spawning grounds leads to abundant stocks of the fish in the Sea of Japan whether the downstream migra-

tion of young fish from the Amur is large or small. This disparity between the sizes of the return and of the downstream migration shows, first, that the pink salmon is not strictly attached to its parental river and, second, that when year-classes of the pink salmon in the Sea of Japan are abundant they are forced to migrate into the Amur basin. These examples show that one of the most important factors determining the abundance of individual year-classes of Amur pink salmon is the degree of severity of the winters and freezing up of the spawning grounds. However, the return of sexually mature fish from these year-classes depends on many factors: the heat content of the waters in the feeding area, the redistribution of water masses, determining the state of productivity of the feeding region (Vedenskii, 1954), the reduction in numbers caused by predators, which are more numerous in the Amur and its approaches than for pink salmon stocks of the Okhotsk coast and of western Kamchatka (Abramov, 1953). In different years different factors naturally play the /95/
decisive role in reducing and increasing the pink salmon population.

Commercial fishing undoubtedly is a significant factor in the sharp decline in the pink salmon population. The intensification of Japanese fishing of Amur pink salmon, judged from the increasing numbers of fish with torn off fish hooks found from 1956 to 1960 (Enyutina and Krykhtin, 1957) must inevitably have reduced the migrations of pink salmon into Amur Sound and, consequently, reduced the occupancy of the spawning rivers by the adult fish. The question of the strict control over commercial fishing of the Amur pink salmon along its migration paths is thus more important than it was formerly.

Comparison of the numbers of downstream migrants of pink salmon with the numbers returning to spawn, given in the above examples, suggests that (other conditions being equal) the downstream migration is small if fewer than 50 million young fish descend from the five monitored rivers of the Amur basin. This figure is adequate for an average level of reproduction of the pink salmon stocks and for limited commercial exploitation (counting barriers) in Amur Sound. If the downstream migration exceeds 100 million fish, commercial fishing of the pink salmon can be permitted.

IX. PREDICTION OF CATCHES

1. Methods and Material

Methods of predicting variations in pink salmon stocks have been developed by TINRO since 1940 to take into account the biological features distinguishing this salmon, such as the post-spawning mortality and the extent of the return to the parental river for spawning.

The pink salmon fishing industry, concentrated in the lower reaches of the River Amur and Amur Sound to the extent of 90 %, yielded high catches of this fish in even years and small catches in odd years. The statistics of the catches reflected differences in the abundance of two successive year-classes of the pink salmon, observed as a regular feature in the Amur basin before 1949, and also served as the main indicator for predicting the size of the expected approaches.

Predictions of catches of the pink salmon were based in 1940-1941 on the size of the runs of this fish in two-year periods, and in 1942-1947 on the size of the runs for periods of four consecutive years.

Since 1951, besides the statistics for catches, data for the number of adult fish on their way to the spawning grounds have also been used to predict the Amur pink salmon population, and since 1952 the first information on the downstream migration of the young salmon also became available for this purpose (the downstream migrants were counted only in the Rivers My and Iski).

After the depression of the pink salmon population in the Amur basin which began in 1950, commercial fishing of its odd year-classes has been prohibited since 1955 and that of its even year-classes has been considerably restricted since 1954. To keep check on the population of the spawning stocks of pink salmon every year a single counting barrier is set up on the right and left shores of Amur Sound. Catches at these barriers, giving some idea of the relative size of the pink salmon population in the Amur basin, indicate the state of the stocks of this salmon and to some extent replace statistics of the salmon catches during its commercial fishing.

Prediction of the size of spawning stocks of the pink salmon has been based since 1957 on the results of control catches, the number of spawners entering the monitored rivers and the number of young fish migrating downstream from these rivers. The number of downstream migrants gives indirect evidence of the survival rate of the population during embryonic and larval development in the bed and indicates the abundance of individual year-classes of the salmon.

In Amurrybvod practice the "coefficient of downstream migration" is /97/
determined (in %) as an index of abundance, using the equation:

$$K = \frac{N \times 100}{n_{♀} \cdot r},$$

where N is the number of downstream migrants, n the number of females migrating into the particular river to spawn (determined assuming a sex ratio of 1:1), and r is the absolute fecundity.

From the coefficient of downstream migration it is possible to judge the conditions of reproduction of the population but it cannot be used for predicting, for it is not an absolute index, being based only on a sampling count. The "coefficient of return", i.e. an index expressing the ratio between the number of adult fish returning from the sea and the number of downstream migrants, in per cent, is more important for predicting. This index can be determined only by tagging salmon, as has been carried out on a large scale in America by Pritchard (1938) during the period 1931-1937. He found that, depending on the method, the return of pink salmon varied from 0 to 3 %. The coefficient of return of the pink salmon in Siberian practice can be taken conventionally, on the basis of this figure, as 1%. For calculating the efficiency of fish hatcheries the coefficient of return is also taken to be 1% (resolution of the Technical Council, Ministry of the Fishing Industry of the USSR, dated 12 February 1953).

Knowing the distribution of the pink salmon among the spawning stock of the Amur basin, the importance of the individual rivers in the reproduction of the stocks of this fish, and the number of downstream migrants, with the aid of the coefficient of return it is possible to predict the size of the year-class returning from the sea.

Let us examine the data on which the prediction of pink salmon catches is based.

2. Fishing Statistics

The original statistics on pink salmon catches in the Amur basin during the history of commercial fishing vary in character but in most cases they are concerned with the main district for pink salmon fishing, namely Amur Sound, with its continental and Sakhalin shores, and the lower reaches of the River Amur up to 150 km from its mouth.

1. The period 1902-1952 is characterized by an intensive coastal fishing

industry in the lower reaches of the river and in the Amur Sound. The catches of the pink salmon in the Nikolaevsk (later the Lower Amur) District in these years reflected the size of the Amur spawning stocks, except in 1933-1944 when, because of the unreliability of the counting, catches obtained on the south-western and eastern coasts of Sakhalin were included in the catches of the Sakhalin enterprises of Amur Sound, thus distorting the over-all size of the pink salmon catch in the Amur basin somewhat at the expense of adjacent stocks.

2. The period 1953-1965 is characterized by irregular exploitation of the pink salmon in the Amur basin (when it was prohibited or restricted because of sharp and noncyclic fluctuations in the fish population), and after 1952, by active sea fishing of the Amur salmon along its migration path by Japanese fishermen. Statistics for pink salmon catches in Amur Sound by control barriers indicate only the relative abundance of these stocks.

These two periods can be compared only with reference to catches of pink salmon in Amur Sound by two barriers which were set up in the same places: in the region of Cape Pronge (on the right bank) and in the region between Cape Ozerpakh and Cape Tabakh (on the left bank). This information is available since 1937 and I give it below in Table 58 together with other statistics from /98/ which it is possible to determine the fraction of the control catch.

In years of a very high pink salmon population (1938, 1942, 1948) the mean catch of the counting barriers was 9.0 % (5.3-12.0) of the total stock fished, while in years of low and average populations it was 5.3 % (2.2-9.5).

3. Data of Fisheries Improvement Stations

Resumption of the work of the fisheries improvement stations of Amurrybvod in 1949 after an interruption of seven years must play an important role in the

TABLE 58. Catches of Pink Salmon in the Period 1937-1952 and the Fraction of its Control Catch in the Amur Sound

Год (1)	Уловы (2)		Доля контрольного лова, % (5)
	в бассейне Амура, тыс. шт. (3)	двух контрольных заездков, тыс. шт. (4)	
1937	1640	44,8	2,7
1938	11780	1418,2	12,0
1939	5600	154,0	2,7
1940	3820	239,2	6,3
1941	1510	88,0	5,8
1942	7600	741,4	9,7
1943	1380	118,7	8,6
1944	4350	190,9	4,4
1945	790	35,6	4,5
1946	5330	319,5	6,0
1947	740	16,4	2,2
1948	10810	575,8	5,3
1949	1310	125,1	9,5
1950	890	58,1	6,5
1951	1690	66,3	3,9
1952	610	36,0	5,9

KEY: (1) Year (2) Catches (3) In the Amur basin, thousands of fish (4) At two counting barriers, thousands of fish (5) Fraction of control catch, per cent

study of the state of the stocks and prediction of the size of individual year-classes of pink salmon in the Amur basin. They supplement the statistics for catches with additional information on the number of adult pink salmon in the spawning rivers, i.e., the residue after commercial fishing directly concerned with reproduction of the stock of this species. The fisheries improvement stations were so arranged as to cover the spawning grounds of the pink salmon as widely as possible. Two of them are situated on the Rivers Samnya and Im in the basin of the River Amgun', two on the main channel of the River Amur, of which the station on the River Beshenava (a right-bank tributary of the main channel covers for practical purposes the highest, while that on the River Ul (flowing into Lake Orel', connected with the main river by a side channel) covers the lowest of the Amur spawning grounds of the pink salmon; finally two are situated on the Rivers My and Iski. These stations, as Levanidov (1965) estimated, monitor about 40 % of the total spawning stock of the Amur pink salmon and are essentially counting and observing stations where the adult fish on their way to the spawning grounds and the downstream migrants are counted.

On the basis of data for the local distribution of stocks of Amur pink salmon in the commercial fishing district only four of the six stations listed above give information that can be used to judge the reproduction of the Amur pink salmon reserves. It should be noted that, starting with the 1940s, /99/ appreciable numbers of pink salmon migrated into the Rivers Beshenaya and Ul only in years of particularly high abundance (1948, 1956, 1958), the number of spawners in these rivers was rarely between 1 000 and 6 000, and usually it was only a few hundred fish. Consequently, the total migration of adults to the spawning grounds and the numbers of downstream migrants in the Amur basin can for practical purposes be judged from three rivers: the Samnya and Im, to which most of the Amur salmon migrate, and the My, frequented by the Primor'e stock. It must be added to this that it is extremely difficult to count the spawners in the Rivers Samnya and Im during the spawning migration because of the distinctive hydrological conditions of the tributaries of the Amgun': high summer flood waters often break the wooden counting fences or undermine them to such an extent that the fish are either counted incompletely or not at all. In the 18 years (1949-1965) of existence of fisheries improvement stations in the Amgun' basin, for instance, the necessary statistics were obtained for the River Im in only ten years and for the River Samnya in nine years. Visual counting of salmon passing through the fences often suffers from subjectivity and the error is sometimes so great that it is unacceptable. This applies in particular to the period of the main run when it is physically impossible to count each fish individually as it passes through.

To judge the abundance of pink salmon in the Amur basin it is necessary to carry out a total count of the young fish migrating downstream in the single channel of the lower reaches of the Amur, a task that is not yet a practical possibility. Estimation of the downstream migration of the young fish by the sampling method, when only part of the main channel of the river is fished and the result is multiplied by a conversion factor for the whole cross-section of the river, gives only approximate figures. The error is increased by the fact that the number of available fisheries improvement stations is completely inadequate for the purpose.

The techniques of sampling the rivers and counting the upstream and downstream migrants so as to determine the abundance of individual year-classes of pink salmon are thus unsatisfactory.

4. Predictions and Their Reliability

Let us examine how the predictions of the numbers of pink salmon in the Amur basin have turned out and the reasons for failures of prediction.

In 1938 about 130 000 centners of pink salmon were caught in the Amur basin, and 46 % of the catch was accounted for by the Sakhalin fisheries (the East Sakhalin, West Sakhalin and part of the Amur stocks). In 1940 the pink salmon catches were reduced by two-thirds, and the contribution of the Sakhalin fisheries in this case was reduced to 15 %. Consequently, the decrease in the number of the spawning year-class of pink salmon in 1940 took place chiefly on account of the Sakhalin stocks. Although details of the numbers of pink salmon of the Sakhalin stocks were known in those years, the actual catch of pink salmon in the Amur basin in 1940 (42 000 centners) almost coincided with the estimated catch of 40 000 centners.

In 1939 the pink salmon stocks of the odd year-classes reached the high level of 1909-1911 and the proportion of the pink salmon catches obtained by the Sakhalin fisheries remained just as high as in 1938. The estimated catch of pink salmon in 1941 was 60 000 centners but the actual size of the catch showed that the expected size of the year-class was three times too large. The abundance of the pink salmon year-class reproducing in the tributaries of the Amur, according to the Amurrybvod statistics, was almost five times less in 1941 than the parental year-class, but this could not be taken into account during prediction because of the absence of corresponding biological observa- /100/ tions.

In 1942-1945 the actual catch of pink salmon was in every case smaller than the expected catch. The fact that it was war time was one reason for the overestimated predictions in these years, for there was no biological basis for its support. The predicted size of the pink salmon migration was particularly wide of the mark (by 79 %) in 1945 when, without any justification, the size of the stock was predicted to be more than twice the size of the parental stock.

The Amur salmoh population was unexpectedly high in 1948: the yield was three times greater than that predicted. A similar phenomenon was observed in 1949 in Alaska and in 1942 in Kamchatka (Vedenskii, 1954).

The predicted catch of pink salmon in 1952 also was unrealistic because it likewise did not rest on a reliable basis: the parental year-class was small, only a few fish migrated into the spawning rivers, and information about the downstream migration of the young fish (about 13 million) was available only for the Rivers My and Iski (not the Amur stock), and it could not be compared numerically with other years for this was the first time that any such observations had been made. As a result the predicted catch was considerably greater than the actual catch.

The evidence shows that the predictions of the pink salmon catch in the

Amur basin were mostly incorrect (Table 59). Strictly speaking they were not predictions but highly relative data for the strength of the expected year-class. The technique for predicting salmon catches as it was in 1946 in the TINRO system was as follows: every year the fisheries reported only the general state of the stocks and the direction in which the stocks were changing through the effects of commercial fishing and natural conditions; the final results of the tests were compared with the results of the commercial or experimental catch and on that basis an approximate estimate of the possible catches was made.

TABLE 59. Predicted and Actual Pink Salmon Catches in the Amur Basin in the Period 1940-1952 (thousands of centners)

Год 1	Прогноз 2	Вылов 3	Отклонение от прогноза, % 4	5 Элементы прогноза
1940	40,0	42,0	+ 5	
1941	60,0	19,5	— 67	
1942	90,0	83,6	— 7	
1943	44,0	19,2	— 56	
1944	66,0	55,0	— 17	
1945	45,0	9,5	— 79	
1946	50,0	9,3	+ 19	Статистика вылова 7
1947	запрет 6	10,4		
1948	40,0	128,5	+221	
1949	запрет 6	15,7		
1950	50,0[1]	12,5	— 75	
1951	60,0	22,0	— 63	Стат. вылова и пропуск 8
1952	20,0	9,1	— 55	Стат. вылова, пропуск, скат 9

[1] Рекомендованная норма вылова 10

KEY: (1) Year (2) Prediction (3) Catch (4) Deviation from prediction, % (5) Elements of prediction (6) Prohibition (7) Catch statistics (8) Catch and escapement statistics (9) Catch, escapement and downstream migration statistics (10) Recommended norm of the catch.

The subsequent period was characterized by regular observations on the migration of the spawners and the downstream migration of the young fish in several rivers of the Amur basin. It was a particularly valuable addition because, instead of statistical information on the pink salmon catches, since 1957 because of the prohibition or restriction of commercial fishing only the catches made at two counting barriers were available.

The modern method of predicting catches of pink salmon is thus based on the important biological rule that the size of the salmon return is usually proportional to the population of young downstream migrants from which these adults have grown (Semko, 1954). Since the number of young fish is largely determined by the survival rate of the year-classes in the prespawning period, prediction of the catches can be reduced to determination of the efficiency of spawning in each year by counting the number of young downstream migrants from the rivers. With this information in hand, and knowing the age of maturation of the pink salmon, it is possible to predict the size of the spawning migration in corresponding years. /101/

On this basis Levanidov (1964a) derived a mathematical expression for calculating predicted catches of pink salmon. He calculated the strength of the expected year-class by the use of a coefficient of return, amounting to 3 % or to 2 % for particularly abundant year-classes. It was assumed that the five monitored rivers account for one-third of the spawning stock and that the intensity of salmon fishing in . Amur Sound is 60 %.

Let us examine the data which were used to obtain the 2-3 % coefficient of return of the pink salmon. Assuming that the work of the fisheries improvement stations of Amurrybvod on the counting of spawners and the downstream migration of young fish was at the required level of technical proficiency, the ratio between the number of fish returning from the sea (the number of spawners passing through the barriers in five spawning rivers) and the number of young downstream migrants in the period 1952-1961 (according to Levanidov) was from 0.5 to 12.5 % (Table 60).

If 10 % of the pink salmon caught in the southern part of the Maritime Territory of this fish by the northern Japanese fishing fleet reproduced in the Amur basin (Kotov, 1957; Semko, 1958), the size of the Japanese catch of the Amur pink salmon on its migration routes does not agree with the residual number of fish after exploitation. The larger the catch of pink salmon, the fewer fish migrate into the spawning rivers and, consequently, the lower the coefficient of return. In fact, however, according to the data in Table 60, this correlation is not observed: in years of particularly intensive Japanese fishing, when between 6 000 and 10 000 tons of Amur pink salmon were caught, the coefficient of return varied from 0.7 (1961) to 12.5 (1956). The considerable difference in the coefficient of return of the pink salmon in the two abundant year-classes of 1956 and 1958 and the very high coefficient of return for the pink salmon in 1955, the abundance of which was small, are stranger still.

TABLE 60. Coefficient of Return of the Amur Pink Salmon from Young Fish and Fraction of this Salmon Caught by the Japanese

Год возврата (1)	Коэффициент возврата % (2)	Японский вылов, тыс. т (3)	Год возврата (1)	Коэффициент возврата, % (2)	Японский вылов, тыс. т (3)
1952	0,9	2,3	1953	0,5	1,9
1954	6,5	2,3	1955	9,3	7,3
1956	12,5	7,0	1957	1,5	9,5
1958	2,7	10,0	1959	10,0	10,1
1960	2,6	6,1	1961	0,7	7,5

KEY: (1) Year of return (2) Coefficient of return, per cent (3) Caught by Japanese, thousands of tons

Commercial exploitation of the pink salmon in Amur Sound can also /102/ introduce a large correction into the coefficient of return. The commercial catch of this salmon in the period 1952-1961 was very irregular: in 1952, 1958 and 1960 the intensity of fishing was 50-60 %, but in the other years, as a result of the prohibition of commercial fishing, the catch was obtained with two counting barriers, and their mean fractions for the odd year-classes of 1953-1961 and for the year-class of 1954 was 5 %, and in 1956 it was 10 % of the stock.

The great variability of the calculated coefficient of return of the pink salmon must evidently be attributed to the imperfect technique used to count the upstream migration of spawners and the downstream migration of the young fish. The investigations of the Amur branch of TINRO aimed at determining corrections to the size of the downstream migration of young salmon by means of vital staining (Levanidov, 1962a) are therefore of great current importance. The mean annual value of this coefficient also was determined without inclusion of the highest values. In that case, therefore, why were the lowest values of this coefficient also not excluded?

The uncertainty of the coefficients thus obtained can be summed up in the words used by Levanidov himself, who carried out the calculations: "The ability of the pink salmon to redistribute itself within the spawning area can lead to great errors when the return from the sea is estimated." Although for 1958 and 1960 the catch of pink salmon predicted by calculation agreed with the actual results of the catch (the prediction was not given beforehand, but was computed by Levanidov several years later), my own attempt to carry out a similar calculation for other year-classes was unsuccessful.

The fact that the return of the year-classes sometimes correlates to a slight degree with the calculated number of downstream migrants is shown by the comparison given in Table 61, where the most complete material for the downstream migration of the young pink salmon from the five most important rivers for reproduction are given as examples. By this means an attempt could be made to find new correlations between the abundance of the year-classes and the conditions of their life in the river. Assistance with this section of the work was given by Yu.E. Lapin, Senior Scientific Assistant at the Institute of Animal Morphology, Academy of Sciences of the USSR. /103/

The technique of the investigation was to compare the abundances of the pink salmon year-classes (determined from catches of the species by two counting fences in Amur Sound) with the hydro-meteorological conditions of their life in the river, especially in the autumn and winter. Other factors studied at the same time included the population of the parental stock, the time of the migration and the periods of spawning, the duration of the incubation period and the time of the downstream migration. Attention was concentrated on the connection between the rate of survival of the year-classes and the depth of the snow cover and the winter air temperature during incubation. The role of these factors in the survival of another Pacific salmon -- the chum -- has been studied in great detail by Kostarev (1964), who showed that the snow cover and winter frosts have a very powerful effect on survival of the eggs and young fish in the redds. This was of course shown previously by Smirnov (1947). These factors can not only kill the young fish directly by causing the bed to freeze, but they can also reduce the survival by interfering with the water supply to the redds.

TABLE 61. Relationship Between Size of Return of Pink Salmon and Number of Downstream Migrants from the Spawning Rivers Im, Samnya, My, Ul and Beshenaya

1 Год рождения поколения	Количество покатной молоди, млн. шт. 2	Уловы двух контрольных заездков, тыс. шт. 3	Примечания 4
1951	11,2[1]	19	
1952	5,4[2]	0	Учет в реках неполный 5
1953	1,2[1]	0	
1954	27,5[1,2]	775	Учет в реках неполный 5
1955	1,8[1]	19	Учет в реках неполный 5
1956	397,1	1720	Учет в реках и улов неполный 6
1957	6,1	269	
1958	44,6	389	
1959	10,8	44	
1960	2,5	87	
1961	12,2	370	
1962	22,1	233	
1963	70,3	370	
1964	17,9[2]	318	

[1] Без р. Самня. 7
[2] Без р. Ул. 8

KEY: (1) Year of birth of year-class (2) Number of downstream migrants, millions of fish (3) Catches of two counting fences, thousands of fish (4) Remarks (5) Count in rivers incomplete (6) Count in rivers and catch incomplete (7) Without River Samnya (8) Without River Ul

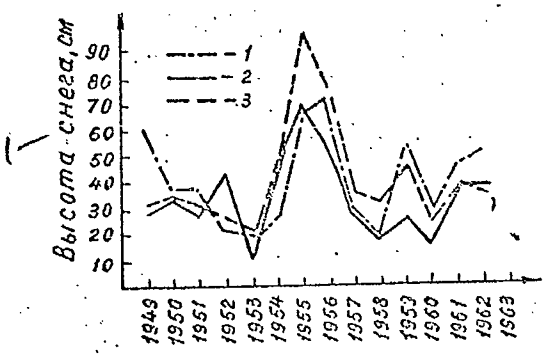

Fig. 14. Variations in depth of the snow cover (mean for December, January and February) in the breeding region of the Amur pink salmon: 1) Nikolaevsk-on-Amur, 2) Aleevka, Amur Sound, 3) Udinsk, River Amgun'.

Key: (1) depth of snow, cm

Since it was essential to estimate the degree of the influence of these factors on the whole population of the Amur pink salmon and not on certain parts of it, an attempt was first made to discover to what extent their changes throughout the area of reproduction of the pink salmon in the Amur basin are uniform. Changes in the depth of the snow cover at three points lying within the breeding grounds of the Amur pink salmon are shown in Fig. 14[1]. Only in two cases were the variations in this parameter asynchronous, and at all the other twelve the variations coincided completely; it was thus possible to judge changes in the depth of the snow cover throughout the area relative to any single observation post. The same conclusion is also true of temperature in the winter period.

The character of the changes (the mean for three months) in the depth of the snow cover in the region of the River Amgun' is shown in Fig. 15; these changes are compared with variations in the abundance of the year-classes.

---

[1] The depth of the snow cover was determined by posts of the Hydro-Meteorological Service in the forest, under the crowns of the trees.

In the period from 1936 to 1948 the catches in even years were fairly high and the size of the year-classes in the even years did not fall below 6 million fish. Except for the 1938 year-class, conditions for their period of life in the river were favourable: the snowfall in winter was considerable. So far as the year-classes born in odd years are concerned, parallel with the decrease in depth of the snow cover in corresponding winters, the numbers definitely diminished. After 1946, when there was much snow and an abundant stock of /104/ fish, the dry winter of 1948/49 corresponded to a sharp decline in the abundance of this year-class, and a further decrease in the depth of the snow cover led to a deep depression of the pink salmon population. In 1954/55 there was more snow and this was reflected in a rise in the abundance of the 1956 year-class. Later the depth of the snow decreased and there was a corresponding tendency for the size of the population to diminish.

Wherever possible in the graph (Fig. 15) I have given the number of fish passing through the counting fence to the spawning grounds. Clearly when the snow was deep, usually the number of young salmon was high, despite considerable fluctuations in the size of the parental stock. However, a very small stock (1955), even given good conditions for breeding, cannot produce an abundant progeny and, conversely, even if the conditions for reproduction are bad (1938 and 1958), an abundant parental stock can produce large numbers of young fish.

The temperatures during the winter months (mean for December, January and February) vary from -21° to $-30^{\circ}C$ and have no definite connection with the results of breeding. This lack of correlation must evidently be interpreted as showing that despite certain fluctuations, winter temperatures are always lethal to the eggs and larvae of the pink salmon of parental year-classes whose redds are inadequately covered with snow.

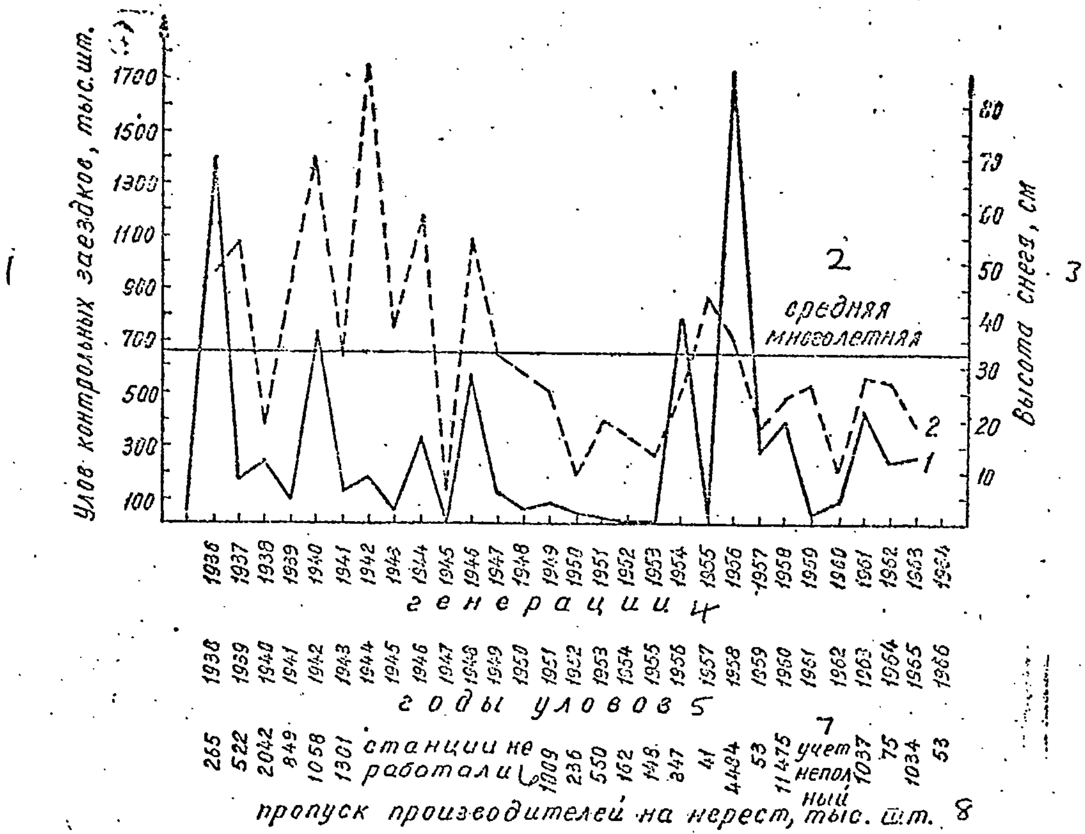

Fig. 15. Variations in pink salmon catches and depth of the snow cover in the Amur basin: 1) catches, 2) depth of snow.

Key: (1) catch at counting fences, thousands of fish (2) mean annual (3) depth of snow, cm (4) year-classes (5) years of catches (6) stations did not operate (7) count incomplete (8) escapement of brood stock to spawn, thousands of fish

Fluctuations in the water level in the river during the migration and spawning of the pink salmon and before freezing over are shown in Fig. 16. Observations show that the importance of changes in the water level at this period as regards the results of reproduction depends on their direction. A low level during migration and an increase in the level before freezing over are favourable for survival whereas an initially high level, falling later, may have undesirable effects: the water supply to the redds is reduced or they may dry up completely. The action of this factor can usually be assessed only in conjunction with what I regard as the main factor of survival: the depth /105/

of winter snow, and they can either strengthen or weaken the action of this factor.

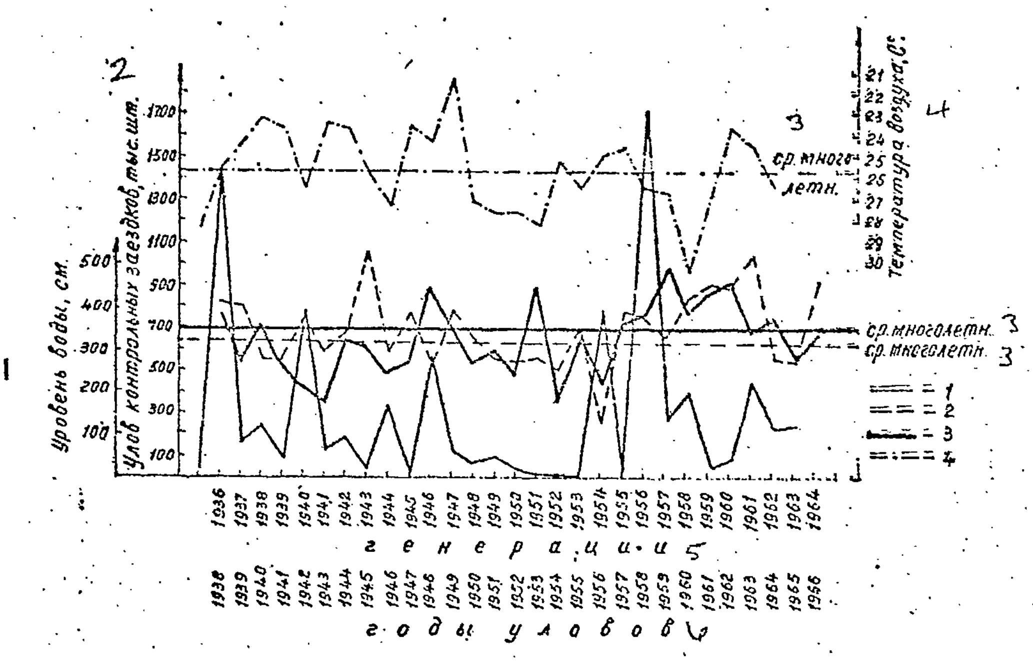

Fig. 16. Variations in catches of pink salmon, water level of rivers and air temperature (at Udinsk) in year of birth of year-class: 1) catches, 2) water level during run and spawning (mean for July and August), 3) level before freezing over (mean for September and October), 4) temperature (mean for December, January and February)

Key: (1) water level, cm (2) catch at counting fences, thousands of fish
(3) mean annual (4) air temperature, degrees C (5) year-classes
(6) years of catches

It will be clear from the observations described that abundant year-classes are usually formed when the snow cover is deep; in dry winters survival of the year-classes as a rule is much reduced. However, observations over a period of 26 years have not revealed any significant connection (Table 62) between the pink salmon population and the depth of the snow cover, expressed mathematically as a tetrachoric index (Plokhinskii, 1961).

The dependence of the return of the pink salmon on the height of the January and February water levels in the River Amgun' (Levanidov, 1964a) is also at the border line of significance ($\chi^2 = 3{,}93$), although there is definite correlation between these parameters.

Consequently, two of the leading external environmental factors -- the depth of the snow cover and the height of the water level in the spawning rivers in the winter period, with a direct influence on the survival of individual year-classes of the pink salmon and determining the general character of changes in their abundance, -- cannot be used as basic data for predicting catches, for significant correlation between them and the return of the fish to spawn is either absent or almost absent. /106/

TABLE 62.

Высота снежного покрова (1)	Численность горбуши (улов двух контрольных заездков) (5)		Σ
	увеличение (6)	уменьшение (7)	
(2) Выше нормы[1]	4	6	10
(3) Ниже нормы	3	13	16
Σ	7	19	n=26

(4) [1] Под нормой понимается средняя многолетняя

$$r_{++} = \frac{4\cdot13-3\cdot6}{\sqrt{7\cdot19\cdot10\cdot16}} = \frac{34}{\sqrt{21280}} = \frac{34}{145} = +0{,}233$$

$$\chi^2 = 26\cdot0{,}233^2 = 1{,}41.\ (p<0{,}95)$$

KEY: (1) Depth of snow cover (2) Greater than normal (3) Less than normal (4) By normal is meant the mean annual (5) Abundance of pink salmon (catch at two counting fences) (6) Increase (7) Decrease

With the available facts no direct correlation can be found between the size of the parental stock and its progeny. However, this does not mean that the abundance of the parental stock does not affect the catch. Even under favourable conditions of reproduction and incubation in 1955, for instance, a small parental stock could not produce an abundant progeny and, conversely, the abundant parental stocks of 1938 and 1958, despite the dry winter and, possibly, the severe freezing and death of the year-classes, nevertheless yielded a comparatively abundant progeny (Fig. 15). A large parental stock, yielding an abundant year-class under favourable conditions, can also compensate to some extent for unfavourable conditions and may give rise to a sufficiently abundant progeny. This means that abundance does not only depend on the conditions of development of the year-class in the river, but it also depends no less on the original quantity of "seed stock" -- on the number of spawners.

At the present time it is much more difficult to alter the natural conditions of incubation of the eggs and development of the young fish in the river (the snow cover and the water level at the site of the redds) than it is to control the abundance of the parental stocks.

In conclusion let us examine the mathematical relationship between the return of the pink salmon and the number of downstream migrants (Table 63). Using the data in Table 61 as the basis, we obtain:

TABLE 63.

Величина ската молоди 1	Численность горбуши (улов двух контрольных заездков) 4		Σ
	увеличение 5	уменьшение 6	
Выше нормы 2	2	1	3
Ниже нормы 3	—	11	11
Σ	2	12	n=14

KEY: (1) Size of downstream migration of young salmon (2) Above normal (3) Below normal (4) Abundance of pink salmon (catch at two counting fences) (5) Increase (6) Decrease

The tetrachoric coefficient of correlation /167/

$$v_{++}=\frac{22}{\sqrt{2\cdot12\cdot3\cdot11}}=\frac{22}{\sqrt{792}}=\frac{22}{28}=+0{,}786,$$

and its significance $U^2_{++} = 14.0 \times 0.786^2 = 8.65$, which fully confirms the significant correlation ($0.999 > P > 0.99$) between these two factors.

As these facts and arguments show, the abundance of young downstream migrants is the most reliable indicator of the size of the return of the spawning year-class. For the Amur pink salmon the principle of prediction based on the size of the downstream migration of the young fish and based on maturation of this species at the age of two years is therefore free from objection.

However, the weak correlation (r = +0.39 for 38 cases) between the number of young downstream migrants and the commercial return of pink salmon shows that the stock of this species is subjected to the action of eliminating environmental factors in the period from the downstream migration from the rivers to the return to fresh waters: the most important of these factors are natural death of the young and adult fish from disease, their consumption by predators, and mortality resulting from commercial exploitation by Japanese sea-fishermen. It is very difficult to allow for these enviromental factors when predicting the abundance of each pink salmon population.

The reliability of our predictions is considerably reduced by the absence of information about the abundance of young pink salmon in the Amur basin as a whole. It is at present virtually impossible to obtain such information. For this reason, improvement of the methods of counting the young pink salmon migrating downstream and the extension of observations to as many spawning rivers as possible are of the utmost importance.

5. Ways of Improving Prediction

With the considerable differences in the size of the annual spawning migrations and the very strained state of the reserves of pink salmon in the Amur basin in recent years there is a particularly urgent need for the rational planning of its commercial exploitation on the basis of biologically based predictions of the numbers of individual year-classes.

To improve prediction of the pink salmon population in the Amur basin the following steps must be taken:

1. The network of fisheries improvement stations must be widened and seasonal counting and observation points must be set up to count adult salmon and young downstream migrants;

2. Counting of salmon brood stock must be improved by setting up counting fences of permanent type, chiefly on rivers where these fences are regularly broken because of sudden considerable rises of the water level (the basin of the River Amgun');

3. Counting the escapement of salmon through counting fences must be changed from visual to automatic;

4. Data obtained by counting spawners and young downstream migrants in the River Iski must be used with very great care because this river is frequented sometimes by the Amur, sometimes by the Sea of Okhotsk stock of pink salmon, depending on the size of the spawning migration;

5. The effect of the number of predators (fishes and mammals) on the pink salmon population during its downstream migration in the river, in the region of the feeding migration, and at the approaches to Amur Sound must be studied;

6. The contribution of Japanese fishing to the reduction of stocks of pink salmon in the Amur basin must be studied.

X. MEASURES TO MAINTAIN AND INCREASE THE STOCKS

1. History

The profits to be made by the sale of salmon products from Nikolaevsk District led to intensive fishing for the pink salmon and summer chum by local entrepreneurs. In the peasant industry salmon were caught often regardless of whether they could be processed in time or not, and for that reason much of the catch was thrown away because of putrefaction. The "rapaciousness", to use Tikhenko's (1915) words, became a usual feature of the commercial fisheries in the lower reaches of the River Amur and Amur Sound and was widespread in character. This aroused fears for the fate of the salmon stocks and led to the institution of measures aimed at their preservation even before the Revolution. The post of controller of fisheries was set up as a first step in the Department of State Resources and was held at that time by the famous ichthyologist V.K. Brazhnikov. On his instructions, as Parakhin (1923) reports, the first measures to safeguard the national wealth of the Amur Region were taken: the restriction of Japanese fishing in the lower reaches of the River Amur and in Amur Sound. Regulations for the organization of fishing also were introduced: the fences were to be a specified distance apart, the length of the fences was limited to two-thirds of the width of the main channel, not more than one trap net was to be fixed to each fence; not more than two seines could be kept on each fishing place (except those used by the indigenous population and the peasants) and the second seine must not be set before the first had been hauled in (Geineman, 1911). However, despite the measures adopted, every year the occupancy of the spawning grounds by the fish was reduced, especially in the upper parts of the spawning area, and the small rivers near Lakes Chlya, Kadi and Kizi, according to Tikhenko (1915) were completely without fish by 1913.

After 1914 failure of the pink salmon catch in odd years came into sharp prominence and the two-year cycle became established, in which commercial exploitation was based on the year-classes of even years.

Brazhnikov (1920) wrote: "The decline of the Amur fishing industry must evidently be ascribed .... to a decrease in the actual reserves of the salmon, ... to the fact that fishing in this region has gone beyond all reasonable limits and that restoration of the previous levels of the catches can hardly be expected unless serious steps are taken to bring order into the fisheries."

In his investigation into the state of the Amur spawning grounds Kuznetsov (1926) found that, besides the wasteful salmon fishing and the irrational /109/ character of the industry in the pre-revolutionary period, exhaustion of the reserves of all year-classes of the summer chum and odd year-classes of the pink salmon was also due to a decrease in the productivity of the spawning grounds as a result of the settlement of the Amur Region and the industrial development in the basin. It was also considered that a sharp and considerable decrease in salmon catches was due to poaching with various types of efficient fishing gear and by the large numbers of poachers operating in the lower reaches of the Amur. The study of the state of the salmon fishing industry and spawning grounds in the Amur basin thus showed that the decrease in the stocks of odd year-classes of the pink salmon and of the summer chum in all years was due to human activity. This activity was expressed both as excessive fishing for salmon and as a deterioration in their spawning grounds and, consequently, a contraction of the spawning area.

Measures adopted by the Department of State Resources included limitation of the size of the fences that could be erected on State land (a reduction in length of the fence line and of the trap, with prohibition of any form of mechanization) and the wider spacing apart of the fishing areas in waters in the vicinity of the town of Nikolaevsk in order to reduce their number to the essential minimum. The number of small-scale fisheries was limited to that required to supply the needs of the industrial population. Fishing areas of appropriate size and fishing efficiency were marked out and it was forbidden to hire workers for fishing or for fish processing; with the object of protecting the fish the creation of new settlements was not allowed below the town of Nikolaevsk or on Amur Sound (Rusanov, 1924b).

By 1918 fences had been replaced by seines for fishing in the commercially exploited waters near Nikolaevsk and a little higher; the number of fences had also decreased, and they had been replaced by seines, in the region of the Amur estuary also, where of the 16 unusually efficient fences of Japanese type only eight remained (Bulletin of the Chief Department of Fisheries and the State Fishing Industry, No. 9, 1923). The number of fences which, during the occupation of Nikolaevsk (1920-1922), had been increased by the Japanese to 31, had decreased in 1924 to only four or five, because of the prohibition of the use of fences for fishing (Economic Life of the Far East, No. 1 (5), 1924).

The following resolution was passed at the Second Provincial Congress of the Fishing Population in 1918: "to maintain fish stocks at the required level, besides the prohibition of barriers, spawning grounds in rivers must be safeguarded as much and as extensively as possible, for which purpose fishing near the mouths of the rivers and in the tributaries of the Amur must be completely forbidden."

In 1923-1924 the first guidelines were introduced for salmon fishing for the commercial enterprises and the local population. They were based on statistics for catches in various districts and areas over a period of years starting from 1914. Standards of consumption also were introduced (for feeding the local population and the haulage dogs), in which the actual needs of the region in connection with the conditions of life were taken into account.

The pages of the journal "Byulleten' Rybnogo Khozyaistva (Fisheries Bulletin)" were filled in 1924-1926 with alarm concerning the fate of the Pacific salmon in the Amur basin. Soldatov (1924a, 1924b) proposed standards for the industry, protection of natural spawning, and the widespread undertaking of fish breeding by the cheap and simplified method of I.I. Kuznetsov (breeding in soil). N.P. Navozov-Lavrov (1924) spoke of the need for protecting salmon and in support of the method of breeding salmon in the bed as suggested by Kuznetsov. To safeguard the salmon stocks and to maintain them at a high enough and stable level, Navozov-Lavrov (1925) and Kuznetsov (1926) suggested /110/
that sufficient spawners be allowed to pass through to the spawning grounds and protected against excessive fishing before spawning, and that excessive salmon fishing be abolished; in other words, a change to rigid application of limits to fishing on a wide scale, not only for the local population, but also for the private and State fishing industry. Although I.I. Kuznetsov's experiments to study incubation of artificially fertilised salmon eggs in the beds of spawning streams were unsuccessful, they nevertheless established the

principle of protection as a sound basis for fish breeding under natural conditions, as he reports in his publications in 1928, 1937 and 1944.

The Amur fishing industry was investigated by a special commission of Dal'RKI and DVKK, which drew conclusions regarding the limitation of subsistence pink salmon fishing and the prohibition of pink salmon fishing in the spawning grounds; it also recommended strengthening the fisheries inspection system in the commercial fishing grounds and spawning areas and the development of fish breeding (Tselishchev, 1924). Some of the proposed measures were embodied in legislative documents of the Far Eastern Revolutionary Committee (Dal'revkom). In 1923, for instance, fishing for all species was prohibited until further notice in the pro-estuarine regions and in the channels of the Rivers Kol', Iski, Avri, Lyangrovaya, Charrakh, Chomi, My, Pal'vo, Zubarevka, Kamora, Beshenaya, Anyui and Gorin and in Lake Kizi, in the pro-estuarine region of the River Amgun' and the tributaries and streams nearest to its mouth, and also Lakes Orel' and Chlya and the Dal'zhinskaya Channel (in the River Amgun'), which were declared to be protected (Bulletin of the Main Department of Fisheries, No. 5, 1923). According to minute No. 7 of the meeting of the Presidium of Dal'gosplan dated 3 April 1925, pink salmon fishing was prohibited everywhere in odd years for eight years and salmon fishing was prohibited in the spawning grounds during the period of spawning. The only exception in this case was the local indigenous population, who were given the right to fish for salmon but only for their own consumption (Fisheries Bulletin No. 4, 1925). The scale of pink salmon fishing to satisfy the needs of the peasant and indigenous population, as laid down by the provincial government (Kraiispolkom) was 5 million fish (minimum), while the annual norm of fish that could be caught as food for a single haulage dog was 250-350 fish (Economic News, 1929).

As the first measures to restore the depleted stocks of summer species of salmon and to promote their reproduction, put into effect before the 1940s, protective measures aimed at controlling the exploitation of the fish and protecting them at the spawning grounds were thus instituted as follows:

1) Replacement of some fishing fences by seines and a decrease in the number of fishing areas near the town of Nikolaevsk;

2) The introduction of prohibition of pink salmon fishing in odd years after 1925;

3) Protecting the spawning grounds along the main tributaries of the Amur -- this was not carried out until 1923 (Kuznetsov, 1926);

4) The specification of standards for the industry, and

5) The creation of counting points on spawning rivers for planting salmon migrating upstream for breeding, in 1925.

In 1925 the Pacific Ocean Fisheries Station was organized by the Far-Eastern Department of Fisheries in Vladivostok; later it became the Pacific Ocean Research Institute of Fisheries and Oceanography (TINRO). This marked the beginning of the study of the biology of the Far-Eastern salmon.

2. Fundamental Research for Fisheries Improvement Measures /111/

Smirnov (1947) summarized protective and other measures carried out in the past and capable of use in the future and concluded that:

Conservation of the spawning grounds of the Amur salmon has been carried out in an extremely lax manner from the very beginning;

Artificial breeding of salmon is superfluous if the fish are able to lay their eggs under natural conditions;

The specification of normal limits for catches can be a useful measure if the established norm is soundly based (does not exceed the actual catch) and if it provides for reproduction of the fish stocks in larger numbers than previously;.

The development of fisheries improvement measures is a very complex problem as regards the actual wording of the measures, their aims, and their economic significance.

Smirnov regards the results of human interference with nature as on the whole beneficial and in order to increase the reproduction of the salmon resources in the Amur basin he proposes measures to encourage fish breeding under natural conditions:

a) to give the largest spawning grounds the status of reservations and prohibited areas under State control;

b) to introduce as quickly as possible the simplest types of improvement work (cleaning out the spawning grounds, side channels, creeks, mouths of rivers and so on);

c) to organize research and counting points in order to study the causes of fluctuations in the salmon stocks and to establish normal limits of catches.

With the organization of the Amur Branch of TINRO in Khabarovsk in 1945 and the establishment of fisheries improvement stations of Amurrybvod in the Amur basin in 1949 planned research began into the state of the Amur salmon stocks and work began to develop a system of measures aimed at their restoration. The main purpose of this research on the pink salmon was to study the way in which its stocks fluctuate (by analysis of catch statistics, the study of the hydro-meteorological factors of the environment, determination of the influence of predatory fish and mammals, the study of the local distribution of stocks) and to develop a method of predicting catches.

Birman and Levanidov (1953) showed that:

The most characteristic feature of the dynamics of the pink salmon population is an invariable increase in the stocks of one year-class immediately after a fall in the level of the stocks of the preceding one (and vice versa);

Alternation of strong and weak year-classes of pink salmon in successive years is an adaptive property, facilitating early maturation of the fish, a rapid rate of renewal of spawning stocks, and numerical superiority over other species of the genus Oncorhynchus;

The increase in the amplitude of fluctuations in pink salmon catches in even and odd years is not the result of the depletion of its stocks in odd year-classes, but the result of intensive commercial exploitation.

The important conclusion was drawn from these findings that prohibiting fishing for pink salmon of weak year-classes cannot make any contribution toward the restoration of the stocks because of the nature of the population dynamics of the pink salmon as a species.

The investigations of Smirnov (1947) revealed the chief cause of fluctuations in the abundance of the Amur salmon as the freezing and drying of the spawning grounds in winters with little snowfall. The finer details of this /112/ problem were investigated later and the position clarified.

Vasil'ev (1958, 1959) considers that the cause of death of the pink salmon (and also of the summer chum) in the early stages is not the freezing of the redds but a disturbance of their water supply as a result of the freezing of certain parts of the rivers down to the bottom: the decrease in percolation of water in the soil in such cases reduced the oxygen concentration in the redds almost to zero, leading to mass destruction of the eggs and larvae. The main practical problem in this case is the prevention of freezing. It is suggested that this can be done by erecting dams on the river before the ice forms in order to produce hanging ice, under which no growth of fresh ice can take place throughout the winter, and a steady flow of ground water is maintained.

Levanidov (1964a) discovered a direct relationship between the January water levels in the River Amgun' (at the village of Udinsk) and the population of Amur pink salmon and found that the most critical months for the eggs and embryos are December to February, when the greatest fall in the water level takes place in the spawning rivers on account of ground water depletion, caused by the low air temperatures and the thinness of the snow cover. He considers that the depression of the pink salmon stocks which began in 1950 is connected with an increase in solar activity: at times of warming of the sea, on the one hand, the atmospheric circulation is increased and this may cause cooling of the air and freezing of the spawning rivers; on the other hand, the mortality of the pink salmon in the sea is increased because of fluctuations in the food supply, changes in the conditions of feeding, or in the numbers and activity of predators. Levanidov thus explains the fluctuations in the stocks of the Amur pink salmon as does Kaganovski (1949) and Birman (1957, 1959), namely by climatic features.

During their departure from the nests and downstream migration many of the young Pacific salmon are eaten by predatory fish. The mortality among the young salmon from predatory fish (young silver salmon and char, adult char) in the basin of the River Bol'shaya on Kamchatka (Karymaiskii Channel), according to Semko (1948) from April until the end of July, 1944-1946, was between 52.1 and 84.2 %. These and other figures, as well as the discovery of young Pacific salmon in the stomachs of the taimen, pike, lenok and whitefish of the Amur rivers led the fisheries conservation authorities of the Amur basin to permit unrestricted fishing of these predatory fish in the salmon spawning rivers.

The study of feeding relations between the young salmon and the freshwater fish of the River Amgun' basin (taimen, pike, lenok, whitefish, ide, grayling, Amur minnow etc.) led Abramov (1954) to conclude that the measures adopted by Amurrybvod, aimed at the complete elimination of the taimen, pike, lenok and whitefish, as practised in the Amgun', were not soundly based; as a result of unrestricted fishing for lenok and pike in the spawning rivers of the Amgun' basin an increase had occurred in the population of the most dangerous predator for the pink salmon and chum -- the Amur ide.

In 1954-1960 Kokhmenko (1964, 1965) studied the food relationships between young Pacific salmon and the freshwater fish and certain diadromous fish of the Amur basin and neighbouring districts. She found that:

1) young downstream migrant salmon in the rivers of Amur Sound are eaten by the whitefish, lenok, the spent smelt and the sexually immature char;

2) the malma is most probably a competitor of the young salmon for food; /113/

3) char (malma and Sakhalin char) eat many nuisance fishes and thus reduce the strain on the feeding relations between the young salmon and the freshwater ichthyofauna; the eradication of these fish cannot therefore be regarded as desirable;

4) the lenok, whitefish and pike eliminate competitors of the young salmon for food, thereby improving the food supply for the salmon.

In order to increase the number of diadromous salmon it is suggested that:

the char population be restricted only during the downstream migration of the young salmon by periodic fishing of shoals of these fish at the mouths of the rivers;

by catching without restriction the Amur ide, minnow, and other nuisance and worthless fish.

According to statistics issued by Glavamurrybprom, the great majority (88 %) of marine mammals caught in 1941-1944 in Amur Sound and adjacent waters consisted of seals and belugas; the mean annual catch of these mammals was 1112 and 861 respectively.

The reports by Arsen'ev (1937) and Sleptsov (1952) that pink salmon are eaten by seals and belugas and the counts of pink salmon wounded by marine mammals, with characteristic traces on the body, undertaken by the Amur Branch of TINRO in the River Amgun' during 1948-1952 (the number of "wounded" in these years was from 2.9 to 10.7 %) showed that considerable losses are inflicted on the Amur pink salmon.

To minimise the effect of predators in reducing the pink salmon stocks and in order to increase the salmon population Abramov (1954) proposed:

that fishing for lenok, whitefish and Amur ide with drag seines in the mouths of spawning rivers be permitted only during the downstream migration of the young salmon;

that the hunting of marine animals (seal, beluga) in the Gulf of Sakhalin, Amur Sound and the lower reaches of the Amur River be intensified during the spawning migration of the pink salmon and chum, i.e., from June to the end of September.

As long ago as in 1926 I.F. Pravdin considered the study of the location of the pink salmon stocks to be an important preliminary step in the restoration of the stocks in the Amur basin. As a result of investigations of the composition of the pink salmon stocks in the Amur fisheries district in 1950-1954 (Enyutina, 1954a, 1954b, 1963) it is now possible:

a) to determine which particular stock the pink salmon belong to when laying down regulations for commercial fishing, for the fluctuations in size of the spawning migrations year by year differ for different stocks and the available numbers of each stock are largely independent;

b) applying fisheries and improvement measures in the right locations, for which the boundaries of the spawning grounds of the Amur pink salmon itself had to be defined and the preference of this salmon for particular spawning rivers within the Amur basin had to be established;

c) to state categorically that pink salmon feeding and growing off the west coast of Japan (the west coast of Hokkaido Island) migrates to some extent into the waters of the River Amur.

Besides studying the way in which the pink salmon stock fluctuates and investigating ways of improving predicted catches of this fish, the Amur Branch of TINRO has also examined some purely practical problems directly connected with measures for restoring the stocks of this valuable salmon.

The main purpose of measures to promote the reproduction of the pink salmon, in Levanidov's opinion, is to obtain the largest number of downstream migrants. This can be done in two ways: /114/

1) by natural reproduction, which demands:

a) the laying down of fishing norms so as to allow sufficient salmon to spawn (35-40 % of the stock of pink salmon in even years);

b) ensuring the optimal concentration of salmon in the spawning grounds (maximum use of the spawning facilities by the fish in order to secure more complete preparation of the bed and to prevent excessive digging over of redds in which eggs have already been laid);

c) protecting the fish during natural spawning;

2) by artificial breeding, which demands:

a) the construction of 25 fish hatcheries on rivers which periodically freeze up or whose spawning grounds have become disused because of human activity in the neighbourhood;

b) releasing annually no fewer than 400-500 million young salmon from these hatcheries into the Amur basin.

Levanidov points out the advantages and disadvantages of natural reproduction and artificial breeding of the pink salmon.

An advantage of the first method is its comparative cheapness. However, the possibility of large-scale death of the eggs and young fish because of unfavourable climatic conditions cannot be ruled out, with consequent instability of the state of the salmon stocks and unreliability of its catches.

An advantage of the second method is that unfavourable climatic conditions during development can be overcome, with the result that stable stocks of pink salmon are ensured and the industry can count on catching from 30 000 to 35 000 centners of pink salmon annually. Because the pink salmon matures quickly (if returned to spawn in the second year of life) artificial breeding is an effective method, for the stocks can be considerably increased within a short time. However, the small individual weight and the low fecundity of the pink salmon make the overhead costs of breeding this fish almost twice those incurred in breeding the summer chum, and considerable funds are required for building a large number of fish hatcheries.

Levanidov sums up by saying that the pink salmon is a difficult fish for effective breeding and, on economic grounds, commercial pink salmon breeding alone cannot be justified, although combined breeding in hatcheries with the summer chum can be recommended.

Abramov (1954) considered that at that time it was premature and unsound to build large fish hatcheries on the Amur until methods of obtaining mature spawning pink salmon in channels of the rivers had been found experimentally and standards for fish breeding had been established. Small fish hatcheries on rivers no longer available for spawning because of industrial development in certain districts may play a role of some importance in the replenishing of the salmon stocks, although preference is given to the creation of artificial spawning grounds (breeding in the bed), combined with the obtaining of mature spawners in the river channels.

The first fish hatchery for breeding summer species of salmon in the Amur basin was built on the River Amgun' 80 km from its mouth, close to where it is joined by the small mountain river, the Verkhnyaya Uda. The plan of this factory was unsound and for many years frequent technical alterations had to be carried out and the water supply from the river had to be replaced by water from wells. In 1963 the first pink salmon eggs were put down there for /115/
incubation.

Wastage of eggs during incubation and of the brood stock of pink salmon during keeping until attaining complete maturity was very great from year to year. However, the reason was evidently not merely faulty techniques of keeping the spawners. It was stated as long ago as in 1956 that fish of the second half of the spawning migration are best used for this purpose, for many of these fish have a well-marked breeding colour (and consequently, they are more mature). However, so as not to run the risk of failing to put down the planned number of eggs for incubation, fish breeders at the Udinsk hatcheries take the very first fish arriving at the counting fence and keep them until they mature. As a result considerable wastage of spawners is observed.

It is worth noting that in recent years pink salmon have migrated into the River Amur with ill-defined features of breeding colour. Silvery fish migrate in large numbers into the River Amgun' and even into the spawning River Samnya, where ponds are constructed every year for keeping spawners. This egg collecting point, nearest to the Udinsk hatcheries, is not really suitable for fish-breeding purposes because most of the pink salmon and summer chum, with their silvery colour and their still unripe sex products, are on their way to the higher spawning tributaries of the Amgun'.

Experience at the Udinsk factory has shown that breeding summer salmon, especially pink salmon, is a highly complex, expensive, and inefficient task. Whereas in Sakhalin, where the spawning rivers are shorter, artificial pink salmon breeding has been used extensively, in the Amur basin it will probably never succeed. In this connection attention is directed to the new, improved, and economically more profitable methods of salmon breeding proposed by A.M. Kol'gaev and A.P. Ivanova (Kol'gaev and Ivanova, 1960; Kol'gaev, 1965):

incubating eggs and keeping salmon in the prelarval stage in gravel with the use of basic copper carbonate as an antiseptic;

incubating the eggs and keeping salmon in the prelarval stage in field apparatus.

The buildings suitable for these suggested methods are much simpler and cheaper than those required for existing fish hatcheries and the amount of labour required in caring for the eggs and prelarval salmon is reduced to the minimum. More natural conditions are created for the eggs and prelarval salmon. These proposed methods are at present undergoing production trials.

Among the measures aimed at increasing the pink salmon stock in the Amur basin, an investigation was made by the Amurrybvod expedition in the period 1952-1962 of nearly all the salmon spawning rivers in the lower reaches of the River Amur and Amur Sound to find out what improvement work is necessary. The expedition found that in years when the water level is low (1959) the pink salmon cannot cross the silted mouths of the Rivers My, Vakkar, Bol'shaya and Malaya Patkha, Tarakanovka, Vaida, etc. Many log-jams and other obstructions to the flow of water were found in the channels of these rivers and the expedition considered that they were unsurmountable obstacles for fish rising to the spawning grounds. As measures of improvement it was therefore suggested that dredging be carried out at the mouths of these rivers to remove the obstructions and to provide a clear channel.

Whereas measures aimed at enabling fish to migrate into the rivers (i.e., dredging at the mouth) are undoubtedly essential, the suggestion that the channel be cleared of all obstructions must be interpreted with great caution. We know from practical experience at mechanized improvement stations, for /116/ example, that hydrotechnical improvements in spawning rivers of the autumn chum can modify the natural conditions.

After analysing the results of work carried out in the system of the River Khor, Levanidov (1969) concluded that the character and aims of improvement work in salmon spawning rivers are problems which are still far from being solved, i.e., he reached the same conclusion as did Smirnov (1947) previously. Levanidov considers that, with the present level of our knowledge, it is difficult to stipulate a detailed biological basis for improvement measures aimed at increasing the natural productivity of the spawning grounds, for the natural reproduction of the pink salmon has still received comparatively little study.

The formation of log-jams and other obstructions in the water course of rivers is a natural phenomenon which was also observed long ago, when the salmon stocks were still very high. In all probability these obstructions, which will disappear in the course of time as a result of the action of the river current, are most probably not of decisive importance to the reproduction of the salmon.

It will be evident from the above facts that the Amur Branch of TINRO has made considerable effort to study the problems connected with reproduction of the Amur pink salmon and to develop measures of increasing its stocks. Investigations have shown that for the state of the pink salmon stocks in the Amur basin to be stabilized the largest possible number of downstream migrants must be obtained every year in the Amur basin as a result of the introduction of fishing norms, the protection of spawning, the optimal utilization of spawning grounds by the fish, the construction of many fish hatcheries, the catching of predatory fish during the downstream migration and of predatory mammals during the spawning migration, and the carrying out of very simple improvements (dredging the silted mouths of the spawning rivers).

As a measure common to all the Amur salmon and aimed at obtaining an adequate rate of its survival in the ocean it is suggested that Japanese fishing be controlled and the zone covered by the fishing convention be extended to include the whole of the feeding area of the Asiatic stocks. Also, to ensure high efficiency of natural spawning of the Pacific salmon, Nikol'skii (1956) described in precise detail a series of tasks for the fisheries improvement stations of Amurrybvod. The main purpose of these tasks was to ensure passage of the spawners to the spawning grounds, successful spawning, a favourable outcome of incubation of the eggs and development of the young salmon in the bed, and also successful foraging of the young salmon in the rivers and their downstream migration to the sea.

Let us examine how these numerous measures aimed at increasing the pink salmon population in the Amur basin have actually materialised.

3. Measures Put Into Practice and Their Results

To maintain and restore the Amur pink salmon stocks belonging to the odd-year year-classes, fishing for this salmon was prohibited in 1925-1937, and this prohibition was strictly observed. Catches of pink salmon of the odd year-classes by the Amur fisheries fluctuated from 1915 to 1923 between 130 000 and 860 000 fish, and they increased considerably (to 3 070 000 fish) only in 1939, i.e., after seven successive year-classes; the catches again fell in 1941 to 950 000 fish and they have continued at even lower levels in subsequent years.

With the lifting of certain restrictions on fishing during wartime (1941-1945) and also as a result of infringements of certain rules of fishing, reproduction of the salmon stocks in the following years was probably on a less satisfactory basis. To improve the reproduction of the weak pink salmon year-classes their fishing was prohibited in 1947, 1949 and 1951 in the Amur River, Amur Sound and the Gulf of Sakhalin (report of Amurrybvod on fisheries for 1951), but this restriction of commercial exploitation had no appreciable effect. /117/

The second depression of the Amur pink salmon population of the odd year-classes began in 1953 and since 1955 pink salmon fishing has been declared closed, with a real and considerable limitation on the industry. Since the time of the prohibition the number of young downstream migrant salmon from rivers where counting is in operation has steadily increased (Table 57), but for four consecutive odd year-classes the pink salmon stocks have remained very low. Undoubtedly pink salmon fishing by the Japanese in the Sea of Japan has had a detrimental effect. In 1963 the pink salmon population was much increased, but in 1965 it was reduced again (Table 56), despite the unprecedentedly large downstream migration (more than 70 million young salmon from four rivers).

Whereas the increase in the pink salmon catches in the Amur basin in 1939 cannot be attributed to the prohibition of commercial fishing, for with the well-known rapidity of maturation of this species the results of the prohibition would have been felt much sooner, the appearance of a large number of pink salmon in the Amur basin in 1963 was definitely the result of the great contraction of the Japanese salmon fishing activity in the Sea of Japan in 1963;

another contributory factor was evidently a change in the cycle of pink salmon catches in Primor'e (since 1963 large migrations of pink salmon have been resumed in odd years).

The absence of correlation between the number of young downstream migrant pink salmon in even years and the return of the adult fish and the constantly small numbers of pink salmon belonging to odd year-classes are evidence of the failure of prohibition of commercial fishing. This failure is probably aggravated by the climatic conditions of the 1950s-1960s, which were unfavourable for survival of salmon in the sea, and also by the very intensive exploitation by Japanese fishermen of the southern groups of Pacific salmon (to the south of latitude 48°N), where the Amur pink salmon also forages (Kotov, 1957).

Prohibition of salmon fishing in even years gave a completely different effect. In the very first spawning year-class after the prohibition there was a considerable increase in the number of migrating fish in 1956, and in 1958 the pink salmon stocks were higher still. The success of prohibition was assisted by the favourable hydro-meteorological conditions in the winters of 1954/55 and 1956/57. The next winter (1958/59) was very unfavourable for the even year-classes of pink salmon and, as a result, the pink salmon population in 1960 fell considerably. The passage of a relatively large number of adults to the spawning grounds in the years of prohibition of commercial fishing thus leads (other conditions being equal) to a relatively larger downstream migration of the young fish and, consequently, to a larger return of sexually mature fish of the dominant year-classes of the Amur pink salmon only. The population of odd year-classes of the pink salmon, as practical experience of fishing prohibition has shown, has not been restored. No useful purpose can thus be served by keeping the prohibition of pink salmon fishing in the Amur basin in operation during odd years, year after year, without regard to the size of the downstream migration of the young fish of the expected year-class unless this migration is less than the annual mean. Nikol'skii (1952) also considers that efforts to restore weak year-class of the pink salmon are unlikely to be successful and that /118/ measures should be concentrated on increasing the combined size of two consecutive year-classes.

Methods of restricting the catching of fish (shortening the fence and pole, prohibition of mechanical devices for fishing and selecting fish from the pond), as carried out before the Revolution, were of no practical value and, consequently, were unsuccessful as control measures.

Another measure also aimed at controlling fishing is the specification of the permitted catch. Attempts to establish norms for pink salmon fishing in the Amur basin were begun, as has already been stated, in the 1920s. The fishing quota was essentially only a rough standard specifying only a relatively probable limit of the permissible catch on the basis of calculation of approximate mean catches over several years, and this could not guarantee the stability of the fish stocks in a given stretch of water. Difficulty of establishing the fishing quota and the unsatisfactory nature of the norms adopted in 1923-1924 were attributed by Somov (1929) to the current instability of the industry and to the single spawning of the Pacific salmon, so that the measure as a whole, in his opinion, was "essentially a good idea, but very much hard work was required before it could be put into practice."

Later, when the industry had become stabilized, planning and limitation of the pink salmon catch were carried out. In practice, however, this measure was almost completely unsuccessful. Having noted the considerable errors made by TINRO in 1940 and 1941 in their estimation of the pink salmon stocks (Table 59), for many years, starting in 1943, the fishing industry planned its catch as a rule without regard to the possible fluctuations in the numbers of individual year-classes (Table 64), and the recommendations suggested by TINRO and its Amur Branch on the size of the catch were often disregarded. Fishery science, in turn, because of the lack of appropriate or sufficiently complete observations, could not always correctly evaluate the results for productivity of the pink salmon in the Amur basin or the possibility of making good the Amur stock with particularly abundant year-classes of pink salmon from adjacent districts.

TABLE 64. Catches Planned by the Lower Amur Trust and Actual Catches of Pink Salmon in the Region of its Activity, thousands of centners

1 Год	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
2 План	18,7	60,0	30,0	43,5	—	48,0	8,2	79,2	15,0	34,8
3 Вылов	7,2	39,2	3,0	43,7	2,7	101,1	2,9	8,3	6,0	6,9

KEY: (1) Year (2) Plan (3) Catch

As Table 64 shows, the planned norms for the pink salmon catch were in most cases higher than the actual catches; conducting the industry in this manner did great damage to the pink salmon stocks. Underestimation of the population of the spawning stocks in 1948, 1956, 1958 and 1963 prevented the industry from making maximum use of the available reserves, for a working basis of this kind had not been foreseen.

This section on measures we have just examined is the most complex and the least completely studied because it is directly linked with the prediction of catches. The specification of norms, like prediction, was complicated by the resumption in 1952 of Japanese salmon fishing in the north-western part of the Pacific Ocean. Moiseev (1956a, 1956b) points out that the Pacific salmon are more susceptible to the influence of natural factors because of their special biological features and he emphasized that the state of the stocks of these fish is largely dependent on the number of fish migrating from the sea to spawn, and that in order to maintain and reproduce them at /119/ the required level measures aimed in the first place at limiting and controlling sea fishing must be instituted. Kotov (1957), developing Moiseev's argument, noted that the coastal salmon fishing industry at the present time is difficult to regulate properly, because the effect of sea fishing on it cannot always be determined accurately.

Among measures of conservation in the Amur basin, pink salmon fishing is prohibited in spawning rivers, fences must be erected not less than a minimum distance (1.5 km) apart, trap nets must be not less than 2 km apart, and adult pink salmon must be protected during the spawning migration in the rivers and at the spawning grounds. In recent years all necessary steps have been taken to increase the degree of protection: the number of fish protection inspectors has been increased, more fisheries protection boats are being sent to the conservation regions, and the efforts of the fisheries improvement stations are also being directed towards the protection of the salmon during spawning in scheduled waters.

Virtually no improvement measures have been undertaken in the Amur basin, disregarding the minor work done by the fisheries improvement stations to remove obstructions in some rivers. In recent years, because of the low abundance of the spawning stocks, the spawning grounds have been inadequately used, and even if the salmon stocks are increased several times there will still be more than enough spawning area for the brood stock.

CONCLUSION

For a long time, in connection with increased solar activity and general changes in the earth's climate, the conditions of reproduction have been unfavourable for the pink salmon of the Amur basin and this has led to a steady decline in the population of this salmon. Commercial and subsistence fishing for pink salmon, however, has been carried on on the same scale as before. Large numbers of Amur pink salmon began to be removed in 1952 when the well equipped Japanese salmon sea-fishing industry resumed its activities.

The almost complete absence of practical steps to maintain and increase the stocks of pink salmon have led to depression of its population in certain years (1949-1955).

The efforts of fisheries science have been directed towards the study of the scientific basis of rational commercial pink salmon fishing in the Amur basin. However, the numerous recommendations on this matter have not yet been put into practice. The Amurrybvod organization has confined its efforts to strengthening the protection of the fish during its spawning migration and to prohibiting commercial fishing of the pink salmon of odd year-classes, although these measures, by themselves, cannot be effective.

Since it is well-nigh impossible to change the natural (climatic) conditions of incubation of the eggs and development of the young fish in the river (the depth of the snow cover and the level of water in the neighbourhood of the redds), and since the construction of a network of fish hatcheries would involve considerable capital expenditure and cannot be justified at present (neither methods of obtaining adult spawners nor normal standards for fish breeding have not yet been developed for practical purposes), the following steps must be taken in order to increase the pink salmon stocks in the Amur basin:

1. Regulation of commercial pink salmon fishing must be placed on a scientific basis.

2. The simplest improvement measures must be carried out in the very near future: dredging operations at the mouths of spawning rivers, especially

the My, Vakkar, Bol'shaya and Malaya Patkha, Tarakanovka and Baida. /120/

3. Collective fisheries must be obliged to catch predatory fish (malma, Sakhalin char, lenok, whitefish, Amur ide, smelt) in the waters fished by them during the downstream migration of the Pacific salmon (from 15 May to the end of June).

4. The compulsory fishing for nuisance and valueless fish (the Amur ide, minnow, etc.) must be included in the plan of operations of fishery collectives, with a wage scale geared to the size of the catch.

5. Hunting the beluga, a predatory mammal, to be organized during the spawning migration of the pink salmon in Amur Sound (June). Production of the necessary equipment for A.M. Kolgaev's method of salmon rearing, which is the cheapest, to be speeded up and the method to be used in regions where the pink salmon spawning grounds regularly freeze up.

All the steps listed above are perfectly practicable and no comment is necessary, except on item 1, which requires special discussion.

Regulation of commercial fishing involves a group of measures based on the prediction of the population of the spawning stocks. It will be clear from the material in this monograph that prediction is the most difficult part of the investigation. Its difficulty lies in the diversity and variability of the external environmental conditions that ultimately determine the survival of individual pink salmon populations. In years particularly favourable for foraging, when the survival rate of the pink salmon in the sea is high, its migration into the Amur can be considerable on account of the Primor'e stock, even though the previous downstream migration of the Amur pink salmon stock was low. In other words, the instinct for the natal river is not always clearly exhibited by the pink salmon as a species. The lack of information at present on the relative abundances of the local pink salmon stocks in the Amur basin makes it difficult to predict the size of its spawning year-classes. The

Japanese sea fishing industry has added a fresh complication to the problem of prediction, for we can only forecast roughly the degree of its effect on the pink salmon migrating into the Amur basin to reproduce. For these reasons it is impossible to determine the future prospects for commercial salmon fishing on the Amur with any degree of accuracy. Some deviation to either side of the true catch has therefore to be accepted.

Besides statistical information on catches the only other sources available to us at the present time when attempting to determine the size of the brood stock and the abundance of young fish are the data of the fisheries improvement stations on migration of the adults into the spawning rivers and the downstream migration of the young salmon. These statistics, as I have mentioned earlier, have many defects. The eradication of these defects will lead to better predictions of the pink salmon population in the Amur basin. The following steps must be taken:

1. The network of fisheries improvement stations must be extended, in the first place to eight by opening three stations on the Rivers Nizhnyaya Uda, Yakker and Chomi, and seasonal counting and observation points must be set up to count the adult salmon and young downstream migrants in the Rivers Kerbi, Nimolen, Khilka and Kenzha (these points must operate during the six months from April to September).

2. The counting of salmon brood stock must be improved by installing fish counting fences of the stationary type, to begin with in rivers where these fences are regularly broken by sudden and considerable rises of the water level (the basin of the River Amgun'). /121/

3. The counting of the escapement of salmon through counting fences must be changed from a visual to an automatic method.

4. Figures for the number of spawners and downstream migrants in the River Iski must be used with great caution because this river is frequented

by both the Amur and the Okhotsk stocks of pink salmon depending on the size of the run.

With the existing scale of fish counting commercial pink salmon fishing in the Amur basin is permissible if the downstream migration of young fish from five monitored rivers exceeds 100 million (the coefficient of return of the pink salmon from young downstream migrants must be taken as 1 % for the Amur stock). A downstream migration of 50 to 60 million signifies an average level of replenishment of the pink salmon stocks and means that limited fishing is permissible. The downstream migration must be regarded as poor if fewer than 50 million young fish are counted in the monitored rivers; in that case only controlled fishing at two barriers in Amur Sound is acceptable. In every case the abundance of the Primor'e stock of pink salmon must be taken into account.

A fundamental line of research for the Amur Branch of TINRO in connection with replenishment of the pink salmon stocks of the Amur basin is the study of ways of improving natural reproduction of the pink salmon and the investigation of biological engineering problems concerned with the breeding of this salmon by the cheapest and most accessible method in the bed and in apparatus with the use of antiseptics.

Clarification of the main elements of prediction -- the size of the downstream migration of the young fish and commercial fishing for pink salmon in the sea -- will enable more accurate predictions to be made of the numbers of individual year-classes of this fish; the industry can then be regulated on a scientific basis, an essential preliminary to the rational management of salmon fishing on the Amur.

TABLE 18. (See Page 36 of the Russian text)
Elemental Chemical Composition of the Scale of Various Species of Salmon and the Eastern Carp (in % of Ash). Mean Data for Several Years

1 Реки, виды рыб, возраст	Si	Al	Mg	Ca	Fe	Mn	Ni
2 Амур, осенняя кета, 3+	$8,9\cdot10^{-1}$	$6\cdot10^{-2}$	$4,1\cdot10^{-1}$	$3,7\cdot10^{0}$	$1,6\cdot10^{-2}$	$9\cdot10^{-3}$	$8\cdot10^{-3}$
3 Амур, летняя кета, 3+	$7,9\cdot10^{-1}$	$4\cdot10^{-1}$	$8\cdot10^{-1}$	$3,3\cdot10^{0}$	$1\cdot10^{-1}$	$9\cdot10^{-3}$	$7\cdot10^{-2}$
4 Иска, кета, 3+	$5,8\cdot10^{-1}$	$2,2\cdot10^{-1}$	$6,5\cdot10^{-1}$	$3,6\cdot10^{0}$	$8\cdot10^{-3}$	$8\cdot10^{-3}$	—
5 Гижига, кета, 3+	$2\cdot10^{-1}$	$9\cdot10^{-3}$	$4,2\cdot10^{-1}$	$4,6\cdot10^{0}$	$6,7\cdot10^{-3}$	$6,6\cdot10^{-3}$	—
6 Яма, кета, 3+	$7\cdot10^{-1}$	$4\cdot10^{-2}$	$3\cdot10^{-1}$	$5\cdot10^{0}$	$7,1\cdot10^{-3}$	$9\cdot10^{-3}$	—
7 Тауй, кета, 3+	$3\cdot10^{-2}$	$2,7\cdot10^{-2}$	$5\cdot10^{-1}$	$2,6\cdot10^{0}$	$8\cdot10^{-3}$	$6,9\cdot10^{-3}$	—
8 Кухтуй, кета, 3+	$1,5\cdot10^{-2}$	$6\cdot10^{-1}$	$5\cdot10^{-1}$	$3,1\cdot10^{0}$	$8\cdot10^{-3}$	$8\cdot10^{-3}$	—
9 Большая, кета, 3+	$1,8\cdot10^{0}$	$3\cdot10^{-1}$	$5\cdot10^{-1}$	$3,2\cdot10^{0}$	$8\cdot10^{-3}$	$7\cdot10^{-3}$	—
10 Найба, кета, 3+	$8\cdot10^{-1}$	$4\cdot10^{-2}$	$2,4\cdot10^{0}$	$6,5\cdot10^{0}$	$7\cdot10^{-3}$	$7\cdot10^{-3}$	—
11 Амур, горбуша, 1+	$1\cdot10^{0}$	$1,5\cdot10^{-1}$	$3,5\cdot10^{-1}$	$4,2\cdot10^{0}$	$7\cdot10^{-3}$	$7,2\cdot10^{-3}$	$1\cdot10^{-3}$
12 Иска, горбуша, 1+	$8\cdot10^{-1}$	$4\cdot10^{-1}$	$6,3\cdot10^{-1}$	$4,1\cdot10^{0}$	$9\cdot10^{-3}$	$1,2\cdot10^{-3}$	—
13 Амур, сима, 2+	$8\cdot10^{-1}$	$1\cdot10^{-2}$	$5\cdot10^{-1}$	$6\cdot10^{0}$	$1\cdot10^{-2}$	$7\cdot10^{-3}$	—
14 Амур, сазан, 4+	$1\cdot10^{-2}$	$1\cdot10^{-2}$	$3\cdot10^{-1}$	$4\cdot10^{0}$	$7\cdot10^{-3}$	$7\cdot10^{-3}$	—
15 Амур, сазан, 7+	$7\cdot10^{-1}$	$8\cdot10^{-1}$	$1\cdot10^{0}$	$5\cdot10^{0}$	$1\cdot10^{-2}$	$3\cdot10^{-1}$	—
16 Амур, сазан, 5+ (январские пробы)	$8\cdot10^{-1}$	$1\cdot10^{-2}$	$7\cdot10^{-1}$	$4\cdot10^{0}$	$1\cdot10^{0}$	$5\cdot10^{-2}$	—
17 Амур, сазан, 5+ (майские пробы)	$10\cdot10^{-2}$	$7\cdot10^{-3}$	$7\cdot10^{-1}$	$5\cdot10^{0}$	$7\cdot10^{-1}$	$5\cdot10^{-2}$	—
18 Амур*, сазан (сеголетки)	$8\cdot10^{-1}$	$8\cdot10^{-1}$	$3\cdot10^{-1}$	$1,5\cdot10^{0}$	$1\cdot10^{-2}$	$7\cdot10^{-3}$	—
19 Амур**, сазан (сеголетки)	$8\cdot10^{-1}$	$1\cdot10^{-1}$	$1,4\cdot10^{-2}$	$1,2\cdot10^{0}$	$3\cdot10^{-2}$	$1\cdot10^{-2}$	—

20 * Молодь естественного нереста.
21 ** Молодь из вырастных прудов.

1	Ti	Cr	Cu	Pb	Ag	Zn	Na	P	[illegible]	[illegible]
2	$1,2\cdot10^{-2}$	$2\cdot10^{-3}$	$2,8\cdot10^{-5}$	$2\cdot10^{-3}$	—	$1,3\cdot10^{-2}$	$5\cdot10^{-2}$	$7\cdot10^{0}$	$1\cdot10^{[illegible]}$	[illegible]
3	$9\cdot10^{-3}$	$7\cdot10^{-2}$	$9\cdot10^{-4}$	$5\cdot10^{-4}$	—	$2\cdot10^{-2}$	$5\cdot10^{-2}$	$7\cdot10^{0}$	$1\cdot10^{[illegible]}$	[illegible]
4	$7\cdot10^{-3}$	—	$1,8\cdot10^{-2}$	$1\cdot10^{-3}$	$1\cdot10^{-4}$	$2,2\cdot10^{-2}$	[illegible]	$5,5\cdot10^{0}$	—	[illegible]
5	$8\cdot10^{-3}$	—	$1,9\cdot10^{-4}$	$1\cdot10^{[illegible]}$	$1\cdot10^{-3}$	$2\cdot10^{-2}$	$5\cdot10^{-2}$	$5,3\cdot10^{0}$	—	[illegible]
6	$7\cdot10^{-3}$	—	$3\cdot10^{-2}$	$2\cdot10^{-4}$	$1\cdot10^{-4}$	$2,3\cdot10^{-2}$	$5\cdot10^{-2}$	$5\cdot10^{0}$	—	[illegible]
7	$8\cdot10^{-3}$	—	$3\cdot10^{-2}$	—	—	$1,8\cdot10^{-2}$	$3,3\cdot10^{-2}$	$6,6\cdot10^{0}$	—	[illegible]
8	$3\cdot10^{-2}$	$2\cdot10^{-3}$	$8\cdot10^{-3}$	$1\cdot10^{-3}$	—	$2\cdot10^{-2}$	$5\cdot10^{-2}$	$7,6\cdot10^{0}$	$1\cdot10^{-2}$	[illegible]
9	$1\cdot10^{-2}$	—	$8\cdot10^{-3}$	—	—	$1\cdot10^{-2}$	$3\cdot10^{-2}$	$5,2\cdot10^{0}$	—	[illegible]
10	$6\cdot10^{-2}$	—	$5\cdot10^{-1}$	—	$1\cdot10^{-4}$	$1,5\cdot10^{-2}$	$1\cdot10^{-1}$	$5,5\cdot10^{0}$	—	[illegible]
11	$7\cdot10^{-3}$	—	$2\cdot10^{-4}$	—	—	$2\cdot10^{-2}$	$3,5\cdot10^{-2}$	$6,1\cdot10^{0}$	—	[illegible]
12	$8\cdot10^{-3}$	—	$5\cdot10^{-4}$	—	—	$1,7\cdot10^{-2}$	$7\cdot10^{-2}$	$7,3\cdot10^{0}$	—	[illegible]
13	$7\cdot10^{-3}$	—	$5\cdot10^{-4}$	—	—	$2\cdot10^{-2}$	$8\cdot10^{-2}$	$10\cdot10^{0}$	—	[illegible]
14	$7\cdot10^{-3}$	—	$5\cdot10^{-3}$	—	—	$2\cdot10^{-2}$	$2\cdot10^{-2}$	$3\cdot10^{0}$	—	[illegible]
15	$7\cdot10^{-3}$	—	$3\cdot10^{-3}$	—	—	$3\cdot10^{-2}$	$5\cdot10^{-2}$	$9\cdot10^{0}$	$1\cdot10^{[illegible]}$	[illegible]
16	$7\cdot10^{-5}$	—	$5\cdot10^{-5}$	—	—	$1\cdot10^{-2}$	$5\cdot10^{-1}$	$5\cdot10^{0}$	—	[illegible]
17	$7\cdot10^{-3}$	—	$5\cdot10^{-3}$	—	—	$1\cdot10^{-2}$	$2\cdot10^{-1}$	$7\cdot10^{0}$	—	[illegible]
18	$1\cdot10^{-2}$	—	$5\cdot10^{-5}$	$1\cdot10^{-2}$	—	$3\cdot10^{0}$	$1\cdot10^{-2}$	$5\cdot10^{0}$	$1\cdot10^{-2}$	[illegible]
19	$7\cdot10^{-3}$	—	—	—	—	—	$1\cdot10^{-1}$	$2\cdot10^{0}$	—	[illegible]

KEY: (1) Rivers, species of fish, age (2) Amur, autumn chum, 3+ (3) Amur, summer chum, 3+ (4) Iski, chum, 3+ (5) Gizhiga, chum, 3+ (6) Yama, chum, 3+ (7) Taui, chum, 3+ (8) Kukhtui, chum, 3+ (9) Bol'shaya, chum, 3+ (10) Naiba, chum, 3+ (11) Amur, pink salmon, 1+ (12) Iski, pink salmon, 1+ (13) Amur, masu, 2+ (14) Amur, eastern carp, 4+ (15) Amur, eastern carp, 7+ (16) Amur, eastern carp, 5+ (January tests) (17) Amur, eastern carp, 5+ (May tests) (18) Amur*, eastern carp (fingerlings) (19) Amur**, eastern carp (fingerlings) (20) * Young produced by natural spawning (21) ** Young from rearing ponds.

TABLE 19. (Opposite page 37 of the Russian text)
Content of Chemical Elements in the Scale of the Chum from Far Eastern Rivers in 1961, Age 3+ (in % of Ash)

Реки 1	Si	Al	Mg	Ca	Fe	Mn	Ni
Амур* 2	$8\cdot10^{-1}$	$7\cdot10^{-3}$	$5\cdot10^{-1}$	$4,5\cdot10^{0}$	$7\cdot10^{-3}$	$7\cdot10^{-3}$	—
Амур** 2	$8\cdot10^{-1}$	$1\cdot10^{-2}$	$7\cdot10^{-1}$	$3\cdot10^{0}$	$1,5\cdot10^{-2}$	$1\cdot10^{-1}$	—
Иски 3	$6\cdot10^{-1}$	$7\cdot10^{-3}$	$1\cdot10^{0}$	$3\cdot10^{0}$	$7\cdot10^{-3}$	$8\cdot10^{-3}$	—
Кухтуй 4	$1\cdot10^{-2}$	$7\cdot10^{-3}$	$7\cdot10^{-1}$	$4\cdot10^{0}$	$7\cdot10^{-3}$	$1\cdot10^{-2}$	—
Яма 5	$8\cdot10^{-2}$	$7\cdot10^{-3}$	$1\cdot10^{-2}$	$8\cdot10^{0}$	$7\cdot10^{-3}$	$7\cdot10^{-3}$	—
Гижига 6	$7\cdot10^{-3}$	$7\cdot10^{-3}$	$6\cdot10^{-1}$	$3\cdot10^{0}$	$7\cdot10^{-3}$	$6\cdot10^{-3}$	—
Тауй 7	$1\cdot10^{-3}$	$7\cdot10^{-3}$	$5\cdot10^{-1}$	$3\cdot10^{0}$	$7\cdot10^{-3}$	$7\cdot10^{-3}$	—
Большая 8	$8\cdot10^{-1}$	$1\cdot10^{-2}$	$7\cdot10^{-1}$	$4\cdot10^{0}$	$1\cdot10^{-3}$	$7\cdot10^{-3}$	—
Найба 9	$8\cdot10^{-1}$	$1\cdot10^{-1}$	$2\cdot10^{0}$	$7\cdot10^{0}$	$7\cdot10^{-3}$	$7\cdot10^{-3}$	$1\cdot10^{-5}$

Реки 1	Ti	Cr	Cu	Pb	Ag	Zn	Na	P	Ba	Sr
Амур* 2	$6,3\cdot10^{-3}$	—	$5\cdot10^{-4}$	—	—	$3\cdot10^{-2}$	$3\cdot10^{-2}$	$5,5\cdot10^{0}$	$1\cdot10^{-2}$	5·[illegible]
Амур** 2	$7\cdot10^{-3}$	—	$5\cdot10^{-3}$	—	—	$1,2\cdot10^{-2}$	$3\cdot10^{-2}$	$7\cdot10^{0}$	—	7·[illegible]
Иски 3	$8,3\cdot10^{-3}$	—	$1\cdot10^{-2}$	—	$1\cdot10^{-4}$	$3\cdot10^{-2}$	$5\cdot10^{-2}$	$7\cdot10^{0}$	—	3·[illegible]
Кухтуй 4	$8\cdot10^{-3}$	—	$1\cdot10^{-2}$	—	—	$7\cdot10^{-2}$	$3\cdot10^{-2}$	$8,5\cdot10^{0}$	$1\cdot10^{-2}$	5·[illegible]
Яма 5	$7\cdot10^{-3}$	—	$1\cdot10^{-2}$	$2\cdot10^{-4}$	—	$2\cdot10^{-2}$	$1\cdot10^{-1}$	$5\cdot10^{0}$	—	8·[illegible]
Гижига 6	$1\cdot10^{-2}$	—	$5\cdot10^{-4}$	$1\cdot10^{-3}$	—	$1\cdot10^{-2}$	$1\cdot10^{-1}$	$6\cdot10^{0}$	—	3·[illegible]
Тауй 7	$7\cdot10^{-3}$	—	$1\cdot10^{-2}$	—	—	$3\cdot10^{-2}$	$2\cdot10^{-2}$	$5\cdot10^{0}$	—	3·[illegible]
Большая 8	$7\cdot10^{-3}$	—	$2\cdot10^{-2}$	—	—	$2\cdot10^{-2}$	$5\cdot10^{-2}$	$7\cdot10^{0}$	—	5·[illegible]
Найба 9	$1\cdot10^{-3}$	—	$5\cdot10^{-4}$	—	—	$2\cdot10^{-2}$	$1\cdot10^{-1}$	$5\cdot10^{0}$	—	5·[illegible]

* Осенняя форма. 10
** Летняя форма. 11

KEY: (1) Rivers (2) Amur (3) Iski (4) Kukhtui (5) Yama (6) Gizhiga
(7) Taui (8) Bol'shava (9) Naiba (10) Autumn form (11) Summer form

NOTE ON THE BIBLIOGRAPHY

The Bibliography which follows is in three parts:

PART A: Translation of the original pages of titles in Russian;

PART B: The original pages of titles in Russian (pages 122-126);

PART C: The original titles in English (page 126).

Since the Russian alphabetical order differs from the English, the order of the authors in lists A and B is not identical. To facilitate cross reference between the two, the titles in list B are numbered in order and the corresponding numbers are to be found after each title in list A.

Citations in the text are by author and year. A Russian author will therefore be found directly in list A and the number at the end of the title will give the appropriate entry in the original Russian Bibliography in Part B.

BIBLIOGRAPHY

A) Translations of References in Russian

Abramov, V.V. (1953). "Adaptive features of adult salmon of the genus Oncorhynchus in fresh water," Zool. Zhurn., 32(6). /1/

Abramov, V.V. (1954). "State of the stocks and ways of increasing the numbers of Amur pink salmon," in: Proceedings of a Conference on Salmon Fishing in the Far East, Izd. Akad. Nauk SSSR. /2/

Aleekseev, K.A. (1905). Our Trade Policy in the Far East. Fishing Industries in Territorial Waters of the Priamur'e Governorship-General, No. 1. /3/

Aleksin, M.S. (1923). "The present situation of the fishing industry in the Far East and its future prospects," in: The Fish and Fur Resources of the Far East. /4/

Andrianov, F.I. (1924). "Fisheries of the Far East," Byull. Rybn. Khoz., No. 6-7. /5/

Andrievskaya, L.D. (1966). "Food relations between Pacific salmon in the sea," Voprosy Ikhtiologii, 6(1/38). /6/

Arsen'ev, V.A. (1937). "Migrations of the beluga in Sakhalin District," Izvest. TINRO, Vol. 10. /7/

Baranenkova, A.S. (1934). "Report on the study of the biology of young salmon (genus Oncorhynchus)," Rybnoe Khozyaistvo Kamchatki, No. 2 (cyclostyled). /8/

Berg, L.S. (1935). "Data on the biology of the Atlantic salmon," Izvest. VNIORKh, Vol. 20. /9/

Birman, I.B. (1954). "Population dynamics and state of the stocks of the chum and pink salmon," Proceedings of a Conference on Salmon Fishing in the Far East, Izd. Akad. Nauk SSSR. /10/

Birman, I.B. (1955). "The effect of maxima of solar activity on the conditions of reproduction of the pink salmon," Dokl. Akad. Nauk SSSR, 103(4). /11/

Birman, I.B. (1957). "The Kuroshio and the population of Amur autumn chum Oncorhynchus keta (Walb.), infrasp. autumnalis," Voprosy Ikhtiologii, No. 8. /12/

Birman, I.B. (1959). "More on the effect of the Kuroshio on the dynamics of the salmon population," Voprosy Ikhtiologii, No. 13. /13/

Birman, I.B. (1960). "Times of formation of the annual rings on the scale of the Pacific salmon and the rate of growth of the pink salmon," Dokl. Akad.

Nauk SSSR, 132(5). /14/

Birman, I.B. (1964). "Distribution pattern of Pacific salmon in the sea and the effect of environmental factors on their numbers," Salmon Fishing in the Far East, Nauka. /15/

Birman, I.B. (1966). "The effect of climatic factors on the population dynamics of the pink salmon Oncorhynchus gorbuscha (Walbaum)," Voprosy Ikhtiologii, 6(2/39). /16/

Birman, I.B., and Levanidov, V.Ya. (1953). "The pattern of fluctuations in the stocks and ways of increasing reproduction of the diadromous fish of the Amur," Proceedings of an All-Union Conference on Fisheries, Izd. Akad. Nauk SSSR. /17/

Borisov, T.M. (1925). "On the fishing season of 1924 on the Amur," Byull. Rybn. Khoz., No. 1-2. /18/

Brazhnikov, V.K. (1900). "Autumn fishing in the lower reaches of the Amur," Rybnye Promysly DV, No. 1. /19/

Brazhnikov, V.K. (1920). "The fishing industry in the Russian Far East," Russkii Dal'nii Vostok, No. 1-2. /20/

Byulleten' Glavnogo Upravleniya Rybolovstva i Gosudarstvennoi Rybnoi Promyshlennosti (Bulletin of the Board of Control of Fishing and of the State Fishing Industry), No. 9 (1923). /21/

Byulleten' Glavnogo Upravleniya po Rybolovstvu (Bulletin of the Board of Control of Fishing), No. 5 (1923). /22/

Byulleten' Rybnogo Khozyaistva (Bulletin of Fisheries), No. 4 (1925). /23/

Chernavin, V.V. (1918). "Nuptial changes in the skeleton of the salmon," Izvest. Otdela Rybovodstva, 1(1). /135/

Darda, M.A. (1965). "Distribution and conditions of life of the pink salmon in the Sea of Japan in 1961," Abstracts of Research Papers on the Available Fish Supply for the Fishing Industry of the Far East in 1959-1962, Dal'izdat. /33/

Derzhavin, A.N. (1930). Material for the Analysis of the Available Fish Supply of the Far East (lecture read at the Provincial Fisheries Conference in February, 1930), Vladivostok. /36/

Derzhavin, A.N. (1953). "The study of sea migrations of the chum and pink salmon," Rybnoe Khozyaistvo, No. 3. /37/

Dobrovol'skii, I.D. (1923). "The fishing industry in the Far East," Byulleten' Glavnogo Upravleniya Rybolovstva i Gosudarstvennoi Rybnoi Promyshlennosti, No. 18. /38/

Dvinin, P.A. (1949). "Migrations of the pink salmon near the shores of Sakhalin," Rybnoe Khozyaistvo, No. 9. /34/

Dvinin, P.A. (1952). "The salmon of Southern Sakhalin," Izvest. TINRO, Vol. 37. /35/

Ekonomicheskaya Khronika (Economic Chronicle) (1929). "Norms for salmon fishing," No. 5. /140/

Ekonomicheskaya Zhizn' Dal'nego Vostoka (Economic Life of the Far East) (1924). No. 1 (15). /139/

Enyutina, R.I. (1954a). "Morpho-biological and morphometric characteristics of the pink salmon of the Rivers Amgun' and Iski," Izvest. TINRO, Vol. 41. /39/

Enyutina, R.I. (1954b). "Local stocks of pink salmon of the Amur basin and adjacent waters," Voprosy Ikhtiologii, No. 2. /40/

Enyutina, R.I. (1955). Local Stocks of Pink Salmon of the River Amur and Contiguous Rivers and Some Special Features of their Biology. Author's Abstract of Dissertation, Vladivostok. /41/

Enyutina, R.I. (1962). "An extra ring in the nuclear part of the scale of the pink salmon Oncorhynchus gorbuscha (Walb.)," Voprosy Ikhtiologii, 2(4/25). /42/

Enyutina, R.I. (1963). "Some data on growth and scale structure of the pink salmon Oncorhynchus gorbuscha (Walb.)," Voprosy Ikhtiologii, 3(4). /43/

Enyutina, R.I., and Krykhtin, M.L. (1957). "Cases of catching salmon with Japanese fish hooks in Amur Sound," Zoologicheskii Zhurnal, 36(9). /44/

Frolov, A.I. (1950). "Local forms of Sakhalin herring," Izvest. TINRO, Vol. 32. /131/

Frolov, A.I. (1965). "Distribution of pink salmon and chum in 1961 in Pacific waters adjacent to the Kurile Islands and in the southern part of the Sea of Okhotsk," Abstracts of Research Papers on the Available Supply of Fish for the Fishing Industry of the Far East in 1959-1962. Dal'izdat. /132/

Geineman, B.A. (1911). "The Fishing Industry in the waters of the Far East in 1910," Material Collected by the Study of the Priamur'e Province, No. 1, Khabarovsk. /31/

Gruzdovskii, V.E. (1925). The Far Eastern Region, Vladivostok. /32/

Hirano, I. (1951). "Pathways of migration of salmon in the north-western part of the Pacific Ocean deduced from the results of tagging in past years," Bull. Jap. Soc. Scientific Fisheries, 18(10). /133/

Il'in, M.D. (1927). "The fish canning industry in Amur Sound," Izvest. GIGA (Leningrad), 5(2-3). /47/

Ioganzen, B.G. (1955). "The study of fecundity of fish," Trudy Tomsk. Gos. Univ., Vol. 131. /48/

Kaganovskii, A.G. (1949). "Some aspects of the biology and population dynamics of the pink salmon," Izvest. TINRO, Vol. 31. /49/

Kokhmenko, L.V. (1964). "Food relations of young Pacific salmon with resident and certain diadromous fish in the foothill tributaries of the Amur," Izvest. TINRO, Vol. 55. /56/

Kokhmenko, L.V. (1965). "Feeding and food relations of the genus Salvelinus with young of the Pacific salmon," Voprosy Ikhtiologii, 5(2-35). /57/

Kol'gaev, A.M. (1965). "Production tests of incubation of the eggs and maintenance of the prelarval salmon in gravel ," Rybnoe Khozyaistvo, No. 5. /52/

Kol'gaev, A.M., and Ivanova, A.P. (1960). A Method of Breeding Young Fish, Such as Salmon, and an Apparatus for Application of the Method. Author's Certificate* No. 127111. /53/

Kostarev, V.L. (1964). "The connection between the abundance of young chum and the depth of the snow cover and air temperature in the winter period," Rybnoe Khozyaistvo, No. 9. /54/

Kotov, V.L. (1957). "Safeguarding and regulating Pacific salmon fishing," Rybnoe Khozyaistvo, No. 12. /55/

Kozakov, M.A. (1923). "The position of the fishing industry in the Far East," Byulleten' Glavnogo Upravleniya Rybolovstva i Gosudarstvennoi Rybnoi Promyshlennosti, No. 2. /50/

Kozakov, M.A. (1924). "Agreement with Japanese fishing industrialists," Byull. Rybn. Khoz., No. 6-7. /51/

Kramarenko, G.A. (1898). "The fishing industry on the River Amur and the island of Sakhalin," Astrakhanskii Listok, Nos. 2 and 6. /58/

Krykhtin, M.L., and Smirnov, A.G. (1962). "Connection between numbers and qualitative indices of spawning stocks of Amur salmon," Voprosy Ikhtiologii, 2(1/22). /59/

* I.e. Soviet patent - Translator.

Kuznetsov, I.I. (1923). "The importance of salmon fishing in the Far East and artificial fish breeding as one of the chief measures for preservation of the fish stocks," in: Fish and Fur Resources of the Far East, Nauchprombyuro Dal'rybokhoty. /60/

Kuznetsov, I.I. (1926). "The role of colonization and forestry in the exhaustion of the salmon stocks of the Far East," Byull. Rybn. Khoz., No. 2. /61/

Kuznetsov, I.I. (1928). "Some observations on reproduction of the Amur and Kamchatka salmon," Izvest. Tikhookeanskoi Nauchno-Promyslovoi Stantsii, 2(3). /62/

Kuznetsov, I.I. (1937). The Chum and its Reproduction. Dal'giz, Khabarovsk. /63/

Lagutin, A.N. (1926). The Far Eastern Province in Statistics. Knizhnoe Delo, Vladivostok. /64/

Lapin, Yu.E. (1963). "The age and population dynamics of the Pacific pink salmon Oncorhynchus gorbuscha (Walb.)," Voprosy Ikhtiologii, 3(2/27). /65/

Lebedev, E. (1916a). "The Japanese fishing industry in Russian waters in 1913", Materialy k Poznaniyu Russkogo Rybolovstva, 5(2). /66/

Lebedev, E. (1916b). "The Japanese fishing industry in the waters of the Priamur'e Governorship-General in 1914," Materialy k Poznaniyu Russkogo Rybolvstva, 5(12). /67/

Levanidov, V.Ya. (1962a). "The use of vital staining of young Pacific salmon for their quantitative study," Izvest. TINRO, Vol. 48. /68/

Levanidov, V.Ya. (1962b). "Stocks of the Amur pink salmon and waterworks," Izvest. TINRO, Vol. 48. /69/

Levanidov, V.Ya. (1964a). "The pattern of the population dynamics of the salmon in the Amur basin and ways of reproducing its stocks," Salmon Fishing in the Far East, Nauka. /70/

Levanidov, V.Ya. (1964b). "The feeding of young autumn chum during their migration along the Amur," Izvest. TINRO, Vol. 55. /71/

Levanidov, V.Ya. (1964c). "The connection between the completeness of occupation of the spawning grounds and the efficiency of spawning of the Amur salmon," Izvest. TINRO, Vol. 55. /72/

Levanidov, V.Ya. (1965). "The present population of Amur summer salmon and their distribution within the spawning ground," Abstracts of Research Papers on the Available Supply of Fish for the Fishing Industry of the Far East in 1959-1962. Dal'izdat. /73/

Levanidov, V.Ya. (1969). "Reproduction of the Amur salmon and available food for their young in the tributaries of the Amur," Izvest. TINRO, Vol. 67. /74/

Levanidov, V.Ya., and Levanidova, I.M. (1957). "Feeding of young downstream migrant summer chum and pink salmon in tributaries of the Amur," Izvest. TINRO, Vol. 45. /75/

Lotsiya Vostochnogo Berega Sibiri Navigation along the East Coast of Siberia), Dal'giz, 1932. /76/

Lukin, E.I. (1955). "The leech fauna in the basin of the River Amur," Zool. Zhurn., 34(2). /77/

Lukin, E.I. (1962). "Characteristic features of the leech fauna of the Amur basin," Izvest. TINRO, Vol. 48. /78/

Lundberg, A.R., and Shelegova, E.K. (1965). "Hydrological conditions of the fish habitat in Sakhalin waters and special features of the waters of the Tatar Straits in 1961," Abstracts of Research Papers on the Available Supply of Fish for the Fishing Industry of the Far East in 1959-1962. /79/

Lysaya, N.M. (1951). "Changes in the blood composition of salmon during the spawning migrations," Izvest. TINRO, Vol. 35. /80/

Makeeva, A.P. (1956). "One cause of prespawning mortality of pink salmon in rivers," Zool. Zhurn., 35(11). /81/

Materialy po perepisi naseleniya v 1926, 1939 i 1959 gg. Khabarovskogo kraevogo statisticheskogo upravleniya (Census Returns for 1926, 1939 and 1959 issued by Khabarovsk Provincial Statistical Department). /82/

Milovidova-Dubrovskaya, N.V. (1937). "Data on the biology and commercial exploitation of the Primor'e pink salmon," Izvest. TINRO, Vol. 12. /83/

Miyaguchi, K. (1959). "On the 'fingerling ring' found on the pink salmon scale," Scientific Reports of the Hokkaido Regional Fisheries Research Institute, No. 20. /84/

Moiseev, P.A. (1956a). "Commercial salmon fishing in the open sea in the northern part of the Pacific Ocean," Rybnoe Khozyaistvo, No. 4. /85/

Moiseev, P.A. (1956b). "Dynamics of the population of the commercially important fauna in the north-western part of the Pacific Ocean and its causes," Zool. Zhurn., 35(11). /86/

Monastyrskii, G.N. (1952). "Dynamics of the population of commercially important fish," Trudy VNIRO, Vol. 21. /87/

Navozov-Lavrov, N.P. (1924). "The environment of the Pacific salmon," Byull.

Rybnogo Khozyaistva, No. 10-12. /88/

Navozov-Lavrov, N.P. (1925). "The fishing industry and combined scientific and industrial research," Ekonomicheskaya Zhizn' Dal'nego Vostoka, No. 2. /89/

Navozov-Lavrov, N.P. (1927). "Results of a study of the commercial exploitation and ecology of salmon in the River Amur in 1923," Proizvoditel'nye Sily DV, No. 4. /90/

Nikol'skii, G.V. (1939). "Instructions for compiling an inventory of the fish fauna in reservations," Nauchno-Metod. Zapiski Glav. Uprav. po Zapov., No. 5. /91/

Nikol'skii, G.V. (1950). "The biological basis for fishing quotas and ways of controlling the numbers of fish stocks," Zool. Zhurn., 29(1). /92/

Nikol'skii, G.V. (1952). "The type of dynamics of the stocks and character of spawning of the pink salmon Oncorhynchus gorbuscha (Walb.) and chum Oncorhynchus keta (Walb.) in the Amur," Dokl. Akad. Nauk SSSR, 36(4). /93/

Nikol'skii, G.V. (1954). Special Ichthyology, Sovetskaya Nauka. /94/

Nikol'skii, G.V. (1955). "The scope, theoretical basis, and main problems of animal ecology," Zool. Zhurn., 34(1). /95/

Nikol'skii, G.V. (1956). "Fisheries improvement stations for the reproduction of far-eastern salmon," Rybnoe Khozyaistvo, No. 2. /96/

Parakhin, S. (1923). "Prospects for the fishing industry in the Far East," Byull. Glav. Uprav. Rybolovstva i Gos. Rybnoi Promyshlennosti, No. 7. /97/

Persov, G.M. (1965). "Redifferentiation of the gonads in the pink salmon (Oncorhynchus gorbuscha Walbaum) as a normal feature of development," Nauch. Dokl. Vyssh. Shkoly. Biol. Nauki, No. 1. /98/

Plokhinskii, A.P. (1961). Biometrics, Izd. Sib. Otdel. Akad. Nauk SSSR. /99/

Pravdin, I.F. (1932). "The Amur pink salmon (Oncorhynchus gorbuscha natio amurensis nova)," Izvest. Inst. Ozern. i Rechn. Rybn. Khozyaistva, Vol. 14. /100/

Pravdin, I.F. (1940). "A survey of research into far-eastern salmon," Izvest. TINRO, Vol. 18. /101/

Pushkareva, N.F. (1951). "The feeding of the pink salmon at the end of the sea stage of its migration path," Izvest. TINRO, Vol. 35. /102/

Red'ko, B.A. (1929). "Fisheries," A Handbook on the Far Eastern Province, Izd. KUBUI. /103/

Rubin, S.I. (1931). "The economic grounds for the DGRT canning factory in Datta Creek," Sots. Rekonstruktsiya Rybnogo Khozyaistva DV, No. 11-12. /104/

Rusanov, P.A. (1924a). "The Amur Fisheries District," Ekonomicheskaya Zhizn' Primor'ya, No. 5(9). /105/

Rusanov, P.A. (1924b). "A brief account of the Far-Eastern fishing industry," Ekonomicheskaya Zhizn' Primor'ya, Nos. 3(7) and 4(8). /106/

Sato, R. (1938). Newly Discovered Pathways of Migration of Salmon after Experimental Release of Tagged Fish in Northern Waters of the Pacific Ocean in 1936 (Paper III). Translated from the Japanese. /107/

Semko, R.S. (1939). "The Kamchatka pink salmon," Izvest. TINRO, Vol. 16. /108/

Semko, R.S. (1948). "Biocoenotic relations between the Pacific salmon and char in spawning and foraging sectors of the River Bol'shaya (west coast of Kamchatka)," Zool. Zhurn., 27(1). /109/

Semko, R.S. (1954). "Stocks of West Kamchatka salmon and their commercial use," Izvest. TINRO, Vol. 41. /110/

Semko, R.S. (1958). "Some data on the commercial exploitation, spread and migrations of the far-eastern salmon in the open sea," Data on the Biology of the Maritime Period of Life of the Far-Eastern Salmon, Moscow. /111/

Shelegova, E.K., and Lundberg, A.R. (1965). "Hydrological charateristics of the habitat conditions of fish in the second half of 1959 and in 1960 in waters surrounding Sakhalin," Abstracts of Research Papers on the Available Supply of Fish for the Fishing Industry of the Far East in 1959-1962. /136/

Shmidt, P.Yu. (1905). The Sea Industries of Sakhalin. Izd. Dep. Zemledeliva. /137/

Shmidt, P.Yu. (1950). The Fish of the Sea of Okhotsk. Izd. Akad. Nauk SSSR. /138/

Sleptsov, M.M. (1952). "The Cetacea of the far-eastern seas," Izvest. TINRO, Vol. 38. /112/

Smetanin, K.A. (1929). "The fisheries of the Far Eastern Province," in: A Survey of the Pre-War and Present State of the Fisheries of the USSR. Proceedings of the Scientific Institute of Fisheries, Vol. 4, Moscow. /113/

Smirnov, A.G. (1947). "State of the stocks of Amur salmon and causes of fluctuation in their numbers," Izvest. TINRO, Vol. 25. /114/

Smirnov, A.I. (1964). "Special features of the ontogeny of Pacific salmon in connection with the reproduction of their stocks," Salmon Fishing in the Far East, Nauka. /115/

Soin, S.G. (1954). "The development pattern of the summer chum, pink salmon and masu," Proceedings of a Conference on Salmon Fishing in the

Far East, Izd. Akad. Nauk SSSR. /116/

Soldatov, V.K. (1912). "Investigation of the biology of the Amur salmon," Rybnye Promysly Dal'nego Vostoka, Vol. 7. /117/

Soldatov, V.K. (1924a). "Is artificial breeding of the Pacific salmon necessary?" Byull. Rybnogo Khozyaistva, No. 4-5. /118/

Soldatov, V.K. (1924b). "Far Eastern problems," Byull. Rybnogo Khozyaistva, No. 10-12. /119/

Soldatov, V.K. (1938). Commercial Ichthyology. Pishchepromizdat, Moscow and Leningrad. /120/

Somov, M.P. (1929). "The importance of the fishing quota under the conditions of fisheries of the Far Eastern Province," Rybnye Khozyaistvo Dal'nego Vostoka, No. 1. /121/

Starovoitov, P.A. (1926). "The salmon catch in the 1926 season in the lower reaches of the Amur," Byull. Byull. Rybnogo Khozyaistva, No. 11-12. /122/

Strekalova, I.I. (1954). "Special features of the biology of reproduction of the summer chum Oncorhynchus keta (Walb.) and the pink salmon Oncorhynchus gorbuscha (Walb.) and their relations with each other in the spawning grounds." Author's abstract of Dissertation. /123/

Susumo Sugano (no date). The Connection Between Salmon Runs and the State of the Sea on the West Coast of Kamchatka. Translated from the Japanese. /124/

Taguchi, K. (1963). Exploitation and State of the Stocks of Salmon in the Northern Part of the Pacific Ocean. Translation from the Japanese. /125/

Taranets, A.Ya. (1938). "Resources of the seas and rivers of the Far Eastern Province," Vestnik DV Filiala Akad. Nauk SSSR, 30(3). /126/

Taranets, A.Ya. (1939). "Investigations of the spawning grounds of the chum and pink salmon in the River Iski," Rybnye Khozyaistvo, No. 12. /127/

Tikhenko, S.A. (1915). "The fishing industries of the Far East in 1913 as reflected in statistics of the Priamur'e Department of State Resources," Materialy k Poznaniyu Russkogo Rybolovstva, 4(7). /128/

Tikhii, M.I. (1926). "The West Kamchatka pink salmon and its age," Izvest. Otdela Prikladnoi Ikhtiologii i Nauchno-Promysl. Issled., 4(2). /129/

Trautshol'd, V. (1912). "The Japanese fishing industry in the waters of Priamur'e in 1910 (report of the Imperial Russian Vice-Consulate in Hakodate)," Materialy k Poznaniyu Russkogo Rybolovstva, 1(4). /130/

Tselishchev, M.I. (1924). "The fur and fishing industries of the Far Eastern

Region," Ekonomicheskaya Zhizn' Dal'nego Vostoka, No. 6(10). /134/

Vasilenko, O.V. (1959). "Problems in the biology of the Primor'e pink salmon," Izvest. TINRO, Vol. 47. /24/

Vasil'ev, I.S. (1958). "The water supply to the redds of the pink salmon and summer chum," Nauch. Dokl. Vyssh. Shkoly. Biol. Nauki, No. 3. /25/

Vasil'ev, I.S. (1959). "Ecological and morphological characteristics of the summer chum and pink salmon in the embryonic and larval periods of their life," Author's Abstract of Dissertation. /26/

Vedenskii, A.P. (1954). "The age of the pink salmon and pattern of fluctuations in its numbers," Izvest. TINRO, Vol. 41. /27/

Volovik, S.P. (1964). "Feeding relations between the young masu and other young salmon in the rivers of Sakhalin," Izvest. TINRO, Vol. 55. /28/

Vorotnikov, V.I. (1927). "The Amur-Sakhalin industries of Dal'gosrybtrest in the fishing season of 1926," Byull. Rybnogo Khozyaistva, No. 5. /29/

Voskresenskii, N.A. (1948). "Rational disposition of static fishing equipment in Amur Sound," Rybnoe Khozyaistvo, No. 5. /30/

Zamakhaev, D.F. (1959). "Types of size and sex correlations in fish," Trudy Moskovsk. Tekhn. Inst. Rybn. Prom. i Khozyaistva, No. 10. /45/

Zueva, K.D. (1965). "The existence of a smoltification process in the pink salmon <u>Oncorhynchus gorbuscha</u> (W.) in the absence of the 'parr' stage," Voprosy Ikhtiologii, 5(2/35). /46/

B) Original References in Russian

ЛИТЕРАТУРА

1 Абрамов В. В. 1953. Приспособительные признаки взрослых лососей рода Oncorhynchus в пресных водах. «Зоол. журн.», т. XXXII, вып. 6.

2 Абрамов В. В. 1954. Состояние запасов и пути увеличения численности амурской горбуши. Тр. совещания по вопросам лососевого хозяйства Дальнего Востока. Изд. АН СССР.

3 Алексеев К. А. 1905. Наша торговая политика на Дальнем Востоке. Рыбные промыслы в территориальных водах Приамурского генерал-губернаторства, вып. 1.

4 Алексин М. С. 1923. Современное положение рыбной промышленности на Дальнем Востоке и ее ближайшие перспективы. Сб. Рыбные и пушные богатства Дальнего Востока.

5 Андрианов Ф. И. 1924. Рыбное хозяйство Дальнего Востока. Бюлл. рыбн. хоз-ва, № 6 — 7.

6 Андриевская Л. Д. 1966. Пищевые взаимоотношения тихоокеанских лососей в море. «Вопросы ихтиологии», т. 6, вып. 1 (38).

7 Арсеньев В. А. 1937. О миграциях белухи в Сахалинском районе. Изв. ТИНРО, т. 10.

8 Бараненкова А. С. 1934. Отчет о работах по изучению биологии молоди лососевых (род. Oncorhynchus). Рыбное хозяйство Камчатки, № 2 (ротаторное оформление).

9 Берг Л. С. 1935. Материалы по биологии семги. Изв. ВНИОРХ, т. XX.

10 Бирман И. Б. 1954. Динамика численности и состояние запасов кеты и горбуши. Тр. Совещания по вопросам лососевого хозяйства Дальнего Востока. Изд. АН СССР.

11 Бирман И. Б. 1955. О влиянии максимумов солнечной активности на условия размножения горбуши. ДАН СССР, т. 103, № 4.

12 Бирман И. Б. 1957. Куро-Сио и численность амурской осенней кеты (Oncorhynchus keta [Walb]. infrasp. autumnalis). «Вопросы ихтиологии», вып. 8.

13 Бирман И. Б. 1959. Еще о влиянии Куро-Сио на динамику численности лососей. «Вопросы ихтиологии», вып. 13.

14 Бирман И. Б. 1960. О сроках формирования годовых колец на чешуе тихоокеанских лососей и темпе роста горбуши. ДАН СССР, т. 132, № 5.

15 Бирман И. Б. 1964. Закономерности распределения тихоокеанских лососей в море и влияние факторов среды на их численность. «Лососевое хозяйство Дальнего Востока». Изд. «Наука».

16 Бирман И. Б. 1966. Влияние климатических факторов на динамику численности горбуши Oncorhynchus gorbuscha (Walbaum). «Вопросы ихтиологии», т. 6, вып. 2(39).

17 Бирман И. Б. и Леванидов В. Я. 1953. Закономерности динамики стад и пути усиления воспроизводства проходных лососей Амура. Тр. Всесоюзной конференции по вопросам рыбного хозяйства. Изд. АН СССР.

18 Борисов Т. М. 1925. К рыболовному сезону 1924 г. на Амуре. «Бюллетень рыбного хозяйства», № 1 — 2.

19 Бражников В. К. 1900. Осенний промысел в низовьях Амура. «Рыбные промыслы ДВ», № 1.

20 Бражников В. К. 1920. Рыбная промышленность на русском Дальнем Востоке. «Русский Дальний Восток», № 1 — 2.

21 Бюллетень Главного управления рыболовства и государственной рыбной промышленности, № 9, 1923.

22 Бюллетень Главного управления по рыболовству, № 5, 1923.

23 Бюллетень рыбного хозяйства, № 4, 1925.

24 Василенко О. В. 1959. Вопросы биологии приморской горбуши. Изв. ТИНРО, т. 47.

25 Васильев И. С. 1958. Водоснабжение нерестовых бугров горбуши и летней кеты. Научн. докл. высш. школы. Биологические науки, 3.

26 Васильев И. С. 1959. Эколого-морфологическая характеристика летней кеты и горбуши в эмбриональный и личиночный периоды их жизни. Автореферат диссертации.

27 Веденский А. П. 1954. Возраст горбуши и закономерности колебаний ее численности. Изв. ТИНРО, т. 41.

28 Воловик С. П. 1964. Пищевые отношения молоди симы с молодью других лососевых в реках Сахалина. Изв. ТИНРО, т. 55.

29 Воротников В. И. 1927. Амурско-сахалинские промыслы Дальгосрыбтреста в рыболовный сезон 1926 г. Бюлл. рыбн. хоз-ва, № 5.

30 Воскресенский Н. А. 1948. Рациональное размещение стационарных орудий лова в лимане Амура. «Рыбное хозяйство», № 5.

31 Гейнеман Б. А. 1911. Рыбный промысел в водах Дальнего Востока в 1910 г. Материалы по изучению Приамурского края, вып. 1, Хабаровск.

32 Глуздовский В. Е. 1925. Дальневосточная область. Владивосток.

33 Дарда М. А. 1965. Распределение и условия обитания горбуши в Японском море в 1961 году. Аннотации научных работ по исследованию сырьевой базы рыбной промышленности Дальнего Востока в 1959 — 1962 гг. Дальиздат.

34 Двинин П. А. 1949. Миграции горбуши у берегов Сахалина. «Рыбное хозяйство», № 9.

35 Двинин П. А. 1952. Лососи Южного Сахалина. Изв. ТИНРО, т. 37.

36 Державин А. Н. 1930. Материалы для учета сырьевых ресурсов Дальнего Востока (доклад, прочитанный на Краевом рыбохозяйственном совещании в феврале 1930 г.), Владивосток.

37 Державин А. Н. 1933. К изучению морских миграций кеты и горбуши. «Рыбное хозяйство», № 3.

38 Добровольский И. Д. 1923. Рыбная промышленность на Дальнем Востоке. Бюллетень Главного управления рыболовства и государственной рыбной промышленности, № 18.

39 Енютина Р. И. 1954а. Морфобиологическая и морфометрическая характеристика горбуши рек Амгуни и Иски. Изв. ТИНРО, т. 41.

40 Енютина Р. И. 1954б. Локальные стада горбуши Амурского бассейна и прилежащих вод. «Вопросы ихтиологии», вып. 2.

41 Енютина Р. И. 1955. Локальные стада горбуши р. Амура и сопредельных рек и некоторые особенности их биологии. Автореферат диссертации. Владивосток.

42 Енютина Р. И. 1962. О дополнительном кольце в ядерной части чешуи горбуши Oncorhynchus gorbuscha (Walb.). «Вопросы ихтиологии», т. 2 вып. 4(25).

43 Енютина Р. И. 1963. Некоторые данные о росте и структуре чешуи горбуши — Oncorhynchus gorbuscha (Walb.). «Вопросы ихтиологии», т. 3, вып. 4.

44 Енютина Р. И. и Крыхтин М. Л. 1957. О случаях поимки лососей с японскими рыболовными крючками в Амурском лимане. «Зоологический журнал», т. XXXVI, вып. 9.

45 Замахаев Д. Ф. 1959. О типах размерно-половых соотношений у рыб. Тр. Моск. техн. ин-та рыбн. пром. и хозяйства, вып. X.

46 Зуева К. Д. 1965. Наличие процесса смолтификации у горбуши — Oncorhynchus gorbuscha (W) при отсутствии стадии «parr». Вопросы ихтиологии», т. 5, вып. 2(35).

47 Ильин М. Д. 1927. Рыбоконсервное производство в Амурском лимане. Изв. ГИОА, т. 5, вып. 2 — 3, Л.

48 Иоганзен Б. Г. 1955. К изучению плодовитости рыб. Тр. Томского государственного университета, т. 131.

49 Кагановский А. Г. 1949. Некоторые вопросы биологии и динамики численности горбуши. Изв. ТИНРО, т. 31.

50 Козаков М. А. 1923. Положение рыбопромышленности на Дальнем Востоке. Бюлл. Главного управления рыболовства и гос. рыбной промышленности, № 2.

51 Козаков М. А. 1924. Соглашение с японскими рыбопромышленниками. Бюлл. рыбного хозяйства, № 6 — 7.

52 Кольгаев А. М. 1965. Производственная проверка инкубации икры и выдерживания предличинок лососей в гальке. «Рыбное хозяйство», № 5.

53 Кольгаев А. М. и Иванова А. П. 1960. Способ разведения молоди рыб, например, лососей, и устройство для осуществления способа. Авторское свидетельство, № 127111.

54 Костарев В. Л. 1964. О связи урожайности молоди кеты с высотой снежного покрова и температурой воздуха в зимний период. «Рыбное хозяйство» № 9.

55 Котов В. Л. 1957. Об охране и регулировании промысла тихоокеанских лососей. «Рыбное хозяйство». № 12.

56 Кохменко Л. В. 1964. Пищевые отношения молоди тихоокеанских лососей с жилыми и некоторыми проходными рыбами в предгорных притоках Амура. Изв. ТИНРО, т. 55.

57 Кохменко Л. В. 1965. Питание и пищевые отношения рода Salvelinus с молодью тихоокеанских лососей. «Вопросы ихтиологии», т. 5, вып. 2(35).
58 Крамаренко Г. А. 1898. Рыбные промыслы на реке Амуре и острове Сахалине. «Астраханский листок», № 2 и 6.
59 Крыхтин М. Л. и Смирнов А. Г. 1962. О взаимосвязи численности и качественных показателей нерестовых стад амурских лососей. «Вопросы ихтиологии», т. 2, вып. 1(22).
60 Кузнецов И. И. 1923. Значение промысла лососевых Дальнего Востока и искусственное рыборазведение как одно из главнейших средств для охранения рыбных запасов. Сб. «Рыбные и пушные богатства Дальнего Востока». Научпромбюро Дальрыбохоты.
61 Кузнецов И. И. 1926. Роль колонизации и лесопромышленности в вопросах истощения запасов лососевых Дальнего Востока. Бюлл. рыбного хозяйства, № 2.
62 Кузнецов И. И. 1928. Некоторые наблюдения над размножением амурских и камчатских лососей. Изв. Тихоокеанской научно-промысловой станции, т. 2, вып. 3.
63 Кузнецов И. И. 1937. Кета и ее воспроизводство. Дальгиз, Хабаровск.
64 Лагутин А. Н. 1926. Дальневосточный край в цифрах. «Книжное дело», Владивосток.
65 Лапин Ю. Е. 1963. О возрасте и динамике численности тихоокеанской горбуши Oncorhynchus gorbuscha (Walb.). «Вопросы ихтиологии», т. 3, вып. 2(27).
66 Лебедев Е. 1916а. Японская рыбопромышленность в русских водах в 1913 г. Материалы к познанию русского рыболовства, т. V, вып. 2.
67 Лебедев Е. 1916б. Японский рыбный промысел в водах Приамурского генерал-губернаторства в 1914 г. Материалы к познанию русского рыболовства, т. V, вып. 12.
68 Леванидов В. Я. 1962а. О применении витального окрашивания мальков тихоокеанских лососей для их количественного учета. Изв. ТИНРО, т. 48.
69 Леванидов В. Я. 1962б. Запасы амурских лососей и гидростроительство. Изв. ТИНРО, т. 48.
70 Леванидов В. Я. 1964а. Закономерности динамики численности лососей в бассейне Амура и пути воспроизводства запасов. «Лососевое хозяйство Дальнего Востока». Изд. «Наука».
71 Леванидов В. Я. 1964б. Питание молоди осенней кеты во время миграции по Амуру. Изв. ТИНРО, т. 55.
72 Леванидов В. Я. 1964в. О связи между плотностью заполнения нерестилищ и эффективностью нереста амурских лососей. Изв. ТИНРО, т. 55.
73 Леванидов В. Я. 1965. Современная численность амурских летних лососей и распределение их внутри нерестового ареала. Аннотации научных работ по исследованию сырьевой базы рыбной промышленности Дальнего Востока в 1959 — 1962 гг. Дальиздат.
74 Леванидов В. Я. 1969. Воспроизводство амурских лососей и кормовая база их молоди в притоках Амура. Изв. ТИНРО, т. 67.
75 Леванидов В. Я., Леванидова И. М. 1957. Питание покатной молоди летней кеты и горбуши в притоках Амура. Изв. ТИНРО, т. 45.
76 Лоция восточного берега Сибири, Дальгиз, 1932.
77 Лукин Е. И. 1955. К фауне пиявок бассейна реки Амура. «Зоологический журнал», т. XXXIV, вып. 2.
78 Лукин Е. И. 1962. Характерные черты фауны пиявок бассейна Амура. Изв. ТИНРО, т. 48.
79 Лундберг А. Р., Шелегова Е. К. 1965. Гидрологические условия обитания рыб в водах Сахалина и особенности режима вод Татарского пролива в 1961 году. Аннотации научных работ по исследованию сырьевой базы рыбной промышленности Дальнего Востока в 1959 — 1962 гг. Дальиздат.
80 Лысая Н. М. 1951. Об изменении состава крови лососей в период нерестовых миграций. Изв. ТИНРО, т. 35.
81 Макеева А. П. 1956. Об одной из причин преднерестовой гибели горбуши в реках. «Зоологический журнал», т. XXXV, вып. 11.
82 Материалы по переписи населения в 1926, 1939 и 1959 гг. Хабаровского краевого статистического управления.
83 Миловидова-Дубровская Н. В. 1937. Материалы по биологии и промыслу приморской горбуши. Изв. ТИНРО, т. 12.
84 Миягучи К. 1959. О так называемом «мальковом кольце», обнаруживающемся на чешуе горбуши. Научные доклады Хоккайдского регионального научно-исследовательского рыбохозяйственного института, № 20.
85 Моисеев П. А. 1956а. Промысел лососей в открытом море в северной части Тихого океана, «Рыбное хозяйство, № 4.
86 Моисеев П. А. 1956б. Особенности динамики численности промысловой фауны в северо-западной части Тихого океана и ее причины. «Зоологический журнал», т. XXXV, вып. 11.

87 Монастырский Г. Н. 1952. Динамика численности промысловых рыб. Тр. ВНИРО, т. 21.
88 Навозов-Лавров Н. П. 1924. Вокруг тихоокеанского лосося. Бюлл. рыбного хозяйства, № 10 — 12.
89 Навозов-Лавров Н. П. 1925. Рыбная промышленность и научно-промысловые исследования. Экономическая жизнь Дальнего Востока, № 2.
90 Навозов-Лавров Н. П. 1927. Результаты работ по обследованию промысла и этологии лососевых р. Амура в 1923 г. «Производительные силы ДВ», вып. 4.
91 Никольский Г. В. 1939. Инструкция по инвентаризации фауны рыб в заповедниках. Научно-метод. записки Гл. упр. по запов., вып. 5.
92 Никольский Г. В. 1950. О биологическом обосновании контингента вылова и пути управления численностью стада рыб. «Зоологический журнал», т. XXIX, вып. 1.
93 Никольский Г. В. 1952. О типе динамики стада и характере нереста горбуши Onc. g. (Walb.) и кеты Onc. keta (Walb.) в Амуре. ДАН СССР, т. 36, № 4.
94 Никольский Г. В. 1954. Частная ихтиология. Изд. «Советская наука».
95 Никольский Г. В. 1955. О содержании, теоретических основах и основных задачах экологии животных. «Зоологический журнал», т. XXXIV, вып. 1.
96 Никольский Г. В. 1956. Рыбоводно-мелиоративные станции по воспроизводству дальневосточных лососей. «Рыбное хозяйство», № 2.
97 Парахин С. 1923. Перспективы рыбной промышленности на Дальнем Востоке. Бюлл. Гл. упр. рыболовства и гос. рыбной промышленности, № 7.
98 Персов Г. М. 1965. Передифференцировка гонад у горбуши (Oncorhynchus gorbuscha Walbaum) как норма развития. Научн. докл. высш. школы. Биологические науки, № 1.
99 Плохинский А. П. 1961. Биометрия. Изд. Сиб. отд. АН СССР.
100 Правдин И. Ф. 1932. Амурская горбуша (Oncorhynchus gorbuscha natio amurensis nova). Изв. Инст. озерного и речного рыбного хозяйства, т. 14.
101 Правдин И. Ф. 1940. Обзор исследований дальневосточных лососей. Изв. ТИНРО, т. 18.
102 Пушкарева Н. Ф. 1951. Питание горбуши в конце морского этапа миграционного пути. Изв. ТИНРО, т. 35.
103 Редько Б. А. 1929. Рыбное хозяйство. «Настольный справочник ДВ край». Изд. КУБУЧ.
104 Рубин С. И. 1931. Экономическое обоснование консервного завода, ДГРТ в бухте Датта. Журн. «Соц. реконструкция рыбного хозяйства ДВ», № 11 — 12.
105 Русанов П. А. 1924а. Район Амурского рыболовства. «Экономическая жизнь Приморья», № 5(9).
106 Русанов П. А. 1924б. Краткий очерк дальневосточной рыбопромышленности. «Экономическая жизнь Приморья», № 3(7), 4(8).
107 Сато Р. 1938. О вновь выясненных путях миграций лососевых на опытах выпуска меченых в северных водах Тихого океана в 1936 году (статья III). Перевод с японского.
108 Семко Р. С. 1939. Камчатская горбуша. Изв. ТИНРО, т. 16.
109 Семко Р. С. 1948. О биоценотических взаимоотношениях тихоокеанских лососей и гольцов в нерестово-выростных участках р. Большой (зап. побережье Камчатки). «Зоологический журнал», т. 27, вып. 1.
110 Семко Р. С. 1954. Запасы западно-камчатских лососей и их промысловое использование. Изв. ТИНРО, т. 41.
111 Семко Р. С. 1958. Некоторые данные о промысле, распространении и миграциях дальневосточных лососей в открытом море. Материалы по биологии морского периода жизни дальневосточных лососей. М.
112 Слепцов М. М. 1952. Китообразные дальневосточных морей. Изв. ТИНРО, т. 38.
113 Сметанин К. А. 1929. Рыбное хозяйство Дальневосточного края. В кн. «Обзор предвоенного и современного состояния рыбного хозяйства СССР». Тр. научного института рыбного хозяйства, т. 4, М.
114 Смирнов А. Г. 1947. Состояние запасов амурских лососей и причины их численных колебаний. Изв. ТИНРО, т. 25.
115 Смирнов А. И. 1964. Особенности онтогенеза тихоокеанских лососей в связи с воспроизводством их запасов. «Лососевое хозяйство Дальнего Востока». Изд. «Наука».
116 Сонн С. Г. 1954. Закономерности развития летней кеты, горбуши и симы. Тр. совещания по вопросам лососевого хозяйства Дальнего Востока. Изд. АН СССР.
117 Солдатов В. К. 1912. Исследование биологии лососевых Амура. Рыбные промыслы Дальнего Востока, VII.
118 Солдатов В. К. 1924а. Нужно ли искусственное разведение тихоокеанских лососей. Бюлл. рыбного хозяйства, № 4 — 5.
119 Солдатов В. К. 1924б. Дальневосточные проблемы. Бюлл. рыбного хозяйства, № 10 — 12.
120 Солдатов В. К. 1938. Промысловая ихтиология. Пищепромиздат, М, Л.

121 Сомов М. П. 1929. Значение контингента вылова в условиях рыбного хозяйства ДВК. «Рыбное хозяйство Дальнего Востока», № 1.

122 Старовойтов П. А 1926. Лов лососевых в сезон 1926 года в низовьях Амура. Бюлл. рыбного хозяйства, № 11 — 12.

123 Стрекалова И. И. 1954. Особенности биологии размножения летней кеты [Oncorhynchus keta (Walb.)] и горбуши [Oncorhynchus gorbuscha (Walb.)] и взаимоотношения их на нерестилищах. Автореферат диссертации.

124 Сусумо Сугано. Связь подходов лососевых с состоянием моря на западном побережье Камчатки. Перевод с японского.

125 Тагучи К. 1963. Промысел и состояние запасов лососей в северной части Тихого океана. Перевод с японского.

126 Таранец А. Я. 1938. Морские и речные богатства ДВК. Вестник ДВ филиала АН СССР, 30(3).

127 Таранец А. Я. 1939. Исследования нерестилищ кеты и горбуши в р. Иски. «Рыбное хозяйство», № 12.

128 Тихенко С. А. 1915. Рыбные промыслы Дальнего Востока в 1913 г. по материалам Приамурского управления государственных имуществ. Материалы к познанию русского рыболовства, т. IV, вып. 7.

129 Тихий М. И. 1926. Западно-камчатская горбуша и ее возраст. Изв. отдела прикладной ихтиологии и научно-промысловых исследований. IV, вып. 2.

130 Траутшольд В. 1912. Японский рыбный промысел в водах Приамурья в 1910 г. (Отчет Российско-Императорского Вице-Консульства в Хакодате). Материалы к познанию русского рыболовства, т. 1, вып. 4.

131 Фролов А. И. 1950. О локальных формах сахалинской сельди. Изв. ТИНРО, т. 32.

132 Фролов А. И. 1965. Распределение горбуши и кеты в 1961 году в тихоокеанских водах, прилегающих к Курильским островам, и в южной части Охотского моря. Аннотации научных работ по исследованию сырьевой базы рыбной промышленности Дальнего Востока в 1959 — 1962 гг. Дальиздат.

133 Хирано И. 1951. Пути миграции лососей в северо-западной части Тихого океана, выведенные по результатам мечения за минувшие годы. Bull. Jap. Soc. Scientific Fisheries, vol, 18, no. 10.

134 Целищев М. И. 1924. Пушной и рыбный промысел ДВО. Экономическая жизнь. ДВ, № 6(10).

135 Чернавин В. В. 1918. Брачные изменения скелета лососей. Изв. отдела рыбоводства т. 1, вып. 1.

136 Шелегова Е. К., Лундберг А. Р. 1965. Гидрологическая характеристика условий обитания рыб во второй половине 1959 года и в 1960 году в водах, омывающих Сахалин. Аннотации научных работ по исследованию сырьевой базы рыбной промышленности Дальнего Востока в 1959 — 1962 гг. Дальиздат.

137 Шмидт П. Ю. 1905. Морские промыслы о. Сахалина. Изд. Деп. земледелия.

138 Шмидт П. Ю. 1950. Рыбы Охотского моря. Изд. АН СССР.

139 Экономическая жизнь Дальнего Востока. 1924. № 1(15).

140 Экономическая хроника. 1929. Нормы вылова лососевых. Экономическая жизнь Дальнего Востока, № 5.

C) Original References in English

Davidson F. A. 1934. The Homing Instinctand Age of the Maturity of Pink Salmon (Oncorhynchus gorbuscha). Bulletin of Bureau of Fisheries, XLVIII — 15.

Davidson F. A. and Vaughan A. E. 1939. Cyclic Changes in Time of Southeast Alaska Pink Salmon Runs. Pacific Fisherman, № 2, 3, 4.

Davidson F. A. and Vaughan A. E. 1941. Relation size to marine growth and time of spawning migration in the pink salmon (Oncorhynchus gorbuscha) of Southeastern Alaska. J. Marine Research, 4 (3).

Pritchard A. L. 1938. Transplantation of Pink Salmon (Oncorhynchus gorbuscha), into Masset inlet, British Columbia, in the barren years. Journal of the Fisheries Research Board of Canada, v. IV. No. 2.

Pritchard A. L. 1945. Counts of gill rakers and piloric caeca in pink salmon. Journal of the Fisheries Research Board of Canada.

Jshida T. and Miyaguchi K. 1959. On the Offshore Distribution and Stocks of Pink Salmon. Reprinted from the Bulletin of the Hokkaido Regional Fisheries Research Laboratory, No. 20.

Hoar W. 1953. Control and timing of fish migration. Departament of Zoology, University of British Columbia, Vancouver, Canada (Received 12 March).