SALMON OF THE NORTH PACIFIC OCEAN—PART III
A REVIEW OF THE LIFE HISTORY OF NORTH PACIFIC SALMON
3. CHUM SALMON IN THE FAR EAST

By S. Sano, Hokkaido Salmon Hatchery
Sapporo, Japan, August 1964

COASTAL DISTRIBUTION AND MIGRATION

Chum salmon, *Oncorhynchus keta* (Walbaum), originating in Far Eastern areas of Asia are distributed from the coast to approximately 144°W in the North Pacific (including waters north and south of the Aleutian Islands). Although their coastal distribution varies somewhat from year to year, particularly with respect to abundance of fish, chum salmon spawn in such rivers as the Lena, Iana and Indigirka flowing into the Arctic Ocean (Soldatov and Lindberg, 1930) in the north and streams in the Nagasaki and Fukuoka Prefectures (approximately 33°N) of Kyushu in the south, although their numbers in these southernmost rivers are very small (personal communication from Dr. Hikita of the Hokkaido Salmon Hatchery and Mr. Kimura of Kyushu University). These chum salmon belong to two major groups: so-called summer chum salmon originating in Kamchatka, the Okhotsk coast and the Amur River, and autumn chum salmon originating in Japan, Sakhalin, the southern Kuril Islands and the Amur River. This division is fairly well established. (Hirano, 1953; Yonemori and Kondo, 1961.) Peak runs occur in June, July and August in northern areas, but the season of coastal migration becomes delayed as the area goes southward (Table 1). Peak runs occur in July and August in Kamchatka; during July and August for summer chum salmon and September and October for autumn chum salmon in the Amur; in September and October in Hokkaido; and during October and November in Honshu.

Both summer and autumn chum salmon occur in the Amur River and in some other areas. In general, autumn chum salmon are larger and have greater fecundity than summer chum salmon found in the same area.

The characteristics of the timing and composition of the coastal runs in various districts are discussed below.

Received for publication August 1964. Original, Japanese.
Source: Joint reporting team, Committee on Biology and Research, INPFC Document 700.
Bull. 18, Int. North Pac. Fish. Comm., 1966.

TABLE 1. Percentages of total catch by month in the coastal waters of northern Far East regions (unpublished data of the Japanese Fisheries Agency).

Region	Month	1957	1958	1959
WEST KAMCHATKA	May	—	—	—
	June	0.56	0.51	0.30
	July	58.12	24.10	50.36
	August	38.72	72.09	48.25
	September	2.60	3.30	1.08
EAST KAMCHATKA	May	—	—	—
	June	0.73	0.29	2.04
	July	64.65	31.91	43.56
	August	34.48	66.89	52.17
	September	0.14	0.91	2.23
OKHOTSK	June	—	0.04	0.09
	July	14.30	7.33	13.72
	August	83.87	92.17	85.55
	September	1.83	0.46	0.64
SAKHALIN-KURILS	June	—	—	—
	July	—	18.71	6.57
	August	19.81	26.98	54.74
	September	80.19	54.31	6.95
	October	—	—	31.73
AMUR (summer chum)	June	2.63	—	—
	July	62.50	20.48	—
	August	34.87	79.52	—
	September	—	—	—
AMUR (autumn chum)	June	—	—	—
	July	—	—	—
	August	11.87	—	13.84
	September	88.13	100.00	86.16

EAST COAST OF KAMCHATKA

The coastal migration of chum salmon in this region, including the Oliutorskii and Anadyr districts, begins in June and ends in September in most years. The peak occurs in July and August, being somewhat earlier in the northern than in the southern areas of this region. These fish are assumed to be bound for such rivers as the Anadyr, Oliutorka, Ozernaia and Kamchatka (Taguchi, 1957), and comprise 3-year-olds to 6-year-olds, 4-year-olds being most numerous followed by 5-, 6- and 3-year-olds, in this order. Six-year-olds and 3-year-olds occur less often than the

others. (From unpublished data of the Japanese Fisheries Agency.) In general, more chum salmon migrate to streams in the northern areas of the east coast of Kamchatka than to the southern areas.

West Coast of Kamchatka

The period of coastal migration for chum salmon in West Kamchatka is, in general, from June to September, with peak runs occurring in July in some years and in August in other years. Among the major chum salmon streams in this region are the Bolshaia, Icha and Kikhchik Rivers, all of which are situated in the southern half of this coast. There are about 18 relatively large streams on the west coast of Kamchatka, but more than 80% of the chum salmon catch on this coast is obtained from the Icha area and southward (from unpublished data of the Japanese Fisheries Agency). There are 12 relatively large streams along the coast north of the Icha area, with an average total stream length of 210 km, but the numbers of chum salmon found in coastal waters and streams of this part of West Kamchatka are relatively small (Semko, 1954).

Chum salmon bound for the Bolshaia River, the largest stream in West Kamchatka, consist mainly of 4- and 5-year-olds, with smaller numbers of 3- and 6-year-olds. Four-year-olds and 5-year-olds dominate almost alternately. Thus, during the period 1940–1951, 5-year-olds were dominant in even-numbered years and 4-year-olds in odd-numbered years. The total abundance tended to be greater in years in which 5-year-olds were dominant. (Semko, 1954.)

Okhotsk

The period of coastal migration in this district is approximately the same as in West Kamchatka. Chum salmon runs occur from June to September, with peak runs in August. In all years, more than 80% of the chum salmon appear in August. Considerable numbers migrate in July, but fish occurring in June and September are much fewer. These chum salmon are bound for the Okhota, Kukhtui and other streams of this district. In some years, chum salmon runs in this district take place somewhat later than in West Kamchatka. Four-year-olds are most numerous, followed by 5-year-olds. The numbers of 3- and 6-year-olds are smaller than the above two age groups.

Amur and Primore

Summer chum salmon occur in the Amur River and on the east coast of Sakhalin; autumn chum salmon are found in the Amur River, along the west coast of Sakhalin and in Primore. Summer chum salmon appear in coastal waters in July and August; autumn chum salmon migrate to the coast from the end of August to early October. In all years, about 90% of the autumn chum salmon appear during the month of September, with smaller numbers appearing in August (from unpublished data of the Japanese Fisheries Agency).

The Amur chum populations are far larger than those in other areas of this region. The summer and autumn chum salmon found in the Amur system are distinguished from each other by various characteristics. Summer chum salmon runs consist of 3-, 4- and 5-year-old fish and the proportions of the different age groups change as the season progresses. Four- and 5-year-olds make up the majority of the runs during June, but 3-year-olds increase in the peak period of July, and 3- and 4-year-olds make up the majority in August. Four-year-olds, however, are the most numerous throughout the season. Autumn chum salmon are much larger than summer chum salmon. They appear in August and September. Four-year-old fish are the most numerous throughout the season, followed by 5-year-olds. Three-year-olds and 6-year-olds are fewer than the other two age groups, but 3-year-olds slightly exceed 5-year-olds in number towards the end of the season. (From unpublished data of the Japanese Fisheries Agency.)

Sakhalin and the Kuril Islands

There are two peaks in the spawning migrations of chum salmon to these areas, one in July and August and the other in September and October. Fish belonging to the former peak appear in coastal waters of the northern Kuril Islands and the east coast of Sakhalin, but their numbers are not great. Chum salmon occur in southern Kuril waters and the east and west coasts of southern Sakhalin in September and October, and fish belonging to these late runs are mainly autumn chum salmon migrating into streams of these areas. On the other hand, fish belonging to the early runs are principally summer chum salmon bound for the Amur River and the Okhotsk district. Part of the autumn chum salmon appearing in these waters are considered to be related to those found along the coast of northern Japan, but the available data are not sufficient to confirm this (Hirano, 1953).

Autumn chum salmon migrating into coastal waters of Sakhalin consist of 3-, 4- and 5-year-old fish, 4-year-olds comprising over 80%. There are some summer chum populations in Sakhalin, such as those in the Tym and Poronai Rivers.

Autumn chum salmon migrate into streams in some of the southern Kuril Islands and on the west coast of southern Sakhalin (Hirano, 1953).

Northern Japan

There are two groups of chum salmon found in waters off Hokkaido and Honshu. One group appears in waters off the Pacific coast of Japan during May and June, migrates towards the north along the coast, and enters the Okhotsk Sea through the Kuril Island straits. The other group appears from August onward and moves towards the southwest. The former is apparently summer chum salmon bound for the Amur River, the Okhotsk district, etc., and the latter (called " akiaji " in Hokkaido) are autumn chum salmon migrating into streams of northern Japan. Migrations of these two groups can be inferred from Figure 1.

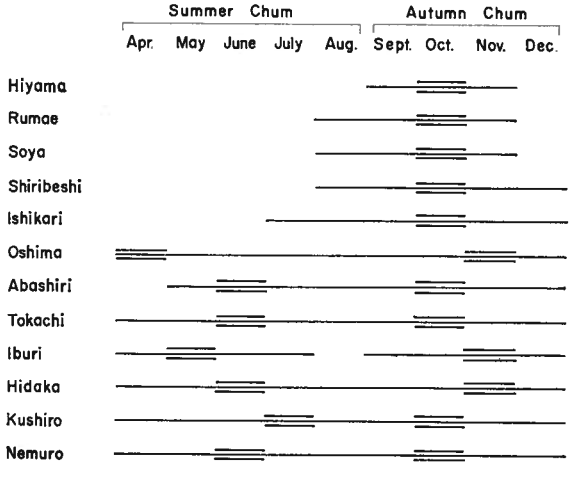


Figure 1. Fishing periods in Hokkaido (1950–1954).

Summer chum salmon begin to appear as early as late April in Pacific waters off the coast from the Iwate Prefecture of Honshu to Hokkaido, become most numerous in June, and continue to be found until mid-August. They form good concentrations in waters off the coast of the Nemuro district, move farther northward, and enter the Okhotsk Sea. Autumn chum salmon begin to appear in late August in waters off the Nemuro district and the Shiretoko Peninsula, move westward along the Okhotsk Sea coast and southwestward along the Pacific coast of Hokkaido, and part of them enter the Japan Sea. Some autumn chum salmon move farther southward along the east and west coasts of Honshu, reaching Chiba Prefecture on the Pacific coast and Nagasaki Prefecture (Kyushu) on the Japan Sea side.

In general, the period of coastal migration for these northern Japan populations is earlier in the north than in the south, peak runs occurring in September and October in Hokkaido and mostly during October and November in areas south of Hokkaido.

The age composition of northern Japan autumn chum salmon varies considerably from year to year, but 4-year-olds predominate in practically all populations, followed by 3-year-olds and 5-year-olds. Two-year-olds and 6-year-olds are much fewer than the other age groups. (Sano, 1959.)

The southern limit of their coastal distribution reaches some streams of northern Kyushu (where small chum salmon runs are known to occur regularly) (personal communication from Dr. Hikita of the Hokkaido Salmon Hatchery), and the Tone River of Chiba Prefecture on the Pacific coast. Catches of commercial importance, however, are made in Niigata Prefecture and north on the Japan Sea side, and in Miyagi Prefecture and north on the Pacific side. Considerable numbers of chum salmon appear regularly in these prefectures to migrate into streams for spawning, and there are coastal fisheries for these fish (Sano, 1959).

Appendix Figure 1 is a map which shows the location of most of the areas and rivers of Hokkaido mentioned in this paper.

EARLY DEVELOPMENT AND SEAWARD MIGRATION

Most of the spawning grounds for chum salmon are found in spring areas of the upper reaches of rivers. Spawning is conducted by pairs of fish. Each pair occupies a certain area of the spawning bed, in order that spawning is not disturbed by other pairs of individual fish. Such optimum distribution of spawners is not possible when too many spawners enter the spawning grounds. Part of the eggs deposited may be dug out by latecomers, and this may become a great source of mortality during the period of spawning and early development. The survival of eggs and larvae is also greatly dependent on the conditions of the spawning grounds, such as the characteristics of beds, availability of water, etc., and on the availability of food for larvae ; other factors such as predators and meteorological conditions may also affect their survival.

In such areas as Kamchatka, the Okhotsk district and Primore, winter air temperature may be as low as $-50°C$, and all the streams except spring areas become frozen. In particularly cold years with light snowfalls, the gravel bottoms of chum salmon spawning grounds may also become frozen, causing large mortalities of eggs or larvae.

West Coast of Kamchatka

The Bolshaia River, the largest stream on the west coast of Kamchatka, has many tributaries, and different races of chum salmon spawn on different spawn-

ing grounds. The spring areas near the junctions of such large tributaries as the Bystraia and Plotnikovo Rivers do not freeze even in mid-winter, maintaining water temperatures above 1°C, and summer water temperatures there are around 10°C. The Karymai Spring, a tributary to the Bystraia, has an area of 36,000 square meters of which 28,000 square meters are utilized by salmon for spawning. During the period from 1925 to 1951, the average number of chum salmon entering this spring to spawn was 11,400, with a range from 2,480 to 68,280 fish. (Semko, 1954.)

Chum salmon spawning in the Bolshaia River occurs mostly during August with peaks in late August or early September. Due to the severe winter climate, the development of eggs to hatching takes a long period of time, three to four months and sometimes as long as five months. The average air and water

TABLE 2. Average air and water temperatures during early development at Karymai Spring (Bolshaia River) (Semko, 1954).

	Air temperature (°C)			Water temperature (°C)		
Period	Egg stage (Sept.–Dec.)	Alevin stage (Jan.–Apr.)	Fry stage (Apr.–June)	Egg stage (Sept.–Dec.)	Alevin stage (Jan.–Apr.)	Fry stage (Apr.–June)
1942–43	3.02	−3.0	7.23	4.40	2.80	5.17
1943–44	−0.17	−7.42	5.97	4.85	2.98	5.47
1944–45	1.3	−7.88	5.37	4.70	2.57	5.10
1945–46	−1.0	−10.22	4.23	4.40	2.40	4.50
1946–47	0.5	−6.8	4.03	4.32	2.52	4.90
1947–48	−1.7	−6.92	5.97	3.90	2.55	5.33
1948–49	−0.86	−10.25	4.00	4.20	2.58	5.17
1949–50	−2.9	−6.97	2.93	4.12	2.65	4.60
1950–51	−0.87	−9.1	3.34	4.37	2.37	4.90

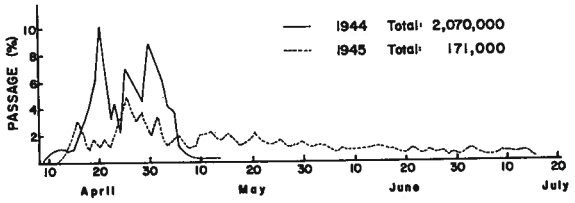


FIGURE 2. Downstream migration of chum salmon fry from the Karymai Spring (Bolshaia River) (Semko, 1954).

TABLE 3. Results of chum salmon spawning in the Karymai Spring (Bolshaia River), 1943–1950 (Semko, 1954).

	Spawning year							
	1943	1944	1945	1946	1947	1948	1949	1950
Total adults arriving at spawning grounds	?	5,480	8,408	7,607	68,281	16,060	3,740	2,932
No. of females	?	2,720	4,204	3,803	34,140	8,028	1,870	1,460
Average fecundity	2,400	2,379	2,160	2,423	2,424	2,480	2,038	2,296
Total no. of eggs carried into the Spring	?	6,411,000	9,072,290	8,937,000	82,691,600	19,909,400	3,810,060	3,461,400
Survival and Downstream Migration	(1944)	(1945)	(1946)	(1947)	(1948)	(1949)	(1950)	(1951)
Recorded hatch of fry in redds	2,866,400	172,700	374,080	111,337	2,649,586	514,825	185,266	460,298
Fry consumed by predators in the Spring	796,400	2,700	240,600	33,264	430,586	201,223	91,566	313,300
Fry consumed by predators, as percentage of hatch in redds	27.8	1.6	64.3	29.9	16.3	39.1*	49.4	68.1*
Downstream migrants from the Spring	2,070,000	170,000	133,480	78,073	2,219,000	313,580	93,700	146,998
Coefficients of:								
Hatch in redds from eggs (%)	?	2.7	4.1*	1.2	3.2	2.6*	4.9*	13.3*
Fry migration from hatch in redds (%)	72.2	98.4	35.7	70.1	83.7	60.9*	50.6*	31.9*
Fry migration from total eggs in the Spring (%)	?	2.7	1.5*	0.87	2.7	1.6*	2.5	4.2
Average fry migration per female	?	63	32	21*	65	39	50	101*
Spawning area per female (m^2)	?	4.4	2.9	2.2	0.3	1.9	7.0	10.1
Fry hatched in redds per female	?	63	89	29	78	64	99	315

* These values were obtained by calculation from data in the table and they differ from the values given in Table 41 of Semko (1954).

temperatures observed at different stages of early development are shown in Table 2. The periods of incubation, larval stage and fry migration are September through December, January through April and April through June, respectively, and seaward migration has practically ended by the end of June. Downstream migration is most intensive during April and May, and some occurs as late as June (Figure 2). (Semko, 1954.)

The number of spawners, the number of larvae in redds and the number of fry going downstream were enumerated for the Karymai Spring during 1943–1950. The results are shown in Table 3. The survival rate from egg to downstream migrant fry during the entire period was very low, being 0.68% to 4.2%. Particularly large mortalities took place during the period between spawning and hatching. (Semko, 1954.)

The mortality of downstream migrants caused by predation varies greatly from year to year and also depends on the numbers and age composition of predators. The major predators on chum salmon fry are coho salmon, sockeye salmon and Dolly Varden. Particularly, Dolly Varden does great damage to salmon fry. Not only young but also adults of this species take large numbers of salmon fry. According to the investigations during 1943–1950 (Semko, 1954), the rate of mortality of chum salmon fry caused by predation varies from 1.6% to 68.0% (of the total number of larvae produced) and is greatly dependent on the absolute quantity of salmon larvae produced. Downstream movements of chum salmon fry occur mostly at night, although they change depending on meteorological conditions and other environmental factors (Table 4).

TABLE 4. Comparison of downstream migration of chum salmon fry from the Karymai Spring (Bolshaia River) in daylight and darkness, 1944–1947 (in %) (Semko, 1954).

Year	Daylight	Darkness
1944	41.5	58.5
1945	1.2	98.8
1946	29.2	70.8
1947	1.8	98.2

The food of chum salmon fry consists mainly of larvae of chironomids, larval and adult forms of other insects, copepods (harpactids), phyllopodans, etc. The biomasses of these food animals are lowest during November and highest in January and February. The quantities of chironomid larvae tend to be particularly greater after large numbers of salmon have spawned, indicating that their abundance is associated with the turnover of stream beds by spawning salmon. On the contrary, inverse relationships are seen between the quantities of Oligochaeta and Hirudinea and the numbers of salmon spawners. (Semko, 1954.)

Chum salmon fry going downstream from the Karymai Spring measure, on the average, 35–37 mm; and they attain an average length of 41.0 mm in mid-April, 46.0 mm in early May, 50.0 mm in mid-May and 53–55 mm in June and July, when they enter the sea (Figure 3). (Semko, 1954.)

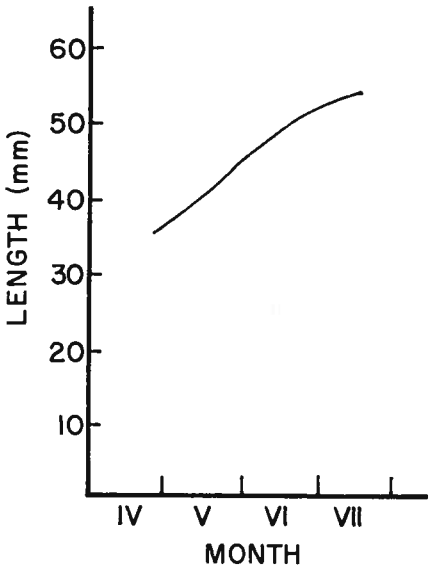


FIGURE 3. Growth of chum salmon fry in the Karymai Spring (Bolshaia River), 1944 (Semko 1954).

OKHOTSK

As mentioned previously, chum salmon spawning in this district is most intensive in August and September. Main spawning grounds are found in the Kukhtui, Okhota and some other rivers, in areas 100–200 km from the sea.

There are counting stations at Ukhan on the Kukhtui River and at Meta on the Okhota River to enumerate spawners and estimate the spawn deposition every year. In 1956 and 1957, the survival rate calculated from the number of eggs deposited (estimated from the number of spawners) and the number of larvae produced was 53% and 36%, which is very high compared with that determined for the Karymai Spring. In some years, however, the survival of eggs is greatly affected by insufficient snowfall and severe freezing. Spawning grounds were greatly damaged by freezing during the 1945–1946 winter and the strength of the year class from the 1945 spawning was greatly reduced. (Sano, 1958.)

Amur and Primore

The greatest chum salmon stock found in the Primore region is the autumn chum salmon stock of the Amur River system, spawning mostly in such upper tributaries as the Khor, Bira, Bidzhan, Iman, Bikin and Kur Rivers. Amur River summer chum salmon spawn mostly in the Amgun and Iski Rivers. In general, summer chum salmon show greater year-to-year fluctuations in abundance than do autumn chum salmon. This is associated with the fact that the spawning grounds of summer chum salmon are more subject to damage by low water levels, freezing, etc., than are those of autumn chum salmon (Smirnov, 1947).

Part of the spawning grounds of Amur summer chum salmon used to be as far from the river mouth as 650–800 km, but stocks have greatly decreased in recent years and the main spawning grounds have been found in areas of the Amgun River approximately 90 km from the river mouth.

On the contrary, the spawning grounds of autumn chum salmon in the tributaries mentioned above are much farther from the Amur River mouth. Chum salmon reach such upper reaches as the Bira or Kumar Rivers, the latter being over 2,000 km from the sea.

Autumn and summer chum salmon have different spawning grounds, the former occupying upper tributary areas and the latter lower tributary areas, and different spawning seasons. Hence, there is practically no competition for spawning grounds between the two groups. Since autumn chum salmon utilize mostly spring areas of upper tributaries, damage by freezing and other severe winter conditions is relatively minor in most years. On the other hand, summer chum salmon spawn earlier in the season, and they do not particularly choose spring areas. Hence, their spawning beds may be completely damaged in years of particularly low temperatures, from freezing of the river beds reaching as deep as 1 m from the surface. (Smirnov, 1947.)

Spawning of summer chum salmon takes place in August and September with water temperatures of 9–11°C; autumn chum salmon spawn during the period from mid-September to the end of November with water temperatures around 6°C. As mentioned previously, autumn chum salmon are larger and more fecund than summer chum salmon (Table 5). Incubation takes 90–100 days under usual conditions, but it can take as long as 140–150 days in particularly cold years. Downstream migration occurs in March and April. Most of the fry migrate into the sea in large concentrations in a short period of time and do not stay very long in streams.

The survival of eggs on the spawning grounds in the Iski River, while varying considerably from year to year, is much better than that in the Karymai

Table 5. Fecundity of the Amur chum salmon, 1927–1929 (Lovetskaia, 1948).

	Autumn chum			Summer chum		
Year	Mean fecundity	Range	No. of fish examined	Mean fecundity	Range	No. of fish examined
1927	3,698	2,948–4,345	7	2,551	1,462–3,233	27
1928	4,046	2,786–5,477	43	2,097	1,900–2,692	9
1929	2,777	1,771–3,374	20	2,300	1,583–3,325	35

Table 6. Mortality rate of chum salmon eggs and fry in the Iski River, 1940–1941 (Smirnov, 1947).

	1940			1941		
Observation area	No. of redds opened	Average no. of eggs per m^2	Mortality rate (%)	No. of redds opened	Average no. of eggs per m^2	Mortality rate (%)
Predatelskii Spring	8	4,164	45.7	9	225	93.0
Shelestova Spring	4	5,701	43.4	3	251	95.6
Iski River, Area 1	3	6,443	22.1	3	481	92.5
Iski River, Area 1 a	10	355	42.3	8	25	93.0
Iski River, Area 2	9	2,855	16.4	7	99	96.5
Iski River, Area 2 a	7	4,034	14.1	6	133	96.7
Ozernaia Spring	12	3,507	44.5	17	165	95.3
Gabrilenko Spring	7	1,417	44.9	6	—	—
Zhokan Spring	8	1,427	16.3	8	253	82.7

Spring, the rate of survival in 1940 and 1941 ranging from 3.3% to 85.9% (Table 6).

Northern Japan

Chum salmon migrating into the streams of northern Japan are different from summer chum salmon bound for the Primore region in the pattern of migration. They enter Japanese waters (from the north) after the summer chum salmon have left there for northern coastal areas, and their coastward migration begins in August or September and continues until November, December and sometimes January, being earlier in the northern areas than in the southern areas of this general region.

The temperature in coastal waters at the time of their migration ranges from 2.4°C (in the Kushiro district) to around 20°C (in the Soya and Monbetsu districts) and the temperature encountered by them in streams ranges from as low as 0.1°C to 20°C. The stream water temperature at the peak of their migration varies from area to area and from stream to stream, but it is generally from 7–8°C to 10–11°C. Year-to-year fluctuations in stream water temperature and timing of upstream migration are relatively small for the same rivers. The speed of upstream migration is considerably different from stream to stream, the

Table 7. Percentage of residual eggs, Hokkaido chum salmon (Sano, 1959).

No. of residual eggs	Memu River[1] (1954–1956)		Nishibetsu River[2] (1955)	
	No. of fish examined	Percent	No. of fish examined	Percent
0	61	30.0	114	43.5
1–10	81	39.9	81	30.9
11–20	15	7.4	9	3.4
21–30	7	3.4	7	2.7
31–40	6	3.0	2	0.8
41–50	1	0.5	4	1.5
51–100	12	5.9	9	3.4
Over 100	20	9.9	36	13.8
Total	203		262	

[1] Tokachi River system.
[2] Nemuro Bay.

Table 8. Rate of mortality between hatching and emergence of chum salmon fry in the Memu River, Hokkaido (Sano, 1959).

	No. of live fry collected	No. of dead fry collected	Total	Rate of mortality (%)
Spawning of October 1956; five redds observed in March 1957	1,011	28	1,039	2.7
	2,321	101	2,422	4.2
	3,283	408	3,691	11.1
	1,661	156	1,817	8.6
	3,045	383	3,428	11.2
Spawning of October 1957; twelve redds observed in March 1958	2,499	675	3,174	21.3
	1,092	300	1,392	21.6
	1,788	189	1,977	9.6
	1,629	102	1,731	5.9
	1,534	141	1,675	8.4
	1,302	743	2,045	36.3
	1,835	194	2,029	9.6
	2,626	22	2,648	0.8
	1,600	332	1,932	17.2
	2,108	18	2,126	0.8
	2,128	166	2,294	7.2
	1,573	346	1,919	18.0
Spawning of October 1958; seven redds observed in March 1959	2,760	18	2,778	0.6
	1,340	44	1,384	3.2
	1,874	25	1,899	1.3
	2,388	10	2,398	0.4
	1,610	100	1,710	5.8
	1,326	82	1,408	5.8
	713	266	979	27.2
Average (24 redds, three years)	1,876.9	202	2,078.9	9.7

average distance travelled per day ranging from 1.9 km to 4.2 km.

Spawning grounds are situated in areas 100–200 km from the sea in such large streams as the Ishikari, Tokachi and Teshio Rivers, but they are very close to the river mouths in such small streams as the Moheji and Kunbetsu Rivers. Some of the fish approaching the coast are fully mature in the latter case.

In general, autumn chum salmon in northern Japan tend to concentrate in spring areas for spawning, as in the case of Amur River autumn chum salmon. They chose places where the water temperature in spawning beds does not become lower than 4°C, even when stream water temperature is approximately 0°C and the stream surface is frozen. This secures normal development of eggs.

The number of eggs remaining in female fish after spawning averages 45–46 eggs per fish, being a little over 1.5% of the average number of eggs carried (3,000) (Table 7). A large proportion of the female fish deposit all of their eggs unless they encounter some particular interference. Thus, spawning is fairly efficient, and the loss of eggs due to retention is rather low.

The rate of survival between spawning and fry emergence determined in the Memu River of the Tokachi River system (Hokkaido) between 1955 and 1958 was over 62%, and the number of fry that emerged from one spawning redd ranged from 713 to 3,283, with an average of 1,877. The mortality for the period between hatching and fry emergence varied considerably depending on conditions on the spawning grounds, but the highest rate encountered was 36.3% and the lowest 0.4%, with an average of 10.1% (Table 8). The overall average mortality to the time of fry emergence is less than 40% of the number of eggs carried by a female. (Sano, 1959.)

In order to determine the number of fry produced from a certain number of spawning females, the total numbers of fry emerging from beds utilized by certain numbers of spawning fish were enumerated in the Memu River in 1957. The results are shown in Table 9. The overall estimated rate of survival varied from 16.2% to 34.4%, with an average of 28.1%. (Nagasawa and Sano, 1961.) This survival rate is much higher than that obtained for the Karymai Spring of the Bolshaia River.

Chum salmon fry begin to appear in coastal waters as early as early April and stay there until late June or mid-July, when they leave the coast for offshore waters with an average length of 100–120 mm. In the Ishikari River on the Japan Sea coast of Hokkaido, downstream movements of chum salmon fry are not very active until early April (stream water temperature as low as 2.0–3.0°C) and their distribution is limited to ponds, streams and springs of upper reaches. Active downstream migration begins by late April with rising temperatures (Table 10). By this period, they measure 35 mm in length and show the characteristic parr marks, but some of them still have some yolk remaining (Sano and Kobayashi, 1952). As water temperature rises to 6.0–10.0°C in early May or mid-May, and water levels increase from melted snow, the downstream migration of fry reaches its height, and schools of chum salmon fry are observed all over the streams. Fry measure about 40 mm, and scales have formed on some of them.

TABLE 9. Rate of fry production in the Memu River (Hokkaido) (Nagasawa and Sano, 1961).

Year class	No. of female spawners	Estimated no. of eggs deposited	No. of fry counted	Rate of survival (no. of fry/eggs deposited)
1957	25	68,000	23,400	34.4
1958	40	114,000	35,300	31.0
1959	24	63,000	10,200	16.2
Average, 1957–1959 year classes	89	245,000	68,900	28.1

TABLE 10. Size of chum salmon fry in streams and coastal waters in Hokkaido.

Area and location[1] of collection	Period of collection	Sample size	Total length (cm) Range	Average
ISHIKARI RIVER (main stream)				
Otoe	April	61	3.1– 3.7	3.45
Chitose	»	142	3.1– 3.9	3.47
Ishikari	»	38	3.1– 4.1	3.51
Asahigawa	»	113	3.4– 5.0	4.08
Chitose	May	138	3.1– 4.1	3.57
Ishikari	»	8	3.4– 4.5	3.63
»	»	65	3.1– 5.2	4.20
Chitose	»	134	3.4– 5.4	3.84
Ishikari	»	35	3.4– 5.6	4.00
»	June	120	3.8– 5.6	4.51
»	»	167	4.1– 5.9	4.66
»	»	26	4.3– 6.9	4.98
ISHIKARI BAY				
Ishikari	May	202	4.4– 9.3	6.12
»	»	45	6.2–10.3	7.75
Furubira	»	8	9.5–10.8	9.51
Hamamasu	June	934	3.7– 8.8	5.43
Ishikari	»	153	4.5– 8.2	5.80
Hamamasu	»	93	6.2– 9.8	7.62
Yoichi	»	11	6.2– 8.8	7.76

[1] See Appendix Figure 1.

Small numbers of chum salmon fry appear in the estuary areas as early as mid-February, but the major portions of seaward migrants appear much later. By late April or early May, fry have reached an average length of 45 mm, their parr marks have disappeared, and scales have formed on most of them. Large schools of chum salmon fry appear in coastal waters in early June, and seaward migration nearly ends by mid or late June. Schools of chum salmon fry are found in coastal waters during the period from April to mid-July, and most of them move towards the east or north. The largest fry found in coastal waters measure over 130 mm, with 8–9 circuli already formed on their scales.

Downstream migration from the spawning grounds of the Memu River of the Tokachi River system varies somewhat in timing and growth rate from year to year, as is shown in Figure 4. Generally speaking, downstream migration occurs from late January to early June, with a peak in April or May in all years.

In northern Japan, the timing of seaward migration is earliest along the coast of Hokkaido west of Cape Erimo and latest along the Japan Sea coast and the rest of the Pacific coast. During the period from April to June, schools of chum salmon fry are found along the entire coast of northern Japan, moving generally towards the north or east. Some of them leave the coast in early July and most of them by August, except in some coastal areas of the Japan Sea and the Pacific. Practically all fry leave coastal waters by mid-August.

RACES AND BIOLOGICAL CHARACTERISTICS OF FAR EASTERN CHUM SALMON

Chum salmon found in far eastern waters may be divided into two large groups: summer chum salmon bound for Kamchatka, the northern coast of the Okhotsk Sea and the Amur area (part of them go through waters off northern Japan) and autumn chum salmon bound for the Amur area, Sakhalin and northern Japan. Each of these two major groups can be further divided into many local stocks, which differ from each other in the timing of migration, the size of fish, age composition, sex ratio or scale patterns.

The differentiation of these stocks has also been confirmed by tagging experiments carried out at sea and on downstream migrants in the rivers.

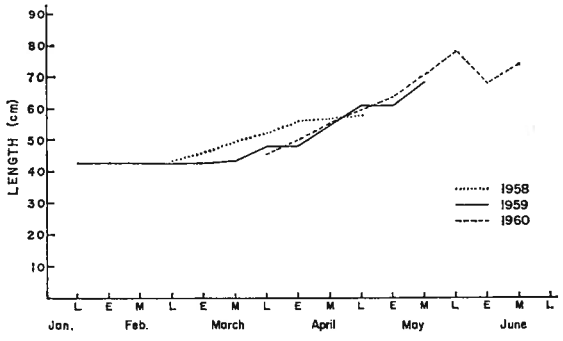


FIGURE 4. Rate of average growth (length) of chum salmon fry in the Memu River (Tokachi River system), 1958–1960 (from data in Table 9 of Nagasawa and Sano, 1961).

TIMING OF MIGRATION

The coastal migration of chum salmon for spawning occurs at different times in different areas. It is, in general, earlier in northern areas than in southern areas (Figure 5). Major runs occur mainly in July and August in northern areas, and in September, October and November in the southernmost areas (northern Japan).

Chum salmon migrating into the streams of the Anadyr district, Kamchatka, and the Okhotsk district and part of the chum salmon going into the Amur system are summer chum salmon which spawn in these streams during the period from the end of

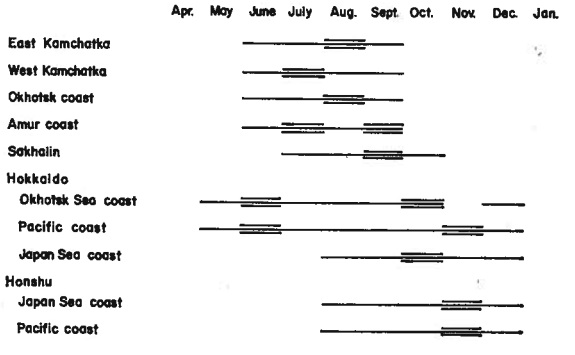


FIGURE 5. Coastal fishing periods for Far Eastern chum salmon (in the U.S.S.R., for 1957–1959; in northern Japan, for 1950–1954).

TABLE 11. Average length and weight for the period 1927–1933, Amur River chum salmon (Lovetskaia, 1948).

	Summer chum				Autumn chum			
	Males	*N*	Females	*N*	Males	*N*	Females	*N*
Average length (cm)	58.5	952	56.9	984	70.4	1,092	65.9	1,692
Average weight (g)	2,492	932	2,266	1,003	4,536	632	3,534	991

summer to early autumn. Those migrating into the streams of the northern Primore district, mainly the Amur River, later in the season are called autumn chum salmon. Two groups of chum salmon are observed in coastal waters of Hokkaido and Honshu. The early fish consist of summer chum salmon passing through these waters to enter the Okhotsk Sea and migrate to the Amur River and other northern areas, while the later fish are autumn chum salmon migrating into streams of the Japanese coast. The migration of the former has its peak in June and that of the latter occurs mostly from September to December.

TABLE 12. Average fecundity for the period 1927–1930, by length, Amur River chum salmon (Lovetskaia, 1948).

	Summer chum		Autumn chum	
Length (cm)	Average fecundity	*N*	Average fecundity	*N*
50	1,952	1		
52	2,005	2		
54	2,044	9		
56	2,260	11		
58	2,550	18		
60	2,556	11	—	—
62	2,335	15	3,426	3
64	2,553	6	—	—
66	2,982	4	3,720	9
68	2,761	9	4,005	12
70	2,382	2	3,636	13
72	2,982	3	4,430	5
74	2,800	1	4,358	3
76			5,159	4
78			—	—
80			4,888	1

TABLE 13. Size of chum salmon[1] in various Far Eastern streams (Birman, 1956).

		Length (cm)		
Area of catch	Year	Range	Average	Sample size
SAKHALIN	1948–1949	49–82	67.1	1,108
PRIMORE				
(Tumnin River)	1948–1949	55–85	69.7	515
AMUR SYSTEM				
Amur estuary	1948–1949	48–87	66.8	6,046
» »	1952–1953	51.5–90.5	67.0	3,597
Khor, Kur and Bira Rivers	1948–1949	45–89	69.7	3,000+
» »	1952–1953	46– ?	69.7	2,500+
Khivanda River	1949	54–81	68.6	367
Amgun River	1948–1949	49–82	64.6	2,540
» »	1952–1953	50–79	64.3	963
OKHOTSK COAST				
Iski River	1953	48–76	62.2	1,002
Okhota River	1948	46–78	62.9	?
Kukhtui River	1952–1953	45–76	61.9	2,351

[1] Autumn chum in all areas except the Okhotsk coast (summer chum).

SIZE OF FISH

In the Amur River, summer chum salmon and autumn chum salmon differ from each other not only in the timing of stream migration, but also in size, fecundity, etc. The average weight of summer chum salmon is around 2.5 kg or less, while that of autumn chum salmon is 3.5 kg or more (Table 11), and the average number of eggs carried by a female autumn chum is 500–1,000 greater than that carried by a summer chum salmon of the same size (Table 12).

Such differences were also observed for chum salmon of other districts in studies made during 1948–1953 (Birman, 1956). Chum salmon bound for the Amur River, Sakhalin and Primore were significantly different in length from those bound for the Okhotsk district (Table 13).

Also, geographical differences are apparent in the fork length and weight of 4-year-old chum salmon as is shown in Table 14 (prepared from 1958–1959 data). There are differences not only between summer and autumn chum salmon, but also between Japanese chum salmon and other autumn chum salmon. Even within Japanese chum salmon, those found in southern Hokkaido and Honshu were con-

TABLE 14. Average fork length and weight of 4-year-old chum salmon in various Far Eastern regions, 1958 (southwest coast of Hokkaido) and 1959. (Data for Hokkaido and Honshu from Kobayashi and Abe (1956; 1959), others from unpublished data of the Japanese Fisheries Agency.)

	Length (cm)		Weight (kg)	
Region	Females	Males	Females	Males
EAST KAMCHATKA	59.8	63.53	2.83	3.49
SOUTHWEST KAMCHATKA	61.7	65.2	2.79	3.29
NORTHWEST KAMCHATKA	63.0	68.3	2.93	3.74
OKHOTSK DISTRICT	59.1	62.6	2.70	3.26
AMUR (summer chum)	55.5	57.7	2.21	2.57
AMUR (autumn chum)	66.1	69.4	3.40	4.16
SAKHALIN	64.7	64.94	3.28	3.68
HOKKAIDO				
Nemuro district	70.3	73.1	3.78	3.97
Okhotsk Sea coast	69.1	70.7	3.99	4.45
Pacific coast	73.3	76.7	4.49	5.62
Southwest coast	77.6	77.2	5.37	5.52
Japan Sea coast	68.7	70.4	4.13	4.26
HONSHU				
Japan Sea coast	73.9	75.9	4.79	5.24
Pacific coast	75.7	76.4	4.55	5.18

TABLE 15. Number of scales on lateral line for Hokkaido chum salmon, 1954–1956 (sample size given in parentheses) (Sano, 1960).

River[1]	1954		1955		1956	
	Range	Average	Range	Average	Range	Average
Ishikari	133–140	135.5(94)	132–143	135.3(96)	133–140	135.3(63)
Tokoro	133–145	137.6(99)	130–143	136.5(43)	133–144	136.0(98)
Nishibetsu	132–145	137.3(100)	130–143	136.6(67)	132–140	135.8(100)
Tokachi	134–147	137.8(99)	132–149	138.1(100)	134–145	136.3(100)
Yurappu	134–144	138.5(50)	134–142	137.6(69)	134–143	137.8(46)
Shiriuchi	138–144	141.1(23)	136–148	140.8(16)	—	—

[1] See Appendix Figure 1.

TABLE 16. Number of vertebrae for Hokkaido chum samon, 1954–1956 (sample size given in parentheses) (Sano, 1960).

River[1]	1954		1955		1956	
	Range	Average	Range	Average	Range	Average
Ishikari	64–68	65.2(95)	61–67	64.5(96)	62–67	64.8(64)
Tokoro	63–67	64.9(100)	62–67	64.7(53)	63–68	64.0(98)
Nishibetsu	62–68	64.8(100)	62–67	64.7(67)	63–67	64.0(100)
Tokachi	63–69	65.6(99)	62–69	65.6(100)	63–69	65.7(100)
Yurappu	64–68	65.5(50)	64–67	65.4(70)	64–67	65.7(26)
Shiriuchi	65–67	66.1(23)	65–67	66.1(16)	—	—

[1] See Appendix Figure 1.

siderably larger than those from northern Hokkaido.

There are also differences between local stocks of Hokkaido chum salmon in such characters as the number of scales on the lateral line (Table 15) or the number of vertebrae (Table 16). Chum salmon from the Shiriuchi River of southwestern Hokkaido showed the highest values in these characters during the period studied, while those from the Nishibetsu and Tokoro Rivers showed the lowest values.

AGE COMPOSITION

The age composition of chum salmon varies considerably from year to year even for the same area. Mature chum salmon consist of fish ranging from 2-year-olds to 6-year-olds. In general, fish of lower ages are more numerous in southern areas than in northern areas. Data for 1959 indicate that 2-year-olds occupied significant proportions on the coast of Honshu and that the proportion of 4-year-olds was not as high as in northern areas. Four-year-old fish constituted overwhelmingly high proportions in the summer chum stocks of Kamchatka and the Okhotsk district, and the proportions of 3-year-olds were very low in these areas. Also, 6-year-olds occupied higher proportions than in the areas southward. Thus, there were fairly characteristic differences in age composition among summer chum salmon stocks (northern stocks), autumn chum salmon stocks (southern stocks) and northern Japan stocks (Table 17).

Age composition, however, varies greatly from year to year due to year class fluctuations (Table 18). Hence, it is difficult to determine typical compositions for individual local stocks. For Hokkaido chum salmon, the average proportions and their confidence limits are shown in Table 19.

SEX RATIO

The sex ratio of chum salmon migrating to the coast varies between age groups (Kobayashi and Abe, 1956; 1959). In general, males outnumber females in younger ages and the proportion of females increases as age increases. Practically all 2-year-olds are males, and 3-year-old males outnumber females of the same age. The sex ratio is nearly 50/50 for 4-year-olds, and females tend to outnumber males among 5- and 6-year-olds. The above tendencies are recognized for the chum salmon of many areas, but the overall sex ratio (including all age groups) for each stock is fairly close to 50/50.

In the areas of northern Japan, however, the sex ratios were normal in 1959, males outnumbering females in younger ages and females exceeding males

TABLE 17. Age composition of Far Eastern chum salmon in 1958 (southwest coast of Hokkaido) and 1959, by region. (Data for Hokkaido and Honshu from Kobayashi and Abe (1956; 1959), others from unpublished data of the Japanese Fisheries Agency.)

Region	Age (%)				
	2-year-olds	3-year-olds	4-year-olds	5-year-olds	6-year-olds
EAST KAMCHATKA	—	0.8	88.6	9.4	1.4
SOUTHWEST KAMCHATKA	—	1.7	94.9	3.4	—
NORTHWEST KAMCHATKA	—	—	88.6	11.4	—
OKHOTSK DISTRICT	—	2.2	86.8	7.9	3.1
AMUR (summer chum)	—	3.5	86.0	10.5	—
AMUR (autumn chum)	—	10.7	81.8	7.2	0.3
SAKHALIN	—	9.0	84.0	7.0	—
HOKKAIDO					
Nishibetsu River	—	—	62.5	37.5	—
Tokoro River	0.4	53.7	44.1	1.8	—
Tokachi River	—	2.0	80.7	17.3	—
Yurappu River	0.6	27.4	70.8	1.2	—
Ishikari River	—	40.5	57.1	2.4	—
HONSHU					
Japan Sea coast	6.9	61.5	31.6	—	—
Pacific coast	1.3	11.2	79.8	7.7	—

TABLE 18. Age composition of Bolshaia River chum salmon, 1932–1951 (Semko, 1954).

Year	Age (%)				Catch in the Bolshaia River area
	3-year-olds	4-year-olds	5-year-olds	6-year-olds	
1932	0	96.5	3.5	0	840,000
1933–1934	—	—	—	—	—
1935	20.7	10.9	67.0	1.4	260,000
1936	1.3	97.4	1.3	0	2,175,000
1937–1939	—	—	—	—	—
1940	0.7	44.6	54.0	0.7	270,000
1941	0.9	53.7	42.4	3.0	540,000
1942	6.0	8.8	85.2	0	197,000
1943	2.5	91.1	3.9	2.5	76,000
1944	9.2	34.8	56.0	0	312,000
1945	0.7	95.3	3.3	0.7	395,000
1946	14.0	21.0	64.5	0.5	1,100,000
1947	0.3	98.2	1.5	0	300,000
1948	0.8	12.5	85.4	1.3	1,430,000
1949	0.4	84.2	11.9	3.5	960,000
1950	3.2	17.8	79.0	0	600,000
1951	0	73.4	22.3	4.3	1,116,000

TABLE 19. Proportions of Hokkaido chum salmon returning at different ages (Sano, 1960).

Age	Average	Confidence limits (95%)
2-year-olds	0.4±0.3%	0.1– 0.7%
3-year-olds	22.0±2.5	19.5–24.5
4-year-olds	62.6±6.3	56.3–68.9
5-year-olds	14.7±4.1	10.6–18.8
6-year-olds	0.3±0.3	0.0– 0.6

in higher ages, the overall sex ratio being close to 50/50. (Table 20.)

SCALE PATTERN

The number of circuli in the first-year band of chum salmon scales shows fairly characteristic differences between northern and southern stocks and also between Asian and North American stocks. The average count is 31.58 and 28.37 for Skeena and Cook Inlet chum salmon, respectively, while it is 29.67, 24.83 and 24.40 for Hokkaido, Okhotsk Sea and Karaginskii chum salmon, respectively. On both the Asian and American sides, the count tends to be higher in southern areas than in northern areas. (Kobayashi, 1959.)

Also, the average number of circuli in the second-year band is different between Asia and North America, being higher in North America than in Asia. Thus, the average count ranges from 21.15 to 17.77 for North American stocks and from 16.42 to 14.41 for Asian stocks. Offshore samples show smaller first-year and second-year circulus counts in waters to the west of 175°W than in waters to the east. (Kobayashi, 1959.) Significant differences are also found between such Asian districts as Karaginskii, Okhotsk and Hokkaido. The frequency distributions of the first-year and second-year circulus counts are shown for these Asian districts in Table 21.

Fish taken from waters off the Kamchatka Peninsula

TABLE 20. Sex ratios of Far Eastern chum salmon in 1958 (southwest coast of Hokkaido) and 1959, by region and by age.

Region	2-year-olds		3-year-olds		4-year-olds		5-year-olds		6-year-olds		All ages	
	F	M	F	M	F	M	F	M	F	M	F	M
EAST KAMCHATKA	—	—	20.0	80.0	55.6	44.4	39.0	61.0	27.0	73.0	52.5	47.5
SOUTHWEST KAMCHATKA	—	—	25.0	75.0	45.0	55.0	40.0	60.0	—	—	51.5	48.5
NORTHWEST KAMCHATKA	—	—	—	—	57.2	42.8	68.8	31.2	—	—	57.5	42.5
OKHOTSK DISTRICT	—	—	36.3	63.7	46.6	53.4	50.0	50.0	60.0	40.0	47.1	52.9
AMUR (summer chum)	—	—	47.6	52.4	48.7	51.3	41.3	58.7	—	—	47.9	52.1
AMUR (autumn chum)	—	—	52.3	47.7	51.3	48.7	44.7	55.3	40.0	60.0	50.0	50.0
SAKHALIN	—	—	11.0	89.0	38.0	62.0	42.8	57.2	—	—	36.0	64.0
HOKKAIDO												
Nemuro district	—	—	12.5	87.5	67.0	33.0	71.8	28.2	—	—	67.5	32.5
Okhotsk Sea coast	—	100	24.3	75.7	50.7	49.3	43.6	56.4	—	—	36.2	63.8
Pacific coast	—	—	44.5	55.5	59.9	40.1	60.4	39.6	75.0	25.0	58.9	41.1
Southwest coast	—	100	40.4	59.6	71.2	28.8	100	—	—	—	48.7	51.3
Japan Sea coast	—	100	26.0	74.0	34.8	65.2	37.5	62.5	—	—	32.0	68.0
HONSHU												
Japan Sea coast	—	100	40.4	59.6	67.5	32.5	50.0	50.0	—	—	55.6	44.4
Pacific coast	—	100	48.7	51.3	56.2	43.8	66.6	34.4	—	—	52.5	47.5

TABLE 21. Frequency distribution of circulus counts, 1957 (from Kobayashi, 1959).

(1) *First-year circulus counts*

Region	No. of circuli														Average	*N*
	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
Karaginskii	3	1	7	12	12	7	2	1							24.40	45
Okhotsk	3	8	27	40	37	20	14	6	2	3	2				24.83	162
Hokkaido					2	2	5	14	28	16	15	12	2	3	29.67	99

(2) *Second-year circulus counts*

Region	No. of circuli											Average	*N*
	11	12	13	14	15	16	17	18	19	20	21		
Karaginskii	1	1	2	6	5	13	9	4	2	2		15.97	45
Okhotsk		1	7	11	29	35	37	26	12	2	2	16.42	162
Hokkaido	1	14	12	27	21	17	4	1		2		14.41	99

indicate regional differences in scale pattern. The chum salmon caught off Cape Kamchatka and near the Kronotskii Peninsula were distinguished from those caught later in waters off Paramushir Island and Cape Lopatka by one very marked feature; more than 25% of the individuals of the first group had, in the first-year growth zone, an accessory ring consisting of from seven to thirteen (on the average, nine) circuli spaced more narrowly than the subsequent circuli. In the second group of fish the proportion with such rings was only 5.9%. (Table 22.)

TABLE 22. Scale characteristics of chum salmon caught in Kamchatkan waters (Birman, 1958).

Area	Period of catch	Percentage with an accessory ring consisting of narrowly spaced circuli	Sample size
Near Is.	6.13–18, 1955	9.1	153
Komandorskii Is.	7.22–25, 1955	24.4	45
Cape Kamchatka-Cape Kronotskii	6.26–29, 1955	28.2	71
Kamchatka River	8.2, 1955	33.0	94
Cape Shipunskii	6.30–7.9, 1955	5.9	51
Utashud I.-Paramushir I.	7.15–19, 1955	5.9	51
Bolshaia River	7.25–8.7, 1955	0.0	100
Penzhinskaia Gulf	1931	66.6	33

FECUNDITY

As mentioned previously, the fecundity of chum salmon varies considerably between different local stocks. Amur River autumn chum salmon carry particularly large numbers of eggs. Although the

TABLE 23. Average and range of chum salmon fecundity in various regions of the Far East.

Region[1], period and source	Fecundity	
	Average	Range
AMUR RIVER—1927–1930—Lovetskaia (1948)		
Summer chum	2,372	1,462–3,325
Autumn chum	3,649	1,771–5,705
SAKHALIN—1946–1947—Dvinin (1952)		
Summer chum	2,366	1,254–3,528
Autumn chum	2,505	1,712–3,928
HOKKAIDO—1955–1958—Sano (1959)		
Nishibetsu River (Nemuro)	2,562	1,259–3,508
Tokoro River (Okhotsk Sea coast)	3,043	1,275–4,379
Iwaobetsu River (Okhotsk Sea coast)	2,544	909–4,959
Tokachi River (Pacific coast)	2,951	1,274–4,768
Yurappu River (southwest coast)	3,361	2,625–4,627
Shiriuchi River (southwest coast)	3,740	1,945–7,779
Teshio River (Japan Sea coast)	3,023	1,759–4,835
Ishikari River (Japan Sea coast)	3,293	1,575–4,644

[1] See Appendix Figure 1.

average number of eggs carried by a female also changes from year to year (Table 5), the ranges of the average fecundity for autumn and summer chum salmon of the Amur River hardly overlap each other. Differences in fecundity are also obvious between chum salmon from the streams of the Nemuro district and those from the streams of the southwestern coast and the Japan Sea coast of Hokkaido. (Table 23.)

OCEAN MIGRATIONS AND HOMING

Tagging experiments conducted before 1945 and from 1956–1960 (Yonemori and Kondo, 1961), have revealed the following: (i) Asian chum salmon occupy very large areas of the North Pacific Ocean during their ocean residence and practically all chum salmon found in the offshore commercial fishing grounds are of Asian origin. (ii) Chum salmon originating in northeastern Kamchatka, during their ocean residence, occupy mainly the Bering Sea and Pacific waters east of 180°. (iii) It is assumed that chum salmon originating in the Okhotsk district and West Kamchatka are found mainly in waters south of the Aleutian Chain (including the Komandorskii Islands) and west of 180°, Okhotsk chum salmon occupying more westerly waters than those of West Kamchatka. (iv) It is assumed that summer chum salmon originating in the Amur and Sakhalin districts are distributed in Pacific waters south of the Kuril Islands and relatively close to the islands of Japan. (v) Amur autumn chum salmon presumably occupy approximately the same waters as described in (iv). (vi) The wintering grounds of Hokkaido chum salmon are assumed to be in waters east of 180° and south of the Aleutian Islands. They migrate northward during May and June and spend the summer principally in the Bering Sea before they commence southward migrations in the autumn. (vii) Chum salmon originating in the Anadyr district and northwestern Alaska are assumed to occupy waters of western longitudes, without extending their wintering grounds into waters of east longitudes.

Marking of seaward migrants of chum salmon has been carried out by many research workers since the early 1900's in the Chitose River of Hokkaido and many other streams. Their return to the streams in which they were released has been established. Fry have been marked by removing fins and other body parts, and such markings have been much more difficult to recognize than tags affixed to adult fish. Also, the regeneration of removed portions has resulted in many unclear or indistinguishable markings. For these reasons, the rate of recovery has not been very high. However, marking experiments have been carried out in Japan under a well-organized program since 1950. Particularly, an experiment carried out in the Tokoro River on the Okhotsk coast of Hokkaido was very successful (Table 24). From 500,000 fry marked (on the adipose fin and on both ventral fins) and released in

TABLE 24. Recovery rate for each area from releases in the Tokoro River in 1954 (Sakano, 1960).

Area[1]	No. of recoveries[2]	Percent[3]
Monbetsu	3	0.2
Yubetsu	61	3.2
Tokoro	997 (269)	52.4 (97.82)
Abashiri	481(1)	25.3 (0.36)
Mokoto	3 (3)	0.2 (1.09)
Utoro	12	0.6
Shari	241 (1)	12.7 (0.36)
Iwaobetsu	100	5.3
Rausu	1	0.05
Kunbetsu	1 (1)	0.05 (0.36)
Nemuro	1	0.05
Offshore fisheries	1	0.05
Total	1,903 (275)	

[1] See Appendix Figure 1.

[2] Recoveries in rivers are in parentheses.

[3] Values in parentheses are percentages of river recoveries.

this river in 1954, 1,903 fish (443 three-year-olds, 1,453 four-year-olds and seven 5-year-olds) were recaptured with unquestionable markings, revealing the homing, coastal migration and other features of each age group. (Sakano, 1960.)

SUMMARY

Chum salmon originating in far eastern areas of Asia are found from the coast to approximately 144°W in the North Pacific in waters north and south of the Aleutian Islands; the northern limit of their coastal distribution is at the Lena and Iana Rivers of the Arctic coast and the southern limit occurs in Nagasaki Prefecture on Kyushu Island. Commercial catches of chum salmon are made from Anadyr Bay in the north to Niigata and Miyagi Prefectures of Honshu in the south, and the runs within this area are somewhat larger than elsewhere.

It has been fairly well established that there are two major groups of chum salmon; autumn chum salmon and summer chum salmon. Summer chum salmon migrate to the Amur River, the Okhotsk district, and the east and west coasts of Kamchatka, during the period from June to September, with peak runs occurring in July and August; autumn chum salmon enter the waters of the Amur River, Sakhalin and northern Japan during the period beginning in September. As a general tendency, summer chum salmon are smaller and less fecund than autumn chum salmon.

Both summer and autumn chum salmon migrate into the Amur River, the former spawning in the lower reaches, such as the Amgun River, and the latter spawning in the upper reaches, such as the Bira River. In waters off the coast of northern Japan, summer chum salmon occur during the period from April to August on their way towards the north, but they do not enter Japanese streams (they are fish bound for the Amur River and the Okhotsk coast). Autumn chum salmon enter the same waters from September onward and migrate into Japanese streams.

Spawning of Bolshaia River (West Kamchatka) chum salmon occurs mostly in August and partly in early September. Due to severe winter conditions, egg development takes a fairly long period of time—from March into April and in some years extending into May. Fry migrate most intensively in April and May, but continue into June. Survival between spawning and hatching is low, but is very good between hatching and seaward migration. Predators on chum salmon fry during the period of downstream migration include coho and sockeye salmon, and particularly Dolly Varden. The mortality rate attributed to Dolly Varden predation is reported to range from 1.6% to over 60% of the fry produced. The most important food for chum salmon fry is chironomid larvae; planktonic forms of crustaceans are also important. These food organisms are most abundant during the winter. Chum salmon fry at the beginning of their seaward migration average 35–37 mm in length. The average length exceeds 50 mm in June and is about 55 mm when the fry reach the sea.

Spawning in the Kukhtui and Okhota Rivers of the Okhotsk district is affected by freezing in some years, and environmental factors have a great effect on the survival of eggs and larvae. In general, however, the survival rate is better than in the Bolshaia River.

Spawning of the Amur River summer chum salmon is apt to be affected by freezing and other severe winter conditions, because they spawn in the lower reaches. On the contrary, eggs of autumn chum salmon are much less subject to damage by freezing and other natural conditions, since they spawn in areas of the upper reaches supplied with ground water. Summer chum spawning occurs during August and September at temperatures around 10°C; autumn chum spawning occurs during the period from mid-September to the end of November at temperatures around 6°C. Egg development takes 90–100 days and up to 140–150 days in particularly cold years. Fry conduct their downstream migration in March and April, forming large concentrations, and do not stay in streams for a long period of time.

In the streams of northern Japan, chum salmon begin to migrate upstream from the end of August, and their migration continues until October in northern streams and until November and December in southern streams. They spawn in areas with ground water, and the development of eggs is relatively rapid. Spawning grounds are situated as far as 100–200 km from the sea in some large rivers, but are very close to the river mouth in other smaller streams. The spawning beds chosen by Japanese chum salmon have temperatures not lower than 4°C. Accordingly, there is practically no damage even in very cold years except by exposure of spawning beds during low water levels. The rate of fry production relative to the number of eggs produced is 16.2–34.4%, with an average of 28.1%, for the period 1957–1960. Fry begin to make active movements in streams during the month of April, their average length being 35 mm. They grow to an average length of 40 mm in May and some exceed 60 mm in June, by which time parr marks have disappeared. Fry appear in coastal waters during March on the Pacific coast, in April on the Japan Sea coast and are found in coastal

waters until mid-August, moving towards the east or north.

Generally speaking, 4-year-old fish are most numerous in chum salmon populations. The proportions of 3-year-olds are very small in summer chum salmon, but are somewhat larger in autumn chum salmon. Japanese autumn chum salmon (akiaji) have much greater proportions of 3-year-olds than the other autumn chum salmon and summer chum salmon.

The overall sex ratio does not vary greatly between populations, being approximately 50/50.

There are differences in scale patterns between northern populations and southern populations. The number of circuli in the first-year band is greater and the number of circuli in the second-year band is somewhat smaller in Japanese chum salmon than in other Asian populations.

Summer and autumn chum salmon of the Amur River differ from each other in fecundity. The average number of eggs carried by autumn chum females is always greater than that carried by summer chum females. Autumn chum salmon in northern Japan fall in between the above two in this respect.

The results of tagging indicate that chum salmon of various geographical stocks seek different habitats during ocean residence. It is assumed that the chum salmon from East Kamchatka, West Kamchatka, the Okhotsk district, the Amur River, Sakhalin and northern Japan differ from each other in their wintering grounds and oceanic migrations.

Results of marking on downstream migrants indicate that chum salmon return to the coast in the region of their home streams and particularly to the streams where they were born or released. It is assumed that each geographical stock and stream population acts independently.

LITERATURE CITED

BIRMAN, I. B. 1956. Local stocks of autumn chum salmon in the Amur basin. *Voprosy Ikhtiologii*, No. 7, pp. 158–173.

BIRMAN, I. B. 1958. On the occurrence and migration of Kamchatka salmon in the northwestern part of the Pacific Ocean. *Material on the Biology of the Marine Period of Life of of the Far Eastern Salmons.* Vsesoiuznyi Nauchno-Issledovatelskii Institut Morskogo Rybnogo Khoziaistva i Okeanografii (VNIRO), Moscow.

DVININ, P. A. 1952. The salmon of South Sakhalin. *Izvestiia Tikhookeanskogo Nauchno-Issledovatelskogo Instituta Rybnogo Khoziaistva i Okeanografii* (Izv. TINRO), Vol. 37, pp. 69–108.

HIRANO, YOSHIMI. 1953. An outline of the results of the tagging experiments on Pacific salmon. *Hokkaido Prefectural Fisheries Experimental Station, 50th Anniversary Publication*, 134 pp.

KOBAYASHI, TETSUO. 1959. Races of chum salmon stocks in the North Pacific and their scale circulus counts. Unpublished working paper, Fisheries Agency of Japan, August 1959.

KOBAYASHI, T., and S. ABE. 1956. Age composition, length composition, weight composition and the pattern of the central portion of scales of adult chum salmon migrating into major streams of Hokkaido. *Data Record, Hokkaido Salmon Hatchery*, No. 105.

KOBAYASHI, T., and S. ABE. 1959. Age composition, length composition and weight composition of chum salmon migrating into major streams of Hokkaido (1956–1957). *Data Record, Hokkaido Salmon Hatchery*, No. 107.

LOVETSKAIA, E. A. 1948. Data on the biology of the Amur chum salmon. *Izv. TINRO*, Vol. 27, pp. 115–137.

NAGASAWA, ARIAKI, and SEIZO SANO. 1961. Some observations on the downstream chum salmon fry (*O. keta*) counted in the natural spawning ground at Memu stream, 1957–1959. *Scientific Report, Hokkaido Salmon Hatchery*, No. 16, pp. 107–126.

SAKANO, EIICHI. 1960. Results from marking experiments on young chum salmon in Hokkaido, 1951–1959. *Scientific Report, Hokkaido Salmon Hatchery*, No. 15, pp. 17–38.

SANO, SEIZO. 1958. A report on fishery investigations in the Far Eastern region of the U.S.S.R. (Lake Dalnee Station). Unpublished working paper, Fisheries Agency of Japan, August 1958.

SANO, SEIZO. 1959. The ecology and propagation of genus *Oncorhynchus* found in northern Japan. *Scientific Report, Hokkaido Salmon Hatchery*, No. 14, pp. 21–90.

SANO, SEIZO. 1960. Ecological study (particularly on spawning) and propagation of the Hokkaido salmon. *Data Record, Hokkaido Salmon Hatchery*, No. 108.

SANO, SEIZO, and TETSUO KOBAYASHI. 1952. A preliminary report on ecological studies of chum salmon fry. *Scientific Report, Hokkaido Fish Hatchery*, No. 7.

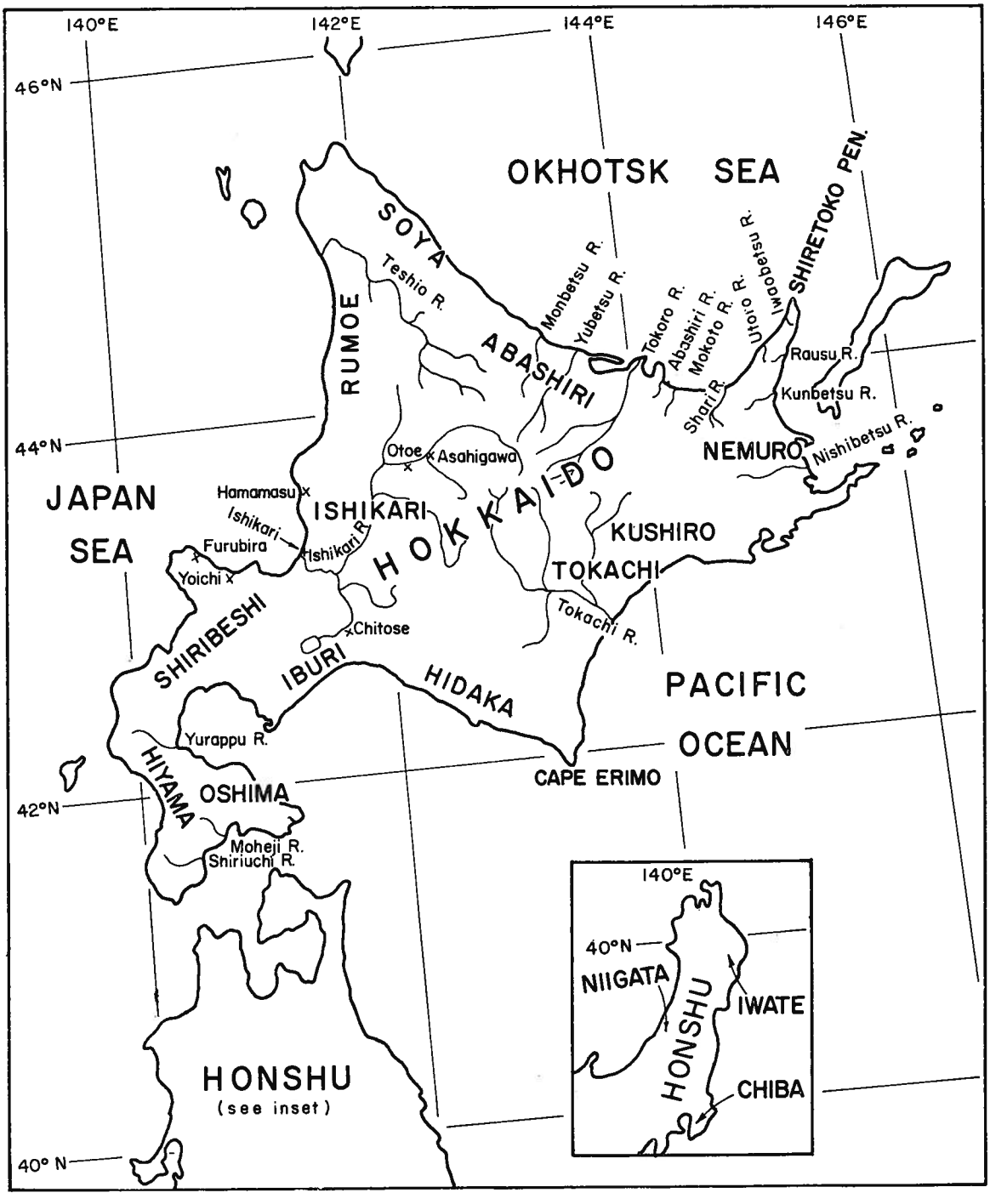
SEMKO, R. S. 1954. The stocks of West Kamchatka salmon and their commercial utilization. *Izv. TINRO*, Vol. 41, pp. 3–109.

SMIRNOV, A. G. 1947. Condition of the stocks of Amur salmon and causes of the fluctuations in their abundance. *Izv. TINRO*, Vol. 25, pp. 33–51.

SOLDATOV, V. K., and G. U. LINDBERG. 1930. A review of the fishes of the seas of the Far East. *Izv. TINRO*, Vol. 5, 576 pp.

TAGUCHI, KISABURO. 1957. *Salmon Fisheries and Salmon Stocks in the Northern Seas.* Nichiro Fishing Company, 166 pp., plus appendices.

YONEMORI, T., and H. KONDO. 1961. The present status of the chum salmon stocks in Asia. Fisheries Agency of Japan.



APPENDIX FIGURE 1. Map showing locations of areas and rivers of Hokkaido referred to in the text.