FISHERIES RESEARCH BOARD OF CANADA

Translation Series No. 370

THE COHO SALMON (*Oncorhynchus kisutch* WALBAUM)--
A BIOLOGICAL SKETCH

By V. I. Gribanov

Original title: Kizhuch [*Oncorhynchus kisutch* (Walb.)]: (biologicheskii ocherk).

From: Izvestiia Tikhookeanskogo N.-I. Instituta Rybnogo Khoziaistva i Okeanografii (TINRO), Vol. 28, pp. 43-101. 1948.

Preliminary translation by W. E. Ricker

Distributed by the Fisheries Research Board of Canada
Biological Station, Nanaimo, B. C.

1962

This is a preliminary translation prepared for the use of the Fisheries Research Board of Canada. It is not a definitive English version of the article, and it has not been checked or approved by the author.

The coho salmon fishery in our far-eastern waters is conducted almost exclusively along the coast of Kamchatka. But even there only a few are taken. Only in recent years has our state fishing authority in Kamchatka begun to give the coho fishery some attention, and landings have risen to 50,000 centners [5000 metric tons].

In particular regions coho do have some considerable commercial importance at the present time. For example, in the region of Ust-Kamchatsk, where the fishery is based on salmon heading for the largest river of the peninsula--the Kamchatka River--coho are second in commercial importance, surpassed only by sockeye. Along almost the whole western coast of Kamchatka, except for the Ozernaia River region, the catches of coho are greater than the catches of sockeye. Nevertheless, in the total landings of salmon for Kamchatka the coho occupies only fourth place, being considerably exceeded in landings by chum and sockeye salmon, not to mention the great preponderance of pink salmon.

However, whereas the fishery for such salmon as sockeye and chums has already reached a very considerable intensity, that certainly cannot be said of the coho.

The less intensive commercial utilization of coho is to be explained by their late arrival, as compared with other salmon. The principal run of coho takes place during the last 10 days of August and continues through September. However, as a rule the marine trap nets are pulled out about the first of September, with the onset of the autumn storms. At the time of the coho migration, work on the curing and shipping of the products of the commercial fisheries is going on, and it is mainly the collective farms along the river front which pursue a fishery for cohoes.

However it should not be thought that the cause of the small catch of cohoes (as compared with pinks, chums and sockeye) stems exclusively from the conditions of the fishery. It is quite obvious that the size of the stock of cohoes in Kamchatka waters is considerably less than the size of the pink and chum stocks. The question of to what extent the low catch of cohoes is a result of the organization and other conditions of the industry, and to what extent it depends on the actual size of the stock, is of great importance for evaluating the prospects of the fishery for this species in Kamchatka.

A scientifically-based solution on this problem will be possible only on the basis of long-term studies of the biology of the coho, including wide application [page 44] of experiments under natural conditions. To solve this question it is necessary to study from all sides the conditions for reproduction and production of the coho, and its ecology: the results of spawning, the conditions of life and survival of the young in fresh waters, the migration of the young fish to sea, the conditions and place of abode of the coho in the sea--these are the principal factors which require examination.

The most important of these is to establish the rate of production of downstream-migrating smolts [as a percentage of the number of eggs in female spawners], and the rate of return of the spawners [as a percentage of the number of smolts]. Obtaining the first of these coefficients will be achieved by an accurate census of number of spawners ascending to spawn in a given river system, on the one hand, and by an accurate quantitative census of the progeny of these spawners at the time of their migration to the sea on the other hand; the coefficient of return can be obtained from a determination of the number of downstream-migrating young from the river system and the number of mature fish returning for spawning to this system after the appropriate number of years; and the duration of such an experiment must correspond at least to one full life cycle of the fish.

The technical organization of work of this sort presents no special difficulties and it can be carried out in its entirety on one of the characteristic spawning waters. Such work in the study of sockeye salmon has already been under way for some years with great success, conducted by the Kamchatka Division of TINRO in the basin of the Paratunka River.

Results of systematic observations on the biology of the coho, and on a quantitative census of the downstream-migrating young and of the mature fish, will certainly give a sufficiently good scientific foundation for increasing the fishery of this species of salmon.

However for reasons of an organizational nature it has not been possible, up to the present time, to undertake studies of coho biology with the vigour that would be desirable, and the first stage of their investigation has been restricted to a collection of materials for a general biological characterization of the species, to observations on the migration, spawning, development of the eggs, and the conditions of life and growth of the young fish in fresh waters.

For a place of work the watershed of the Paratunka River was selected, which empties into Avachin Gulf on the east coast of Kamchatka. The selection of this region for study was determined by the following considerations: (a) the Paratunka River is the best studied region as regards the water on the spawning grounds and from the point of view of the distribution of spawners of the various species of salmon in the basin; (b) it is convenient for the establishment in the future of the proposed experimental work on coho (marking, quantitative census), partly because it is easy to enumerate and inspect returning marked fish, both in the river itself and in the parts of the sea which lie in the immediate vicinity; (c) similar work on sockeye has already been going on there for a number of years, and this will make possible valuable comparisons in future.

The present work has as its purpose to give a general biological characterization of the coho. Its basis is the results of our observations on the migration of the mature fish and their spawning, and the development and growth of the young coho in the Paratunka basin in 1935 and to some extent in 1936. In addition we have worked out and used the ages and other material from the Observation Points of the Kamchatka Division [of TINRO], which have been collected in various years at different points along the Kamchatka coast. For the times of migration of coho we have utilized the reports of the inspectors of the [page 45] fisheries administration [Upravlenie Regulirovanaia Rybolovstva]. Data on the chemistry of the water on the spawning areas of coho in the rivers of the west coast have been supplied by E. M. Krokhin.

I. Distribution

The region of distribution of coho salmon is considerably more restricted than that of a number of other species of Oncorhynchus--the chum, pink and sockeye salmons. On the Asiatic coast its extreme northern point of distribution is the Anadyr River, which it reaches in small numbers and where it has no commercial importance. Farther to the south it is distributed along the eastern and western coasts of the Kamchatka peninsula. It ascends the rivers of the Okhotsk Sea coast in small numbers. Occasional individuals occur on the Shantar Islands, and on the islands of Sakhalin and Hokkaido.

Along the North American coast it is distributed from Alaska south to San Francisco.

In Kamchatka the coho occurs everywhere in commercial quantities, and ascends almost all the rivers both of the east and of the west coast of the peninsula. The most important region for the coho fishery on the east coast is the Kamchatka River. On the west coast the most important regions are the Kikhchik and Bolshaia Rivers,

II. Morphometric characteristics

There is no really complete characterization of coho salmon, based on the study of an adequate number of individuals, either in the Soviet or in foreign literature. Nevertheless with each year broader studies of our far-eastern salmons are being directed to the question of the racial composition of each species. For this there arises the necessity of a more careful description of typical characteristics of each species to be used for a comparison of the fishes of one and the same species from different regions, or of fish which differ in time of migration, in conditions and time of spawning, and so on. Therefore in the present work I consider it advisable to give a description of the basic morphometrical characteristics

of the coho. For this purpose in the fall of 1935 I made measurements on 100 female and male cohoes at the mouth of the Paratunka River, and at the same time P. A. Dvinin and R. S. Semko, scientific workers of the Kamchatka Branch of TINRO, made measurements of 50 males and 50 females at Cannery No. 5 in the Bolshaia River region of the west coast of Kamchatka. The variability of both groups of measurements was computed by statistical methods. In both rivers the fish were in stage III-IV of maturity of the sexual products, and breeding colour was absent.

The system of measurements recommended by Pravdin (9) for salmon was used, with somewhat fewer quantitative characters.

The following meristic characters were included: 1) number of scales in the lateral line; 2) number of rays in the dorsal fin, simple and branched [these being counted separately]; 3) number of rays in the anal fin, simple and branched; 4) number of branchiostegal rays; 5) number of gill rakers on the first arch; 6) number of pyloric caeca (only for fish from the Paratunka River); 7) number of vertebrae.

[page 46] The morphometric study of Pacific salmon is made difficult by great variability and plasticity in their characters. The sizes of the parts of the body and of the head, expressed as percentages of the length of the body or of the length of the head, in most cases exhibit marked differences in relation to their stage of physical maturity, especially in the males. Comparison of fish from two or several regions commonly must be carried out with individuals which are taken either in the rivers or in the mouths of rivers of the regions in question, because for fish taken in the sea it is not always possible to say what region they are going to for spawning. In addition, fish taken in the mouths of rivers frequently show different degrees of development of the changes associated with spawning, and in comparing their morphological characters it is not difficult to fall into error.

That is certainly so in cases where it is necessary to examine morphological resemblances or differences among fish of one and the same watershed, which differ either in time and conditions of spawning, or in some other biological peculiarity. In such a situation the comparison can be made only on fish from the spawning grounds, after the nuptial changes have already reached their maximum development. As a result of this, indexes of different characters expressed as fractions of the length of the body, or the length of the head, of the fish are frequently not usable for comparing two samples of fish of the same species.

Therefore as basic measurements to which we refer a majority of the morphometrical characters we have adopted the length of the trunk [tushka], and the length of the head from the anterior end of the maxillary bone, these being characters

which change little with the attainment of sexual maturity and elaboration of nuptial dress.

Indexes of characters that are subject to change [in the spawning season] are expressed by us, as a rule, as percentages of the length of characters that change [similarly] (length of the head, and length of the body to the fork of the tail); while indices of quantities which are not subject to significant [nuptial] change are expressed as percentages of the length of little-changing characters (length of the head from the anterior end of the maxillary bone, and length of the trunk).

The following are expressed as percentages of the fork length: 1) length of the head; 2) length of the trunk; 3) predorsal distance; 4) preventral distance; 5) preanal distance.

The following are expressed as percentages of the length of the head: 1) length of the snout; 2) length of the head from the origin of the maxillary bone.

[page 47] The following are expressed as percentages of the length of the trunk: 1) length of the insertion of the dorsal fin; 2) height of the dorsal fin; 3) length of the pectoral fin; 4) length of the ventral fin; 5) length of the insertion of the anal fin; 6) height of the anal fin; 7) length of the upper lobe of the caudal fin; 8) length of the middle rays of the caudal fin; 9) greatest depth of the body; 10) least depth of the body; 11) greatest circumference of the body; 12) length of the caudal peduncle; 13) distance from the ventral to the anal fin.

The following are expressed as percentages of the length of the head from the beginning of the maxillary bone: 1) length of the snout from the beginning of the maxillary bone; 2) diameter of the eye in the horizontal plane; 3) diameter of the eye in the vertical plane; 4) length of the head in front of the eye; 5) length of the maxillary bone; 6) breadth of the maxillary bone; 7) depth of the head through the middle of the eye; 8) depth of the head at the occiput; 9) breadth of the forehead.

The results of a statistical analysis of the variability of the measurements of 300 specimens of coho are shown in Table 1.

The total [absolîûtnaîa͡] length of the body of cohoes at the mouth of the Paratunka River is from 45 to 72 cm, while the fork length of the body is 96-97% of the total length.

There are no clear indications of differences between males and females. The number of scales in the lateral line varies from 127 to 141, the average being 135-136. Berg (2) uses 120 as the minimal number of scales on the lateral line.

Table 1. [pages 48-51] List of morphometric characters of Kamchatka cohoes.

Character	Sex	Paratunka River				Bolshaia River			
		Range	M	±m	σ	Range	M	±m	σ
Total length (cm) [tips of tail in natural position]	♂	45-72	60.50	0.59	5.37				
	♀	46-70	60.70	0.40	4.04	...	...	...	...
Fork length [FL] (cm)	♂	42-70	58.32	0.56	5.60	46-66	56.22	0.67	4.76
	♀	46-66	58.80	0.38	3.82	46-64	57.34	0.43	3.42
FL as % of total length	♂	89-99	96.14	0.15	1.30				
	♀	89-99	97.05	9.13	1.27	...	...	...	...
Scales in lateral line	♂	127-141	135.20	0.33	3.29	127-141	135.48	3.46	3.23
	♀	128-141	136.32	0.26	2.61	130-142	136.32	0.32	2.28
Dorsal fin rays	Both	II-V 8-10	...	...	...	...	...	...	...
Anal fin rays	Both	III-V 11-14	...	...	...	...	...	...	...
Branchiostegal rays	Both	12-15	13.97	0.05	0.66	11-15	13.89	0.08	0.81
Gill rakers on the 1st arch	Both	19-24	21.41	0.06	0.78	19-25	21.94	0.10	1.08
Pyloric caeca	♂	46-78	59.44	0.63	6.34				
	♀	43-75	61.16	0.66	6.02	...	...	...	...
Vertebrae	Both	63-72	68.67	0.08	1.19	64-69	66.19	1.08	0.89
Morphology of the head									
Head length [HL], as % of FL	♂	20-28	24.33	0.11	1.15	18-25	23.24	0.16	1.14
	♀	19-24	21.95	0.10	0.97	19-24	21.50	0.11	0.75
HL from the origin of the maxillary [hl], as % of HL	♂	77-87	79.36	0.30	3.02	79-91	83.94	0.28	2.08
	♀	81-91	82.40	0.25	2.50	81-92	85.94	0.28	1.98

[Table 1, continued]

Length of snout, as % of HL	♂	29-41	36.44	0.23	2.39	29-39	34.20	0.28	1.92
	♀	25-35	30.96	0.19	1.90	26 38	30.98	0.22	1.55
Length of snout from origin of maxillary, as % of hl	♂	13-23	18.54	0.17	1.68	16-25	20.30	0.23	1.62
	♀	11-22	17.36	0.17	1.72	15-22	18.52	0.19	1.37
Horizontal diameter of eye, as % of hl	♂	8-14	10.99	0.11	1.05	8-13	10.75	0.18	0.95
	♀	9-15	11.58	0.08	0.80	9-13	10.94	0.09	0.68
Vertical diameter of eye, as % of hl	♂	7-15	10.70	0.13	1.80	8-13	10.34	0.13	0.95
	♀	8-14	11.10	0.11	1.14	8-13	10.58	0.10	0.72
Interorbital distance, as % of hl	♂	54-72	63.74	0.16	1.62	56-70	66.18	0.22	1.56
	♀	52-70	65.02	0.22	2.16	58-72	67.38	0.28	1.98
Length of the maxillary, as % of hl	♂	36-54	45.82	0.31	3.14	40-50	45.54	0.26	1.85
	♀	34-48	65.02	0.25	2.48	40-48	43.78	0.22	1.54
Width of maxillary, as % of hl	♂	7-13	9.71	0.11	1.08	7-11	9.88	0.11	0.79
	♀	6-12	9.72	0.10	0.10	8-12	9.96	0.10	0.77
Depth of head at the occiput, as % of hl	♂	66-94	81.06	0.58	5.84	70-88	79.50	0.56	3.96
	♀	66-92	81.22	0.48	4.82	72-92	80.42	0.62	4.40
Depth of head through the middle of the eye, as % of hl	♂	62-68	60.66	0.32	3.22	48-62	56.94	0.45	3.15
	♀	50-70	59.40	0.32	3.22	62-63	58.10	0.46	3.26
Width of the forehead, as % of hl	♂	36-50	45.46	0.24	2.47	38-48	48.50	0.26	1.82
	♀	36-52	44.88	0.24	2.40	40-48	44.02	0.25	1.78

[Table 1, continued]

Character	Sex	Paratunka River Range	M	±m	σ	Bolshaia River Range	M	±m	σ
Morphometry of the fins									
Length of the insertion of the dorsal fin, as % of the length of the trunk [TrL]	♂	10-17	13.84	0.13	1.33	10-14	13.18	0.12	0.82
	♀	10-16	13.43	0.11	1.07	10-14	12.56	0.09	0.61
Height of the dorsal fin, as % of TrL	♂	12-19	15.64	0.15	1.55	10-15	13.94	0.12	0.88
	♀	11-18	14.67	0.13	1.32	11-16	13.06	0.12	0.88
Length of the pectoral fin, as % of TrL	♂	15-22	19.21	0.16	1.14	14-20	17.94	0.13	0.96
	♀	14-21	17.75	0.11	1.13	13-19	16.88	0.14	1.05
Length of the anal fin, as % of TrL	♂	12-21	17.24	0.14	1.14	13-17	15.04	0.10	0.77
	♀	13-19	15.83	0.11	1.13	11-16	13.92	0.11	0.82
Length of the insertion of the anal fin, as % of TrL	♂	12-19	15.72	1.12	1.14	13-17	15.64	0.12	0.87
	♀	11-18	15.30	1.13	0.77	12-17	15.40	0.12	0.84
Height of the anal fin, as % of TrL	♂	9-16	12.77	0.13	1.32	9-13	11.78	0.10	0.76
	♀	9-16	12.87	0.12	1.20	7-13	11.38	0.13	0.89
Length of the upper lobe of the caudal fin, as % of TrL	♂	17-23	20.48	0.13	1.37	17-23	20.62	0.15	1.09
	♀	16-22	19.41	0.12	1.24	17-23	19.70	0.14	1.01
Length of the middle rays of the caudal fin, as % of TrL	♂	7-12	7.70	0.08	0.85	7-11	9.30	0.09	0.67
	♀	7-12	9.35	0.08	0.83	7-10	8.94	0.07	0.54

[Table 1, continued]

Morphometry of the trunk									
Length of the trunk, as % of FL	♂	67-75	72.09	0.14	1.42	69-77	72.14	0.20	1.49
	♀	67-80	74.52	0.16	1.57	69-76	73.14	0.15	1.07
Depth of caudal peduncle, as % of TrL	♂	28-39	33.34	0.21	2.12	27-36	33.20	0.27	1.90
	♀	26-37	32.39	0.20	2.04	28-38	32.58	0.25	1.78
Greatest depth of body, as % of TrL	♂	8-12	10.28	0.06	0.65	7-11	9.94	0.07	0.50
	♀	7-11	9.81	0.07	0.71	8-12	9.90	0.07	0.53
Greatest circumference of body, as % of TrL	♂	70-92	81.18	0.45	4.52	...	...	...	...
	♀	68-90	78.90	0.46	4.56	...	...	...	...
Length of caudal peduncle, as % of TrL	♂	18-24	21.85	0.09	0.94	18-23	21.48	0.13	0.93
	♀	17-24	21.69	0.10	1.05	19-23	21.06	0.12	0.83
Length from snout to insertion of ventral fin, as % of FL	♂	38-54	46.19	0.31	3.07	42-50	47.30	0.15	1.08
	♀	38-48	44.60	0.24	2.42	42-50	46.40	0.16	1.22
Length from snout to insertion of dorsal fin, as % of FL	♂	42-54	50.13	0.27	2.70	46-54	51.86	0.16	1.15
	♂	42-56	49.77	0.27	2.72	46-54	50.98	0.17	1.22
Length from snout to insertion of anal fin, as % of FL	♂	60-70	67.17	0.20	1.96	65-71	68.22	0.15	1.12
	♀	61-72	67.15	0.21	2.06	63-70	67.50	0.18	1.28
Distance from pectoral to anal fin, as % of TrL	♂	20-38	26.05	0.24	8.40	...	...	...	...
	♀	21-32	26.42	0.23	8.02	...	...	...	...

The number of rays in the dorsal fin is II-V 8-11, most frequently IV-V 9-10. The number of rays in the anal fin is III-IV 11-15, most frequently IV-V 12-13. The number of branchiostegal rays is: minimum 11, maximum 15, most common 13-14.

The gill rakers are short and thick, the number of the first arch is from 19 to 25, most frequently 21-22; in this respect cohoes are easily distinguished from sockeye.

The number of pyloric caeca sharply distinguishes the coho from the chum salmon. The number in the coho varies from 46 to 78, average 59-61. The number of vertebrae is from 63 to 72, most frequently 66-69.

The length of the head when coho first enter the river from the sea is on the average 23-24% of the length of the body for males, and 21-22% for females. The difference in the length of the head is caused by the lengthening of the snout of the males, mainly of its anterior portion. The length of the snout on arrival of the fish in the river is for the males 34-35% and for the females 30-31% of the length of the head. The length of the snout from the anterior margin of the maxillary bone, as a percentage of the length of the head from the anterior end of the maxillary bone, shows less difference between females and males.

The horizontal and vertical diameters of the eye are almost the same. Differences between males and females in the size of the eye were not observed. The diameter of the eye is 10-11% of the length of the head from the end of the maxillary bone. The preoptic length of the head in both sexes is 63-67% of the length of the head from the beginning of the maxillary bone, and in coho from the Paratunka River there were differences between males and females in this respect. The average for males was 63.74% and for females 65.02%. However in cohoes from the Bolsheretsk region the difference between the sexes was insignificant. The maxillary bone in males is somewhat longer than in females. For males it is 45-46% of the length of the head from the origin of the maxillary bone on the average, and for females 42-44%. The width of the maxillary bone in both sexes is 10% of the length of the head from the origin of the maxillary bone. The remaining measurements of the head did not exhibit differences between [page 52] males and females. The depth of the head at the occiput as a percentage of the length of the head from the origin of the maxillary bone was 79-81% in both sexes; the depth of the head through the middle of the eye was 58-60%, and the breadth of the forehead 43-45%.

The height of the dorsal fin, the length of the pectoral and pelvic fins, and the length of the upper lobe of the caudal fin were greater in males than in females, in both regions. The length of the insertion of the dorsal fin was 12-14% of the length of the trunk in both sexes. The average height of the

dorsal fin was 13.94-15.64% of the length of the trunk in males, and 13.06-14.67% in females. The average length of the pectoral fins was 17.94-19.21% of the length of the trunk in males, and 16.88-17.75% in females. The average length of the ventral fins was 15.04-17.24% of the length of the trunk in males, 13.92-15.83% in females. The length of the insertion of the anal fin was 15-16% of the length of the trunk in both sexes. The height of the anal fin was 11-13% of the length of the trunk. The length of the upper lobe of the caudal fin was 20.5% of the length of the trunk in males, and 21.5% in females. The length of the middle rays of the caudal fin was 7.70-9.30% of the length of the trunk in males, and 8.94-9.35% in females.

The length of the trunk was 72% of the fork length of the body in males and 73-74% in females. The greatest depth of the body in both sexes was 32-34% of the length of the trunk, and the least depth was 9-10%. The predorsal, preventral and preanal distance was greater in males than in females, which however is explained by the greater length of the anterior portion of the snout in males. The distance from the ventral to the anal fin was 26% of the length of the trunk.

In the sea just before entering the river the coho has a bright silvery colour. It is to this external appearance of the fish that it owes its American name "silver salmon", and also the Russian name "white fish" [belaîa ryba] which I have read of in Krasheninnikov (3) but which today is no longer encountered.

The back and the upper part of the head is greenish, sometimes with a bluish cast. The upper part of the head, back and sides above the lateral line, and also sometimes the lower part of the dorsal fin and the base of the upper lobe of the caudal fin are covered with rather sparse black spots of irregular form. The rays of the caudal fin close to its base have a silvery sheen that is not found in chums or sockeye.

In breeding dress the basic tone of the body colour is a dark mulberry shade, rather dusky, not as bright as in the sockeye. The flesh of the fish in the sea is rosy red, but at the time of spawning it has become white or slightly yellowish.

III. Age of the coho

Cohoes attain sexual maturity and go up to spawn mainly in their third year of life; a considerably smaller part of them go in their fourth year. Coho and pink salmon are the fastest growing representatives of the genus Oncorhynchus, since the great bulk of sockeye, chum and chinook salmon commonly have a more prolonged life cycle.

In all, I have determined the age of more than 1500 cohoes, from different parts of Kamchatka, and in different years.

I have at my disposal age material from cohoes from the region of the Avachin Gulf, the Kalyger Bay and the basin of the Kamchatka River on the east coast, and from the Ozernaia River, Bolsheretsk and Kikhchik on the west coast.

[page 53] In contrast to pink, chum and sockeye salmons, coho never go to sea during their first summer after hatching from the egg. All specimens examined of this species showed one and sometimes two years of freshwater growth. Therefore a characteristic feature of coho scales is the invariable presence of a narrow river annulus in the center of the scale, which represents the time spent in fresh water.

The age composition of cohoes is more uniform than in other species of Pacific salmons, with the exception of pinks. Commonly only two age categories are encountered: the first--one year spent in fresh water, and a year and a half in the sea; the second--two years in fresh water and a year and a half in the sea. In addition precociously maturing males are everywhere encountered in small numbers, males which have spent one summer only in the sea, following a one-year or two-year stay in fresh water. In what follows we will designate the first age-group mentioned above as 2_1+, that is two years plus a bit more, of which one year is spent in the river; and the second group above will be designated as 3_2+, that is, three years and a bit more, of which two are river years.

Table 2 shows the results of all of our age determinations for coho.

As the Table shows, age 2_1+ is the predominant one among migrating fish. Among the total number of fish examined more than two-thirds were representatives of this category and only one-third were 3_2+.

This total does not include 4 fish captured in Lake Ushki in 1927, which apparently had spent 3 years in fresh water and after this a year and a half in the sea, that is, the total age of these fish was 4_3+. Such specimens evidently are exceptional and occur rarely. I have never observed any case of migration of young coho to the sea in the first summer after their hatching from the egg.

The relationship between the two principal age categories of coho is not the same throughout the various regions of Kamchatka. Along the east coast of Kamchatka, coho of age 3_2+ predominate, while on the west coast age 2_1+ predominate. Gilbert (13) shows that on the Pacific coast of North America the proportion of cohoes of 3_2+ increases from south to north; so that whereas along the California coast, in Puget Sound and in the rivers of British Columbia fish of age 2_1+ greatly predominate, in the Yukon River in Alaska the importance of this age group decreases and fish having the age of 3_2+ constitute about 60%.

Table 2. [page 54] General results of the analysis of age composition of cohoes (age-groups in percentages).

Region	Sex	Age 2_1+	Age 3_2+	Number of fish
East coast of Kamchatka				
Paratunka River, 1935	♂	67	33	94
	♀	49	51	103
Avachin Gulf, Solevarka Bay, 1934	♂	75	25	44
	♀	80	20	39
The same, 1935	♂	76	24	29
	♀	95	5	19
Kalyger River, 1929	♂	26	74	64
	♀	29	71	34
Kamchatka River, mouth, 1927	♂	6	94	36
	♀	5	95	59
The same, mouth, 1933	♂	87	13	44
	♀	35	15	32
The same, mouth, 1932	♂	80	20	117
	♀	90	10	46
Lake Ushki, 1926	♂	13	87	23
	♀	...	100	12
The same, 1927	♂	4	96	27
	♀	6	94	16
The same, 1928	♂	...	100	9
	♀	...	100	21
Kyrganik River, 1931	♂	95	5	58
	♀	92	8	36

[Table 2, continued]

Region	Sex	Age 2_1+	Age 3_2+	Number of fish
West coast of Kamchatka				
Ozërnaîa River, 1936	♂	100	...	55
	♀	100	...	41
Bolshaîa River, 1930	♂	100	...	119
	♀	100	...	63
Bolshaîa River, 1934	♂	90	10	58
	♀	90	10	88
Bolshaîa River, 1935	♂	96	4	47
	♀	94	6	48
Kikhchik River, 1930	♂	100	...	115
	♀	100	...	83

A comparison of the age composition of the coho from the Avachin Gulf, the most southern point of our observations, with those from the Gulf of Ust-Kamchatsk, the most northerly point on the east coast, does not support this rule. However the rather small distance between these two regions--the distance between them is about 250 miles--is not sufficient to definitely demonstrate the inapplicability in our waters of the abovementioned rule which was established for the coast of North America. Unfortunately we do not have coho material from our northern rivers--from the Oliutory-Navarin region or even from the Anadyr River.

In the basin of the Kamchatka River, the most important spawning region for coho, age samples were taken not only at the mouth of the river but also on the spawning grounds. The extensive basin of the Kamchatka River, with its numerous spawning grounds situated not only along the whole extent of the river but also in its numerous tributaries, presumably has biologically isolated [page 55] local stocks of fish associated with different parts of the basin. These stocks presumably are characterized by different times of migration and spawning, by peculiarities of their spawning grounds, and also by their age composition.

Differences in age composition of the runs of coho in different tributaries of the Kamchatka River are indicated by the materials which have been collected throughout this body of water. For example in Lake Ushki, which is in the middle course of the Kamchatka, it is mainly cohoes of age 3_2+ that spawn, and occasional specimens even of age 4_3+. An analysis of the materials collected in Lake Ushki over 3 years shows either a quite insignificant number of specimens of age 2_1+, as was true in the samples of 1926 and 1927, or this age group was completely absent, as in 1928.

In spite of the small number of specimens studied in each year, the unvaried predominance of age 3_2+ during 3 years, in this spawning area, shows that this age composition is apparently a characteristic feature of this spawning region.

On the other hand, in the Kyrganik River, one of the large left-bank tributaries of the Kamchatka River situated considerably farther upstream than Lake Ushki, 94% of the fish were of age 2_1+.

The age composition of coho from the mouth of the Kamchatka River was not uniform. In the three samples collected in 1927, 1932 and 1933, in two cases there was a preponderance of fish of age 2_1+, while in the 1927 sample age 3_2+ predominated.

If we take into consideration that the different tributaries of the Kamchatka River can have stocks of fish with age compositions which differ one from the other, this phenomenon

becomes understandable. It is necessary to assume that the different age compositions of coho in the samples from Ust-Kamchatsk (in the years mentioned) can be explained not by changes in age composition from year to year, but by the fact that samples were taken from different local stocks of fish migrating at the period in question up through the mouth of the river.

In general, no differences in age composition were observed between males and females; in individual regions there were nonsignificant deviations toward preponderance of one of the age categories both among the males and among the females.

In the Table of age compositions above precociously maturing males are not included. They occur in all regions of Kamchatka in small numbers. These cohoes are from 27 to 33 cm and their age is 1_1+ or 2_2+. In all cases they were males which had spent only one summer in the sea.

In October, 1936, 22 mature cohoes were captured from Lake Maloe Sarannoe, which does not communicate with the sea. Both males and females had fully developed nuptial colour, similar to ordinary anadromous cohoes. Inspection of the scales of these fish showed that the cohoes of this inland body of water were 3+ years of age, all of them years of freshwater growth which they had spent in the relict lake. In contrast to the anadromous form, no sudden changes in the width of the sclerites were apparent in them, such as is common when the slow growth of the freshwater period is followed by the sharp increase in rate of growth in the sea. The widths of the sclerites in the cohoes acclimatized in the inland lake were more or less uniform throughout the first, second and third summers of their life. Winter [page 56] rings were clearly developed on the scales. Along the edges of the scale there were narrow sclerites of the winter type, corresponding apparently to a slowing up of growth in the pre-spawning autumn period.

A typical scale of an anadromous coho has around the center an annulus of the freshwater period of life, which contains commonly from 10 to 23 sclerites, most often 19-20. This part of the scale has thin, narrow sclerites and is sharply distinguished from the part of the scale which is developed during the period that the fish spends in the sea. Immediately adjacent to the centrum there are several sclerites corresponding to the first summer after leaving the nest, then there is a series of narrow river sclerites representing the winter of the first year, and then again there are broader sclerites laid down in the second summer, prior to migration to the sea.

The freshwater portion of the scale is frequently separated from the adjacent broad marine sclerites by some

thin crumpled or broken sclerites, which represent the slowing-up of growth during the transition from fresh water to salt water.

In the second year of life of fish of age 2_1+, there are a number of river sclerites and a broad field of widely spaced sclerites of the marine type. Then there follows the winter ring, which is laid down during the single winter the fish spends in the sea. Finally, the external margin of the scale is completed by a large zone of broad sclerites of the second and last summer in the sea. Among fish which are captured very late in life with the traces of breeding colours, along the margin of the scale there are sometimes present narrow sclerites, which are laid down apparently during the period of the spawning migration and the reduction in food consumption which is associated with this.

Coho scales of the second age category, 3_2+, are distinguished from the first type only in their central portion, laid down during the period spent by the young fish in the river. In them the field of freshwater sclerites is almost twice as broad, while the number of sclerites varies from 25 to 35. The character and distribution of the second river year is similar to the first river year.

In the marine part of its scales a fish of age 3_2+ is similar to fish of the first group; it also has two bands of broadly spaced sclerites, which represent the third and fourth summers of life of the fish. Between them lies the single marine winter ring.

Thus in both types the fish has only two summer periods of marine growth and one marine winter ring.

On scales of precociously maturing coho, following the band of narrow river sclerites that represent the one or two years of life in the river, there follows a band of typical marine sclerites corresponding to the single summer spent by the fish in the sea.

IV. Length and weight of the coho

In considering the length of the coho we have chosen to use length according to Smitt [fork length], that is, from the end of the snout to the end of the middle rays of the tail fin.

In all, more than 3000 fishes from various regions of Kamchatka were measured in various years. If we exclude from consideration the prematurely maturing small males, whose numbers in general are not great, then the minimum observed size of the sexually mature [page 58] coho can be considered as 40 cm, and the maximum 88 cm.

Table 3. [page 57] Length of cohoes from different parts of Kamchatka.

Region	44.5	46.5	48.5	50.5	52.5	54.5	56.5	58.5	60.5	62.5	64.5	66.5	68.5	70.5
M A L E S														
East coast														
Kamchatka River	...	...	3	5	8	8	25	48	66	58	36	25	43	
Kyrganik River	1	...	...	...	2	6	2	2	10	11	16	19	23	
Lake Ushki	...	...	...	...	...	...	...	...	...	1	...	2	...	
Kalyger River	...	1	...	11	11	18	25	41	44	79	99	109	49	
Avachin Gulf	...	...	...	...	...	3	7	8	12	17	21	10	13	
Paratunka River	2	6	2	4	6	13	13	9	14	15	5	4	1	
West coast														
Kikhchik River	...	...	3	3	8	8	15	22	43	33	32	31	18	
Bolshaîa River	...	...	2	1	1	8	6	13	6	4	6	6	3	
Ozernaîa River	...	...	...	...	...	...	...	2	4	14	11	12	8	
F E M A L E S														
East coast														
Kamchatka River	...	...	...	2	5	17	43	72	110	121	69	38	16	
Kyrganik River	...	...	...	1	3	...	2	5	5	12	22	34	41	
Lake Ushki	...	...	...	...	...	...	1	...	...	...	...	...	...	
Kalyger River	1	1	7	9	13	28	21	32	52	66	108	85	19	
Avachin Gulf	...	...	2	...	1	2	3	16	17	28	21	9	1	
Paratunka River	...	2	...	2	1	6	17	15	18	21	19	2	...	
West coast														
Kikhchik River	...	...	...	1	1	7	17	32	61	63	52	23	6	
Bolshaîa River	...	1	1	5	4	7	8	9	1	...	2	...	...	
Ozernaîa River	...	...	...	1	...	...	3	2	4	10	14	2	...	

[Table 3, continued]

Region	70.5	72.5	74.5	76.5	78.5	80.5	82.5	84.5	86.5	88.5	90.5	N	M
M A L E S													
East coast													
Kamchatka River	3	2	...	...	...	...	...	...	...	...		300	61.8
Kyrganik River	25	31	16	10	13	2	...	...	1	...		190	70.0
Lake Ushki	1	4	2	2	3	4	3	1	...	...		23	76.0
Kalyger River	33	8	1	...	...	...	...	...	...	...		529	64.6
Avachin Gulf	5	2	1	...	...	...	...	...	...	...		99	64.6
Paratunka River	...	...	...	...	...	...	...	...	...	...		94	58.3
West coast													
Kikhchik River	12	7	3	...	...	...	...	...	...	...		238	62.0
Bolshaîà River	...	2	...	...	...	...	...	...	...	...		58	60.7
Ozernaîà River	3	1	...	...	...	...	...	...	...	...		55	64.5
F E M A L E S													
East coast													
Kamchatka River	1	...	...	...	...	...	...	...	...	...		494	60.4
Kyrganik River	20	9	1	1	1	...	...	...	...	...		157	67.5
Lake Ushki	2	4	4	...	1	...	...	...	...	...		12	74.3
Kalyger River	7	...	...	...	...	...	...	...	...	...		49	63.0
Avachin Gulf	...	...	...	...	...	...	...	...	...	...		100	62.7
Paratunka River	1	...	...	...	...	...	...	...	...	...		104	59.1
West coast													
Kikhchik River	1	...	...	...	...	...	...	...	...	...		264	61.2
Bolshaîà River	...	...	...	...	...	...	...	...	...	...		38	56.5
Ozernaîà River	...	...	...	...	...	...	...	...	...	...		41	62.6

The range of variation in length in males is considerably greater than in females; the maximum observed length of the female is 80 cm, that is, 8 cm less than in the males.

In coho as in other species of Pacific salmon males are usually longer than females.

The lengths of cohoes from various regions of Kamchatka are shown in Table 3.

A comparison of the average lengths of coho in different regions indicates some variability.

Along the coast of America the phenomenon of an increase in length of coho from south to north has been observed (14). The same thing is indicated by the data of F. V. Krogius for sockeye of the Kamchatka coast (4). The material at our disposal is not sufficient to verify this rule for coho. The average length of coho given in the Table show that fish of the greatest length occur in the largest river of the peninsula, the Kamchatka River--in one of its left-bank tributaries, the Kyrganik River, the average length of males is 70 cm, and of females, 67.5 cm. A small number of cohoes measured in the region of Lake Ushki also indicates an extremely large size of the fish there.

Along with these very large fish in certain tributaries of the Kamchatka River, the latter also has stocks of smaller cohoes, as indicated by measurements of fish taken at the mouth of the river--here the average length of males is only 61.8 cm and of females is 60.4 cm. The Table shows that the smallest average length known is at the mouth of the Paratunka River, and also the Bolshaîa River.

The differences in length of cohoes of different regions cannot be explained by differences in the age composition of the stock of the fish. Table 4 gives a comparison of average lengths of coho of the same age group, 2_1+, from different regions.

[page 59] These data show that when we consider only one of the two age groups, maximal size of the fish is still characteristic of the Kyrganik River, and minimal size of the Paratunka and Bolshaîa Rivers.

Thus the cause of the differing lengths of cohoes in the Kamchatka Region must be sought not in age differences, but in different rates of growth.

The average weight of the coho is 3-3.5 kg, the greatest observed weight is 6.8 kg and the least is 1.2 kg. Differences in the average weight of coho in the various regions in general correspond to differences in length of the fish, as is clearly shown by Table 5.

Table 4. [page 58] Average length of cohoes of age-group 2_1+.

Regions	Males	Number of fish	Females	Number of fish
East coast				
Kamchatka River	61.0	93	60.9	41
Kyrganik River	69.9	187	68.1	154
Kalyger River	63.3	17	61.0	10
Avachin Gulf	55.9	33	55.4	31
Paratunka River	57.5	63	59.4	50
West coast				
Kikhchik River	58.8	35	58.6	15
Bolshaîa River	56.4	45	57.4	45
Ozernaîa River	64.5	55	62.6	41

Table 5. [page 59] Weight of cohoes (in kilograms).

Regions	1	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	N	M
M A L E S															
East coast															
Kamchatka River	...	...	11	59	66	74	48	21	6	1	...	...		286	3.6
Kalyger River	...	40	21	54	57	89	109	95	68	19	11	1		529	4.1
Paratunka River	1	10	26	15	32	14	4	...	...	...	...	...		102	2.9
West coast															
Kikhchik River	3	6	6	21	12	4	4	...	...	...	...	...		56	2.8
Bolshaia River	7	17	37	28	21	1	...	...	...	...	...	...		111	2.4
Ozernaia River	...	...	...	4	16	14	17	4	...	...	...	...		55	3.8
F E M A L E S															
East coast															
Kamchatka River	...	...	90	107	167	145	36	8	1	...	...	...		494	3.5
Kalyger River	2	15	30	44	44	95	128	69	21	4	...	...		449	3.8
Paratunka River	...	5	12	36	46	8	1	...	...	...	...	...		108	2.9
West coast															
Kikhchik River	1	8	6	20	13	1	1	...	...	...	...	...		50	2.7
Bolshaia River	1	10	23	21	9	5	2	...	...	...	...	...		71	2.6
Ozernaia River	...	1	1	7	16	12	3	1	...	...	...	...		41	3.4

Table 6. [page 60] Coefficient of condition of cohoes.

Regions	Number of determinations	Coefficient of condition			Change %
		Male	Female	Both	
Mouth of the Paratunka River, August 31, 1935	200	1.31	1.30	1.31	100
Nikolaevsk kliuches[a] (time of spawning November 15-17, 1935)	100	0.91	0.83	0.89	68

[a]Distance from the mouth of the river, 16 km.

Males as a rule are heavier than females. Since we have not had the opportunity to follow changes in the condition of the fish, in relation to the maturity of its sexual products, by determining the chemical composition of its fat, I have made a determination according to Fulton's formula, while recognizing all the inadequacies of this method.

The first sample was taken in the mouth of the Paratunka River on September 1, 1935. The cohoes at this time were "silvery", and there were no traces of breeding colours. The stage of maturity of the sexual products was III-IV. A second sample was taken November 15-17 on the spawning grounds of the Nikolaevsk kliuches (in the Paratunka watershed) during the spawning period. Some of the specimens were already spawned out, and the remainder had running eggs and milt. The fish exhibited the final spawning coloring.

In computing the coefficient of condition by the formula, I [page 60] have calculated it not on the weight of the whole fish but on the weight of the fish less the weight of the sexual products. The average coefficients so obtained are shown in Table 6.

The maximum coefficient of condition in the first case is 1.75, and in the second case 1.15.

Thus the average coefficient of condition of the fish had decreased by 32% from the time of its arrival in the river, that is by almost a third.

In Fig. 2 and 3 each curve represents the average weight of the fish at a particular length. The fish used for analysis were a sample from the mouth of the Kamchatka taken August 15 to September 1, and another from one of the upper tributaries of that river, the Kyrganik River, from October 19 to November 24. In the former instance the fish did not show any noticeable breeding changes, in the second instance the breeding colour was quite clearly developed. From the first locality to the second the distance by river is about 560 km.

These graphs show that the weights of fish taken 560 km upstream from the river's mouth are 0.5-1.0 km less than at their arrival in the river, but lie along a line parallel to the latter.

V. Rate of growth [page 61]

Back calculation of rate of growth was done from the scales of 499 fish, among which were 198 fish from the mouth of the Paratunka River, 202 from the Kamchatka River, and 99 from the Bolshaia River on the west coast of Kamchatka. In the samples from the Paratunka and Kamchatka Rivers both of the age categories of coho were represented, 2_1+ and 3_2+. In the

Fig. 1. [page 46--not reproduced here] Female coho from the mouth of the Paratunka River. Total length [tail in natural position] 58 cm.

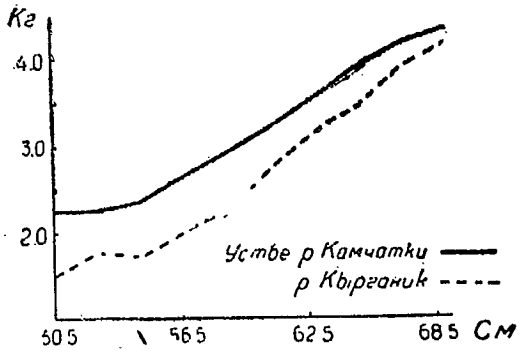

Fig. 2. [page 60] Average weight of female cohoes at a given length. Solid line--mouth of the Kamchatka River; broken line--Kyrganik River.

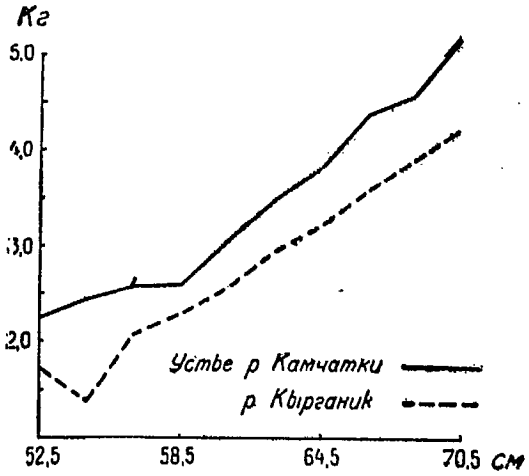

Fig. 3. [page 60] Average weight of male cohoes at a given length (lines as in Fig. 2).

Table 7. [page 61] Body length of cohoes in the first year of life.

Age-group	Sex	Length in cm: 4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	N	M
Paratunka River, 1935														
2_1+	♂	...	...	12	20	23	6	12	7	6	7	...	87	8.4
	♀	...	...	14	25	30	8	14	2	...	...	...	93	7.9
3_2+	♂	...	...	...	...	...	2	3	2	1	...	...	8	9.7
	♀	...	...	3	...	2	2	3	...	...	...	...	10	8.2
Bolshaîa River, 1935														
2_1+	♂	1	1	7	17	20	3	...	...	...	...	...	49	7.3
	♀	...	...	5	17	17	8	3	...	...	...	...	50	7.8
Kamchatka River, 1932														
2_1+	♂	...	...	...	5	21	29	29	12	7	2	1	106	9.5
	♀	...	...	1	2	6	18	11	9	7	...	...	54	9.7
3_2+	♂	...	...	...	1	7	6	10	3	2	...	...	30	9.6
	♀	...	...	...	1	...	3	2	4	2	...	...	12	10.2

Table 8. [page 62] Body length of cohoes in their second year of life.

Age-group	Sex	Length in cm												
		10.5	12.5	14.5	16.5	18.5	20.5	22.5	24.5	26.5	28.5	30.5	32.5	34.5	36.5
Paratunka River, 1935															
2_1+	♂	...	...	...	...	...	...	...	...	...	1	4	8	17	
	♀	...	...	...	...	...	...	...	...	...	1	3	15	18	
3_2+	♂	1	1	...	4	2	...	...	...	...	...	...	...	...	
	♀	1	1	4	3	1	...	...	...	...	...	...	...	...	
Bolshaîa River															
2_1+	♂	...	...	...	...	...	...	...	...	...	...	...	4	5	
	♀	...	...	...	...	...	...	...	...	...	...	...	2	4	
Kamchatka River															
2_1+	♂	...	...	...	...	...	...	...	...	...	...	...	1	2	
	♀	...	...	...	...	...	...	...	...	...	...	...	1	...	
3_2+	♂	...	6	8	11	4	2	...	...	...	...	...	...	...	
	♀	...	4	3	1	4	...	...	...	...	...	...	...	...	

sample from the Bolshaîa River only the younger age category of coho (2_1+) occurred, in which the scales had only one river year.

From every specimen 3 scales were examined, and from these an average index of growth of the fish was obtained for the corresponding years. Tables 7-13 show both the average size by years, and also the limits of variation and the growth increment each year (by age-groups and by fishing regions).

In inspecting these Tables and the graphs (Fig. 4, 5) we must bear in mind that for age-group 2_1+ the third year, and for age-group 3_2+ the ourth year, is not complete and includes only about 4 months of intensive growth after formation of the last winter ring.

In the coho, as in all anadromous salmons, there is a marked acceleration of growth after the young migrate to sea. Age-group 2_1+, which migrates to sea a year earlier than age-group 3_2+, exceeds the latter in growth by a whole year.

The marked difference in rate of growth between the two age-groups of coho is exhibited in the second year of life; group 2_1+, whose growth is made under marine conditions, reaches 38-43 cm in length at the end of its second year of life, and exhibits an increment of 400% over the first fresh-water year; while at the same time fish of group 3_2+, which remain one year longer in the river, grow more slowly in the second year of life than in the first year. In the sea the rate of growth of the two age-groups is almost the same, the graphs of their marine growth run parallel. The average length of the two groups after one year spent in the sea is almost the same; the difference between them consists only in the fact that one of them is a year older than the other.

[page 65] Increment in the last year, which includes only a few months of intensive summer growth in the sea, amounts to from 160 to 270% of the increment of the first year, in both groups.

No qualitative differences in growth were observed between males and females; in general the growth of the two sexes runs parallel.

Lack of specimens of young coho taken during their sea life makes it impossible for me to verify the calculated sizes by actual measurements of coho during the marine period of their life cycle. Comparison of the actually observed lengths of young coho from the Paratunka River with the sizes computed by back calculation from the scales indicates agreement between the two quantities, as the following figures show:

[Table 8, continued]

Age-group	Sex	Length in cm 36.5	38.5	40.5	42.5	44.5	46.5	48.5	50.5	52.5	54.5	N	M
						Paratunka River, 1935							
2_1+	♂	16	16	14	7	5	...	...	...	...		87	38.3
	♀	11	20	6	13	6	...	...	...	...		93	38.3
3_2+	♂	...	...	...	...	...	...	...	...	...		8	16.7
	♀	...	...	...	...	...	...	...	...	...		10	15.9
						Bolshaia River							
2_1+	♂	12	9	12	3	4	...	...	...	...		49	39.3
	♀	16	12	12	4	1	...	...	...	...		50	39.0
						Kamchatka River							
2_1+	♂	8	11	14	21	17	19	6	4	3		106	48.1
	♀	10	9	11	11	4	6	2	...	...		54	41.9
3_2+	♂	...	...	...	...	...	...	...	...	...		30	16.9
	♀	...	...	...	...	...	...	...	...	...		12	17.0

Table 9. [page 63] Body length of cohoes in their third year of life.

Age-group	Sex	Length in cm: 28.5	32.5	36.5	40.5	44.5	48.5	52.5	56.5	60.5	64.5	68.5	72.5	76	N	M
Paratunka River, 1935																
2_1+	♂	...	...	...	...	1	6	6	19	20	23	8	2	...	83	58.3
	♀	...	...	...	...	...	...	3	21	33	34	2	...	...	93	60.0
3_2+	♂	...	...	1	5	2	...	...	...	...	...	...	...	...	8	33.9
	♀	...	1	2	4	3	...	...	...	...	...	...	...	...	10	38.1
Bolshaîa River, 1935																
2_1+	♂	...	...	...	...	...	3	9	16	12	7	2	...	...	49	55.9
	♀	...	...	...	...	...	1	3	14	24	8	...	...	...	50	56.9
Kamchatka River, 1935																
2_1+	♂	...	...	...	...	...	...	2	5	24	44	21	8	2	106	62.6
	♀	...	...	...	...	...	...	...	13	18	20	3	...	...	54	59.5
3_2+	♂	...	...	...	2	6	14	7	1	...	...	...	...	...	30	46.4
	♀	...	...	...	...	4	6	2	...	...	...	...	...	...	12	45.9

Table 10. [page 63] Length of the body of cohoes in the 4th year of life.

Age-group	Sex	Length in cm: 46.5	48.5	50.5	52.5	54.5	56.5	58.5	60.5	62.5	64.5	68.5	70.5	72.5	N	M
Paratunka River																
3_2+	♂	1	...	...	...	...	1	1	2	2	1	...	...		8	60.0
	♀	2	...	...	2	1	...	1	2	2	...	...	...		10	56.7
Kamchatka River																
3_2+	♂	...	...	1	...	1	2	3	5	9	4	4	1		30	62.7
	♀	...	...	...	...	...	...	5	3	1	2	...	1		12	62.2

Table 11. [page 64] Combined table of coho growth (in cm).

Region	Age-group	Sex	Length of body at age: 1	2	3	4
Paratunka River	2_1+	♂	8.4	38.3	58.3	...
		♀	7.9	38.3	60.0	...
" "	3_2+	♂	9.7	16.7	38.9	60.0
		♀	8.2	15.9	38.1	56.7
Bolshaia River	2_1+	♂	7.3	39.3	55.9	...
		♀	7.8	39.0	56.9	...
Kamchatka River	2_1+	♂	9.5	43.1	62.6	...
		♀	9.7	41.9	59.5	...
" "	3_2+	♂	9.6	16.9	46.4	62.7
		♀	10.2	17.0	45.9	62.2

Table 12. [page 64] Increase in length of the body of cohoes (in cm).

Region	Age-group	Sex	Age 1	2	3	4
Paratunka River	2_1+	♂	8.4	29.9	20.0	...
		♀	7.9	30.4	21.7	...
" "	3_2+	♂	9.7	7.0	22.2	21.1
		♀	8.2	7.7	22.2	18.6
Bolshaia River	2_1+	♂	7.3	32.0	16.6	...
		♀	7.8	31.2	17.9	...
Kamchatka River	2_1+	♂	9.5	33.6	19.5	...
		♀	9.7	32.2	17.6	...
" "	3_2+	♂	9.6	7.3	29.5	16.3
		♀	10.2	6.8	28.9	16.3

Table 13. [page 64] Increase in size of cohoes as percentage of initial size.

Region	Age-group	Sex	Age 1	2	3	4
Paratunka River	2_1+	♂	100	356	238	...
		♀	100	384	274	...
" "	3_2+	♂	100	72	228	217
		♀	100	94	279	226
Bolshaia River	2_1+	♂	100	438	227	...
		♀	100	400	229	...
Kamchatka River	2_1+	♂	100	364	205	...
		♀	100	331	181	...
" "	3_2+	♂	100	76	307	169
		♀	100	66	283	159

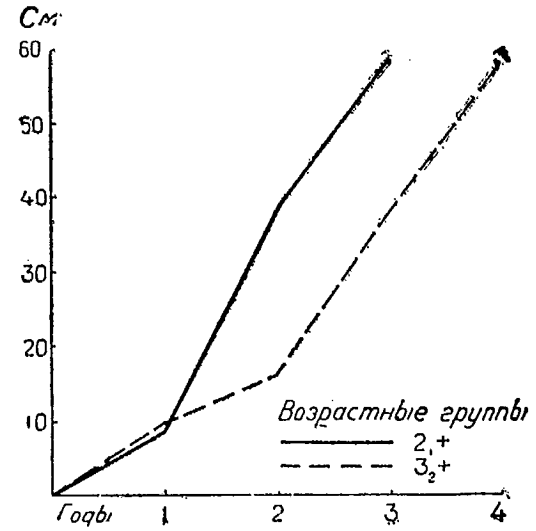

Fig. 4. [page 65] Rate of growth of cohoes from the Paratunka River (males and females).

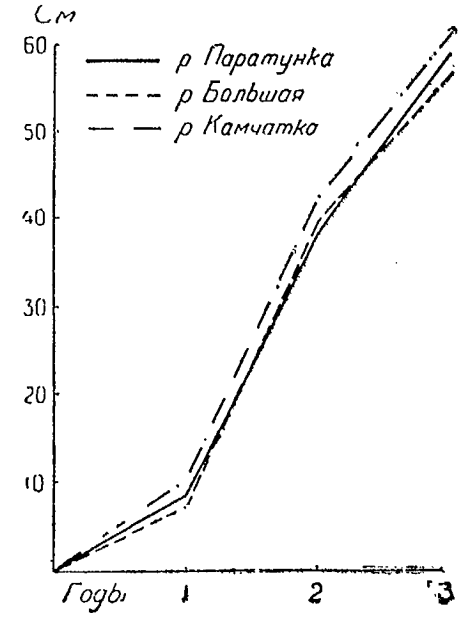

Fig. 5. [page 65] Rate of growth of cohoes from the Paratunka, Bolshaia and Kamchatka Rivers (age 2+).

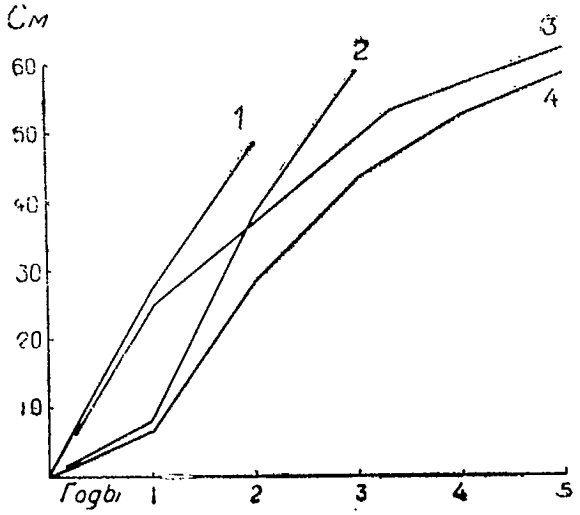

Fig. 6. [page 66] Rate of growth of cohoes (2), chum salmon (3), pink salmon (1) and sockeye (4).

	1st year	2nd year
Length actually observed	6-13 cm	10-16 cm
Length obtained by calculation from the scales of mature fish	6-14 cm	10-19 cm

Comparison of rates of growth of cohoes from the different regions of Kamchatka have not revealed any marked differences. The rate of growth of cohoes from the Paratunka River on the east coast of Kamchatka with those from the Bolshaia River on the west coast coincide almost completely. The Bolsheretsk cohoes grow somewhat more quickly during their first sea year, but later marine growth is more intensive than in the Paratunka cohoes. Cohoes from the Kamchatka River exhibit a more rapid growth than the Paratunka or Bolsheretsk cohoes from their first year onward.

[page 66] The coho has very rapid growth in comparison with other species of Pacific salmon, its only rival in this respect being the pink salmon (Fig. 6). The sockeye, which like the coho frequently spends one or two years in fresh water before migrating to the sea, has already lagged behind the coho in size during its first year, and only in its fifth year does it reach the same size as cohoes of age 2+.

The chum salmon, which migrate to sea when fingerlings, have a more rapid rate of growth in the first year than do the coho during their first year in the river; however, during their first year of life in the sea cohoes overtake chum salmon in growth. The coho reaches sexual maturity two years earlier than the chum, and at almost the same size as is attained by the chum only in its fifth year.

Pink salmon, along with cohoes, are the earliest maturing and most rapidly growing fish of the lot. After 13-14 months in the sea pink salmon have increased their body length to 48 cm. In almost the same length of time, that is 14-15 months of sojourn in the sea, cohoes grow to 50-52 cm.

VI. Coho migrations

The total duration of the spawning migration of coho is rather great. In the immediate vicinity of the coast of Kamchatka the first specimens of coho appear during the last ten days of June, and the last individuals are observed in the sea in December. The peak of the migration in marine areas begins in the middle of August and reaches its greatest intensity during the last ten days of August. Study of the duration and times of the run is made difficult by the fact that as a rule the fishery ceases considerably before the end of the run of this fish. Hence statistics of commercial catches of coho reflect the time of appearance of the coho in

commercial quantities reasonably well, and also the time of the peak of their migration, but they cannot indicate the time of the end of the run with any accuracy.

In 1935, during the research voyage of the schooner Sosunov, a coho was taken in the region of Zhirovaĭa Bay, 3 miles off the coast, on the 20th of June. I myself saw this specimen. It was a male 2+ years of age, 50 cm long, and the stage of sexual maturity was III. The first two specimens in the Paratunka River were taken off the village of Paratunka on July 5-7. In the mouth of Avachin Bay, in the Solovarka fishery, cohoes began to be taken at the beginning of July in small numbers; the main run began August 17 and continued to September 10. During our visit to the Solovarka fishery on August 20 [page 67] cohoes comprised the main bulk of the catch, chum and sockeye occurred only as occasional individuals. At the mouth of the Paratunka River, where it enters Avachin Bay, the main run of cohoes began August 23. The run of coho in the Kolyger River in 1927 lasted from July 15 to September 7, and the most intensive run was August 5-15. In 1928 and in 1929 cohoes began to be caught later than in 1927 by 7-6 days. Occasional cohoes are encountered in the mouth up to December.

In the Ust-Kamchatsk region in 1933 the first scattered cohoes were observed in the marine sectors on July 12. I. I. Kuznetsov recorded the occurrence of the first coho specimens in 1927 in the Kamchatka River on July 12. The migration of coho in commercial quantities in marine sectors of the Ust-Kamchatsk Gulf, according to 8 years' data, begins July 17-20. The most intensive run takes place during the second half of August. Occasional examples at the mouth of the river are encountered up to the 20th of October (8) and, according to the stories of the local inhabitants, even up to December. Variations in the time of mass appearance of cohoes, from year to year, are not great and do not exceed 6-7 days. For example, in 1929 the beginning of the main migration of coho was 6 days later than it was in the same marine fisheries during the previous year 1928, and this delay was identical to the day for 10 trap nets situated in different parts of the Bay of Ust-Kamchatsk.

The beginning of the commercial run of cohoes in the marine fisheries situated close to the Uka River is August 10-12. In the sea fisheries off the mouth of the Pankara River, from 3 years observations, the main run begins between the 2nd and 10th of August, the most intensive run being in the second half of August.

Along the west coast of Kamchatka, in the Bolsheretsk region, coho begin to be encountered as odd individuals on July 25-26. The beginning of the commercial run is on the 1st or 2nd of August, and the main run is in the second half of August. Cohoes are caught in small quantities near the mouth of the Bolshaĭa River up to the last 10 days of October.

Variations in the times of appearance of coho, in different years, do not exceed 5-7 days. For example in 1927 all sections in the Bolsheretsk region experienced the beginning of the coho run 5-6 days later than in 1926.

In the Kikhchik region the first cohoes are observed July 23, and the beginning of the run in commercial quantities is August 10-14. The most intensive run, according to observations over a series of years, is from August 19 to September 3. Occasional specimens continue to be taken up to December. In the Tigil River the beginning of the run is August 5, the main run is from the 15th to the 20th of August. In the Gizhiga occasional examples are caught beginning July 18, and the main run is in the last 10 days of August. On the coast of the Sea of Okhotsk, also, the intensive run of cohoes is during the second half of August. From the data cited it is evident that, in general, cohoes migrate at about the same time in the southern and in the extreme northern parts of its range. On both the east and the west coasts of the Kamchatka peninsula, and also along the Okhotsk coast, the main run occurs during the last 20 days of August.

According to observations made in the Kamchatka watershed, the arrival of cohoes at any particular spawning ground in different years varies within the range of 5-10 days.

On the Kamchatka, the local people everywhere distinguish two runs of coho by their time of arrival: in some regions they are called the summer and the autumn run, and in other regions [page 68] the autumn and the winter run. In the region of Avachin Bay, a summer and an autumn run are distinguished in the Paratunka and the Avacha Rivers.

As mentioned earlier, in 1935 the first cohoes were taken in the middle course of the Paratunka River on July 5-7. At the end of August, in this region, cohoes collected together in large schools in the deep parts of the channel below Paratunka bridge. Above the bridge, in a side channel from Lake Dalnee, I observed the first coho spawning on September 5. In the kliuches[1] of the upper part of the river, in particular the Tundrov kliuch, spawning of cohoes began September 20. In the second half of September in the region of Paratunka bridge, that is, the place where the big accumulations of cohoes had been observed at the end of August, cohoes did not occur at all.

From this the conclusion can be drawn that the run of summer cohoes in the middle part of the river had already ceased at this time. A few days later, while sailing in a

---

[1] [Kliuch can be approximately translated as "spring creek", but the Russian word is used here. See page 44 for a description of the different kinds of kliuches.]

sloop in the lower parts of the Paratunka River, I observed resting cohoes in very large quantities in the deep holes; presumably these were fish of the second or autumn run. We were not able to obtain regular observations on the intensity of the run of cohoes at the mouth of the river, because there is no continuous fishery in this region. Nevertheless from my own observations, and also from questioning operators of the collective farm of the village of Nikolaevsk, who conduct the fishery in the lower river, it is possible to say that there are two peaks in the coho run. The first of these is at the end of August and beginning of September, and the second is at the end of September and beginning of October. In September I observed spawning of the summer cohoes in a tributary of Lake Dalnee, the Tundrov kliuch. Apparently the main mass of summer cohoes spawns in October, and only a few of them in September. The spawning grounds of summer cohoes are situated in the upper and middle parts of the Paratunka River. Summer cohoes do not enter the Nikolaev kliuches which are situated not far from the mouth.

The fish of the second or autumn run go into the lower reaches of the river at the end of September, in October, and later. Spawning of autumn cohoes takes place mainly in November and December, both in the upper spawning grounds and in the kliuches below the village of Nikolaevsk. I was not successful in finding any morphological differences between the cohoes of the early and late runs in the Paratunka watershed.

In the upper reaches of the Kamchatka River the local people also distinguish two runs of cohoes, the summer and the winter run. Here the summer run begins in August and ends at the middle of October. The first spawned-out specimens of summer coho were observed September 23. The beginning of the spawning of summer coho can be regarded as September 18, at the beginning of October spawning is in full swing, and by October 20-25 spawning of summer coho is finished.

In the second half of October the run of winter cohoes begins and continues to the middle of December. Spawning of winter coho begins at the end of November, lasts through December, and ends in January. In the upper parts of the river both the summer and the winter cohoes migrate in breeding condition. The percentage of fully mature individuals in the winter coho run is greater than in the summer. Summer and winter cohoes in the upper reaches of the Kamchatka River, in the region of the village of Verkhne-Kamchatsk, are distinguished not only by time of run but also by the places where they spawn. The summer coho spawn mainly in the tributaries of the Kamchatka River; along the Andrianovka and Poperechnaîa Rivers the spawning grounds of the summer coho extend for a distance of 25-30 km from the place where these rivers empty into the Kamchatka. The winter coho, by contrast, do not ascend the Andrianovka River more than 2-3 km, and they spawn in the main channel of the Kamchatka River in places where ground water emerges.

[page 69] Along the west coast of Kamchatka, also, a summer and an autumn run of cohoes is distinguished in the Kikhchik River. A morphometric analysis of summer and autumn cohoes from the Kikhchik River did not reveal any differences between them.

The coho is a very strong and fast-swimming fish. Its fishery is carried out usually with greater difficulty than the fishery for the other Kamchatka anadromous salmons. In calm weather the migration of cohoes in the sea takes place in the uppermost layer of water, as fishing experiments with floating and bottom-set gill nets have shown. In 1934 and 1935 I was successful in observing the run of coho not far from the mouth of Avachin Bay, in Solevarka Bay. These cohoes moved in discrete schools of 20-30 each. The rapid movement of such schools of large salmon causes a characteristic ripple on the surface of the water, shifting as the school moves. The fishery for cohoes in the sea, as well as the fishery for other Kamchatka salmons, if carried out with trap nets, and in bays and coves also with drag seines, and sometimes even with fixed gill nets. The coho is a speedy "lukavaĭa" fish, as it is called by the kamchadals; when it encounters the wing of the net, it frequently does not go into the heart, but turns back and swims around the heart on the sea side. In 1935 in Solevarka Bay the collective farm "Amurskii Partizan" had set out a trap net with which they caught sockeye, chum and pink salmon with great success. At the end of August the run of cohoes began; the fish migrated in great numbers, and they could be observed from the shore, but the number of cohoes which were captured in the heart of the trap net was very insignificant. Hence the members of the collective farm found it necessary to use not only the trap net but to undertake a fishery with drag seines.

Before they enter a river, cohoes enter the brackish stream of water which is projected by rivers far out into the sea: the brackish stream of such rivers as the Bolshaĭa on the west coast of Kamchatka occurs in the sea up to 20 miles from the mouth, in the upper layer of water. The approach of the fish to the mouth of the river takes place under conditions of gradually decreasing salinity. The path of migration of cohoes in Avachin Bay indicates this, for the fish arrive there heading along the northwestern part of the bay into which the Avacha and Paratunka Rivers discharge. Hydrological work carried out here over the course of several years has shown that the fresh water discharged by the Paratunka and Avacha Rivers, having been deflected in the bay to the right, freshens mainly the western part of the bay then goes out to sea on the falling tide.

The eastern part of Avachin Bay is less subject to the action of these rivers and remains considerably more salty. The main mass of the cohoes in Avachin Gulf are caught in the region of the "vorot" narrows; that is, in Lagernaĭa and Solevarka Bays. Additional fisheries are concentrated along

the western fresher part of the gulf--in Tarin and Turpanka Bays. Along the eastern shore of the gulf cohoes and other salmon are very seldom taken; the fishery districts situated in this part of the gulf yield comparatively small catches of salmon. At the time of a falling tide, before their entry into the river, coho are concentrated close to the shoals just off the mouth of the Paratunka River.

The different temperatures of the sea and of the river are apparently not a factor affecting the entrance of the fish into the river. In 1935 during the period of coho migration the temperature in Avachin Gulf was higher than in the Paratunka River. Thus in this region the coho, entering the river from the sea, changed from warmer water to cold water.

A different situation was observed in the Ust-Kamchatsk region. The water of the Kamchatka River warms up considerably more in its lower course than [page 70] does the Paratunka River and most other Kamchatka rivers of smaller size, and coho entering the Kamchatka River change from colder sea water to warmer river water.

The most intensive entry of fish in a river takes place at the beginning of a rising tide. At the time of a falling tide the cohoes remain in the brackish region just off the mouth of the river. Huge schools of cohoes accumulate at the time of the falling tide along the Paratunka and Avachin "laidaia" (shoals just off the mouth of the river). At the start of the rising tide the schools of coho stream into the mouth of the river. On arriving in the river the majority of cohoes do not show breeding colour and look silvery; only in some males have the jaws begun to curve. The majority of the fish are in the III-IV stage of maturity of the sexual products. Only toward the end of the migration do fish appear that are somewhat lilac coloured and have curved jaws in the males, and sometimes have ripe sexual products.

The observations which I have made on the migration of coho in the river show that the movement of the fish upriver does not take place as rapidly as might have been expected for so strong a fish as the coho.

Kuznetsov (8) in 1927 attempted to determine the rate of movement of coho in the Kamchatka River. For this purpose he made use of the sequence of appearances of coho at settlements from the lower part of the Kamchatka River to points successively farther upstream. The data he obtained are shown in Table 14.

From these data I. I. Kuznetsov came to the conclusion that the distance of 696 km from Ust-Kamchatsk to the village of Pushchino was covered by the coho in 49 days at an average speed of 14-18 km per 24 hours. Comparing these data with similar materials on [page 71] the rate of migration of other salmon in the Kamchatka River he came to the conclusion that

Table 14. [page 70] Times of migration of cohoes up the river (after Kuznetsov).

Distance from mouth km	Name of village	Beginning of run	Main run	End of run
696	Pushino	September 1	September 20	September 5[a]
624	Sharomy	" 1	October 1	...
590	Bolshoi-Kamchatsk	" 1	December 1-5	December 20
578	Milkovo	August 20-25	October 1	December 1-5
564	Kyrganik	September 1	September 20-25	November 1
416	Mashura	...	...	...
366	Shapino	September 5	...	...
324	Tolbachkik	September 1	September 15	End of September
302	Srednii-Kamchatsk	...	...	September 1
219	Kozyrevsk	End of August	...	End of September
199	Ushki	August 20	September 1	September 10
160	Kresty	...	...	...
...	Elovka	August 25	...	...
125	Kliuchi	August 15	...	September 20
65	Komaki	August 5	...	To October
30	Nizhnii-Kamchatsk	August 1	August 15-24	To October 15
0	Ust-Kamchatsk	July 15	...	...

[a][Probably should be October 5.]

coho went upriver more slowly than sockeye, chum or chinook salmon. The information cited above can be used only for general orientation and naturally it cannot pretend to accuracy. The author himself points out that "the glaring absence of a regular sequence of times of arrival of the run between the lower and the upper settlements must presumably be ascribed not only to the sometimes inaccurate information obtained from the inhabitants, but also to the fact that at some villages the fish could migrate past by night or even during bad storms, when fishing from the Kamchatka boats is out of the question. In addition, at the upper villages (from Sredne-Kamchatsk on upriver) fishing is conducted mainly by weirs in the Kamchatka tributaries, where the arrival of the fish does not always correspond to their migration in the main channel." In addition, in estimating the rate of migration of a fish by the times of its appearance in places situated at various distances from the mouth of the river it is easy to fall into error because fish which entered at a particular period at the mouth of the river might spawn in the lower or middle tributaries of the Kamchatka River. Reviewing Table 14, we cannot exclude the possibility that the fish observed on July 15 at Ust-Kamchatsk spawned somewhere in the middle part of the watershed and did not reach the upper parts of the river.

This is quite likely, actually, since in the Kamchatka River there is no strict sequence of arrival on the spawning grounds, and it is a known fact that some lower spawning grounds are occupied earlier than the time that coho arrive to spawn on the spawning grounds situated farther upriver; and contrariwise, there are examples where spawning begins first on the upper spawning grounds and later on the lower ones.

F. V. Krogius (5) has also indicated that the coho move more slowly than other Kamchatka salmon, on the basis of her observations of the coho run in 1934 in the basin of the Bolshaia River.

From unpublished data of I. A. Polutov, in the Kikhchik River cohoes ascended from the mouth up to a village 18 km upstream in two days.

From observations on the Paratunka River in the autumn of 1935, in the lower part of the river in the zone of tidal influence the migration of fish becomes more intensive on a rising tide, and on a falling tide it becomes weaker. Coho commonly do not go all the way to the spawning grounds without resting; rather they rest in deep holes of the channel which are found mostly in the numerous bends of the river. In straight stretches of the river, where there are no pools or deep holes, the cohoes usually move close to the deeper parts of the channel with the faster current.

According to the testimony of the inhabitants of the village of Paratunka, coho migration becomes specially intensive

during days of bad weather. The coho which have accumulated in the deep holes will, with the onset of unpleasant rainy days, quickly move upstream; and when the weather becomes clear and fine again, where previously there had been many fish they are no longer to be found, because they have gone upstream.

Apparently here a rise in the level of the river, caused by heavy precipitation, exerts an influence on the intensity of the coho migration.

At places where spawning streams fork, and at places where spawning tributaries join the main channel of the river, coho accumulate in large schools and remain for some time. Such delay and formation of accumulations of fish at junctions of different spawning rivers is characteristic [page 72] not only of coho, but also of other Pacific salmons. Along the Paratunka River such accumulations of fish were observed at the mouths of the rivers Mikizha, Khaikovaia, Blizhnaia, the Kosogorchik kliuch, and others.

During their migration in the river cohoes are frequently observed to break the water surface and to make rather high leaps out of the water.

Where the coho fishery is carried out with continuous weirs right across the river, it was observed that cohoes were much more uneasy in the trap than were sockeye and chum salmon, and sometimes they made leaps into the air up to 1 metre high in their attempts to get over the barrier.

It is the general opinion of fishermen in the various parts of Kamchatka, on the west and the east coasts both, that coho fishing in a river is accompanied by greater difficulties than the fishery for other salmon except the chinook salmon. This is one of the reasons for the rather limited development of the coho fishery by the local people.

At the time of the coho fishery in the Paratunka River a longer net is used than at the time of the fishery for chums and sockeye. Along the whole of the Kamchatka River the local inhabitants prefer catching sockeye to coho, not only for the reason that preparation of balyki and yukoly[1] from coho is more difficult because it is already cold weather when they arrive, but also for the reason that they are more difficult to catch. A fixed gill net several meters long set out from a shallow bank will yield a fisherman a large catch of sockeye, chum and pink salmon, but the cohoes commonly travel along deep banks with swift current where it is more difficult to set a net, and the net itself must be longer.

---

[1] [Singular, balyk, yukola; these seem to be local names for dried or smoked salmon products of some sort.]

In the upper course of the Kamchatka River the fishing apparatus most frequently takes the form of weirs. It is interesting that when these are used to catch chum or sockeye, the fishermen commonly do not close more than two-thirds of the channel of the river or brook; but when an attempt is being made to catch cohoes, then as a rule they construct a complete weir, that is, one which goes all the way across the river.

The coho fishery in the upper reaches of the rivers continues during the winter; in the parts of the upper course of the Kamchatka River that don't freeze cohoes are caught by gill nets up to the second half of December.

VII. Spawning grounds

The spawning grounds of the Kamchatka salmons are bodies of water having clear transparent water, stoney to gravelly bottom, and rather low temperature. Salmon spawning grounds can be divided into three groups: the spawning grounds of lakes, of rivers and of kliuches. Coho spawning grounds belong to the two latter groups.

Coho spawning grounds are usually distributed throughout the whole extent of the basins of the Kamchatka rivers, beginning at the zone of tidal influence and extending up to the very headwaters. Even places at the headwaters of rivers to which pinks, chums and sockeye do not penetrate, are seeded by the coho.

Cohoes do not spawn in lakes. Lake Ushki in the Kamchatka River watershed, where the cohoes spawn in large numbers, is not really a lake in its morphology nor yet in its hydrological regime--it is an ordinary spawning kliuch of large expanse.

In the basin of the Paratunka River cohoes spawn mainly in the same kliuches and in the same parts of the river as chums and sockeye spawn in. It is only the spawning grounds at the very headwaters of the river which are seeded exclusively [page 73] by cohoes. In Lakes Dalnee and Blizhnee, which contain the main mass of spawning sockeye of the Paratunka River, cohoes do not spawn at all. Cohoes spawn in the Dalniaia River, which drains Lake Blizhnee, and in some years in quite considerable numbers. Scattered coho individuals enter Lake Dalnee from the river, remain there for some time not far from the outlet, and then swim back again into the Dalniaia River where they lay their eggs.

In Lake Kuril the coho do not spawn (6), but in the Etamynk River, which discharges into that lake, there is always a spawning of coho; obviously, then, in order to get to their spawning grounds cohoes will sometimes cross a considerable expanse of lake water and, leaving it again, find suitable conditions for spawning. The same is observed apparently in Lake Azabach in the Kamchatka River basin: there an intensive

Table 15. [page 74] Current speed on coho spawning grounds.

Spawning ground	Current in m/sec
Shliapnikova Channel	0.25
Orlovka Channel	0.39
Main channel of the Paratunka River	0.24
Korkin Channel	0.11
Tikhaia River	0.40
Yakutsk Kliuch	0.33
Povorotnyi Kliuch	0.20
Dalnii Shirokii Kliuch	0.10
Blizhnii Shirokii Kliuch	0.10
Main channel of the river opposite the village of Nikolaevsk	0.40
Staraia Channel	0.23
Kosogorchik Kliuch	0.43
Dalniaia River	0.52
Dalniaia River	0.37
Dalniaia River	0.43
Dalniaia River	0.55
Dalniaia River	0.54
Dalniaia River	0.50
Dalniaia River	0.44
Average current speed	0.35

Limits of variation are from 0.10 to 0.55 m/sec.

spawning of cohoes takes place in the rivers which are tributary to the lake, but in the lake itself there is no coho spawning.

The kliuch-type spawning grounds are the most important ones for coho. Krokhin (5) separates spawning kliuches into two types: "1) long brooks of uniform breadth, similar to abandoned river channels; 2) small expanses of irregularly elongate form, with a strongly dissected shore line, connected with each other and with the river by narrow channels".

Spawning kliuches are generically associated with channels and abandoned channels of the river in whose valleys they are situated. One of the banks of a kliuch, commonly the one next to the river channel, is low-lying, while the opposite side has a steep bank, being a river terrace. Kliuches of the second type have a more ancient origin, their systems frequently include lake-like expanses called "kurchazhiny", with a considerable inflow of ground water and a slow current.

River spawning grounds are situated in not very deep parts of the river, most frequently not in the main channel but in side channels. The most intensive spawning usually takes place in those parts of the side channels where there is some seepage of ground water.

Current speed is one of the most important factors determining the choice of a spawning ground by the different species of salmons. As indicated above, cohoes do not lay their eggs in lakes at all, where the current is extremely slow and variable; by contrast, lakes apparently have optimal conditions for the sockeye. On the other hand sockeye rarely spawn at current speeds greater than 0.10 m/sec, while the most frequently encountered current speeds on the spawning grounds of pink and coho salmon are 0.30-0.50 m/sec.

In Table 15 I show measurements of the current speed on the spawning grounds of coho in the Paratunka River basin (measurements of current speed were made by a bathometer-tachometer).

The range of variation is from 0.10 to 0.55 m/sec.

Spawning kliuches ordinarily have a somewhat slower current in their outlets and their lakelike expansions, the "kurchazhiny". From numerous personal observations I have come to the conclusion that the cohoes, in contrast to chums and sockeye, avoid such places and prefer to spawn in the channels of kliuches that have the faster currents. However when a run of fish is very heavy and when the kliuches are overpopulated with fish, they will also spawn in the kurchazhiny where the current is almost imperceptible. In 1935 in the Dalniaia River I observed spawning of coho in an area where the current [page 74] veered around and even had a reverse direction, so that the spawners turned round to point their heads downriver.

Temperature of the water on spawning grounds during the spawning period fluctuates from 0.8° to 7.7°. The average temperature, on the basis of data from 41 stations on different spawning grounds, is 4.5°.

Year-to-year changes in temperature are not great, and the average temperature on one and the same spawning grounds in January-February is 3.4°, and during the warmer times of the year--in July and August--it is 7.3°.

It must be observed that during the period of mass spawning of cohoes in October and November, temperature on the river spawning grounds is somewhat lower than in the spring creeks, where the influence of ground water plays a greater role.

The temperature of the water in the second half of October, 1935, on the spawning grounds near Nilolaevka fluctuated within the following limits: on the river spawning grounds, from 1.0 to 5.5°, the average being 2.9°; and on the kliuch spawning grounds, from 4.5 to 6.1°, average 5.3°.

A considerable part of the kliuch spawning grounds, having a strong eruption of ground water, do not freeze in winter, even during the very heaviest frosts. Sometimes at night during a hard frost a considerable part of a kliuch will be covered by a thin sheet of ice, but during the day this ice thaws even if the air doesn't warm up very much. However parts of the surface of a kliuch that are more distant from the source of the ground water commonly freeze for 1½-2 months.

Spawning grounds in rivers and in side-channels of rivers are more often covered by ice; however in them too open leads, or "propariny", usually occur, thanks to the presence of warmer ground water. The main channel of the river, where spawning does not occur, is commonly covered at this time by solid thick ice. It sometimes happens that river spawning grounds become covered with ice several times during the course of a winter, then lose it again.

The parts of the spawning grounds in kliuches that are situated near the edge of the water become covered by snowdrifts, under which there is a thin layer of free spring water.

The data presented below on the chemistry of the water on coho spawning grounds [page 75] was obtained during studies of these spawning grounds in the basin of the Paratunka River by E. M. Krokhin and myself in 1935. I have also used some of the data which Krokhin collected on coho spawning grounds in the Bolshaia River basin in 1934.

Waters on coho spawning grounds are adequately supplied with oxygen. The least quantity observed on the spawning grounds was 9.90 mg/l, and the greatest was 15.00 mg/l.

The average quantity of oxygen in 28 analyses was 12.41 mg/l. The saturation of the water by oxygen was usually close to 100%. In 13 cases out of 28 supersaturation was observed. Places with reduced oxygen content are avoided by cohoes. For example, in the Blizhnii Shirokii kliuch spawning occurs over almost the whole extent of the kliuch with the exception of a small bay in the northeast portion, where the oxygen content does not exceed 7.8 mg/l. The distribution of oxygen in the spawning kliuches is not uniform. In places where ground water emerges, most frequently at the heads of the kliuches, there is commonly a reduced quantity of oxygen; farther downstream the quantity gradually increases, and the greatest quantity of oxygen is observed in the lower reaches of the kliuches and the places where it joins the channel of a river. For example, in the upper part of the Tundrov kliuch near where ground waters emerge the oxygen content is 11.34 mg/l, but at the same time in the middle of the kliuch it was 14.24 mg/l; in the upper part of the Blizhnii Shirokii kliuch near the place where ground water issues forth the oxygen is 10.76 mg/l, at the middle of the kliuch it is 14.51 mg/l, and at the outlet of the creek, 15.23 mg/l.

In the spawning kliuches of the Paratunka River watershed, in places where ground water wells up the oxygen content is 11.60 mg/l, and the average for all the spawning kliuches of this basin is 12.97 mg/l.

The content of free carbon dioxide on coho spawning grounds varies from 15 mg/l to complete absence. The average quantity of free CO_2 in the autumn period is 6.61 mg/l.

The greatest quantity of CO_2 is encountered in places where the ground water emerges, usually at the upper end of a kliuch, and the minimum quantity is in the lower reaches. In general, the distribution of free CO_2 in the spawning kliuches is the reverse of the distribution observed for O_2.

The active reaction (pH) on coho spawning grounds varies from 6.3 to 8.6, and the average of 59 analyses is 7.03.

The most characteristic situation for coho spawning grounds is a weakly alkaline or neutral reaction; acid reaction is encountered rather rarely.

In the spawning grounds of kliuches there is commonly observed a lower pH in places where ground water comes up, and a high or average pH in the lower course of the kliuch, as is shown in Table 16.

Changes in pH in the course of the year are as a rule inconsiderable.

Table 16. [page 75] Active reaction [pH] on coho spawning grounds.

	Emergence of ground water	Lower reaches of the kliuch
Kosogorchik Kliuch	6.7	6.9
Tundrov Kliuch	6.7	6.9
Blizhnii Shirokii Kliuch	7.0	8.4
Minaev Kliuch	7.1	7.6

Table 17. [page 76] Fecundity of salmon from the Kamchatka River.

Name	Maximum	Minimum	Average
Chinook	14,005	4512	8254
Sockeye	6,443	1570	3763
Chum	4,638	1101	2544
Coho	5,974	2881	4883

VIII. Spawning [page 76]

The average fecundity of the coho in the Paratunka River is 4350 eggs, the minimum 2800 and the maximum 7600.

In comparison with other Kamchatka salmons, the fecundity of the coho is rather high and exceeds the fecundity of chum salmon and sockeye, as is evident from Table 17.

The routine fish-cultural fecundity[1] of cohoes at the Ushki hatchery in 1933-34 was 5804 eggs, and in 1934-35 it was 4760 eggs. So large a change in the average routine fecundity is apparently associated with the smaller size of the spawners in 1934/35. The average size of the eggs of coho is 4.5 mm. The weight of the sexual products, as a fraction of the weight of the body, at the time coho enter the river varies widely in relation to their stage of sexual maturity. According to data which I obtained at the mouth of the Paratunka River, the weight of the sexual products for females as a percentage of the body weight was: minimum 5%, maximum 32%, average 11%. The weight of the testes as a percentage of the weight of the body of the males was: minimum 5%, maximum 12%, average 8%.

As their sexual products mature the cohoes enter the spawning kliuches or come onto the spawning portions of the river, and take part in egg-laying. The less mature individuals remain for a while in rather deep places in the immediate vicinity of the spots where spawning occurs.

Coho spawning is very protracted, and in different bodies of water of Kamchatka it takes place from the end of August to the middle of March. However the main mass of the coho spawn in October-November and in December.

In the basin of the Paratunka River in 1935 the first spawning cohoes were observed on September 3. In the kliuches of the upper course of the river, spawning continued to the end of January. In January some hunters from the village of Paratunka fished spawning coho out of the spring creek for food for their dogs.

In the Dalniaia River, which flows from Lake Dalnee, coho spawned at the beginning of September. In the Tundrov kliuch also, spawning began during the first ten days of September, and at the time of our inspection of this kliuch on October 19-20 intensive spawning was in progress. Particularly heavy spawning of coho took place in the Kosogorchik kliuch, which is situated somewhat farther downstream than the Tundrov kliuch. In the

---

[1] ["Rabochaia rybovodnaia plodovitost"--this apparently refers to the number of eggs per female taken in the fish-cultural operations.]

Table 18. [page 77] Nests of cohoes in the Dalnīaîa River (October 22, 1935).

Length of the depression cm	Width of the depression cm	Height of the column of water above the surface of the gravel cm	Depth to which eggs are buried cm
130	125	28	25
130	105	33	20
125	110	20	22
115	107	22	20
130	100	21	25
130	110	20	20
125	108	21	24
125	110	28	19

Table 19. [page 77] Nests of cohoes in the Blizhnii Shirokii Kliuch (November 21, 1935).

Length of the depression cm	Width of the depression cm	Height of the column of water above the surface of the gravel cm	Depth to which eggs are buried cm
195	135	5	23
170	120	14	27
140	120	16	15
135	100	10	25
125	110	13	26
115	112	10	19
120	114	4	16

Nikolaevsk kliuches, very close to the mouth of the river, there were as yet no cohoes on September 28; but in the Tikhaia River, into which the Nikolaevsk kliuches empty, cohoes were abundant enough. These cohoes were still silvery and were headed apparently for the upper end of the Tikhaia River, where they spawned somewhat later in the lake-like kliuches.

Mass spawning in the Nikolaevsk kliuches took place from the middle of October to the middle of December; occasional individuals were spawning still [page 77] in the second half of January. Near the source of the Tikhaia River the most intensive spawning took place at the end of October and in November.

In the various tributaries of the basin of the Kamchatka River spawning also takes place at different times. In the upper course, in the region of the Andrianovka River, cohoes spawn from the middle of September to February. In Lake Ushki, where a fish hatchery is located, in February spawning was still under way here and there, and occasional individuals were spawning up to the middle of March.

According to the data of I. I. Kuznetsov (8), in the Nikolka and Belaia Rivers spawning begins at the end of August or beginning of September.

In the rivers of the west coast of Kamchatka spawning of cohoes takes place in general at the same times. In the basin of the Bolshaia River it occurs from the beginning of September to February.

In the Dalniaia River and in the Blizhnii Shirokii kliuch measurements of coho nests were carried out during the spawning period. Length and breadth was measured of the pit constructed by the female in the bottom, also the height of the water column above the surface of the gravel, and the depth the eggs were laid below the surface of the gravel. Thirteen nests were examined, of which 8 were in the Dalniaia River and 7 were in the Blizhnii Shirokii kliuch. The results of these studies are given in Tables 18 and 19.

[page 78] The form and the depth of the depression apparently depends both on the size of the female and on the character of the bottom and current speed at the place in question. It is natural that the larger the female, the longer the pit she will excavate, since at the moment of depositing the eggs she must place herself at the bottom of the pit, almost touching the bottom with her belly. The looser the bottom and the stronger the current, the more elongated in form will be the nest, because with the digging movements of the tail fin the sand and gravel will be carried farther away by the current.

In lake-like expanses of kliuches where the current is extremely slow the nests excavated by females have a more rounded form.

At all coho spawning grounds I visited there was a considerable excess of males over females. Behind each spawning pair, several meters downstream, stood 2 or 3 additional males, who had been deprived of the possibility of spawning with the female in question, and who were chased away from the nest from time to time by the dominant male that took part in spawning.

Among these males that are not taking direct part in spawning at a given moment, fish of a length of 30-35 cm are frequently found, such as we have already mentioned in describing the length and age of sexually mature cohoes.

It is not clear whether the males which stay close to one of the spawning pairs have already taken part in spawning or whether they have yet to do so. However the predominance of males on the spawning grounds, when there are usually equal numbers of the sexes in the schools migrating up the river, indicates that males survive for a longer period after the beginning of spawning.

IX. Development of coho eggs and hatching of the larvae

During October and the beginning of November of 1935, in the Blizhnii Shirokii kliuch some nests of spawning coho were marked by means of a rod driven into the ground. On January 29-31 1936 these nests were opened by R. S. Semko. The results of opening these nests are described below.

Nest No. 1. Mound over the nest well marked. Bottom of the nest fine pebbles [melkaīa golka] with a considerable mixture of sand. Depth of water above the mound 8 cm. The nest is situated in a rather rapid current. Depth of covering of the eggs from the surface of the bottom 30 cm. Inside the eggs the moving larvae were tapping on the wall of the egg with light swimming movements. The number of eggs in the nest was 780, dead eggs not more than 10. Temperature of the water in the nest 3.4°.

Nest No. 2. The limits of the nests were easily observed. The bottom was of medium and fine pebbles with a mixture of sand. Temperature of the water in the nest 2.1°, depth of the water over the surface of the gravel 6 cm, eggs situated 18 cm from the surface of the bottom. The eggs were in the "eyed" stage. No dead eggs were found in the nest. The current in the water above the nest was rather swift.

Nest No. 3. The bottom was of pebbles of medium size with a mixture of sand and dark mud. There was no current above the nest. The temperature of the water in the nest was 2.7°, height of the water over the bottom 9 cm, eggs situated up to 21 cm below the surface of the bottom. About 60% of all eggs had

perished at early stages of development. But over the layer of dead eggs there occurred [page 79] live eggs in the eyed stage. The water over the nest was covered with ice 3 cm thick.

Nest No. 4. Bottom of small and medium pebbles. Near the nest on the pebbles a deposit the colour of ochre. The nest was well marked. Around the nest were dry pebbles [obsokhshaia golka]. Water over the mound 8 cm. Current swift. Temperature of water in the nest 5.3°. Depth of covering of the eggs from the surface of the bottom 22 cm. Dead eggs very few in number, 2-3%. In the nest larvae were observed which had not moved very far from the eggs. Larvae were 20-22 mm long. In some the yolk sac had noticeably decreased in size. This is the earliest example of hatching of coho larvae.

Nest No. 5. Bottom of medium and small pebbles. Limits of the nest not very well marked. The nest situated on a rather small sandbank, current over the nest swift, depth of the water above the bottom 10 cm, eggs situated 19 cm below the bottom. About 30% of the eggs were dead, having died in early stages, a part of these eggs being apparently infertile. The live eggs were in the eyed stage. The temperature of water in the nest 2.3°.

Nest No. 6. Bottom primarily medium sized pebbles. Nest well marked. Around the nest dried pebbles. Alongside the upper part of the nest there flowed a slow stream of ground water which had welled up near by. The depth of the water over the mound was 4 cm. The eggs were situated 16 cm below the surface of the gravel. Dead eggs were very few. Live eggs at the eyed stage. Temperature of the water in the nest 3.5°.

Nest No. 7. Bottom medium sized pebbles. Limits of the nest well marked. The upper surface of the nest was bathed by ground waters which emerged near by. Depth of the water over the mound 3 cm. Eggs situated 23 cm from the surface of the gravel. In the nest 940 eggs were observed, of which 75 were dead. The eggs were in the eyed stage, as in nest No. 6.

Nest No. 8. Bottom medium and small sized pebbles with a small mixture of mud. Nest well marked. The top of the mound was out of water and projected above the level of the water about 3 cm. The eggs were situated 21 cm below the surface of the mound and 18 cm below water level. Temperature of the water in the nest 2.9°. Eggs in the same stage as in the two previous nests. No dead eggs at all.

Nest No. 9. Bottom medium and small pebbles with a yellow deposit on them the colour of ochre. Nest well marked. Depth of the water over the bottom 6 cm. Eggs situated 19 cm below the surface of the bottom. Temperature of the water in the nest 3.4°. Eggs all in good condition, in the eyed stage. No dead eggs at all.

In the same Blizhnii Shirokii kliuch, two months later, on the 28th of March another nest was opened, in which it appeared that the eggs were in the same stage of development as in several nests January 29-31, 1936.

This fully corresponds with the length of the intensive spawning period of cohoes, which took place here from the middle of October to the middle of November.

Nests of coho were also opened and studied in the kliuch which is at the source of the Tikhaia River, where spawning of cohoes took place somewhat later than in the Blizhnii Shirokii kliuch. An intensive spawning of cohoes occurred in this kliuch in December, according to the inhabitants of the village of Nilolaevsk.

On February 9, when the opening of the nests was done, the spawning mounds [page 80] were not noticeable, which apparently is the result of dense spawning. Since the location of each nest was difficult to detect on the level surface of the bottom; we dug up a complete square area of the bottom 2½ by 2 meters. In this area there were 4 separate nest positions with a total number of 3250 eggs, among which the number of dead eggs did not exceed 5-7%. On another day, February 10, another 3 nests in this kliuch were opened. The eggs in these nests also were in the eyed stage. In the first nest there were 310 eggs, in the second 1160, and in the third nest 926 eggs; dead eggs did not exceed 1-2% of the total number. The eggs were placed in the bottom at a depth of 10-15 cm. The depth of the water over the bottom also did not exceed 15 cm. Temperature of the water was 3-4°.

Along the banks of the kliuch the bones of the fish which had died after spawning (carcasses) lay about in great abundance, eaten by foxes, whose tracks and holes were evident round about on the snow. In places the snow was completely trampled down by the animals.

According to Kuznetsov's (8) data also, which he obtained by digging up coho nests in the Bolshaia and Kamchatka Rivers in 1926-27, the mortality of coho eggs in natural spawning grounds was not very large, being 6.5% on the average.

Excavations of coho nests and enumeration of the eggs in them have shown that most frequently there are 800-900 eggs in the nests, however the number found varies from 300 to 1200 eggs. The nests are situated in such a manner that not more than one nest is found under one mound.

On the basis of the average fecundity of the coho--about 4000 eggs--we must suppose that the female coho lays her eggs in 3-4 batches, digging a new pit each time and heaping up a spawning mound in different positions in a given spawning ground. In October 1935 on the Dalniaia River I observed how a

female coho, which had finished covering one nest, moved off about 50 metres upstream and there again began the construction of a nest.

Soldatov (10) has observed the same behaviour in chum salmon, indicating that the Amur keta move from one place to another for spawning.

I observed no instances of the presence of several nests in one depression or under one mound, as has been described by I. I. Kuznetsov. Nor did I observe any kind of pre-determined arrangement or checker-board pattern in the situation of the nests.

The duration of embryonic development of the coho depends on the temperature conditions on the spawning grounds. The nests opened in the Blizhnii Shirokii kliuch in 1935-36 showed that under natural conditions 100-115 days elapse from the day of fertilization to hatching of the larvae.

At the Ushki hatchery, with an unchanging temperature of 4.5°, hatching of the larvae begins 86-101 days after fertilization; the duration of the process of development from the moment of fertilization to the beginning of hatching of the larvae at the Ushki hatchery takes about 378 degree-days. The larva becomes fairly apparent after 30 days, development of the eyes takes place 45 days after fertilization.

As indicated already, mortality of the eggs under natural conditions is not great. Of the 15 nests of coho opened during the winter of 1936 in the basin of the Paratunka River it is evident that in the majority of cases mortality of the eggs did not exceed 4-5%, in 3 cases there were no dead eggs observed at all. [page 81] Only in one nest of the Blizhnii Shirokii kliuch was there observed 60% mortality of the eggs. In this case apparently there had been an effect of the almost complete absence of current and a considerable mixture of mud into the bottom; the character of the bottom material in this nest differed markedly from typical bottom of coho spawning grounds. So high a mortality of the eggs must be considered a rare exception. We must observe that in all cases mortality of the eggs took place in the early period of development before the stage of appearance of the eyes.

The average mortality of the eggs in the coho nests opened by Kuznetsov on the Kamchatka River and the Bolshaia River also did not exceed 6.5%. At Lake Ushki in 1937, of the 10 nests he opened only 1 nest occurred in which all the eggs were dead; in the remaining nests the number of dead eggs was inconsiderable.

Comparison of the mortality of eggs under natural conditions with the loss of eggs in fish hatcheries is not favourable to the latter. Artificial rearing of coho is carried out on a very small scale at the only fish hatchery in the basin of the

Kamchatka River, at Lake Ushki[1]. This establishment in 1934 liberated 7,819,000 coho fry, and in 1935 10,371,000 fry. According to the superintendent of the hatchery, G. D. Gromov, the loss of eggs in 1934 was 12.7% and in 1935 6.2%.

G. D. Gromov reports that, during the 20-25 days after fertilization of the eggs, as a rule they developed normally and losses were small. The greatest mortality of the eggs takes place in the following 5-6 days, that is, 25-31 days after fertilization. The loss of eggs in some batches during this time sometimes approaches 60%. About 30-35 days after fertilization, as the eyed stage approaches, mortality of the eggs declines rapidly, and during the later period of development loss of eggs is very slight.

From a collection of eggs and larvae of coho obtained for me by the Ushki fish hatchery, preserved at different times after fertilization--that is, in different stages of development--it is evident that the average size of the newly-hatched larvae is 17-19 mm, after 15 days the larvae grow to 22-24 mm, after 30 days 24-25 mm, and after 45 days from hatching the young cohoes have the appearance of young fish, with remains of the yolk sac in a sort of crease along the belly--the length of these fry is 27-30 mm.

Fish similar in external appearance and in size were repeatedly caught by us in the free-swimming condition, in kliuches and in backwaters of the spawning rivers; on the other hand, larvae 24-25 mm long, and corresponding in external appearance to the 30-day larvae from the Ushki hatchery, were observed by me in all cases only in the gravel.

Thus we must consider that from hatching to absorption of the yolk sac and leaving the gravel takes about 40 days.

The earliest time of hatching of larvae was observed in the Blizhnii Shirokii kliuch. At the end of January, 1936, in opening the nests in this kliuch hatched larvae were observed 22-25 mm long; in some the yolk sac had already been partly absorbed. Comparing these larvae in size and external appearance with larvae from the Ushki hatchery, we may conclude that they had hatched 15 days beforehand, that is, in the middle of January. Apparently these were the progeny of cohoes [page 82] that spawned in the first half of October. In a number of other nests the eggs were in the moving-embryo stage and close to hatching; with light pressure on the eggs the membrane broke and a very active embryo swam out of the egg, indistinguishable at first glance from a normally hatched larva.

---

[1] [Or possibly: "at the only fish hatchery on Lake Ushki, in the basin of the Kamchatka River".]

Two months later, on the 28th of March, in a nest that was opened in this same kliuch, eggs were found in exactly the same stage of development as on January 30, that is, the larvae swam out when slight pressure was applied to the egg. In the same place on May 21, on opening a nest larvae were found 25-27 mm long with a yolk sac already partially absorbed. On June 2 in the same place I captured larvae which had just left the nest, which were 27-30 mm long. In the Yakutsk kliuch on May 21 the average length of young fry which had just left the nest was 29-27 mm, and among them were some fingerlings of 45-50 mm, though in smaller numbers. Coho fry of the same size were captured on May 20 in the Aleshka side channel.

The latest emergence of fry from the gravel that I observed was in the Tundrov kliuches. In them, as late as July 25 coho fry were captured with a length of 30 mm and with wrinkled skin on the belly; among them there were also larger specimens which had emerged from the gravel of the same kliuch considerably earlier--these exceptional fingerlings were up to 52 mm long.

The time of emergence of fry from the gravel in the rivers of the west coast Kamchatka apparently agrees with my observations in the Paratunka watershed. In samples that F. V. Krogius sent to me, the average length of coho fry taken in the Yavinaiā River on May 21 was 27-32 mm; a majority of them still had traces of the yolk sac on the belly.

In samples of coho fry captured by R. A. Kostīūchenko on June 23 in the lower reaches of the Ozernaīā River, fish 34-36 mm long were encountered. From the materials listed above, we may suppose that hatching of the larvae from the eggs takes place from the middle of January to the middle of June, and emergence of the fry from the gravel extends from the beginning of March to the end of July, which is in full agreement with the duration of the spawning period of the coho in the Paratunka River basin as shown in Table 20.

However we must keep in mind that development of the eggs in different parts of the basin depends not only on the time of fertilization of the eggs, but also on temperature conditions.

X. Growth of the young in fresh waters [page 83]

The size of young cohoes in the Paratunka River basin is indicated in the tables below.

The length of fingerlings encountered in fresh water varies markedly with the time of emergence of the fry from the gravel. In autumn, in September and October, it was frequently possible to see fingerlings less than 4 cm along with young fish 6-7 cm long.

Table 20. [page 82] Extreme limits of spawning times and extreme limits of times of hatching of the larvae for coho in the Paratunka watershed.

Spawning		Hatching of the larvae	
First spawning	Beginning of September	Beginning of hatching	Mid January
Last spawning	Beginning of February	End of hatching	End of June
Length of spawning period	5 months	Length of the hatching period	5 1/2 months

Table 21. [page 83] Size of yearling and two-year-old cohoes in the Paratunka River basin.

Date	Place of capture	Fork length in cm										N	M
		3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5		
8.ii	Blizhnii Shirokii Kliuch	18	21	21	25	12	3	2	..	..	..	100	6.07*
2.vi	" " "	..	..	15	14	18	37	26	18	10	..	138	9.00
20.vi	Lake Blizhnee	..	..	8	28	12	19	9	9	3	..	88	8.18
25.vi	Lake Dalnee	..	..	4	14	17	14	15	1	..	..	48	8.6
24.vii	Lake Blizhnee	..	..	5	15	35	28	7	..	..	..	90	8.20
17.ix	Blizhnii Shirokii Kliuch	..	..	3	16	7	11	17	6	4	11	75	9.60

*In this sample the young cohoes did not yet have the winter ring.

The latest sample of fingerlings I obtained was on February 8 from the Blizhnii Shirokii kliuch--in almost all the specimens examined the winter ring was still absent; only on a few of the larger fish were there up to 2 narrow sclerites on the outer edge of the scale. The size of the fingerlings in the sample varied from 4 to 10 cm, with a mean of 6 cm.

About 4 months later, on June 2 in this same kliuch the size of the yearlings varied from 6 to 12 cm, with an average of 9.0 cm. The majority of fish in this sample had an already completed winter ring on their scales plus a small amount of the second summer's increment. About 30% of the fish did not yet show the second summer's growth.

Thus the time of formation of the winter ring on the scales of the young fish must be considered to be the period February-May.

It is interesting to notice that at the beginning of July, both in the Blizhnii Shirokii kliuch and in other parts of the Paratunka River basin, the minimal size of the yearlings that had wintered over almost coincided with that of the fingerlings which had emerged early from the gravel. For example, on June 2 in the Blizhnii Shirokii kliuch, in one sample yearlings were taken with a winter ring on the scales whose length was 5.8-6.0 cm, and along with them were fingerlings, occasional specimens of which had reached 5.2 cm. This phenomenon becomes understandable, if we remember that the period of spawning of coho lasts about 6 months. In a particular sample we may have fingerlings which had come from the earliest spawners, and yearlings which were the progeny of fish that had spawned their eggs near the end of the spawning period.

As the Table shows, the average size of the 2-year-olds taken September 17 in the Blizhnii Shirokii kliuch was only insignificantly larger than the size of the yearlings captured there on June 2. However these dates are separated [page 84] by the period most favourable for growth and feeding of the young. This at first sight incomprehensible fact is explained by the fact that up to the moment of taking of the latter sample, that is in the middle of September, the heavier yearlings and the 2-year-olds had already migrated to sea; so that the young fish left behind, which are represented in the September sample, consist of the smaller fish which would remain for a second year to winter in fresh water.

The observed sizes of 2-year-olds in the Paratunka River basin (Table 22) varied from 10 to 17 cm. A striking fact is that the minimal size of the 2-year-olds coincides with, and in certain cases is even less than, the size of year-olds. This again indicates the influence of the varied times of emergence from the gravel, which in turn is associated with the extended spawning period of the coho. In addition, as was mentioned above and is shown by back-calculation from the scales of the

Table 22. [page 84] Size of two-year-old cohoes in the Paratunka River basin.

Date	Place of capture	Fork length in cm 9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	N	M
2.vi	Blizhnii Shirokii Kliuch	..	4	15	6	6	2	..		33	12.87
25.vi	Lake Dalnee	1	5	7	7	16	6	3		45	13.17
20.vi	Lake Blizhnee	..	..	..	5	2	4	..		11	14.00

Table 23. [page 84] Growth of young cohoes during their first year in fresh water (Lake Dalnee).

Length in cm	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	N	M
Back-calculated from scales of yearlings (1+)	..	..	1	8	3	3	2		17	8.9
Back-calculated from scales of two-year-olds (2+)	4	9	10	11	2	1	..		37	7.00

Table 24. [pages 85-86] Results of checking the sclerites on scales of young coho.

No.	Age	Fork length cm	Total sclerites	First-year sclerites		Second-year sclerites		Third-year sclerites	
				Summer	Winter	Summer	Winter	Summer	Winter
Sample from Blizhnii Shirokii Kliuch, June 2, 1935									
1	1	5.5	8	4	4				
2	1	5.8	8	5	3				
3	1	5.7	9	4	5				
4	1	5.4	8	4	4				
5	1	5.4	8	4	4				
6	1	5.8	10	5	5				
7	1	5.6	10	4	6				
8	1	5.7	9	5	4				
9	1	5.5	10	5	5				
10	1	5.0	8	5	3				
11	1	5.2	10	6	4				
12	1	5.7	12	8	4				
13	1	5.6	10	6	4				
14	1	4.7	8	4	4				
15	1	5.4	8	5	3				

Table 24 (continued)

Dalnīaīa River, July 1, 1935

1	1+	9.9	15	4	7	4	
2	2	10.9	20	4	6	6	4
3	1+	10.3	18	7	6	5	
4	1+	7.2	16	6	6	4	
5	1+	7.2	15	7	5	3	
6	1	7.7	12	7	5		
7	1+	8.8	14	6	5	3	
8	1+	10.0	15	6	5	4	
9	1+	9.3	16	6	5	5	
10	1+	8.0	15	5	6	4	
11	1+	8.8	16	6	6	4	
12	1+	8.6	17	7	6	4	
13	1+	8.7	14	8	4	2	
14	1+	6.3	12	3	6	3	
15	1+	6.2	12	4	6	3	
16	1+	8.4	13	5	5	3	
17	1+	7.3	15	6	7	3	
18	1+	7.6	12	5	7	2	
19	1+	7.8	16	8	6		
20	1+	7.6	10	6	7	2	
Av.	1+	8.3	15	6	6	3	

Table 24 (continued)

No.	Age	Fork length cm	Total sclerites	First-year sclerites		Second-year sclerites		Third-year sclerites	
				Summer	Winter	Summer	Winter	Summer	Winter
			Dalniaia River, July 1, 1935						
1	2+	14.9	30	7	7	6	5	5	
2	2+	14.6	35	6	8	9	6	5	
3	2+	13.7	25	5	4	7	4	6	
4	2+	14.3	31	5	9	8	5	3	
5	2+	15.5	28	4	6	8	5	5	
6	2+	16.4	26	3	4	6	7	6	
7	2+	13.5	26	6	6	5	6	3	
8	2+	17.2	32	6	9	8	5	4	
9	2+	14.3	33	5	11	8	8		
10	2+	15.6	32	7	6	7	7	5	
11	2+	14.4	25	7	5	6	4	3	
12	2+	15.3	26	6	4	7	4	5	
13	2+	14.7	24	4	4	7	5	4	
14	2+	14.9	32	6	9	8	6	3	
15	2+	14.6	25	6	7	6	4	2	
16	2+	14.6	34	6	8	9	6	5	
17	2+	13.6	34	4	11	8	7	5	
18	2+	13.0	24	4	6	8	5	4	
19	2+	13.0	36	4	10	10	7	5	
20	2+	15.2	27	4	6	7	5	5	
Av.	2+	14.7	29	5	7	7	5	5	

Table 25. [page 87] Ratio of number of yearlings to number of 2-year-olds in the Paratunka River basin.

Date of capture	Number of fish	Place of capture	Percentage yearlings	Percentage 2-year-olds
2.vi	200	Tikhaĭa River	82	18
1.vii	100	Dalnĭaĭa River	67	33
25.vii	100	Lake Dalnee	66	34
20.vi	100	Lake Blizhnee	90	10
24.vii	100	Lake Blizhnee	96	4
17.ix	100	Tikhaĭa River	100	0

Table 26. [page 90] Age and length of young cohoes taken in Avachin Gulf, June 28, 1935.

Length in mm	65	75	85	95	105	115	125	135	145	155	165	N	M
1+	1	6	37	65	65	37	12	1	..	..		224	10.6
2+	..	..	..	..	..	..	2	3	2	..		8	14.2

Fig. 7. [page 87--not reproduced here] Young cohoes: a--a fingerling which has just emerged from the gravel (magnified 3 times); б--young-of-the-year fingerling (magnified 1.5 times); B--yearling migrating down the Paratunka River (9/10 natural size).

2-year-olds, the age 1 fish which remain a second winter in fresh water and do not go to sea at age 1+ are the smaller ones, since the larger ones of age 1+ go to sea in June, July and August, at the end of the first winter which they spend in fresh water.

In both cases their length at the end of the first year was fixed at the external edge of the winter ring. Thus from these data it is evident that the length of the young fish which remain a second winter in fresh water is almost 19 mm less than the average length of the yearlings. The same is indicated by the average length of the yearlings captured in the Avachin Gulf after their migration from the river, as we noticed earlier.

The fry which have emerged from the gravel do not as yet have a scale covering; this is developed some time later. In order to determine the size of the fry when the scale cover is formed, I took [page 85] a sample from the Tundrov kliuch on June 25, in which there were some newly emerged fry about 30 mm long and also larger fingerlings.

The following results were obtained. In fry up to 4 cm long the scales could not be found; only in certain individuals 4 cm long was there a central nucleus of the scale, but without sclerites; on fish 4.2 cm long there was a central nucleus of the scale and a small increment (1 sclerite); at 43 mm there was the nucleus and 1 sclerite; and at 46 mm there was a nucleus and 2 sclerites.

These data show that the scale covering on young cohoes appears at a length of about 40 mm.

For greater accuracy in determining the growth of young coho I made a count of the sclerites on 57 specimens of fry of different sizes. Results are shown in Table 24.

[page 86] The Table shows that the total number of sclerites in one year varies from 8 to 16, which agrees with the results obtained by Baranenkova (1), who in analyzing the scales also found 9-16 sclerites. During the second year of life in fresh water another 10-17 sclerites appears on the scale. The average number of sclerites changes with the age of the fish in the following manner: at an age of 1 year there are usually 10-12 sclerites on the scales, at an age of 1+ (the yearlings--dvukhletki)--there are 15 sclerites, and at age 2+ (2-year-olds with a little growth of the third freshwater summer) there are 26-36 sclerites, most often 28-30.

The relative number of year-olds and 2-year-olds in the Paratunka watershed is not the same in all parts of the basin, and also varies with time, as Table 25 shows.

[page 87] The young were all captured by a drag seine, so

the samples shown in the Table (which are not very large in number) can nevertheless characterize the relationship between these age groups at the time and in the place indicated. Among the young fish captured on September 17 in the Tikhaia River, 2-year-olds were completely absent, since at that time migration to the sea was already finished.

[page 88] The external appearance and colour of the young coho fingerlings and yearlings which I have seen in fresh water (Fig. 7а, 7б) agrees completely with those described by Baranenkova (1). In young fish 28-41 mm long, which still have remains of the yolk sac as thin whitish folds, parr marks are well developed. They are dark pigmented blotches, oval in form, situated along the lateral line. The back and sides are cinnamon yellowish, the belly is silvery, the fins are orange, the snout is blunt. Year-old young 10-11 cm in size have 8-14 well-developed parr marks, 11 on the average (Fig. 7в). The general tone of the colour is dull gold [zolotistomatovyi]. The back and the upper part of the head are covered with a large number of star-shaped spots. The fins are orange, but not so clearly so as in fish of smaller sizes. The tail fin has a deep fork, the snout is blunt, the forehead broad.

The colour of the young fish of these sizes varies a great deal even within one sample; darker specimens occur with sharply pigmented parr marks and with more brightly orange coloured fins.

Young cohoes of 14-16 cm size, which have spent two winters in fresh water, have a lighter colour and the parr marks are less evident. Below the lateral line the colour is yellowish, the belly is bright silvery. The back and upper part of the head are dark green and covered with dark spots, as in the yearlings. The fins are light coloured, sometimes lightly yellowish. The end of the tail fin is orange.

In cases where the young coho and sockeye live in the water in common schools, the young cohoes are easily separated from the sockeye by their more lightly coloured backs.

XI. Place of abode of the young in fresh water

Young cohoes in fresh water are rather widely distributed. In spring and summer the young in the Paratunka River basin can be encountered in almost all kinds of waters: in side channels, in lakes, and in the main channel of the river both in the upper and in the lower parts of the basin.

The young which have just emerged from the gravel remain for some time not far from their nests in the kliuches and side channels, selecting places with slow current. Accumulations of small fry of cohoes can most frequently be observed in quiet backwaters near the bank of a kliuch or a small creek, in shady

places under branches of trees hanging over the water where there are large quantities of fallen leaves, roots and trash in the water.

Larger fingerlings and yearlings also avoid places with swift current and mostly stay along quiet and deep reaches of the kliuches, river backwaters and side channels, and under overhanging banks of the main channel of the river.

Young cohoes usually stay in rather large schools, sometimes along with young sockeye and char of the same sizes.

In winter the young fish are encountered rather rarely in the shallow parts of the spring creeks over the spawning grounds: and these are mainly wintering fingerlings which remain near shore under the snowbanks which overhang the water. The main mass of the young at this time apparently live in the deeper waters. In sampling the spawning grounds of the kliuches in January and February I encountered there young cohoes much less in size than during the spring and summer months.

[page 89] In some cases young cohoes may make a considerable feeding migration within a river basin. From this point of view the large quantity of young cohoes in Lakes Dalnee and Blizhnee is of interest. It can be regarded as fully established that cohoes do not spawn at all in Lake Blizhnee or in the Blizhniaia River which flows from it. They also do not spawn in Lake Dalnee, and only a small number of cohoes lay their eggs in the Dalniaia River flowing out of Lake Dalnee. Hence it is quite obvious that the large accumulation of young cohoes in these lakes occurs as a result of migration from other parts of the Paratunka basin. Both in Lake Dalnee and in Lake Blizhnee young cohoes are present all the year round, but apparently in differing quantities.

During the winter of 1938 in these lakes I found occasional specimens of young coho among catches of young sockeye which had been caught in a fine-meshed fixed gill net, in the pelagic parts of the lakes, at different levels. Throughout the whole warm part of the year after the opening of the lakes, and up to the time they freeze over again, young cohoes are observed there in large quantities. The time of migration of young cohoes into the Paratunka lakes has as yet not been determined, but since cohoes of about 40 mm are caught in June and July, we must suppose that they migrate there no very great length of time after their emergence from the gravel. This indicates the great capacity for movement of young cohoes even at so early a period of their life. The coho spawning grounds are situated a rather long distance from Lake Blizhnee, and young fish recently emerged from the gravel, 38-45 mm long, surmount the river's current which has an average speed of not less than 0.30 m/sec for a distance of at least 10-15 km.

XII. Downstream migration of the young fish to the sea

The main mass of young cohoes migrate to sea in their second year after hatching from the egg, and a considerably smaller part migrate in their third year, that is, at age 2+. The relationship of these two groups in different rivers of the Kamchatka coast was described in the chapter on age composition of the mature fish. As mentioned earlier, in examining the scales of mature fish not a single example was found which had migrated to sea as a fingerling, that is during the first summer after hatching; all the scales had at their center a completed annulus of the river type.

The young of North American cohoes spend a minimum of one year in fresh water before going to sea. In more northern regions the young fish remain even two years in fresh water.

The fishery for young cohoes in the Avachin Gulf also confirms that cohoes in Kamchatka waters do not migrate to sea immediately after emerging from the gravel, as chum and pink salmon do, but remain in fresh water at least for one year and sometimes for two.

In the catches of young cohoes from Avachin Gulf near the village of Seroglazka on June 28, 1935, among 232 fish there was not a single fingerling and fish of age 2+ numbered only 8, so that almost all the catch consisted of fish which had migrated from the river at an age of 1+ (their scales did not as yet show any marine growth). The composition of this catch of young is shown in Table 26 [page 63 of the translation].

[page 90] During the second summer of their life in fresh water the yearling fish either migrate to sea or else remain in the river for one more year. The ones which migrate to sea at age 1+ are apparently those which have reached a larger size at the beginning of their second year of life, while the smaller ones remain a second year in fresh water. This is shown by the fact that the average size of yearlings migrating to sea, and caught in Avachin Gulf in June, exceeded the yearlings caught at the same time in the Paratunka River watershed by 10 mm and more. The average size of yearlings taken on September 17 in the Tikhaia River measured 9.7 cm, at a time when the downstream migration of young to the sea was already over and consequently the samples in question consisted of fish which would remain a second year in fresh water; while the June sample of young taken in Avachin Gulf had an average length of 10.6 cm.

I do not have sufficient data to make any very exact determination of the period during which young cohoes leave the river for the sea.

My observations in 1935 showed that the downstream migration of the young cohoes from Lake Dalnee into the Paratunka River takes place along with the sockeye and lasts from the end of May to the end of August, the most intensive migration occurring in July. A. S. Barahenkova (1), observing the same downstream migration in 1933, cites approximately the same interval. But when, exactly, these young fish from Lake Dalnee reach the sea remains unknown.

Like the young of most Pacific salmon, young cohoes sometimes remain in the lower reaches of the river in the region of tidal influence, in side channels of the delta and inlets having brackish water, where they gradually become acclimatized. This is indicated by the presence on the scales of some fish of interrupted and broken circuli, separating the marine and river periods of the fish's life.

I have never observed a concentrated migration [druzhnyi skat] of the young from the river to the sea, such as occurs among young sockeye; this indicates that the migration of young coho is more spread out in time. As early as the beginning of June anglers caught young cohoes 9-10 cm long along with char in the sea near the city of Petropavlovsk. At the end of June the young cohoes occur in large schools near the shore in Avachin Gulf, especially in places protected from surf.

On the other hand, in the Paratunka River and in its side channels accumulations of young cohoes were observed throughout the summer and up to the end of August, but no longer. But observations in the lower and middle part of the river have shown that by the first half of September the number of young cohoes in the Paratunka River has decreased markedly, in comparison with the masses observed earlier. In catches of young fish made in September two-year-olds were completely absent.

[page 91] These data permit us to say provisionally that downstream migration of coho from the Paratunka River into Avachin Gulf takes place from the beginning of June to the end of August, but further work is necessary to confirm this period.

Young sockeye, which also migrate from the river to the sea at age 1+ and 2+, and are similar in size to the migrating cohoes, usually do not remain close to the mouths of the river from which they came, but rather rapidly disappear from the regions near the river mouth. Fishing for the young using a fine-meshed seine in Avachin Gulf, which is frequently undertaken by the workers at the Kamchatka station, yielded young sockeye only on extremely rare occasions and in very small numbers. It is usually necessary to work really hard, and to undertake seining in different parts of the Gulf, in order to catch a few specimens of young sockeye; but seine hauls in places where surf is absent almost always provide young coho in some quantity or other.

Young cohoes migrating from the Paratunka and Avacha Rivers, stay in Avachin Gulf for rather a long time; they can be found there almost any time throughout the whole summer and autumn up to December, and apparently they winter within the boundaries of the Gulf. However no fishery has been conducted for the young fish in January and subsequent months, so it is only speculation to say that the young fish winter in the gulf. It also remains unknown whether all the young remain in Avachin Gulf or whether some part of them, like the young of the sockeye, take off for a more distant region of the sea immediately after leaving the river.

Within Avachin Gulf young cohoes live mainly in bays and coves, and they sometimes enter brackish-water lagoons, but they also occur along the open sea coast.

Experimental catches of sardines made by the Kamchatka Station in the central part of the gulf, using floating gill nets, never took any incidental cohoes; consequently cohoes prefer to remain in rather shallow places in the shore zone during their first summer following downstream migration.

According to A. S. Baranenkova's data young cohoes caught in Petropavlovsk ship basin in December of 1933 at age 1+ were 17-22 cm long. In the autumn of 1933 young cohoes were observed in Lake Kultuk (within the limits of the city of Petropavlovsk); this lake is a brackish lagoon separated from the sea by a long sandy barrier, and is connected with it by a long and narrow channel. In December, 1933, cohoes 25-28 cm long were caught in the lake by anglers and by traps set under the ice. All specimens had an age of 2+ years, of which two were river years.

Lake Kultuk is rather extensively polluted by city sewage. Its bottom is silted in and the mud in places has a strong odour of hydrogen sulphide. This indicates, in Baranenkova's opinion, a greater tolerance of environmental conditions by young coho, in comparison with young of other Pacific salmons. I have doubts concerning the correctness of this conclusion, since the young fish apparently entered the lake when there was as yet no ice cover and the gas regime in the lake was undoubtedly more favourable; in November and December the departure of the young fish back to the sea was made more difficult by clogging of the channel with wood [page 92] wastes from a sawmill which had been set up there. Hence the presence of the young cohoes there during the winter might have been enforced.

XIII. Migrations of cohoes in the sea

The marine migrations of Kamchatka coho have not been studied at all, and we do not yet know where their foraging grounds are in the sea.

At the present time the marine migrations of coho along the Pacific coast of Canada have been rather well studied. As a result of the work in marking coho done by Canadian scientists during the period 1925 to 1930, it has been discovered that the cohoes there do not perform very distant migrations. At all times of year young immature cohoes of different sizes and ages are caught in the coastal waters of Canada. Fish marked on their foraging grounds, in the coastal region off the Queen Charlotte Islands and Vancouver Island, have in most cases been captured again during their spawning migration, close to the mouths of the spawning rivers of the mainland coast of Canada in the region from the Nass River on the north to Puget Sound on the south (12, 16, 18).

However, it is impossible to make any hypothesis about the migrations of Kamchatka cohoes from an analogy with the Canadian cohoes, because environmental conditions in the sea along our coast are considerably different from the corresponding places off the shores of Canada; nevertheless certain considerations permit us to suppose that the Kamchatka cohoes also do not prefer distant migrations in the sea, but feed and grow within the limits of Kamchatka coastal waters.

Coho and pink salmon have a less extended period of existence in the sea than do the other Pacific salmons. Both species spend in the ocean one summer, a winter, and then another incomplete summer; that is, about 15 months under usual conditions. The difference between these species consists in the fact that young pink salmon, after leaving the rivers, immediately disappear from the region off the river mouths and all their marine period is passed in regions of the sea unknown to us, during the time the young cohoes remain for 5-6 months in the coastal brackish waters of Kamchatka.

Thus the cohoes spend only 9-10 months in visiting regions unknown to us. It is scarcely possible to imagine that during this comparatively short period, which coincides with the time of their most intensive increase in weight and length, cohoes can perform as distant a migration as chum or pink salmon.

Among cohoes migrating upstream to spawn some males are encountered which are maturing prematurely: after migrating from fresh water, they have spent only one summer in the sea, that is, no more than 3-4 months, and during this time some of them have attained a length of 35 cm, which is only 10 cm less than the minimum size of the normal maturing fish [which are a year older].

The almost simultaneous appearance of sexually mature cohoes at the mouths of spawning rivers in north and in south Kamchatka also agrees with the hypothesis that the foraging grounds of coho are situated not far from the Kamchatka coast.

I think this hypothesis will be confirmed by marking experiments being planned for the future, and by the development of a fishery in the open sea.

XIV. Food of the coho [page 93]

The food of young coho in fresh waters has been studied using material collected from May to September, 1935, in the Paratunka watershed.

The identification of the contents of stomachs and intestines has been done by M. P. Sheina. Eighteen samples have been studied, consisting of 315 stomachs and intestines.

Examination of the contents of stomachs and intestines gave the following results.

1. Dalniaia Creek, May 15. Length of the young fish 26-37 mm. Stomachs moderately full. A majority of the fry still had traces of the yolk sac. Two-thirds of the stomachs were filled with remains of adult insects. Midge larvae were in second place, mainly belonging to the family Orthocladiinae. The stomach of one specimen contained diatoms. In a majority of the fry there occurred the rotifer Anurea aculeata, copepod crustaceans, and the flagellate Volvox; these apparently came down into the river from Lake Dalnee.

2. Tundrov Kliuch, May 19. Length of the young fish 39 to 57 mm. Stomachs well to moderately filled. In the smaller specimens (up to 37 mm) larvae of Orthocladiinae predominated, and certain other small chironomids; along with them there was a considerable quantity of Chydorus. Three specimens of small fish had a large quantity of Cladocera in their stomachs. In fish larger than 40 mm the stomachs were filled with the remains of adult insects. Only chironomids were encountered.

3. Dalniaia Creek, July 1. Length of the young fish 28-34 mm. Stomachs well to moderately filled. The young fish, which had only just emerged from the gravel, contained remains of the yolk sac, appearing as whitish folds along the belly. Larval chironomids predominated in the stomachs: Lepnevia, Trichocladius and Orthocladiinae.

4. Lake Blizhnee, July 24. Length of the fingerlings 36-49 mm. Stomachs and intestines well filled. Contents consisted exclusively of the mature stages of insects, mainly Diptera, and also some Hemiptera and Coleoptera. Only one chironomid was found. There was no plankton.

5. Kosogorchik Kliuch, July 27. Length of the fingerlings 30-50 mm. Stomachs well filled. Remains of mature insects predominated in all specimens, larval chironomids were rare, mostly Orthocladiinae. Cyclops occurred in some specimens.

6. Yakutsk Kliuch, July 29. Length of the fingerlings 34-42 mm. Stomachs well filled. Remains of adult Diptera, Hymenoptera and Hemiptera predominated. Occasional chironomid larvae.

7. Topolov Channel, August 28. Length of fingerlings from 39 to 64 mm. Stomachs moderately filled. Remains of adult insects predominated. Chironomid larvae were mostly Orthocladiinae, larvae of other groups occurred occasionally.

8. Blizhnii Shirokii Kliuch, June 2. Length of the young fish 52 to 115 mm. Stomachs well or moderately filled. Aerial feeding greatly predominated. All stomachs were filled with remains of adult insects, mostly Diptera, more rarely [page 94] Hemiptera, Hymenoptera and Coleoptera. Some specimens had a large quantity of Cumacea crustaceans. Larval chironomids and other insects occurred in insignificant numbers. About 25% of the fish contained young salmonids, 25-30 mm long. In some specimens the number of such fry amounted to 5. This shows that while still in fresh water coho yearlings frequently become predators.

9. Lake Blizhnee, June 26. Length of the young fish 42-111 mm. Aerial feeding predominates--insect remains. In 3 specimens well-digested young fish occurred in the stomachs.

10. Lake Blizhnee, July 13. Length of the young fish from 68 to 157 mm. Remains of adult insects greatly predominated, among which were many Diptera. In some specimens Amphipoda occurred in large quantities.

11. Lake Blizhnee, August 16. Length of the young fish from 90 to 104 mm. Stomachs very full. All stomachs contained nothing but aerial food. Remains of insects, very many remains of adult Diptera.

12. Dalnîaîa Creek, August 10. Length of the young fish from 90 to 118 mm. Most fish had mature Diptera, many larvae of Orthocladiinae, also larvae of Ephemeridae.

13. Lake Dalnee, September 24-25. Length of the young fish from 44 to 136 mm. Stomachs moderately filled or, in some, poorly filled. Almost all of the fish contained mature insects. Many Diptera, Hymenoptera and Hemiptera. It is interesting that in some fish there were large numbers of water-measurers, sometimes up to 170 specimens. In a sample from Dalnîaîa River also, taken July 1, the stomachs of a few young fish were filled with Hydrometridae.

14. Lake Blizhnee, September 26. Length of the young fish 57-118 mm. Stomachs poorly filled. Remains of adult insects predominated.

A. S. Baranenkova (1), who studied the food of young salmons, observed a preference for benthic food among coho. "In the stomachs examined of young cohoes 29-41 mm in length, captured along the Pravaîa Paratunka River on May 25, 1933, chironomid larvae predominated (in 15 cases out of 20), there were a few stonefly larvae, and only in one specimen were small crustaceans found." "On August 21, 1933, among downstream-migrating cohoes of age 1 and 1+ years and 9.5 to 15.5 cm long, taken along the Dalniaîa River, various insect larvae and sockeye eggs were found in the stomachs. The presence of eggs of the mature fish in the stomachs of young coho is explained by the fact that near the place the cohoes were captured on the Dalniaîa River there was a fishery conducted by a collective farm. The young cohoes ate the eggs which had fallen into the water."

From the above data we can come to the following conclusions concerning the feeding of young cohoes in fresh water: young cohoes begin intensive feeding immediately after emerging from the gravel, while they still have remains of the yolk sac.

The principal food of young cohoes during the spring and summer months consists of aerial food--adult insects. At the time of my visit to the kliuches and the Paratunka lakes I was frequently able to observe how young cohoes in large groups broke the surface and even jumped clear when chasing insects flying over the water.

[page 95] Second in importance in the food of young coho, after insects, are insect larvae, primarily chironomid larvae. Among the latter, the sub-family Orthocladiinae are of greatest importance in the food.

Concurrently with the collection of stomachs of young coho, samples of the benthos were taken with a grab; these make it possible to say that the young coho made a very wide use of bottom fauna in feeding, since almost all the forms found in the dredge samples were used by cohoes to greater or less degree.

Plankton organisms are encountered in the food very rarely, and only in small fingerlings not more than 5 cm long. It must be observed that the absence of plankton from the food cannot be explained by its absence from places where the young fish feed. Plankton is absent from the food of young cohoes not only in the kliuches where it is actually scarce, but also in Lakes Dalnee and Blizhnee which are rather rich in plankton. In contrast to young sockeye, which live in the pelagic parts of these lakes and feed almost wholly on plankton, young cohoes stay mainly in the littoral region. Analysis of their stomach contents shows that they feed exclusively on aerial and bottom foods. Young cohoes living in lakes do not consume plankton at all.

While they are still in fresh water, coho yearlings 10-12 cm begin to shift partially to predacious feeding, eating small fingerling salmon, including some of their own species.

During the period from May to September stomachs were well filled in all instances, and only in the September samples, when flying insects had decreased, was feeding reduced. In the September samples, both in Lake Dalnee and Lake Blizhnee, the stomachs of young cohoes were poorly filled, however in these stomachs too, adult insects still predominated.

We must suppose that during winter the larval insects are the principal food of young cohoes in fresh water.

The food of cohoes which have just migrated out of the river into Avachin Gulf is shown in Tables 28 and 27.

During the first period after migration from the river aerial food still predominated, as it did in fresh water, and crustaceans were in second place. In the sample from the quite brackish Seroglazka Bay, occasionally Orthocladiinae were found in the stomachs. In young cohoes captured in the Petropavlovsk ship basin, which is more distant from the mouths of rivers and has a higher salinity, crustaceans began to predominate over adult insects; however the latter were found in the stomachs of most fish in greater or less numbers.

The presence of salmon eggs in the stomachs of young cohoes, as indicated above, is explained by the fact that commercial processing of fish was going on close to their place of capture--and the young cohoes ate some of the discarded eggs.

In young cohoes from the Petropavlovsk ship basin young fish played a considerable role in the food. Five of the 13 stomachs examined contained young fish.

As the fish grow the importance of predacious feeding increases. In cohoes captured in this same Petropavlovsk basin in September and October, fish food greatly predominated.

[page 96] In young cohoes 16-23 cm long taken in Petropavlovsk basin October 21-27, 1933, Gammarus predominated in only 3 stomachs, and in the remaining 20 stomachs [page 97] there were found only young smelt, navaga and also sticklebacks.

Young cohoes which had entered the brackish Lake Kultuk in the city of Petropavlovsk in the autumn of 1933 ate mainly sticklebacks and crustaceans during the winter there.

I am unable to describe the food of coho during the time they are foraging in the sea, when the most intensive growth in length and weight takes place, for lack of material. However there is considerable basis for belief that cohoes, like all Pacific salmon, are predacious, and even more typically so than the other salmons, it would seem.

Table 27. [page 96] Contents of stomachs and intestines of young cohoes taken in Seroglazka Bay, Avachin Gulf, June 28, 1935. [Abbreviations: S--stomach; I--intestine; G--good [khoroshoe]; A--average [srednee]; P--poor [slaboe]; E--empty [pusto]; M--many [mnogo]; F--few [malo]; S--single [edinitsa].]

Length of the fish mm	Fullness		Insects		Insects		Crustaceans		Others	
	S	I	S	I	S	I	S	I	S	I
134	G	P	F	A	S	..	..	..	filamentous algae	..
131	P	P	A	F	..	..	..	..	sand	
136	G	G	S	F	..	..	M	M	..	S
129	G	P	6	S	S	..	..	..	salmon eggs	
140	E	A	..	M	..	..	..	..	..	..
131	G	G	F	A	..	..	M	M	..	..
127	G	A	M	M	S	S	..	..	salmon eggs	
134	G	G	S	M	..	..	A	M	..	..
137	G	G	..	M	..	..	M	A	salmon eggs	
129	A	A	..	F	S	S	..	A	..	..
105	P	G	S	M	S	..	..	..	..	..
107	A	A	A	A	S	..	..	..	..	..
112	A	A	S	M	A	..	..	..	..	..
96	E	G	..	M	..	S	..	..	..	..
94	G	E	M	..	S	..	..	..	salmon eggs	
80	P	A	A	M	..	..	..	..	..	..
83	G	P	A	F	S	..	..	..	fish eggs	
73	G	G	A	M	A	A	..	..	filamentous algae	
71	A	G	A	M	..	..	..	..	..	..
67	G	A	M	M	S	..	..	..	..	..

Table 28. [page 96] Contents of stomachs and intestines of young cohoes taken in Petropavlovsk Basin, Avachin Gulf, June 27, 1935. [Abbreviations as in Table 27.]

Length of the fish mm	Fullness		Insects		Crustaceans		Others	
	S	I	S	I	S	I	S	I
104	A	E	..	..	A	..	..	..
110	A	A	1	A	1	..	macrophyte rem.	
100	A	G	..	..	M	M	..	..
86	G	G	M	M	..	..	..	..
95	G	G	..	1	M	M	..	..
90	A	G	..	..	F	M	..	..
94	G	G	1	M	..	..	young fish	
86	G	E	A	..	..	..	fish eggs and young	
74	G	A	1	..	M	M	1 fish	
79	P	P	F	F	..	..	..	..
123	P	G	..	..	F	M	..	..
122	A	G	..	..	..	1	young fish	
124	G	G	..	..	..	M	young fish	

The shorter, more widely spaced, and less numerous gill rakers of the coho indicate this indirectly.

Examination of 15 stomachs of third-year barren non-maturing cohoes from a closed relict lake, where cohoes spend their whole life cycle, showed that the stomachs of these fish were filled with threespine sticklebacks and benthic crustaceans. At the same time, an analysis of the food of the lake form of sockeye of the same age (from Lake Kronotsk) showed that the sockeye under analogous conditions feed exclusively on plankton (7). Cohoes continue to feed during their spawning migration, up to the time of their entry into a river. To learn what food the migrating cohoes ate, I examined the contents of the stomachs of 100 fish taken by trap nets of the Mikoĭanovsk Fishing Combine in the Bolsheretsk region. It appeared that in 90% of the fish the stomachs were empty and only 10% contained food. The contents of the stomachs were exclusively fish; only in one specimen was a shrimp found along with fish remains. In the stomachs we found herring, sand lance, navaga and young gadids--apparently cod and walleye pollock [Theragra]. In one specimen the stomach contained about 200 young cod 4-5 cm long, partly digested. In the stomach of another coho I found 9 sand lances, 15 cm in average length. Herring and navaga found in the stomachs were up to 25 cm long.

In Solevarka Bay near the entrance of Avachin Gulf, on August 21, 1935, about 20% of all the fish examined had full stomachs. A considerably larger percentage of the fish contained food remains, a pasty digested mass. Stomachs of the remaining fish, even those which were empty, had a completely normal appearance. No sign could yet be seen of the atrophy of the digestive tract that is characteristic of the breeding fast. In contrast to cohoes from the Bolsheretsk region, here there was a preponderance of invertebrates in the stomachs, crustaceans occurring most often. In two stomachs half-digested polychaetes were found, and vertebrae and scales of small salmon and badly fragmented digested remains of fishes occurred. In 1933, while gutting commercial catches in this same Solevarka Bay, I observed in the coho stomachs a great quantity of young herring. According to unpublished data of N. A. Polutov (1928), in the Kikhchik region herring are very frequently encountered in coho stomachs.

The data above on coho food characterize of course only the "incidental" food which they obtain along the path of their spawning migration. This food in this case serves only to support the organism along the route of its approach to the mouth of the spawning river.

[page 98] At the time of their spawning migration, coho continue to feed up to the time they enter the river, but after entering into the river feeding ceases. An analysis of the contents of stomachs of fish caught by seines in the Paratunka River, at a distance of about 1½ km from the mouth, showed

complete absence of any kind of formed food, and only in a few specimens was there an inconsiderable quantity of digested remains of crustaceans in the intestines.

Nevertheless it is a well-known fact that cohoes are caught in the river by rod and line. At Ust-Bolsheretsk coho are caught by rod from the bridge across the Bolshaĭa River using live eggs of salmonids as bait. Along the Paratunka River too, opposite the village of the same name, the local people, mostly children, fish for cohoes with hooks baited with eggs. But these facts cannot contradict the assertion that cohoes do not feed in the river. Here apparently I disagree with the phenomenon which V. K. Soldatov (11) observed in respect to Atlantic salmon. It is an habitual physiological reflex for coho to snap at the eggs, and when they are not successful in spitting them out again they are captured by the angler. Apparently this is common to other Kamchatka salmons as well; I once observed that sockeye which had already attained their breeding colours also made a pass at a baited hook in the middle of the Paratunka River, at the time a pole fishery for char was in progress.

XV. Conclusions

The purpose of this work has been to give a general biological description of the coho. Its basis has been the studies conducted by the author in 1935/36 in the Paratunka River watershed, and also materials obtained at the observation points of the Kamchatka Division of the Pacific Institute for Fisheries and Oceanography.

From statistical examination of measurements of 300 specimens of coho, a detailed morphometric description of the species is given.

Among Pacific salmons, the coho matures at the earliest age, except for the pink salmon. Coho attain sexual maturity in their third or fourth year of life, the former being more frequent. Before they go to sea young cohoes always spend one or two years in fresh water.

The length of the body of the coho from the tip of the snout to the end of the middle rays of the caudal fin averages about 60 cm; the maximum is 87 and the minimum 40 cm. The average weight of the coho is 3.5 kg; maximum is 6.5 and the minimum 1.2 kg. The coefficient of condition for coho on the spawning grounds is about 30% less than among those taken at the mouth of the river.

Calculations of the rate of growth of cohoes made from the scales of mature fish have shown that, as in other anadromous salmons, a sharp increase in growth rate occurs after the young leave the river and enter the sea. Cohoes have

the most rapid rate of growth among Pacific salmons, except for pinks.

In the rivers of Kamchatka the coho migration begins with a few individuals at the beginning of June, but its greatest intensity is attained in the second half of August; it continues through September and October, and occasionally specimens enter the mouths of rivers up to December. Everywhere in Kamchatka two runs of coho are distinguished--an early run and a late run.

On approaching the mouths of the spawning streams cohoes remain in the brackish [page 99] layer carried by the rivers into the sea. The difference in temperature between the sea and the river is not, apparently, a factor affecting the entry of the fish; cases are known where cohoes in going from the sea into a river move from colder water into warmer water, and in contrast, there are cases where cohoes from rather warm sea water change to medium with a lower temperature on entering a river.

The entry of the fish into the river is most intensive at the time the tide begins to rise; during falling tides schools of coho remain in the brackish zone off the river mouth.

An increase in the level of water in the river, usually associated with bad weather, increases the run of coho up the river; on the other hand during clear dry weather, when the river level falls, the ascent of cohoes slackens off.

Spawning grounds of coho are found throughout the whole extent of the basins of Kamchatka rivers, beginning at the zone of tidal influence and on upstream to the very sources of the rivers. Cohoes spawn in kliuches, in river side-channels and in main channels, which have transparent cold water and a gravelly bottom, but they never lay their eggs in lakes.

Spawning is very protracted and takes place from the end of August to the middle of March. However the main mass of the cohoes in Kamchatka rivers spawn in October and November.

At the time of spawning there are usually more males than females on the spawning grounds, which is explained by the longer survival of males than females after the beginning of spawning.

The form and depth of the redd depends on the size of the female, also on the character of the bottom and speed of the current on the spawning grounds. The larger individuals excavate a larger redd. The looser the bottom and the swifter the current, the more elongate is the shape of the redd. Where the current is slow the pits excavated by coho in the bottom are round.

Eggs are laid in the bottom at a depth of 10-30 cm; the

number of eggs in one nest varies from 300 to 1200. The female coho lays eggs 3 or 4 times, excavating a new nest each time and building spawning mounds at different points on a given spawning ground.

The length of the incubation period varies with temperature. From observations in the Paratunka watershed, larvae begin to hatch about 100-115 days after fertilization. At the Ushki Fish Hatchery, where the temperature stays steadily at 4.5°, hatching of the larvae begins 86-101 days after fertilization.

Mortality of coho eggs under natural conditions as a rule does not exceed 4-6%, however in individual cases mortality can be as high as 60%, and sometimes complete mortality of the eggs is observed. The loss of eggs in a fish hatchery is no less than under natural conditions, and amounts to 12%.

Mortality of eggs both under natural conditions and in the hatchery occurs almost always in an early period of development, previous to the eyed stage.

From the moment of hatching up to absorption of the yolk sac and emergence of the larvae from the gravel, about 40 days elapses. The size of newly hatched larval coho is 17-19 mm; after 40-45 days the larvae have grown to 27-30 mm and have the appearance of young fish, the yolk sac has been absorbed and the young fish begin an independent existence.

[page 100] In the Paratunka watershed, hatching of the larvae from eggs takes place from the middle of January to June, and emergence of larvae from the gravel lasts from the beginning of March to the end of July; this corresponds to the length of the spawning period of cohoes in this watershed.

The size of fingerlings encountered in fresh water varies markedly in relation to the time of year they are caught and to the time of emergence of the young fish from the gravel. In the autumn months fingerlings from 4 to 7 cm long are encountered. The first winter ring on the scale of a young coho is formed during the period February-May.

The size of yearling cohoes in the Paratunka watershed varies from 5 to 13 cm, and the two-year-olds are from 10 to 17 cm. The larger of the young fish migrate to sea at age 1+. The smaller yearling coho remain for a second winter in the river.

Young cohoes are widely distributed throughout the whole watershed of the rivers where coho go for spawning. They are found in kliuches, in side channels, in lakes and in the main channel of the river, both in the head-waters of large river systems and in the lower reaches of rivers, not far from their mouths.

The downstream migration of coho from the Paratunka River into Avachin Gulf takes place from the beginning of June to the end of August. Young cohoes occur everywhere in Avachin Gulf throughout summer and autumn, up to and including December.

Young cohoes begin active feeding immediately after emerging from the gravel, while they still have remains of the yolk sac.

The principal food of young cohoes in spring and summer consists of aerial food--insects. Larval insects are second in importance, consisting mainly of chironomids.

Plankton is rarely encountered in the stomachs of the young fish, and only in small fingerlings. While still in fresh water, coho yearlings 10-12 cm long frequently begin predacious feeding.

At the time the young are living in brackish regions near river mouths, after their migration out of the river, aerial food continues to predominate in their feeding, and crustaceans are second in importance. In young fish from the regions of the sea which are more distant from the mouths of the river, where the salinity is close to that of the ocean, crustaceans begin to predominate in the food; however insects are still encountered in some quantity in the stomachs of the majority of the fish. As the young fish increase in size the importance of predacious feeding increases. In September and October the fish greatly predominate in the food of young cohoes from the Petropavlovsk ship basin.

At the time of the spawning migration, mature cohoes continue to feed up to the time they enter the river. In a majority of cases fish occur in the stomachs of migrating adult cohoes: young and adult herring, sand lances, navaga, young gadids and also crustaceans.

The place occupied by coho in the Kamchatka salmon catches is not a large one. This is a result not only of the smaller natural stocks of coho, but also on a lesser degree of commercial exploitation of the coho stocks, which is associated with the late migration of this fish. Intensification of the fishery will undoubtedly permit a considerable increase in coho landings.

Literature [page 101]

1. Baranenkova, A. S. [An account of studies made on the biology of young salmonids.] Biulleten Kamch. otd. TINRO, No. 2, 1934 (hectographed).

2. Berg, L. S. [Fishes of fresh waters of the USSR and neighbouring countries.] Izd. 3, Part 1, 1933.

3. Krashenninikov, S. [A description of Kamchatka.] Vol. 1 SPB. 1818.

4. Krogius, F. V., A. S. Baranenkova and V. S. Bool. [A review of the biology of the Kamchatka salmons.] Biulleten Kamchat. otd. TINRO, No. 1, 1934 (hectographed).

5. Krokhin, E. M., and F. V. Krogius. [An account of the Bolshaia River watershed and the spawning grounds of salmon situated in it.] Izv. Tikh. Inst. Rybn. Khoz. i Okeanograf., Vol. 9, 1937.

6. Krokhin, E. M., and F. V. Krogius. [An account of Lake Kuril and the biology of sockeye salmon in its basin.] Tr. Tikh. Kom. AN SSSR, Vol. 4, 1937.

7. Krokhin, E. M., and F. V. Krogius. [The lake form of sockeye from Lake Kronotsk in Kamchatka.] Dokl. Ak. Nauk SSSR, IV. XIII, 2, 1936.

8. Kuznetsov, I. I. [Some observations on the reproduction of Amur and Kamchatka salmons.] Izv. Tikh. Nauch. Prom. St., Vol. 4, 3, 1928.

9. Pravdin, I. F. [Morphometric characteristics of west Kamchatka pink salmon.] Izv. Tikh. Nauch. Prom. St., Vol. 4, 1, 1929.

10. Soldatov, V. K. [Studies on the biology of the Amur salmons.] Part 1, 1912.

11. Soldatov, V. K. [Fishery ichthyology.] Part 1. Snabtekhizdat. 1934.

12. Clemens, W. A. Pacific Salmon migration: the tagging of the coho salmon on the east coast of Vancouver Island in 1927 and 1928. Biol. Board Can., XV, 1930.

13. Gilbert, C. H. Age at maturity of Pacific salmon of the genus Oncorhynchus. Bull. Bur. Fish., XXXII, 1912.

14. Gilbert, C. H. The salmon of the Yukon River. Bull. Bur. Fish., XXXVIII, 1924.

15. Powers, Ed. Chemical factors affecting the migrating moments of the Pacific salmon. Publ. of the Am. Ass. for the Advancement of Sci., 8, 1939.

16. Pritchard, A. L. Pacific salmon migration; the tagging of the coho salmon in British Columbia in 1929 and 1930. Biol. Board Can., XL, 1934.

17. Pritchard, A. L. Factors influencing the upstream spawning migration of the pink salmon. Biol. Board Can., II, 4, 1936.

18. Williamson, H. C. Pacific salmon migration; report on the tagging operations in 1925. Contr. Can. Biol. and Fish., III, 9, 1927.