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by V.K. Klokov

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THE POPULATION DYNAMICS OF SPAWNING SCHOOLS OF SALMON ON THE NORTH COAST OF THE SEA OF OKHOTSK

By V.K. Klokov

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The rivers on the north coast of the Sea of Okhotsk are spawning grounds for five species of far-eastern salmon of the genus Oncorhynchus: the pink salmon, O. gorbuscha (Walb), the chum salmon, O. keta (Walb), the coho salmon, O. kisutch (Walb), the sockeye salmon, O. nerka (Walb) and the chinook salmon, O. tschawytscha (Walb).

The most populous species which form the base of the salmon fishery in this region are the pink salmon and the chum salmon. Coho salmon, the annual catch of which runs to a few hundred centners, enter the rivers in smaller numbers. The sockeye salmon is sporadically distributed, and its spawning grounds are located in the Taui, Ola and Gizhiga rivers, where it is encountered now and then at the beginning of the salmon fishing season in commercial catches of other fish. Catches of chinook

[1] Numbers in the right-hand margin indicate the corresponding page numbers in the original.

salmon are rather rare, and individual specimens are sometimes encountered in drag seine catches in the Taui, Yama and Gizhiga rivers.

At the present time, the salmon fishery on the north coast is carried on by kolkhozes of the Magadan oblast and by enterprises of the Magadan fisheries trust. The total salmon catch in this region has run to 150 thousand centners (in 1944); in recent years, in connection with the reduction in the abundance of spawning stocks, the salmon catch has declined to 10-20 thousand centners annually. Of the total catch of such salmon species as pink and chum by Soviet enterprises along the entire far-eastern coast, approximately 18% and 12%, respectively, is caught on the north coast.

It is possible to distinguish three fisheries regions on the coast, each of which is more or less isolated geographically from the others and differs moreover in the nature of population dynamics, in the prevalence of particular species in catches, and in the biological features of the spawning salmon stocks: the Taui Gulf with the major salmon spawning rivers, the Taui, Yana, Arman' and Ola; the Yama Gulf, where the fishery is based mainly in the river of the same name, and in addition, the Iret', Tumany and Takhtoyama rivers, around the estuaries of which coastal fishing with trap nets is usually carried on, are located here; and the Gizhiga Gulf, where the important spawning rivers are the Gizhiga, Nayakhan and the Big and Little Garmanda.

All of the rivers enumerated are up to 200-250 kilometres in length; besides these, there is a multitude of small spawning

rivers of secondary size, from 50 to 80-100 kilometres in length, such as the Avekovo, Chaibukha, Vilinga, Varkhalam and others, which play a considerable role in the general equilibrium of spawning areas of far-eastern salmon.

The major fisheries area is the Taui Gulf, where three fish combines, the Taui, Ust'-Magadan and Ola, take 81% of the total catch of pink salmon on the north coast and about 37% of the chum salmon catch. In the Yama Gulf, the main target of the fishery is the chum salmon, the catch of which amounts to about 43% of the total chum catch on the coast; the pink salmon is caught here in considerably smaller quantities, and catches amount to no more than 5% of the total catch of this species. About 15% of the pink salmon and 20% of the chum salmon are caught 170
in the rivers of the Gizhiga Gulf. In perspective of the catch on the entire coast, the chum and pink salmon are equally important targets of the fishery: the average-annual catch of pink salmon, as determined from long-term data for 1940-1968, is 30 thousand centners; the average-annual catch of chum salmon has run to 32 thousand centners.

Analysis of the dynamics of salmon catches on the north coast from 1940-1968 indicates, during an almost thirty-year period in this region, a few rather specific periods in variations of usable stocks of both pink and chum salmon have been observed (fig. 1). This paper is based on the assumption of a correspondence between change in the size of salmon catches and abundance of the spawning stocks which are fished, similar to that

which was established by A.G. Smirnov (1947) for Amur salmon. To what extent this premise applies to the region under investigation will be shown below.

First of all, it should be noted that there is a well marked periodicity in fluctuations in abundance of pink salmon in even and odd years, whereby greater catches occur in odd years. A similar type of fluctuation in catches of pink salmon in even and odd years has been observed in many regions of the Far East, in particular in West Kamchatka (Semko, 1954). The opposite relation of abundant and poor year-classes is observed in the Amur river (Krykhtin, Smirnov, 1962).

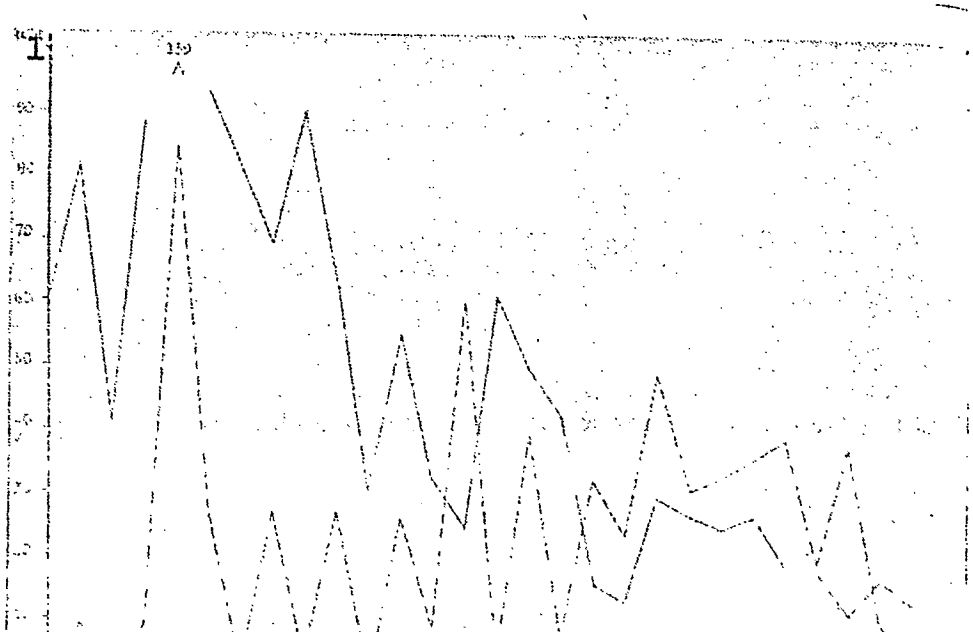

Figure 1. Salmon catches on the north coast: ——— chum; -------- pink; 1 - thousands of centners; 2 - year

This established regularity was disrupted on the north coast only in 1944, when the catch of pink salmon for this year

reached a record size - 85 thousand centners. There is archival information that greater catches of pink salmon occurred in even years in the period from 1936 to 1940, which also agrees with the findings of R.S. Semko for West Kamchatka. It is possible that the increase in the abundance of spawning stocks of pink salmon in 1944 was a consequence of the onset of a transitional period, when the cyclical fluctuations in the abundance of pink salmon 171
shifted to the opposite phase. After 1944, a reduction occurred on the north coast, as well as in West Kamchatka, in the abundance of pink salmon in even years, but in the adjacent odd years abundance immediately began to increase. This phenomenon also confirms A.P. Vedenskii's conclusion that in those periods when "depressions" occur in catches (in this case, in 1942-1943), adjacent years, on the other hand, yield unprecedently large catches, indicating an increase in the strength of the succeeding year-class. A similar sharp increase in the abundance of pink salmon against a general trend towards decrease in usable stocks, was also observed in 1963, which was preceded by three comparatively poor years (1960-1962). G.V. Nikol'skii (1952), A.P. Vedenskii (1954), I.B. Birman and V.Ya. Levanidov (1953) associate this regularity with the availability of food to the pink salmon population and its occurrence between adjacent year-classes.

Three stages can be traced in the variations in pink salmon catches from 1940 to 1968. In the period from 1940 to 1945, the abundance of spawning salmon schools did not show a clearly defined periodicity in fluctuations in even and odd years.

It is most probable that this period, as has already been remarked, was a transitional one in which fluctuations in pink salmon catches in even and odd years shifted to a reverse trend. The average-annual catch of pink salmon was rather high (about 50 thousand centners). From 1946 to 1959, fluctuations from odd strong year-classes to even poor year-classes of pink salmon were clearly defined. Catches in abundant years fluctuated from 27.4 to 32.5 thousand centners, and in even years, the abundance of pink salmon yielded catches in the order of 0.8 to 24.7 thousand centners. The size of the catch in abundant years in this period sometimes exceeded the catch in adjacent years by 15 times. This stage was marked by a comparatively low average-annual catch of about 26 thousand centners.

Finally, the third period in the dynamics of abundance of pink salmon on the north coast, from 1960 to 1968, is marked by a general trend towards reduction of the size of the salmon catch, following a reduction in the abundance of spawning stocks of pink salmon. The reduction in usable stocks of pink salmon made it necessary to introduce at the present time a ban on the fishery for pink salmon in both even and odd years, especially since the fish is taken only incidentally in drag seine catches in the fishery for other species of salmon. In this period, the average-annual catch of pink salmon amounted to about 25 thousand centners, while in the last three years, from 1966 to 1968, the annual catch did not exceed one thousand centners.

Variations in catches of chum salmon also revealed three clearly defined periods. In the first period, from 1940 to 1953,

a rise in abundance occurred initially and reached a maximum in 1944 and 1946. In this stage, the average annual catch was about 59 thousand centners, but afterwards a rather rapid increase began: the lowest level was reached in 1953 - 24 thousand centners. Two-three year alternations of abundant and poor fishing years are observed in the trend of the curve of variation of chum salmon catches in this period.

The second period is fairly short and covers in all only five years (1954-1958), but during this time considerable fluctuations occurred in usable stocks of chum, which in 1954 reached a size yielding a record catch of 61 thousand centners. Afterwards, in 1958, the sharply reduced abundance of spawning salmon stocks led to a decrease in average annual catches to 12 thousand centners, that is, by almost five times in comparison with 1954.

The third period is marked, as is shown in figure 1, by a gradual decrease in chum salmon catches, which was a result of the reduction in the abundance of spawning salmon stocks on the 172 entire north coast. At the present time, chum salmon catches, as well as pink salmon catches, have dropped to the lowest amount in all of the periods examined - in 1968, in all, only about 8 thousand centners of chum salmon was caught.

Comparison of catches of chum salmon and pink salmon shows that there is, as a rule, a clearly defined inverse relation between them, especially in years of marked fluctuations in catches of these salmon species.

In 1953, one of the smallest catches of chum salmon coincided with a good pink salmon catch (respectively 24 and 60 thousand centners), and the same was again observed in 1957, when 32 thousand centners of pink salmon and about 16 thousand centners of chum salmon was removed. On the other hand, in years of high abundance of chum salmon, catches of pink salmon are reduced: in 1954, 61 thousand centners of chum salmon and 4 thousand centners of pink salmon was removed. This regularity was disrupted in 1944, when catches of both chum and pink salmon ran to a considerable size. Deviations from the rule have also been observed in other years (1949, 1955 and 1959), basically over 4-5 years.

The explanation for this periodicity in the appearance of strong year-classes of chum salmon, coinciding with a rise in the abundance of pink salmon, could be the regularly observed alternation of strong and weak year-classes of chum salmon, the life cycle of which is completed in 5-6 years. In the absence of data on the age composition of chum salmon for the period up to 1961, it is difficult to resolve the question of regularities in the variation of abundance of particular chum salmon year-classes from 1940 to 1960. Nevertheless, it can be assumed that the fundamental cause lies in the nature of the splitting of year-classes into separate groups which return to spawn in the mass either in the fourth year of life (3 plus) or in the fifth year (4 plus). Depending on the abundance of adjacent year-classes and the nature of the splitting, a combination is possible such that when the two age groups 3 plus and 4 plus, which make up the chum salmon catch in one year of the fishery represent the larger parts of their year-

classes, the result is an increase in the total abundance of the spawning chum salmon population. According to V.L. Kostarev, (1960), this occurs in Okhotsk chum salmon in even years of the fishery when year-classes of chum salmon spawned in even years maturing in the mass (up to 78%) in the fourth year of life and individuals from year-classes spawned in odd years, up to 71% of which mature in the fifth year of life, return to spawn. Year-classes of Okhotsk chum salmon spawned in odd years have a higher abundance in the order of that which is observed for pink salmon of this region.

Table 1

Age composition of year-classes of Taui chum salmon (in % of the abundance of the entire year-class)

Год рождения поколений a	b Возраст			
	2+	3+	4+	5+
1955	3,0	25,0	71,0	1,0
1956	12,5	35,0	40,0	12,5
1957	—	49,0	49,0	2,0
1958	2,2	71,0	21,4	2,4
1959	5,2	74,6	20,6	0,2
1960	3,6	64,0	32,0	0,4
1961	2,9	50,0	47,0	0,1
1962	2,1	61,2	32,1	0,6
1963	3,5	89,0	7,5	—

Key:

a - year of origin of the year-class
b - age

The increase in catches of chum salmon in a number of odd years which has been observed on the north coast points to a fairly frequent deviation from the regularity arrived at by V.L. Kostarev for Okhotsk salmon.

The splitting of individual year-classes of the Taui population (table 1) is given as an example of the nature of the splitting of chum salmon on the north coast of the Sea of Okhotsk.

The data of the table confirm that for Taui chum salmon as well as for Okhotsk chum salmon, a splitting of year-classes was observed such that the greater part of the fish spawned in an odd year matured at the age of 4 plus (the 1955 year-class); the mass of the fish of the year-class spawned in the even year 1956 also matured at the age of 4 plus, but the ratio of these fish decreased considerably. Of the 1957 year-class, the parts of the foraging population which had matured in the fourth and 173
fifth years of life, already made up an equal ratio, and beginning with the 1958 year-class, the majority of fishes spawned in both even and odd years matured in the fourth year of life. The latter phenomenon can be associated with the general decline in the abundance of salmon, which was observed in the last period. A number of authors (Nikol'skii, 1950, 1965; Birman, 1951) have pointed out that decline in abundance of the fish population leads to rejuvenation of the stock. In this case, a predominance of fish in the fourth year of life and a decrease in the ratio of older fish (5 plus) are observed.

As has already been mentioned, fluctuations in catches of chum salmon and pink salmon occur in opposite phases. This situation is clearly apparent upon comparison of fisheries statistical data, grouped in four year periods (fig. 2), according

to the method which was applied by R.S. Semko (1954) and I.B. Birman (1964) in analyzing the state of usable stocks of salmon in West Kamchatka. The pattern obtained is very consistent with the data cited by the above authors for West Kamchatka. R.S. Semko explains the opposite phase in fluctuations in catches of chum salmon and pink salmon by the indirect influence of pink salmon on the survival of chum salmon fingerlings. He points out that those generations of chum salmon which, while migrating from river estuaries, encountered at sea abundant spawning populations of pink salmon heading into rivers, have never at any age achieved a predominance in spawning stocks. V.L. Kostarev (1960) takes the cause of the increased strength of chum salmon spawning approaches in years of low abundance of pink salmon to be the aggravation of the food interrelation resulting from the similarity of the food spectrum of these species of salmon. According to L.D. Andrievskaya (1958), during the period of the spawning migration of salmon, the degree of similarity in food of pink and chum salmon amounts to 49%. During earlier stages in the marine period of the life of the salmon, it is evidently considerably higher. I.B. Birman (1964) associates differences in the type of fluctuations in abundance of spawning stocks of chum salmon and pink salmon with the different behaviour of these species in the periodic warming and cooling of the sea in the region of Kuroshio. This view is also maintained by G.V. Nikol'skii (1965). It is clear that all of the factors mentioned affect the nature of the population dynamics of salmon, and that in particular years

one of them could prevail, but on the whole, an entire complex of factors, of which those enumerated are apparently the most important, affects the abundance of salmon.

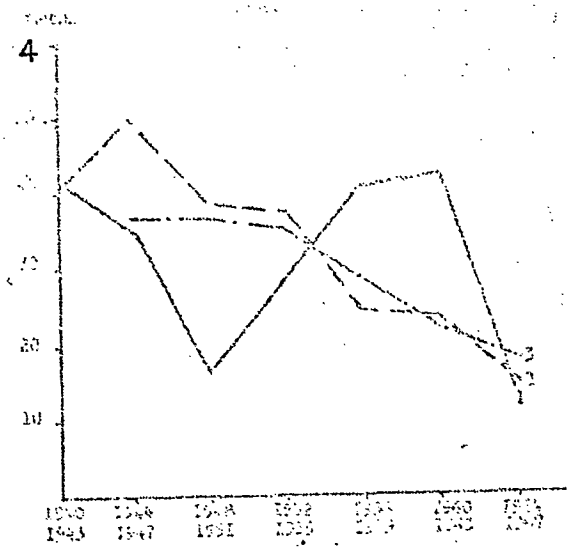

Fig. 2. Catches of salmon and herring for four-year periods: 1 - pink salmon; 2 - chum salmon; 3 - Taui spawning herring. 4 - thousands of centners.

A number of authors associate fluctuations in usable 174
stocks of salmon with the catch of herring, which is a species having a mass distribution in far-eastern seas. A.P. Vedenskii (1954) has observed, that increase in usable stocks of herring is accompanied by a decrease in the abundance of salmon, especially of pink salmon. I.B. Birman, in a number of studies (1964, 1967) has pointed out that the fluctuations in catches of chum salmon and herring, on the one hand, and pink salmon, on the other hand, are mutually opposite. Figure 2, where curve 3 shows variations in catches of Taui spawning herring (from findings of B.V. Tyurnin, 1965) is an illustration of this situation on the north coast.

These data confirm that the interdependence of abundance of different species of fish described by the above authors also extends to the north coast of the Sea of Okhotsk.

Of special interest is the period after 1960, when a decrease was observed in usable stocks of all of the fisheries targets examined. In 1968, the catch of chum and pink salmon declined to its lowest level, and the fishery for Taui spawning herring was also curtailed. The similarity in the trends in variations of abundance of such diverse species of fish indicates that they are presently under the influence of an all-embracing factor. It is obvious that the predominating or leading factor (according to Dement'eva, 1961-a) is that factor which in preceding periods was of secondary importance in the complex of natural conditions affecting fish population dynamics. The fishery is that factor which has acquired primary importance in its effect on usable stocks of salmon.

As is known, the mass fishery of the Asian stock of far-eastern salmon is presently carried on by Japanese ships on the open sea and by Soviet enterprises in coastal zones, with which the total yearly catch of Japan amounts to more than 70% of the total salmon catch of both countries.

I.B. Birman, analysing the present condition of usable stocks of West Kamchatka salmon, observed that the decrease in the abundance of pink salmon in odd years did not entail the increase in abundance of pink salmon of adjacent year-classes because of excessive exploitation by the fishery on the open sea. For this reason, the contemporaneous warming up of the waters

of the Kuroshio current could not favour increase in the abundance of chum salmon. I.B. Birman's final conclusion was that the basic factor underlying the present depression in the state of usable stocks of chum and pink salmon of the Asian population, is over-fishing. There can be no doubt, the author stresses, that in relation to usable stocks of these fish, the intensity of the Japanese fishery is still excessive. For R.S. Semko (1964) it is also indisputable that the reduction which is observed in coastal catches and in the total level of usable stocks of far-eastern salmon, is caused by the unreasonable fishery on the open sea.

Given the existing overtaxed state of usable stocks of salmon, due to the great intensity of the fishery, any other unfavourable factor can lead to a sharp drop in abundance. Evidently this is precisely the explanation for the disastrous reduction of usable stocks of salmon spawning in the rivers of the north coast in 1966-1968. Unfavourable conditions for the reproduction of a number of generations of salmon in the fresh-water period of life have been observed in recent years (1962-1966). In addition, conditions unfavourable to the abundance of the year-classes which arrived to spawn in 1968 were apparently felt in the marine period of life. Thus, the combination of all such causes led to an unprecedentedly low abundance of chum and pink salmon spawning in the rivers of the coast; but the marine fishery, the scale and methods of which are not in accord with the existing potentials of the natural supply is still the factor of prime importance in the reduction of usable stocks of salmon (Semko, 1961). 175

Table 2

Use of fishing gear in the salmon fishery on the north coast of the Sea of Okhotsk

a Годы промысла	Колич. неводов b		e Улов на невод, ц				h Доля вылова, %	
			закидные c		ставные d			
	закидные c	ставные d	колхозы f	гос. лов g	колхозы f	гос. лов g	закидными неводами c	ставными неводами d
1961	45	53	800	91	640	360	54,0	46,0
1962	32	52	1 250	—	1 154	710	43,3	56,7
1963	39	56	1 170	—	1 030	645	45,7	54,3
1964	39	47	570	—	730	280	45,4	54,6
1965	28	57	850	—	790	300	38,0	62,0
1966	32	48	575	—	390	64	39,6	60,4
1967	31	37	360	—	145	54	34,5	65,5
1968	26	28	290	—	380	29	41,4	58,6

Key:

a - year of the fishery
b - number of nets
c - drag seines
d - trap nets
e - catch per net, centners
f - kolkhozes
g - state catch
h - share of the catch %

Trap nets and drag seines are the main fishing gear used in the salmon fishery on the north coast. The former are used in marine coastal areas, while salmon swimming to spawn are caught in river estuaries with drag seines. Trap nets are in most cases set up in fisheries areas confined to the estuaries of rivers where the fishery with drag seines is carried on (the Taui, Ola, Yama, Big Garmanda, and Gizhiga rivers), and therefore it can be assumed that both fish the same spawning stocks of salmon in their passage into rivers to spawning grounds. According to available data for the period from 1961 until 1968, the number of trap nets varied annually between 57 to 28, and the number of drag seines varied from 45 to 26 (table 2).

The data in table 2 indicate a decline in recent years in the catch per unit of gear for the fishery, and the figures for the trap net catch by kolkhozes also show a general trend to decrease after 1963, but differ in the type of variation in the last three years due to methodical errors in calculations arising from the impossibility of isolating the indices for average catch in the Anadyr liman.

As T.F. Dement'eva observes (1961-b), the average catch for a given gear declines considerably with increase in the amount of gear used by the fishery. The catch per unit of fishing effort (average catch) also can decline as the result of decrease for one reason or another in the level of the stocks available to the fisheries. The number of nets on the north coast, as shown in table 2, was reduced in 1968. This fact indicates that the decrease in the catch per net is indicative of a reduction in usable stocks of spawning salmon.

The nature of variation of total salmon catch for 1961-1968 and fluctuations in average annual catch per trap net and per drag seine are shown in figure 3. For drag seines, data on the kolkhoz fishery are used, and for evaluation of the performance of trap nets, the state fishery statistics are used as being the most reliable indicators of variation in the catch per unit of effort in the region investigated.

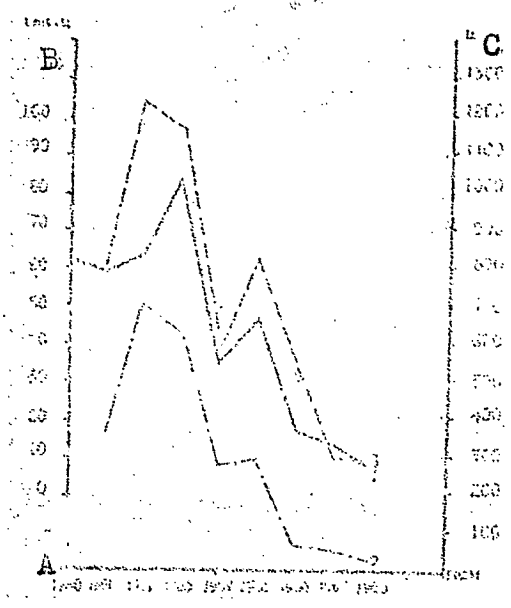

Figure 3. 1 - total salmon catch; 2 - average catch per trap net; 3 - average catch per drag seine; A - years B - thousands of centners C - centners

The curves of variation in catches for both trap nets and drag seines indicate a synchroneity in the fluctuation of these indicators with variation in the total salmon catch. Based on the data cited, and on the inference of a connection between reduction in the abundance of spawning salmon stocks and decrease in the catch for unit of fishing effort, it is possible to propose that at the present time, the scale of the coastal fishery be limited by the size of the spawning stocks and be responsive to fluctuations in abundance.

Thus, the present decline in the coastal salmon fishery on the north coast is indicative of a general reduction of usable stocks. As stated above, this phenomenon is caused mainly by the great intensity of the marine fishery, as a result of which the level of the catch at the present time has apparently exceeded the compensatory capacities of salmon populations to maintain

abundance. The comparatively low share of the coastal fishery on the north coast in the total balance of catches along the entire far-eastern coast indicates, that even the introduction of a unilateral ban on the salmon take on the coast with the aim of increasing reproduction, will not give the desired effect unless there is also a substantial restriction of the marine fishery. At the same time, the reinforcement of controls on the fishery through the SYaRK[1] gives priority in reasearch on rational exploitation of stocks of far-eastern salmon to studies on methods of increasing the effectiveness of the natural reproduction of salmon which will favour a general increase in the usable stocks of these valuable fisheries targets.

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