Action #1 Rebuild local salmon stocks
Action Goal: Rebuild wild Kunashir Island pink and chum salmon stocks within five years
PIs 1.1.1, 1.1.2

In order to develop an effective strategy for rebuilding Pink Salmon and Chum Salmon stocks on Kunashir Island, at the first stage of the FIP Workplan, the client company set several tasks aimed at understanding the following issues:

1) What is the current level of salmon stocks?
2) What factors can negatively affect and which of them can be adjusted by the company and the entire salmon management system?
3) What level of reproduction can be considered sustainable? What are the escapement goals?

Extensive work was carried out in 2022, the results of which are presented in this review.

1. What is the current level of salmon stocks?

According to the definition given by Kaev (Kaev, 2022), reproduction is understood as a continuous process of formation of the number of generations as a result of the emerging ratio of recruitment and loss. Since 2006, standardized calculations of the number of spawners in rivers, smolts and returns, reproduction efficiency, and biological parameters of fish of individual generations have been used in the Sakhalin Region. However, from 2014 to 2020, such work was not carried out separately for Kunashir Island.

In order to get an answer to the first question, since 2021, scientific research during the spawning run of Pink and Chum Salmon has been resumed in Kunashir with the direct financial participation of the company PCF Yuzhno-Kurilsky Ryibokombinat Co., Ltd. (hereinafter referred to as YKRK). The complex of conducted studies included studying the dynamics of fish return to the coast and their biological parameters, determining the number of spawners on spawning grounds and collecting statistical information on catches in various fishing areas of the island.

Estimation of the number of spawners on the spawning grounds was carried out according to their visual count by the employees of the Sakhalin branch of FSBI Glavrybvod (SakhRybVod) during walking tours along rivers (state monitoring). In addition to the State monitoring program, additional surveys funded by YKRK were conducted.

At the stage of preliminary assessment for the purposes of creating FIP "Russia Kunashir salmon" the most significant water bodies were identified. There are eight significant watercourses and water bodies with anadromous fish populations in the area of the YKRK fishing parcels (Table 1). The largest of them include Lake Lagunnoye. On the Pervukhina River, which flows into it, there is the Lagunnoye Lake Salmon Hatchery.

Table 1. Populations of Pink and Chum Salmon living in watercourses associated with the fishery of PCF Yuzhno-Kurilsky Ryibokombinat Co., Ltd. on Kunashir Island. *

No.	Watercourse / Water body	Length, km / Water Surface Area, km^2	Total Spawning Area, m^2	Pink		Chum	
				Type	Area, m^2	Type	Area, m^2
1	Zolotaya River (Nochka)	7.0	No data	Wild	No data	Wild	No data
2	Severyanka River	6.5	15,000	Wild	13,000	Wild	2,000
3	Valentiny Lake	30.8	10,240	Wild	740	Wild	9,500
4	Lagunnoye Lake	3.5	25,000	Mixed	0	Mixed	25,000
5	Pervukhina River	2.2	990	Mixed	750	Mixed	240

6	Asin River	6.0	5,000	Wild	5,000	Wild	0
7	Peschanoye Lake**	7.4	30,000	Wild	0	Wild	30,000
8	Filatova River	11	10,520	Wild	9,820	Wild	700
9	Ilyushina River ***	9.3	25,000	Wild	21,000	Wild	4,000

Note:
* according to tables No. 3.1; 3.4.1.1.; 4.3.1.1. - 4.3.1.3 from Zhivoglyadov 's report;
** according to archival data of SakhRybVod;
*** The Ilyushina River is not located in the areas where the YKRK fishing gear is placed, but it is an index river for ichthyologists from SakhRybVod.

In addition to counting the fish in the spawning grounds, a careful record of the fish caught is kept. The YKRK company is the largest on the island of Kunashir, and the share of Pink and Chum Salmon caught by other fishing companies on the island is very insignificant.

The Kunashir Pink Salmon fishery is based solely on the returns of wild populations. According to the data from Figure 31 of T. Tochilina's report, the YKRK company caught only a minuscule amount - 2.648 tons of Pink Salmon, which accounted for 96.3% of the total recorded catch on Kunashir (Fig. 1).

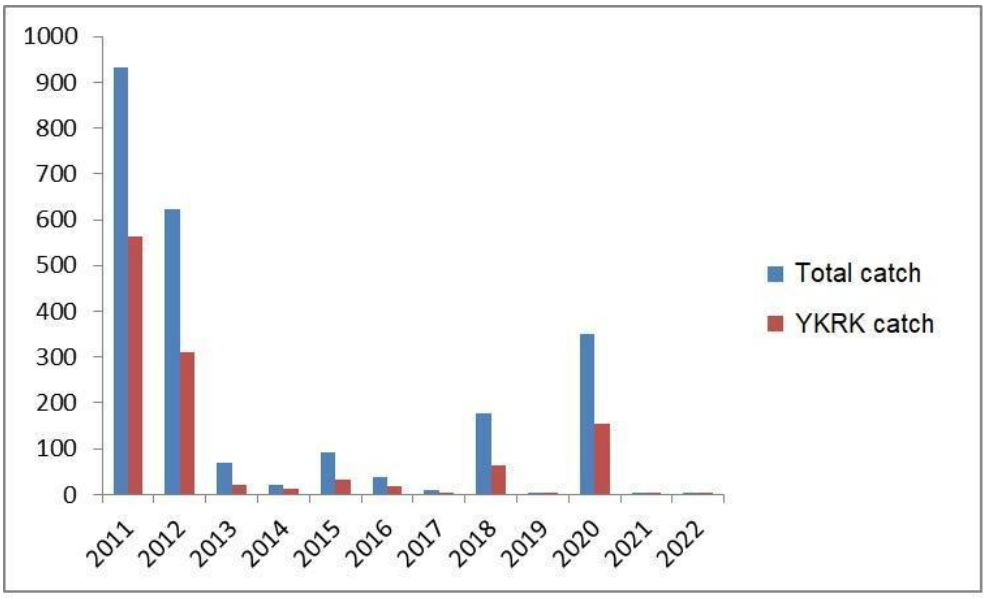

Fig. 1. The volume of Pink Salmon caught by PCF Yuzhno-Kurilsky Ryibokombinat Co., Ltd. (YKRK) in the total harvest on the island of Kunashir, in tons

The Chum Salmon fishery consists of mixed aggregations of fish, but a much larger proportion were fish of the "wild" stock. In 2022, 275.13 tons of Chum were caught; the company's share in the total Chum Salmon fishery of Kunashir Island was 86.0% (Fig. 2). Of this amount, 39.23 tons (14.7%) were caught at the hatchery weir of the Lagunnoye Lake Salmon Hatchery. It is not yet possible to find out the share of hatchery Chum Salmon in the catches of coastal trap nets, because the work on marking hatchery juveniles was started only in the 2021-2022 season.

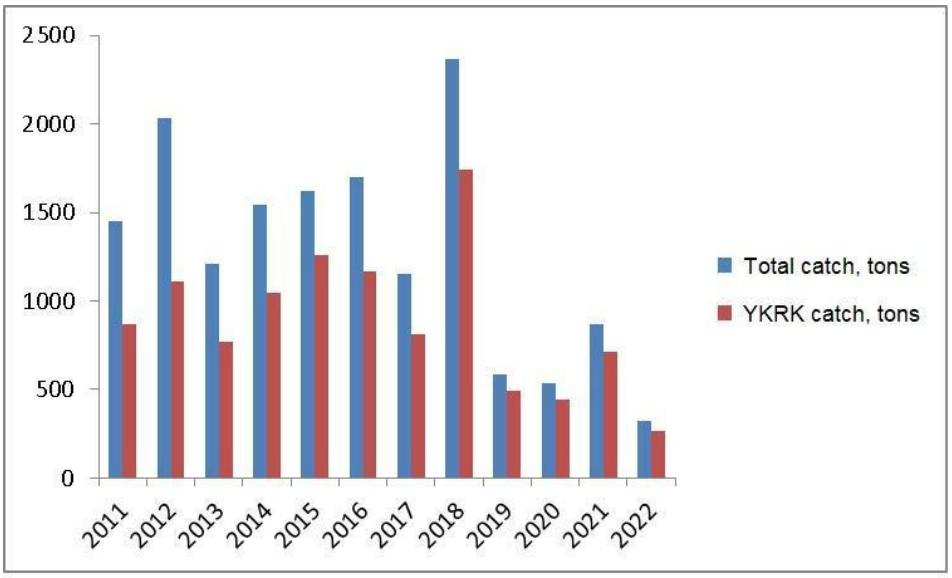

Fig.2. The volume of catch of the YKRK company relative to the total Chum Salmon harvest on the island of Kunashir, in tons

There is also information about genetic studies of the Kunashir Chum Salmon. In his article, Lev Zhivotovsky cites data that in Kunashir, and in the system of Lake Lagunnoye in particular, there are two forms of Chum Salmon - "lake" and "river" forms (Zhivotovsky, 2022). Kunashir Chum Harvest Data does not contain information on the shares of "river" or "lake" forms of Chum Salmon in catches.

The structure of fished populations of the Kunashir Chum (including "transit" fish) and the calculated total abundance are estimated and presented in Table 4.3.2.2 of A. Zhivoglyadov's report. At the same time, the number of the local Chum Salmon landed by the island fishery was calculated based on the 60% harvest rate of the total return. The abundance of Chum Salmon in the internal island waters was estimated via extrapolation of the accounted escapement data to all spawning grounds of the island (Table 2).

Table 2. Abundance of Chum Salmon in 2011-2020 in thousands fish

Indicator		Years of fish returns									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total catch	522.69	760.19	445.5	576.15	645.87	625.69	465.69	871.19	215.41	198.17	305.71
Transit Chum, catch	518.83	758.69	439.54	576,15	625.38	615.47	463.78	863.73	214.36	196.25	302.65
Local Chum, catch	3.86	1.5	5.96	–	20.49	10.22	1.91	7.46	1.05	1.92	3.06
Escapement*	2.57	1	3.97	–	13.66	6.81	1.27	4.97	0.7	1.28	4.5
Total return*	6.43	2.5	9.93	–	34.15	17.03	3.18	12.43	1.75	3.2	7.56
Note:*— fish originated in the Kunashir Island watersheds											

The total monitoring data for the last seven years, collected and presented in Table 3.4.1.2 of Zhivoglyadov's report, show that the abundance of the spawning part of the Pink Salmon populations of even generations is unstable: although in 2018 and 2020 the escapement to spawning grounds was above 70%, in 2016 and 2022 it was below 30%. The number of generations in odd years (2017, 2019, and 2021) was critically small (Table 3). The amount of

fish eaten by predatory animals and birds is not indicated, but most likely it is extremely small and therefore this value can be neglected.

Table 3. Average Pink Salmon spawner density by year, 2016 - 2022

Year	2016	2017	2018	2019	2020	2021	2022
Total surveyed spawning area, m^2	38,727	26,816	42,157	67,376	53,566	70,860	59,880
Cumulative number of spawners, N of fish	20,962	single occurrence	65,346	10,100	80,105	5,598	26,999
Average density of spawners on spawning grounds, fish/m^2	0.54	-	1.55	0.15	1.50	0.08	0.45089
Escapement - according to the SakhRybVod's standard of 2 fish/m^2, in %	27.1	single occurrence	77.5	7.5	74.8	4.0	22.5

The summary monitoring data of the spawning part of the Chum Salmon populations, presented in Table 3.9 from the SakhNIRO's report, show that since 2016 the escapement has been at a critical level and is below 20% (Table 4).

Table 4. Average Chum Salmon spawner density and escapement, 2016-2022

Year	2015	2016	2017	2018	2019	2020	2021	2022
Total surveyed spawning area, m^2	19,930	17,410	16,770	18,755	6,455	6,455	42,550	37,440
Cumulative number of spawners, N of fish	12,580	5,059	887	4,160	310	574	1,294	2,500
Average density of spawners on spawning grounds, fish/m^2	0.63	0.29	0.05	0.22	0.05	0.09	0.03	0.06
Escapement - according to the SakhRybVod's standard of 1.6 fish/m^2, in %	39.5	18.2	3.3	13.9	3.0	5.6	1.9	4.2

In the 12-mile economic zone of the Russian Federation in 2022, Russian and Japanese fishermen were drift-net fishing for Pacific salmon, catching mixed stocks. In the course of this, a certain number of Pacific salmon of the Kunashir Island, mainly Chum Salmon, were caught. However, the presented scientific reports do not contain data on the assessment of the levels of commercial catch and reproduction areas of salmon caught by drift-net fishing.

During the spawning season of Pink and Chum Salmon, population characteristics were monitored, such as the timing of the spawning run, as well as the age, sex and size composition for both hatchery and wild populations. Among other things, it was found that the timing of the entry of Chum Salmon into the Pervukhina Stream (the main watercourse of the Lagunnoye Lake Salmon Hatchery) was shifted a month later compared to the timing of entry of the Chum Salmon into the channel of Lake Lagunnoye.

In 2022, an anomalous age structure (rejuvenation) of the Kunashir Chum was noted in both marine and freshwater samples.

In 2022, Tatiana Tochilina studied in detail the age structure of Chum Salmon populations. Her report shows that the data on the age composition of Chum Salmon in 2022 are very different from the data for the earlier observation period from 1994 to 2013. Previously, the age composition of the Kunashir Chum Salmon usually consists of four classes - from 2+ to 5+. Four-year-olds and five-year-olds dominated in number. The proportion of three- and six-year-olds did not exceed 10%. In 2022, fish of age 2+ accounted for a large proportion (18–23%), which is not at all typical for Kunashir Chum Salmon. Also, significantly more than usual in percentage terms were fish of age 3+ (68 - 80%). A very small percentage was the group of fish with an age of 4+ (2 - 9%). The proportion of fish in the oldest age group 5+ was negligible. Moreover, in the analyses of October 9 and 20, adult Chum Salmon was completely absent.

Such a skew in the age structure of Chum Salmon could be explained by the entry of fish of "hatchery" origin into the fishery. However, there are no fish hatcheries in Golovnin Bay and on the Ilyushina River.

When comparing the age composition of Chum Salmon from Pervukhin Bay and Pervukhina Stream, it is clear that fish aged 2+ prevail in the stream, and fish aged 3+ prevail in the bay. The data on Pervukhin Bay are more consistent with the data on Golovnin Bay, i.e. with a sample of marine fish caught in the area where there are no hatcheries.

2. What factors can negatively affect and which of them can be adjusted by the company and the entire salmon management system?

In order to get an answer to the second question, not only the reports of scientists who carried out work on Kunashir in 2021-2022 were studied. A large number of articles and publications on Pacific salmon have been reviewed.

Changes in the size and weight structure, age composition and abundance of the Kunashir Pink and Chum Salmon are mainly associated with the current change in climatic epochs (general warming of the World Ocean). Quite a lot of publications by both Russian and foreign authors are devoted to this topic: Bugaev et al., 2021; Krovnin et al., 2021; Marchenko, 2021; Hirokazu Urabe, 2021; Laurie Weitkamp, 2021.

Sergey Marchenko concludes his article with the following: "Global warming has had a multilateral impact on the Pacific salmon of the Russian Far East: both their numbers and, accordingly, the volumes of catch have increased. The main areas of their fishing have shifted in the north and north-east direction. The timing of spawning migration and the species composition of Pacific salmon catches have undergone significant changes, as well as the quality indicators of spawners have changed - the age of puberty and size and weight indicators have decreased."

Hirokazu Urabe studied the dependence of the Chum Salmon return rate on the surface temperature of coastal waters during the period of outmigration of smolts to the ocean. He concludes that in the early marine period of the Chum Salmon life, this may be the main factor in the formation of the abundance of the species. "…these results suggest that the decline of Chum Salmon stock levels in Hokkaido would have been mainly caused by cold ocean conditions at the Pacific coast during spring."

Laurie Weitkamp provides interesting data on the abundance of Pacific salmon off the US Pacific coast from 1991 to 2020 in her article. She provides charts (this text only shows charts for Pink Salmon and Chum Salmon - Figures 3 and 4) and concludes that "The data collected indicate that many salmon populations from Alaska to California had both exceptionally high and low return rates during the period of warming of sea waters in the northeastern part of the Pacific Ocean, starting from 2014. The patterns varied depending on the species of fish and the area, although there were general trends for both Chum Salmon (a "wave-like" trend) and Coho Salmon (a decrease after a high number in 2014).

These dramatic fluctuations in stock dynamics of North American Pacific salmon, combined with the corresponding response from other marine species, point to the likely role of unprecedented ocean conditions in the formation of salmon returns."

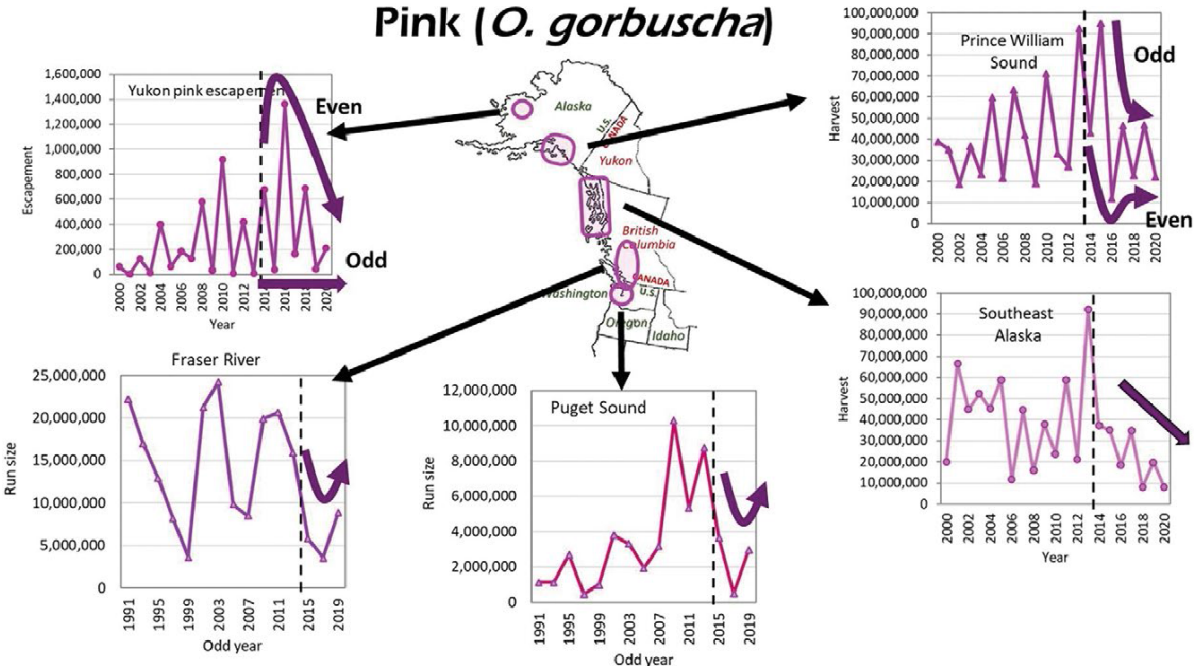

Fig. 3. Trends in adult Pink Salmon (*O. gorbuscha*) returns from Alaska to Oregon for 2000–2020. Puget Sound has the southernmost Pink Salmon population in North America. General trends since 2014 (dashed vertical line) are indicated by hand-drawn arrows.

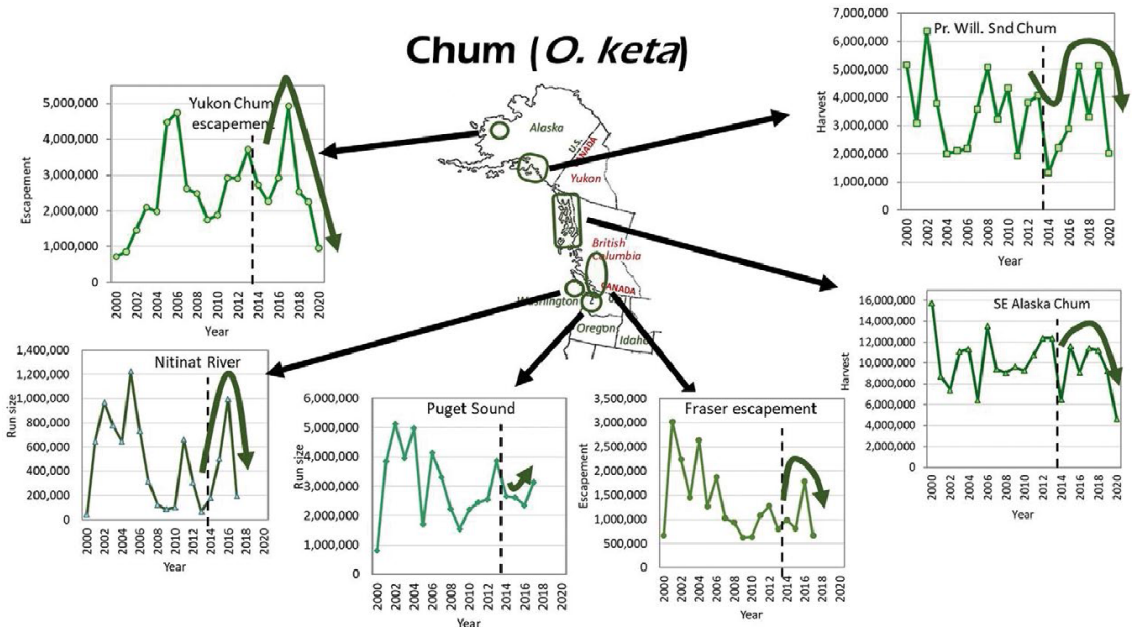

Fig. 4. Trends in adult Chum Salmon (*O. keta*) returns from Alaska to Oregon for 2000–2020. The Oregon coast has the southernmost population of Chum Salmon in North America. General trends since 2014 (dashed vertical line) are indicated by hand-drawn arrows.

To understand the completeness of the picture, information about the reproduction of salmon, especially Pink Salmon, on Iturup Island, located near Kunashir, is important. In 2022, the journal "Izvestiya TINRO" (Vol. 202, No. 1. pp. 71–91) published an article by A. Kaev

"Features of fishery and indices of reproduction for pink salmon *Oncorhynchus gorbuscha* of Iturup Island (Kuril Islands)."

In his article, Alexander Kaev notes that the Pink Salmon fishery on Iturup is concentrated mainly in the central and northern parts of the Sea of Okhotsk coast, while in its southern part the catches are very small, and practically no fishing is carried out on the ocean coast. This situation is not consistent with the presence on Iturup of a number of rivers with Pink Salmon spawning grounds and high productivity of marine waters, typical in general for the southern Kuril Islands.

To understand the reasons for such a heterogeneous distribution of Pink Salmon along the coast, the author examines the system of currents near Iturup Island. "Along the oceanic coast of the island, a powerful cold-water Oyashio Current is moving in a southwesterly direction. On the opposite side, the island is under the influence of the warm Soya Current coming from the west. As a result of the penetration of part of the waters of these currents into the straits, an anticyclonic circulation is created around the island, and in the straits themselves, oppositely directed water flows are observed, separated in the summer-autumn period by a well-defined front with a horizontal temperature gradient of up to 3 °C per mile. In terms of thermohaline characteristics, this flow of cold waters directed towards the Sea of Okhotsk corresponds to those of the Oyashio Current.

When entering the sea, this flow mixes with the branch of the Soya Current, which moves along the island in a northeasterly direction. At the same time, part of the waters of this cold flow is pressed, especially during northwestern winds, against the southern part of the Sea of Okhotsk coast of the island, as a result of which thousands of dead Iwashi sardines (West Pacific Sardines) approaching the mouths of the rivers, apparently in search of warm water, had to be observed in the Dobroe Nachalo Bay."

Kaev also notes that in the southern part of Iturup Island (which is a zone close to the northern part of Kunashir Island), water masses close in temperature to the Oyashio Current periodically appear in coastal shallow waters, which do not provide acceptable conditions for feeding migrating downstream juveniles.

The author also provides interesting up-to-date information about Pink Salmon migrations: "Fish of Sakhalin-Kuril origin migrate mainly through the straits of the middle part of the island arc (Vries Strait, Bussol Strait and Krusenstern Strait), and in years of very high abundance - also through the straits of its northern part. Moreover, it has been suggested that Pink Salmon are feeding in the process of returning to the southern Kuril Islands in the southern deep-water hollow of the Sea of Okhotsk [Shuntov, Temnykh, 2011]."

"With such a migration pattern, the later appearance of this species in the fishing parcels of the southern part of Iturup Island becomes clear. It is noteworthy that at the same time (the third decade of July) Pink Salmon began to return to the island of Kunashir. However, if catches were minimal on the Iturup coast of the Catherine Strait, then about a third of the Kunashir total catch of this species was harvested on the adjacent Kunashir coast in 2001-2012. The migration of Pink Salmon through the Catherine Strait, but only in the opposite direction (from the Sea of Okhotsk) can be evidenced by the detection of marked (tagged) fish in the Yuzhno-Kurilskaya Bay (Kunashir Island), which was marked in the Kurilskiy Bay on the island of Iturup [Ivankov, 1966]."

The information provided by Kaev may indicate that in some years a part of the Kunashir Pink Salmon may be caught by the Iturup fisheries on the migration routes to the Sea of Okhotsk, and then on the return migration routes to the Pacific coast of Kunashir.

There is still no information about the influence of predatory fish and competitors in the diet for young Pink and Chum Salmon in the coastal waters of Kunashir.

In recent years, the number of species such as Pacific Herring, West Pacific Sardines and Chub Mackerel has increased significantly. There is an opinion that another reason for the decline in the number of Kunashir Pink and Chum Salmon may be a sharp increase in the

number of these species. There is evidence that the spawning run of Pacific Herring is observed off the coast of Kunashir from April to June (Perov, 2021). The terms of spawning and further development of herring larvae and juveniles coincide with the timing of the early marine life period of Pink and Chum Salmon juveniles. West Pacific Sardines and Chub Mackerel, living near Kunashir Island, also feed on zooplankton, mainly copepods, euphausids, as well as amphipods and chaetognaths (Kuznetsova et al., 2021), which also feed on juvenile Pink and Chum. Are these species food competitors for fattening juveniles of Pink and Chum Salmon off the coast of Kunashir, and then in the Kuril waters in autumn? – the question remains open. So far, there is no scientific confirmation of this theory (Shuntov, Ivanov, 2021).

Despite the prevailing opinion that the number of Pink and Chum Salmon is influenced solely by factors of climate change and hydrological conditions in coastal waters, during additional surveys of rivers, other "internal" factors of natural and anthropogenic negative effects were also identified for Kunashir Island, preventing normal spawning of fish: blockages of riverbeds with trees, sedimentation in river mouths and signs of IUU fishing. These phenomena were discovered and described by Andrey Zhivoglyadov:

1) in the bed of the Filatova River during the examination on September 29: "Logs swept into the river channel by the current at the time of flooding were encountered here and there. In some locations they form log jams that block the entire river from bank to bank." Also, in this river, during a re-examination on November 11, "signs of IUU fishing were noted on the spawning grounds of Chum Salmon (net fences, ripped fish)."

2) in the Severyanka River during the second examination on November 19: "In the autumn period, a complete blockage of the Severyanka riverbed (by a pebble barrier) at the confluence with the sea was revealed, apparently caused by severe storms. The water flow in this section has completely gone into the ground. During that period, there was no way for the spawners to return."

3) in Valentiny's Lake during the examination on November 17: "During the examination, the presence of signs of IUU fishing was noted - the remaining nets, ripped fish and road tracks from vehicles."

Thus, today there is a complex of various conditions that prevent an increase in the level of reproduction of local populations of Pink and Chum Salmon.

3. What level of reproduction can be considered sustainable? What are the escapement goals?

Chapter 6 of Andrey Zhivoglyadov's report is devoted to the study of this issue. The author points out the following:

"Since the publication of works by I.I. Kuznetsov and A. Ya. Taranets (Makeev, 2010), even to this day, in addressing the issue of regulating the number of salmon in spawning grounds, the approach prevails, according to which the ratio of the area of the spawning ground to the area of the spawning nest corresponds to the optimal (or “standard”) number of spawners, the excess of which leads to repeated digging of spawning redds.

However, despite the efforts of many researchers, the issue of the salmon escapement rate remains open. The point is not so much that the areas of spawning grounds are inconsistent, and not that there is a wide variety of estimates of nest areas by different researchers, but that this approach does not take into account the relationship of fish (Shevlyakov et al., 2019).

In the Sakhalin-Kuril region, for Pink Salmon, the value of the "standard" escapement, proposed by F.N. Rukhlov is 2 fish/m^2, which was calculated based on the area of the spawning redd (Rukhlov, 1969).

It is known that the distribution of spawners across spawning grounds is a consequence of rather tough "asymmetric competition" (Bigon et al., 1989), and not at all a uniform distribution of spawners over available spawning areas. It follows from this that in different fishing areas that

differ in the quality and availability of spawning areas, even for spawning grounds of the same area, the standard spawner escapement may be different, as well as for the same spawning areas in different years, which differ in reproduction conditions for Pacific salmon spawners.

In this regard, for the purposes of ensuring the annual guaranteed effective reproduction of salmon, it becomes necessary to obtain clear escapement goals not to specific water bodies, but to a set of water bodies that forms a common stock unit in the local region. Thus, guarantees will be provided for the preservation of the entire species and genetic diversity of forms and life strategies of Pacific salmon.

Since the Kunashir Pink Salmon is a separate stock unit (Kaev, 2011), in the practice of SakhNIRO, attempts were made to determine the value of the optimal escapement in the rivers of the island based on the Ricker's stock recruitment curve (one of the stock-recruitment models). At the same time, it was noted that, on average, in 1990-1991 and 2004-2010, annual fish returns amounted to 1.26 million fish (Kaev, Romasenko, 2017). After spawning of these fish, an average of 99.2 million smolts migrated downstream. In accordance with this, the returns of spawners to the rivers varied from 0.17 to 2.89 million fish. From the analysis of the abundance ratios of Pink Salmon at different stages of the life cycle, it follows that the size of the offspring (smolts) largely depended on the number of parents. At the same time, a positive relationship was found between the density of spawners on spawning grounds and the survival of offspring during the freshwater reproduction period.

Nevertheless, the optimal escapement of spawners into the Kunashir Island rivers has not been set to this day partly due to the wide range of correlation between the early and late temporal forms in the spawner portion of the stock using different parts of the island river systems. Judging by the correlation within the “return - outmigration” pairs, the optimal escapement value should be at least two million spawners since higher escapements have historically resulted in declines of smolt abundance.

Taking into account the current low state of the stock in the spawning grounds of the Kunashir rivers, in the short term it is unrealistic to achieve both the indicators of the previous period and the formal value of the "optimum" escapement (2.0 - 2.2 fish/m^2) established in general for Pink Salmon of the Sakhalin-Kuril region .

In accordance with the ongoing changes, the conditions of reproduction of Pacific salmon are also changing, and on the island of Kunashir such changes are most pronounced. In addition to a general decrease in the abundance of both even and odd lines of Pink Salmon and the abundance of Chum Salmon that reproduce in the rivers of the island, the spawner density is decreasing. Currently, according to the results of field studies, the average escapement rates for Pink Salmon of the odd line are 0.12 fish/m^2, of the even line – 1.01 fish/m^2. The average escapement level for even and odd lines is 0.7 fish/m^2. We propose to consider this value as a target escapement for Pink Salmon spawning grounds in the modern period of low abundance.

Unlike Pink Salmon, there is much less information on the optimal escapement to spawning grounds with Chum. In the Sakhalin-Kuril region, a normative value equal to 1.6 fish/m^2 of spawning areas has been adopted (Rukhlov, 1969), however, in fact, this level has not been reached for a long time on most rivers where natural reproduction of this species has still been preserved, since the stock of Chum Salmon of the Sakhalin Region is based on fish of the "hatchery" reproduction.

In this regard, it is worth noting that in the period from 2011 to 2022, the density of Chum Salmon spawners in Kunashir water bodies varied from 0.03 to 0.63 fish/m^2 and averaged 0.2 fish/m^2. Probably, this level of escapement can be considered as the escapement goal for the Chum spawning areas in the current time period on the island of Kunashir."

Thus, the following values are proposed as the escapement goals:

- for Pink Salmon – 0.7 fish/m^2;
- for Chum Salmon - 0.2 fish/m^2.

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