International seminar on pink salmon in The Barents Region and in Northern Europe 2021

October 27th and 28th | NIBIO Svanhovd, Norway

Statsforvalteren i Troms og Finnmark
County Governor of Troms and Finnmark

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Preface

The County Governor of Troms and Finnmark arranged an International seminar on Pink salmon on October 27th and 28th 2021. The seminar took place at NIBIO Svanhovd in Pasvik and for those who could not attend in person, participation was available in digital platforms.

The aim for this seminar was to gather scientists and management for sharing experiences and knowledge about the invasive species Pink salmon in the Barents Region and in Northern Europe and find needs for the future research and managements. The topics was related to development, monitoring, and removal of pink salmon, and effects on other fish and organisms after the increasing invasion of pink salmon.

The following is a report with paragraphs from the topics presented during the two days.

Referent for the seminar and editor for this report is Camilla Kvitberg Lehne from the County Governor's office. The paragraphs are written in cooperation with the participants. The contribution from Sergey Prusov, who was unable to present his topic as planned, is presented as appendix in this report.

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Opening and welcome speech by Lisa Bjørnsdatter Helgason, Director of Environment, County Governor's office.

Today we are very happy that we could gather so many people digitally and here at Svanhovd to exchange knowledge about pink salmon.

The seminar brings together participants from Russia, Finland, Sweden, Faroe Islands, UK, Ireland, and Canada, and we are very grateful that so many people have agreed to give lectures on this seminar.

Looking at the seminar agenda we anticipate that this seminar will facilitate important information exchange and the opportunity to build networks between researchers and managers and inspire further cooperation on research on pink salmon. The seminar will also give information about what we know about impacts of Pink salmon on native fish species and ecosystems, in addition to address important research needs.

Section 1: Occurrence of pink salmon in the Barents region and the Norwegian sea – overview of status per 2021

1. Pink salmon occurrence in Northern Norway- *Eirik Frøiland, County Governor of Troms and Finnmark, Norway*

We monitor pink salmon, where they are and how many. Our sources of information are catch reports, snorkeling counts and eDNA surveys. Catches from sportfishing represent 10 % of the total catch of pink salmon in rivers in 2021. The rest comes from organized removal by gillnets, weirs and spearfishing. Data from pink salmon catches at sea could provide us with important information on catches from hundreds of fishing sites used on a yearly basis, but Statistics Norway (SSB) are not authorized to disclose these numbers. Drift counts also give a picture of the number of pink salmon in rivers, but this year the counts were made after many of the pink salmon already had been removed from rivers. These numbers could however be representative of the spawning populations.

Most of the pink salmon in Norway are found in the north and especially in the eastern- Finnmark. Many rivers in Varanger had a large increase in 2021. Three rivers which had high removal by weir in 2019, had a smaller increase in 2021 compared with neighboring rivers without a weir in 2019. Sandneselva was the only river where we did not find smolts in 2020, and this river seems to have a decrease in 2021. Grense Jakobselv is a border river between Norway and Russia. This river had no measures for removal of pink salmon, and drift counts show a large increase.

Rivers of different characteristics may have very different occurrence of pink salmon, even if they are geographically close. Cold, rocky rivers running from high altitudes, with no shallow estuaries in the river mouth seem to have fewer pink salmon.

In 2021, some rivers in Troms have similar numbers of pink salmon as Finnmark had two and four years ago. Troms will probably have an increase in pink salmon in 2023. The overall increase in Troms and Finnmark county seems to be 10-fold from 2019 to 2021.

Observations from local fishermen indicate that pink salmon are aggressive towards the Atlantic salmon. It has been observed that Atlantic salmon avoid known holding pools when pink salmon is present, but after the pink salmon are taken out of the river, Atlantic salmon may return to these grounds.

Small surveys show hatching already in mid-October in 2021, but we need to learn more about hatching time and how long they stay in the river after hatching.

2. Pink salmon in Norway – historical development of occurrence and number of pink salmon in Norway until today- *Henrik H. Berntsen, Norwegian Institute for Nature Research (NINA)*

Since the first major invasion in 2017 the numbers of pink salmon in Norway are increasing all over the country. Preliminary catch statistics from 2021 shows more than a 10-fold increase in numbers of pink salmon compared to 2017. Pink salmon has been observed in rivers along the entire coast of Norway, but the largest numbers of pink salmon are observed in the North-Eastern Norway. Catches in this region make up more than 90 % of the total catches in the country.

The number of pink salmon observed in rivers in northern Norway, from Vesterålen to the Russian border, in 2021 is over 90 000, with some rivers receiving up to 20 000 pink salmon. In comparison the number of Atlantic salmon returning from the sea to this region was estimated to be 129 000 individuals in 2020. Pink salmon is hence on the verge of becoming as numerous as Atlantic salmon in this part of the country and even occurring in much bigger numbers than local salmonid species in certain rivers.

The sources of data on pink salmon in Norway are sportfishing in rivers and in the sea, targeted removal fishing in rivers, coastal fisheries, drift counting in rivers. The quality of the data is varying depending on the source and varying between years. For example, before 2019 pink salmon was not included in official catch statistics in sports fishing in rivers and the sea or in coastal fisheries. Catch statistics on pink salmon has therefore improved since 2017. The large increase in pink salmon abundance in Norway is on the other hand not only an artifact of improved statistics but reflects a real increase in the pink salmon population.

We used data from sportfishing (2017 and 2019) in combination with variables that describe the characteristics of the rivers to predict where pink salmon will be found in the future. The analysis show that pink salmon is distributed in rivers with largely the same characteristics in both northern Norway and in southern Norway in both 2017 and 2019. Rivers close to the Russian border receive larger numbers of pink salmon in both years than rivers in southern Norway, and large rivers (m^3/s) receive more fish than small rivers. The size of the river is however less important when the number of pink salmon in a region increase, as reflected by a smaller influence of river size in 2019 compared to 2017 in northern Norway. It is likely that pink salmon will be found in rivers of all sizes also in the future, but with the largest numbers occurring large rivers in Troms and Finnmark. A new model will include climate.

Because of the two- year life cycle we only get updated information about the odd-year pink salmon population every second year. We need to observe the even-year population as well. We need knowledge of biological effects. It's important to continue good surveillance and improve catch statistics in rivers and especially in the sea.

3. Pink salmon in Finland – status report- *Tapio Hakaste, Ministry of Agriculture and Forestry, Finland*

Pink salmon is recognized as a locally harmful invasive species in Finland with a large increase after 2015 in the rivers Tana and Neiden. We have many questions and need for more knowledge on the

life cycle and behavior of pink salmon. We need more information about the relationship between Atlantic salmon and pink salmon. We need information on the outcomes of removal fisheries to plan management.

The invasion of pink salmon is extensive, and individuals seem to stray into new watersheds in Northern Atlantic. The potential for invasion from other sources is large and it is not possible to solve problems with pink salmon in one river alone. The removal of pink salmon can be harmful to other species, especially Atlantic salmon. We need methods for removal with low bycatch of Atlantic salmon and with reasonable expenses.

In 2022 the focus will be on developing efficient fishing gear and methods for removal of pink salmon. Amendments for fisheries agreement for Tana and Neiden are needed. Finland aims to find and implement reasonable practical measures for managing pink salmon, that are not harmful for Atlantic salmon.

4. Pink salmon- the case of the border river Tana- *Jaakko Erkinaro, Nature Resource Institute Finland (LUKE)*

Tana/Teno is the one of the largest salmon rivers in the Barents Sea area with 1200 km accessible for Atlantic salmon. The river has 30 genetically distinct populations of Atlantic salmon. We have been monitoring the Tana salmon populations have been monitored in different parts of the system by electrofishing, video monitoring, snorkeling and sonar, and by collecting catch statistics and catch samples.

The first observation of pink salmon in catches was in 1960. In the following years the occurrence in catches was varying, but mostly on a low level. There was a sharp increase in pink salmon occurrence in 2017 and further in 2019, followed by a tenfold increase from 2019 to 2021. Current distribution of pink salmon is mostly in the main stem and in large tributaries, but they have not been found so far in small tributaries.

In 2019 and 2021 the occurrence of pink salmon in different parts of the Tana system was detected by using eDNA. In 2021 40 pink salmon was tagged with radio- transmitters in the Tana river. Data analysis of the spawning migration, searching behavior, post- spawning movements are underway. Spawning area characteristics of pink salmon were also investigated in 2021 as well as egg and alevin development. The spawning sites are mostly close to the shoreline and very shallow, 20-50 cm. Spawning occur between late July and mid-September and most of the eggs hatched already by late September- early October.

Large-scale removal activities have not taken place in the Tana so far, but there are lots of interests, questions and demands among the local people both in Finland and Norway.

5. Pink salmon in Faroe Island- *Kristin Eliasen, Fiskaaling Ltd., Faroe Islands*

Faroese Islands has trout in most rivers and lakes. There are no wild Atlantic salmon population and the population of arctic charr is small. Prior to 2017 pink salmon was caught occasionally and in 2018 local anglers were encouraged to report catches of pink salmon. In 2017, 1 out of 5 pink salmon in catches were verified. In 2019, 6 individuals were reported in catches from late June to late September. In 2021, 7 pink salmon was reported, and we are beginning to see a repetitive pattern on where pink salmon is found. The concern is related to effect from pink salmon on local wild and introduced salmonids and introduction of diseases to the Faroese salmon farming industry.

6. A perspective on pink salmon in Scotland- *Colin Bean, University of Glasgow, Scotland*

In the 56 years between 1960 -2016 only 16 pink salmon had been recorded in Scotland, all but one of which were captured in 'odd' years, and 87% of them from the east coast catchments. In 2017, as happened in other parts of northern Europe and Iceland, the number of pink salmon catches rose dramatically to 139 fish. The reasons for this sudden increase are poorly understood but thought to be linked to climate change. Pink salmon catches in Scotland have continued to be higher than those recorded previously with an additional 21 fish recorded in 2019 and 169 fish in 2021. Without a systematic program of monitoring in place for this species, it is likely that these are significant underestimates of the true number of pink salmon in Scottish rivers and elsewhere in Europe. Difficulties in distinguishing between freshly run pink salmon and Atlantic salmon grilse may also lead to misidentification by anglers in some instances, exacerbating this issue. In Scotland, as elsewhere in Europe, pink salmon enter freshwater in late June-early July and spawn in the main stems of rivers during the month of August. Almost all fish have died by mid-September following spawning.

Whilst pink salmon have been recorded in rivers across the country, data from 2017-2021 suggest that Scottish east coast rivers are most likely to be invaded by this species. A total of eight east coast rivers have been impacted by pink salmon in every 'odd year' over this period. These are the rivers Dee, Deveron, Ness, North Esk, Oykel, Spey, Tay, and Tweed, which together, accounted for 66% of the total Atlantic salmon rod catch in 2020.

Giver the state of Atlantic salmon stocks, is important that we understand the direct interactions which may exist between pink salmon and all life stages of Atlantic salmon, as their impact on the wider ecosystem processes which support all native species, such as anadromous and resident trout. Negative impacts may include the input of marine derived nutrients on sensitive species such as freshwater pearl mussel (*Margaritifera margaritifera*), the disturbance or displacement of native fish (including non-salmonids), competition for food or space by juvenile pink salmon, disease/parasite transmission and predator attraction. There can, of course, be some positive impacts related to pink salmon invasions, such as the input of marine-derived nutrients on freshwater invertebrates and consequent impacts on the growth and productivity of native fish. In some instances, they may also offer the potential for the establishment of an alternative fishery. However, the protection of native biodiversity, and the ecological processes which support native species, must be our primary concern.

Whilst acknowledging the likelihood of financial and other resource constraints it is imperative that we gain an understanding as to the real ecological impacts of pink salmon on native biodiversity and local economies. To do this there is a need for meaningful co-operation between those countries affected, and an appropriate forum is required to allow the exchange of data and expertise. Examples of this include the development of monitoring tools in freshwater (such as the use of acoustic telemetry, traps or eDNA) or at sea (to describe marine feeding behaviors).

7. Pink salmon – status in Ireland- *Michael Millane and Paddy Gargan, Inland Fisheries Ireland*

Pink salmon were first recorded in Ireland in August 1973 in the River Moy when a single specimen was caught by an angler. Until 2017, pink salmon have been infrequently observed in Irish waters. Since then, pink salmon have been recorded in unprecedented numbers in odd years (2017, 2019 and 2021) in a number of river systems. In 2021, a total of 45 pink salmon were caught from 8 rivers. Some pink salmon have been encountered in rivers well upstream of the sea point. This includes a specimen caught 34 km upstream of the head of tide in the River Corrib system as well as others in the River Moy caught from 6- 25 km upstream of the head of tide in 2017.

July has been the peak period of occurrence of pink salmon in Ireland. All the fish examined in 2017 were considered mature (22 male and 7 females, with mean length 45.1 cm) and no significant pathogens and parasites of concern were identified.

Through an education and awareness campaign initiated by Inland Fisheries Ireland (IFI) and highlighted by the Irish media, anglers have been requested to report observations and catches of pink salmon in Irish river systems to assist the authorities with monitoring of the occurrence and distribution of the species and enable the collection of specimens for verification and examination. In 2019, IFI published a report, "Assessment of potential ecological impacts of pink salmon and their capacity for establishment in Ireland" which concludes that environmental and ecological conditions are considered favorable for establishment of pink salmon but the information to evaluate the potential impacts remains limited. Potential impacts may include aggressive intimidatory behavior of pink salmon towards native Atlantic salmon in shared holding habitat. The scope for direct food resource competition is considered to be limited and pink salmon juveniles may even provide a novel food resource for native salmonids. Overall, the level of impact is likely to be predicated on the extent of establishment and local abundance of pink salmon in Ireland.

If pink salmon become a regular feature in Irish rivers, better understanding of their lifecycle will be required to evaluate their potential for long-term establishment and concomitant impacts. IFI is currently involved in the PinkSIES project which aims to assess impact on native salmonids both at sea and in recently invaded rivers by determination of the distribution of pink salmon feeding grounds in the Northern Atlantic, assessment of competition with Atlantic salmon at sea, determination of field metabolic rates (hence thermal sensitivity) of both salmon species, prediction of future marine distributions, and evaluation of the ecological role of pink salmon fry in recently invaded rivers.

8. Bycatches of pink salmon in the Norwegian sea and along the coast of Norway- *Kjell Rong Utne, Institute of Marine Research (IMR), Norway*

We do surveys in the Norwegian sea along the coast. The observation of pink salmon is not the purpose of the surveys, but the bycatches are documented. The total catch from 2013 to 2021 is 243 individuals of pink salmon. These are collected from Faroe Island to the Barents Sea. The number of pink salmon in bycatch has been increasing gradually. A survey mapping herring larva along the Norwegian coast in 2017 got more than 50 pink salmon.

Ecosystem survey started in 1995 in May and are ongoing. In these surveys the main objective is mapping the distribution and abundance of herring and plankton. The survey has occasional trawl hauls in the surface. The catch of pink salmon is depending on the geographic occurrence of herring. Captures can tell us about the general migrating into the Barents in May/ June. They follow the currents, small individuals in the south and bigger in the north. This may be related to the timing of the surveys; hence they grow during this period. Or it can be the effect of bigger fish coming into the coast further north. The main size of pink salmon in bycatch is 40-50 cm in June.

Visual diet analyses show (83 individuals in June) 33 % amphipods large zooplankton, 33 % fish larvae, 15 % krill and 20 % other zooplankton. Large zooplankton is an important part of the Atlantic salmon diet. The analyses from the Norwegian sea showed mostly zooplankton. We don't know if pink salmon eat at night at the surface or if the fish go deeper. In the north fish larvae is dominating the diet.

In the mackerel survey (July/august 2007- ongoing) the yearly number of Atlantic salmon in bycatches is about 50 individuals, but no pink salmon. This is also the case for ecosystem survey in the Barents Sea in august- October. Why no pink salmon? - could be related to distribution or size, tool, or timing.

Analyses of 83 fish give no indications virus infections in marine pink salmon.

Section 2: Methodology for detecting and monitoring pink salmon

1. Screening of pink salmon distribution in the Tana River using eDNA methodology- *Frode Fossøy, Norwegian Institute for Nature Research (NINA)*

Environmental DNA (eDNA) can detect pink salmon based on filtering of water samples, with no need for collecting or even observing the fish. eDNA-concentrations reflect variation in fish abundance and could be used as a proxy for monitoring changes in fish density for both pink and Atlantic salmon across years.

We have analyzed eDNA samples from Tana in 2019 and 2021, focusing mainly on different tributaries. In 2019, pink salmon was detected in 6 out of 18 sampled localities. In 2021, we detected pink salmon in 17 out of 24 sampled localities. We also detected Atlantic salmon in 17 out of 24 sampled localities but some of the positive detections were in different tributaries. Pink salmon eDNA-concentrations showed large variations among sites, whereas Atlantic salmon had a more homogenous distribution across different tributaries. We also screened for the presence of European bullhead and found that most detections were restricted to the lower parts of Tana.

Future studies should resample the localities selected in this study to reveal temporal changes in eDNA-concentrations for both pink and Atlantic salmon. I addition, we suggest that the existing DNA-samples can be reanalyzed to look at all fish species in Tana as well as diversity of benthic invertebrates.

2. Pink salmon detection by eDNA and pink salmon on Svalbard- *Guttorm Christensen and Jenny Jensen, Akvaplan-niva, Norway*

Akvaplan-niva, NIVA and NIRAS conducted a project on behalf of the Norwegian Environment Agency in 2019-2021, where the main objective was to develop and test a system for eDNA as a supplementary tool in monitoring and mapping of invasive freshwater fish species. Pink salmon was one of 12 species in the project. Sampling started in 2019 in three rivers in Finnmark (Neiden, Karpelva and Grense Jakobselv), and revealed that the method works well for detection of pink salmon and that eggs and fry can be detected without the presence of adults. Findings included presence of Pink salmon in Karpelv in 2020, *i.e.* in an even numbered year. Further, sampling at six stations from downstream to upstream started in Grense Jakobselv in 2021, with the aim of investigating if the amount of eDNA can be used to document how far up the river pink salmon migrate and in which numbers. Results will be reported before the end of 2021.

Pink salmon has been observed on Svalbard since the 1960ies. During surveillance gillnetting of Arctic charr around Svalbard, bycatches of pink salmon has occurred. A project established in 2015 on behalf of the Governor of Svalbard aims at finding the distribution of pink salmon around Svalbard, and examine their diet, genetics, and parasite composition. Pink salmon has so far been registered in most marine coastal areas around Svalbard (1,2- 3,5 kg, mature fish). Arctic charr overlap with pink

salmon in diet in the marine environment, but pink salmon feed on fewer types of prey (2) than Arctic charr (17). Pink salmon have been observed to migrate into rivers on Svalbard, and the described eDNA methodology will be used to evaluate if they have reproductive success on the archipelago in 2022.

3. Monitoring of pink salmon stocks: methodology and experience from Northern Norway- *Rune Muladal, Naturtjenester i Nord, Norway*

It has been over 30 generations with odd year pink salmon in the region of Varanger since the first smolt release in Russia. There is no doubt – the pink salmon population is expanding. The situation with pink salmon population size in Varanger fjord rivers in 2021 is comparable with the White Sea rivers in 1995.

When monitoring pink salmon; decent data from the entire life cycle is needed. From hatching in late autumn to smolt run in spring, and to the spawning and post-spawning period in august-October. Monitoring pink salmon also include data on abiotic parameters (temperature, spawning substrate, distance from sea etc.). Due to hectic, specialized but predictable life stages, the time window on each stage is short compared to the long-lived Atlantic salmon. Meaning monitoring pink salmon is challenging without timing and a wide understanding of the salmonid biology, local condition etc. in the different rivers/regions. e.g., smolt migration may occur only some weeks. We have practice using several tools for monitoring. E.g., electrofishing, fish traps for juveniles and smolts. Adults by direct observation by helicopter, drone, video camera, drift counts and seine/gillnets (sea). Helicopters are effective for locate spawning activity and large gatherings in larger rivers, for instance Tana river.

Monitoring results are used in local and regional management and based on different methods we can get precise info on timing (egg deposition, hatching, alevins), numbers of spawners and spatial distribution. Already when monitoring the hatching success, followed by smolt run, we get some forecast about the next season, as we did in 2018 and 2020, for the coming 2019 and 2021 adult run.

Typical river temperature in Northern Norway is about 10-12 degrees Celsius at spawning time in August. From November to April the temperature is about 0 degree Celsius and in the beginning of May the temperature rises and the ice breaks. There is a tendency that “warmer” water temperature in both river and sea (early spring, late autumn) is positive correlated to returns of pinks, leading the species to be a “climate winner”. Compared to the native Atlantic salmon population, indicating opposite trend (speculative).

In 2021 The County Governor of Troms and Finnmark initiated a follow up-project with the purpose of collecting data on the spawning stock of pink salmon in different regions (35 rivers) and compare this data to earlier observations. In 2017 and 2019, native salmonids were the dominant spawners in the Northern parts of Norway, except in Varanger rivers where the pink salmon was dominant. In 2021 the pink salmon was dominating in almost all the considered rivers in this project.

Komag river has the longest time series (2003- 2021) of snorkeling count data in Troms and Finnmark. The spawning stocks of Atlantic salmon, charr and trout have been stable and dominating since 2010, spawning stock of pink salmon showed an increasing trend in this period. For the first time, in 2021 pink salmon spawners surpass the native species spawners in numbers and biomass.

Questions to discuss: What factors resulted in the in great run from 2015 to 2017? Did “almost all” pink salmon come from other regions (NW Russia) into the Norwegian rivers in 2017? Observations; Atlantic salmon parr, trout and charr crowding on spawning areas feeding pink salmon eggs, maybe a positive effect, or ecological disturbance with unknown consequences?

Naturtjenester i Nord will in the future extend the monitoring on different life-stages for better understand the dynamic between pink salmon and native species, as well the effect on ecosystems. Data on different life-stages is needed for future adult run predictions relevant for mitigations.

Section 3: Pink salmon genetics

1. Two decades of population genetic research on pink salmon introduced in the White Sea basin- *Natalia Gordeeva, Institute of Oceanology, Moscow, Russia*

About 380 million of fertilized eggs or fry of pink salmon were transplanted in last century within and outside of the native range in Russia, North America, Chile, Japan, and China, but most introductions were unsuccessful. Out of 80 documented introductions, only 5 were successful (3 within the native range and 2 outside the range). This indicates the limited adaptability of pink salmon.

Long-term introductions of Far East pink salmon into the European North of Russia showed different result for alternative broodlines and for different donor populations within broodlines. Introductions of odd year broodline in most cases were more successful and were resulted in more abundant returns or establishing of new population. Despite on sympatric distribution over range, broodlines are likely to have different complex of local adaptations to the same habitats.

The success of “southern” (Sakhalin) and “northern” (Magadan) pink salmon populations used as a source for transplantations were also different. Despite the short-term occupying of freshwater habitats, pink salmon has strict requirements for conditions of the early development. Spawning success of introduced pink salmon was critically related from temperature and hydrological regimes in rivers. On the first stage, the late maturation and spawning time inherited from the populations of southern Sakhalin led to the elimination of local pink salmon after introductions were stopped. Currently, odd-year broodline originated from Magadan was successfully naturalized, with even-year generations are much less in numbers, although both broodlines were taken from the same river (Ola River).

The number of returned fish strongly varies between generations of introduced. In 1989- 2019, the catch size of odd-year pink salmon has varied from 43 to 381 tons. Returned pink salmon have good body condition (estimates of body weight are much higher than in source population). It means suboptimal conditions for reproduction in the new range.

Dramatically loss of genetic diversity in odd year pink salmon after introduction accompanied by high abundance of introduced fish may be considered as specialization in new environment. Despite larger numbers of returned fish, predominance of females (up to 70%) and higher fecundity in introduced odd- year pink salmon, effective population size NE is very small, and relatedness in population is increased. All these facts assume differential survival in the early freshwater period, i.e. strong directional selection. In introduced even year pink salmon, no changes were found despite sharp decline of return numbers since second generation.

The increased abundance can be an effect of low mortality in the early stages of ontogeny and may be closely related with warming in last years. Strong requirements of this species to the freshwater habitat may prevent colonization of northwards regions despite wide stray of migrating adults.

The future perspectives of pink salmon population genetic studies may be whole- genome analyses to reveal “hot spots” regions of local adaptations. And estimation of homing rate and level of inter-population divergence within Barents- White Sea region.

Important to know who is doing what and with who. International collaboration is needed.

2. Building a genetic database for pink salmon as a tool for science and management – vision, plans and progress- *Snorre Hagen, NIBIO Svanhovd, Norway*

We know too little about pink salmon, and more research is warranted. For instance, phenology of spawning, survival of different life stages, competition with native species, effects of dead pink salmon in rivers and many more topics.

Pink salmon was introduced since the 1950s, and the expansion has been rapid during the last 5 years both geographic and demographic. The situation in Russia and Norway allows tests of spatial invasion- gradient from east to west, time since the establishment and range expansion. Does the behavior change along the spatial invasive gradient? The goal at NIBIO Svanhovd wildlife genetic laboratory is long- term ecological genetic research on pink salmon in collaboration between Norway and Russia.

A genetic database helps to establish population status and tracking changes in space and time. The immediate goal is systematic sample collection in Norway and Russia for odd and even years. Some long-term goals are to add populations from other countries to this collection and if possible, to add samples from Norway and Russia back in time. A good genetic database depends on samples from anglers.

The genetic sampling in Norwegian rivers in 2021 was done by volunteers engaged in removing pink salmon from local rivers. The equipment and procedures were provided by NIBIO Svanhovd. The sample collections come from about 30 rivers, with tissue samples from 30 male and 30 females of pink salmon. The preliminary results from method development using 71 samples from 2019 shows a high mixture using all SNPs. Using only a selection of the most informative SNPs allow river specific pattern to emerge.

The potential impact of high pink salmon densities can affect the offspring of native species caused by aggressive spawning behavior and decaying carcasses effect on water conditions. Competition for food resources and spread of diseases can affect the mortality of native species. Rivers with most removal (Munkelva and Karpelva) of pink salmon had less bacteria than rivers with less removal.

Section 4: Factors influencing the success of pink salmon

1. Climate change and pink salmon- an analysis of sea surface temperature- *Kyrre Kaustad, Norwegian Veterinary Institute (VI), Norway*

Pink salmon is influenced by climate fluctuations both in the oceanic and riverine parts of its life cycle. The genetically isolated populations are connected through delayed effects of shared river resources and trends in ocean and river climate. While temperature changes did not cause the initial movement of pink salmon from the Pacific, changes in oceanic climate are hypothesized to be helping pink salmon establish self-sustaining large populations in rivers running into the Arctic Ocean.

There is so far seen as positive associations between sea surface temperatures and pink salmon returns to Norwegian rivers. Especially when taking the internal dynamics of pink salmon into account. Extrapolation is difficult due to non- stationary underlying processes in immigration,

establishment, and climate, but the best guess seems to be increasing returns of pink salmon over near future. Pink salmon may not be affected by temperature directly, there may be other factors mediating the effect, but warmer temperatures in May when pink salmon leaves the rivers seem to be of particular importance.

The changes of the conditions in the arctic are rapid and we are now standing outside our historical reference frame on sea-surface temperatures. Ecological and statistical models may forecast the probability of peak years of returning pink salmon, and together with simulations of temperatures in the North Atlantic and Arctic Oceans allow us to predict how it will interact with Atlantic salmon and rising river temperatures.

2. The Parasite Fauna of Pink Salmon (*Oncorhynchus gorbuscha*) From Chupa Bay in the White Sea, Republic of Karelia- *Evgeny Ieshko, Sergey Sokolov and Aleksey Parshukov, Institute of Biology Karelian Research Centre of the Russian Academy of Sciences, Petrozavodsk, Russia*

The first recorded data of parasites found in invasive pink salmon (*Oncorhynchus gorbuscha* Walbaum, 1792) were obtained during the period 1961 to 1969, in rivers of the White Sea drainage basin. In total 17 species of parasite were found in pink salmon, of which the most frequent found were the trematodes *Brachyphallus crenatus*, *Lecithaster gibbosus*, larvae of cestodes *Scolex pleuronectis* and the nematodes *Anisakis* sp. and *Hysterothylatium aduncum*. Parasitological surveys in this area were repeated in 2003 and revealed a decrease in the number of species detected (13 in total), while the core species composition remained unchanged.

In July 2021 25 pink salmon were caught at several locations of Chupa Bay prior to entering rivers. The fish were examined by standard parasitological methods. The results revealed 13 parasite species, which are represented by two groups: the first - frequently occurring species forming the core of the parasite community and the second group - rarely occurring species or satellites. The species composition of frequent occurring parasites in the introduced pink salmon in North European seas reflects its diet in marine foraging areas.

The parasite fauna in pink salmon entering rivers of the White Sea basin to spawn has a poorer species composition in comparison with than pink salmon in its native range in North Pacific. It is known that parasite species richness or prevalence is lower in host populations inhabiting invaded ranges compared to those in native ranges.

The core of the parasite community of invasive pink salmon is made up of species whose life cycles involve pelagic animals, - planktonic crustaceans and young marine fish species. Thus, introduced pink salmon occupy the same trophic niche as in its native range. The core of the parasite fauna in introduced pink salmon is similar in composition to that of Atlantic salmon (*Salmo salar* L.), suggesting the species use the same foraging grounds and their trophic niches significantly overlap. The variability in the composition of rare parasite species in pink salmon from the White Sea is most likely associated with the place of capture (marine or freshwater environment) and incidental factors.

3. Health monitoring of pink salmon in Norway- results from 2019 and 2021- *Åse Helen Garseth, Norwegian Veterinary Institute (VI), Norway*

The Norwegian Veterinary Institute (NVI) conduct health monitoring of pink salmon to gain knowledge about the potential health risk that this species constitutes for wild and farmed fish in Norway.

We monitor for pathogens that cause serious notifiable diseases. Two of these are not present in Norway today (IHNV/VHSV), while two are present (ISAV and R. salmoninarum). Finally, we investigate the presence of PRV-1, a virus that is very common in farmed Atlantic salmon and present in wild Atlantic salmon. This virus can serve as a model–virus for disease interaction between pink salmon and farmed and feral Atlantic salmon.

The health monitoring programme included Karpelva in 2019, and Karpelva, Skibotnelv, and Skallelv in 2021. In addition, NVI received frozen pink salmon from several other rivers. In 2021 more than 222 pink salmon have been sampled and 181 were tested. Notifiable infections were not detected in PCR- analyses, but PRV-1 was found in several samples from three locations.

Mostly no growth of bacteria was found when culturing from frozen pink salmon.

A reporting system for diseases in wild fish was established in 2020. Anglers and researchers report to Norwegian Veterinary Institute if they find dead fish (salmonids, freshwater, marine species). A reported pink salmon had hemorrhagic septicaemia caused by the bacteria *Aeromonas hydrophila.* The bacteria is mostly known for causing diseases fish in warmer climates and may cause disease in humans as well.

The primary disease related concerns are that pink salmon may translocate infections between populations (farmed and wild), but also that opportunistic bacteria and virus may multiply in weakened moribund pink salmon that are destined to die. Finally, the decomposition of pink salmon in rivers may also constitute a human health risk.

Section 5: The impacts of pink salmon on native fish species and ecosystems

1. Transfer of marine energy and nutrients from pink salmon to the aquatic and terrestrial environment- a study from Vesterelv, Norway- *Katherine M. Dunlop, Institute of Marine Research (IMR), Norway*

Pink salmon subsidize freshwater and terrestrial ecosystem through direct consumption of carcasses or eggs, and recycling of products through decomposition, leaching and excretion. In this study the aim was to identify and quantify pathways of marine-derived energy and nutrient (MDN) from pink salmon carcasses and eggs to the terrestrial and aquatic ecosystem. Studies like this has been done in Alaska and Canada.

Sampling was before spawning (mid-July 2019), during spawning (end-August 2019) and after spawning (end-September 2019) in Vesterelv. To native species, Atlantic salmon and trout, were examined. Stomach contents were analysed, and results showed that in the pink salmon site 14 % of large (> 55 cm fork length) juvenile Atlantic salmon and 20 % of brown trout had pink salmon eggs in their diet. Eggs dominated the diet composition of both species in terms of mass. The diet of all large

Atlantic salmon and brown trout sampled showed 96 % and 87 % pink salmon eggs respectively. Pink salmon eggs had higher $\delta^{15}N$ and $\delta^{13}C$ values compared to freshwater and terrestrial food resources and the body tissues of juvenile Atlantic salmon and brown trout. Some individuals had high $\delta^{15}N$ and $\delta^{13}C$ values, indicating a long-term diet subsidized by MDN from pink salmon eggs. Pink salmon in Vesterelv were estimated to contributed within the range of 0,3 –0,9 million kJs of energy in egg deposits to the river in 2019.

Pink salmon carcasses are a part of the diet of wolf, bear, and seagull in Alaska. Energy and nutrient are transported to the riparian zone via carcasses. Carcasses left on the riparian zone at Vesterelv were monitored and 5 bird species, European red fox and goosander were detected as pink salmon scavengers.

The large pink salmon runs entering rivers in northern Norway represent a significant increase in energy and nutrients, and a little is known about the potential ecological effects. We need:

- To identify which species benefit, which do not, and which might suffer negative consequences from invasive pink salmon in Norway.
- To examine the effect on nutrient-poor river ecosystems where energy and nutrient effects are likely more pronounced.
- To examine the role of pink salmon eggs in the overwintering survival of native salmonids.

A good understanding of the ecological effects is vital to ensure the suitable management measure at the right place and time.

2. Features of pink salmon reproduction in rivers and its impact on native fish species-

Denis Efremov, Institute of Biology, Petrozavodsk, Russia

We have studies of adult fish, embryo, larvae and smolts of pink salmon from Kola Peninsula, White Sea and Barents Sea. To follow developments of pink salmon, drift counts in shallow water and counts of eggs in some areas are done. The eggs hatches in February, larvae are examined in March and in April smolts are studied. When the river opens in May the majority survives and migrate to the White sea.

There has been an increase of pink salmon in White Sea rivers. Fishermen caught a lot of pink salmon and less Atlantic salmon. In 2021 the occurrences of pink salmon have been unusual large. By July 14th the catches were 380 tons of pink salmon in one river (Varzuga) in the White Sea area. It was about 270 000 individuals with an average weight of 1,4 kg. Per 100 square meter the estimated maximum density of pink salmon was 180-200 individuals, and average density 40-50 individuals per 100 square meters.

There are no negative effects on the juveniles of Atlantic salmon, they can co-exist. The juveniles of these two species does not compete for food in the river. Spawning grounds can be positively affected by the early migrators of pink salmon, as they clean the spawning grounds from sand and sediment. However, since 2017 the period of spawning migration of pink salmon has been extended. Late entering pink salmon ripens and spawns together with Atlantic salmon, which can be a negative factor for the latter. Limiting the number of pink salmon entering the salmon rivers, and removing the late emerging group, could reduce negative impact on Atlantic salmon.

There has been a massive entry of pink salmon to the rivers in 2021, and a colossal amount of eggs were laid. Especially if the weather is warm during May of 2022, we can expect a significant increase in pink salmon in 2023.

3. Pink salmon risk assessment report. What do we know today about ecological effects?- *Kjetil Hindar, Norwegian Scientific Committee for Food and Environment/ Norwegian Institute for Nature Research (NINA), Norway*

Pink salmon is one of seven Pacific salmon of *Oncorhynchus.* Pink salmon was introduced from Russian rivers in the Pacific to rivers in the White Sea. Populations in the White Sea were likely dependent on releases, but since a new source population was used from 1985 onwards, strong self-sustaining pink salmon populations built up in the White Sea. Since 2007 East- Finnmark has had regular occurrence of pink salmon in rivers. The invasion had an explosive increase in 2017 all over Norway, and spreading in Europe south to France, Iceland, Greenland, and Newfoundland.

Norwegian Scientific Committee for Food and Environment published "Assessment of the risk to Norwegian biodiversity and aquaculture from pink salmon (*Oncorhynchus gorbuscha*)" in 2020. The report considered the effects to be depending on numbers of pink salmon. Pink salmon juveniles may prey heavily on zoobenthos and compete with native salmonids. The river pearl mussels are threatened when native hosts are affected. The ecosystem effects are unknown.

There is little or no risk for interbreeding with native salmonids. There is overlap in spawning time with Arctic charr and sea trout in North Norway. No overlap in spawning time with Atlantic salmon is documented in Norway, but later pink salmon spawning and overlap with Atlantic salmon has been reported from the Kola peninsula at this meeting. Pink salmon is aggressive before and during spawning. There is a risk for competition between juveniles of pink salmon and native salmonids, and the strength of this competition depends on density of pink salmon and time spent in freshwater. The largest temporal overlap is in rivers where pink salmon migrate long distances and in rivers with lakes.

Fish diseases is the primary threat to aquaculture, but there are no known new pathogens introduced with pink salmon yet. We know that marine fish are attracted to marine cages, but we have no knowledge of pink salmon is attracted to cages of farmed fish.

If pink salmon is caught early and, in the ocean, the fish can provide a new ecosystem service. But pink salmon is the least valuable of the Pacific salmon and bycatch of native salmonids may be difficult to avoid. Pink salmon reduce the value of recreational fishing in Norway. So, there are more negative than positive effects on ecosystem services in Norway.

We are now facing temperatures in the Barents Sea and Arctic Ocean which we have not studied earlier. Hence, the future marine ecosystem effects of pink salmon are hard to predict.

4. The Norwegian Action plan against pink salmon – considerations before and after the season 2021- *Tor Atle Mo, Norwegian Institute of Nature Research (NINA), Norway*

The action plan proposal was written by researchers at NINA in collaboration with the County Governor of Troms and Finnmark. The overall objective of the action plan is to remove as many pink salmon as possible from Norwegian rivers. This will prevent negative impacts on local native salmonids, other biodiversity, fishing, and other ecosystem services. It will also prevent the production of pink salmon in Troms and Finnmark county so that the return to this area and further west and south is low in years to come. The removal will contribute to reduce spread of pink salmon from Norwegian rivers to rivers in other countries around the Atlantic Ocean.

With no action we can expect that pink salmon will establish in many Norwegian rivers, and gradually expand the geographical distribution in the Atlantic Ocean and associated rivers.

About 6 600 pink salmon were caught or observed in 262 Norwegian rivers in 2017, and 83 % of these catches was caught in Troms and Finnmark. In 2019, about 20 000 pink salmon were caught in 180 rivers. 96 % of pink salmon were caught in Troms and Finnmark. Therefore, the action plan prioritizes the rivers in this county. Other criteria for selecting rivers are the vulnerability of Atlantic salmon stocks and trout populations in these rivers, as well as occurrence and status of sea charr and river pearl mussel.

The best method for most rivers is a floating trap near the river outlet. Native fish get minimal damage, and farmed fish, and pink salmon are sorted out and removed. If the river is deep and have high water velocity, traps are difficult. Methods like fishing with nets and other gear can be effectful. If the number of pink salmon is low, snorkeling harpooning and rod fishing will be able to take out a significant proportion.

The action plan also suggests the establishment of a national competence group for the work related to removal of pink salmon. This group should have a regional affiliation and headed by the County Governor of Troms and Finnmark. The group should consist of persons with administrative responsibility, experience with measures, knowledge of the development and use of capture equipment and biological expertise. The costs of removal are high and the allocations must be large enough for effective and adequate measures to be implemented. The plan estimated 12 000 000 kroner for the purchase of 15 traps and 3 000 000 kroner for annual operation of traps per river in odd years. The annual costs for operating the traps in even years is 750 000 kroner.

The knowledge needs are huge:

- Good capture statistics are needed
- How do pink salmon find their way back to the rivers?
- What is the spreading potential in pink salmon?
- How much of a river do pink salmon use?
- How and how much do pink salmon affect spawning in native salmon species?
- Do pink salmon affect yearlings and parr of native salmon species?
- How will pink salmon affect the access and use of ecosystem services in Norwegian Atlantic salmon rivers?

International cooperation is necessary to control the occurrence of pink salmon. Exchange of experience and knowledge is desirable.

Section 6: Fishing regulations and socioeconomics

1. A Socio-Economic Perspective of Pink Salmon in Norway- *Ekaterina Aasmaa, student at the Arctic University of Norway (UIT), Norway*

The objectives of this study are to collect, evaluate and compare the perceptions of anglers and public regarding the occurrence of pink salmon in Norwegian rivers and the national management program in term of removal of pink salmon from the Norwegian rivers. With questionnaire respondents give answers about fishing activities, perception to pink salmon and social-demographic information. So far, 79 respondents have participated, and the preliminary results show that the majority belong to NJFF (association for hunters and fishermen in Norway), they are highly educated

and experienced fishermen. Most respondents want total removal of pink salmon from rivers, and 20 % wants to implement measures so that pink salmon can co-exist with other fish species in the river ecosystem. 61 % agree to participate in voluntary activity to remove pink salmon. When asked if they were willing to contribute financially, 52 % answered no contributions. 68 % of respondents consider the available information on pink salmon to be scarce.

This study is scheduled for completion in the spring of 2022.

Appendix

International Seminar on Pink Salmon in the Barents Region and Northern Europe
2021 NIBIO Svanhovd, Kirkenes, Norway and via videoconference
27-28 Oct 2021

Pink salmon in the Murmansk region

S.V. Prusov, A.V. Zubchenko
Polar Branch of FSBSI "VNIRO" ("PINRO" named after N.M. Knipovich)

Among the members of the family Salmonidae, pink salmon (*Oncorhynchus gorbuscha*) has the shortest life cycle (becomes matured at 22-23 months after an egg gets fertilized) and a very fast growth rate (45-65 cm in length and 1-3 kg after one year of feeding in the sea).

In the native area, pink salmon has a wider distribution than other Pacific salmon. Along the Arctic coast, small numbers of pink salmon ascend rivers west of the Bering Strait up to the Lena river that flows into the Laptev Sea of the Arctic Ocean east of the Taymyr Peninsula.

Pink salmon is a non-native species for waters of the Murmansk region. Its introduction to the European North of Russia was started in 1956. Except for rivers in the Murmansk and Arkhangelsk regions and the Karelia republic, in the 1960s, at the early stages of the introduction, matured pink salmon was also seen in rivers of Scotland, North Norway, Iceland and in the waters of the Spitsbergen island (Azbelev, 1960; Berg, 1961; Williamson, 1974).

Before 2021, numerous ascends of pink salmon were recorded in the White Sea rivers only, whereas in the Barents Sea rivers the abundance of adults was modest. Pink salmon was seen east of the Kola Peninsula in the rivers flowing into the Kara Sea (the Ob, the Taz, the Yenisey (Figure 1)). Currently, the Pyasina river, whose mouth is located in the southwest of the Taymyr Peninsula, is the easternmost location of pink salmon distribution in the Kara Sea basin (Bogdanov, Kizhevatov, 2007, 2015), and the Taymyr Peninsula appears to be a natural border that divides pink salmon populations in the native and new ranges of the species.

Figure 1. Pink salmon distribution in Russia in rivers of the Barents, White and Kara seas.

In the North Atlantic region, pink salmon also occurs in rivers of Norway, Finland, the UK, Ireland, countries of the western continental Europe, Iceland and eastern coasts of Canada (ICES, 2018).

Feeding grounds and migration routes of smolts and adult pink salmon in sea are unknown but they likely overlap with those of Atlantic salmon.

The population genetic analysis results showed that the introduction of odd-year pink salmon from the Ola river (Magadan) into the White Sea basin was more successful than that of an even-year and the odd line invaders showed signs of adaptation to the conditions of reproduction in the new area (Gordeeva et al., 2015).

In the conditions of the Murmansk region spawning migration of pink salmon in rivers usually starts in late June – early July and ends in late August – early September, with the peak in the first half of July. In 2019, spawning migrants of pink salmon appeared in the fish ladder at the Lower-Tuloma dam (the Barents Sea basin) from 30 Jun to 01 Aug, with 554 individuals counted in a trap over the period. At the counting fence in the Varzuga river (the White Sea basin), first pink salmon individuals were recorded on 25 Jun. 176 000 pink salmon individuals were recorded in total up to 26 Aug, with the migration peak in the first ten days of July (Figure 2).

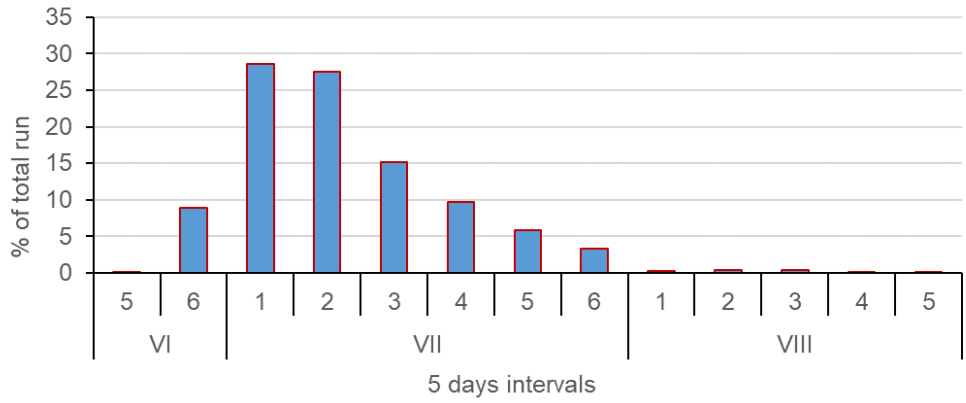

Figure 2. Migratory dynamics of spawning pink salmon in the Varzuga River in 2019.

Pink salmon spawners ascend both rivers where Atlantic salmon spawn and smaller watercourses and usually cover shorter migration distances upstream where they spawn on the rapids and rifts of the middle and lower courses of a river. In large water systems (Ponoi, Umba, Varzuga), however, pink salmon individuals were seen in the spawning tributaries of the upper course (more than 100-200 km upstream from the mouth).

Pink salmon usually starts spawning in early August and finishes in early October, with the water temperature of 9.5-4.5 °C. According to V.V. Azbelev and M.Ya.Yakovenko (1963), later spawning results in greater mortality in eggs of early stages. Spawning was successful and embryos survived and properly developed only in years when the water temperature in the spawning period was 13.0-9.0 °C.

In rivers of the Murmansk region pink salmon smolts start migrating downstream when the water temperature hits 4-5 °C in the second half of May and end on the first days of June.

Like in the native area, pink salmon introduced into rivers of the Murmansk region has two broodlines (even and odd) that do not interbreed due to the short life cycle and 100% mortality of spawners after spawning. However, unlike in the native area, in the Russian North pink salmon builds commercially harvestable numbers only in odd years.

Since the 1960s, pink salmon fishery in the Murmansk region has been conducted in coastal waters and rivers of the White Sea basin and up to the 2000s catches exceeded 100 t only four times (1973, 1975, 1977 and 1997). It was in 2001 when a pink salmon catch reached 300 t for the first time but later up to 2015 in odd years catch varied from 45 to 118 t. Starting from 2015, the catch has been annually increasing, with 380 t in 2019 (Prusov et al., 2021). An estimated catch in 2021 was a record one (Figure 3).

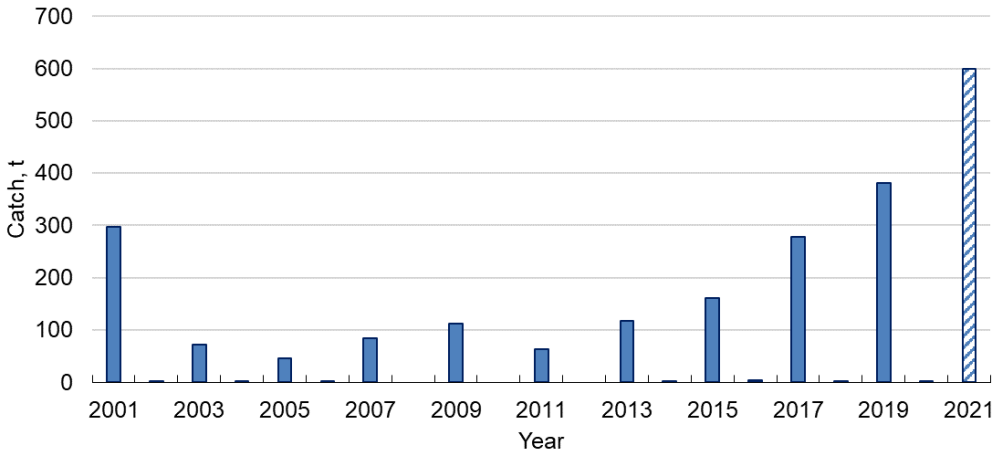

Figure 3. Pink salmon catches in Murmansk region in 2001-2021. Catch for 2021 is provisional.

In 2019, the total catch of pink salmon in coastal fishery in the White Sea in the Murmansk region was 142 t including a catch of 77 t in the Kandalaksha Gulf where the fishery was conducted with trap nets at 15 fishing sites. The average catch per site was 5.1 t (4,000 fish), with min of 2.0 t (1,500 fish) and max of 12.6 t (9,700 fish). In 2019, the maximum catches of pink salmon recorded at the counting fences in the Varzuga and Kitsa rivers were 194.2 t (175,600 fish) and 29.2 t (26,300 fish) respectively (Prusov et al., 2021).

Under the current fisheries regulation for the Northern Fisheries Basin the fisheries targeting anadromous fishes (Atlantic salmon and pink salmon) in the Barents Sea is forbidden and is allowed in designated fishing sites of the White Sea and inland waters of the Murmansk region for the following purposes:

- historical Saami fisheries in fishing grounds of the White Sea;
- tourist recreational fishery in rivers on fishing sites;
- commercial fishery at the counting fences of the Varzuga and Kitsa rivers (the White Sea basin);
- coastal fishery in fishing grounds of the White Sea.

Fishery for scientific purposes is conducted according to work plans at any of the water entities.

Despite the absence of plausible evidence of the adverse impact of pink salmon on Atlantic salmon's reproduction, unlimited exploitation of this species in all types of fisheries is needed. In large rivers, all pink salmon individuals are recommended to be harvested during the entire spawning run (Alekseev et al., 2019).

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