Analysis of Impact Factors Adversely Affecting Atlantic Salmon Stocks in the Russian Federation

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Introduction

As a part of the preparation for the Fourth Reporting Cycle and following the Future of NASCO – a Ten-Year Strategy, CNL(24)71rev, at its 2024 Annual Meeting the Council agreed, CNL(24)88rev, that Parties / jurisdictions would undertake analyses of stressors to identify the primary threats and challenges to wild Atlantic salmon. The three stressors (threats) identified as the highest priority in each stress analysis and their associated baseline data will be used as the basis for planned salmon conservation actions and the Party's annual progress reporting in the Fourth Reporting Cycle.

The northeastern part of the Atlantic salmon range is in the European North of Russia and extends from the Scandinavian Peninsula to the border with Asia, covering three geomorphological provinces. The physical and geographical features of the region determine the high variability of abiotic conditions in salmon rivers, such as the size of river systems, the ratio of various channel elements, types of ground, thermal, hydrological and hydrochemical conditions. Moving from the Murman to the east, towards the border of the species' range, the length of salmon rivers increases (from a few kilometers to 1,000-1,800 km), areas of lacustrine environment in river systems grow smaller, and continental climate factors play a greater role (Martynov, 2007). The diversity of Atlantic salmon habitat in the region has contributed to the formation of unique salmon populations with the strong genetic divergence both between the three main population clusters – the rivers of the eastern part of the region (right bank tributaries of the Northern Dvina River, the Mezen and Pechora rivers), the rivers of the White Sea, the Barents Sea rivers of the Kola Peninsula, and between subgroups within each cluster (Tonteri et al., 2009; Ozerov et al., 2017).

In the region, salmon juveniles stay in rivers from two to seven years before migrating to sea. The marine migration lasts from one to five years (Martynov, 2007). Starting from the Barents and White seas rivers of the Kola Peninsula and off to the east, there are two Atlantic salmon groups with different ascending time and the duration of freshwater period before spawning. These are Summer and Autumn run salmon (Berg, 1948). Autumn run fish do not spawn in the year they enter the river but stay in freshwater for the winter and spawn in the autumn of the following year, i.e. 10-15 months after entering freshwater and stopping feeding.

Methods

To evaluate the risks posed by various impact factors (stressors) to Atlantic salmon populations in the Russian Federation, experts from the Polar and Northern branches of FSBSI 'VNIRO' ranked the importance of a number of stressors to Atlantic salmon in five areas: the Barents Sea rivers of the Kola Peninsula, rivers of the Kola Peninsula of the White Sea basin, Karelian rivers, rivers of the Arkhangelsk region, and the Pechora River. The work is based on previously published works, information from annual state reports on the status of the environment and protection measures in the Russia's regions as well as on data from the annual state programs for monitoring anadromous fish. These areas were defined based on genetic divergence, differences in the quantitative and qualitative features of the salmon populations, their habitat, and the region based anadromous fish fisheries management system.

Experts were asked to assign and integers from 0 (no threat) to 3 (strong impact) to ordinally score the threat posed by each stressor:
0 – no threat
1 – minor impact
2 – moderate impact
3 – strong impact

In cases where the impact of a stressor was considered possible but its magnitude was too uncertain to estimate, that stressor was not ranked.

Each stressor was also classified based on the exposure period:
P – Permanent exposure
E – Episodic exposure
H – Historic: an effect that has been noted previously but has consequences
N – New impact

The groups of stressors were made for the three major areas earlier defined by NASCO for the annual reporting:

1. Fisheries
2. Habitat
3. Aquaculture

Results

The results of the analysis are given in the table.

Table – Expert assessments of the risks posed by stressors to salmon populations in five regions of the Russian Federation (explanations in the text)

Stressor	**Kola Peninsula Barents Sea**	**Kola Peninsula White Sea**	**Karelia**	**Arkhangelsk region**	**Pechora River**
			Fisheries		
Mixed stock fisheries	3P	2P	2P	2P	1P
IUU fishing	3P	3P	3P	3P	3P
By-catch	1E	2P	1E	2P	2P
Catch-and-release mortality	1N	1N	0	1N	0
			Aquaculture		
Sea lice *Lepeophtheirus salmonis*	N	0	0	0	0
Parasite *Gyrodactylus salaris*	2N	0	3P	0	0
Fish farming related infections	N	N	N	N	N
Farm escapees	1E	0	0	0	0
Stocking	1E	2P	3P	2P	0
			Habitat		
New fish species (*Sander lucioperca*)	0	0	0	N	0
Diseases of unknown etiology (UDN)	2N	N	N	0	0
Impassable dams	1H	1H	3H	1H	0
Flow regulation	1E	1E	2P	E	0
Eutrophication	0	0	P	2P	0
Water pollution (industry, domestic wastewater, agriculture)	1P	1E	P	3P	E
Deforestation	1H	1H	3H	2P	1H
Timber rafting	1H	1H	3H	2P	1H
Changes of river bed, dredging	1H	1H	2H	2P	1P
Predation (marine phase)	P	P	P	P	P
Predation (freshwater period)	P	P	P	P	P

Discussion

Some regional differences in the set of stressors and the magnitude of impact of various threats on Atlantic salmon were identified. A summary of the main factors that negatively affect Atlantic salmon stocks in the study areas is given below.

Kola Peninsula, rivers of the Barents Sea

In most Barents Sea rivers of the Kola Peninsula, the habitat remains intact (Zubchenko et al., 2022) despite some consequences of the human activities identified (Inventory…, 2011). In rivers, located in hard-to-reach areas of Eastern Murman, natural conditions for salmon reproduction have been preserved. Artificial barriers in the form of dams of various hydraulic structures have been built on six rivers, and there is a fish pass only on one hydropower dam (the Tuloma River). It is worth noting that natural salmon reproduction remains in tributaries of some rivers below dams. Regulated water discharge through the dams of two hydropower stations has a considerable impact on dynamic of salmon migrations in the Tuloma River. The barrier also makes it easier for bearded seal to hunt salmon below the lower dam. On the Voronya River, where salmon might spawn below the hydropower dam, the spawning grounds are drained in some years due to the large amplitude of the regulated flow. The catchments of some rivers are under constant pressure from industrial complexes and populated areas due to repeated cases of high and extremely high water pollution, high average levels of chemicals in water, their accumulation in bottom sediments of water bodies (Ministry of Natural Resources..., 2024). Some tributaries of the Pechenga River are heavily polluted with industrial and domestic wastewater. The heaviest anthropogenic impact in the Kola River is observed in the lower section of the river, where three streams polluted by stormwater runoff from abandoned poultry farms flow into it (Ministry of Natural Resources..., 2024). Another threat for salmon of the Barents Sea coast of the Kola Peninsula is *Gyrodactylus salaris* first found in 2015 and 2017 on Atlantic salmon juveniles in two rivers that run into the Nizhne-Tulomskoe reservoir (the Tuloma River). It is assumed that the parasite was introduced to the reservoir with live rainbow trout (*Oncorhynchus mykiss*) from Karelia as it was identified as a strain associated with this species (Hansen et al., 2022). There are two rainbow trout farms in the Ura River. One farm is located in a channel lake in the middle section of the river, and the other one is on the riverbank near the mouth of the river. Since 2015, a disease diagnosed as ulcerative dermal necrosis (UDN) has been causing massive adult salmon mortality in a number of the Barents Sea rivers during the spawning run. This resulted in a sharp decline in salmon juveniles densities in the Kola and Tuloma rivers. Atlantic salmon juveniles of hatchery origin used to be released in the Kola River for decades. However, no juvenile releases have been occurred since 2017 due to UDN (high mortality of broodstock). Previously, juveniles of hatchery origin were also released in a number of the Barents Sea rivers. Atlantic salmon and rainbow trout marine aquaculture is well developed in the coastal waters of the Barents Sea from the Norwegian-Russian border to the Teriberka Bay. In 2021-2022 the fish biomass in cages was estimated up to 60,000 t. Marine farms are located in bays where salmon rivers flow into. The impact of salmon louse (*Lepeophtheirus salmonis*) on wild salmon in these rivers has not been studied yet. However, the parr densities in the index rivers of Western Murman do not show a downward trend. Monitoring of salmon migrations in the coastal waters of the Barents Sea and in the fish ladder of the Tuloma hydropower dam has shown that escaped salmon are rarely found in the wild (Prusov, Potutkin, 2023). Estimated as 25-70% of the spawning stock illegal catches have a strong impact on the Atlantic salmon in the Barents Sea rivers (Prusov et al., 2021). The rivers located near settlements and well-developed road infrastructure are first to be affected. Research have shown that parr densities are higher on the rivers where 'catch-and-release' recreational salmon fishery is practiced compared to the rivers where ‘catch-and-take’ fishery or poaching occur (Zubchenko, Prusov, 2013). According to the data from the 'Kolarctic Salmon' project, salmon of Russian origin amounted up to 18% of catches in the coastal salmon fishery in Finnmark and the greatest proportion (65% of catches) of salmon from Russian rivers occurred in Sør-Varanger Municipality

(Varangerfjorden) (NASCO, 2014). Most 'Russian' salmon in Norwegian catches come from the Barents Sea rivers of the Kola Peninsula (Ozerov et al., 2023). Salmon fisheries at sea that harvest fish from two or more river stocks are mixed-stock fisheries that are considered to pose a serious threat to Atlantic salmon stocks below conservation limits. (NASCO, 2014). Atlantic salmon fisheries in the Russian part of the Barents Sea are prohibited under the Fisheries Regulations for the Northern Fisheries Basin.

Kola Peninsula, rivers of the White Sea

Overall, surveys showed good status of the Atlantic salmon habitat in the White Sea rivers of the Kola Peninsula (Zubchenko et al., 2018). Conditions for the salmon reproduction in all rivers located in remote areas of the Tersky Coast and the White Sea Throat remains natural. Only one river in this area (the Niva River) was blocked with an artificial barrier in the form of a hydropower station, which led to the complete disappearance of the salmon population of this river. In the 1930-40s when massive logging in the basins of some rivers of the Kandalaksha Gulf was conducted (Kobyakov, Smirnov, 2001) the timber rafting led to the clogging of river beds with wood and its waste. Some consequences of timber rafting can still be seen in some rivers today as sunken logs, broken dams and temporary wooden bridges. Since 2019, Atlantic salmon with signs of UDN have been found in some rivers. The majority of sick salmon were observed in the Umba River. There is a salmon hatchery operating in the Umba and Atlantic salmon juveniles of hatchery origin have been released into the river for decades. Previously, juveniles of hatchery origin were also released in a number of the White Sea rivers. There are no Atlantic salmon farms in the coastal waters of the White Sea along the Kola Peninsula. Similarly to the Barents Sea rivers of the Kola Peninsula, illegal fisheries conducted in the rivers and coastal waters have a great impact on the White sea Atlantic salmon. In the Umba, it reached 26% of the declared catches in the early 1990s, and almost 70% in the early 2000s (Alekseev et al., 2006). In the Varzuga, Atlantic salmon harvest reached 83% from all the fisheries and 3/4 of that was from illegal fisheries (Alekseev, Zubchenko, 2016). Coastal fisheries for Atlantic salmon are still in operation on the Tersky Coast of the White Sea. The genetic analysis of Atlantic salmon from commercial catches showed that salmon from rivers of the Murmansk and Arkhangelsk regions, and Karelia were exploited and the bulk of the catches were fish originating from the rivers of the Tersky Coast, mainly from the Varzuga River (Prusov et al., 2014). Atlantic salmon occurs as by-catch in commercial fisheries for pink salmon (*Oncorhynchus gorbuscha*) and the White Sea herring (*Clupea pallasii marisalbi*).

Karelia

This area includes rivers of the southern coast of the Kandalaksha Gulf, rivers of the Karelian Coast, and the Pomor Coast within the Republic of Karelia. In this area, watercourses are mostly river-lake systems that have greater heat content than salmon rivers of the adjacent areas. Eastwards (western slope of the Ural) and northeastwards (the Murman) the heat content in salmon rivers decrease by 25-40% (Martynov, 2007). Given the climate change, this feature may impact the ability for restoration of salmon populations in the area. In the 1930s-1960s, timber rafting was massively carried out in the Karelian rivers. Timber rafting wastes were found in great amounts in rapids and riffles of most rivers. This was also the time when dams were being constructed. They blocked spawning migration routes of salmon spawners which led to a collapse of certain populations or a dramatic drop in their abundance. There are hydropower dams in the Kovda River (Murmansk region). The river is accessible for anadromous salmonids for 15 km up from the sea. The Kem and Vyg rivers (Karelia Republic) were blocked and regulated with hydropower dams and lock systems. In between the upper border of the estuary and the lower dam, either had only one rapid left which was of little use for juveniles to feed and for spawners to spawn as the natural watercourse dynamics had been lost. A considerable drop in the Atlantic salmon abundance and deterioration of salmon habitat in Karelia's salmon rivers were caused by unregulated fisheries, water engineering, household wastewater, deforestation and some other things. Atlantic salmon catches in all rivers of the area dramatically dropped and by the mid 1970s up to 96% of all Atlantic salmon in Karelia were taken in the Keret River where annual salmon catch at the counting fence amounted to 1700 fish (Yakovenko et al., 1974). In the early 1990s, the Atlantic salmon population from this river suffered an outbreak of gyrodactylysis caused by the invasion of the parasite *Gyrodactylus salaris*. It is assumed that it was transported to the river during live fish moving operations. The decrease of juveniles infested with G. salaris resulted in a decline of the spawning stock by more than 25 times (Ieshko et al., 2008). Some small rainbow trout marine farms are operative in the coastal waters along the southern coast of the White Sea. They do not farm Atlantic salmon in the White Sea as the environment is unfavourable for the species in winter so the industry focuses on rainbow trout farming in freshwater. Most part of the White Sea river basins in Karelia overlaps with well-developed road infrastructure that makes them available and eventually contributes to IUU fisheries. Salmon populations in many rivers are lost or endangered. Nowadays, only a few spawners are taken in some of the rivers to reproduce fish in hatcheries. Atlantic salmon may occur as by-catch in commercial pink salmon catches.

Arkhangelsk

A part of smaller salmon river basins in the Arkhangelsk region are directly or indirectly affected by the activity of diamond mining plants. Water pollution and landscape change are major types of the impact from the diamond industry on the environment. In addition, fish in remote rivers are under pressure since watercourses and lakes are getting more accessible for people (Novoselov, Matveev, 2021). The Northern Dvina is one of the largest watercourses in the European North of Russia (357,000 sq.km.^{2}). It provides 70% of freshwater influx in the White Sea within the Arkhangelsk region and its basin is one of the most urbanized in the region. About half of all enterprises of the region are located here. There is one of the largest industrial centers of the region at the mouth of the river – Arkhangelsk. The river basin is permanently affected by the human activities from industries, households, agriculture, mining, shipbuilding, transport, and fisheries (Tortsev, 2022). The water quality has not changed significantly over the last five years (Center for Nature Management…, 2023). Anthropogenic drivers have both an indirect negative impact on fish fauna by deteriorating the habitat, feeding opportunities, and conditions for natural reproduction of fish, and a direct negative impact by commercial, recreational and illegal fisheries. The first group of the drivers include wastewater from industries and households containing high amounts of pollutants, timber industry (deforestation, timber rafting), dredging in the riverbed and tributaries (habitat deterioration), agriculture (eutrophication of the basin that occurs when organic substances come in water in excessive amounts), water transport (water pollution with fuel and lubricants). The second group of the drivers has a direct impact on fish by taking them from the wild and thereby decreasing the abundance. These include legal fisheries (resulting in selection of larger spawners), recreational fishery and illegal fisheries (poaching) that are mostly aimed at catching valuable salmon species (Novoselov, Studenov, 2014). Continued impact of a number of the drivers resulted in the overall reduced production in the river ecosystem which entailed changes in the structure of commercial catches at the population level first with valuable species of salmon and whitefish (Atlantic salmon, whitefish (genus *Coregonus*), nelma (*Stenodus leucichthys nelma*). Additionally to the population deterioration of salmon and whitefish, there are changes in the fish fauna structure observed in the river basin. Over the past 50 years, cyprinids have replaced salmon and whitefish in catches and become the dominant species (Novoselov, Studenov, 2014). Pikeperch (*Sander lucioperca*) appeared in some water bodies of the Arkhangelsk region due to introduction and further spread. After 2003, pikeperch began to be observed in the middle reaches of the Onega River, where the main spawning and nursery grounds of Atlantic salmon are located. It was found that the salmon downstream migration peak coincides with the end of pikeperch spawning and the beginning of its intensive feeding. Up to five salmon smolts were found in the stomachs of pikeperch. As the pikeperch abundance increases in the Onega's basin, the species will have a greater impact on native species (Novoselov, 2020). In the Northern Dvina River, pikeperch is now found in the entire river up to the estuary and adjacent coastal waters. At present, we can talk about the naturalization of pikeperch in the Northern Dvina River basin, since both adults weighing up to 4 kg and juveniles of different ages are observed in the river. Apparently, the introduction of the species has led to an increased risk of mortality of Atlantic salmon juveniles (Novoselov, 2020). In the Arkhangelsk region, there are some freshwater fish farms in operation. They mainly focus on rainbow trout. In the White Sea, there is some coastal salmon fisheries remaining within the Arkhangelsk region. The genetic analysis of Atlantic salmon showed that in fishing sites of the Winter Coast salmon from Arkhangelsk rivers, the Tersky Coast, the Kandalaksha Gulf and the White Sea Throat of the Murmansk Region are found in commercial catches (Prusov et al., 2014). Atlantic salmon by-catch may occur in pink salmon fisheries in coastal waters of the White Sea and in freshwater fisheries in large rivers of the regions.

Pechora

The Pechora is the largest Atlantic salmon river in Russia. It is 1,809 km long and its catchment area is 322,000 sq.km. It originates from the Northern Urals and runs into the southeastern part of the Barents Sea. About 130 km from its mouth, the river divides into two branches. These are eastern one (the Bolshaya Pechora) and the western one (the Malaya Pechora). The river has a delta 45 km wide downstream of Naryan-Mar (the administrative centre and the only city of the Nenets Autonomous Okrug). In the Pechora's basin, the major water pollutants are power, oil, coal, gas, and lumber industries. The polluted areas of the main stem are transit areas for fishes migrating to spawning and sea feeding grounds. The water quality in the Pechora in the mouth area near Naryan-Mar has slightly improved. There are less oil products now found in the water and the related index has been eliminated from the list of the critical water pollution indices. Downstream of Naryan-Mar the content of easily oxidized organics decreased (Center for Nature Management…, 2023). Mainly, the main stem is subject to pollution. Hydrological and hydrochemical regimes remain natural in the major salmon spawning and nursery grounds. Created in the western slopes of the Ural in the southeastern part of the Komi Republic, the Yugyd Va national park contributed to the conservation of the natural reproduction conditions for Atlantic salmon in the Pechora River. As a result, 80% of Atlantic salmon spawning and nursery grounds are located in the protected area of the park and the nearby Pechora-Ilych Nature Reserve (Martynov, 2007). In 1955-1965, the Atlantic salmon spawning stock in the Pechora River had the highest abundance of about 140,000 fish. In these years, the maximum catch of 750 t was recorded. With the onset of ‘perestroika’, illegal salmon fishing (poaching) increased sharply in the 1990s and exceeded the declared catches in 3–4 times (Reshetnikov et al., 2016). Currently, commercial and recreational fisheries with drift nets are carried out in the lower reaches of the river, which most likely exploit salmon populations from different tributaries of the river. These populations are genetically distinct to some extent (Ozerov et al., 2017). However, there are no data on salmon origins and the catch composition in the lower Pechora. At present, the fisheries are considered as single stock river fisheries and are managed accordingly. Salmon by-catch occurs in fisheries targeting other species in the lower reach of the river.

Conclusion

General forms of aquatic degradation include physical conversion and degradation of natural habitats, various forms of water pollution, development of freshwater resources, introduction of exotic organisms, and overfishing (Leidy, Moyle, 1998). Many wild Atlantic salmon populations in the North Atlantic and Arctic oceans have declined to record lows or disappeared. The anthropogenic stressors causing these declines and losses are well known (Forseth et al., 2017; Lennox et al., 2021; Gillson et al., 2022; Marine Scotland…, 2023). The climate change is enhancing the impact of the stressors. The decline in biodiversity as a result of the decrease in the abundance or a population collapse hinders wild salmon adaptation to the changing environment in sea and freshwater.

Many populations of Atlantic salmon in the European North of Russia are in a depressed state due to anthropogenic transformation. The healthiest populations are mainly located in the northern boundaries of the species range – northeastern (Eastern Murman) and southeastern (the White Sea Throat) parts of the Kola Peninsula where aquatic ecosystems are less affected by anthropogenic factors, with an exception of illegal fisheries that has a strong impact in all five studied areas. It can be concluded that the main impact factor adversely affecting salmon stocks in the Russian Federation at regional and national levels is illegal, unreported and unregulated (IUU) fishing.

The mixed stock fishery (MSF) that exploits several salmon populations at the same time may occur where some populations partly or totally overlap in their migration routes or feeding grounds. The interceptory Atlantic salmon MSF in the northern Norway, in particular in the Varanger Fjord, has the strong impact on salmon stocks in Russian rivers, especially in the rivers of the Western Murman and the Kola Bay. Although regulatory measures taken by Norway in the 2010s–2020s have led to a decline in the proportion of salmon of Russian origin in Norwegian catches (Ozerov et al., 2023), the catches remain at high level. Considering that MSF has also persisted in the White Sea and affects salmon populations in three regions of the Russian Federation, the interceptory Atlantic salmon MSF appears to be a significant stressor to wild Atlantic salmon.

In Russia, *Gyrodactylus salaris* was first recorded as a pathogen for Atlantic salmon in the Keret River (Karelia, the White Sea basin) in 1992. In the Murmansk region, the parasite was first detected in the Pak River in 2015 and in the Shovna River in 2017. Rainbow trout escaped from the fish farm in the Nizhne-Tulomskoye reservoir was considered to be the source of the infection. Later, the parasite was found in the Imandrovskoye reservoir (the Niva River flows out from it) where there are some trout farms (Hansen et al., 2022). The parasite is common amongst farmed rainbow trout. It lives on fish in small numbers without giving any clinical signs. Infested rainbow trout transportation is an important vector for the spread of G. salaris (Hansen et al., 2022). Taking into account the further development of the trout farming in all regions of the North-West of Russia and the transportation of live fish from the regions where G. salaris is native to the regions where wild Atlantic salmon populations exist, the risk of an accidental parasite spread is considered high and the stressor remains on the list of the most significant ones (IP(19)05rev).

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