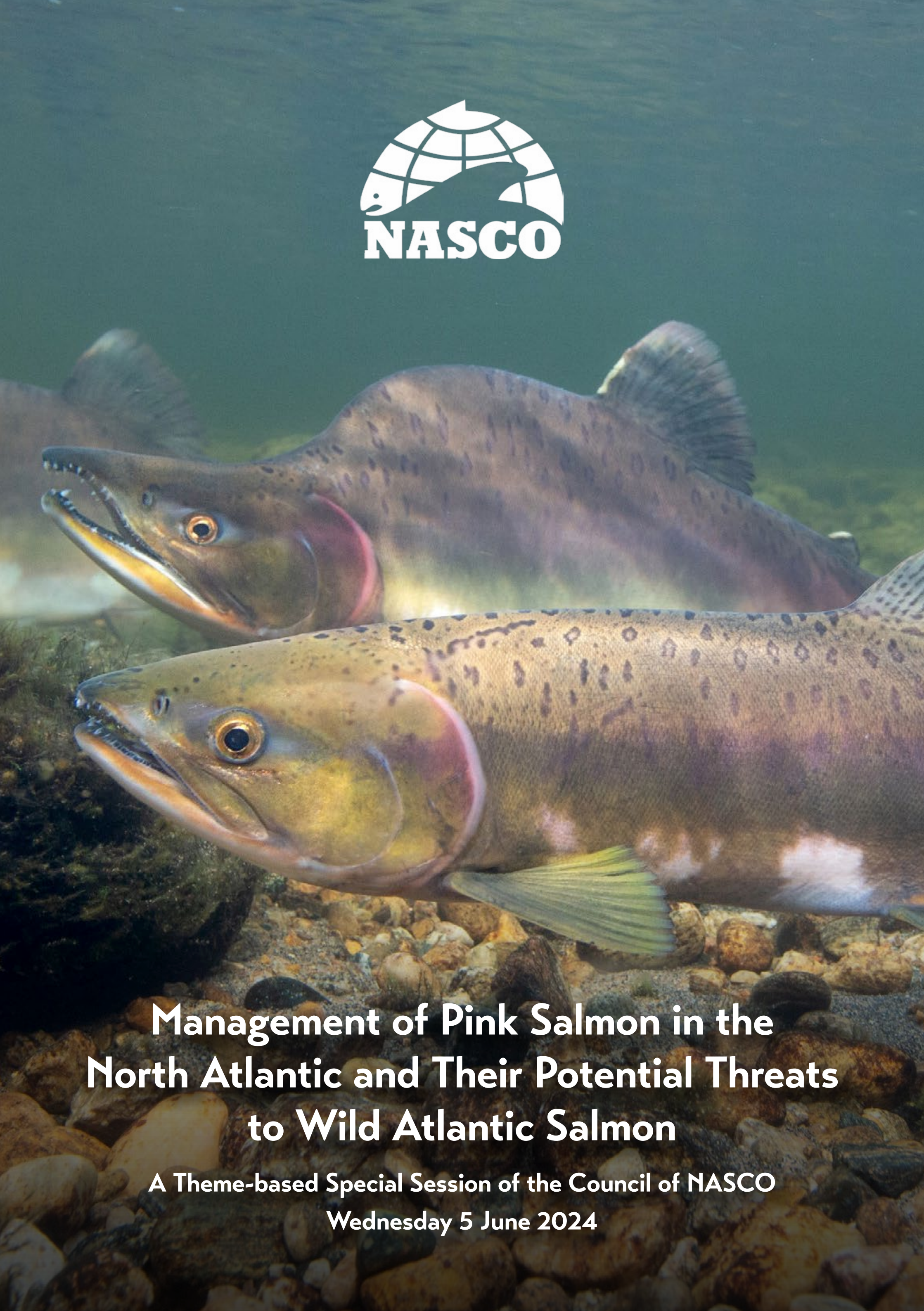

NASCO

Management of Pink Salmon in the North Atlantic and Their Potential Threats to Wild Atlantic Salmon

A Theme-based Special Session of the Council of NASCO

Wednesday 5 June 2024

Cover photo: Pekka Tuuri

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CNL(24)89

Management of Pink Salmon in the North Atlantic and Their Potential Threats to Wild Atlantic Salmon

Contents

Executive Summary

The North Atlantic Salmon Conservation Organization (NASCO) is a Regional Fisheries Management Organization whose objective is to conserve, restore, enhance and rationally manage Atlantic salmon through international co-operation, taking account of best available scientific information. In 2023, the Council of NASCO agreed that a Theme-based Special Session (TBSS) would be held in 2024 on the theme of pink salmon, with the overarching goal to provide an overview of pink salmon's distribution, biology, potential impacts on native Atlantic salmon and management actions in the North Atlantic.

The Steering Committee charged with organising the TBSS tackled this via four targeted objectives:

1. **Describe the natural distribution and life history of pink salmon and review its Arctic and North Atlantic range expansion.**
2. **Review the potential for interactions between pink salmon and Atlantic salmon in freshwater and marine environments and the potential for parasite and disease transfer.**
3. **Review the management of pink salmon in Atlantic salmon systems.**
4. **Introduce the new NASCO Working Group on Pink Salmon.**

The TBSS took place on 5 June 2024, in Westport, Ireland, as part of the 41st NASCO Annual Meeting. Invited experts presented under each of these objectives and discussions took place involving all Parties / jurisdictions and invited organizations.

The pink salmon (*Oncorhynchus gorbuscha*) is an anadromous fish native to the Pacific Ocean. Pink salmon was stocked in the Kola Peninsula in Russia, from 1956-1979 and again from 1985-1999, to serve as a fisheries resource. It has recently spread throughout the North Atlantic Ocean in unprecedented numbers and has now been reported in most countries within the NASCO Convention Area. Most pink salmon occurring in the North Atlantic has an odd-year spawning cycle. In some areas of Northern Norway and Finland, there are now more pink salmon than Atlantic salmon entering the rivers in odd years.

Although pink salmon has been reported for many years in Northern Norway and its abundance has increased tremendously in recent years in Norway and across the North Atlantic, relatively little research has been conducted regarding the impacts and interactions of pink salmon with native fish species, notably other salmonids. Being anadromous and sharing similar life history traits with the Atlantic salmon, pink salmon inhabits marine environments to grow and mature before returning to fresh water to spawn, and subsequently dies. Therefore, determining potential impacts and ecological consequences at both local and international scales throughout these environments can be challenging. The utilisation of environmental DNA (eDNA) has become an important tool, especially in areas where pink salmon abundances are not so dominant, for monitoring and understanding the presence, distribution, abundance and recruitment potential of the species.

It is important to note that in Russia, pink salmon is deemed a resource, but in most other NASCO Parties, it is classed as an invasive or alien species. To mitigate against increasing numbers of pink salmon, several countries have adopted special fishing licences, created new regulations regarding catching pink salmon and produced risk assessment documents. In 2023, Norway enacted ambitious local and national management efforts to construct traps in the lower part of over 50 rivers to remove and kill as many pink salmon as possible before they spawn. This effort was estimated to have successfully removed 250,000 adult pre-spawned pink salmon in total. Mitigation measures in Norway aiming to reduce and control the abundance of pink salmon can reduce the risk that pink salmon will establish in high numbers in other parts of Europe.

In response to the concern raised by NASCO Parties / jurisdictions, NASCO established a new Working Group on Pink Salmon to facilitate the exchange of information on the status of pink salmon across the Convention area. The Group is also tasked with identifying best practices for monitoring, knowledge gaps and corrective measures as related preventing adverse effects from pink salmon on wild Atlantic salmon stocks. The Group will also facilitate the sharing of information and the status of pink salmon within each Party / jurisdiction biennially.

Introduction

Photo: Pekka Tuuri

Introduction

The objective of NASCO's Theme-based Special Sessions (TBSS) is to allow for greater exchange of information on a topic related to NASCO's Resolutions, Agreements and Guidelines. In 2023, the Council of NASCO agreed that a half-day TBSS would be held in 2024 on pink salmon.

The pink salmon (*Oncorhynchus gorbuscha*) is an anadromous fish native to the Pacific Ocean. It was stocked in the Kola Peninsula in Russia from 1956-1979 and again from 1985-1999, to serve as a fisheries resource, and has recently spread throughout the North Atlantic Ocean in unprecedented numbers. Most pink salmon occurring in the North Atlantic have an odd-year spawning cycle. From 2017-2023, the distribution and abundance of pink salmon has increased tremendously, and the species now occurs in most countries where Atlantic salmon occurs. Norway has had an enormous increase in pink salmon catches over this time, particularly in the north. Approximately 250,000 adult pink salmon were removed when entering rivers for spawning, mainly by use of traps in lower parts of rivers, nets and removal from fishways in Troms and Finnmark County during 2023. An additional catch of adult pink salmon was taken (99,000) in licenced coastal Atlantic salmon fisheries (bag nets). About 13,000 pink salmon were also caught by sports fishing in rivers. There are additional unreported marine catches. This by far outnumbers the abundance of native Atlantic salmon returning to spawn in this region.

Invasive species may have large negative effects, but the potential biodiversity and societal threats of the pink salmon invasion are still largely unknown. The native Atlantic salmon, sea trout and Arctic char are among the most culturally valuable fish species in the North Atlantic. These fish species have supported commercial, sustenance and recreational fisheries, and are highly prized fish among anglers, creating the basis for tourism and recreation. Atlantic salmon, sea trout and Arctic charr are exposed to a multitude of threats in freshwater and marine environments and have declined during the last few decades, which has severely reduced population abundance and reduced or eliminated harvestable surpluses. There are worries that competition from pink salmon will further reduce the productivity of these species and negatively impact other estuarine and marine species. From the Pacific region, it is known that pink salmon is a species that can become very numerous, highly impact other species and alter entire ecosystems in fresh and marine waters.

Given the dramatic odd-year increases in pink salmon numbers in some North Atlantic and Arctic regions, ecological interactions between native and introduced species may have consequences for recruitment of both Atlantic salmon and pink salmon. Potential interactions could include competition (for space in rivers and for food in oceans), predation (juvenile Atlantic salmon may be feeding on larval and juvenile pink salmon) and indirect effects of altered nutrient dynamics and transmission in freshwater and marine environments. Pink salmon has been found to reproduce successfully in Norway, North-West

Russia, Iceland and Scotland. The increase in pink salmon in remote areas of Russia may have potential socio-economic benefits for regional economies through commercial, artisanal and recreational fishing, but potential negative effects in Norway through reducing the opportunities for, and value of, Atlantic salmon fisheries.

Concerns related to the presence of pink salmon within the NASCO Convention Area and the potential for negative impacts to wild Atlantic salmon productivity have been voiced since as early as 2011. Given the unprecedented increase in abundance and expansion of their distribution circa 2017, these conversations have become more focused and targeted. During the NASCO Annual Meetings in 2022 and 2023, significant concerns were raised about the ongoing and future threat of non-native pink salmon to native wild Atlantic salmon stocks in the Convention Area. To date, very little research has been carried out on the impacts of pink salmon across the North Atlantic region, which means more information on distribution, and hypothesised potential impacts, needs to be discussed and taken into consideration to enable the informed management of aquatic ecosystems.

NASCO's Actions on Pink Salmon

2021

In 2021, NASCO's request for scientific advice from ICES included a request to:

> *'provide an update on the distribution and abundance of pink salmon across the North Atlantic and advise on potential threats to wild Atlantic salmon' (paragraph 1.3).*

The advice was provided by ICES in 2022 and the summary states, CNL(22)64:

> *'ICES notes that both the abundance and geographic range of pink salmon (Oncorhynchus gorbuscha) have substantially increased in the North Atlantic since 2017. In 2021, the total number of observed and reported pink salmon was over 500 000, with the distribution ranging from northern Russian Federation to as far south as Scotland, Ireland, the Netherlands, and France.*
>
> *ICES advises that pink salmon pose several potential threats to wild Atlantic salmon (Salmo salar) both in freshwater and marine ecosystems. In freshwater the main potential threats are competition for spawning sites and interspecific aggression during the spawning season, space and food for juveniles, potential transfer of pathogens and decreased water quality caused by the decomposition of dead post-spawning pink salmon. In the marine ecosystem the main potential threat is from competition for food.'*

2022

Prior to the 2022 Annual Meeting of the North-East Atlantic Commission, Norway requested that a supplementary item on pink salmon be added to the Draft Agenda, NEA(22)03. Under this Agenda item, Eirik Frøiland (Norway) made a presentation on the issue of pink salmon in the Commission Area, NEA(22)16. He noted that:

- pink salmon is effectively reproducing in most rivers in Northern Norway;
- pink salmon has become the dominant species in many rivers in odd years;
- gradually, a high number of spawners is being seen further west and south; and
- it is possible that pink salmon can colonise all of Norway – and thus other countries around the North Atlantic Ocean.

He also highlighted the potential negative impacts of pink salmon, as follows:

- displacement of native anadromous fish species in the river;
- poor water quality when high number of pink salmon die and decompose after spawning;
- impacts on biodiversity from changes in nutrient load;
- risk of disease spreading between fish farms – pink salmon as vector; and
- negative for sportfishing and related economy.

Finally, he recommended that pink salmon should be recognised as a threat to Atlantic salmon, that the occurrence of pink salmon through the North Atlantic should be monitored and counteracted and that Parties should organize to share information and work together in the coming years.

The discussion on pink salmon continued at the Annual Meeting of the Council in 2022, with the President noting that the magnitude of pink salmon entering many Atlantic salmon rivers is very concerning, CNL(22)53rev. The Council adopted a 'Statement of the Council Regarding Pink Salmon, *Oncorhynchus gorbuscha*, in the NASCO Convention Area', CNL(22)47. This included agreement to establish a standing NASCO working group on pink salmon.

2023

In 2023, pink salmon featured on the agenda of the Council meeting where Eirik Frøiland (Norway) again made a presentation on pink salmon in Norway, CNL(23)79. The Council adopted the 'Terms of Reference for the NASCO Working Group on Pink Salmon', CNL(23)69, requiring it to submit its report to the Council by April 2024, for consideration at the Annual Meeting in June 2024. The Working Group was scheduled to meet in spring 2024.

Norway and the UK provided papers to the Council with updates on pink salmon (CNL(23)62 and CNL(23)61 respectively).

The Council also agreed that a TBSS on pink salmon would be held during the 2024 Annual Meeting. A Steering Committee was formed in September 2023 and met periodically to develop the programme for the TBSS, CNL(24)16. The Steering Committee agreed that the overarching objective for the TBSS would be 'to provide an overview of pink salmon's distribution, biology, potential impacts on native Atlantic salmon and management actions in the North Atlantic'.

The TBSS addressed this overarching objective through four detailed sub-objectives:

1. Describe the natural distribution and life history of pink salmon and review its Arctic and North Atlantic range expansion.
2. Review the potential for interactions between pink salmon and Atlantic salmon in freshwater and marine environments and the potential for parasite and disease transfer.
3. Review the management of pink salmon in Atlantic salmon systems.
4. Introduce the new NASCO Working Group on Pink Salmon.

Invited speakers presented under each of these sub-objectives.

Contributed Papers

The Natural Distribution and Life History of Pink Salmon and a Review of the Arctic and North Atlantic Range Expansion

Photo: Pekka Tuuri

Overview

The first sub-objective of the TBSS was to provide background information for the attendees to understand the history of pink salmon within the North Atlantic. A single speaker was asked to outline the basic biology and life history of pink salmon and to explain and to describe the introduction and eventual spread of the species throughout the North Atlantic. The speaker was asked to explain the odd- and even- year patterns, the species' natural geographic range as well as its introduction history into North-West Russia and to describe the abundance increases and distributional spread across the Arctic and North Atlantic. After the presentation there was a question and answer session (Q&A), which can be found at the end of the report.

- Michael Millane presented a summary on the introduction of pink salmon into the North Atlantic and Arctic regions.

CNL(24)52rev[1]

Introduction to Pink Salmon in the North Atlantic and Arctic (Why Are They Here and Where?)

Michael Millane, Seán Kelly and Cathal Gallagher – Inland Fisheries Ireland

Life History

Pink salmon *Oncorhynchus gorbuscha* (Walbaum, 1792) typically have a two-year anadromous lifecycle. Populations principally comprise either odd- or even-year stocks which can co-exist in the same river systems but are reproductively separate from each other (Heard 1991). Odd-year stocks (i.e. adults spawning in odd years such as 2021, 2023) predominate in the introduced range (Gordeeva *et al.* 2015; Niemelä *et al.* 2016). Pink salmon generally spawn on gravel substratum in shallow riffles or adjacent areas with a moderate to fast flow of well-aerated water, with spawning occurring in late summer to mid-autumn (Heard 1991; Alexeev *et al.* 2019; Erkinaro *et al.* 2022) predominantly in the lowermost sections of streams, rivers, their tributaries and the inter-tidal zone (Heard 1991). They have also been documented to migrate hundreds of kilometres upstream in large river systems to spawning areas (Heard 1991). This is notably evident in its non-native range in Finland / Norway, where pink salmon have been detected in the upper tributaries of the River Teno / Tana system (Fossøy *et al.* 2022) and observed in the Kola Peninsula region of northwestern Russia (Alexeev *et al.* 2019). Pink salmon are semelparous and die soon after spawning (Cederholm *et al.* 1999).

Pink salmon require good river water quality to successfully reproduce and are comparable to Atlantic salmon in this regard (Heard 1991). Across its range, spawning water temperatures for pink salmon can range from 5 °C to 19 °C but are typically around 10 °C at the onset of spawning (Erkinaro *et al.* 2022). Warmer water temperatures within their tolerable range can increase the rate of egg to fry development (Heard 1991; Niemelä *et al.* 2016). Fertilized eggs typically develop in the spawning gravels through the winter over a five-to-eight-month period (Heard 1991). On emergence, normally in the following spring to early summer period, fry usually quickly migrate from the river to the estuarine or coastal environment typically in schools, but the latter may less so be the case in smaller systems (Heard 1991). Migration typically commences when the water temperatures exceed 4 °C to 5 °C (Skóra *et al.* 2023). In coastal environments, pink salmon further mature as post-smolts in nursery areas mainly comprised of irregular shorelines sheltered from strong tidal currents and wind-generated waves before moving further offshore where they over-winter until the following spring or early summer in advance of their return

[1] Minor editorial changes made on 11 June.

migration as adults to spawn re-entering freshwater from June to September (Heard 1991). The schooling behaviour of pink salmon in the open ocean in their native range appears to be limited and unstructured, with any shoals of fish comprised of a low number of individuals unlikely to be commonly associated with their stock of origin (Heard 1991).

The most important environmental factors influencing survival in freshwater are density-dependant mortality which may increase as the population level increases, predation pressures and non-biological factors such as river flow and water temperature during the spawning to migration period (Heard 1991). Natural marine survival rates from smolt to adult returns are approximately 4.3 % (Heard 1991). Homing to natal rivers is considered to be less precise than in Atlantic salmon stocks (Thedinga *et al.* 2000; Mortensen *et al.* 2002) with straying rates of around 10 % for wild spawned pink salmon reported from parent systems in its native range (Heard 1991). However, higher straying rates may be a notable feature of transplanted populations (Sandlund *et al.* 2019). Straying rates for pink salmon that spawn in intertidal zones are estimated to be higher than those spawning further upstream (Thedinga *et al.* 2000).

Emergent fry do not routinely feed in freshwater but may do so particularly if there is a significant distance of outward migration towards the sea (Mo *et al.* 2018; Sandlund *et al.* 2019; Lennox *et al.* 2023; Erkinaro *et al.* 2024) or river hydromorphology delays migration (Veselov *et al.* 2016). Freshwater diet principally comprises the larval and pupal stages of dipteran insects but may also include other invertebrates and zooplankton (Heard 1991). Diet at sea is variable and mainly comprised of small fish and fish larvae, amphipods, krill and zooplankton and it overlaps with the diet of Atlantic salmon in its introduced range (Heard 1991; Diaz Pauli *et al.* 2023). Having entered freshwater as adults, pink salmon do not feed (Heard 1991; Diaz Pauli *et al.* 2023).

Adult pink salmon typically range in length from 45 to 55 cm and migrating fry approximately 3 cm in length (Heard 1991; Niemelä *et al.* 2016; Muladal *et al.* 2022; Skóra *et al.* 2023). Adults are distinguishable from other native anadromous salmonids by their characteristic large oval black spots on the tail fin, absence of spots on the gill cover, white-coloured mouth with black-rimmed gums and black tongue and relatively smaller fish scales. Both males and females are predominantly silver in appearance in their marine phase with a blueish dorsal hue, a white underbelly and a dark tail fin. On return to freshwater, both males and females notably darken in appearance except for their white belly. Their skin becomes thickened and their scales are absorbed (Heard 1991; Niemelä *et al.* 2016). The males develop a pronounced humped-back and kype with large teeth on both the upper and lower jaws (Heard 1991; Niemelä *et al.* 2016).

Although not common, pink salmon may have some degree of lifecycle plasticity as notably evidenced by the one to three-year lifecycle of the non-native population that established in the Great Lakes of North America (Heard 1991; Crawford 2001) and their non-migration to the sea which highlights their adaptability to new environments (VKM *et al.* 2020). Indeed, established odd-year pink salmon stocks in their introduced range in northwest Russia have been documented to display adaptive changes compared to their source population which includes shifts in genetic character, phenological adaptions, altered morphology, and increased body weight and fecundity (Gordeeva *et al.* 2005; Gordeeva and Salmenkova 2011). There is also some evidence for such genetic-mediated adaptions in the Great Lakes populations despite the limited genetic diversity of the founder stocks (Sparks *et al.* 2023). This demonstrates their capacity for quick acclimatisation and enhanced establishment potential in favourable environments (Niemelä *et al.* 2016; Lennox *et al.* 2023).

Natural and Established Geographic Range

Pink salmon are native to river systems in the northern Pacific Ocean and adjacent regions of the Bering Sea and Arctic Ocean (Page and Burr 1991). In addition to its native range, pink salmon are established in river systems draining into the Barents Sea and White Sea in the Kola Peninsula region of northwest Russia as a consequence of periodic stocking programmes undertaken there since the mid-1950s (Gordeeva *et al.* 2015; Alexeev *et al.* 2019). Self-sustaining populations of non-anadromous pink salmon have established in the Great Lakes region of North America after their unauthorised introduction into the Lake Superior drainage basin in the 1950s (Crawford 2001). In more recent decades, in the North Atlantic region, pink salmon have become established in rivers in northern Norway (notably in Finnmark county) and Finland (Niemelä *et al.* 2016; VKM *et al.* 2020; Erkinaro *et al.* 2022; Muladal and Fagard 2022) with further successful spawning activity documented or reported in some rivers in Iceland (Skóra *et al.* 2024), Scotland (Armstrong *et al.* 2018; Skóra *et al.* 2023) and southern Norway (ICES 2018), although it is yet to be determined whether such activity has since resulted in the generation of any self-sustaining populations in these locations or if the spawning adults are vagrant fish from elsewhere (Skóra *et al.* 2024). Once established in a river system, pink salmon have the capacity to quickly expand their range within it (Sandlund *et al.* 2019).

In northwest Russia, pink salmon fisheries focusing on odd-year stocks have predominantly taken place in the White Sea basin region since the 1960s with annual catches in northwest Russia reported to have exceeded 100 tonnes on four occasions before 2000 and peaking at approximately 300 tonnes in 2001 (NASCO 2024a; Prusov 2024). From then until 2015, catches ranged from 45 to 118 tonnes and increased from 2013 until 2021 where they exceeded 600 tonnes (Prusov and Zubchenko 2021). In 2023, the harvest was 206 tonnes which represents a 71 % reduction on 2021 and a 47 % reduction on the preceding five-year mean (NASCO 2024a; Prusov 2024).

Introduction History

Pink salmon have been widely transplanted within the bounds of their native range. These efforts typically aimed to enhance natural runs or establish opposite-year populations for commercial fishery purposes but have largely been unsuccessful (Heard 1991). Such initiatives to establish pink salmon outside of its natural range for these purposes have also generally been ineffective as self-sustaining populations did not result (Heard 1991). These include programmes in eastern North America including in Maine, Hudson Bay and Newfoundland and in the Baltic, Black and Caspian Sea regions of Europe (Heard 1991; Northern Hemisphere Pink Salmon Expert Group 2023) as well as a minor introduction attempt in southern Norway in 1976 (Sandlund *et al.* 2019). However, significant efforts to introduce pink salmon to northwest Russia, which originally commenced in the mid-1950s and concluded by 2003 (Niemelä *et al.* 2016), eventually proved more widely successful when between 1985 and 1998 / 1999 eyed eggs were periodically transported from further north in the Russian Pacific region (River Ola) than previously the case (Niemelä *et al.* 2016; Alexeev *et al.* 2019; NASCO 2024a; Prusov 2024). This has ultimately resulted in more well-established, self-sustaining populations in northwest Russian rivers since that time, predominated by odd-year cohorts (Gordeeva *et al.* 2015). Earlier introductions up to 1979 were considered to have largely failed due to the unsuitability of the more southerly-derived donor stock, from the South Sakhalin and Kuril Islands (Niemelä *et al.* 2016; Alexeev *et al.* 2019; NASCO 2024a; Prusov 2024), spawning too late in the season in prohibitively cold temperatures to ensure successful juvenile development (Gordeeva *et al.* 2015). From the 1990s, the stocking of fry in this area of Russia was mainly derived from local catches of odd-year broodstock (Niemelä *et al.* 2016). Attempts to develop large self-sustaining populations of even-year stocks of pink salmon in northwest Russia proved largely unsuccessful despite being sourced from the same far-east area as odd-year stocks (Gordeeva 2005; Niemelä *et al.* 2016; ICES 2018). This has been attributed to the relatively poorer ability of the even-year cohorts to adapt to their introduced range (Gordeeva 2005; Niemelä *et al.* 2016) and as such, established even-year stocks in northwest Russia are considered to be modest (Prusov 2024). It is worth noting that since stocking ceased in northwestern Russia, all occurrences of pink salmon in the last two decades or so outside of its native range are wild-spawned (VKM *et al.* 2020).

Spread from Introduced Range

Until 2017, pink salmon were generally sporadically detected in low or very low abundance in North Atlantic jurisdictions further south and west of its established range (ICES 2022). However, in 2017 pink salmon were widely recorded in unprecedented numbers in the North Atlantic and this has been the case in odd-years since that time (ICES 2018; ICES 2022; ICES 2024). Outside of northwestern Russia, reported numbers of pink salmon in the North Atlantic region have progressively increased in odd-years from 17,148 in 2017 to 20,014 in 2019, 201,694 in 2021 and 575,106 in 2023 (Table 1) (ICES 2024). Apart from Norway and northern Finland, during this time, this includes records from Canada, west and east Greenland, Iceland, the Faroe Islands, Ireland, the UK, France, the Netherlands, Germany, Denmark and Sweden (ICES 2022; ICES 2024). Even-year cohorts have typically rarely been observed outside of the introduced range of pink salmon (ICES 2024) but are more regularly recorded in some northernmost Norwegian and Finnish rivers (Niemelä *et al.* 2016; Sandlund *et al.* 2019; ICES 2024). In general, it should be noted that reported numbers of pink salmon are likely to be underestimates as they are largely dependent on the fish being caught or observed. Nevertheless, since 2017, it is clear that there has been a substantial increase in odd-year pink salmon abundance and distribution outside its introduced range in the North Atlantic region.

It is considered likely that the pink salmon vagrants recorded in the North Atlantic ultimately or directly originated from the non-native populations established in northwest Russia. Indeed, Gilbey *et al.* (2022) found that pink salmon sampled from Scottish rivers in 2017 were genetically indistinguishable from White Sea populations. In addition, recent specimens from eastern Canada were found to be genetically similar to Norwegian samples (Northern Hemisphere Pink Salmon Expert Group 2023).

Northern North-East Atlantic Commission Area

As a likely consequence of the stocking activities in northwest Russia, the first records of pink salmon in Norwegian rivers were in 1960 (Sandlund *et al.* 2019; Diaz Pauli *et al.* 2023) when large numbers of pink salmon were observed in rivers in northernmost Norway and individual fish were encountered as far south as Bergen (Mo *et al.* 2018). The following two decades recorded high numbers of pink salmon in both northern Norwegian and northwestern Russian rivers notably odd-year returns in the years after stocking (Niemelä *et al.* 2016; Mo *et al.* 2018). Despite the cessation of odd-year stocking by 2001, pink salmon continued to be recorded in Norwegian rivers in variable numbers and again this was notably higher in odd-years (Mo *et al.* 2018). Indeed, observations since 1976 show that pink salmon have been recorded in a wide geographic range of Norwegian rivers from north to south in variable abundance and are distributed across the whole latitudinal range of the Norwegian Sea on its eastern side towards the Norwegian coast (Diaz Pauli *et al.* 2023). Pink salmon were not detected in southernmost Norway until 1997 with annual occurrences here reported in most years, particularly odd-years, since 2015 (Diaz Pauli *et al.* 2023). Records of pink salmon have increased in Norway annually in odd-years since 2015 and have dramatically increased since 2017 (Table 1) (Diaz Pauli *et al.* 2023; ICES 2024). This is reflected in odd-year annual catches (comprising river removals, river angling and coastal fisheries) which progressively increased from 11,654 in 2017, to 14,633 in 2019, to 151,437 in 2021 and 361,548 in 2023 (Table 1) (ICES 2024; NASCO 2024b). The vast majority of pink salmon in Norway are recorded in Finnmark and, to a lesser extent, Troms counties which adjoin northwest Russia (Sandlund *et al.* 2019; Diaz Pauli *et al.* 2023; Frøiland and Høstmark 2024). In many waterways there, pink salmon are reportedly outnumbering Atlantic salmon, with the species recorded in at least 41 waterways in this region (Muladal and Fagard 2022).

Since the 1960s up until 2017, there have been variable occurrences of pink salmon in the River Teno / Tana which is a cross-jurisdictional river system between Norway and Finland and has its sea point in northeasternmost Norway adjacent to northwestern Russia. Since 2017 estimated abundances range from approximately 5,000 in 2017 and 2019 to approximately 50,000 in 2021 and 170,000 in 2023 (Table 1) (Erkinaro *et al.* 2023; ICES 2024). Large-scale spawning was first evident in this system in 2021 (Erkinaro *et al.* 2022) and the species has now colonised the main stem and tributaries, including three notable headwaters in the upper catchment as well as an increasing number of the smaller tributaries there (Erkinaro *et al.* 2023).

Pink salmon were first observed in Icelandic fisheries in 1960-1961 (n=22) and were not reported in any notable abundance since then until 2017 when 52 fish were recorded (Þórðardóttir and Guðbergsson 2022; Skóra *et al.* 2023). In the following odd-years approximately 340 and 492 pink salmon were reported in 2021 and 2023, respectively (Þórðardóttir and Guðbergsson 2022; ICES 2024). In Sweden, pink salmon were first recorded in 2017 (n=44) (ICES 2018; ICES 2024). In 2021, 70 pink salmon were reported from six rivers with relatively lower numbers recorded in 2019 (n=5) and 2023 (n=13) (Staveley and Ahlbeck Bergendahl 2022; ICES 2024). Very low numbers of pink salmon have been reported in Denmark and the Faroe Islands in some odd-years since 2017 (Table 1) (ICES 2024).

Southern North-East Atlantic Commission Area

Until 2017, pink salmon have been infrequently recorded in very low abundance in the southern North-East Atlantic Commission (NEAC) area (ICES 2022). After the first record of pink salmon in UK (Scotland) in 1960, low numbers of pink salmon were intermittently documented in Scotland up until 2016 with a total of 15-16 fish recorded from 12 locations (Armstrong *et al.* 2018; Bean 2023). Prior to 2017, pink salmon have only rarely been observed in Ireland with the only confirmed record from the River Moy in 1973 and sparse anecdotal reports of individual fish besides this (Millane *et al.* 2019a). This is also the case in UK (England and Wales) with only occasional reports since the 1960s (ICES 2018). Since 2017, all three jurisdictions have documented an unprecedented increase in odd-year pink salmon abundance with occurrences in multiple rivers and / or from interceptions in coastal fisheries (Table 1) (Armstrong *et al.* 2018; Bean 2023; Millane and McCormick 2023; ICES 2024). In Ireland, pink salmon have now been recorded in 15 rivers; in UK (Scotland) in at least 23 separate catchments (Bean 2023); and in UK (England & Wales) the species has been recorded in a few catchments with records predominantly from northeastern coastal net fisheries (NASCO 2023). A notable relative increase in occurrence of pink salmon in preceding odd-years was anticipated in these jurisdictions in 2023 and potentially elsewhere in southern NEAC, but based on reported records this did not materialise (Table 1) (ICES 2024).

Although very low numbers of pink salmon have been recorded in France, Germany, the Netherlands and UK (Northern Ireland) since 2017 relative to other southern NEAC jurisdictions (Table 1) (ICES 2024), these observations further highlight the widespread presence of this non-native species in the southern NEAC area of the North-East Atlantic in recent years.

North American Commission Area

Pink salmon stocks remain well-established in the Laurentian Great Lakes since their introduction. Since 2017, pink salmon have been sparsely recorded in low numbers in odd-years in eastern Canada, notably in Newfoundland and Labrador and Quebec (Table 1) (ICES 2024; NASCO 2024a). Previous stocking in Newfoundland in the 1950s and 1960s did not ultimately result in self-sustaining populations (Heard 1991). There are no reported incidents of pink salmon in US Atlantic waters in recent times (ICES 2024; NASCO 2024a) with the stocks introduced to the State of Maine in the 1900-1920s believed to have disappeared by the late 1920s (Heard 1991).

Table 1. *Numbers of pink salmon reported to ICES in NASCO commission areas (2017-2023). These numbers are from catches, removals, counts or observations (reproduced from ICES 2024).*

Country/Jurisdiction	2017	2018	2019	2020	2021	2022	2023
Canada	4		5		14		3
Denmark	10				8		4
Faroe Islands	1		6		7		
Finland*	5,000		5,000		49,500	20	170,000
France	3				4		
Germany	3		1		1		2
Greenland	6	4	78		62		1021
Iceland	79	1	251		340	5	492
Ireland	36		11		45		1
The Netherlands	3				6		
Norway	11,654		14,633	254	151,437	219	361,548***
Russia (north-west)**	220,000		223,529		352,941		
Sweden	44		5		70		13
UK (England and Wales)	208	1	3		26		2
UK (Northern Ireland)	2		3		3		2
UK (Scotland)	131		18		171	1	47

** Figures for Finland are for the River Tana / Teno.*

*** Russian numbers estimated from t caught; assume a mean weight of 1.7 kg per fish as per ICES (2018). Russian data for 2018 and 2020 not currently available but catches were relatively much lower than 'odd-years' as per graph in Prusov and Zubchenko (2021). Data from 2022 and 2023 are not available.*

**** a provisional figure of 403,519 reported in ICES 2024; amended to 361,548 as in NASCO (2024b).*

East and West Greenland

Pink salmon were first observed in Greenland in 1969 (Nielsen *et al.* 2020) and have been documented in at least 22 locations there since 2013 with the vast majority of specimens encountered since 2017 (Nielsen *et al.* 2020). There was a notable increase in reports in 2023 (n=1,021) compared to preceding odd-years when between 62 and 78 pink salmon were recorded (Table 1) (ICES 2024). The majority of records are from western and southern Greenland (Nielsen *et al.* 2020). However, in the relatively more isolated areas of south-east Greenland, pink salmon have also been observed in the lower reaches of some rivers and specimens encountered in adjacent near-shore areas (G. Wightman, N. Jepsen and K. Aarestrup pers. comm.)

High Arctic Region

Pink salmon commonly occur in Svalbard in both the marine and freshwater environments having been first recorded there in 1961 (Bengtsson *et al.* 2023). However, they have no current potential to spawn there as the rivers run dry or freeze in the autumn and winter (Bengtsson *et al.* 2023). In the eastern Canadian Arctic between 2017 and 2019, individual pink salmon have been documented at three locations (McNicholl *et al.* 2021). In addition, since 2011, some westward expansion of pink salmon from its native range has been documented in the Russian Arctic, where further expansion is likely constrained by prohibitive climatic conditions with the Taymyr Peninsula considered to separate native and introduced ranges (Northern Hemisphere Pink Salmon Expert Group 2023).

Potential Reasons for Increased Abundance and Distribution in the North Atlantic since 2017

It is difficult to comprehensively establish the causative factors which resulted in the dramatic increase in pink salmon abundance and their wide geographic occurrence as observed in the North Atlantic region in odd-years since 2017. However, more favourable warmer water temperatures experienced in recent years in both the freshwater and marine environments in its northernmost established non-native range is considered to be one of the main drivers of the increased abundance observed (VKM *et al.* 2020; Paulsen *et al.* 2022; Lennox *et al.* 2023; Northern Hemisphere Pink Salmon Expert Group 2023). In this region, increasing sea surface temperatures have been associated with an increased abundance of adult returns (VKM *et al.* 2020). In freshwater, increased temperatures have been reported to result in higher growth and smolt survival (Veselov *et al.* 2016; Farley *et al.* 2020) and a warmer receiving marine environment for smolts and post-smolts is considered to enhance survival prospects (Mo *et al.* 2018; Farley *et al.* 2020; Kaustad 2021). It is notable that in its native range, the abundance of juvenile pink salmon in summer is known to be highly correlated to the harvest of adults in the following year (Miller *et al.* 2022) and increases in odd-year cohorts in recent decades have been associated with increasing sea temperatures there (Irvine *et al.* 2014).

Homing instinct to natal rivers in at least some introduced stocks is considered to be less precise than native stocks which may facilitate increased vagrancy potential over a wide geographical range (Niemelä *et al.* 2016; Lennox *et al.* 2023). However, despite stocks in northwestern Russia considered mainly to return to natal rivers, even with low straying rates, high abundances of pink salmon in a given year may result in the straying of significant numbers of individual fish (Sandlund *et al.* 2019). It has been speculated that straying to Greenland and to jurisdictions in the southern NEAC area from northwesternmost Europe could be promoted by vagrants following the course of typical ocean circulation patterns used by Atlantic salmon (Diaz Pauli *et al.* 2023). It has been further speculated that if homing has inherited features, transplanted stocks would be more susceptible to straying (VKM *et al.* 2020).

Future Prospects for Establishment and Occurrence Outside of Established Introduced Range

The future prospects of pink salmon establishment and occurrence outside of its currently colonised range in northwesternmost Europe are difficult to determine (Lennox *et al.* 2023; Northern Hemisphere Pink Salmon Expert Group 2023). Climatic factors are likely to be key determinants influencing the abundance of pink salmon here in upcoming decades and consequently affect their capacity for further spread south and west in the wider North Atlantic region (Niemelä *et al.* 2016; VKM *et al.* 2020). Sustained periods of more favourable water temperatures both in the freshwater and marine environments, particularly during the smolt emigration and post-smolt periods, are likely to increase pink salmon survival and as such increase the propagule pressure experienced elsewhere, enhancing the potential for further self-sustaining populations to establish (Mo *et al.* 2018; Sandlund *et al.* 2019; Farley *et al.* 2020; Kaustad 2021). This is particularly important for jurisdictions more distant from the current range of colonisation (Millane *et al.* 2019b; Skóra *et al.* 2023). However, this has more immediate concerns for proximal areas to its current non-native established range, particularly further south in Norway, increasing the importance of effective control measures to inhibit further spread. With the climatically-induced increase in water temperatures already observed in northernmost latitudes likely to continue, it is anticipated that pink salmon will become a northern circumpolar species (VKM *et al.* 2020). Successful reproduction has already been documented in some rivers outside of its established northwesternmost range in Europe, which demonstrates that rivers in many jurisdictions throughout the North Atlantic capable of supporting the biological requirements for pink salmon spawning and juvenile development are therefore potentially susceptible to colonisation. Indeed, modelling thermal preferences may be particularly important to better ascertain the likely spread of pink salmon both in the North Atlantic and Arctic regions (Northern Hemisphere Pink Salmon Expert Group 2023). In addition, the documented ability of pink salmon to rapidly adapt and acclimatise to new areas of introduction is likely to enable their capacity for further establishment (Lennox *et al.* 2023). However, such range expansion cannot be assessed in isolation as climate warming, particularly in more northern latitudes, may result in gross ecosystem changes with novel predator pressures emerging or other currently unknown factors potentially tempering any expansion that may otherwise occur (Lennox *et al.* 2023). Further curtailment of pink salmon establishment in more southerly latitudes is also possible as river temperatures may increase above its current reproductive capability (VKM *et al.* 2020).

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Contributed Papers

The Potential for Interactions Between Pink Salmon and Atlantic Salmon in Freshwater and Marine Environments and the Potential for Parasite and Disease Transfer

Photo: The River Näätämöjoki-Neidenelva, Skoltefossen © Jaakko Erkinaro

Overview

The second sub-objective of the TBSS was to provide information related to the myriad interactions that may occur between pink salmon and Atlantic salmon. Speakers were requested to cover the potential species interactions across all life stages within both freshwater and marine environments. Such interactions could include the impacts on terrestrial systems from altered marine-derived nutrients dynamics, potential angling impacts on angling, diet impacts given spatial and temporal overlap within the ocean or altered disease and / or parasite issues dynamics.

The invited experts were chosen by the Steering Committee based on their status in their field of expertise and their contribution to peer-reviewed scientific literature. The following three presentations were delivered to address this second sub-objective, with all the invited speakers providing a paper to NASCO prior to the TBSS. After the presentations there was a question and answer session (Q&A), which can be found at the end of the report.

- Eva Thorstad presented a summary of current knowledge, overlap and potential interactions of pink salmon in rivers;
- Beatriz Diaz Pauli presented a summary of current knowledge, overlap and potential interactions of pink salmon at sea; and
- Åse Helen Garseth presented an overview of current knowledge of the transfer of diseases, infections and parasites.

CNL(24)51

Pink Salmon in Rivers: Current Knowledge, Overlap and Potential Interactions with Atlantic Salmon

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Summary

We summarise the current knowledge of and possibilities for interactions between pink salmon and Atlantic salmon in river systems. Pink salmon overlap with Atlantic salmon in timing of river entry and upstream migration of adults, spawning habitats and juvenile habitats, but spawn earlier in the season. Pink salmon can reach and spawn on most river stretches where Atlantic salmon occur. Over the next years and decades, pink salmon has the potential to substantially spread and increase in abundance within the distribution range of Atlantic salmon in the north Atlantic region.

Threats to Atlantic salmon from pink salmon are:

1. Competition for space, out crowding and aggressive attacks from adult pink salmon during the upstream migration and spawning – which may lead to migration delays, altered behaviour, and altered distribution of adult Atlantic salmon.
2. Competition for food and space between juvenile pink salmon and Atlantic salmon which could cause reduced growth and survival of Atlantic salmon.
3. Deteriorated water quality due to decomposition of dead pink salmon after spawning – which may cause eutrophication and hypoxia in existing nutrient-rich rivers and increased river productivity with uncertain outcomes for Atlantic salmon in nutrient-poor rivers.

The impact of pink salmon on Atlantic salmon in rivers depends on their abundance and thousands of pink salmon will likely have a large impact. We now know that pink salmon do occur in very large numbers in many rivers in northwest Russia and northern Norway, and the possibility for interactions between these species in freshwater is large. However, there are huge knowledge gaps regarding the impacts of pink salmon on Atlantic salmon in rivers. Research is urgently needed to fill in these gaps and understand the role and potential future impacts of pink salmon and to what level subsequent migration measures might be employed.

Introduction

Pink salmon is an invasive species to areas in and around the Barents Sea and North Atlantic Ocean. They spread to this region after repeated, intentional introductions to north-west Russia, beginning in the 1950s. They are native to the north Pacific area and like most Pacific salmon, they die after the first spawning season. Pink salmon usually have a strict 2-year life cycle (Figure 1), with some rare exceptions. They spawn in rivers in late summer and early autumn, and the eggs hatch in winter or spring. Then pink salmon migrate to the sea as smolts in the spring or early summer the same year as they hatch, when they are approximately 3-6 cm long. They spend about one to one and a half years feeding at sea and return to the rivers in the summer usually as 0.5-3 kg adult fish. After some weeks in the river, they spawn and die. Hence spawners one year will be the parents of spawners two years later.

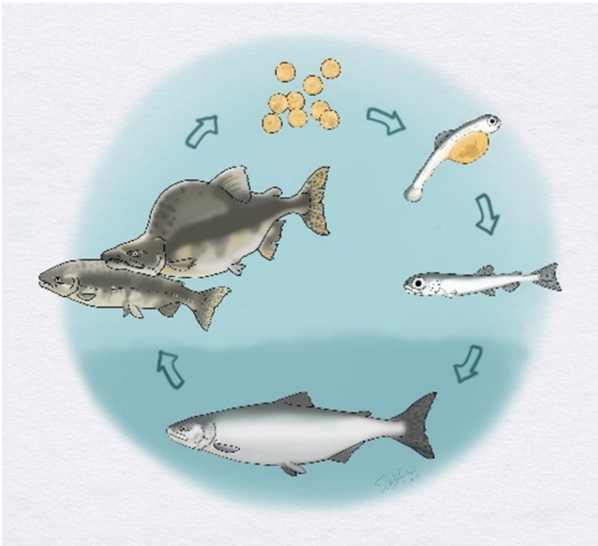

Figure 1. *Pink salmon life cycle. Illustration: Sigrid Skoglund, ©Norwegian Institute for Nature Research*

Pink salmon is the most abundant Pacific salmon in their native range, with some populations constituting hundreds of thousands of fish (Heard 1991) and is thus a much more numerous species than Atlantic salmon. In northwest Russia and northern Norway, many rivers now receive thousands of adult pink salmon in odd years (Figure 2), outnumbering, by far, the spawners of Atlantic salmon. Pink salmon overlap in time and space with Atlantic salmon in the rivers both during the spawning migration and juvenile phase. The possibility for interactions between pink salmon and Atlantic salmon in freshwater environments is therefore large.

Figure 2. *Pink salmon occur in large numbers in some rivers in Northern Europe. Photo: Malin Solheim Høstmark ©County Governor of Troms and Finnmark.*

Here we summarise the current knowledge of and possibilities for interactions between pink salmon and Atlantic salmon during different stages of the freshwater phase. We begin with the upstream migration of adult salmon in rivers and follow the life cycle through spawning and the juvenile phase until they leave the rivers and enter the sea.

Upstream Migration of Adults

In the Barents Sea and North Atlantic Ocean region, pink salmon usually enter rivers and migrate upstream in July and during the first half of August, but some enter rivers as late as September (Sandlund *et al.* 2019; Prusov and Zubchenko 2021; Norwegian Environment Agency 2024). So far, at least in Norway, there seems to be no north-south pattern in the seasonal timing of river ascent (Diaz Pauli *et al.* 2023).

Pink salmon can exhibit short upriver migrations and even spawn in the intertidal zones of rivers (Hanavan and Skud 1954; Scott and Crossman 1973; May *et al.* 2023). However, they can also migrate long distances upstream, up to several hundred kilometres (Heard 1991). For example, in the Fraser River in Canada, pink salmon must negotiate several reaches with rapids and steep gradients before reaching spawning sites (Crossin *et al.* 2003). Hence, pink salmon would be expected to pass an array of challenging river reaches in the shorter and often less steep Atlantic rivers (Lennox *et al.* 2023). In northwest Russia, pink salmon migrate more than 300 km upstream in the Ponoy and Tanya rivers, and in Norway / Finland, pink salmon have been encountered > 200 km upriver from the sea in the Tana / Teno river system (Bakshtansky 1980; Niemelä *et al.* 2016). Introduced pink salmon may gradually occupy more remote spawning grounds as the abundance increases over time (Veselov *et al.* 2016), which has indeed been the case in some Norwegian rivers.

Adult pink salmon have been regarded as relatively poor swimmers (Heard, 1991) but are, as pointed out by Lennox *et al.* (2023), in fact strong and energetically efficient swimmers that can attain instantaneous swim speeds of 1.5-2 m/s (Standen *et al.* 2002; Crossin *et al.* 2003). Pink salmon is also the superior species of Pacific salmon in terms of adults' aerobic scope and thermal tolerance (Clark *et al.* 2011). Clark *et al.* (2011) found the optimal aerobic scope at 21 °C and pointed out that this may confer a selective advantage over other species when river temperatures increase with climate change.

In the weeks before spawning, there may be negative interactions between adult pink salmon and Atlantic salmon in rivers, particularly when pink salmon occur in high densities. Most Atlantic salmon enter the rivers during the same period as pink salmon (Klemetsen *et al.* 2003; VRL 2023), but in some areas, for instance in Scotland, Atlantic salmon enter rivers all year round. According to anecdotal observations, pink salmon and Atlantic salmon have been observed swimming together in rivers seemingly undisturbed; nonetheless, agonistic behaviours from pink salmon towards Atlantic salmon can occur (Figure 3) (Veselov and Zyuganov 2016; Frøiland *et al.* 2024). The presence of high densities of pink salmon may in itself lead to Atlantic salmon altering behaviour and habitat use. For instance, in some cases hundreds and thousands of pink salmon gathered below traps aimed at removing pink salmon in the lower parts of rivers in Norway in 2023. People operating the traps reported that Atlantic salmon were delayed in the river mouths downstream of the pink salmon and did not move further upstream before the pink salmon were removed (Frøiland *et al.* 2024). This indicates that Atlantic salmon are reluctant to enter areas with high densities of pink salmon, which has also been observed by Veselov & Zyuganov (2016).

Figure 3. *There may be negative interactions between adult pink salmon and Atlantic salmon in the rivers, particularly when pink salmon occur in high densities. Photo shows an Atlantic salmon (left) outside a group of pink salmon in a river in northern Norway. Photo: Malin Solheim Høstmark ©County Governor of Troms and Finnmark.*

Atlantic salmon usually hold position in the river close to their spawning area up to several weeks or even months before spawning (Økland *et al.* 2001; Thorstad *et al.* 2008). Atlantic salmon may be disturbed and stressed, and perhaps crowded out from their normal holding areas, if large numbers of pink salmon are present during this period (Hindar *et al.* 2020). Pink salmon can be aggressive at their spawning sites and have been reported to attack Atlantic salmon at these sites (Veselov and Zyuganov 2016). The result of this agonistic behaviour by pink salmon could cause Atlantic salmon to move to river sections less suitable as holding areas prior to, and during, spawning.

Studies of the interaction between pink salmon and Atlantic salmon during the upstream migration in rivers are largely lacking. A Norwegian risk assessment (Hindar *et al.* 2020) nevertheless concluded that agonistic behaviour by pink salmon in the weeks before the spawning period of native salmonids is likely to occur in rivers with pink salmon. They further concluded that it is likely, with high confidence, that pink salmon will compete with native salmonids for space in the river in the weeks before and during the pink salmon spawning.

Spawning

Pink salmon spawn in both main rivers and tributaries. Spawning by pink salmon in the Barents Sea and North Atlantic Ocean region generally occurs in August, but there are also reports of spawning in September. This means that pink salmon usually spawn earlier than Atlantic salmon and brown trout, but there may be overlap between the latest spawners of pink salmon and the earliest spawners of particularly Arctic char, but also brown trout in northern Norway (Hindar *et al.* 2020). However, there are also some reports of spawning pink salmon as late as October in northwest Russia (Bakshtansky 1980; Efremov 2021; Prusov and Zubchenko 2021), which would overlap with the spawning period of Atlantic salmon in many areas. Efremov (2021) suggested that the spawning migration of pink salmon has been extended since 2017, and that late entering pink salmon spawning together with Atlantic salmon can have negative consequences for Atlantic salmon.

Like Atlantic salmon, pink salmon females dig nests in the riverbed, called redds, where the eggs are laid and then covered by gravel. Pink salmon aggressively defend their redds before, during, and for some days after spawning until they are too weak and die (Scott and Crossman 1973).

Figure 4. *Pink salmon and Atlantic salmon can spawn in the same area. Photo shows eggs and one-year old Atlantic salmon juveniles and pink salmon smolts caught at the same site. Photo: ©Rune Muladal, Naturtjenester i nord.*

The habitat requirements for spawning are very similar between pink salmon and Atlantic salmon; both species prefer to spawn in areas with coarse gravel with a flow through of aerated water. Pink salmon sometimes tend to spawn closer to riverbanks, in shallower water, and in finer substrate than Atlantic salmon. However, there are also observations of common spawning areas between Atlantic salmon and pink salmon in several rivers in Norway and Russia (Figure 4) (Vistnes 2017; Alekseev *et al.* 2019; Muladal and Fagard 2020; Anon. 2022; Kanstad Hanssen and Monsen 2022; Muladal and Fagard 2022; Sørvik 2022), which can lead to redd superimposition for pink salmon. There are several records of pink salmon juveniles together with eggs of Atlantic salmon, with pink salmon seemingly having a high survival even though the Atlantic salmon must have spawned in the same redd after the pink salmon have spawned (Muladal and Fagard 2020; Kanstad Hanssen and Monsen 2022; Muladal and Fagard 2022). Lennox *et al.* (2023) concluded that it is not clear whether the superimposition of late-spawned Atlantic salmon redds over earlier spawned pink salmon redds will have a negative effect on the ability of pink salmon to colonize new watersheds. Bakshtansky (1980) suggested that spawning pink salmon could have a beneficial effect on the gravel, clearing it of silt and organic material, to the benefit of Atlantic salmon spawning later in the autumn. On the other hand, there are worries that extensive digging activity by large numbers of pink salmon will cause mortality of freshwater pearl mussels living in this habitat (Veselov and Zyuganov 2016).

Hybridization between pink salmon and Atlantic salmon has not been documented in the wild, and in the laboratory pink salmon crossed with Atlantic salmon have only produced sterile offspring (Hindar *et al.* 2020; Devlin *et al.* 2022; Lennox *et al.* 2023). Hybridization between pink salmon and Atlantic salmon is not expected, but also cannot be excluded (Hindar *et al.* 2020).

Death of Spawners

After they die, decomposing pink salmon (Figure 5) affect the water quality of rivers. Pink salmon gain most of their body mass at sea but die naturally in rivers, which leads to the transport of organic matter and nutrients from marine to freshwater environments. Dead and decomposing pink salmon are utilized by all types of scavengers and may therefore affect both freshwater and terrestrial food webs and biodiversity (Cederholm *et al.* 1999; Dunlop *et al.* 2021a).

Figure 5. *Decomposing pink salmon affect water quality of rivers. Photo: Eva B. Thorstad, Norwegian Institute for Nature Research.*

In nutrient-rich rivers, excess nutrients and increased oxygen demand resulting from decomposition of pink salmon may result in hypoxia and negative consequences for the river ecosystems by eutrophication. In nutrient-poor rivers, extra nutrients lead to increased productivity, which may eventually enhance the growth of juvenile Atlantic salmon. The outcome of enhanced juvenile growth for individuals and populations of Atlantic salmon is uncertain, and whether this may be regarded as positive or negative for population growth may vary among populations and needs to be investigated. The worst-case scenario is that Atlantic salmon smoltify at an earlier age and size, which may lead to lower marine survival in Atlantic salmon (e.g. Gregory *et al.* 2018; Gregory *et al.* 2019). The impacts of dead and decomposing pink salmon on water quality and ecosystems likely depend on the number of pink salmon, river morphology and current nutrient status of the river (Hindar *et al.* 2020). Alekseev *et al.* (2019) pointed out that for acidified and cold-water rivers in northwest Russia, river eutrophication is connected to the slower decomposition of dead fish than in warmer rivers in the Pacific, and that the fauna of microorganisms, invertebrate detritivores and vertebrate scavengers is poor in these northern rivers.

From Hatching to Juveniles Leaving the Rivers

Pink salmon eggs hatch during winter or early spring depending on timing of spawning and river temperature. The alevins stay in the gravel until the yolk sac has been absorbed, and when they are approximately 30 mm long, they are saltwater tolerant and can swim up from the gravel. In their native range, they are commonly known to immediately migrate to sea before they start feeding. Though some feeding on nymphal and larval insects may occur in some rivers where there is a long migration distance to the sea (Scott & Crossman 1973) or where they migrate through lakes (Robins *et al.* 2005).

It may seem more common that pink salmon smolts start feeding and remain in the rivers for some weeks or months before migrating out to sea in the Barents and Atlantic region than in their native range, but this is not well studied. However, several studies from northwest Russia, Norway, Finland, and Iceland have reported that smolts caught in different rivers have been feeding (Figure 6) (Bakshtansky 1980; Veselov *et al.* 2016; Sandlund *et al.* 2019; Erkinaro *et al.* 2024; Skóra *et al.* 2024). Food items reported from these studies were cyclopoid copepods, and larvae and pupae of Chironomidae, Simuliidae and Ephemeroptera. Also, smolts caught in Scottish rivers were assumed to have been feeding based on the length of time they had spent in the rivers (Skóra *et al.* 2023). Pink salmon juveniles may even start eating copepods and early instar chironomid larvae while some yolk remains (Veselov *et al.* 2016, Sandlund *et al.* 2019). Veselov *et al.* (2016) found that, in the Russian Kola Peninsula, late captured smolts (June) were a couple of cm longer (total length 4.4-4.8 cm) than the smallest early migrating smolts (May), and that 84 % of the early captured smolts and 100 % of the late captured smolts had food in their stomachs. They pointed out that greater abundance of late migrants of pink salmon smolts may cause competition for food resources with native fish species. More recently, Erkinaro *et al.* (2024) concluded that the active freshwater feeding of non-native juvenile pink salmon suggests potential resource competition with native fluvial fishes, particularly salmonids.

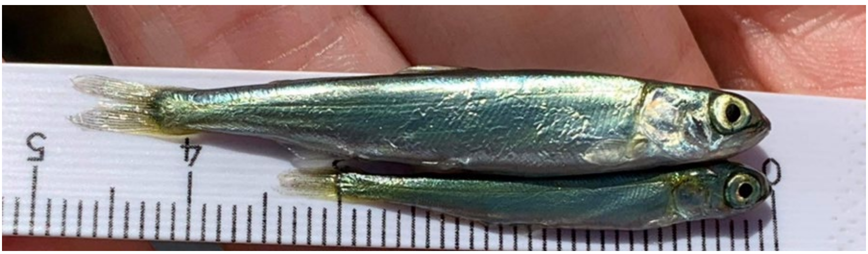

Figure 6. *Pink salmon juveniles caught in a river in northern Norway, showing the size (cm) of a newly hatched juvenile (under) and one that has been feeding in the river (above). Photo ©Håvard Vistnes.*

Hindar *et al.* (2020) concluded that pink salmon juveniles and smolts impact juveniles of native salmonids in the Barents and Atlantic regions through competition for food and space and the invertebrate fauna through predation. The impact depends on pink salmon densities and on the duration of their stay in the rivers. Fry densities of 0.1 to 589 per square meter (average 250) have been observed in stream sections consistently favoured by spawning Pacific salmon (Bailey *et al.* 1975). Availability of spaces to hide among the gravel is important both for pink salmon and Atlantic salmon, and competition for space in terms of a safe place to feed and hide may occur. Hence, competition for space may impact Atlantic salmon negatively when high densities of pink salmon occur, but this has not been well studied.

Eggs and juveniles of pink salmon may be a food source for Atlantic salmon. Dunlop *et al.* (2021b) found that although egg foraging and assimilation of marine-derived nutrients in fish body tissues were minor at the population level, a few juvenile Atlantic salmon and trout had eaten large quantities of pink salmon eggs. There have also been anecdotal observations of individual Atlantic salmon eating pink salmon smolts (Sandlund *et al.* 2019).

More research is needed to understand the ecological implications of pink salmon in rivers in the North Atlantic Ocean and Barents Sea region during the juvenile and smolt stage.

Conclusion

In rivers, the threats to Atlantic salmon from pink salmon are through: 1) competition for space, out crowding and aggressive attacks from pink salmon during the upstream migration and until the pink salmon spawning is over – which may lead to migration delays, altered behaviour and altered distribution of adult Atlantic salmon; 2) competition for food and space between juveniles of pink salmon and Atlantic salmon, which may lead to reduced growth and survival of Atlantic salmon, and; 3) deteriorated water quality due to decomposition of dead pink salmon after spawning – which may lead to eutrophication and hypoxia in already nutrient-rich rivers. In addition, should pink salmon evolve towards a later spawning period, this may lead to direct interactions between pink salmon and early spawners of Atlantic salmon at spawning grounds. Pink salmon eggs and juveniles can be eaten by Atlantic salmon, but it is unknown if this can serve as an important food source and have any population-level consequences for Atlantic salmon.

The impact of pink salmon on Atlantic salmon in rivers depends on their abundance, where a few pink salmon will likely have minor impacts, but thousands of pink salmon will likely have a large impact. We now know that pink salmon do occur in very large numbers in many rivers in northwest Russia and northern Norway. Pink salmon have the potential to reach and spawn on most river stretches where Atlantic salmon occur around the North Atlantic, and they can, in addition, reproduce in intertidal areas in river mouths.
Pink salmon may be a climate winner in temperate and sub-Arctic regions.

With a short life, they can adapt quickly to new conditions, as seen after the introduction in the Great Lakes in North America. Over the next years and decades, pink salmon have the potential to substantially spread and increase in abundance within the distribution range of Atlantic salmon in the North Atlantic.

As an additional note, recreational anglers in Norway have reported widespread dislike of invasive pink salmon (Guay *et al.* 2024). If pink salmon come to dominate the number of salmonids in rivers, this will likely also negatively affect the economic value and ecosystem services of Atlantic salmon angling in rivers (Hindar *et al.* 2020).

In conclusion, the possibility for interactions between pink salmon and Atlantic salmon in freshwater is large. However, there are huge knowledge gaps regarding the impacts of pink salmon on Atlantic salmon in rivers, because very few studies have been conducted so far. New research is needed to understand the role and potential future impacts of pink salmon and which level of mitigation measures are subsequently needed.

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Pink Salmon at Sea: Current Knowledge, Overlap and Potential Interactions

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1. Spatial and Temporal Distribution in the North Atlantic Ocean.

Pink salmon, *Oncorhynchus gorbuscha*, is a new species in the Atlantic Ocean due to intentional introductions to create new fishing opportunities. Attempts of introductions occurred in the early 20th century in the east coasts of USA and Canada, and in the northwest coast of Russia (NHPSEG 2023). There is also a record of one stocking in southern Norway in 1978 (Sandlund *et al.* 2019). It is believed that the introduction in 1984 of ova to Kola Peninsula rivers in Russia from rivers in the Magadan region was the only successful one that led to natural spawning in rivers flowing to the North Atlantic Ocean (NHPSEG 2023). Up to date, presence of pink salmon has been recorded in odd years in rivers in the Fennoscandian peninsula, Svalbard, Scotland, Germany, France, Netherlands, Denmark, Ireland, Faroe Islands, Iceland, Greenland and as far as Newfoundland and Nunavut in the northwest Atlantic. Reports of even-year pink salmon outside the Fennoscandian peninsula have remained low with only one report in the UK (ICES 2022; NHPSEG 2023). Other records outside the native range of pink salmon have been in the western Canadian Arctic, were strayers originated from Pacific populations due to warming temperatures and expansion of their native range (NHPSEG 2023). These results were confirmed by genetic analyses (NHPSEG 2023). In addition, those genetic analyses concluded that even-year pink salmon from all areas analysed were more alike than odd-year pink salmon. Moreover, Norwegian odd-year samples genetically diverged from the samples representing the Russian odd-year source population (Asian Pacific), while the Norwegian even-year samples were still genetically similar to the source population (NHPSEG 2023). A recent ecological niche modelling and population genomics study suggested that the river Neiden in northern Norway could be serving as source population for secondary spread of pink salmon in Norway and the North Atlantic (Maduna *et al.* 2024).

Pink salmon are experiencing distribution changes both in their native and introduced areas due to ocean warming. Many southern populations are negatively impacted, while northern ones have increased in abundance and expanded distribution to Arctic waters in North America and Asia (Farley *et al.* 2020; NHPSEG 2023). Expansion of distribution in the Atlantic has also been linked to high temperatures by different models. VKM *et al.* (2020) found a positive correlation with sea surface temperature in May around Finmark coast and Svalbard with the number of pink salmon returning to rivers the following year. Maduna *et al.* (2024) concluded that habitat suitability in rivers was driven by temperature and precipitation at the time of river ascent and identified a high number of suitable habitats across the Arctic and North Atlantic Oceans. Therefore, there is potential for expansion of pink salmon in the North Atlantic towards southern Europe and the northwest in the coming decades (Maduna *et al.* 2024).

2. Potential Migration Patterns

The above presented range of pink salmon in the North Atlantic is based on river records. Little is known of their distribution and behaviour in their offshore areas in the Atlantic as there are no targeted large-scale and comprehensive monitoring programs on either side of the Atlantic (NHPSEG 2023). Norway has the most experience collecting data on pink salmon. In coastal waters, this data comes from a licensed salmonid fisher using bag-nets, and recreational fishing, using angling, gillnetting, or trolling. In offshore waters, data comes from bycatch in commercial fisheries reported by the Norwegian Reference Fleet (Clegg and Williams 2020) and in scientific trawl surveys targeting other pelagic fish such as the International Ecosystem Survey in Nordic Seas (IESNS) (Diaz Pauli *et al.* 2023). This Norwegian pink salmon bycatch is mainly adult individuals caught in May and June in the Norwegian Sea during their migration back to rivers (from 2013-2023: N =274). In addition, there were 12 post-smolts caught in the Barents Sea in December 2018, 8 post-smolts caught in the Barents Sea in August 2022 and 4 more post-smolts caught by the coast of Finmark in October 2022. A possible sea migration pattern could be that some individuals stay the whole marine life cycle in the Barents Sea, while others go westward to the northern and western Norwegian Sea, which is a feeding and overwinter area for Atlantic salmon (Jacobsen and Hansen 2001; Rikardsen *et al.* 2021). The latter ones could migrate with Arctic water flowing southward during the winter, potentially explaining the strays in Ireland and Scotland and the presence of pink salmon in the southern Norwegian Sea (Diaz Pauli *et al.* 2023). Some pink salmon may probably migrate in spring northwards from the southern Norwegian sea, relatively close to the coast, after spending one year in the sea until reaching rivers in northern Norway and Russia (Diaz Pauli *et al.* 2023). However, it should be noted that the temporal and spatial patterns are linked, limiting our ability to make clear conclusions. Little is known about the individuals staying in the Barents Sea. One possibility is that post-smolts are rapidly taken eastwards by the Norwegian coastal currents towards Novaja Zemlya, as post-smolts occupy the upper layers (Farley *et al.* 2020). This could explain why pink salmon post-smolts are very seldom caught in Norwegian surveys in the eastern and central Barents Sea catching other small pelagic fish. Whether these two different migration patterns result in different populations exploiting different feeding grounds remains unknown.

3. Marine Diet in the Northeast Atlantic

Pink salmon diet in the Norwegian Sea and around Svalbard was dominated by euphausiids, fish and amphipods (Bengtsson *et al.* 2023; Diaz Pauli *et al.* 2023) and is similar to that observed in the Pacific Ocean (Radchenko *et al.* 2018). However, the relative abundance of the dominant prey species in the pink salmon diet depend on their geographical distribution. Pink salmon preyed most on herring, saithe and pricklebacks when caught on the shelf along the Norwegian coast and into the Barents Sea, while they preyed on Mueller's pearlside and lanternfishes when caught south in the Norwegian Sea. Pink salmon caught in the deep basin of the Norwegian Sea (north of 67.5oN) mainly preyed on the amphipod *Themisto sp.* (Diaz Pauli *et al.* 2023). Finally, pink salmon caught around Svalbard preyed mainly on the amphipod *Onisimus litoralis* (Bengtsson *et al.* 2023). Preliminary unpublished stable isotopes analyses indicate pink salmon exploit feeding grounds over a wide area in the North Atlantic and at different trophic levels (Skóra *et al.* 2023), as also observed in the stomach content analyses presented above.

4. Potential Interactions: Overlapping Diet and Distribution

Data on interactions between pink salmon and native salmonids is lacking from both the river and the sea phases in the North Atlantic making any prediction difficult (VKM *et al.* 2020). From the data on geographic distribution and diet in the Norwegian Sea presented above, one could conclude that migration patterns and diet preference of pink salmon overlaps with that of Atlantic salmon, *Salmo salar*, and there is a potential for interaction (Diaz Pauli *et al.* 2023).

There is no consensus on the pink salmon impact on marine ecosystem in the Pacific Ocean (NHPSEG 2023). Most publications concluding that pink salmon impose top-down effects on other marine species are from North America, while most publications concluding negligible effects are from Asia and mostly written in Russian (NHPSEG 2023). In the North American side, pink salmon can initiate trophic cascades by reducing herbivorous zooplankton and engage in interspecific competition with many economically important forage fish as well as other marine species (Ruggerone *et al.* 2023). However, there is also evidence suggesting that the feeding areas and habits among Pacific salmon species often indicate complimentary interactions, instead of competitive (NHPSEG 2023). The different impact of pink salmon on the ecosystem in the American and Asian part of the Pacific Ocean could be related to their differences in productivity. The Pacific Ocean provided approximately 58 % of the total marine catches in the world in 2020, but from this, 24 % occurred in the Northwest Pacific area (i.e. total 19.15 million tonnes) and 4 % in the Northeast Pacific (i.e. total 2.86 million tonnes; FAO 2023). The Atlantic Ocean provided 26 % of the marine catches in 2020, from which 11 % was caught in the Northeast Atlantic (i.e. total 8.31 million tonnes) and 2 % in the Northwest Atlantic (i.e. total 1.54 million tonnes; FAO 2023). The higher productivity in the Northwest Pacific relative to the Northeast Pacific could potentially explain why the impact of pink salmon is lower in the Northwest. The Northeast Atlantic is a relatively high productive area, and thus it might be more comparable to the Northwest Pacific when considering the potential influence of pink salmon on other species.

Just for comparison, in the Northwest Pacific Ocean, 146,423 tonnes of pink salmon were fished at sea in 2022, while 112,085 tonnes of pink salmon were fished in the Northeast Pacific Ocean in the same year (NPAFC 2023). This is roughly equivalent to 179,473,000 individual pink salmon fished in the Pacific Ocean in 2022. In Norway in 2023, approx. 350,000 individual pink salmon were fished out, including license salmon fishery and removal of individuals from mitigation programs (SSB 2023). Given an individual body weight of 2.0 kg (average body weight of pink salmon caught in the recreational fishery in rivers in 2023), the biomass of pink salmon caught in Norway in 2023 was 700 tonnes, which is equivalent to 0.08 ‰ of the total fish catches in the Northeast Atlantic in 2020. Despite little knowledge about pink salmon species interactions offshore in the North Atlantic, the biomass of pink salmon is presently too low to have a noticeable grazing effect on the large offshore ecosystems which supports large pelagic or semi-pelagic marine stocks such as herring, capelin, saithe, haddock, mackerel, and blue whiting. However, pink salmon might have some local impact on estuaries, fjords, and coastal areas both during the smolt migration and the spawning migration (Diaz Pauli *et al.* 2023).

Sea trout, *Salmo trutta*, are distributed from the Bay of Biscay in the south to the Barents Sea in the north and sea-going Arctic char, *Salvelinus alpinus*, are common in polar regions such as Canada, Iceland, Norway, Sweden and Russia (Klemetsen *et al.* 2003), and these species mainly feed in coastal waters. Therefore, adult pink salmon feeding intensively in coastal areas when migrating towards rivers can potentially have a negative impact on prey availability for Arctic char and sea trout along the coast. The only direct diet comparison between pink salmon and native salmonids that we are aware of is from Svalbard with Arctic char (Bengtsson *et al.* 2023). They sampled Arctic char and pink salmon in six locations around Svalbard between 2015 and 2018 and concluded that their invertebrate diet overlap was intermediate to high ($O_{obs} = 0.59$), when both species co-occurred in the same fjord (1 out of 5 fjords studied; Bengtsson *et al.* 2023). However, pink salmon fed more on intertidal invertebrates. In addition, the salmonid species differed in their fish diet. Arctic char ate most pelagic fish, while pink salmon ate demersal species, indicating that they occupy different areas and parts in the water column. Bengtsson *et al.* (2023) concluded pink salmon fed in intertidal areas on bottom-dwelling prey, while Arctic char fed more in pelagic areas further offshore than in the intertidal zone. It should be noted that all pink salmon sampled were adults with developed gonads which might explain their preference toward the intertidal zone, while juveniles were present in the Arctic char samples (Bengtsson *et al.* 2023). Therefore, adult pink salmon feed close to the coast and fjords, before entering the rivers, where they could potentially impact food availability for other salmonids, such as Arctic char and sea trout.

There is no information about how long pink salmon remains in estuaries in their introduced habitat before their sea migration. While in their native range they might remain between a few weeks to a few months in estuaries and inshore waters, depending on availability of resources (Radchenko *et al.* 2018; NHPSEG 2023). Evidence from the Pacific shows that pink salmon in estuaries feed heavily on pelagic zooplankton and less on benthic and intertidal forms (VKM *et al.* 2020). Pacific pink salmon growth rate in the estuary and first months at sea is extraordinarily high (Radchenko *et al.* 2018). Recent work of Erkinaro *et al.* (2023) showed that pink salmon juveniles sampled in the estuaries in late May and June have stomachs 50-75 % full. Therefore, there is a potential for competition for resources with other species in estuaries and inshore waters. However, in these areas, salmonids also suffer great mortality, mainly by predation. In this case, small individuals like pink salmon are expected to be most vulnerable to a wider range of potential predators, as it has been observed in estuaries of the Pacific (Duffy and Beauchamp 2008). Thus, in estuaries and inshore areas, pink salmon might be a good food source for other salmonids (ICES 2022). Little is known about when migration to open ocean occurs in either the native or introduced ranges. It does not seem related to size or time in freshwater, but there are some indications that it could be driven by an increase in temperature (Radchenko *et al.* 2018). Knowledge about this life history phase in the introduced range is important for understanding potential interspecific interaction with native species.

Lack of knowledge is the limiting factor in assessing the ecological impact of pink salmon in the Northeast Atlantic. Studies from their native range are very useful for predicting potential impacts. However, there is evidence that the introduced population are rapidly adapting to the new environment. Thus, the comparison with the native range might be less relevant than previously expected. Comparison of individuals (adults, juveniles and smolts) from the Ola River (source of the introduction in Russia) and several rivers in the basins of the White and Barents Seas (introduction areas) showed that native and introduced individuals differed in body weight, and various morphological and life-history traits (Gordeeva and Salmenkova 2011). The differences between source and introduced populations were due to a mixture of adaptation, phenotypic plasticity and random genetic change (Gordeeva and Salmenkova 2011). Changes in morphology in the introduced odd-year populations seem to be linked to the slower flow and the larger size of gravel in the rivers of the White Sea basin (Gordeeva and Salmenkova 2011). Changes in life cycle and reproduction in odd-year populations were larger than the morphological ones. The start of the smolt migration occurred one month later, while the spawning migration happened earlier, resulting in a shorter foraging marine phase in the introduced population compared to the source. However, the introduced individuals were on average equal in size or larger, and hence they grew faster than the individuals in the source area (Gordeeva and Salmenkova 2011). The extended freshwater phase in the novel habitats was probably due to later water warming in spring and early decrease in water temperature in fall (Gordeeva and Salmenkova 2011). Introduced pink salmon in Russian rivers also had higher fecundity but lower ovary weight and smaller eggs. The migration-cost hypothesis in salmonids postulates that reproductive investment directly depends on migration distance and therefore populations with longer migrations generally have smaller eggs (Kinnison *et al.* 2001). If this is true, Gordeeva and Salmenkova (2011) postulated that the migration routes of introduced pink salmon in the North Atlantic could be longer than those of the source population in the Pacific Ocean. Another example showing differences between introduced and source pink salmon populations comes from the Great Lakes, where introduced pink salmon are no longer anadromous and spawn as three year olds (Anas 1959). Overall, there is little knowledge on the introduced pink salmon ecology in the marine phase. Particularly important is the beginning and the end of the marine phase, as pink salmon impact might be strongest in local habitats, as estuaries, fjords and coastal areas. A key question is whether post-smolt stay inshore for months where they are important prey and predators or whether they are taken by currents rapidly offshore. Communication and collaboration among researches throughout the whole pink salmon distribution is crucial for ensuring knowledge is evenly distributed among all areas where pink salmon may have an impact (NHPSEG 2023). However, pink salmon is not only on the move, but also changing and adapting to the new environments, and thus knowledge might not always be directly applicable in the new introduced areas. Therefore, direct research on pink salmon ecological impact on introduced areas is key, as well as assessing changes in its life history relative to native areas to better understand its invasive potential.

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Parasites and Diseases Associated with Pink Salmon

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Abstract

The objective of this abstract is to present a concise overview of parasite and diseases potentially associated with pink salmon and the potential risks for Atlantic salmon. What does monitoring show so far, what are potential future risks, and what are the knowledge needs?

What Does Monitoring Show so Far?

Parasites

Several Russian researchers have conducted systematic studies of the parasite fauna in pink salmon in the White Sea and Barents Region and some of these have compared with the fauna of pink salmon in the Pacific region (Ninburg 1963; Grozdilova 1974; Barskaya *et al.* 2005; Ieshko *et al.* 2016; Rullestad 2021). In Norway, two comprehensive studies of parasite fauna have been conducted from pink salmon caught in rivers on the west coast in 2017 (Fjær 2019) and from pink salmon caught in the Norwegian Sea during the period 2013-2019 (Rullestad 2021). Table 1 presents an overview of parasites found in pink salmon in the White Sea / Barents Sea area and Northern Atlantic Ocean. In 2023, the Institute of Marine Research in Norway (IMR) included pink salmon in the national surveillance program for salmon lice. The results are presented here:

https://hi.no/hi/nyheter/2023/november/fant-lus-ogsa-pa-pukkellaks.

The studies show that the parasite fauna of pink salmon is dominated by marine parasites, corresponding to pink salmon spending the majority of their life in the marine environment. The parasite fauna indicate that pink salmon in the North Atlantic and the Barents Sea / White Sea occupy the same niche in the ecosystem as they do in their native habitats (Sokolov *et al.* 2024).

Risk for Atlantic salmon: Parasites may have a simple direct life cycle or a complex life cycle involving several hosts. For parasites that have a direct life cycle, susceptible pink salmon will increase the number of susceptible hosts and thus contribute directly to the infection dynamics by increasing the reproduction rate R, increase the risk of transmission to wild Atlantic salmon, bridge the gap between farmed and wild populations or between geographical areas. The impact of this contribution is highly dependent on the number of pink salmon present.

Human health risk: Rullestad (2021) found the zoonotic nematode *Anisakis simplex* in the muscle of 23 % of examined pink salmon. Sokolov and co-workers also recorded an increase in *A. simplex* abundance in 2021 compared to earlier years. Although freezing kills the parasite, and eliminates the risk of human anisakidosis, it should be noted that allergic reactions may occur in humans.

Microparasites, Virus and Bacteria

PCR- based screening has so far been focused on a very limited number of pathogens, notably those that are relevant for the aquaculture industry. Table 2 presents an overview of results from PCR based studies of micro parasites in pink salmon in Norway and Ireland.

Culture based screenings for bacteria and virus are rare, but were conducted by the Norwegian Veterinary Institute (NVI) in 2023. Cultures from the kidney of pink salmon on suitable agars for bacteria did not detect *R. salmoninarum* or *Aeromonas salmonicida* subsp. *salmonicida* (listed as category F infections in Norway), but there was growth of other bacteria commonly found in the environment, several of which can be opportunistic pathogens in fish. Culture for viruses was only conducted from nine pink salmon and were without any findings (Sommerset *et al.* 2024).

In summary, listed virus or bacterial infections have not been detected so far. However, the virus PRV-1 has been detected in several cases. PRV-1 is a common virus in farmed and wild Atlantic salmon in Norway and has also previously been detected in pink salmon in the Pacific Ocean (Purcell *et al.* 2018).

Risk-based Health Monitoring

The health monitoring efforts described so far have been conducted in randomly selected, apparently healthy pink salmon, while examination of fish showing signs of disease may be more informative.

In 2021, a pink salmon with symptoms resembling typical furunculosis (*Aeromonas salmonicida* subsp. *salmonicida* infection) was found in the River Gjersjøelva near Oslo, Norway. Culturing from internal organs and muscle yielded significant growth of the bacterium *Aeromonas hydrophila*, an ubiquitous opportunistic pathogen, meaning it can cause disease in fish, humans, and a wide range of other animal species when conditions are favourable (Sommerset *et al.* 2020). This finding may be an example of how susceptible pink salmon are either covert carriers of an infection that is activated during spawning or get infected by an opportunistic pathogen that is present in the freshwater environment. Either way, such pink salmon will shed bacteria to the environment and increase the infection pressure for native fish in affected rivers.

In 2022, the parasite *Ichthyophonus* sp. was detected in a moribund pink salmon from the River Lakselva in Norway. *Ichthyophonus* sp. occurs in a wide range of fish species in freshwater and marine environments and has caused mass mortality of herring. In Chinook salmon in the Yukon River, the parasite has caused significant challenges affecting survival, spawning success, and fillet quality (for consumption) (Kocan *et al.* 2004; Kocan *et al.* 2006). In the specific pink salmon from Lakselva, there was little evidence that tissue reactions with white nodules affected fillet quality. However, the examination only involved one fish (Sommerset *et al.* 2023; Erkinharju *et al.* submitted 2024). The pink salmon was most likely infected by ingesting infected prey (Kocan *et al.* 2019). The prevalence of this parasite in pink salmon is currently unknown, and the impact on Atlantic salmon is also unknown due to lack of knowledge regarding the parasite's potential for horizontal transmission between these species.

Potential Risks for Atlantic Salmon

Introduction of an alien invasive species is associated with a risk of introducing new pathogens or alternatively a risk of expanding the range or impact of pathogens that already exist in the particular geographical area or environment.

Pink salmon were translocated from the Pacific Ocean to the White Sea area as fertilised eggs. The risk of introducing new pathogens is therefore primarily associated with pathogens that can either be present within the fertilised egg (true vertical transmission), as contamination on the surface of fertilised eggs, or in the transport water. This reduces the probability of introducing for instance larger parasites. The biosecurity measures during the translocation operations are of interest in this context. Were the broodfish healthy? Were the eggs disinfected before translocation or upon arrival at the hatchery? The translocations ended in 1999, which means that this particular threat is not active today. But we cannot rule out the possibility that pathogens were introduced and established in the new environment.

Long distance marine migrations and straying into new rivers and regions may create a connection between geographical areas that may lead to movement of pathogens between areas. Pink salmon may for instance be exposed to pathogens from aquaculture sites in one geographical area and carry it to new regions (Hindar *et al.* 2020).

The significant increase in population and spread of the pink salmon in recent years suggests that they are well adapted to the new environment. During health checks, pink salmon may appear 'healthier' than for instance wild Atlantic salmon. Several pathogens may persist in fish after infection and potentially be activated later in life. Accordingly, the prevalence of certain pathogens increases with age. The short life cycle of pink salmon can thus result in less time to be exposed to and accumulate pathogens, both in the freshwater phase and the marine phase. It has also been suggested that introduced species may have fewer enemies in the new environment (Paterson 2023). According to the ‘enemy release hypothesis’, introduced species are released from their ‘old’ enemies - competitors, predators, and disease-causing organisms - when transferred to a new area. This release should provide a basis for growth and success in the new area. Thus, the pink salmon now spreading in Europe are conquering new areas without encountering the same challenges that native species in established ecosystems face (Paterson 2023).

There is still a lack of knowledge about the susceptibility of pink salmon to virus, bacteria and parasites that are present in wild and farmed fish in the North Atlantic and Barents region. There are already enemies present, either as pathogens that are native to the North Atlantic region and more pathogenic to Pacific salmonids, or already established by previous introductions of other pacific salmonids (Infectious hematopoietic necrosis virus (IHNV).

Potential Future Risks

The most essential factor pertaining to the risk of pathogen interactions and disease caused by the presence of pink salmon is the number present on a local scale. Accordingly, all factors contributing to an increase of the number of pink salmon constitute a risk. This includes changing climate (melting of the ice cap), proliferation of even-year pink salmon or unhindered spread of the species.

Knowledge Needs

The reservoir of many of the pathogens reside in farmed salmonids in open net pens along the coast. Accordingly, knowing how pink salmon interact with marine aquaculture sites is essential for understanding their role in pathogens transmission and disease interaction between pink salmon, and farmed and wild native populations.

Detection of pathogens in samples from pink salmon does not provide sufficient information about the host-pathogen interaction. Meaning that pathogen presence is not evidence of infection, and furthermore not evidence of proliferation and shedding of the pathogen. Experimental transmission trials and cohabitation trials makes it possible to study host-pathogen interactions, for instance how susceptible pink salmon are to some of the important pathogens that are present either in European salmon farming or in wild salmonid populations (for instance common bacteria, virus, G. *salaris*).

After spawning, the pink salmon carcasses provide nutrients to both the freshwater and the terrestrial ecosystems. Bacteria, oomycetes and fungi that establish and proliferate in the moribund fish and contribute to the decomposition of the carcasses are released into the aquatic environment and influence the microbial community. Some of these microorganisms are opportunistic pathogens - we need more information about the impact of altered microbiota on Atlantic salmon.

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Table 1. *Comparative overview of parasites found in pink salmon in North Atlantic (Norway, Ireland) and the White Sea / Barents Sea region.*

	Norway, Ireland	White Sea and Barents Sea
Fungi, Microsporidia	*Desmozoon lepeophtherii* (syn. *Paranucleospora theridion*)	
Animalia, Protozoa	*Ichthyophonus* sp., *Ichthybodo* sp	*Ichthybodo* sp
Animalia, Gnidaria, Myxozoa	*Parvicapsula pseudobranchicola*	
Animalia, Plathyhelminthes, Trematoda	*Apatemon gracilis (Diplostomata), Brachyphallus crenatus, Cryptocotyle lingua, Derogenes varicus, Hemiurus communis, Hemiurus levinseni, Hemiurus luehei, Lecithaster gibbosus,*	*Brachyphallus crenatus, Derogenes varicus, Digenea gen* sp., *Diplostomum* sp. *Ichthyocotylurus erraticus Lecithaster gibbosus, Podocotyle atomon, Podocotyle reflexa*
Animalia, Plathyhelminthes, Monogenea		*Gyrodactyloides bychowskii, Discocotyle sagittata*
Animalia, Plathyhelminthes, Cestoda	*Bothriocephalidea gen.* sp, *Clistobothrium* sp., *Diphyllobothrium* sp., *Eubothrium crassum, Scolex Bothriosimplex*[1], *Scolex pleuronectis*[2]	*Bothriocephalidea gen.* sp, *Cyathocephalus truncatus, Diphyllobothrium* sp., *Eubothrium crassum, Diplocotyle olrikii, Scolex pleuronectis*[2]
Animalia, Acantocephala		*Echinorhynchus gadi*
Animalia, Nematodea	*Anisakis simplex* (kveis), *Hysterothylacium aduncum,*	*Anisakis simplex* (kveis), *Hysterothylacium aduncum, Pseudoterranova decipiens*
Animalia, Crustacea	*Caligus elongatus, Lepeophtheirus salmonis, Salmincola salmoneus*	*Lepeophtheirus salmonis, Salmincola salmoneus*
Animalia, Mollusca (glochidia)		*Unionidae* gen. sp. (glochidia)
Reference	Fjær 2019; Garseth *et al.* 2020; Rullestad 2021; Sommerset *et al.* 2023	Ninburg 1963; Grozdilova 1974; Barskaya *et al.* 2005; Ieshko *et al.* 2016

Table 2. *Overview of results from PCR analyses for microparasites, virus and bacteria from North Atlantic pink salmon.*

Year	**2007**	**2017**		**2019**	**2013-2019**	**2021**	**2023**
Location (number tested)	Tana (38), Neiden (36)	Etne, Ekso, Norway	Ireland, several rivers	Karpelv, Norway (60)	Norwegian Sea (86)	Several rivers in Norway (181)	Six rivers in Finnmark
Pathogens							
IHNV (Infectious haematopoietic necrosis v.)	0	0/40	-	0	0	0	0
VHSV (Viral hemorrhagic septicemia v.)	-	-	0/13	0	-	0	0
ISAV (Infectious salmon anaemia virus)	0	0/40	-	0	0	0	0
SAV (Salmonid alphavirus)	-	0/40	0/15	0	0	-	-
IPNV (Infectious pancreatic necrosis v.)	0	0/40	-	-	0	-	-
SGPV (Salmon gill poxvirus)	-	-	-	0	-	-	-
ASCV (Atlantic salmon calicivirus)	-	-	-	0	-	-	-
PRV-1 (Piscine orthoreovirus-1)	-	-	-	4	2	8/181	0
PRV-3 (Piscine orthoreovirus-3)	-	-	-	0	-	-	-
PMCV (Piscine myocarditis virus)	-	0/40	-	0	0	-	-
Renibacterium salmoninarum	-	-	0/13	0	-	0	0
Ca. Branchiomonas cysticola	-	1/43	-	0	-	-	-
Desmozoon lepeophtherii	-	26/43	-	2	-	-	-
Spironucleus spp.	-	0/43	-	-	-	-	-
Parvicapsula pseudobranchicola	-	4/30	-	0	0	-	-
Paramoeba perurans	-	-	-	0	-	-	-
Ichthyobodo sp.	-	39/43	-	-	0	-	-
References	Skjåvik 2008	Fjær 2019	Millane *et al.* 2019	Garseth *et al.* 2020; Sommerset *et al.* 2020	Rullestad 2021	Sommerset *et al.* 2022	Sommerset *et al.* 2023

Contributed Papers

Management of Pink Salmon in Atlantic Salmon Systems

Photo: Tom Staveley

Overview

The third sub-objective of the TBSS was to provide an overview of both management approaches and management perspectives associated with pink salmon. The speakers within this session provided a detailed overview on the use of environmental DNA (eDNA) to monitor the presence and abundance of pink salmon and to describe case studies where this technology has been employed successfully. They provided an overview of the current monitoring and management approaches to controlling the pink salmon invasion within Norway as well as approaches being used in areas outside of Norway where the abundance levels are estimated to be much lower. They also provided an overview of pink salmon within the Russian Federation where the species is considered a positive socio-economic resource. Speakers were also asked to comment on what are the management-focused knowledge needs moving forward.

The invited experts were chosen by the Steering Committee based on their status in their field of expertise and their experiences related to the management of pink salmon within these Atlantic salmon systems. The following four presentations were delivered to address this third sub-objective, with all the invited speakers providing a paper to NASCO prior to the TBSS. After the presentations there was a question and answer session (Q&A), which can be found at the end of the report.

- Frode Fossøy presented a summary of using environmental DNA (eDNA) to estimate pink salmon distribution;
- Sergey Prusov presented a summary of Russian perspectives on pink salmon;
- Eirik Frøiland and Malin Høstmark presented a summary of measures undertaken to control pink salmon in Norway; and
- Tom Staveley presented an overview of the monitoring and management of pink salmon outside of Norway and the Russian Federation

CNL(24)50

Using Environmental DNA (eDNA) to Estimate the Distribution of Pink Salmon

Frode Fossøy, Norwegian Institute for Nature Research (NINA), Norway

eDNA as a Monitoring Tool

Analysis of environmental DNA (eDNA) is a cost-efficient method for detecting single species and / or monitoring biodiversity in water samples collected in rivers and lakes (Taberlet *et al.* 2018). eDNA consists of genetic material such as saliva, faeces, scales, hair, etc. that are shed to the environment by living organisms. By filtering water, we can collect this eDNA and use genetic analyses to identify the species living in the environment. Comparisons with conventional methods show that analyses of eDNA often are more sensitive in detecting rare species and can recover a larger part of the total biodiversity in each locality (Valentini *et al.* 2016). The method has also proven very effective in monitoring invasive species (Fossøy *et al.* 2019; Sepulveda *et al.* 2020; Taugbøl *et al.* 2021). At the Centre for Biodiversity Genetics (NINAGEN) at the Norwegian Institute for Nature Research (NINA), we have developed genetic tools for analysing eDNA and implemented standard protocols for many aquatic organisms (Fossøy *et al.* 2017; Taugbøl *et al.* 2017; Fossøy *et al.* 2018; Taugbøl *et al.* 2018; Fossøy *et al.* 2019; Wacker *et al.* 2019). Together with colleagues at the University College in Dublin (UCD), NINA has recently verified a new genetic eDNA marker for detecting pink salmon *Oncorhynchus gorbuscha* (Gargan *et al.* 2021). Several studies suggest that eDNA-concentrations also can reveal quantitative information on fish biomass (Rourke *et al.* 2021), hence making this tool suitable for monitoring population changes.

Monitoring the Distribution of Pink Salmon in River Tana Using eDNA

The river Tana represents one of the largest catchments in Norway and supports the largest Atlantic salmon *Salmo salar* population among Norwegian rivers (VRL 2022). However, the Tana salmon stocks have declined dramatically in recent years (Anon 2021) and salmon fishing has been ceased since 2021. At the same time the invasive pink salmon have increased explosively, particularly in odd years. From the occasional catch of tens or hundreds of fish per year during the last decades, ca. 5,000 pink salmon were assumed to enter the river in 2017 and 2019, more than 50,000 in 2021 and 170,000 individuals in 2023. Conventional monitoring has traditionally been limited to a few sites, and increasing the number of sites is costly. eDNA has therefore been implemented as a cost-effective alternative since 2019, monitoring 24 different tributaries covering most of the Tana Catchment (Fossøy 2022). Whereas pink salmon was detected in 6 out of 19 localities in 2019, it was detected in 15 out of 24 localities in 2021 and 22 out of 24 localities in 2023, showing a large increase in DNA-concentration. In comparison, the eDNA-concentration of Atlantic salmon has remained quite stable across the same period. The river Tana was also sampled in one even year, in 2022, where only 4 out of 24 localities showed sign of pink salmon (Figure 1). Results from this and other studies suggest that eDNA can be used for monitoring changes in abundance using longitudinal data, at least within localities or rivers.

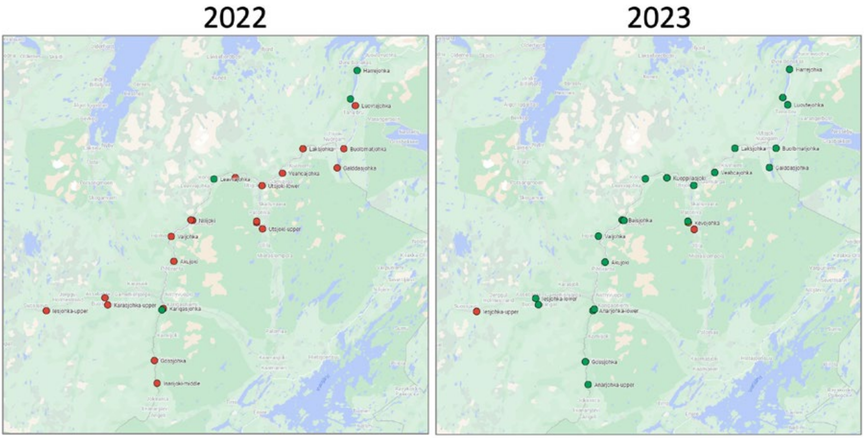

Figure 1. *Map showcasing the difference between an even and odd year in the river Tana. Green circles show presence of pink salmon eDNA and red circles show negative results.*

Monitoring Pink Salmon Across Europe Using eDNA – The PINKTrack Project

This EU-funded project intends to address the concern about pink salmon invasion under the beneficiary of NASCO, through a consortium comprised of state agencies and research institutes based in EU jurisdictions which is supported by technical expertise from Norway. The project will undertake work to better understand the extent of occurrence of pink salmon in EU waters through the use of eDNA, which will enable it to elucidate temporal and geographic patterns of spread and provide an 'early warning system' of their presence to inform appropriate management responses. The project includes development of standardised protocols for eDNA sampling and standardised approaches for the analyses of eDNA with the intention that such methods can continue to be utilised in routine national monitoring programmes after the project concludes. This includes preparatory work to evaluate different approaches to sampling and analyses and their effect on the results for detection. Establishment of a repository of eDNA samples collected during the project and in subsequent years will be made to provide valuable material for future assessments as analytical technologies develop.

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CNL(24)47

Perspectives on Pink Salmon in the Russian Federation

Sergey Prusov[1]

Introduction

In the Northern fisheries basin pink salmon (*Oncorhynchus gorbuscha*) is an introduced species of Pacific salmon. First experiments to introduce salmon from the Far East into waters of the Kola Peninsula were carried out in the 1930s, when chum salmon (*Oncorhynchus keta*) was chosen as a species for introduction. The experiments were, however, unsuccessful and the project was closed. It was resumed in 1956 when pink salmon was chosen as a target species for experiments. This species was considered most suitable for introduction since its juveniles do not stay for a long time in rivers, they feed poorly during the migration period and adult fish return to spawn after only 13-15 months of their sea migrations. It was suggested that the White Sea rivers had many spawning grounds suitable for pink salmon and that the fish would make use of food availability in the White Sea and would not undertake extensive migrations. The goal of the project was acclimatization of pink salmon in the area. With abundant enough fishable stocks established the Northern basin fishing industry would get additional resources for the fishery.

From 1956 to 1980 over 200 million artificially fertilized eggs were transferred to the Kola Peninsula, mostly from South Sakhalin. During that period, significant year-to-year variations in returns of adult fish were observed in the area of introductions as well as a rapid decline of abundance of developing stock in the absence of additional transfers of eggs from the native area. As the temperature conditions in the White Sea rivers were found to be the only constraint for the natural pink salmon reproduction, it was decided to use the northern pink salmon populations from the Magadan region as donors. For introductions fertilized eggs of pink salmon from the Ola River were used, which at the stage of eyed egg were transferred to the Murmansk region hatcheries for artificial incubation (Gordeeva *et al.* 2015).

The 1985 introduction using eggs from the Magadan pink salmon of odd-year spawning line laid the foundation for the growth of its natural production in the new area. In 1989 a massive run of pink salmon from natural spawning was observed in rivers of the Kola Peninsula. In the same year, odd-year spawning pink salmon eggs from the Far East were transferred for the last time. There were no transfers of eggs until 1998, when even-year spawning pink salmon eggs from the Ola River were incubated for the last time (Alekseev *et al.* 2019).

[1] Polar branch of VNIRO («PINRO» named after N.M.Knipovich), 6 Academician Knipovitch Street, 183038, Murmansk, Russian Federation

In the new area pink salmon have spread widely in rivers of the White and Barents Seas. To the east of the Kola Peninsula they come into rivers flowing into the Kara Sea - Ob', Taz, Yenisey. Now, the Pyasina River, which estuary is located in the south-west of the Taymyr Peninsula, is the eastern most point of pink salmon distribution in the Kara Sea basin (Bogdanov and Kizhevatov 2007; Bogdanov and Kizhevatov 2015), while the Tymyr Peninsula is considered a natural border between native and new area of pink salmon distribution.

Regulation

There are at present two anadromous species in the Northern fishery basin, Atlantic salmon (*Salmo salar*) and pink salmon, whose life cycles include extensive periods in marine and freshwater habitats. Both are included in the List of Anadromous Fish (Rosrybolovstvo's Order 147 of 26 Feb 2009). Their fisheries in the Russian Federation's internal waters and territorial sea are carried out in accordance with Article 29.1 of Federal Law 166-FZ of 20 Dec 2004 'On fisheries and conservation of aquatic biological resources'.

Management of anadromous fish fisheries in the Russian Federation is based on decisions of a commission for regulation of fishery of anadromous fish (hereinafter referred to as Commission). The Commissions are established by the relevant subjects of the Russian Federation. They are headed by the highest rank official of the subject. Annually, the Commissions decide on the catch limits, times, locations of harvesting as well as other conditions of fisheries for anadromous fish.

Fishing for anadromous species in commercial, coastal, traditional and recreational fisheries is only allowed on the basis of contract for use of fishing site and within its limits, except for recreational fishing for pink salmon outside the limits of fishing sites, in waters which are not Atlantic salmon spawning grounds, within the boundaries of the Murmansk and Archangelsk regions, Nenets Autonomous Okrug, Republic of Karelia and Komi Republic.

Fishery of aquatic biological resources in the Northern fisheries basin is regulated by the Fisheries Regulations for the Northern fisheries basin (current version is approved by Order No. 292 of 13 May 2021 by the Ministry of Agriculture of Russia (hereinafter referred to as the Fisheries Regulations).

The Fisheries Regulations stipulate some restrictions in relation to pink salmon and most of them are similar to those established for Atlantic salmon and aimed, in the first place, at conserving the native species. For instance, fishing for Atlantic salmon and pink salmon is prohibited:

- in the Barents Sea from the Varanger Fjord in the west to Cape Svyatoy Nos in the east;
- outside the fishing sites in rivers and creeks, which are Atlantic salmon spawning grounds;

- on days (periods), as established by the Commission, to allow spawners to migrate to spawning grounds;
- in estuaries of Atlantic salmon rivers and creeks in the Murmansk region, at the distance less than 500 m from each side of the estuary and at the same distance offshore where the rivers enter the sea;
- in commercial fisheries in Atlantic salmon rivers and creeks of the Murmansk region where net gears are used, except for counting fences deployed in accordance with the decision of the Commission; and
- in recreational fishery in the Murmansk region with stationary pound nets of different types and with gill nets both drift and fixed.

Catches

Similarly to its native area, pink salmon introduced into waters of the North West of Russia have two genetically distinct lines (odd-year and even-year). In the new area, however, the species forms commercial fish stocks only in odd years in the White Sea basin where it has been harvested in coastal areas and at counting fences in some rivers since 1960s. The largest catches were recorded in the Murmansk region, where before the 2000s they exceeded 100 t four times – in 1973, 1975, 1977 and 1997. In 2001 the catch for the first time was as big as 300 t, but later, until 2015, the catch in odd years varied from 45 to 118 t. Since 2015, the catch of pink salmon in odd years was increasing and reached 382 t in 2019 and in 2021 exceeded 600 t, with 400 t taken at the counting fence in the Varzuga River. In 2023, the pink salmon catch in the Murmansk region was 155 t, with 137 t of it taken in commercial fisheries and 17 t in recreational fishery on fishing sites. There are no estimates of recreational catches by anglers catching pink salmon outside the fishing sites, in waters that are not Atlantic salmon spawning grounds. In 2023, the total nominal catch of pink salmon in the European North of Russia amounted to 206 t which was 71 % less than in 2021 and 47 % and 21 % less than the average catch of pink salmon in previous 5 and 10 odd years, respectively (Table 1).

The pink salmon fishery in the White Sea is conducted both in 'traditional' fishing sites used mostly for Atlantic salmon fishery and in 'new' sites allocated for pink salmon fishery, e.g. in sites in the Kandalaksha Bay where Atlantic salmon fishery is prohibited by the Fisheries Regulations. In the Murmansk region, at one fishing site, as a rule, one stationary pound net of a design typical for the White Sea is used (Figure 1).

Table 1. *Total reported nominal catches of pink salmon by Northwestern regions of Russia (in tonnes round fresh weight), 1993-2023.*

Year	Murmansk Region			Arkhangelsk	Nenets	Karelia	Total
	Barents Sea	White Sea	Total	region	AO	Republic	catch
1993	0,0	32,5	32,5	28,0	0,0	3,0	63,5
1994	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1995	0,0	19,4	19,4	15,0	0,0	8,2	42,6
1996	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1997	0,0	110,9	110,9	23,9	0,0	3,9	138,7
1998	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1999	0,0	27,6	27,6	16,5	0,0	6,6	50,7
2000	0,0	8,6	8,6	0,7	0,0	1,7	11,0
2001	0,0	296,5	296,5	35,0	0,0	8,1	339,6
2002	0,0	0,8	0,8	0,4	0,0	0,2	1,4
2003	0,0	71,6	71,6	33,3	0,0	46,5	151,4
2004	0,0	0,2	0,2	0,9	0,0	0,1	1,2
2005	0,0	45,4	45,4	46,4	0,0	33,8	125,6
2006	0,0	0,5	0,5	0,3	0,0	0,0	0,8
2007	0,0	84,4	84,4	34,2	0,0	44,3	162,9
2008	0,0	0,0	0,0	0,5	0,0	0,0	0,5
2009	0,0	113,0	113,0	19,5	0,0	6,0	138,5
2010	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2011	0,0	64,0	64,0	34,2	0,1	0,0	98,3
2012	0,0	0,0	0,0	0,1	0,1	0,0	0,2
2013	0,0	117,7	117,7	82,8	0,5	0,0	201,0
2014	0,0	2,8	2,8	7,3	1,0	0,0	11,1
2015	0,1	160,7	160,8	58,7	1,0	0,0	220,5
2016	0,0	3,9	3,9	4,3	0,1	0,0	8,3
2017	0,5	277,1	277,6	92,8	3,1	0,0	373,5
2018	0,0	1,4	1,4	2,9	0,0	0,0	4,3
2019	0,2	381,5	381,7	30,6	2,9	2,6	417,8
2020	0,0	0,3	0,3	0,4	0,2	0,0	0,9
2021	1,1	603,0	604,1	105,8	1,3	4,3	715,5
2022	0,0	2,0	2,0	2,1	0,9	0,1	5,0
2023	6,5	148,1	154,6	44,8	5,8	0,5	205,7
Means (odd years only)							
5YM (2013-2021)	0,4	308,0	308,4	74,1	1,8	1,4	385,7
10YM (2003-2021)	0,2	191,8	192,0	53,8	0,9	13,8	260,5

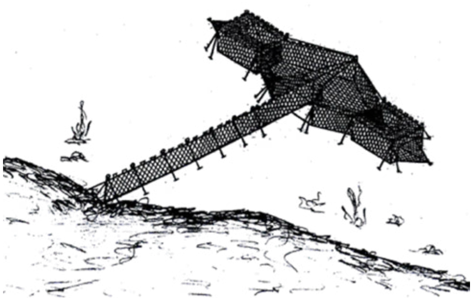

Figure 1. *A stationary pound net used in coastal fisheries in the White Sea.*

The number of fishing sites for harvesting pink salmon in the Kandalksha Bay in the Murmansk Region increased from 15-16 in 2011-2021 to 41 in 2023, while the number of fishing sites for harvesting Atlantic salmon and pink salmon on the Tersky bereg remained unchanged, annually during pink salmon migration season nets there were deployed at 9-11 'traditional' sites. In odd years of 2011-2021 the total catch of pink salmon and the average catch per fishing site (CPUE) in the Kandalaksha Bay over the season showed notable upward trend. Total catch increased from 13-20 t to 182 t, CPUE from 0.8 t to 11.4 t (Figure 2A). On the Tersky bereg the total catch of pink salmon varied from 23 t to 93 t, CPUE from 2.3 t to 9.3 t (Figure 2B). There was no fishery for pink salmon there in 2021 due to administrative reasons. In 2023 both the catch and CPUE in the pink salmon fishery declined sharply in both areas.

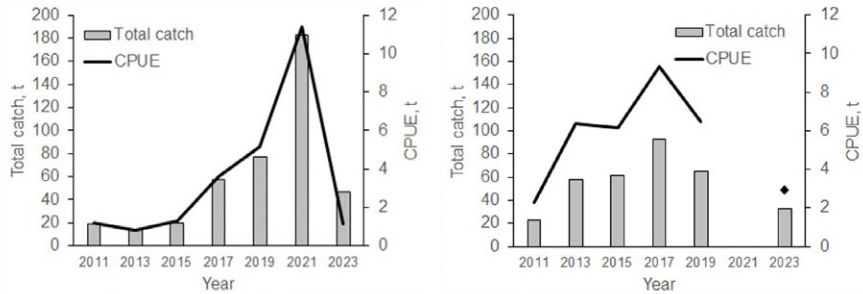

__Figure 2.__ Total reported nominal catch of pink salmon and seasonal mean catch per fishing site (CPUE) in coastal fisheries for anadromous fish in the Kandalaksha Bay (A) and on Tersky bereg (B), 2011-2023.

The catch of pink salmon at barrier fences on the Varzuga and Kitsa (tributary to Varzuga) rivers showed similar dynamics – upward trend before 2021 and sharp decline in 2023 (Figure 3).

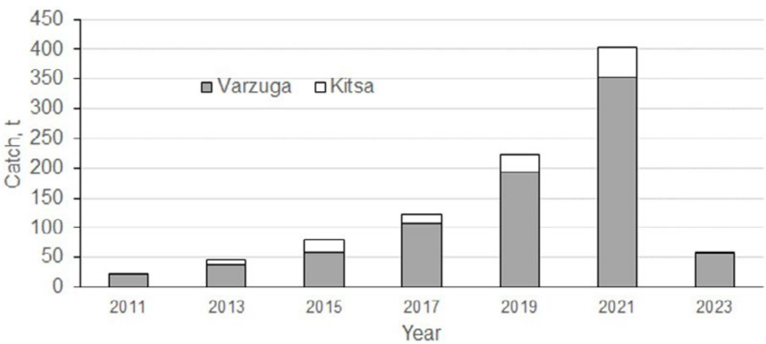

__Figure 3.__ Catch of pink salmon in in-river commercial fisheries for anadromous fish at barrier fences on the Varzuga River and its tributary Kitsa River, 2011-2023.

Pink salmon fishery at counting fences is considered the most efficient way of harvesting the fish that run to spawn. However, for example, in the Murmansk region, where there are more than 27 fishing sites designated for recreational fishery in 23 rivers of the Barents Sea basin and 44 fishing sites in 24 rivers of the White Sea basin, the deployment of counting fences on sites for recreational fishery is prohibited by the Fisheries Regulations. Over the last 20 years, there have only been two counting fences annually deployed for anadromous fish commercial fishery – in the Varzuga River and its tributary Kitsa River (the White Sea basin), whereas in 1958-1997, when Atlantic salmon was exploited commercially on a large scale, the total number of rivers where counting fences were deployed in different years was 36, with the largest number of fences deployed in one year in 1978 – in 23 rivers (Prusov *et al.* 2021).

In 1997, the total nominal catch of odd-year line pink salmon in the Northern fisheries basin for the first time exceeded Atlantic salmon nominal catch (does not include fish caught and released in recreational rod fisheries) and in 2001 it exceeded the nominal catch of the native species by three times (Figure 4).

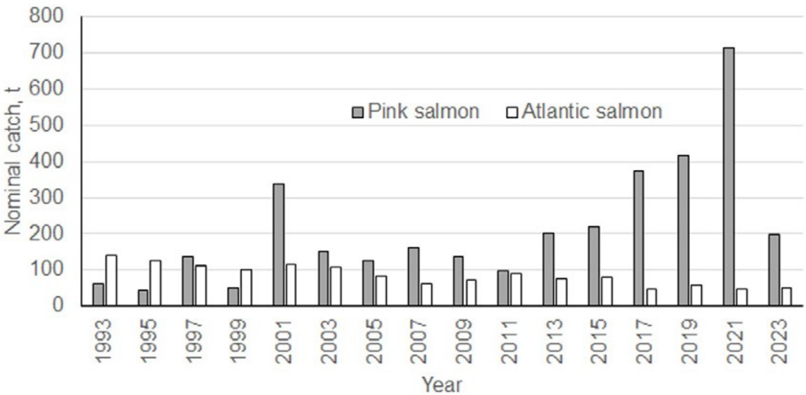

Figure 4. *Total reported nominal catches of pink salmon and Atlantic salmon (does not include fish caught and released in recreational rod fisheries) in the Northern fisheries basin of Russia, 1993-2023.*

Conclusions

Pink salmon in the Northern fisheries basin is a fisheries-targeted species harvested in commercial and recreational fisheries since the 1960s, with numbers of pink salmon of even-year line being quite small in its new area, therefore there is practically no targeted fishery of this group. Since the 2000s the nominal catch of pink salmon of odd-year line has consistently exceeded the catch of the native species, Atlantic salmon. However, in contrast to the Far East where pink salmon is one of the main fisheries-targeted species providing the basis for salmon fisheries (Somov *et al.* 2023), the abundance of pink salmon in the Northern fisheries basin is significantly smaller.

Pink salmon is a short-cycle species of anadromous fish having the life cycle of about two years. It spends only one year in feeding migrations in the sea before spawning, it then migrates into rivers and dies massively after spawning. Because of this specific life pattern, the fishery of pink salmon is supported by only one year-class whose abundance is significantly influenced by various environmental factors both in its river habitat and in the sea. That makes it difficult to forecast the abundance of its spawning run and raises considerably the risks for fisheries as commercial fishery with low catch per unit effort may be economically unjustified.

In the light of the high level of involvement of local communities in the fishery, small size of fishing sites and catch, and short fishing season close to the shore, the fishery for pink salmon in the White Sea can at present be viewed only as artisanal (small-scale), with relatively small investment of funds and energy, small fishing vessels (if there are any) and mainly for local consumption.

In years of high abundance of pink salmon it also becomes quite an attractive species in recreational fishery. However, negative attitudes have been noted among users of fishing sites on some rivers where high numbers of pink salmon may have adverse effects on the quality of exclusive Atlantic salmon catch-and-release fishing, while, on the contrary, attitude towards massive run of pink salmon is more tolerant and even positive on salmon rivers where catch-and-retain fishing also takes place.

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CNL(24)49

Measures to Control Pink Salmon in Northern Norway

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Since 2017 the number of pink salmon in Norway have increased dramatically. The total reported catch in Norway 2017 was 6,289 individuals, at that time seen as an 'explosion' in the occurrence compared with previous years. In 2023, the total catch from targeted measures, coastal fishery and angling have reached 361,548 individuals (miljodirektoratet.no; https://www.ssb.no/).

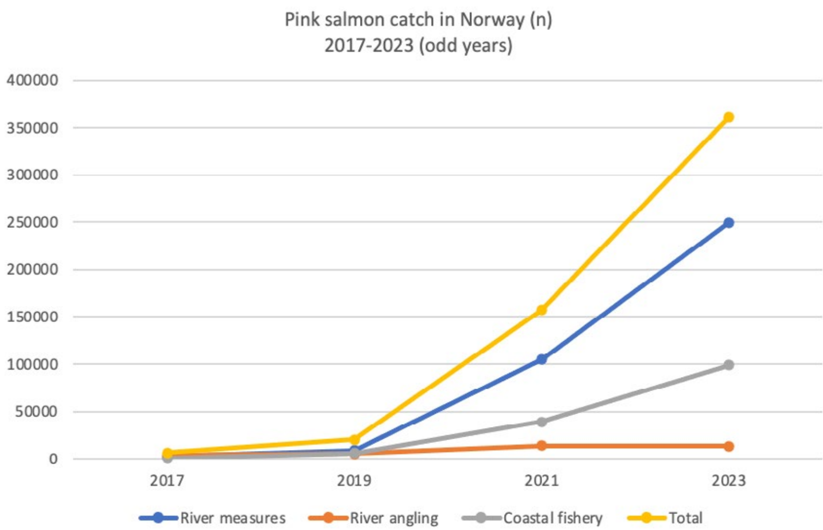

Figure 1. *Numbers of pink salmon caught in Norway (odd years). Data from NEA (river measures, miljodirektoratet.no) and Statistics Norway (coastal bag net fishery and river angling, https://www.ssb.no/).*

Following the second large invasion in 2019, a risk assessment was performed by the Norwegian Scientific Committee for Food and Environment. Several potential threats from pink salmon were identified, towards Atlantic salmon and other biodiversity, water quality and fish health including the aquaculture industry. This was followed up by a national action plan suggested by the Norwegian Environment Agency (NEA) in 2021 (Mo *et al.* 2021). Even though there still is a lack of research and scientific knowledge on the potential adverse impacts from pink salmon, the NEA cannot see the probability of any of the individual risk factors having been reduced since 2019. Furthermore, as the consequence of each factor is related to the number of pink salmon, our assessment that there is a need for precautious action remains.

The NEA is responsible for the measures against pink salmon in Norway. The task of implementing the measures in Northern Norway was given to The County Governor of Troms and Finnmark, as this county is most affected.
The main measure in the action plan is to establish physical control of the spawning migration of all fish in all salmon rivers in a selected target area. The strategy was to use state funded temporary weirs / traps, operated by local anglers' organizations and remove all ascending pink salmon, and at the same time release all native fish with minimal harm and delay.

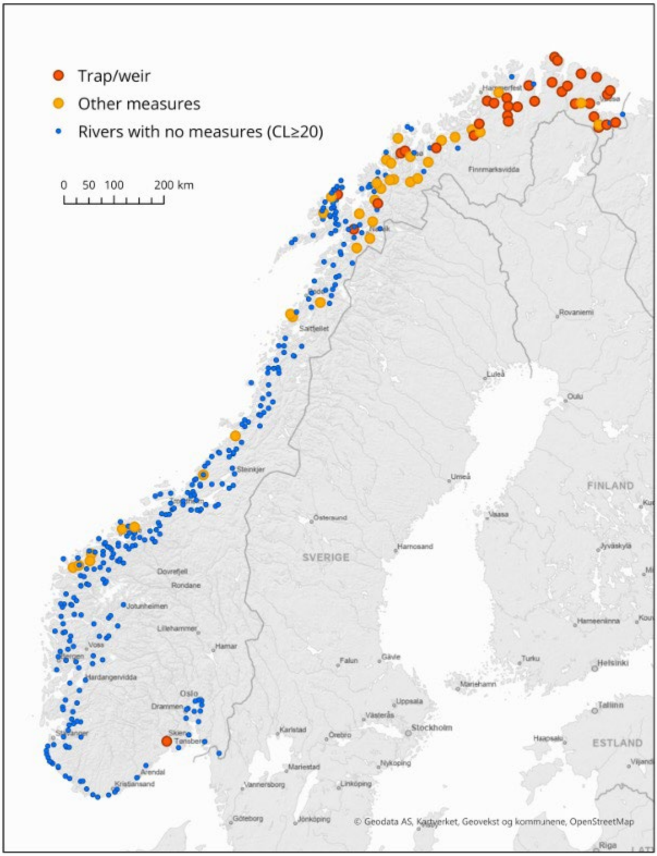

Figure 2. *Geographical location of the weirs (red), other methods (orange) and rives with no measures (blue) in 2023. Figure: Marianne Kvaal.*

In the summer of 2023, there were state funded weirs / traps in 32 rivers from Karpelv in eastern Finnmark to Kvalsundelva in Western Finnmark. The weirs are operated by local anglers' organizations that the County Governor made contracts with, regarding the funding and how to operate. Rivers were prioritised according to their proximity to the Russian border, as there has been a strong relationship with this localisation and the occurrence of pink salmon in previous years.

The County governor has mainly funded two types of traps / weirs: picket weir and resistance board weir. These have been almost 100 % efficient in some rivers in removing pink salmon and releasing native salmonids. The total catch of pink salmon in targeted measures in 94 rivers was 249,496 individuals, and 170,293 of these were caught in the traps (miljodirektoratet.no).

Some of the larger rivers had challenges regarding equipment and operation, and the efficiency of the traps was much lower than expected in some rivers. The most pronounced example is the largest river Tana, where 7,666 pink salmon was caught but an estimated 170,000 escaped. This was mainly due to a special type of guiding fence that proved to be permeable for both pink salmon and other fish (Nasjonal kompetansegruppe for tiltak mot pukkellaks 2023).

Injured native salmonids have been observed, but a low number of Atlantic salmon (101 individuals) died or had to be put down because of the trapping. In comparison, a total of 18,433 Atlantic salmon were successfully released. In some rivers, collapse of the weirs occurred during floods caused by heavy rain. We believe that most of the challenges can be solved, and a thorough evaluation of the causes and solutions has been performed by a national competence group for measures against pink salmon appointed by the NEA (Nasjonal kompetansegruppe for tiltak mot pukkellaks 2023). The report includes advice on how to improve the catch and minimize the negative impact on native fish in future operations. With our current knowledge and experience we believe that picket weirs and resistance board weirs are suitable methods to control the pink salmon invasion in most rivers. Home-made traps have been used in approximately 25 rivers, most of which were not state funded but built and operated by volunteers with permission from the County Governor's office. These weirs made from nets instead of pickets are more likely to collapse during floods, and more often cause harm to native fish in various ways. We aim to replace them with picket or resistance board weirs before 2025, depending on funding from the government.

Beach seine was used in some rivers downstream from the trap, with great efficiency. We assess that it is suitable as an additional measure to remove pink salmon, given that the local anglers' organizations have the gear, skills, capacity, and are careful enough with the native salmon so that they can be released upstream from the trap (Nasjonal kompetansegruppe for tiltak mot pukkellaks 2023).

Sea salmon fishery with bag nets for Atlantic salmon is allowed on parts of Norway's coast and has been considered for use as a measure to control the pink salmon invasion (miljodirektoratet.no). However, a field study performed by the Norwegian Institute of Nature Research in 2023 show that more than 60 % of bag net caught Atlantic salmon was either dead or too injured to be released. Bag net fishing in the fjords is not suitable as a measure to control the pink salmon invasion because of the high risk of overexploitation of Atlantic salmon, except from bycatches in the coastal fishery targeting Atlantic salmon (Havn *et al.* 2023). This fishery is regulated according to the stock status of salmon in the respective areas, where some are closed for fishing whilst other had a fishing season of 8 weeks in 2023 (Lovdata.no). The total catch of Atlantic salmon in 2023 was 30,268 individuals with a bycatch of 98,770 pink salmon (https://www.ssb.no/sjofiske-etter-laks-og-sjoaure).

Figure 3. *Picket weir in the river Máskejohka, a tributary to the Tana. Photo: Eirik Frøiland*

Figure 4. *Resistance board weir in the river Vestre Jakobselv. Photo: Jan Harald Tomassen*

Experience shows us that the local anglers' organizations must receive sufficient funding to provide a salary to their workers to manage a weir operation throughout the run of pink salmon in a way that is both efficient and safe, for both people and fish. We are dependent on the help and co-operation, manpower, skills, and local knowledge that can only be found in the local anglers' organizations to carry out this project. A salary will make the work more stable and keep the motivation up. Relying on volunteers alone is a vulnerable strategy, as the pink salmon run may culminate at the same time as the summer holiday for students and others is over.

We had different solutions to deal with the pink salmon removed from the rivers. Agreements with local companies were made in advance of the season, to pick up pink salmon daily and provide clean boxes with ice. This pink salmon could be used as food commercially or as ensilage and biogas. Pink salmon was also donated to the local communities as food, dog food or crab bait. It is highly important to have a logistics plan for this in advance of the season, or else the removed pink salmon will become a waste problem. The preferred solution is to use the catch as food, either commercially or in private households, due to the costs imposed from other solutions and the ethical side of wasting the resource that the catch represents. However, it is important to underline that the purpose of the measures is to minimize adverse impacts of pink salmon on native fish and other biodiversity, and not to create an industry based on pink salmon as a resource (Mo *et al.* 2021). Hopefully, the number of pink salmon will not reach a level that can support a large-scale industry in Norway.

The NEA will consider the advice from the national competence group and aim to improve and expand the measures against pink salmon in 2025 (Nasjonal kompetansegruppe for tiltak mot pukkellaks 2023). Some of the home-made weirs have been substituted with picket weirs, and this will continue as far as funding is available. Minor changes to the design of both the picket weirs and the resistance board weirs are being implemented. There is special attention on the unsolved problems in the large rivers, like Tana and Alta. With lessons learned from 2023, new weir designs will be tested at new locations in 2024 in these rivers. There is also an ongoing pre-commercial procurement of AI-based traps with automatic recognition and sorting by species. We are aiming at testing the prototypes in 2025.

In the spring of 2024, the survival of the pink salmon fry originating from the 2023 spawning season will be surveyed. The occurrence of adult spawning pink salmon will also be monitored by video and drift counting in selected rivers. The even-year population have not shown the same capability of increasing, but Norway will keep an eye on this as well, as a part of the national action plan.

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Overview of the Monitoring and Management of Pink Salmon Outside of Norway and the Russian Federation

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Introduction

Since the human introduction of pink salmon in north-west Russia in the 1950s, in order to increase fishery resources, the majority of catches and reports have been recorded in Russia and Norway (particularly in Troms and Finnmark in Norway) (ICES 2022). In 2017, many other countries in the North Atlantic began reporting the presence of pink salmon in their river, coastal and marine waters (Northern Hemisphere Pink Salmon Expert Group 2023). The odd-year spawning population is the main population found throughout the North Atlantic region, and reports on pink salmon have continued to be highest in odd years, i.e. 2019, 2021 and 2023, as opposed to fewer even-year reports. Outside of Norway and the Russian Federation, pink salmon reports have been relatively low in comparison and variable over the last eight years, i.e. four pink salmon spawning cycles for the odd-year population. Nonetheless, as this alien species has been reported in unprecedented numbers throughout countries in the northern North Atlantic region from Europe, across to Greenland and Canada, many countries have thus began monitoring for up-to-date distributions and initiating management responses to potential impacts and risks.

For this paper, in order to collect the most thorough and up to date information, scientists with expert knowledge about salmon from North Atlantic countries (N=15), outside of Norway and the Russian Federation, were contacted (over email) and asked to answer five questions relating to monitoring and management of pink salmon in their respective country. The following questions were posed:

1. Has any monitoring of pink salmon been conducted between 2017-2023 (can include non-target monitoring e.g. cameras)?
2. Have any management actions been taken for pink salmon e.g. barriers, removals?
3. Are there any management decisions for pink salmon e.g. rules, regulations?

[2] Minor editorial changes to text made on 19 June 2024 to include information provided by Spain.

4. Are there any strategies to prevent further introductions?
5. Has there been any awareness / educational work?

All fifteen countries responded, namely USA, Canada, Greenland, Iceland, Faroe Islands, Ireland, UK, Denmark, Sweden, Finland, Germany, Netherlands, France, Spain and Portugal (Table 1).

A summary of the answers from the above questions, split by country, is shown in Table 1. Out of the 15 responding countries, all but one had some sort of monitoring (e.g., traps, catch reports, eDNA, snorkelling). Roughly 60 % of the countries had taken some type of management action or management decision (not necessarily the same country had taken both a management action and decision). Only two countries had implemented prevention strategies against further introductions, while all but two had taken actions to create and increase awareness of pink salmon in their respective countries. Where relevant, certain answers received via email are given as examples, and explained in more detail in the following sections.

Monitoring of Pink Salmon

Monitoring of pink salmon employs various techniques and differs largely between countries; some have targeted monitoring through environmental DNA (eDNA) and counter fences, while many make use of established monitoring equipment and methods already in place for other target species (Table 1). For example, in the UK (Scotland) and Ireland, eDNA monitoring was conducted across 31 and 13 river systems, respectively, during 2023 to detect the geographic spread of pink salmon not only across the country but also in different stretches of the river systems. Also in Sweden, eDNA monitoring was introduced for pink salmon spawners in 2023 (part of the project Pink salmon in Sweden), which sampled 27 rivers, mainly on the west coast region where pink salmon have been reported previously (Staveley and Ahlbeck Bergendahl 2022). Monitoring was also conducted in some rivers draining into the Baltic Sea, which was particularly important, as this species has not been reported in that region for several decades (Staveley and Ahlbeck Bergendahl, 2022). In addition, eDNA (as well as electrofishing) has been used in order to try to detect pink salmon juveniles in some Swedish rivers where spawning adults had previously been detected (part of the project Pink salmon in Sweden). At an international level, there is an ongoing NASCO EU project, PINKTrack, which involves some EU countries and Norway. The aims of this project are to better understand pink salmon distribution using eDNA, identify temporal and geographic patterns of spread and provide an 'early warning system', and inform appropriate management responses.

At the beginning of detecting and monitoring for alien invasive species, catch reports from both commercial and recreational fishers are vital to gain knowledge regarding the distribution of non-native species, and are encouraged throughout many of the countries here (Table 1). This can prove to be of great help to understand the spread of pink salmon outside of Norway and the Russian Federation. Many countries encourage reporting and have information and websites to register pink salmon reports. In the UK (Scotland and England), for example, there is a specific online application system where anglers can register their pink salmon catches and observations.

The most common monitoring occasion is to monitor spawning pink salmon adults, but there have been some efforts using nets in Iceland (Skóra *et al.* 2024) and in the UK (Scotland) (Skóra *et al.* 2023) to catch the downstream migration of pink salmon smolts before heading out to sea. These studies showed evidence of successful spawning which could lead to potential self-sustaining populations in these regions. Snorkelling surveys to try to detect pink salmon redds have been conducted in Ireland (though none found) (Table 1).

In the northern parts of Finland, sonar and snorkelling methods have been used in order to gain a better understanding of pink salmon numbers in freshwaters (Table 1). Whilst in European countries in the southern part of the pink salmon distribution (i.e. Netherlands, France, Germany), that have very low numbers, reports are solely from angling catch reports and existing fish counters (Table 1).

Table 1. *Summary of answers regarding the monitoring and management of pink salmon questions per country.*

Country	Q1. Monitoring	Q2. Management actions	Q3. Management decisions	Q4. Prevention strategies	Q5. Awareness / education
USA	Indirect monitoring traps	No	No	No	Among scientists only
Canada	Targeted & non-targeted counting fences, cameras, eDNA	Planned targeted removal, anglers asked to retain and report catch	Regulation to allow retention by anglers with no bag limit	Yes – regulations, action plans & official committees	Awareness campaign – posters, leaflets, radio, social media
Greenland	Catch reports, snorkelling, eDNA	Some removal – harpoon	Reported as bycatch	No	Social media
Iceland	Catch reports, camera fish counters, smolt traps, eDNA	Some targeted removal with nets	Temporary exemptions allowing seine netting in rivers	No	Website – biology & ID, social media, reports
Faroe Islands	Citizen science project, catch reports	No	No	No	Citizen science project – interviews, articles

Ireland	Catch reports, camera fish counters, eDNA, snorkelling	Anglers asked to retain and report catch	No	No	Awareness campaign – press, social media, ID guide, website. Anglers to report and provide specimens
UK	Catches / observations – reporting app, eDNA, smolt traps, cameras	Single trap, public encouraged to kill if caught, redd excavation	Illegal to fish and retain, bycatch possible	No	Awareness materials, websites – biology & ID, previous observations, reporting
Denmark	No	No	No	No	Website – biology & ID, previous observations
Sweden	Catch reports, camera fish counters, eDNA, electrofishing	No	If caught, kill and do not return to the water	No	Website – biology & ID, reporting, social media, magazines, posters, stickers, webinars, exhibitions
Finland	Sonar, video, snorkelling, eDNA, catch reports & observations	Local restricted fishery	Specific fishing rules	No – all stocking of fish / eggs forbidden	Meetings, talks – biology & ID, potential threats, mitigation
Germany	Catch reports, camera fish counters	No	No	No	Scientist briefing, magazines, brochure, website
Netherlands	Catch reports, camera fish counters	No	No	No	Online article
France	Catch reports, camera fish counters	No	Recommend no release after catch	No	Public awareness
Spain	Indirect monitoring stations	No	If caught, killed immediately	No	No
Portugal	Catch reports	No	No	No	No

Management of Pink Salmon

Since pink salmon numbers are generally low across these countries, little effort has focused on removal in general (Table 1). Nevertheless, some targeted removals with nets have occurred in Iceland, and snorkelling with harpoons have been used in Greenland (Table 1). In contrast, in Finland, where thousands of pink salmon have been reported, locals with fishing rights were able to apply for a permit to fish pink salmon using gill, drift and seine nets in 2023. Canada and Iceland reported that some changes and exemptions from fishing regulations were put in place in order to allow for pink salmon fishing during migration times (Table 1).

Only Canada and Finland mentioned any kind of prevention strategies for further introductions of pink salmon in their home waters, although other countries may also have such regulations regarding restrictions on the introduction of non-native species (Table 1).

Conducting risk and impact assessments helps evaluate the potential impacts of pink salmon on native ecosystems and species. The UK was the first country to produce, firstly, a rapid risk assessment in 2017 (Copp 2017), followed by a full risk assessment in 2018 (Cowx 2019). In addition, in response to the unprecedented pink salmon migration in 2017, Sweden (Petersson *et al.* 2018) and Ireland (Millane *et al.* 2019) published risk and impact assessment reports. However, as more knowledge is gathered on the distribution of pink salmon, potential impacts and appropriate mitigation measures, the need for more, evidence-based, up to date management plans and actions, as well as resources to conduct such activities, is expected and needed.

Pink salmon populations often transcend national borders, necessitating international co-operation for effective management. Countries can collaborate through international organizations (e.g. NASCO) to share information, co-ordinate monitoring efforts (e.g. project PINKTrack) and develop harmonized management strategies.

Awareness & Education

Most countries, especially where pink salmon have been regularly reported since 2017, have conducted awareness and educational campaigns focusing on pink salmon (Table 1). Much has been done through social media to reach the general public and specific target groups, such as recreational anglers. Websites, set up through government agencies, universities and institutions have also been widely created which are great tools in spreading information, particularly on identification of pink salmon, species biology, and how and where to report any sightings / catches. Some examples can be found here from Ireland, Denmark, UK (Wales) and Germany. Other media channels, such as TV, radio, newspapers and magazines articles have also aided in the spread of pink salmon awareness in some countries. Information has also been distributed to relevant stakeholders and the public through webinars, meetings, talks and exhibition events (Table 1).

Acknowledgements

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Contributed Papers

The NASCO Working Group on Pink Salmon

Photo: Malin Solheim Høstmark

Overview

The fourth sub-objective of the TBSS was to introduce NASCO's new Working Group on Pink Salmon. The Working Group had its inaugural meeting in March 2024 during which it drafted Terms of Reference for consideration by the Council of NASCO, CNL(24)21. The Chair of the Working Group was asked to provide an overview of the Group, its inaugural meeting and its draft Terms of Reference moving forward. After the presentation there was a question and answer session (Q&A), which can be found at the end of the report.

- Jarle Steinkjer presented an introduction to NASCO's new Working Group on Pink Salmon.

Summary of the Discussions Held During the Theme-based Special Session

Photo: Tom Staveley

Summary of the Discussions Held During the Theme-based Special Session

Questions to Speaker Michael Millane following his presentation:

Gavin Scott (Maritime Aboriginal Peoples Council): first off, Michael, very well presented. I just have two quick questions for you. The first one is I'm very familiar with the different habitat selections of Atlantic salmon as they go through their progressive life stages. But is there any difference, distinct differences, with pink salmon during those same life stages, or are we looking at a carbon copy, so they'd be in the same places that some of the salmon would be? And the part two to that is are they more sensitive or tolerant to other water quality characteristics, namely something like pH? How does pH affect pink salmon development?

Michael Millane (European Union): I think, from what I've read anyway, they're not as sensitive as Atlantic salmon to water quality, but they need good quality water and habitat to successfully spawn. And so there is some evidence to say they're a bit more tolerant of very moderate water pollution or water quality. So that's the second part.

Your first question about overlapping between spawning and habitat areas in rivers for Atlantic salmon, yes, I have to think about this. Other authors here that may actually address that question as far as I know.

I might leave that for that. But, of course, they overlap in rivers. They come in at different times, but there is a lot of overlap and some interesting stuff you mightn't obviously think of, like even Atlantic salmon juveniles may prey on pink salmon fry that emerge and different things like that. I think pink salmon are generally more aggressive as well, from even talking to people that have directly seen them in action in the water, in the river.

And I've seen them myself as well in the trap at the National Salmonid Index Catchment at the Erriff. Yes, so they can be quite aggressive and stress out Atlantic salmon that are sitting in pools, holding for the winter to spawn, or even sea trout and things like that.

Carl McLean (Canada): in the report of the Working Group, in section 3.1, it talks about – I think it's related to a presentation given by Colin Bean, UK, Scotland. It talks about two reported in 2022, of which one was eliminated after being found to be a salmon trout hybrid. I'm wondering what a salmon trout hybrid is?

Michael Millane (European Union): yes, it's a good question. We do get them. They're rare. Less than 4 % of what you think is an Atlantic salmon stock, it could be 1 %, but I've heard less than 4 %, they can hybridise. Native Atlantic salmon and brown trout can hybridise. So, we do get, what's the word, reports that aren't true, like Colin had. And I went down last year to look at an unusual salmon. It was an Atlantic salmon, but the local staff down there thought it was a pink salmon. But that's why it's so important to verify records when you can.

Questions to Speakers (Eva Thorstad, Beatriz Diaz Pauli and Åse Helen Garseth) following the second session of the TBSS:

Tim Sheehan (USA): thank you very much. Tim Sheehan with NOAA Fisheries. This is for Beatriz. Are you aware of any ongoing or planned marine research to look into competition, the marine issues? We've got a good overview of what we know, but I'm wondering if there are plans to learn more.

Beatriz Diaz Pauli (University of Bergen, Norway): I am aware of many researchers who want to do all these things that are asking for money, but the money doesn't come. Because most of this work is coming from side projects that we have to do, which is very interesting. So, there's a lot of thoughts and there's a lot of rejected proposals.

Guðni Magnús Eiriksson (Iceland): thank you for excellent presentations. As demonstrated in the presentations, we have had some rapid increase of pink salmon in our waters, which is quite alarming. But compared to what is being faced in Norway, this is still small numbers. With Eva's summary of potential and obvious threats, we are quite worried. So, this was just a comment but not a question, but I'm interested in if there are studies on the genetic variation. And as you mentioned in your presentations, of course, there may be evolution within the population. We may have changes in the environment or the populations. Are there any indications, direct indications of genetic change that might explain this change in distribution? Thanks.

Beatriz Diaz Pauli (University of Bergen, Norway): well, I'm not an expert in this, but there have been these genetic studies that show, again, this population is similar to that population and is different from that population. So, there are these. But what gene is doing, what this gene is doing to make that behaviour, to make it more invasive, that we don't have any data on. Yes, so there was this study that the Norwegian populations are different from the source, and the Eastern Canadians, it seems to be very similar. I'm talking about odd years only, similar to the Norwegian ones. But what is the difference? What do these genes actually mean into something that we understand? That we don't know.

Kim Damon-Randall (President): I was wondering, in response to your last question, or the response to the last question, yes, about having to try to find resources, is it a situation where researchers and even managers are having to divert the limited resources that they have for Atlantic salmon away from Atlantic salmon to address issues for pink salmon? Or is it not that those resources are in competition? Because that's an indirect negative impact to Atlantic salmon, if you're taking resources away from them to deal with pink salmon.

Eva Thorstad (Norwegian Institute for Nature Research, Norway): yes, okay, I'm on the side of applying for grants, not handing out grants. So, I guess that's more a question for those people here. But yes, well, it's a limited sum of money for salmonid research, so I guess there is competition.

Jaakko Erkinaro (European Union): Jaakko Erkinaro, Natural Resources Institute, Finland. There's been a couple of times that the habitat use has been mentioned in different life stages in fresh water, and especially this possibility of overlapping or competition during the spawning time. It's both temporal and a spatial question, of course. Eva, you mentioned that there is later spawning time for pink salmon. And in our area, what we have done and seen in the large river system of the Teno / Tana in the north, there's actually quite a substantial difference in spawning time. But the question is how much it can actually expand over time, as has been suggested by some Russian scientists earlier. About the spawning areas, what we have seen in this large main stem river is that the pink salmon are spawning definitely in very different spawning areas compared to Atlantic salmon, very close to riverbanks in very shallow water. But this is the large main stem. And my question, to you, Eva, is that are you aware of any studies actually looking into pink salmon spawning area preferences in different types of rivers? Are there any quantitative or any systematic work going on this potential habitat overlap in terms of spawning areas?

Eva Thorstad (Norwegian Institute for Nature Research): I'm not familiar with those kind of studies from the Pacific. So, there might be studies from the Pacific area. But from the Norwegian side, there's no systematic studies, but there's quite a lot of observations on where they spawn. And I guess the Tana River, the Tana watershed is a quite special watershed. So, in many of these smaller rivers, they will spawn in the same areas as Atlantic salmon will, also in the main rivers. Also, as a comment to these questions of genetics and adaptations, and which you mentioned as well, pink salmon, they're in big numbers. They live a short life. There's variation. There's variation in spawning time, there's variation in a lot of different traits. So, they do have a big scope for adaptation and for change. And I think we have seen that from the introduction in the Great Lakes. Should have learned from there that they are able to change and adapt quite quickly over a few decades. It will be very interesting to see what happens in our areas in that respect. Yes. Thank you for the question.

Questions to Speakers (Frode Fossøy, Sergey Prusov, Eirik Frøiland / Malin Høstmark and Tom Staveley) following the third session of the TBSS:

Øyvind Fjeldseth (Norwegian Association of Hunters & Anglers): my name is Øyvind Fjeldseth. I'm from the Norwegian Association of Hunters and Anglers. I'm not sure if this is going to end up as a question. It might be more of a request, I guess. I saw a lot of pink salmon last summer. It was not a pleasant thing to see, it was shocking to see, at least.

I saw my first pink salmon in 1993 when we treated the River Rauma for *Gyrodactylus salaris*, a threat that we saw as an existential problem for Norwegian salmon stocks. Little did I know then that that 760 gram male pink salmon should arise as a new potential existential problem when we were about to win the fight against *Gyrodactylus salaris*, which we are.

My organization's local clubs and others are doing a huge job trying to remove this fish, with the help of good people from the Environmental Agency and the County Governor and others. We need funds. And I guess this is the request, because funds are needed, and we need a lot of funds, and we need it for a lot of years, unfortunately, as it looks like.

For my organization, we work for getting the government giving those funds each autumn. But the request, I guess, is that the NASCO Parties have to support Norway's fight in this and support and give clear advice for the Norwegian Government to stay in there and give the needed funds. And I would thank the Norwegian Environmental Agency for being so clear for the years that has passed, and we will support you wholeheartedly in the years to come. So, thank you.

Gavin Scott (Maritime Aboriginal Peoples Council): I've got a comment for the gentleman who spoke about eDNA today. I just want to bring to your attention that in North America, a common eDNA method is to use two litres in their sampling regime. I know that you guys had mentioned that the European Union needs a uniform sampling regime for their eDNA, so moving forward with North Atlantic salmon as a whole across all transboundaries, it should be discussed as to finding a nominal amount that's uniform across all different countries. Thank you.

Steve Sutton (Atlantic Salmon Federation, Canada): Norway has taken a position that pink salmon are an invasive species and must be eradicated. This is a strong and appropriate position. I understand the desire to find a use for the large amounts of fish that are removed, but finding human uses for the fish comes with a risk that some people will come to value the pink salmon for those uses and may eventually come to be opposed to the goal of eradication. I wonder if Norway has given any thought to this and has any plans for how they will prevent people from coming to view pink salmon as a positive thing.

Eirik Frøiland (Norway): yes, this is something we have thought about, but I don't think you can stop people for having these thoughts anyway. People see this as a resource already in some communities, and in some organizations, they work to alter the regulations, to shift the policy. But the policy in Norway is that it's an unwanted, harmful species, but we have to get rid of the fish. We can choose to treat it as a waste, but I don't think that will stop the same people for thinking of this as a resource. I don't think that's a solution, to control people's minds, to say it like that. There are different opinions on this. The Norwegian Government has been clear on what is the status and the goal, and we are working to achieve that.

Eva Thorstad (Session Chair, Norwegian Institute for Nature Research): we have another comment from the Norwegian Government.

Håvard Nilsen (Norway): thank you, Eva. My name is Håvard Nilsen. I'm from the Ministry of Climate and Environment in Norway. I just want to more or less echo what Eirik said, that the Norwegian position regarding this question is that pink salmon is an invasive alien species, and we do not want to establish commercial interests around that species. That being said, we still want to utilise the catch as much as possible when we implement these measures. But this has been an ongoing discussion in Norway as well. And I saw that Tom asked the question in his presentation, will there be any fishing opportunities for pink salmon in Finland in the future? And hopefully the answer for that is no. And that's the Norwegian Government's position. Thank you.

Eva Thorstad (Session Chair, Norwegian Institute for Nature Research): another question from Tapio or a comment?

Tapio Hakaste (European Union): Tapio Hakaste from Finland Ministry of Agriculture and Forestry. Thanks for Eirik for a good presentation. And I'm aware of the Norwegian strategy, but still, I have a comment or question that should there be a plan B when everything goes wrong? Because I must say that in Tana, everything went wrong last summer. The dam structure stopped Atlantic salmon for ascending, but it didn't stop the pink salmon at all. And that was very evident from the very beginning. But this doesn't work. And unfortunately, continuing it for the whole season has done a lot of damage for the attitudes towards this work in the Tana Valley. So, should there be more focus also on the effects on Atlantic salmon that sometimes appear and a plan, what to do if measures do not work? Because it might be better to stand out and then think again and try next time. But yes, this is the view, but we would like to also share and know, besides many successful things, where are these kinds of possibilities also. Thank you.

Eirik Frøiland (Norway): well, I think we disagree on the question of whether or not the Atlantic salmon was stopped by the weir. We don't think that everything went wrong with the Tana trap. The most important thing was not to stop the Atlantic salmon spawning migration. And we don't think we did, even though you imply that we did. We opened the fence on a daily basis when we saw that the salmon did not pass. We made a big hole in the fence, and we saw that the salmon passed. We don't think we stopped the Atlantic salmon. I have to be clear on that. We were not happy with the number of pink salmon caught, and we are working to improve. We are working on a new design and a new location. You were asking for a plan B. We have tried other methods. We don't think it's effective enough to do net fishing or being drift net, gill net. Other kind of net fishing alone will never take us where we want to go to achieve high enough removal of pink salmon. So, we think we still can make a trap for pink salmon work in Tana, and we are working to do that. We have not changed our view on that. And we would very much like Finland to contribute and co-operate on achieving that.

Alan Wells (Fisheries Management Scotland): really impressive to see all these talks today and see the massive amounts of work that are going on. And we also view pink salmon as being an invasive non-native species. So, I'd really like to support the comments by our friends in the NGOs from Norway. We've been quite lucky so far in that we've had relatively few pink salmon coming to Scotland. We don't want to be in the situation that Norway found themselves in. So, I very much support the comments about supporting that work, making sure it's funded. And Norway are right in the front line of this fight against pink salmon. Long may it continue to fight against that. Thank you.

Tim Sheehan (USA): Tim Sheehan with NOAA Fisheries. I actually do have a bunch of questions if we need to fill time, so I can keep going for a while. But this is for Sergey. If I understood correctly, I thought, towards the end of your presentation, you said something about there being no limits on exploitation or the recommendation was for no limits on fishing. And I wasn't sure if that was a recommendation or if it was actually within the fishing regulations.

Sergey Prusov (Russian Federation): thank you for the question, Tim. That was a recommendation developed for the Regional Commissions on Anadromous Fish and Fisheries. The aim was to allow commissions to regulate pink salmon fisheries in a different manner than we regulate Atlantic salmon fisheries. So, as you know, for Atlantic salmon fisheries, we have to set conservation limits, provide spawning escapement and so on. With pink salmon, with the lower homing of pink salmon, we don't have to use that approach as we use for Atlantics. So, we recommend not to establish such measures in pink salmon fisheries. We don't recommend to establish such measures as passage days, as we established for Atlantic salmon, not to establish limits for catching fish and that we can do this. Well, by Russian regulation, we have to establish limits, but if we see a lot of pink salmon coming in the rivers, we can change those limits and let people catch more salmon. So, this recommendation is to maximise commercial catches, to maximise fisheries. That was a recommendation for our regional commissions. Yes.

Tim Sheehan (USA): this was for Frode and possibly Tom. And I think this is an overly simplistic view of the eDNA sampling. But I couldn't tell from the Tana sampling if all of the sampling was only conducted in tributaries. And this is related to the Scottish sampling too, where you had positive detections, whether it be a fish detected, a fish seen in the Scottish situation, or green marks upriver but there was no eDNA detection downriver. And I know it's a very simplistic view of eDNA, but you would expect if you have them upriver, you would detect them downriver. And I was wondering if you could comment on that a little bit.

Frode Fossøy (Norwegian Institute for Nature Research): sure. So for the Tana, it was different tributaries basically, so you don't expect that downstream effect. But even if there's a downstream effect, we're talking about a really huge river. So basically, you would think 1 km, 2 km, 3 km, 4 km, you will have transport, but then the DNA is gone. So, if you don't have that in extremely long rivers, you won't have that transport all the way, because... yes.

Tim Sheehan (USA): So there's a limit in terms of when the DNA is going to degrade. Then you likely wouldn't be able to detect it. Yes, awesome.

Frode Fossøy (Norwegian Institute for Nature Research): that's depending on thousands of factors. That's the volume and size of the river. Is there a lot of waterfalls? Is it slow flowing water, etc? Yes.

Katrine Kærgaard (Denmark (in respect of the Faroe Islands and Greenland)): thank you. Katrine Kærgaard from the Government of Greenland. This question is for the guys from Norway. Thank you very much for all of your presentations. It was very interesting. So, I wonder if you have drawings or sketches for those homemade traps that you have. Thank you.

Malin Høstmark (Norway): yes, we do have that. And a manual was developed that we sent out to all organizations that wanted to build them themselves that said how to build them, what materials to use, dimensions, and also how to assess the river, if it was suitable for it. Yes, it is in Norwegian. I'm not sure if we have a translation, but yes.

Niall Greene (Salmon Watch Ireland): Niall Greene, Salmon Watch Ireland. I was very struck by an expression used by one of the Norwegian presenters, but there have been so many that I don't remember who, that Northern Norway was the gateway to the North Atlantic. It certainly is in respect of the dissemination of pink salmon. I'm encouraged by the development of things like PINKTrack, with multinational co-operation and so on, but much more national / international co-operation is going to be needed to combat the pink salmon, I suppose, invasion or invasions. And that kind of co-operation is going to be needed just to make sure that the funds we have at the moment are spent in the most fruitful way. But it may be necessary for some kind of international funding too, as has been said by some other contributors, some kind of international funding mechanism to be put in place so that all of those who benefit from successful interventions against pink salmon contribute to the cost of that. That may be not achievable within the framework of NASCO. I understand there's some disagreement on this issue within the Parties. But it's not beyond the abilities of all of us to put together a coalition of the willing, such as the PINKTrack project, and others who may join us, to achieve that. So that's all. That, well, it's not even a question.

But a question is, notwithstanding what I've just said, I'm intrigued by the fact that the Russian Federation, according to Sergey's presentation, they take their conservation of the wild Atlantic salmon very seriously. As any of us who have fished in Russia know, it is a serious matter, backed up by serious law. And yet they seem to have found some way of cohabiting or having their wild stocks cohabit with the wild Atlantic salmon, whereas we're taking a very different attitude, perhaps necessarily. Perhaps our numbers are bigger or whatever. But it's an interesting dichotomy that needs to be teased out. Thank you.

Sergey Prusov (Russian Federation): yes, I'd like to comment. Yes, people who have visited the Kola Peninsula could see salmon abundance in our rivers and the quality of recreational fly fishing. And the matter is we have a bit different Atlantic salmon in the White Sea rivers. Most of fish, most of Atlantic salmon belong to so-called autumn run fish. They enter rivers in autumn time, in August, now October, November, even in December, and spawn in the autumn, following year. So, when big pink salmon run occurs in the summer, in beginning, and it usually occurs in the beginning of July, we have very few salmon in the White Sea because there are very few summer run fish there. So, people can catch pink salmon in the sea with bag nets without bycatching Atlantic salmon. And so Atlantic salmon come later and they don't overlap. Different situation in the Barents Sea rivers. As I told you, we have some problems in recreational fishing in the Barents Sea, because pink salmon come in those rivers in so-called prime weeks of recreational fishing in beginning of July. And people who pay a lot of money for exclusive Atlantic salmon fishing in prime weeks in beginning of July start asking questions. What have I paid for? Because when pink salmon come in big numbers in small rivers, pink salmon, Atlantic just stop biting flies. That's a problem. And another problem we have, we had in 2023 in the White Sea rivers, in the White Sea coast, when local people who invested into fishing gears for commercial pink salmon fishery didn't catch any and asked another question. Where have all pink salmon gone? So, it's a bit different in Russia's White Sea region, different even to Russia's Barents Sea region, because of the different Atlantic salmon biological groups that exist there.

Questions to Speaker (Jarle Steinkjer) following the fourth session of the TBSS:

Guðni Magnús Eiriksson (Iceland): we have recently nominated someone to take part in the work. And as I have expressed earlier, this is an important work, and we look forward to take part in the Working Group. Thank you.

Tom Chrosniak (Connecticut River Salmon Association): hi. I'm Tom Chrosniak from the Connecticut River Salmon Association, NGO. And I'd like to say I'd like to encourage the Working Group to meet more than annually, if necessary, to deal with this issue, one. Two, I'd like to say that we support Norway in their efforts to halt the invasion of pink salmon, and we support NASCO in supporting them in any way you can. And lastly, I'd like to say that this has been a fantastic Theme-based Special Session, and it shows the real benefit of NASCO. You really showed off what NASCO can do to bring people together on specific issues and share information and hopefully bring a focus to the issue. Thank you.

Alan Walker (United Kingdom): Alan Walker from Cefas in the UK here. Just a little thing that is not new to... this isn't a question. This is really a statement or a suggestion. It's not new to anybody here, but it hasn't really been mentioned today, so I thought I would mention it. The Pacific. Just, we've heard all about the collaboration and the knowledge exchange, but just a reminder that, of course, the Pacific has a great deal of experience on pink salmon and to remember that through the IYS framework that we had, collaborations and knowledge exchange networks have been set up with the North Pacific and Anadromous Fish Commission. And just a reminder to the Working Group and others to make use of those collaborations. Thank you.

Bénédicte Valadou (European Union): I just wanted to ask a question to the Working Group. According to the IPBES, invasive non-native species is one of the five major causes of the loss of biodiversity. So, we have four barriers to recognise these species as well as invasive non-native species. These barriers are introduction to the territory, acclimatisation, naturalisation and expansion. So here we are. So, my question is, how can we classify these species as invasive non-native species at the international level? The Working Group could do something for that, or not? Or should we classify these species by our own? For example, in Europe, we can activate the recommendation about non-native species. So, I think that the Working Group could do something for that, but I don't know yet what you could do. Thank you.

Jarle Steinkjer (Norway): I have some difficulties to hear the question. But of course, I think it's very important, when we are working with an alien species, it's very important to bear in mind the obligation under the various conventions. We cannot only look at the pink salmon and the Atlantic salmon. We also need to look at the conventions. So, in the beginning and the first meeting of the Group, we have most discussion and not so many recommendations. So, we have a discussion to be able to make new Terms of Reference. And we will, of course, discuss this in more detail at our next meeting. But when I'm talking now, I just want to say something more for my own and not only for the Group. For us in Norway, who are sitting in the centre of the problem with pink salmon, we have recommendations we think should be implemented. We have almost removed the threats from *Gyrodactylus salaris* in Norway and have now started work to reduce the threats from pink salmon. So firstly, it is of great importance that Norway continues the work of catching pink salmon before they can spawn. This measure will help us to save the threatened salmon stocks in the rivers with large quantities of pink salmon. The measure will also reduce the possibilities of pink salmon to spread to new rivers in Norway, which also will help to reduce the risk of spread in the rest of the Atlantic. So, I don't like expressions like adverse effects on Atlantic salmon. I would prefer the Precautionary Approach rather than waiting for an adverse effect. If you are waiting, it may be too late or too difficult to implement the necessary measures, and the probability of further spread is high.

I would recommend that all Parties draw up a contingency plan in the same way as we have been done for *Gyrodactylus salaris*. To implement such plans, we must first define a common platform, which can be a challenge, but it should be possible to come up with good solutions.

When we see what is happening in the river in the northernmost part of Norway, it is, in my view, a potential disaster that is about to occur. I am afraid that what we are seeing now is only the beginning. So, I hope we are able to go on to work to reduce the amount of pink salmon in the rivers and get good co-operation with other countries so we can do a good job to help to get rid of the problem.

Carl McLean (Canada): in Canada, we're seeing certainly warming oceans, warming waters, and there have been instances of pink salmon coming from west to east across the Canadian Arctic. So, I don't think that that's a natural occurrence. That's just because of climate change and the warming oceans. We're also seeing Atlantic salmon going up the east coast into the Arctic Ocean. There's been instances of that, that have been identified. So that's just food for thought on that could be another issue that we'll have to deal with over time. Thank you.

Raoul Bierach (Norway): I could have spared this one for the Council, but I thought it might be the appropriate time to say it. If Council so decides and this Working Group is going to continue, we would be very pleased to welcome the Working Group, whoever that will be, to actually go and look in 2025 up in the north and see what's happening firsthand. I think that will make an impression. And so you are very welcome. We would be very pleased to organize that, if that's so desired. Thank you.

Conclusions of the Theme-based Special Session Steering Committee

Photo: Pekka Tuuri

Conclusions of the Theme-based Special Session Steering Committee

Conclusions

Considering the overall objective of this TBSS was 'to provide an overview of pink salmon's distribution, biology, potential impacts on native Atlantic salmon and management actions in the North Atlantic', no recommendations have been drafted for presentation by the Steering Committee. Instead, the Steering Committee has provided a brief overview of the conclusions provided under each sub-objective.

Describe the Natural Distribution and Life History of Pink Salmon and Review its Arctic and North Atlantic Range Expansion

This section was represented by one presentation that started by introducing the biology and life history of pink salmon. Subsequently, the presentation addressed how pink salmon appeared in the North Atlantic and Arctic along with recent information on distribution and abundance. As pink salmon has a distinct life history and morphology, different to the native salmonids across the North Atlantic Ocean region, it has been relatively easy to distinguish when caught, particularly when entering the freshwater phase.

Much information is known about pink salmon in the native range from the Pacific Ocean, however, much knowledge is lacking where this species has recently been reported and established across this new region. Information from the Great Lakes in North America, where the non-native pink salmon has established over several decades, demonstrates how this species can thrive in new environments and, interestingly, does not need marine conditions to complete its life cycle. Apart from the regions in Russia where pink salmon was introduced, it is only in recent years that pink salmon abundance has increased exponentially in Northern Norway and has been recorded in unprecedented numbers throughout many countries in the North Atlantic. Countries with the highest numbers reported of pink salmon are Russia, Norway, Finland, Iceland and Greenland.

Review the Potential for Interactions Between Pink Salmon and Atlantic Salmon in Freshwater and Marine Environments and the Potential for Parasite and Disease Transfer

In this section, two presentations summarised current knowledge and the potential for interactions in rivers and at sea. A third presentation summarised knowledge and the potential for transfer of diseases, infections and parasites.

Pink salmon has the potential to spread substantially and increase in abundance within the distribution range of Atlantic salmon. Threats to Atlantic salmon from pink salmon in rivers are related to competition for space, crowding and aggressive attacks from adult pink salmon during the upstream migration and spawning, competition for food and space at the juvenile stage and deteriorated water quality due to decomposition of pink salmon carcasses post spawning. The impact of pink salmon on Atlantic salmon in rivers depends on their abundance with expected impacts increasing with increasing pink salmon abundance. Pink salmon do occur in very large numbers in many rivers in North-West Russia and Northern Norway, and the possibility for interactions between these species in fresh water is considered significant.

At sea, migrations and diet of pink salmon overlap with Atlantic salmon, hence, there is a potential for interaction. The biomass of pink salmon presently is believed to be too low to have a noticeable grazing effect on the large offshore ecosystems. However, there is a potential for competition for resources with other species in estuaries, fjords and coastal areas, both during the post-smolt and spawning migration.

The parasite fauna of pink salmon is dominated by marine parasites. Listed virus or bacterial infections have not been detected so far, but the virus PRV-1 has been detected in several cases. Originally, pink salmon were translocated from the Pacific Ocean to North-West Russia as fertilised eggs, which limits the probability of introducing, for instance, larger parasites. Long distance marine migrations and straying into new rivers and regions may lead to movement of pathogens between areas. Pink salmon may, for example, be exposed to pathogens from aquaculture sites in one area and carry them to new regions. The most essential factor pertaining to the risk of pathogen interactions and disease is the number of pink salmon present on a local scale. Accordingly, all factors contributing to an increase of the number of pink salmon contribute to the risk.

All three presentations emphasised the huge knowledge gaps regarding the impacts of pink salmon on Atlantic salmon. There is a lack of information for all habitats (rivers, estuaries, fjords and ocean) and life stages, and there is a lack of knowledge about the susceptibility of pink salmon to viruses, bacteria and parasites that are present in wild and farmed fish. Research is needed urgently to fill in these gaps and understand the role and potential future impacts of pink salmon and to what level subsequent migration measures might be employed.

Review the Management of Pink Salmon in Atlantic Salmon Systems

In this section, three presentations focused on pink salmon management in North-West Russia, Northern Norway, and areas outside of these regions. A fourth presentation was given on using environmental DNA (eDNA) to estimate the presence and abundance of pink salmon.

Introduced pink salmon has been harvested in commercial and recreational fisheries in North-West Russia since the 1960s. Pink salmon in the Russian Federation is a fisheries-targeted species and fisheries are carried out in accordance with Article 29.1 of Federal Law 166 FZ of 20 Dec 2004 ‘On fisheries and conservation of aquatic biological resources’. The management of stocks is based on decisions of regional commissions for regulation of fisheries of anadromous fish. The Fisheries Regulations stipulate some restrictions in relation to pink salmon and most of them are similar to those established for Atlantic salmon and aimed, in the first place, at conserving the native species. Since the 2000s, the nominal catch of pink salmon of the odd-year line in North-West Russia has exceeded the catch of the native species, Atlantic salmon, consistently. The commercial fishery for pink salmon at present is viewed as a small-scale artisanal fishery. In years of high abundance of pink salmon, it becomes a targeted species in recreational catch-and-take fisheries on the White Sea coast and in the Barents Sea rivers.

The management of pink salmon in Norway, where the species occurs in numbers comparable to those in North-West Russia, is different. Here, the eradication of pink salmon, instead of commercialised management, has been the preferred approach applied. The extensive removal of pink salmon from many rivers with weirs, traps and other methods has been carried out in Norway every odd year since 2021. The main measure is to establish physical control of the spawning migration of all fish in all salmon rivers within a targeted area. The strategy is to use state funded temporary weirs / traps, operated by local anglers' organizations, to remove all ascending pink salmon while releasing all native fish with minimal harm and delay. It is believed that this approach may limit the ability of pink salmon to continue to spread to other jurisdictions in the NASCO Convention Area.

Since pink salmon numbers are generally low across other countries, little effort has focused on removal outside of Northern Norway. Nevertheless, some targeted removals with nets have occurred in Iceland and snorkelling with harpoons has been used in Greenland. In Finland, where thousands of pink salmon have been reported, locals with fishing rights were able to apply for a permit to fish pink salmon using gill, drift and seine nets in 2023. Canada and Iceland reported that some changes and exemptions from fishing regulations were put in place to allow for pink salmon fishing during migration times.

Environmental DNA (eDNA) is a cost-efficient method for detecting single species and / or monitoring biodiversity in water samples collected in rivers and lakes. Results from the Tana / Teno River and other studies suggest that eDNA can be used for monitoring the distribution of pink salmon and changes in abundance within rivers. The use of eDNA may also provide an 'early warning system' of pink salmon presence to inform appropriate management responses.

Introduce the new NASCO Working Group on Pink Salmon

NASCO's Working Group on Pink Salmon was established during the 2023 Annual Meeting of the Council, CNL(23)87. Its initial terms of reference (ToRs) charged the Group with considering research and data collection needs related to pink salmon within the Convention Area, possible threats pink salmon pose to Atlantic salmon populations, how Parties should co-operate to minimise adverse effects of pink salmon on Atlantic salmon, what corrective measures could be implemented to minimise the risks that pink salmon pose to Atlantic salmon, what are good practices for producing outreach materials to communicate the issue effectively and to develop revised ToRs for the Group, CNL(23)69. The Group met in March 2024 in Galway, Ireland and addressed all their ToRs successfully, as detailed within its meeting report, CNL(24)21.

In regards to its final ToR, the Group developed a draft set of ToRs, including a proposed meeting schedule, which was then considered and accepted by the Council, CNL(24)88. The established ToRs for NASCO's Working Group on Pink Salmon, CNL(24)64, are as follows:

1. Exchange information among the Parties / jurisdictions on the status of pink salmon across the NASCO Convention Area.
2. Identify best practice methodologies to monitor pink salmon distribution and abundance in the marine and freshwater environments.
3. Report biennially on the status of pink salmon, within each Party / jurisdiction, at an appropriate spatial scale.
4. Identify knowledge gaps to understand the potential impacts of pink salmon on wild Atlantic salmon.
5. Identify proportionate corrective measures that could be implemented by Parties / jurisdictions to prevent adverse effects on wild Atlantic salmon stocks.
6. Review and modify, as necessary, these Terms of Reference for agreement by the Council.

The Working Group proposes to meet annually with the timing and duration of the meeting to be considered by the Chair and Secretariat in consultation with the Group. The Group suggested that even-year meetings will be in person and odd-year meetings will be virtual to coincide with the continued expected invasion of odd-year adult pink salmon spawning. If the need arises, the Working Group will consider meeting inter-sessionally.

Looking forward, in terms of management of pink salmon in the North Atlantic and the potential threats to wild Atlantic salmon, we can expect an increase in monitoring and research throughout the NASCO Convention Area as well as more adaptive management actions depending on the severity of the invasion. However, to achieve much of this, investments and resources need to be made available if we are to understand more regarding the non-native pink salmon effect upon wild Atlantic salmon populations. Mitigation measures in Norway aiming to reduce and control the abundance of pink salmon can reduce the risk that pink salmon will establish in high numbers in other parts of Europe.

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