CNL(24)72

Introduction to pink salmon in the North Atlantic and Arctic
(why are they here and where?)

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Theme-based Special Session of the Council:

Management of pink salmon in the North Atlantic and their potential threats to wild Atlantic salmon

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CNL(24)52

Life history

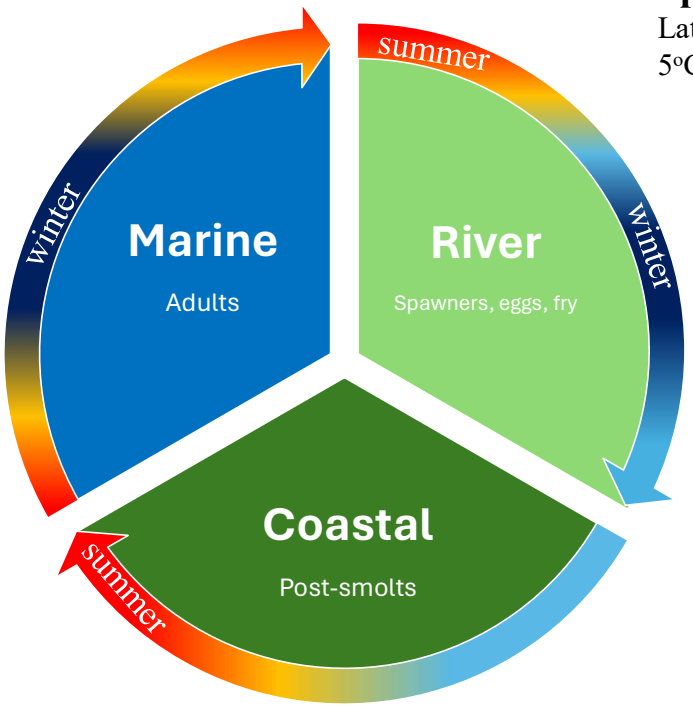
- Typically have two-year anadromous lifecycle*
- Populations principally either *odd*- or *even*-year*
- Odd-year stocks predominate in the introduced range
- Spawning*
- Die soon after spawning. (i.e. single reproductive episode before death; semelparous species)

Life history

At sea
Over-winter until following spring or early summer in advance of their return migration to spawn

Schooling behaviour in open ocean 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

Enter freshwater
June to September



Spawning* **
Late-summer to mid-autumn;
5°C to 19°C; typically 10°C at onset

Fertilized eggs development
Five-to-eight-month period through the winter
Warmer water temperatures can increase rate of egg to fry development

Emergence and migration
Spring to early summer when
water temps exceed 4 ° to 5°C;
quick migration from the river to the estuarine or coastal environment

Smolts / post-smolts
Further mature in nursery areas mainly comprised of irregular shorelines sheltered from strong tidal currents and wind-generated waves before moving further off-shore

Water temp

Life history

- **Natural marine survival rates** from smolt to adult returns are *c*. 4.3%.

- **Homing** to natal rivers is considered to be less precise than Atlantic salmon
  - Straying rates of c.10% for wild spawned pink salmon reported in native range
  - Higher straying rates may be a notable feature of transplanted populations
  - Straying rates for spawners in intertidal zones estimated to be higher than those spawned further upstream

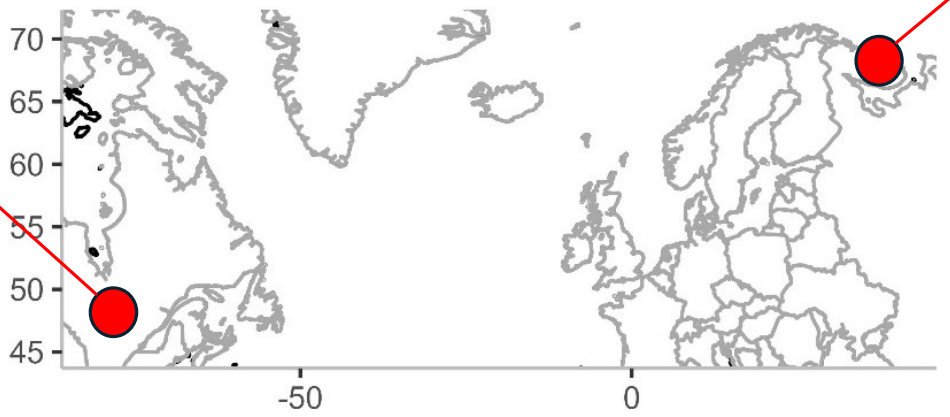
Identification

- Adult typically 45 to 55 cm; fry *c*. 3 cm.
- Adults distinguishable from other native anadromous salmonids by characteristic large oval black spots on the tail fin, absence of spots on gill cover, white-coloured mouth with black-rimmed gums and black tongue and relatively smaller fish scales.
- Both males and females are mainly 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.
- Males develop pronounced humped-back and kype with large teeth on both the upper and lower jaws

Lifecycle plasticity

Although not common, pink salmon may have some degree of lifecycle plasticity

One to three-year lifecycle of the non-native population and their non-migration to the sea



Established odd-year stocks in their introduced range in northwest Russia have been documented to display adaptive changes compared to their source population (including shifts in genetic character, phenological adaptions, altered morphology, and increased body weight and fecundity.

Gordeeva *et al*. 2005;
Gordeeva and Salmenkova 2011

Some evidence for genetic-mediated adaptions in the Great Lakes populations despite the limited genetic diversity of the founder stocks

Sparks *et al*. 2023

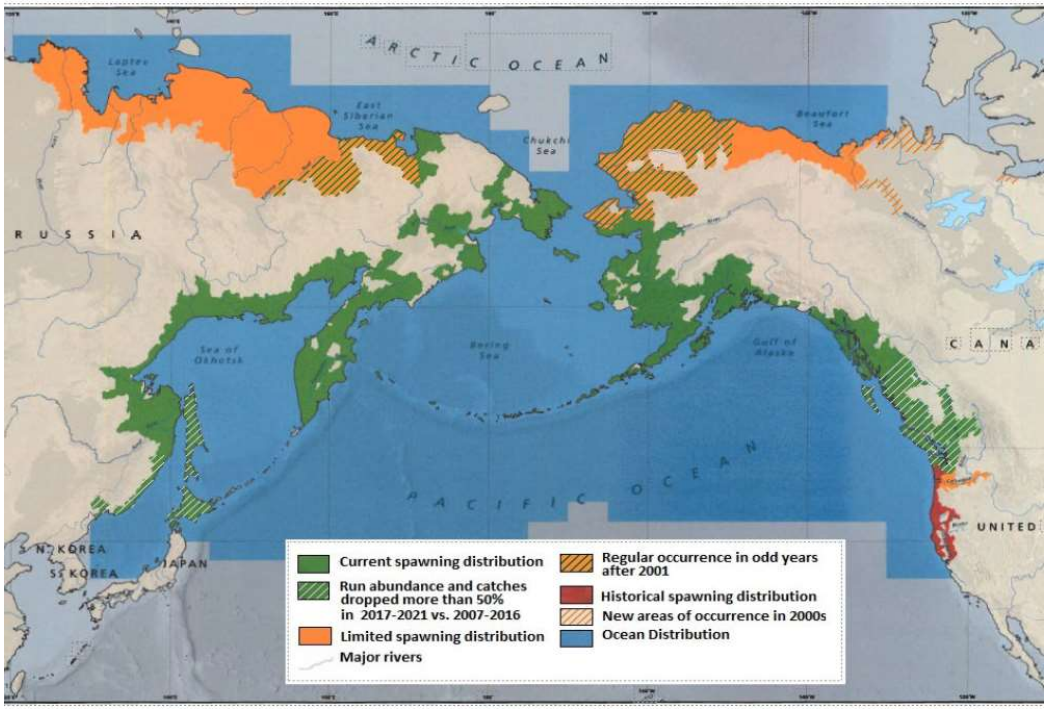
- This demonstrates capacity for quick acclimatisation and enhanced establishment potential in favourable environments

Natural and established geographic range

- Native to river systems in the northern Pacific Ocean & adjacent regions of the Bering Sea and Arctic Ocean.

- Non-anadromous populations established in the Great Lakes region of North America after their unauthorised introduction into the Lake Superior drainage basin in the 1950s.

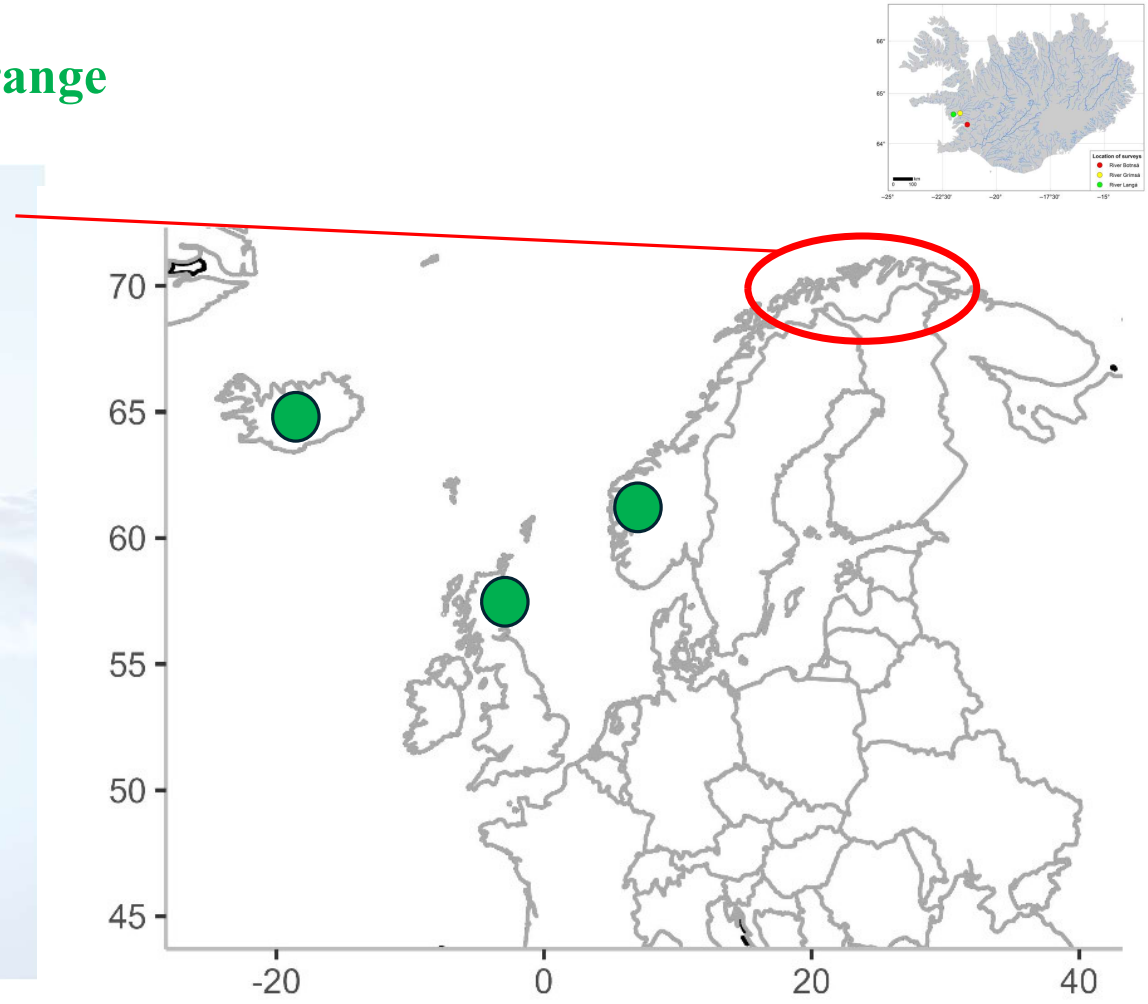
- Established in river systems draining into the Barents Sea and White Sea in the Kola Peninsula region of NW Russia as a consequence of periodic stocking programmes undertaken there since the mid-1950s



Credit: Northern Hemisphere Pink Salmon Expert Group (2023)

Natural and established geographic range

- 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
- Further successful spawning activity documented or reported in some rivers in Iceland, Scotland and southern Norway
- Yet to be determined whether this has since resulted in the generation of any self-sustaining populations in these locations or if the spawning adults are vagrant fish from elsewhere



Natural and established geographic range

- annual catches in northwest Russia reported to have exceeding 100 tonnes on four occasions before 2000 and **peaking at *c*. 300 tonnes in 2001**

  (NASCO CNL(24)21 2024; Prusov 2024).

- From then until 2015, catches ranged from 45 to 118 tonnes and increased from 2013 until **2021** where they **exceeded 600 tonnes**

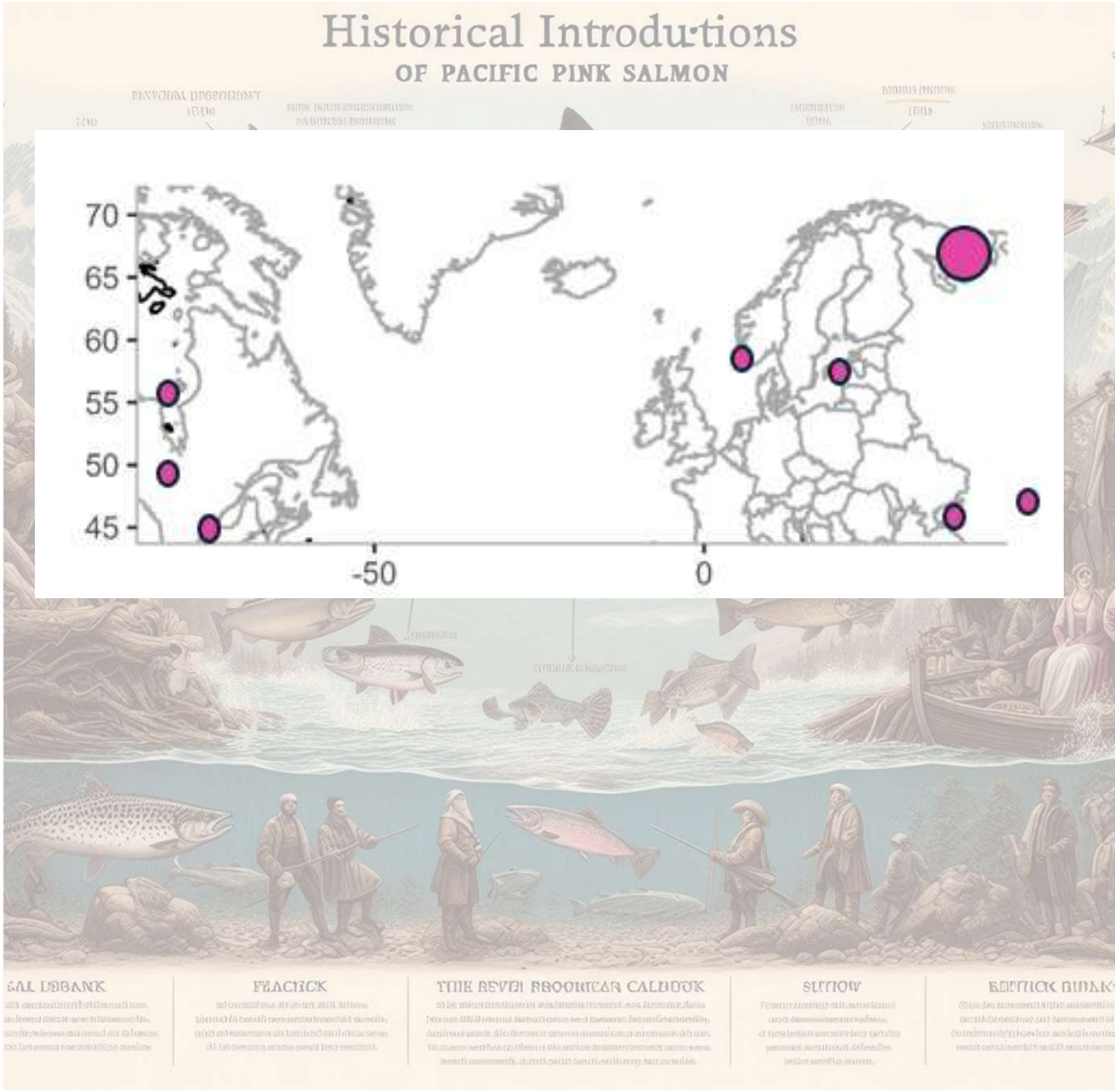
  (Prusov and Zubchenko 2021).

- 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 PSWG(24)08; 2024; Prusov 2024).

Introduction history

- Widely transplanted within the bounds of their native range.
- Efforts typically aimed to enhance natural runs or establish opposite-year populations for commercial fishery purposes but have largely been unsuccessful
- Establishment efforts outside of natural range also generally been ineffective as self-sustaining populations did not result
  - eastern North America including in Maine, Hudson Bay and Newfoundland;
  - Baltic, Black and Caspian Sea regions of Europe;
  - as well as a minor introduction attempt in southern Norway in 1976.

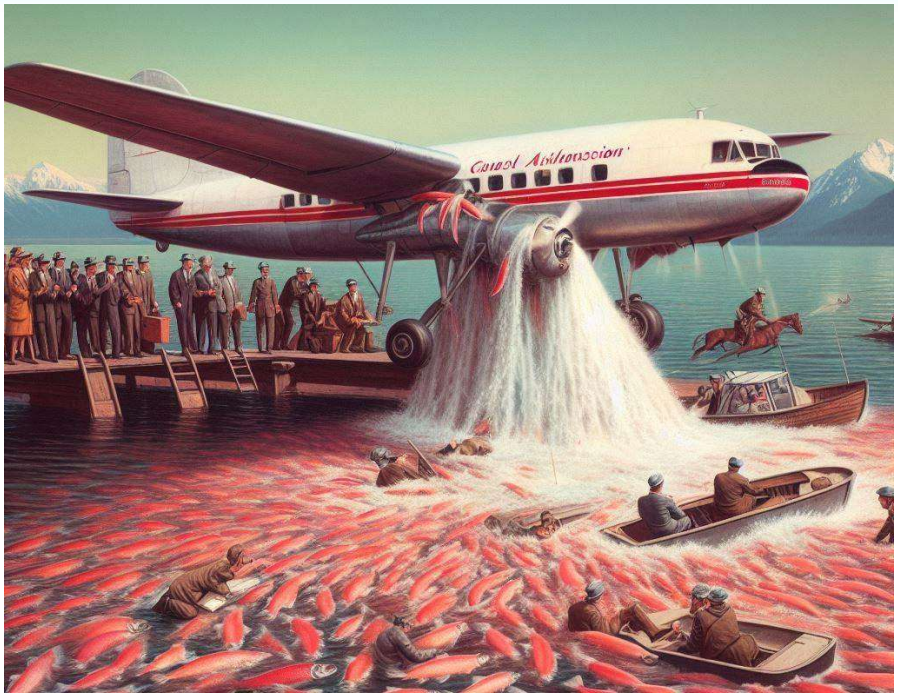


Introduction history

- Great Lakes

Extract from Crawford (2001)

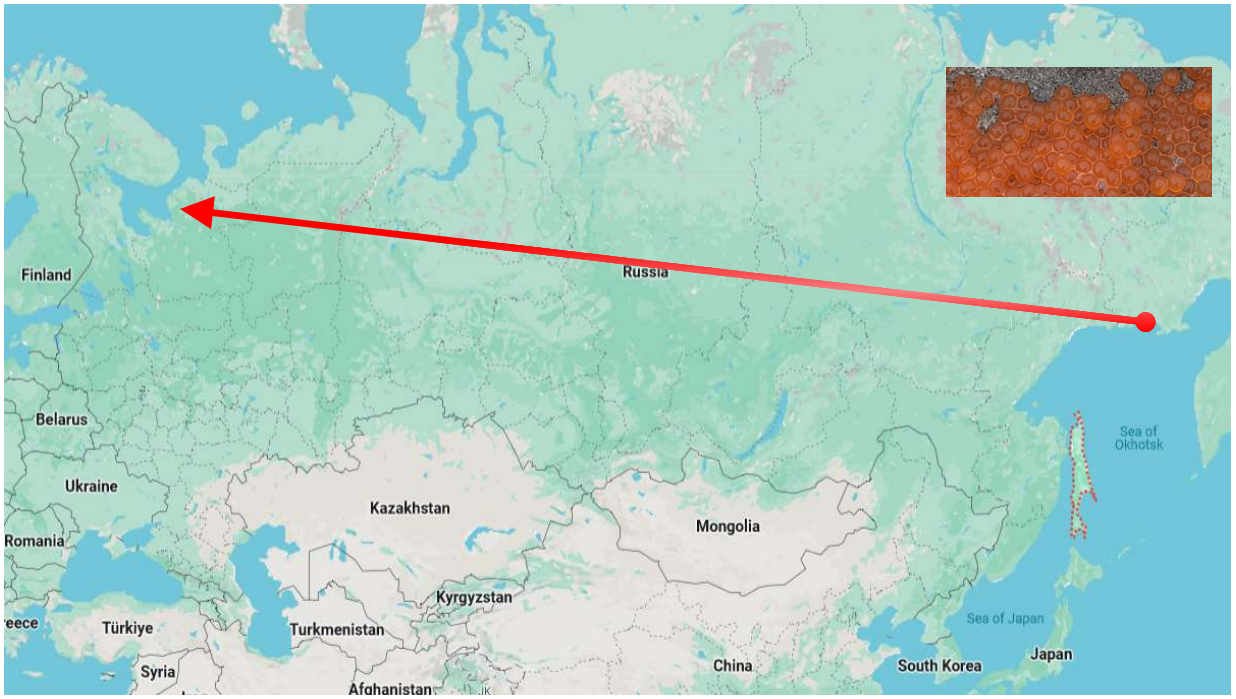
> *"At the hatchery it was admitted that not only had a few hundred young pink salmon escaped into the Lake during the loading of an Otter aircraft in 1956, but that several thousands of young fish had been discarded into a sewer discharging into the Current River through which there was ready access to Lake Superior."* (MacCrimmon 1977, p. 148)



AI generated images

Introduction history

- **NW Russia**
  - mid-1950s to 2002
  - Introductions up to 1979 largely failed
  - 1985 and 1998/1999 eyed eggs
- From the 1990s, mainly derived from local catches of odd-year broodstock
- Predominated by odd-year cohorts

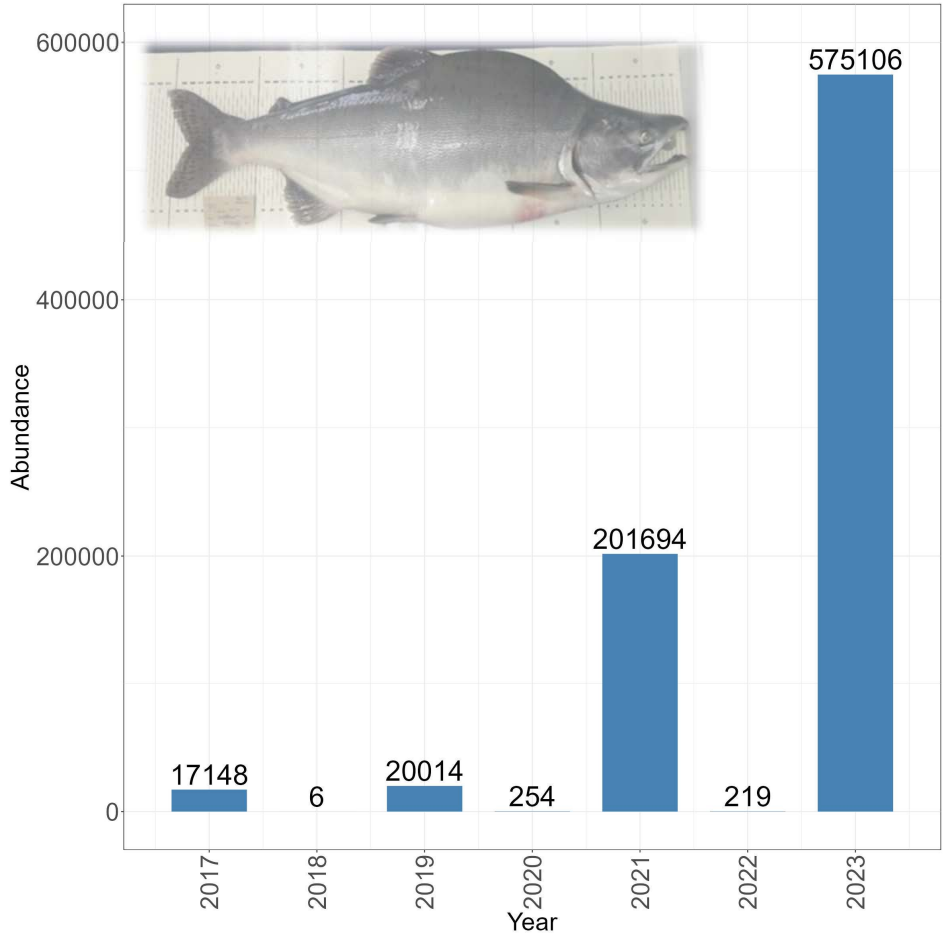


- Attempts to develop large self-sustaining populations of even-year stocks largely unsuccessful, established even-year stocks considered to be modest

- Since stocking ceased in NW Russia, all occurrences of pink salmon in the last two decades here & in N. Atlantic are of wild-spawned origin

Spread from introduced range

- Until 2017, generally sporadically detected in low or very low abundance in N. Atlantic jurisdictions further south and west of its established range.
- However, in 2017, widely recorded in unprecedented numbers in the N. Atlantic and this has been the case in odd-years since.
- In the N. Atlantic region, progressively increased in odd-years from 17,148 in 2017, to 20,014 in 2019, 201,694 in 2021 and 575,106 in 2023.



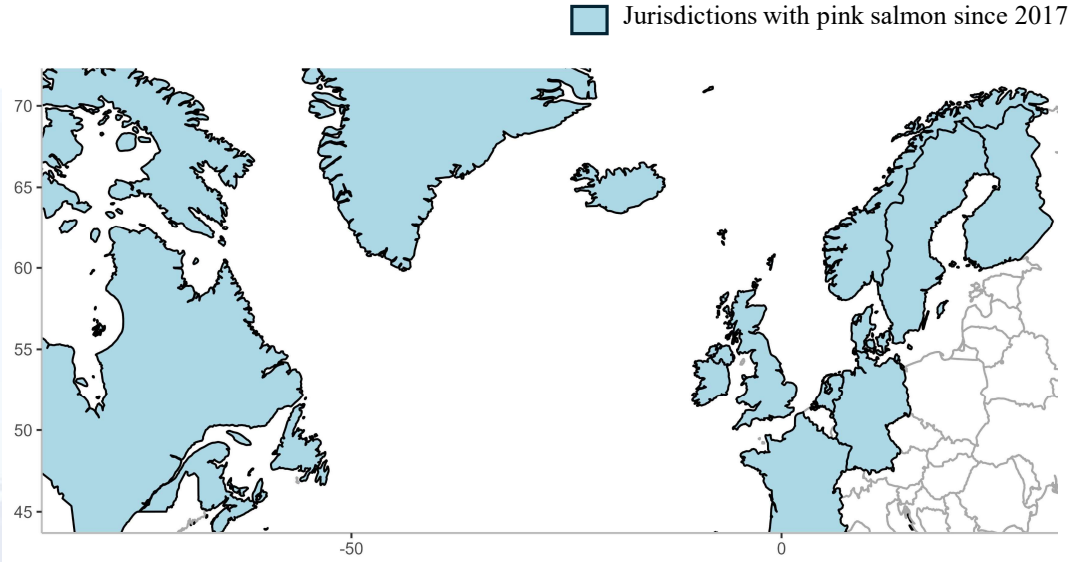
Reported numbers likely to be underestimates as they are largely dependant on the fish being caught or observed.

Spread from introduced range since 2017

- Apart from Norway and northern Finland, records from Canada, west and east Greenland, Iceland, the Faroes Islands, Ireland, the UK, France, the Netherlands, Germany, Denmark and Sweden.

- Even-year cohorts rarely recorded but are more regularly recorded in some northernmost Norwegian and Finnish rivers

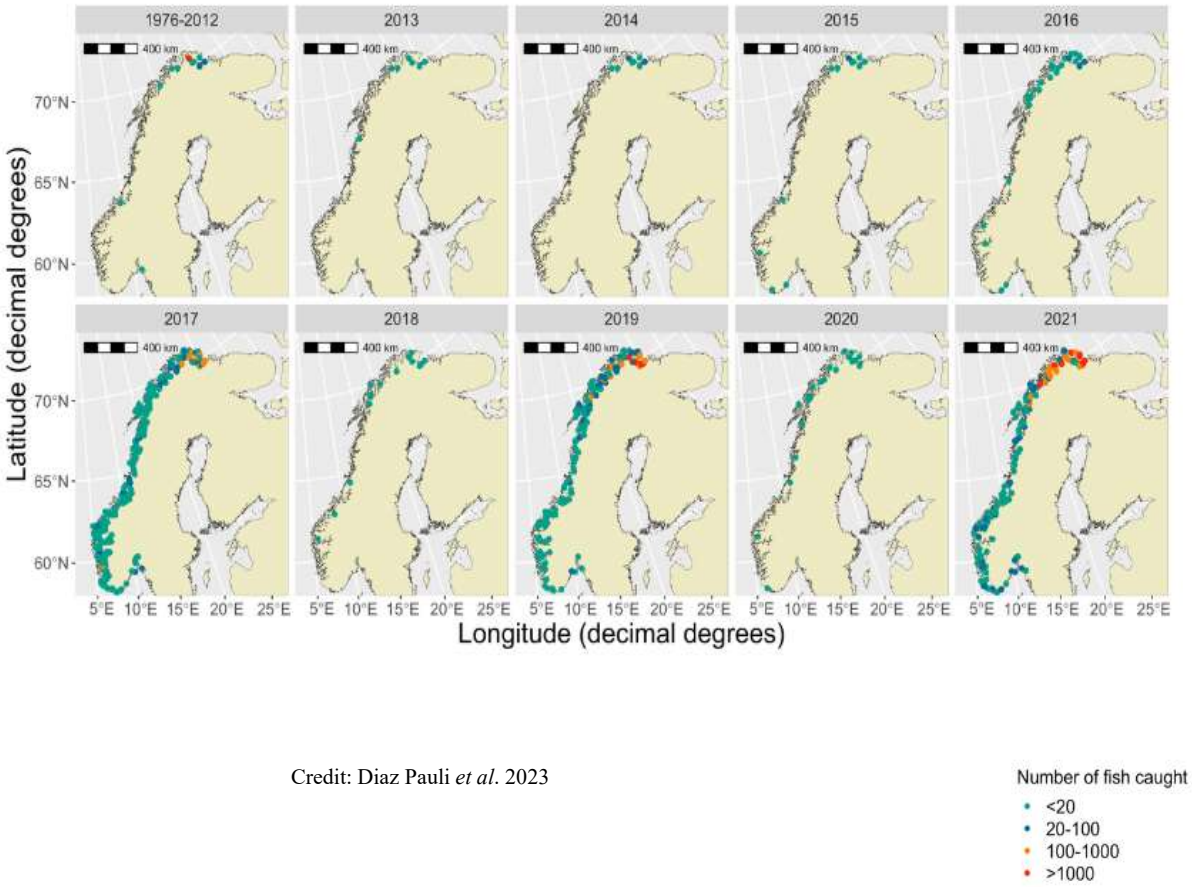
- It is considered likely that the vagrants recorded in N. Atlantic ultimately or directly originated from the non-native populations established in NW Russia.
  - Gilbey *et al.* (2022) found that pink salmon sampled from Scottish rivers in 2017 were genetically indistinguishable from White Sea populations.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



Credit: G. Whightman, IFI; east Greenland 2023

Spread from introduced range *Northern NEAC - Norway*

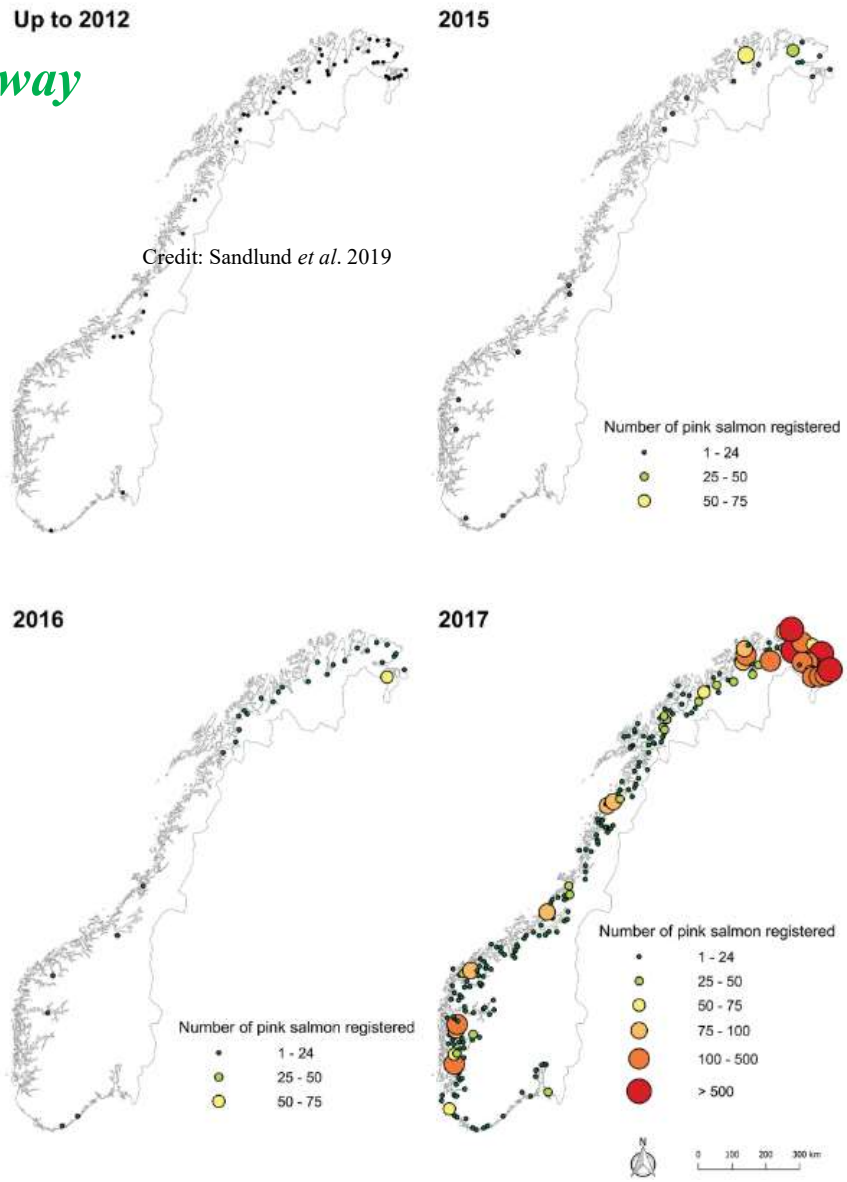
- First recorded in 1960*
- Notable numbers recorded in following two decade in N. Norwegian (& NW Russian) rivers notably odd-year returns in years after stocking
- Despite the cessation of odd-year stocking by 2001, continued to be recorded in rivers in variable numbers and again this was notably higher in odd-years
- Since 1976 recorded in a wide geographic range of rivers from north to south in variable abundance, are distributed all along the Norwegian Sea on its eastern side (Diaz Pauli *et al.* 2023).



Credit: Diaz Pauli *et al.* 2023

Spread from introduced range *Northern NEAC - Norway*

- Not detected in southernmost areas until 1997 with annual occurrences here reported in most years, particularly odd-years, since 2015 and increasing abundances thereafter (Diaz Pauli *et al.* 2023).
- Reflected in odd-year annual catches which progressively increased from 11,654 in 2017, to 14,633 in 2019, to 151,437 in 2021 and 361,548 in 2023 (ICES 2024; NASCO CNL(24)35 2024).
- Vast majority are recorded in Finnmark, and to a lesser extent, Troms counties (Sandlund *et al.*, 2019; Diaz Pauli *et al.* 2023; Froiland and Hostmark 2024).
- Reportedly outnumber Atlantic salmon in many waterways there, species recorded in at least 41 in this region (Muladal and Fagard 2022).

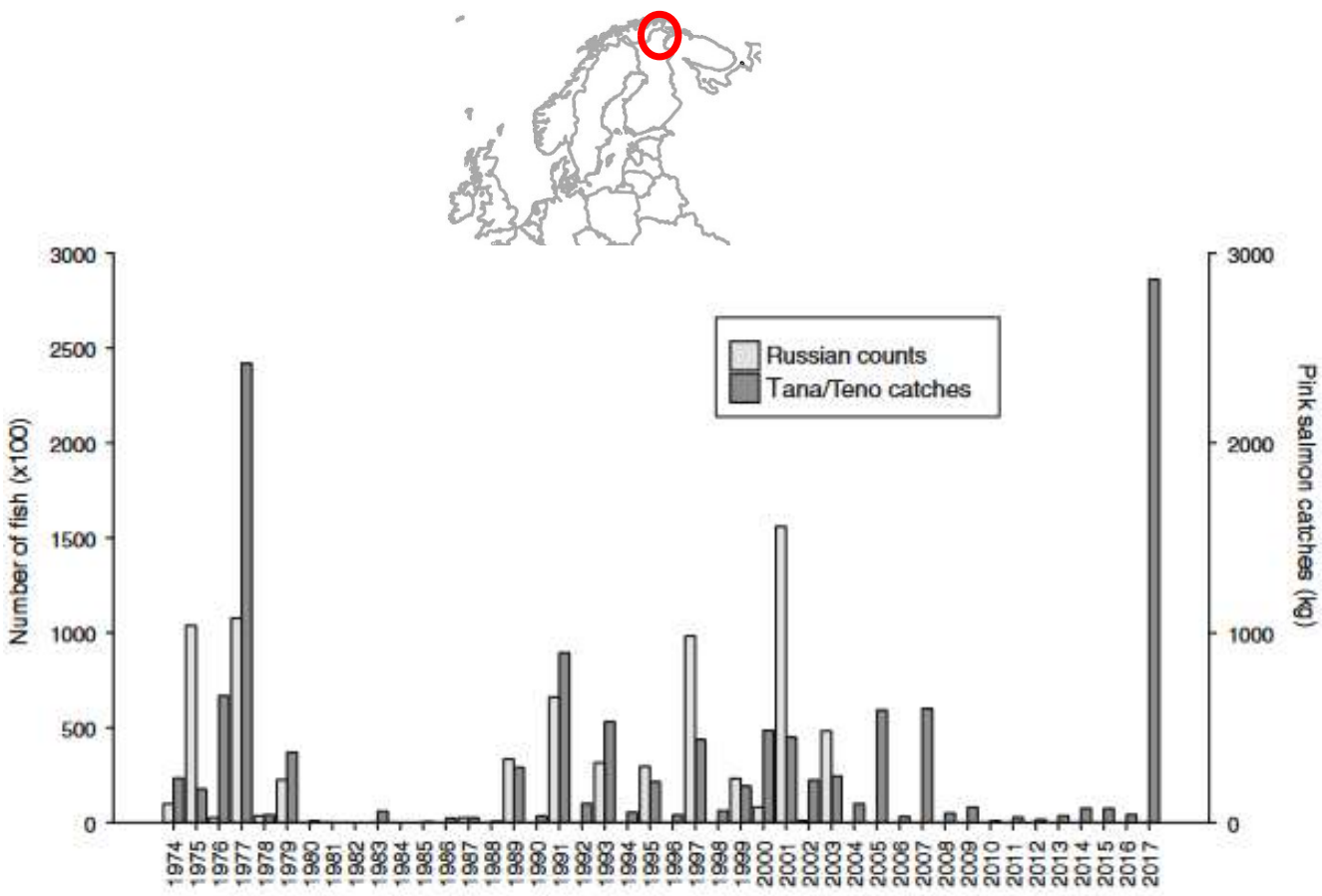


Credit: Sandlund *et al.* 2019

Spread from introduced range *Northern NEAC – Teno/ Tana system*

- Since the 1960s up until 2017, there have been variable occurrences
- Since 2017 *c*. 5,000 in 2017 and 2019 to *c*. 50,000 in 2021 and 170,000 in 2023 (Erkinaro *et al*. 2023; ICES 2024).
- Large-scale spawning was first evident in this system in 2021

  (Erkinaro *et al*. 2022 and references therein)
- Main stem and tributaries, including three notable headwaters in the upper catchment now colonised as well as an increasing number of the smaller tributaries there (Erkinaro *et al*. 2023).



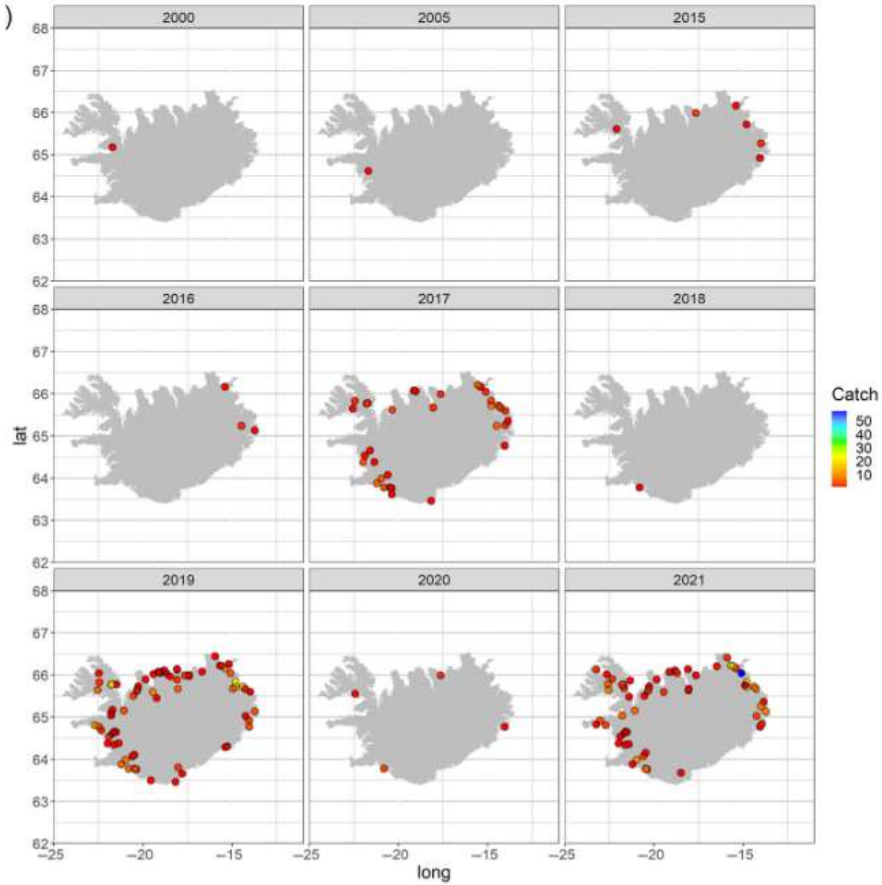
Credit: Sandlund *et al*. 2019

Spread from introduced range *Northern NEAC – other jurisdictions*

- First observed in **Iceland**ic 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; reviewed in Skóra *et al*. 2023).
- In 2021 and 2023 *c*. 340 and 492 were reported (Þórðardóttir and Guðbergsson 2022; ICES 2024).

- In **Sweden**, first recorded in 2017 (n=44) (ICES 2018; 2024).
- In 2021, 70 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 reported in **Denmark** and the **Faroe Islands** in some odd-years since 2017 (ICES 2024).



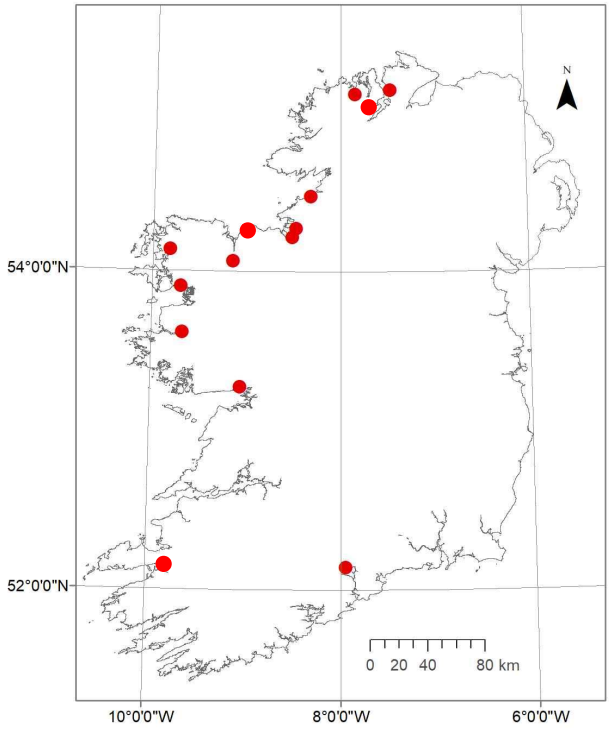
Credit: Skóra *et al*. 2014 and refs therein

Spread from introduced range *Southern NEAC*

- Since 2017, IE, UK(Scot), UK(Eng & Wal) - unprecedented increase in odd-year abundance with occurrences in multiple rivers and/or from interceptions in coastal fisheries

- In **Ireland**, 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 (ICES 2024)

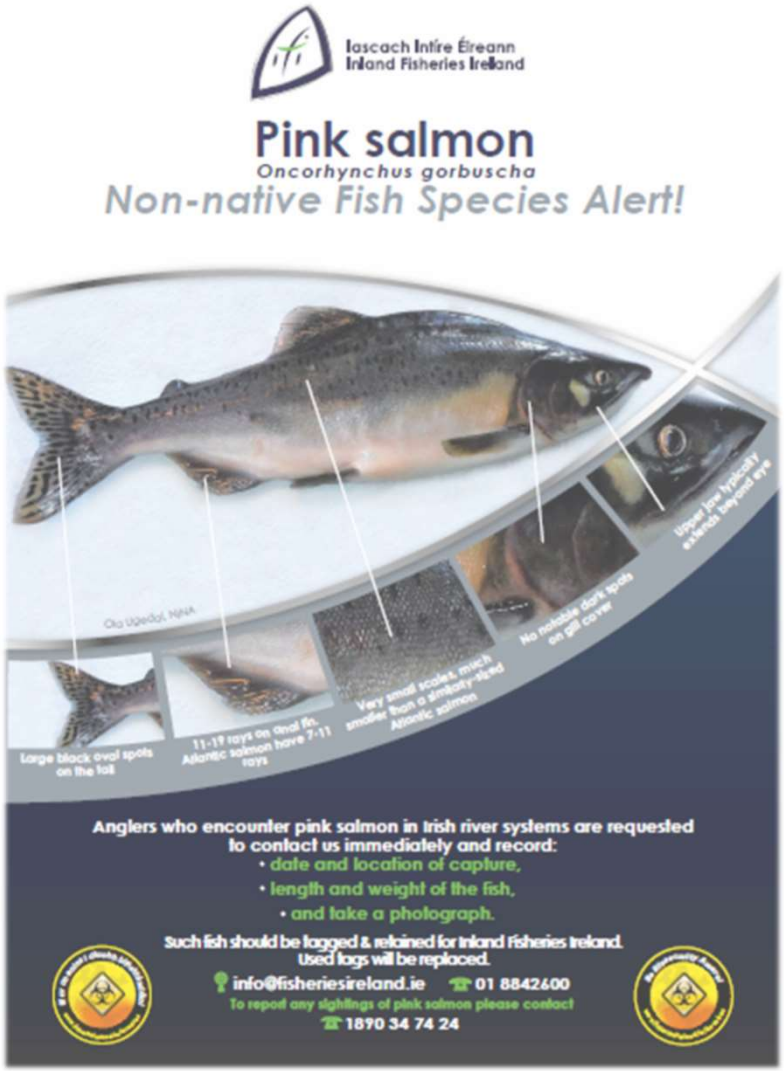
- In 2023, increase in occurrence on preceding odd-years was anticipated, but this did not materialise



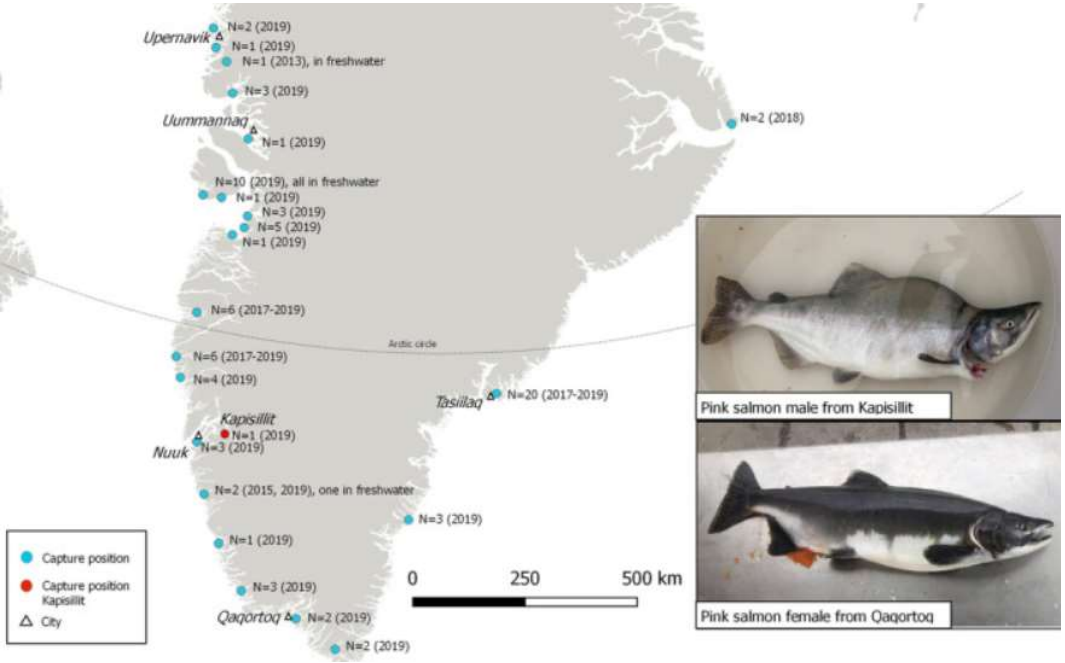
- Although very low numbers recorded in **France**, **Germany**, the **Netherlands** and **UK (Northern Ireland)** since 2017 relative to other Southern NEAC jurisdictions (ICES 2024), these observations further highlight the widespread presence of this non-native species in the Southern NEAC area of the Northeast Atlantic in recent years.

Spread from introduced range *NAC*

- Stocks remain well-established in the Laurentian Great Lakes since their introduction.
- Since 2017, sparsely recorded in low numbers in odd-years in eastern Canada, notably in Newfoundland and Labrador and Quebec (ICES 2024; NASCO CNL(24)21 2024).
- Previous stocking in Newfoundland in the 1950s and 1960s did not ultimately result in self-sustaining populations (reviewed in Heard 1991).
- There are no reported incidents of pink salmon in US Atlantic waters in recent times (ICES 2024; NASCO CNL(24)21 2024) with the stocks introduced to the State of Maine in the 1900–1920s believed to have disappeared by the late 1920s (Heard 1991).

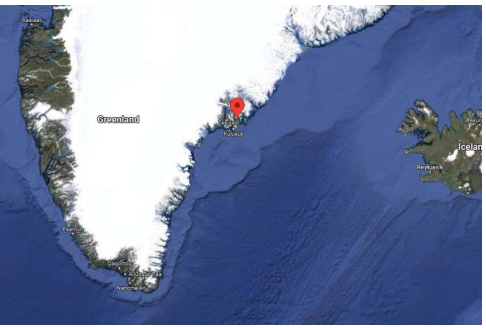


Spread from introduced range *East and West Greenland*



Credit: Nielsen *et al*. (2020)

- First observed in 1969 (reviewed in Nielsen *et al.* 2020), documented in at least 22 locations there since 2013, vast majority encountered since 2017 (Nielsen *et al.* 2020).
- Notable increase in reports in 2023 (n=1,021) compared to preceding odd-years when between 62 and were recorded (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, have also been observed in the lower reaches of some rivers and encountered in adjacent near-shore areas (G. Wightman, N. Jepsen and K. Aarestrup pers. comm.)

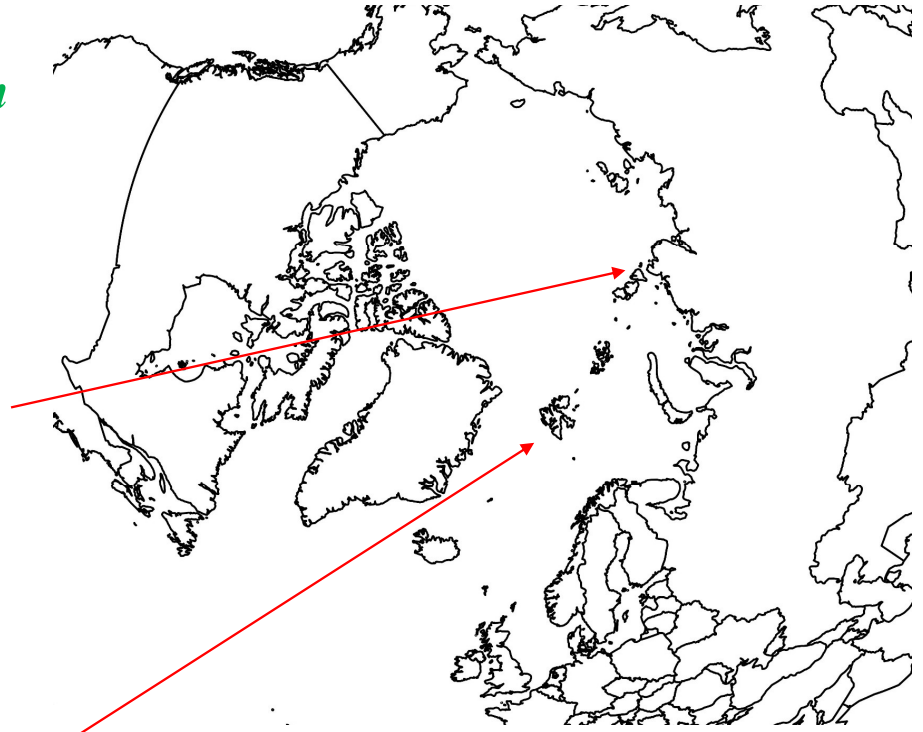


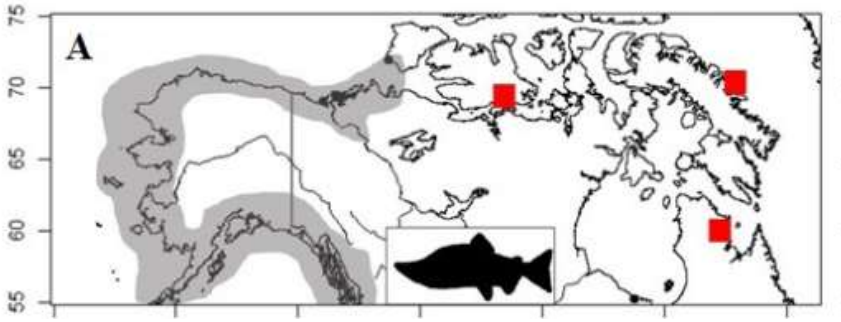
Credit: G. Whightman, IFI; east Greenland 2023

Spread from introduced range *High Arctic region*

- **Russian Arctic**
  - some westward expansion from its native range documented since 2011
  - further expansion is likely constrained by prohibitive climatic conditions with the Taymyr Peninsula considered to separate native and introduced ranges

    (reviewed in Northern Hemisphere Pink Salmon Expert Group 2023).
- **Svalbard**
  - first recorded in 1961
  - commonly occur in both the marine & freshwater
  - no current potential to spawn as the rivers run dry or freeze in the autumn and winter. (Bengtsson *et al.* 2023).
- **Eastern Canadian Arctic**
  - between 2017 and 2019, individuals documented at 3 locations (McNicholl *et al.* 2021).





Credit: McNicholl *et al.* (2021)

*Why the increased abundance and distribution in the North Atlantic since 2017?**

- In general,
  - Increased temps associated with higher growth and survival in freshwater (reviewed in Veselov *et al.* 2016; and Farley *et al.* 2020)
  - Warmer receiving marine environment considered to enhance survival prospects (Mo *et al.* 2018; Farley *et al.* 2020; Kaustad 2021)
- Main drivers attributed to more favourable warmer water temps in recent years in both the freshwater and marine environments (VKM *et al.* 2020; Paulsen *et al.* 2022; Lennox *et al.* 2023; Northern Hemisphere Pink Salmon Expert Group 2023).
- Increasing SSTs have been associated with an increased adult returns (VKM *et al.* 2020) ***
- In native range:
  - abundance of juveniles in summer highly correlated to harvest of adults in following year (Miller *et al.* 2022)
  - Increases in odd-year cohorts in recent decades associated with increasing sea temperatures (Irvine *et al.* 2014).

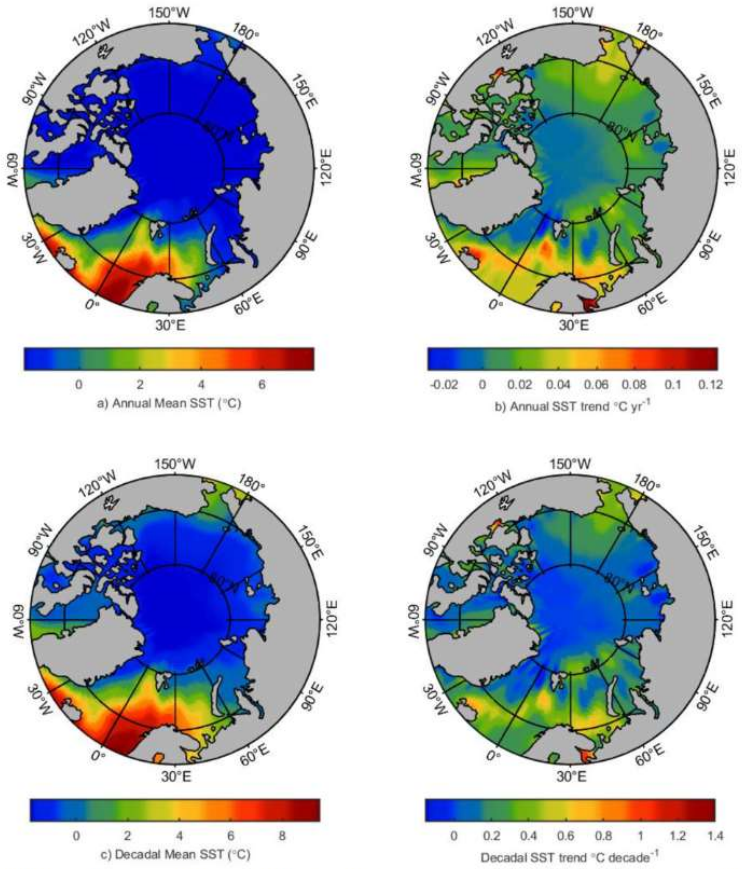
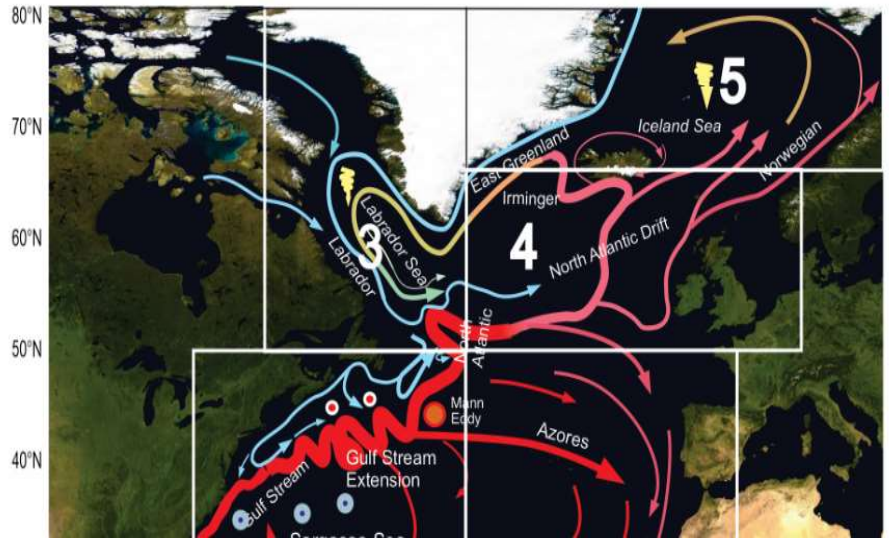


Fig. 2. Spatiotemporal distribution of a) Annual Mean SST b) Annual SST trends c) Decadal Mean SST and d) Decadal SST trends for the period 1982–2018. The maps represent annually/decadal averaged means and trends.

Credit: Carvalho and Wang (2020)

*Why the increased abundance and distribution in the North Atlantic since 2017?**

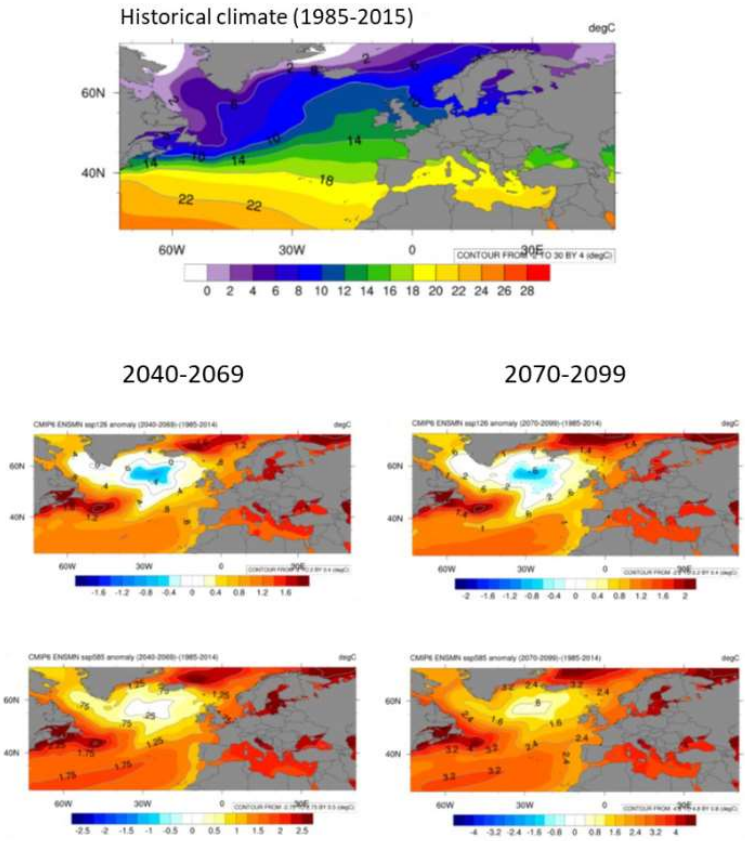
- Homing instinct to natal rivers in at least some introduced stocks is considered to be less precise than native stocks* (reviewed in Niemelä *et al.* 2016; and in Lennox *et al.* 2023).
- Despite stocks in NW Russia considered mainly to return to natal rivers, even with low straying rates, high abundances in a given year may result in straying of significant numbers (Sandlund *et al.* 2019)
- Speculated that:
  - straying to Greenland and further south could be promoted by vagrants following course of typical ocean circulation patterns used by Atlantic salmon (Diaz Pauli *et al.* 2023).
  - if homing has inherited features, transplanted stocks would be more susceptible to straying (VKM *et al.* 2020).



Credit: Mishonov *et al.* (2024)

*Future prospects for establishment and occurrence outside of established introduced range**

- Climatic factors are likely key determinants influencing abundance in upcoming decades and consequently affect their capacity for further spread (Niemelä *et al*. 2016; VKM *et al*. 2020).
- Continued years of more favourable water temperatures are likely to increase survival and increase the propagule pressure elsewhere
- Particularly important for jurisdictions more distant from the current range of colonisation
- More immediate concerns for proximal areas, particularly further south in Norway, increasing importance of effective control measures
- With the climatically-induced increase in water temperatures already observed in northernmost latitudes likely to continue, it is anticipated to become a northern circumpolar species (VKM *et al*. 2020).



Future prospects for establishment and occurrence outside of established introduced range

- Successful reproduction already documented in some rivers outside of its established NWmost range in Europe*
- Demonstrated ability to rapidly adapt and acclimatise to new areas of introduction
- Prospects for range expansion cannot be assessed in isolation
- Further curtailment of establishment in more southerly latitudes also possible

Thank you

Aasleagh Falls, NSIC River Erriff

Acknowledgements

- Full reference list can be found in CNL(24)52