# Unraveling the demographic response of Atlantic salmon to a rapidly changing environment by the analysis of their scales

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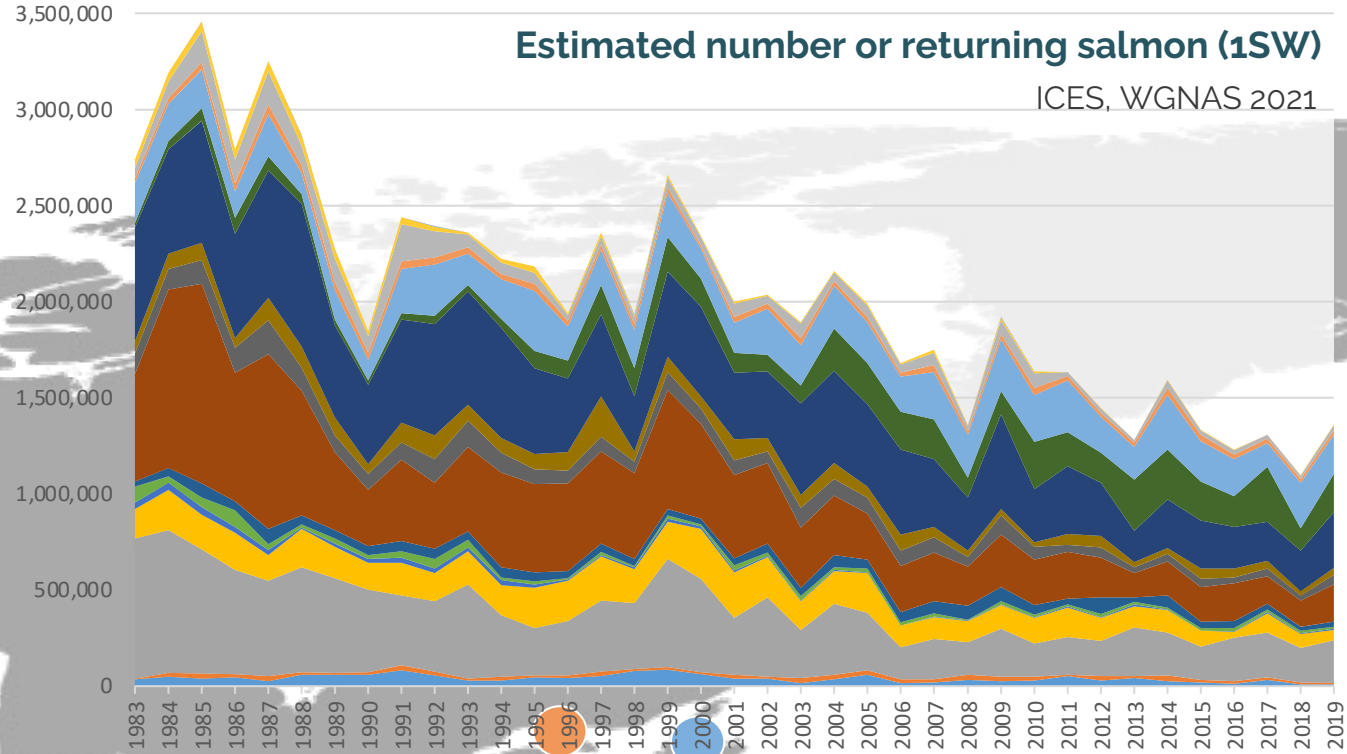
INRAE, Ecosystem Dynamics and Sustainability Research Unit, France

**4-6 October 2022 / International Year of the Salmon Synthesis Symposium / 'Salmon in a Changing Salmosphere' theme session**

# ‘Salmon in a Changing Salmosphere’ theme session

Global decline in Atlantic salmon and global change

## Synchrony in the decline of salmon abundance across multiple stocks



# ‘Salmon in a Changing Salmosphere’ theme session

Global decline in Atlantic salmon and global change

Synchrony in the decline of salmon abundance across multiple stocks
Large scale changes in the ecosystem of the North Atlantic Ocean

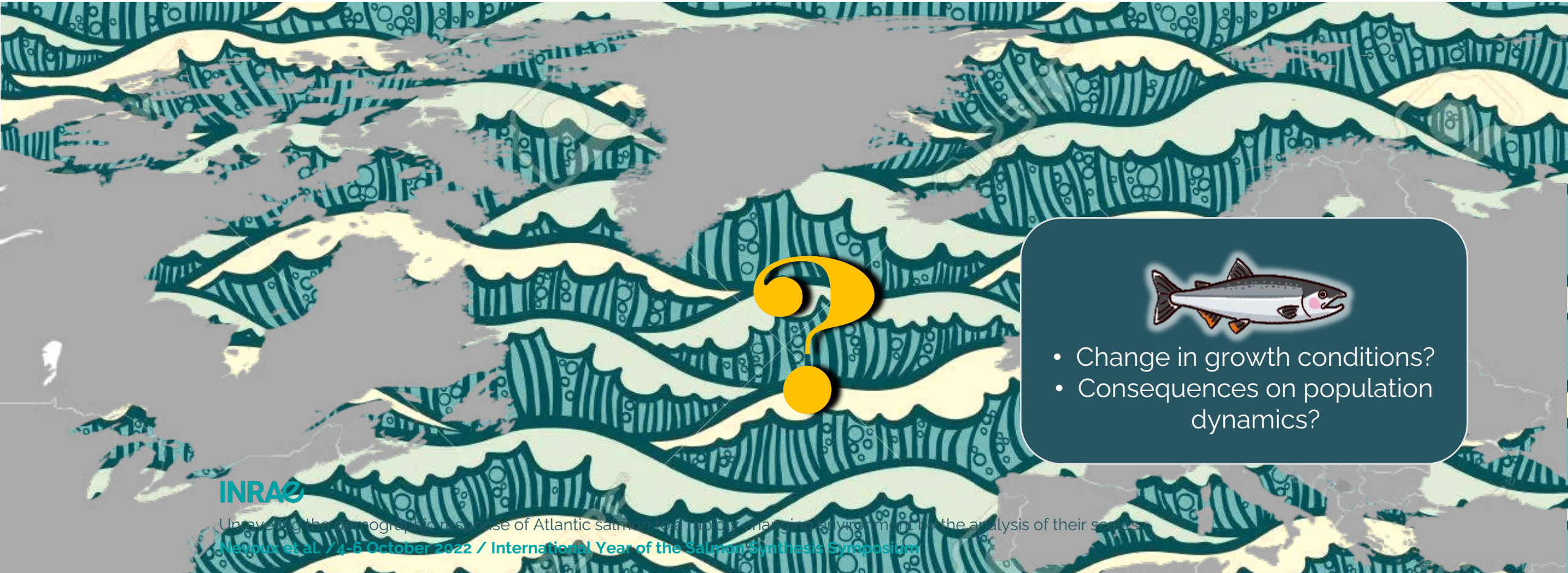
Unraveling the demographic response of Atlantic salmon to a rapidly changing environment by the analysis of their scales

**Nevoux et al. /4-6 October 2022 / International Year of the Salmon Synthesis Symposium**

# ‘Salmon in a Changing Salmosphere’ theme session

Global decline in Atlantic salmon and global change

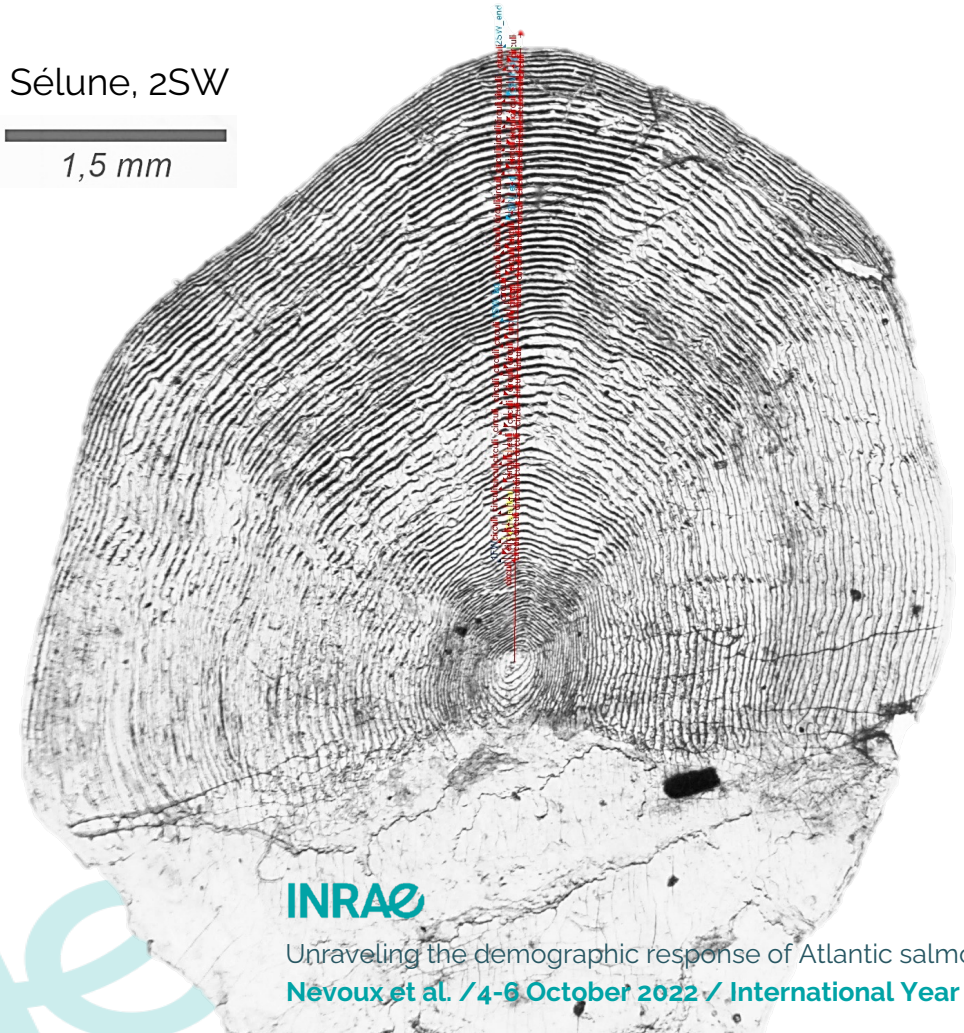
Synchrony in the decline of salmon abundance across multiple stocks
Large scale changes in the North Atlantic ecosystem
**→ How to link salmon decline and changes at sea?**



# Understanding the marine phase of the salmon life cycle

## Scales are archives of individual growth history

Retrospective analysis of salmon growth



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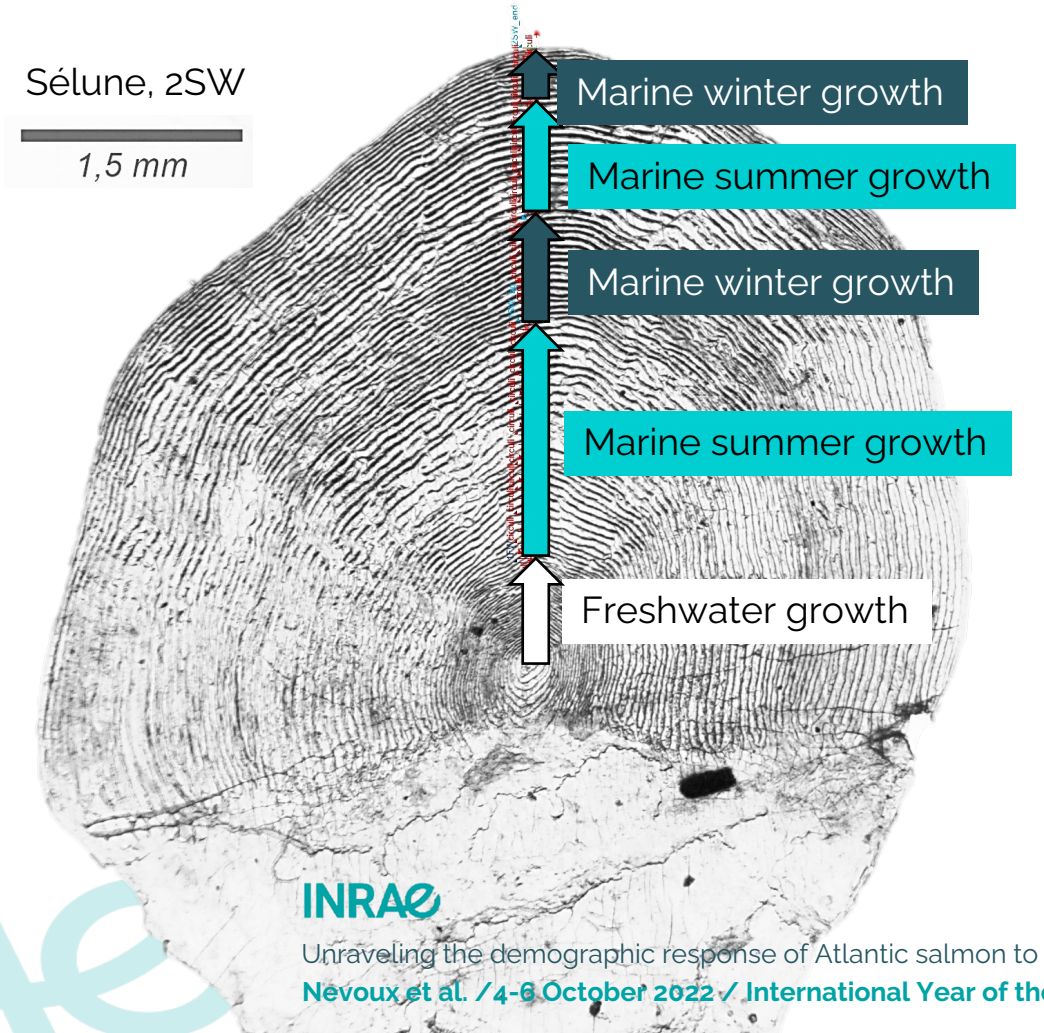

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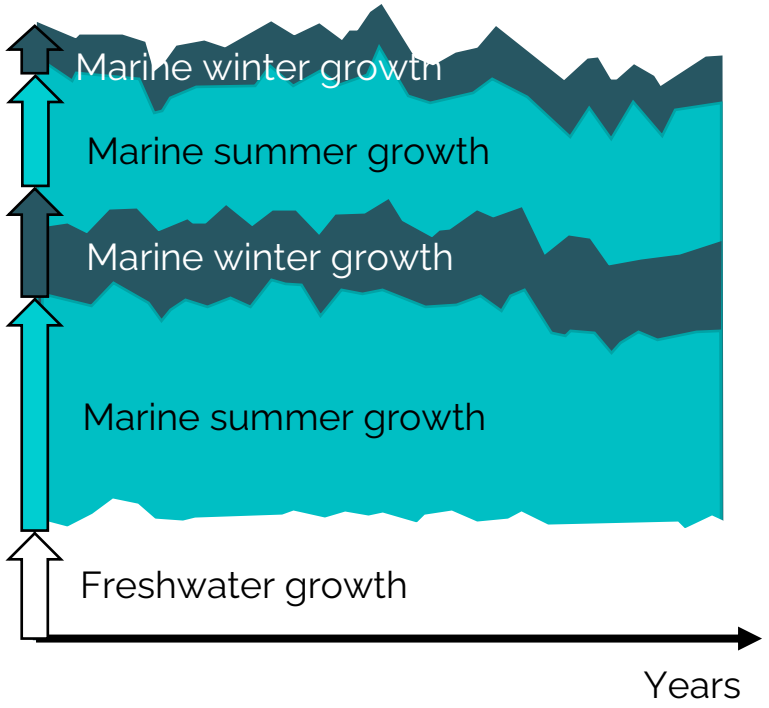
Sélune, 2SW



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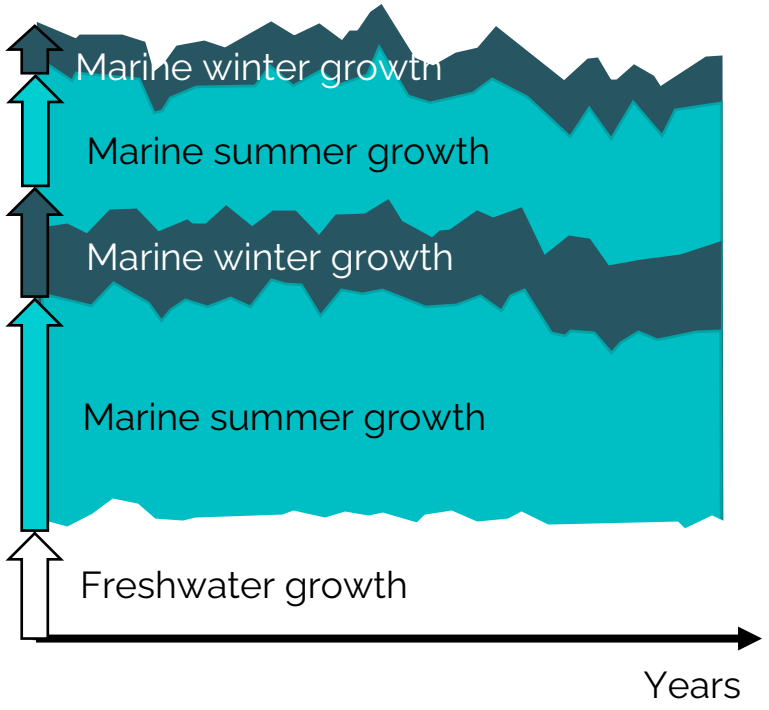
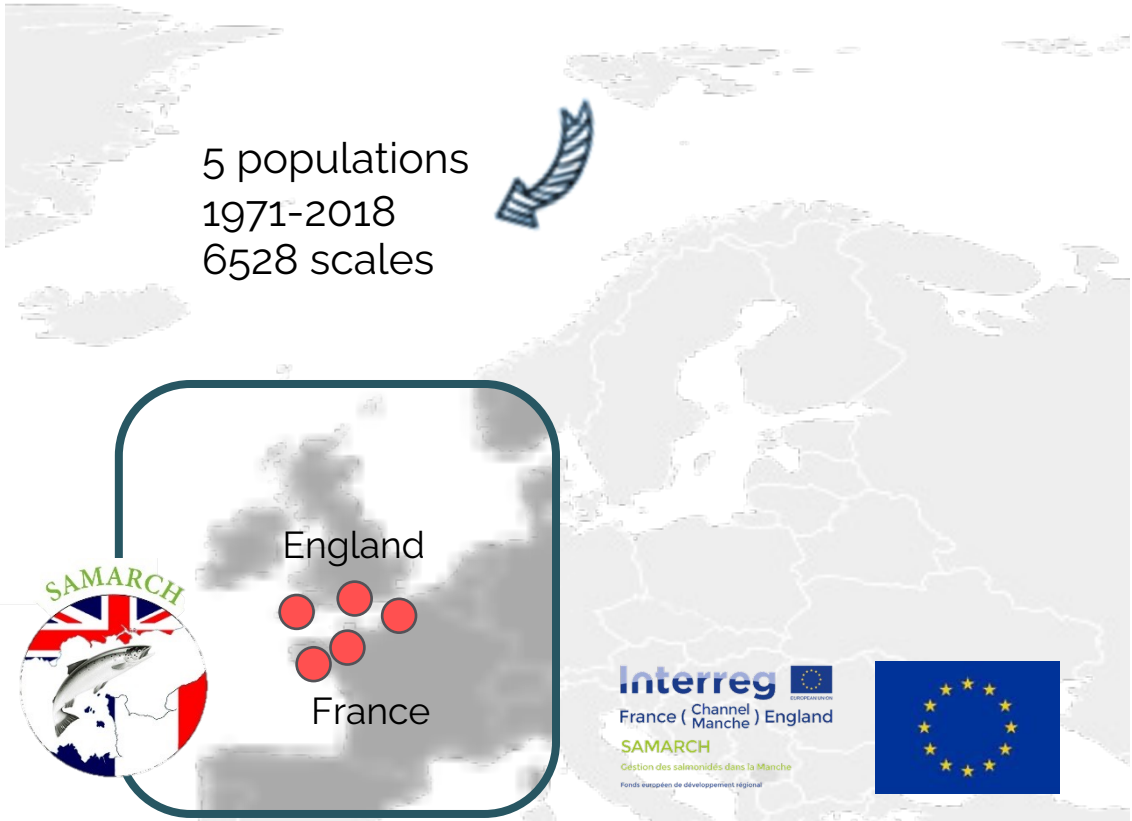
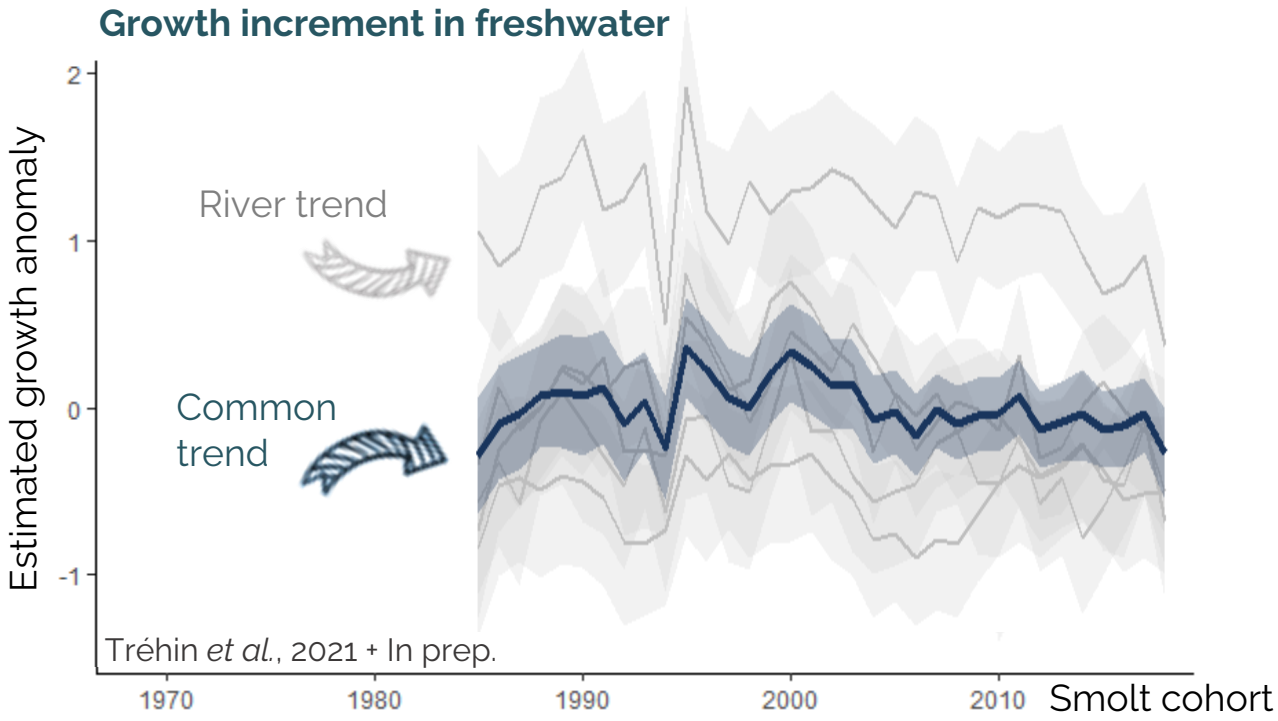



→ **Describe long-term change in marine growth**
→ **Identify the spatial scale of changes**
→ **Link growth to life history and population dynamics**

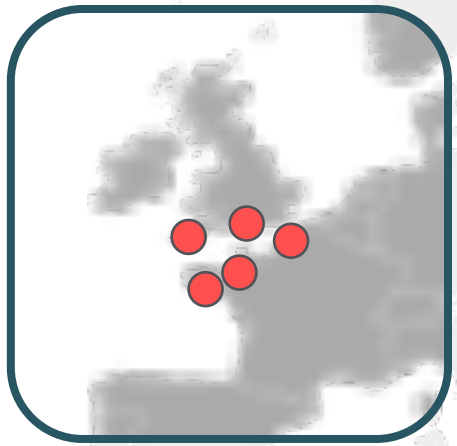


# Salmon growth in freshwater

Stable growth with population specific variability

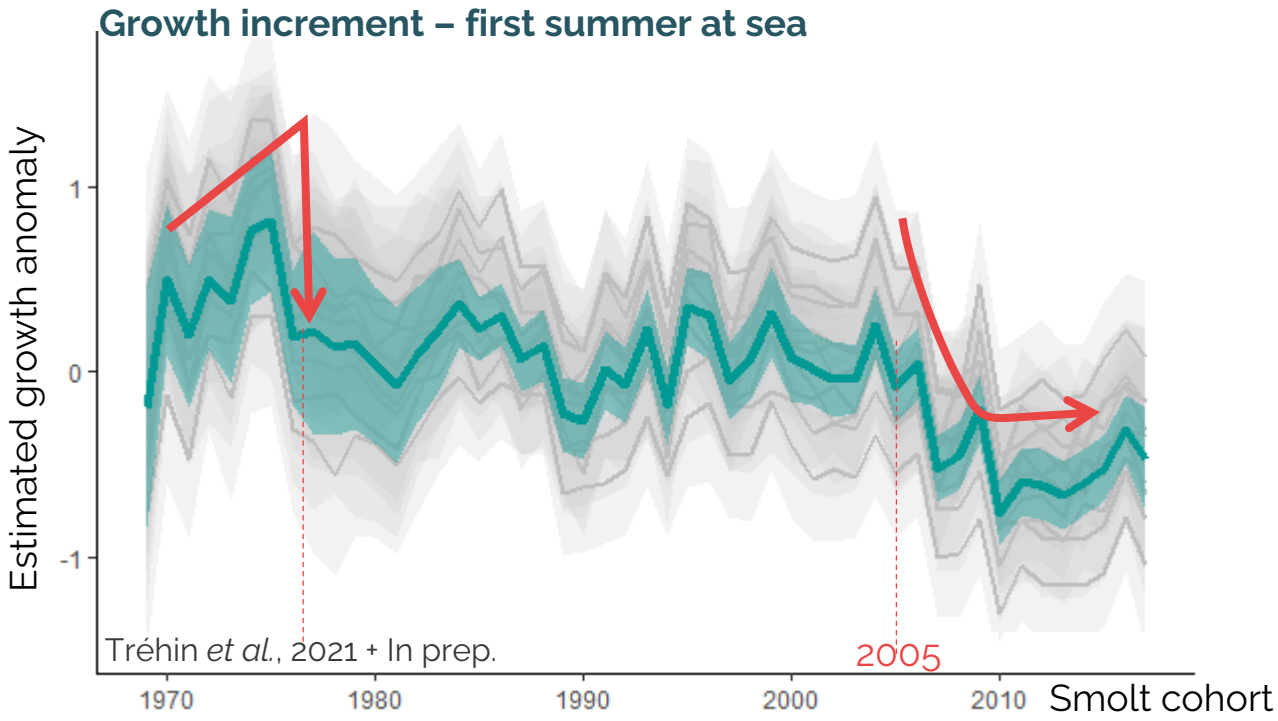


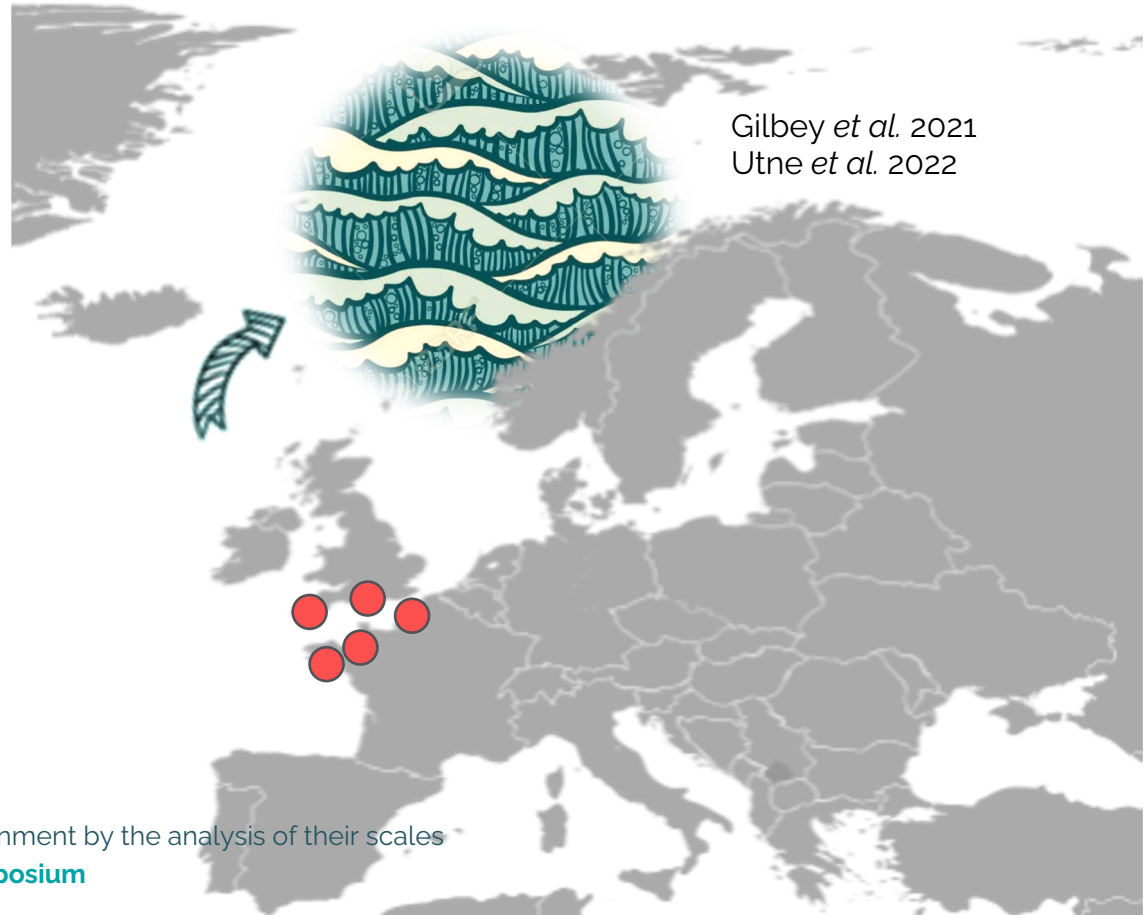

No evidence of long term change in smolt size
Freshwater growth is population-specific



# Decline in early marine growth

Spatial synchrony in growth pattern




Marine growth at record low since 2005
Similar decline in summer growth in all 5 populations
→ Early marine growth drives decline in salmon?

# Decline in early marine growth

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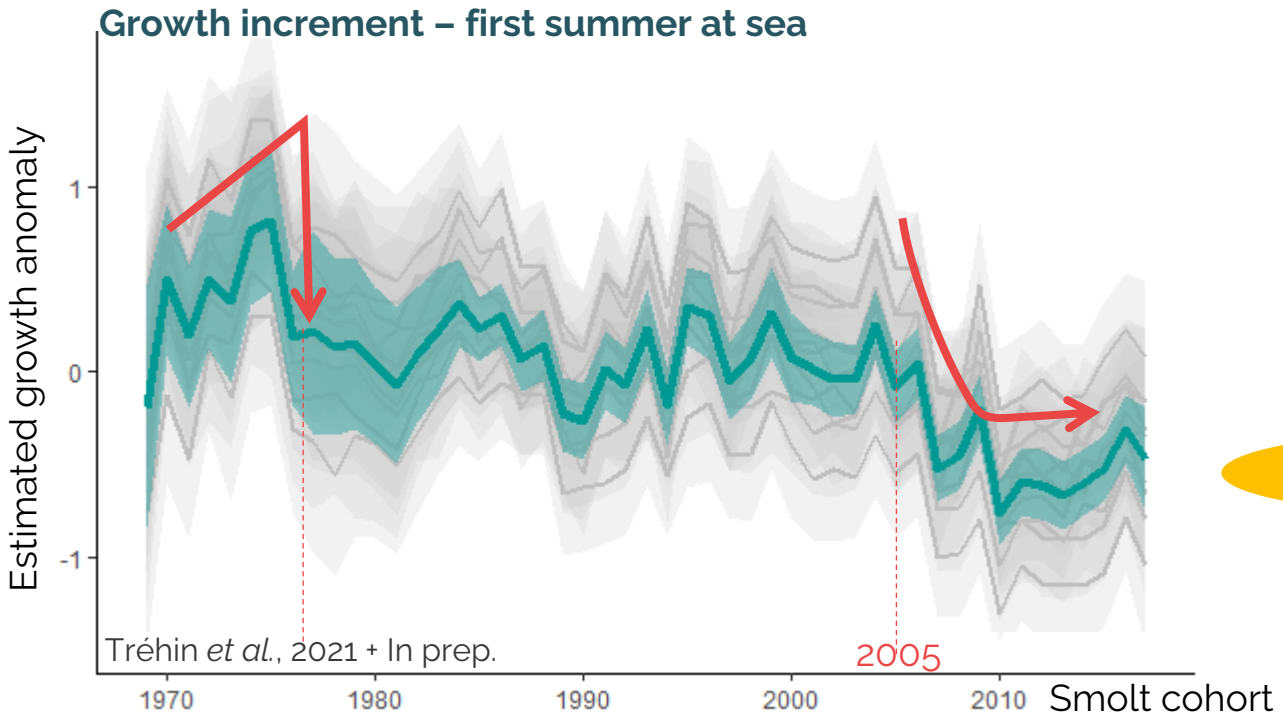
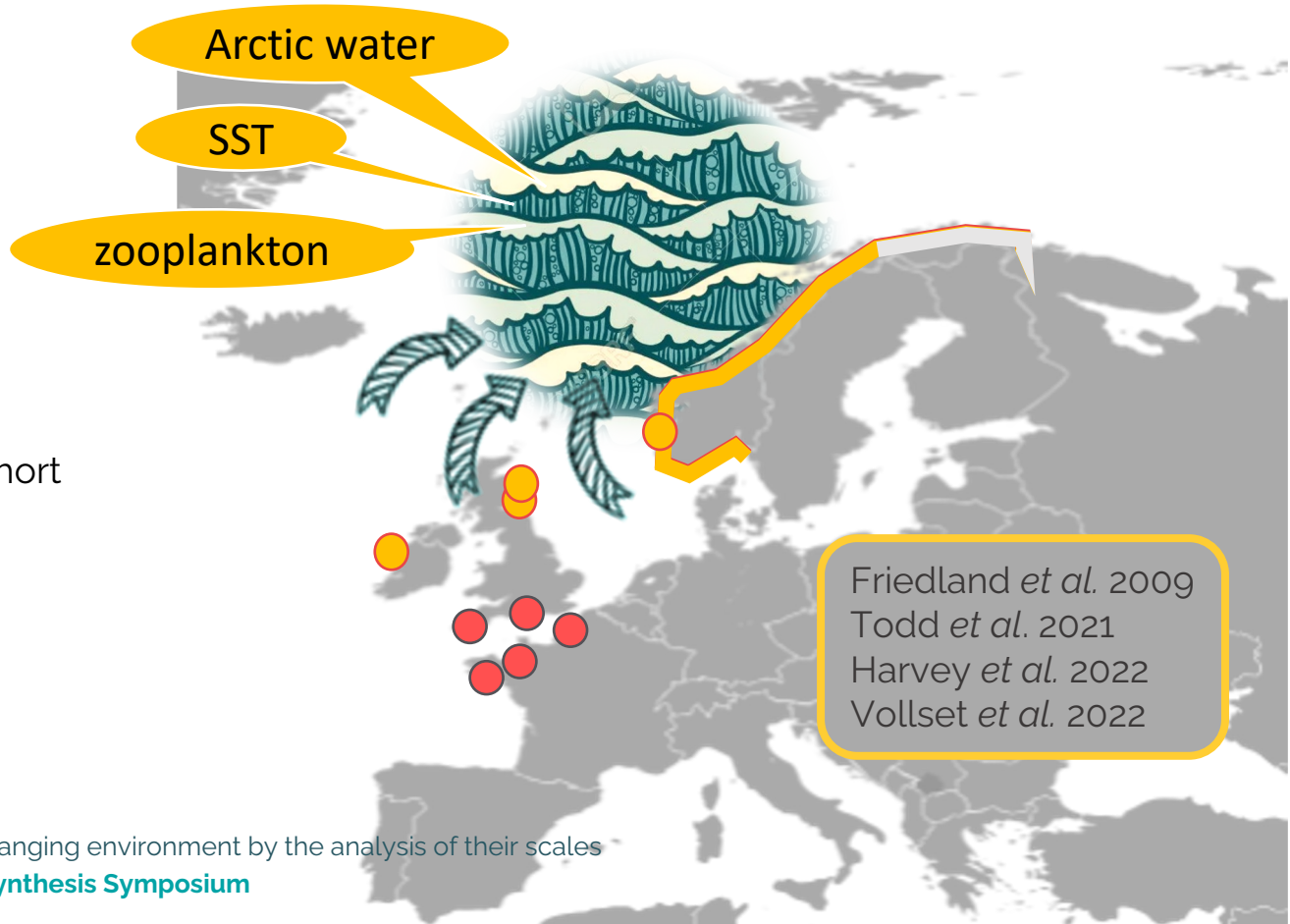



Marine growth at record low since 2005
Similar decline in summer growth in all 5 populations
→ Early marine growth drives decline in salmon?

Similar trends recorded across Southern Europe…
… but not in North American populations (Barajas *et al.* 2021)
→ Change in growth condition in the Norwegian sea

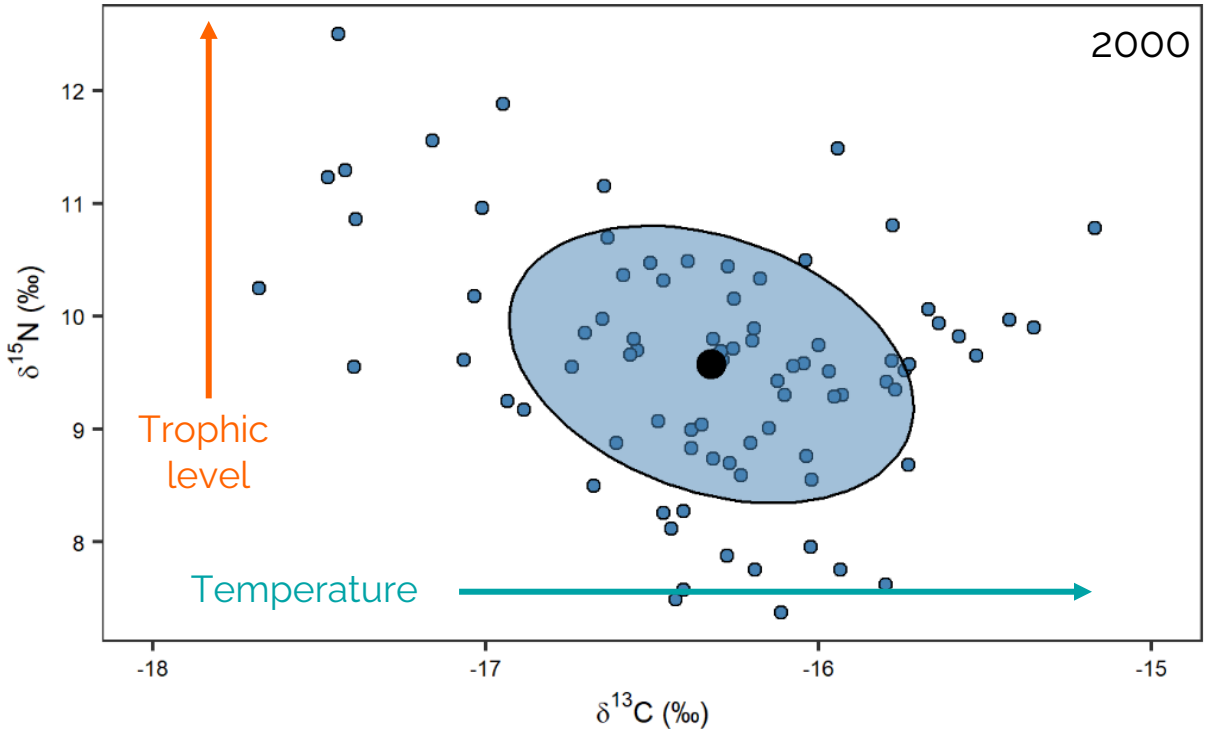


# Change in marine feeding conditions

## Tracking salmon isotopic niche in the ocean

Analysis of the isotopic composition of scales

- Nitrogen ($\delta^{15}N$): a proxy of trophic level
- Carbon ($\delta^{13}C$): a proxy of source and temperature

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Analysis of the isotopic composition of scales
- Nitrogen ($\delta^{15}N$): a proxy of trophic level
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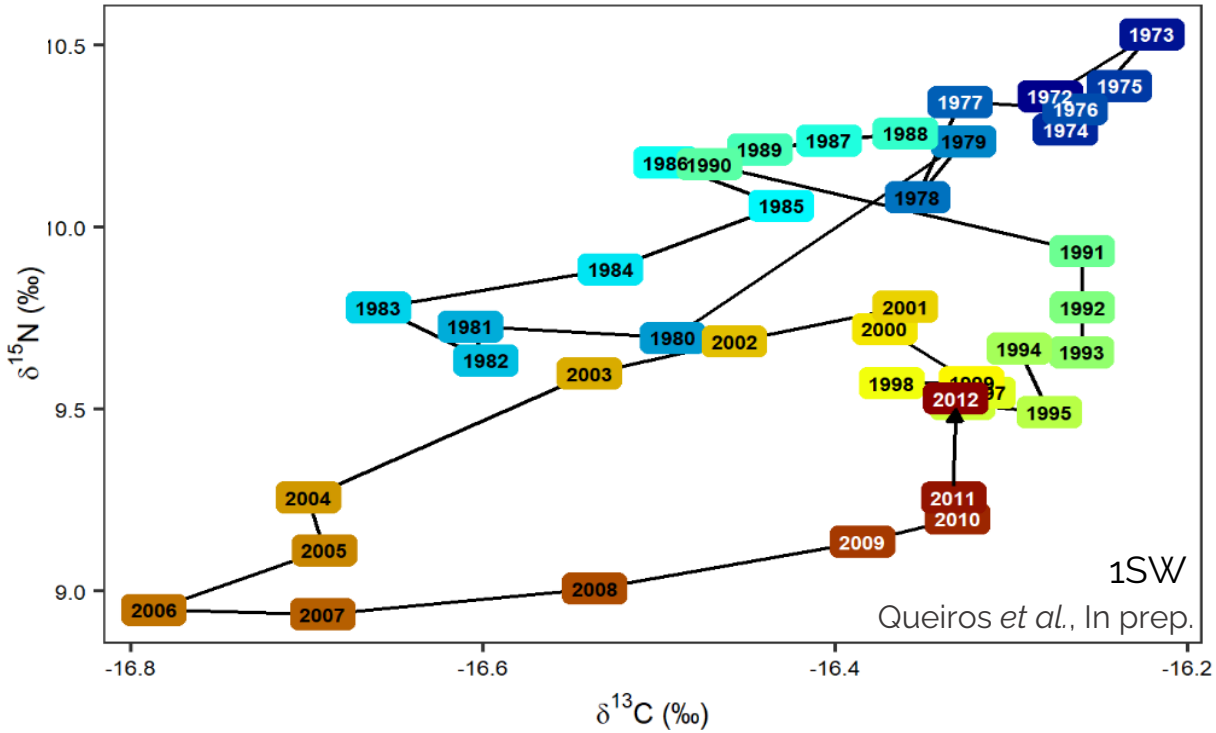
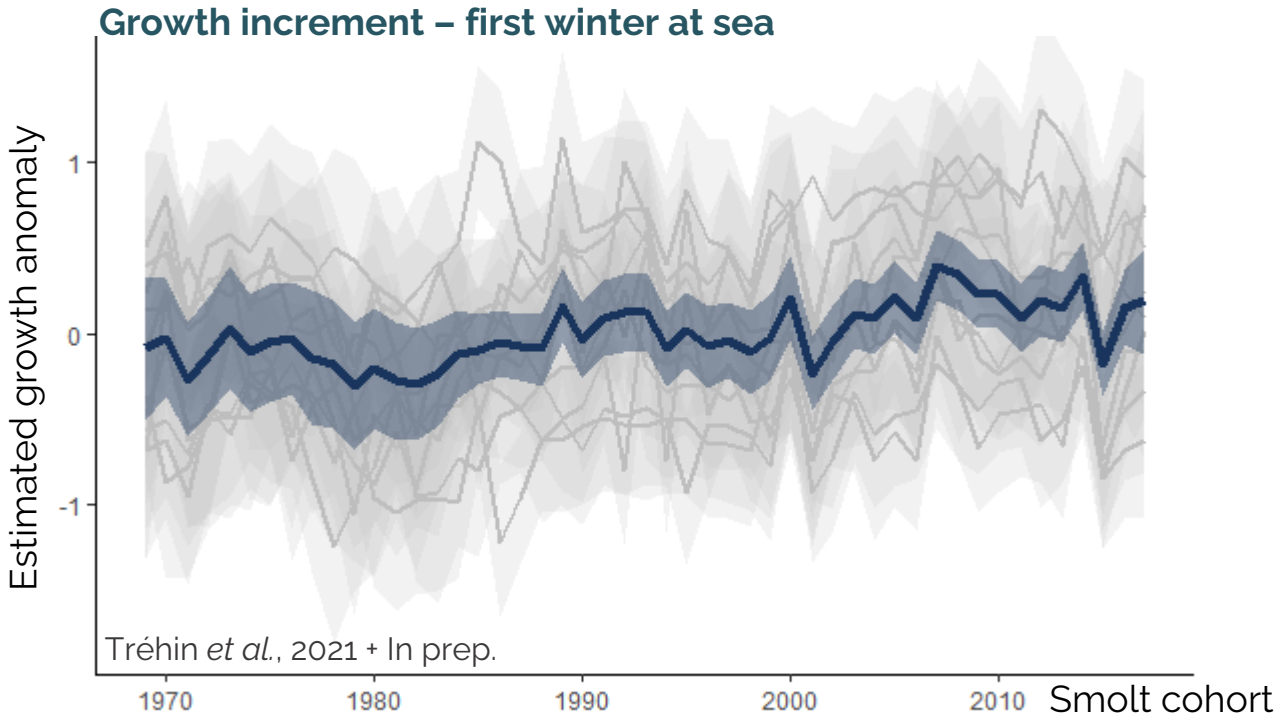
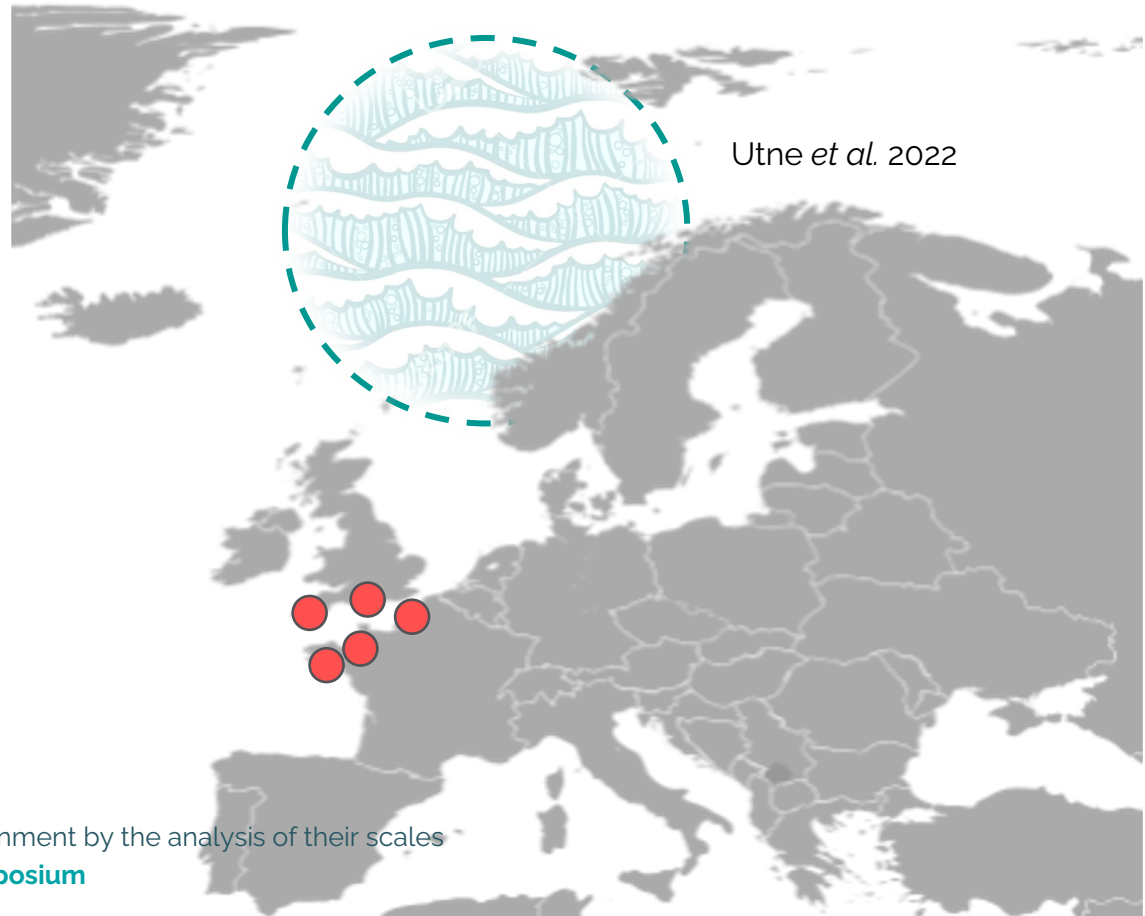
→ Different diet on the same feeding ground?
→ Same diet on a different feeding ground?




# What about later marine growth?

Contrasted signals in growth patterns




Increasing trend in winter growth at sea
High variability in growth trajectories…

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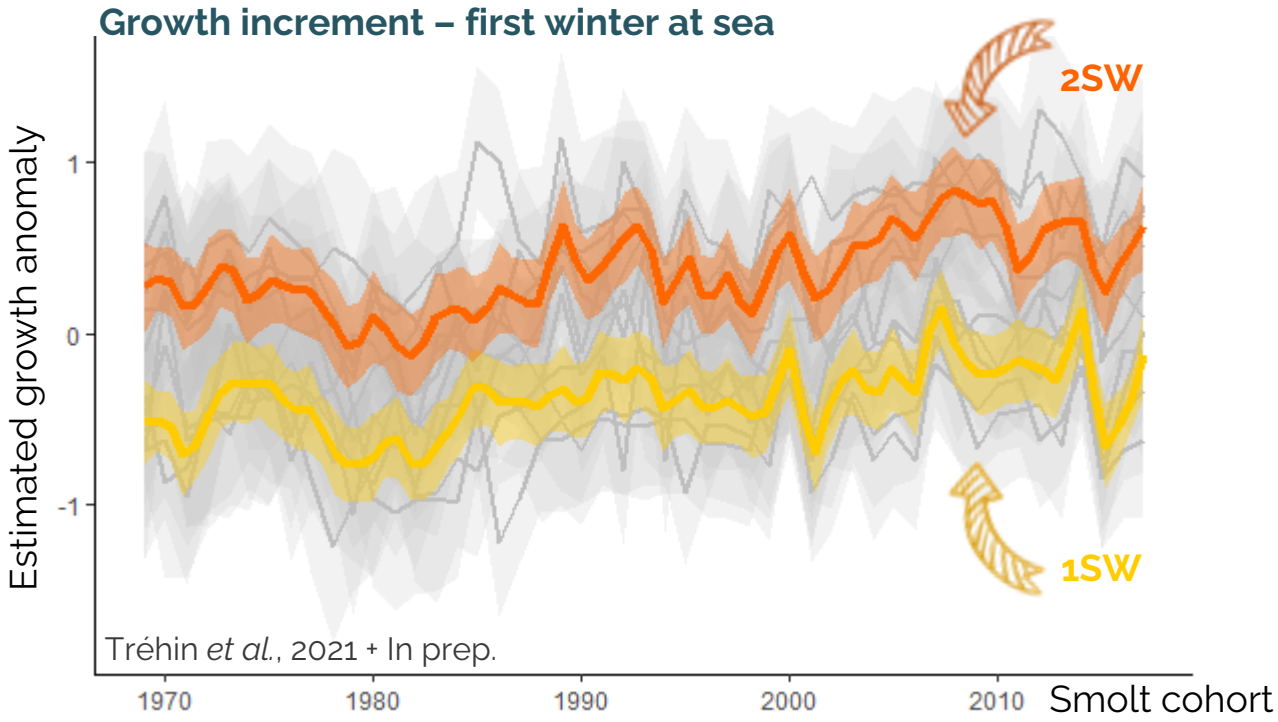
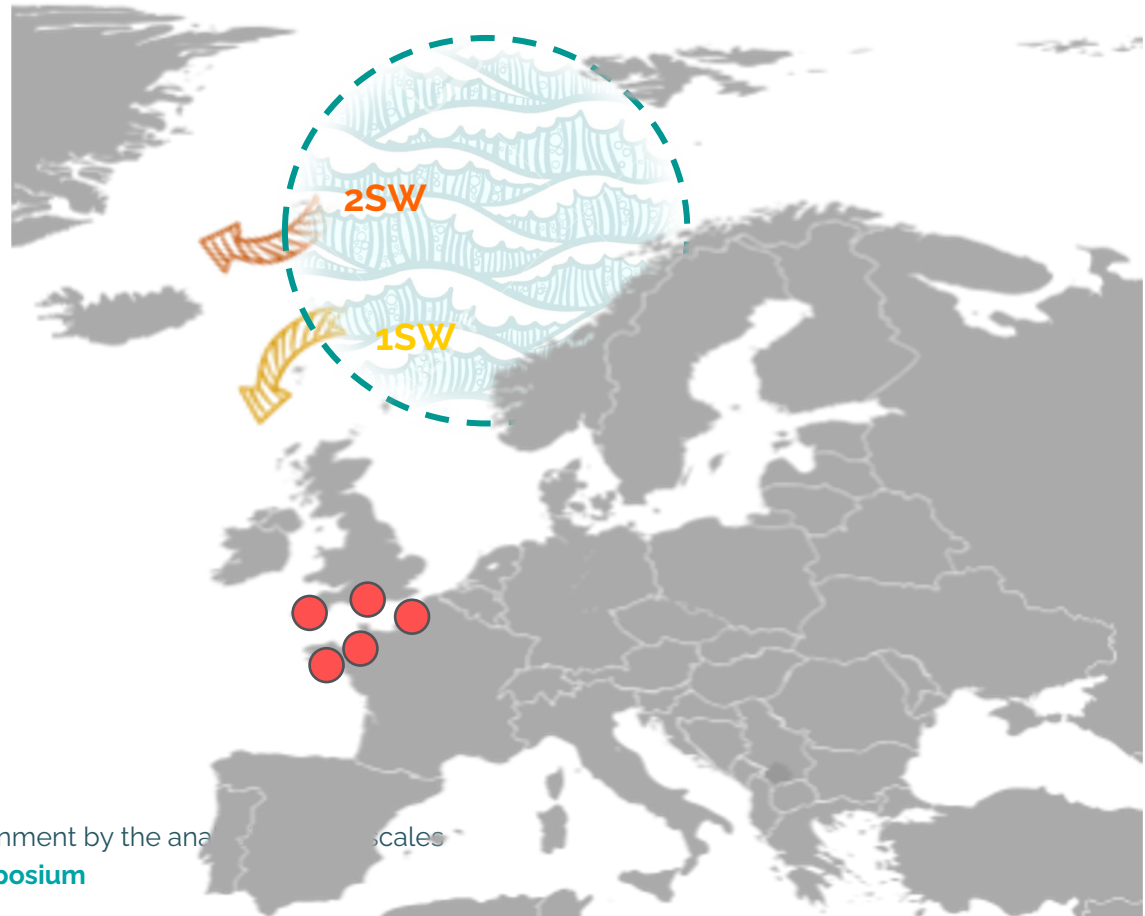



Increasing trend in winter growth at sea
High variability in growth trajectories…

Asynchrony in 1SW and 2SW: different locations
→ Seasonal contrast in response to oceanic changes

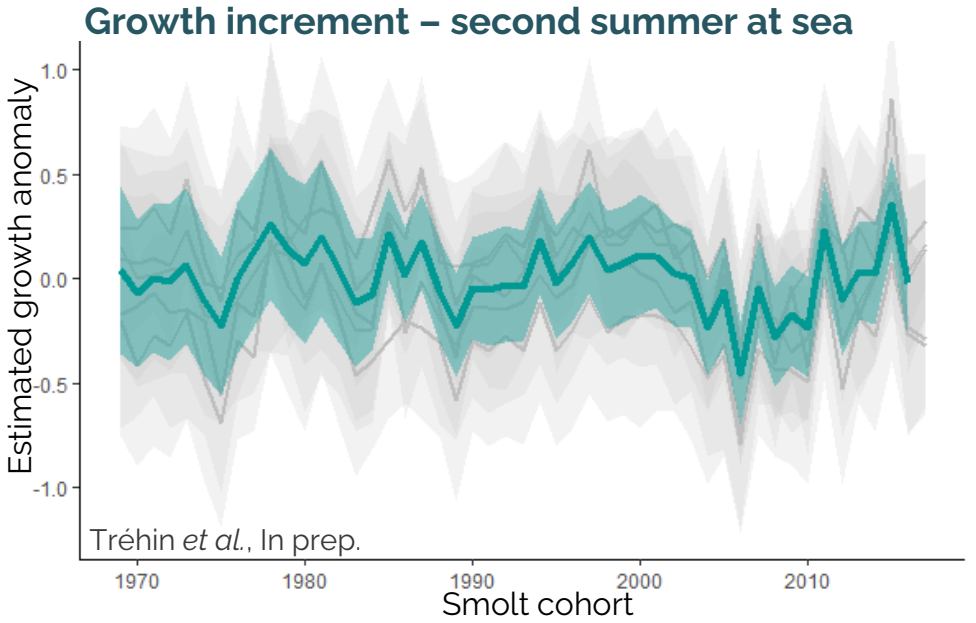


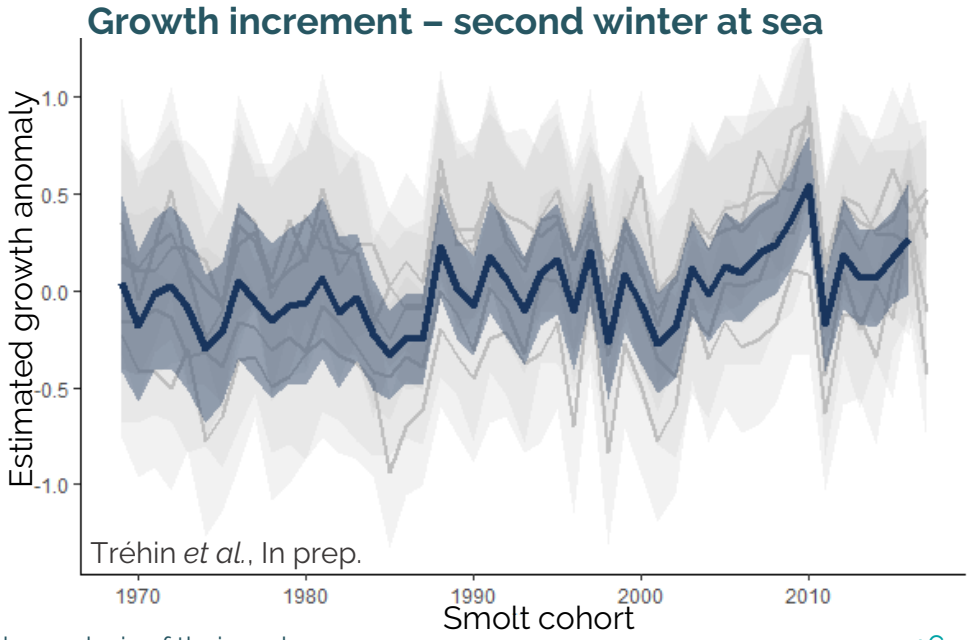
# What about later marine growth?

Contrasted signals in growth patterns

Variability in later marine growth to explore
→ Link with trends in North American populations?


Barajas *et al.* 2021

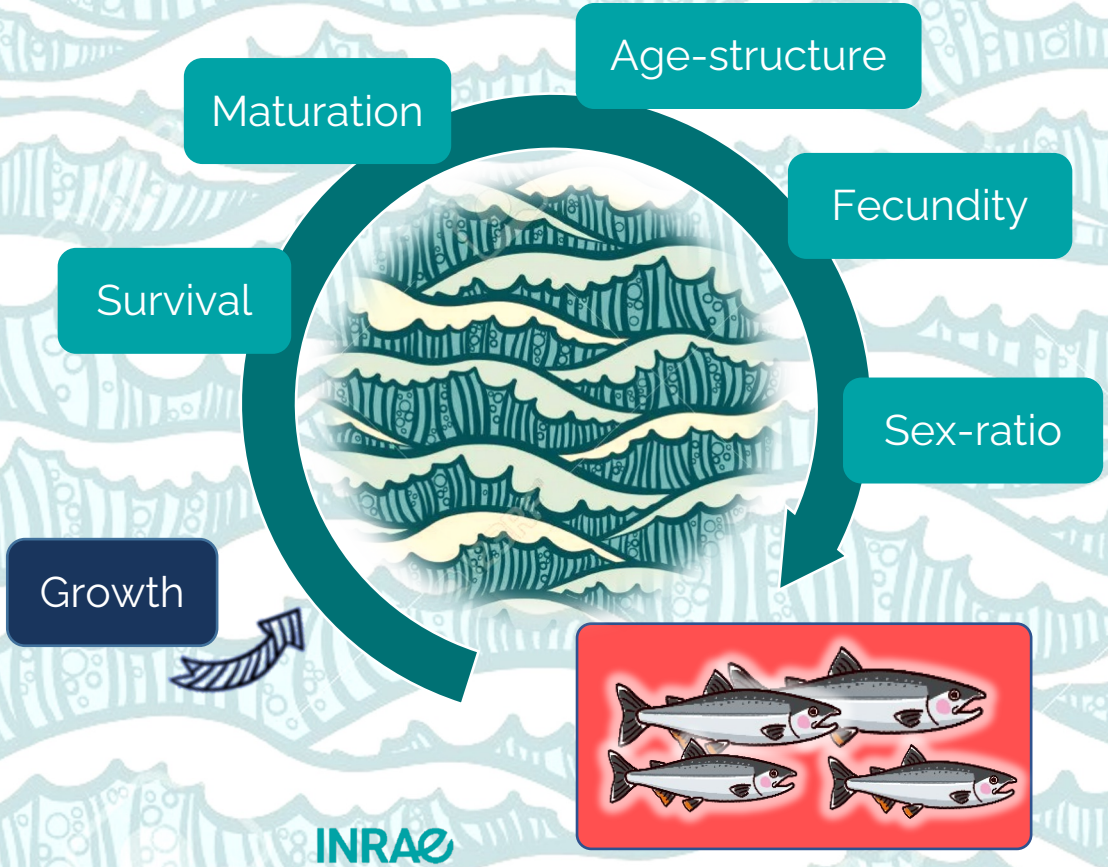


# A life cycle approach of salmon life at sea

## Cascading effects of change in growth on salmon life history

Account for variability in demographic transitions
in response to a rapidly changing environment



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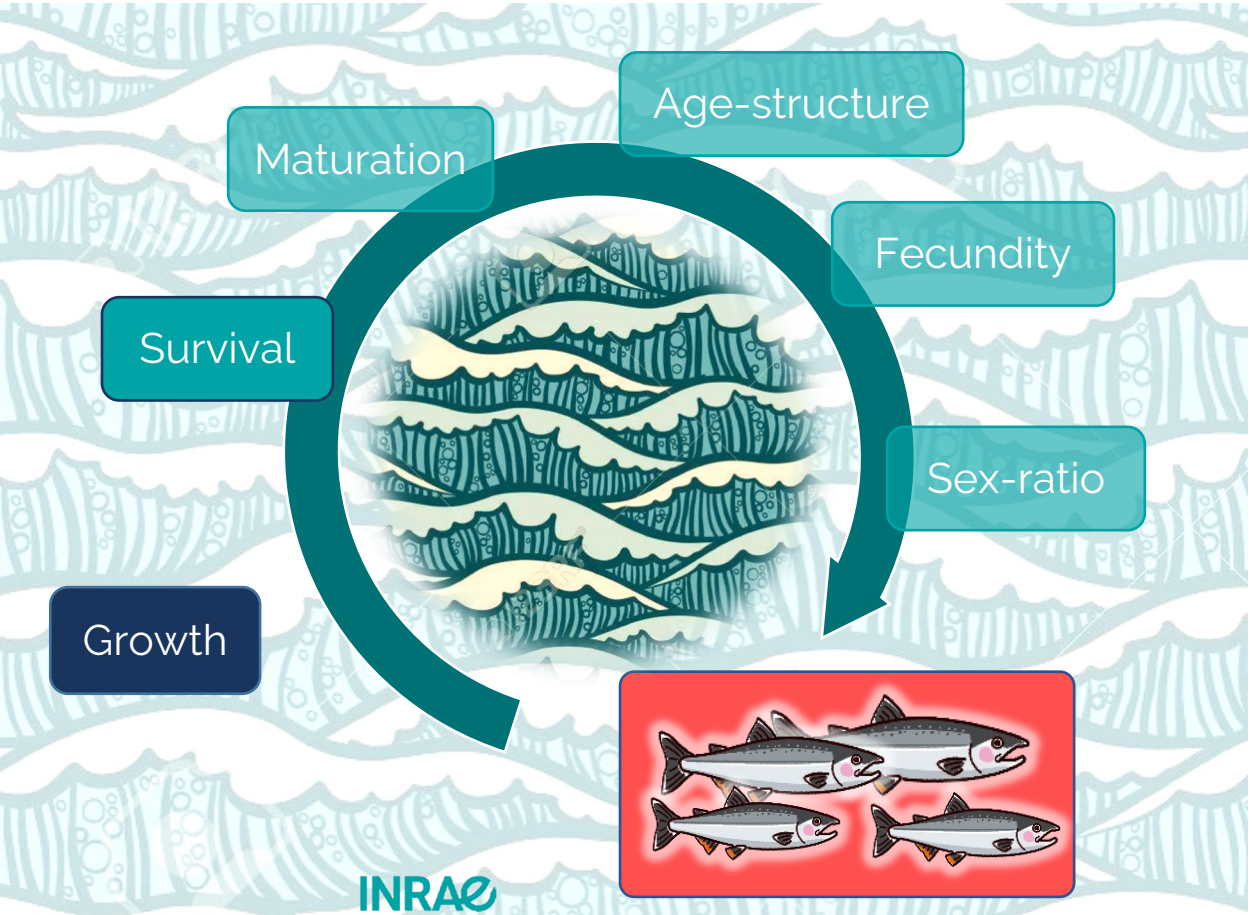


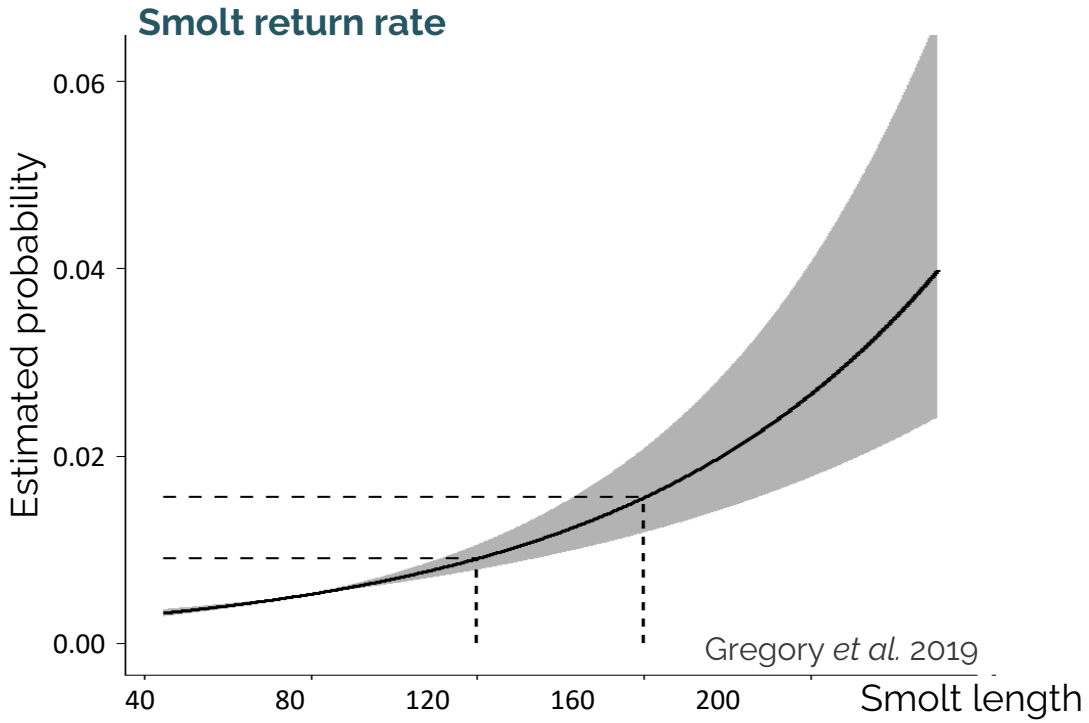


Larger smolts survive better at sea
→ Carry-over effect of freshwater growth

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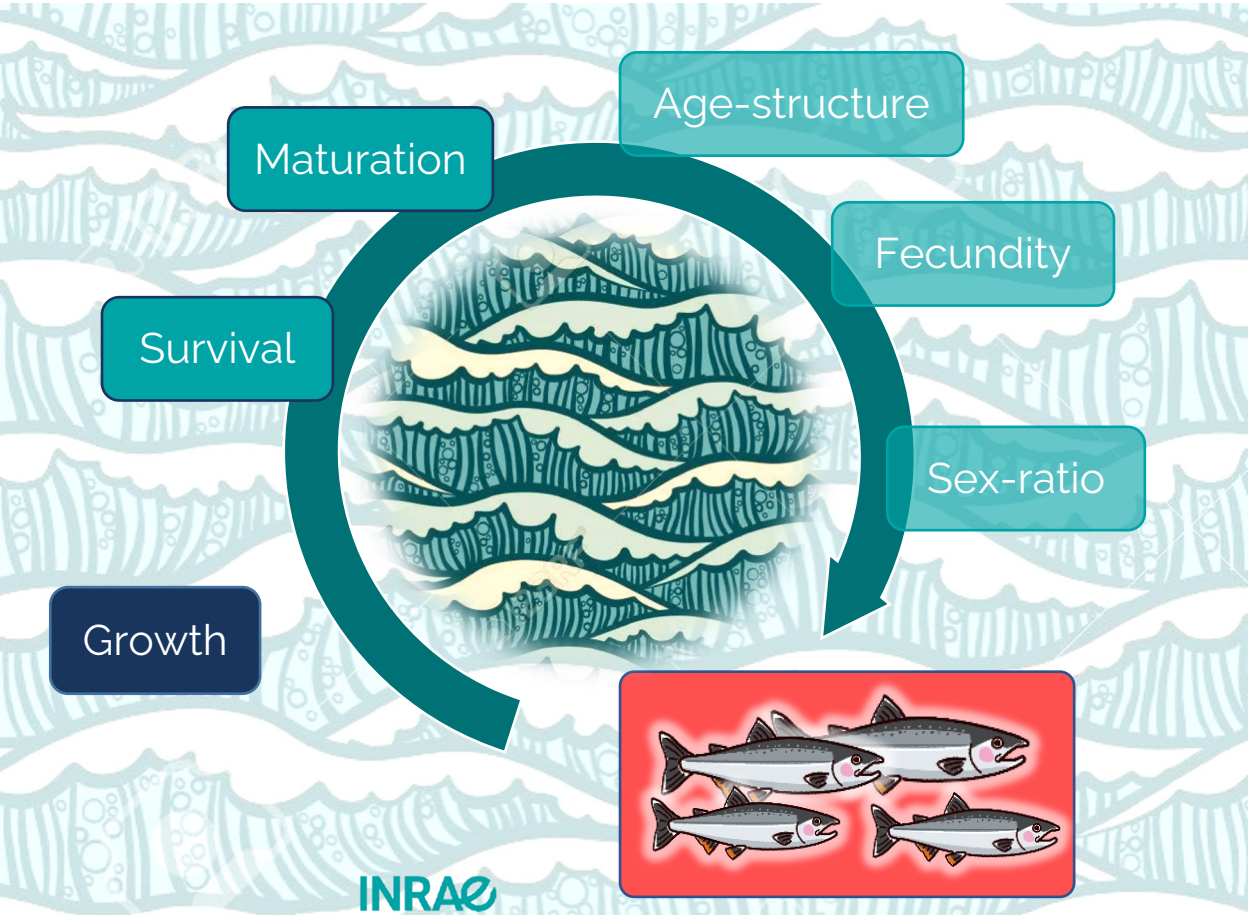


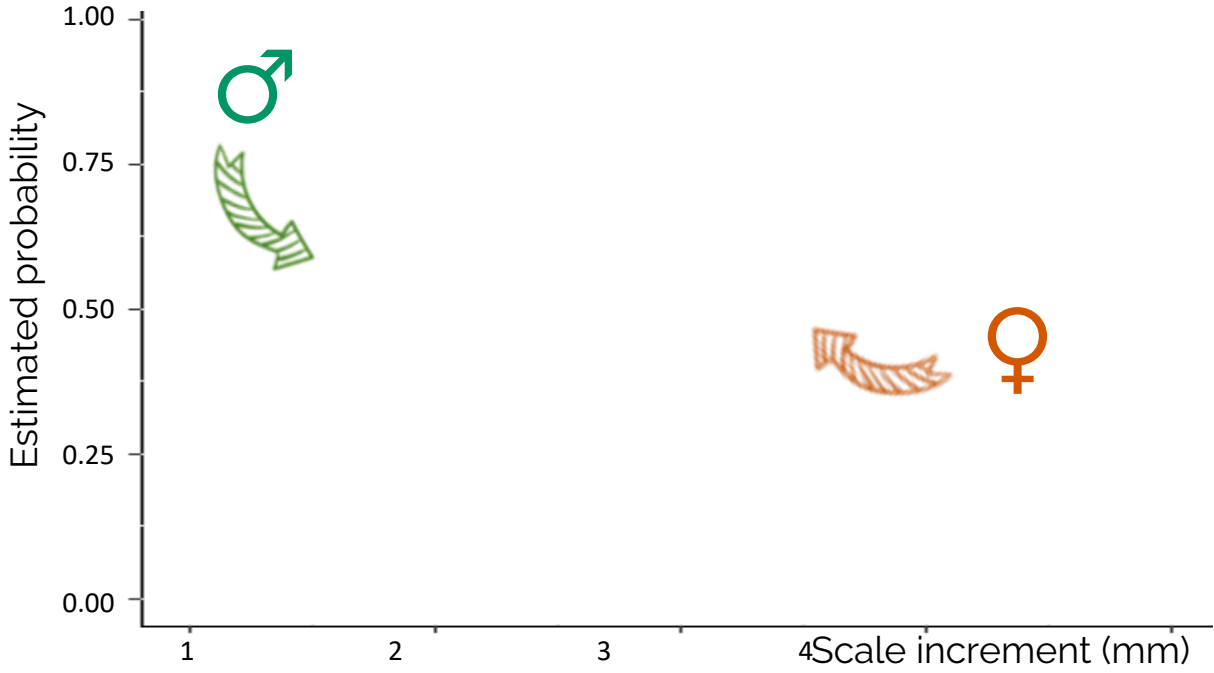

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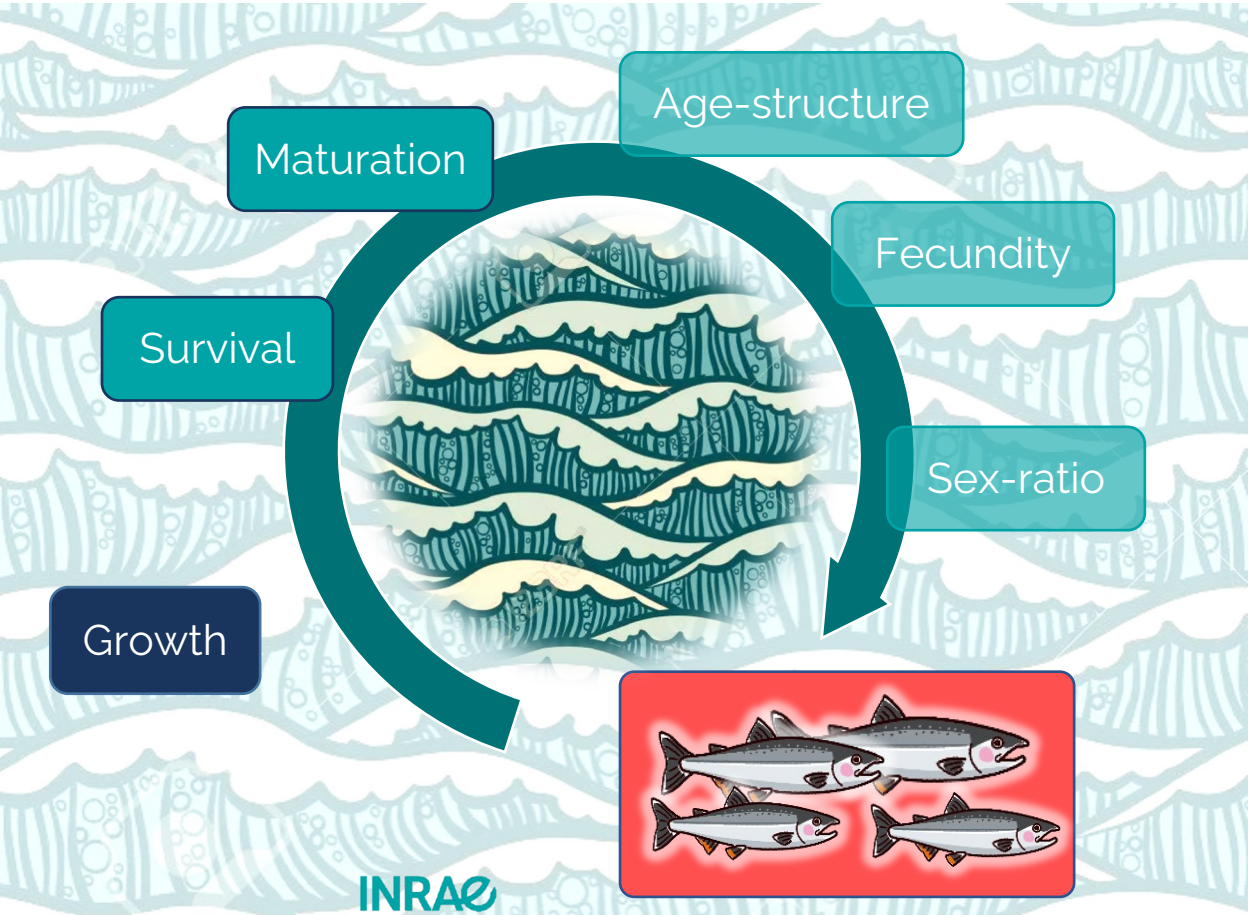


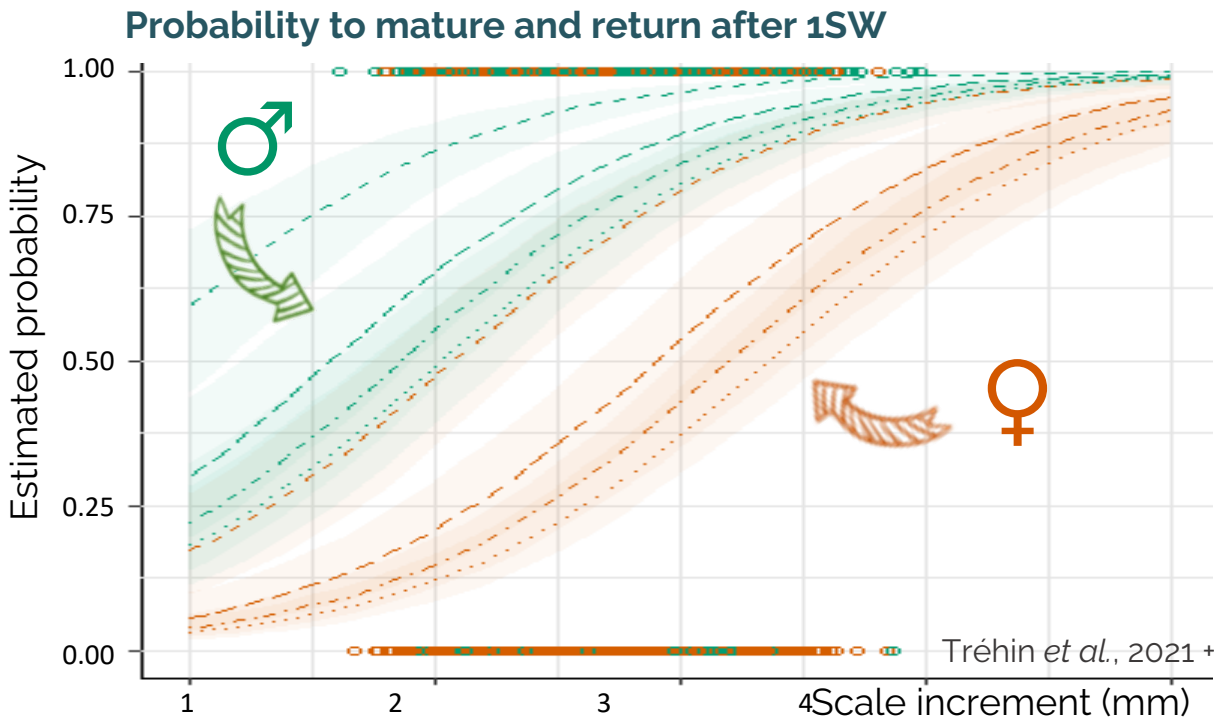


→ Size at the end of summer drives maturation decision
Post-smolt growth is similar in females and males
Males mature at a smaller size than females

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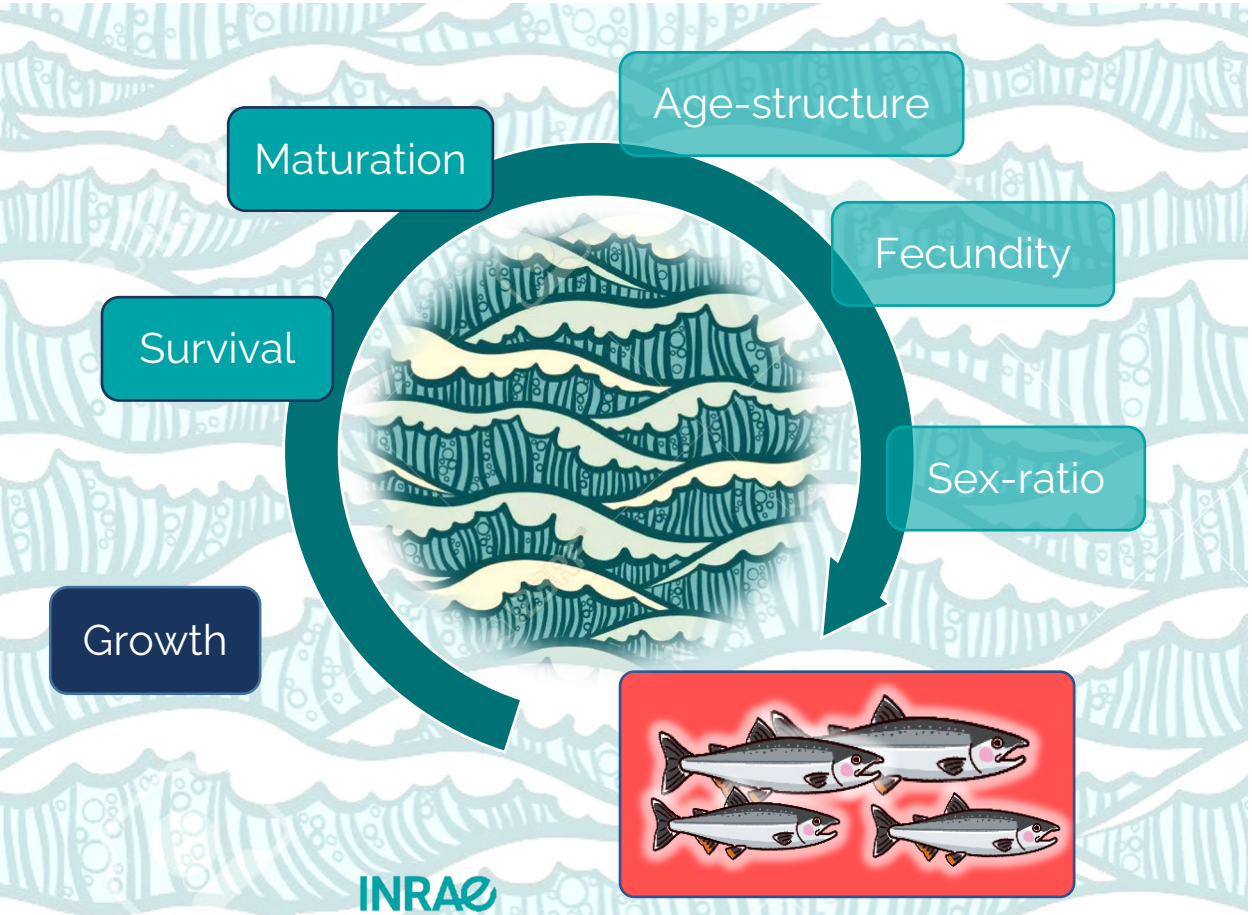
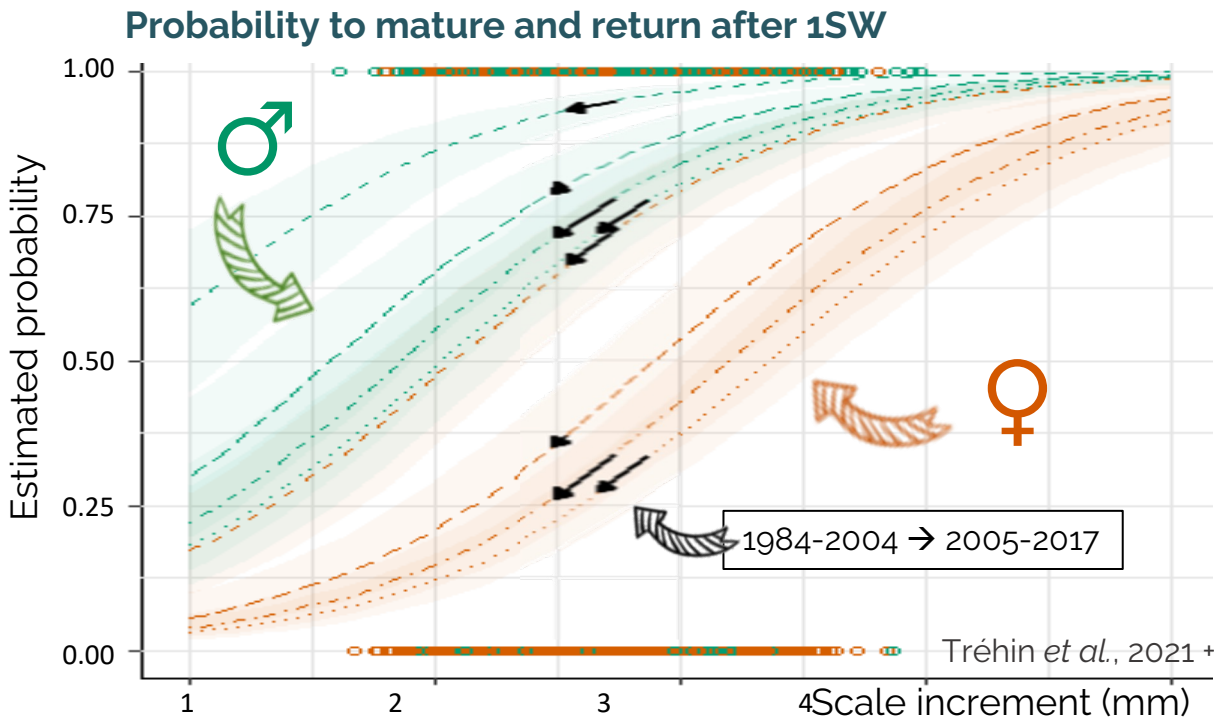



Effect of decrease in early marine growth:

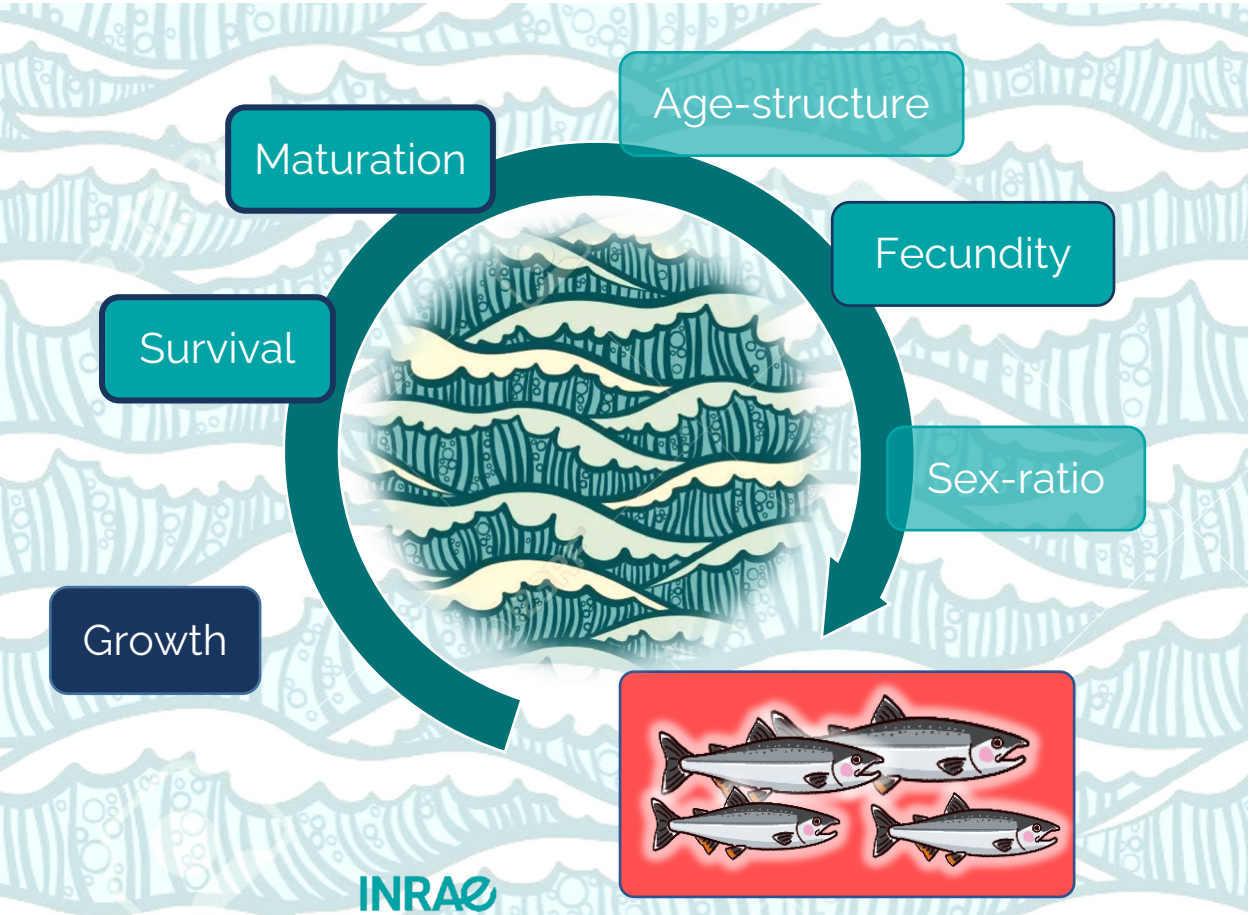
→ Decrease in probability to mature at 1SW

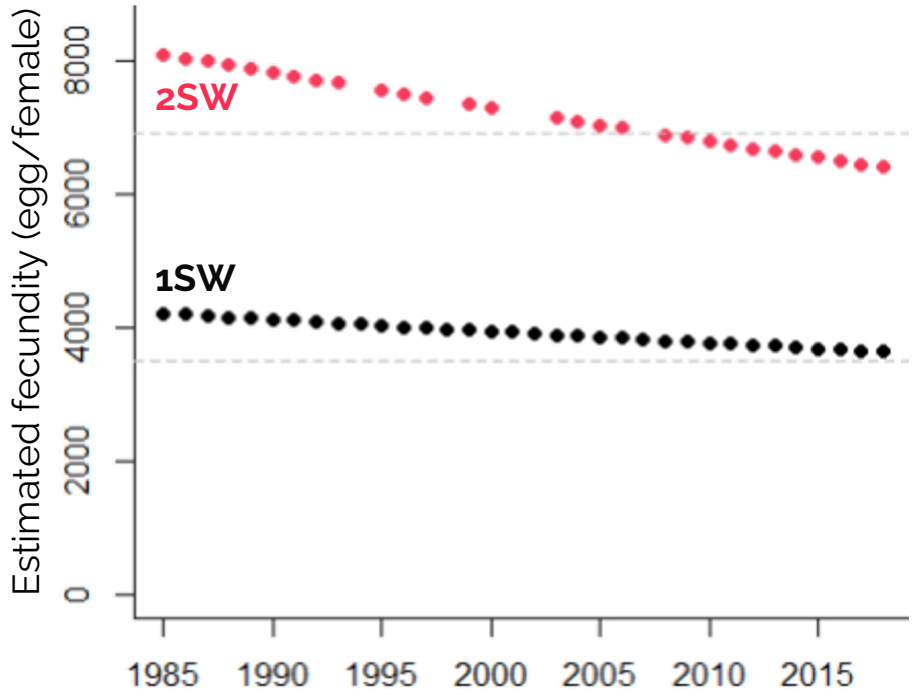
→ Difference in the response between rivers

# A life cycle approach of salmon life at sea

## Cascading effects of change in growth on salmon life history

Account for variability in demographic transitions in response to a rapidly changing environment

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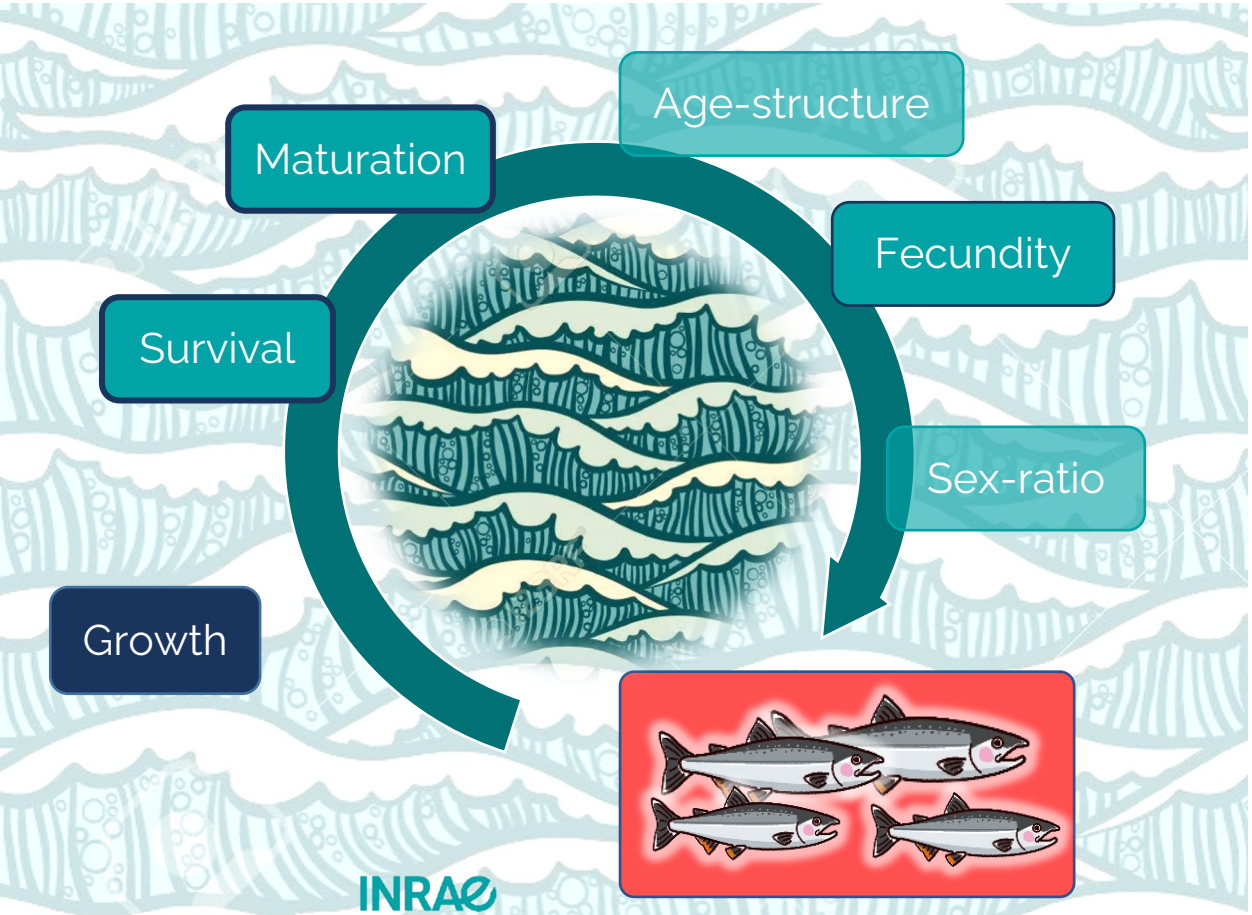
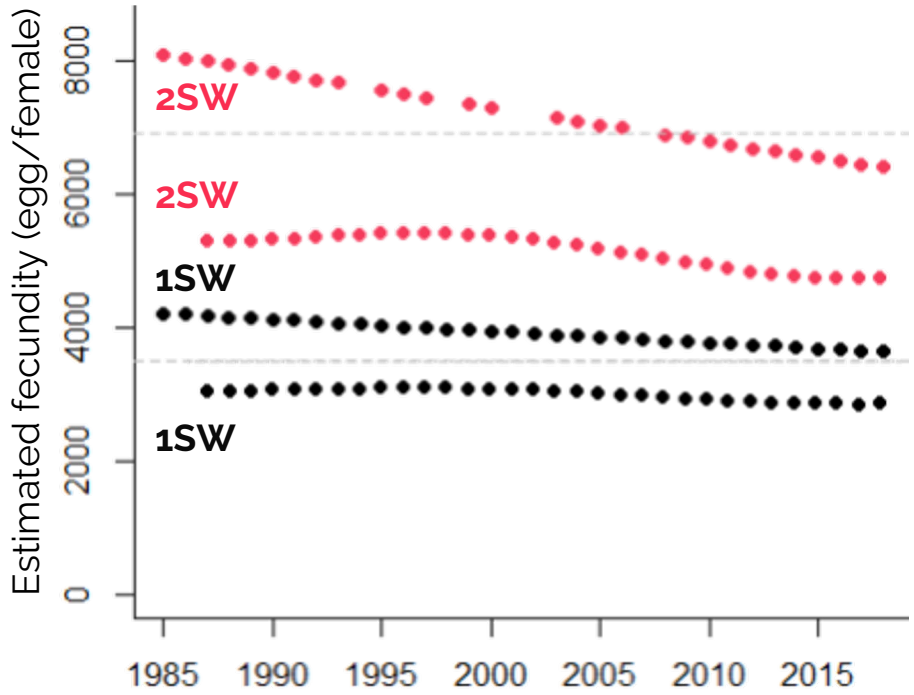



**Fecundity – Rivers Scorff and Bresle**




Decrease in growth leads to decrease in fecundity
Response specific to each population

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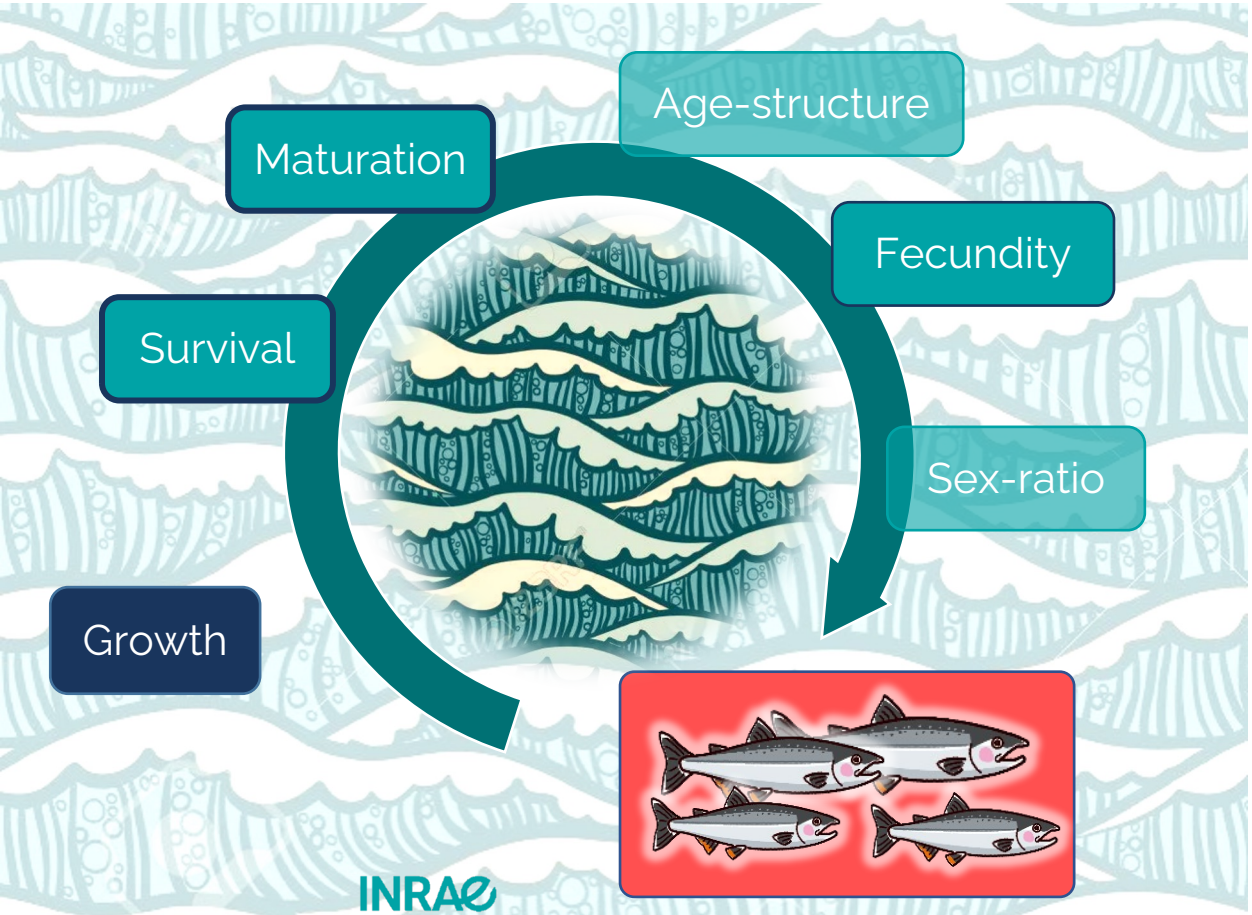


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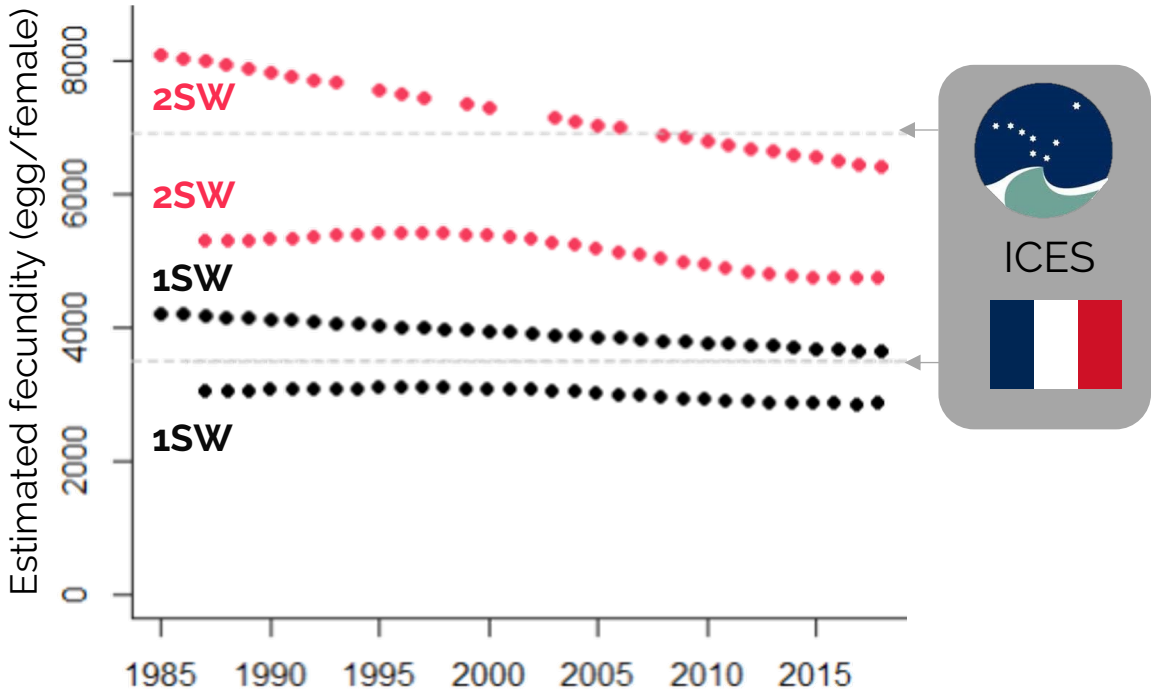


Decrease in growth leads to decrease in fecundity
Response specific to each population
Deviation from references used in management
→ Non-stationarity in salmon population dynamics

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# Conclusion

Can scales open the black box of salmon life at sea?

## Retrospective analysis of marine growth from salmon scales

Scales as a tool to track individual growth trajectories in a changing environment
→ Investigate change at different spatial and temporal scales

## Compare salmon growth across the Atlantic Ocean

Many labs analyze growth on scales BUT metrics are not easily comparable yet
→ Opportunity for collaboration and harmonization of approaches

## Replace growth at the center of salmon life history

Carry-over effect of freshwater life into marine life – and back!
Non-stationarity in ecological mechanisms
→ A life cycle approach is relevant for ecology and management

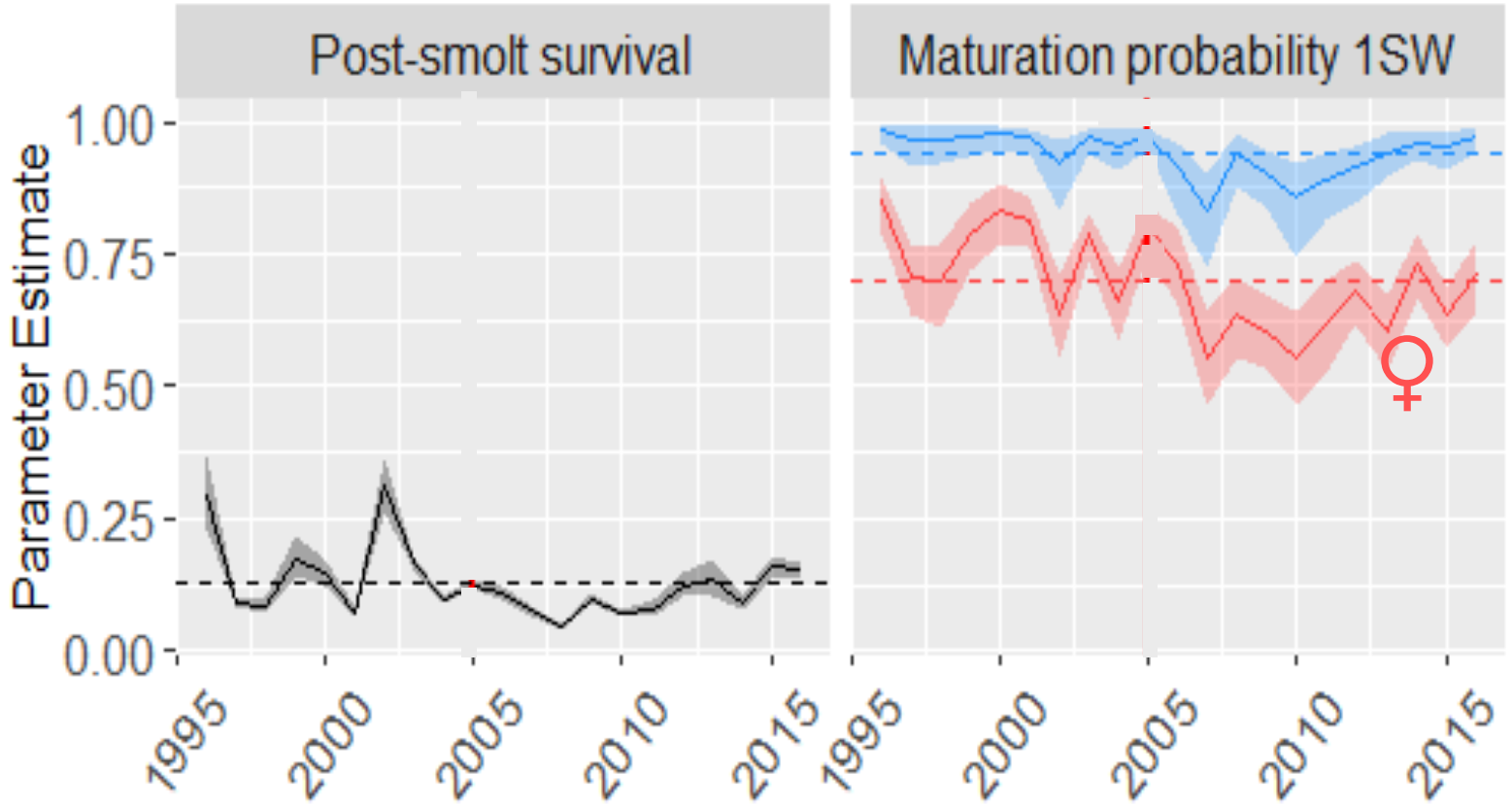

Didier Azam
Nicolas Jeannot
Julien Tremblay
J-P Destouches
Quentin Josset
Richard Delanoé

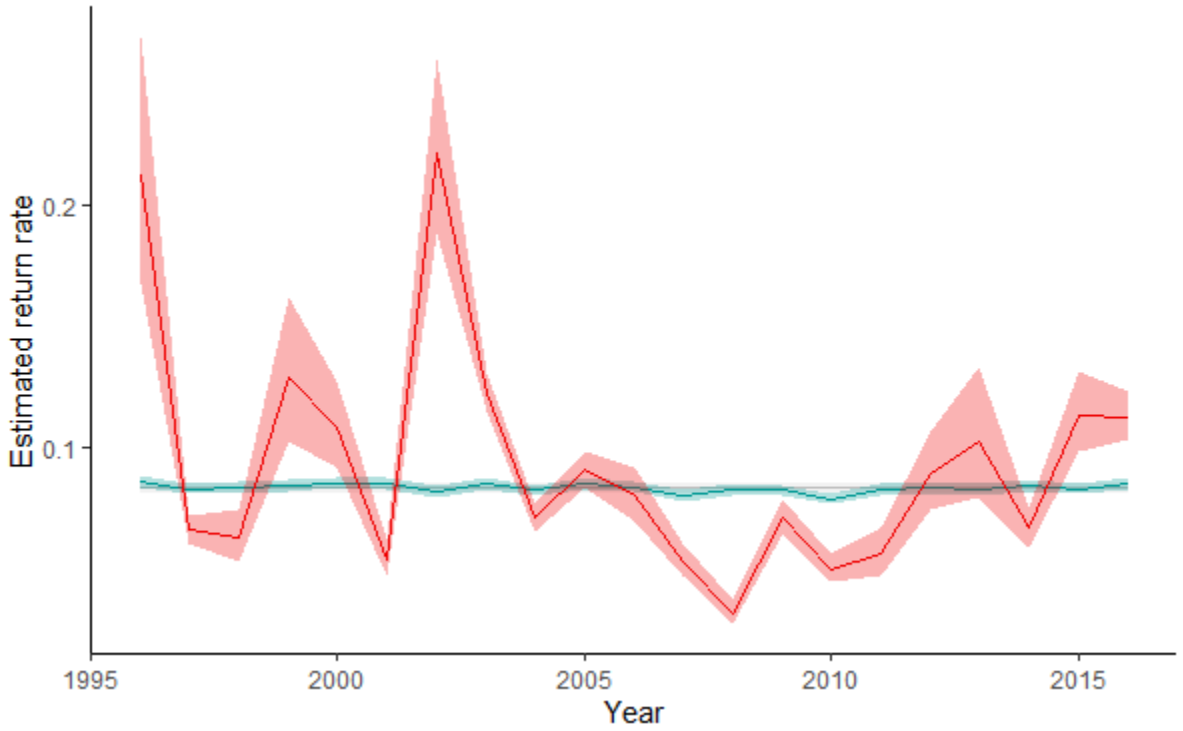
A-L Besnard
Sophie Launey
P-Y Boisson
Lisa Meslier
Nadine Herrard
Benjamin Bagot

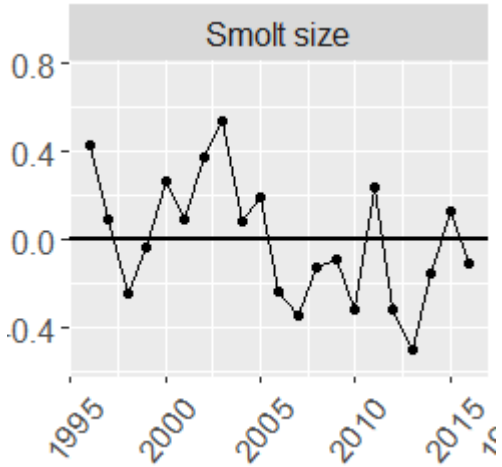
Stephen Gregory
Dylan Roberts
Rasmus Lauridsen
Rob Hillman
Simon Toms
Andy King
Jamie Stevens

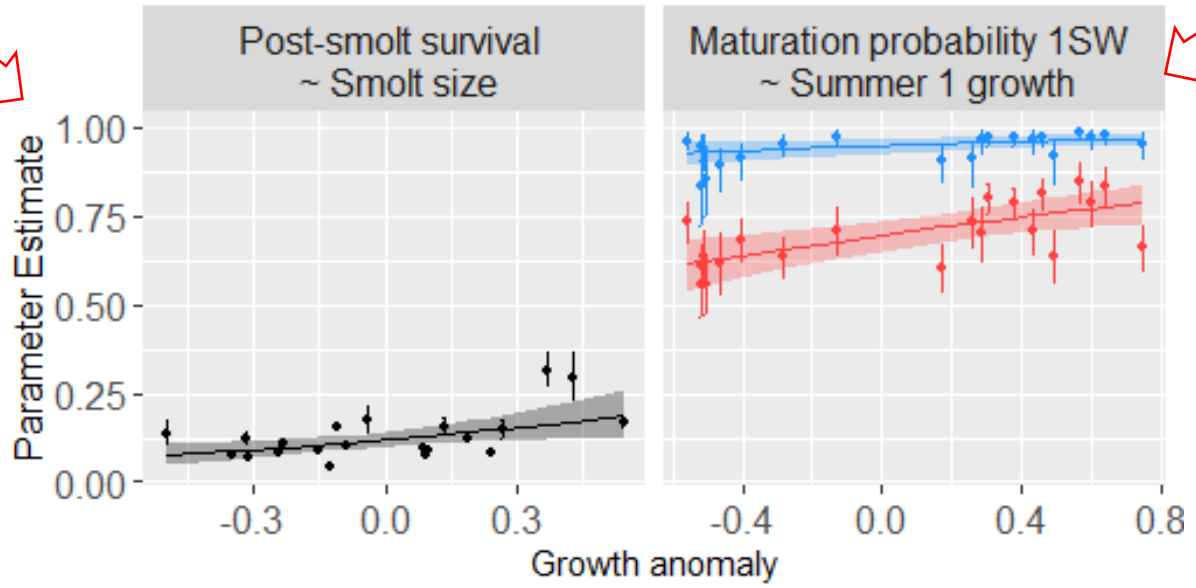

## Thank you for your attention

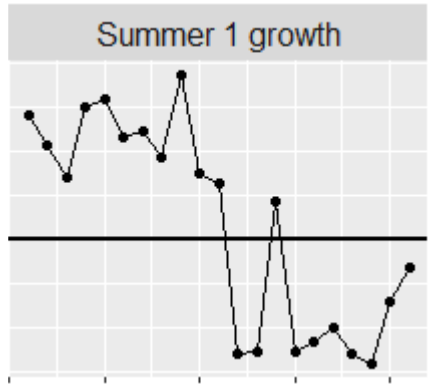

4-6 October 2022 / International Year of the Salmon Synthesis Symposium / 'Salmon in a Changing Salmosphere' theme session


Post-smolt survival
Maturation probability 1SW
Parameter Estimate
1.00
0.75
0.50
0.25
0.00
1995
2000
2005
2010
2015
♀


Estimated return rate
0.2
0.1
1995
2000
2005
2010
2015
Year




**Smolt Size** anomaly

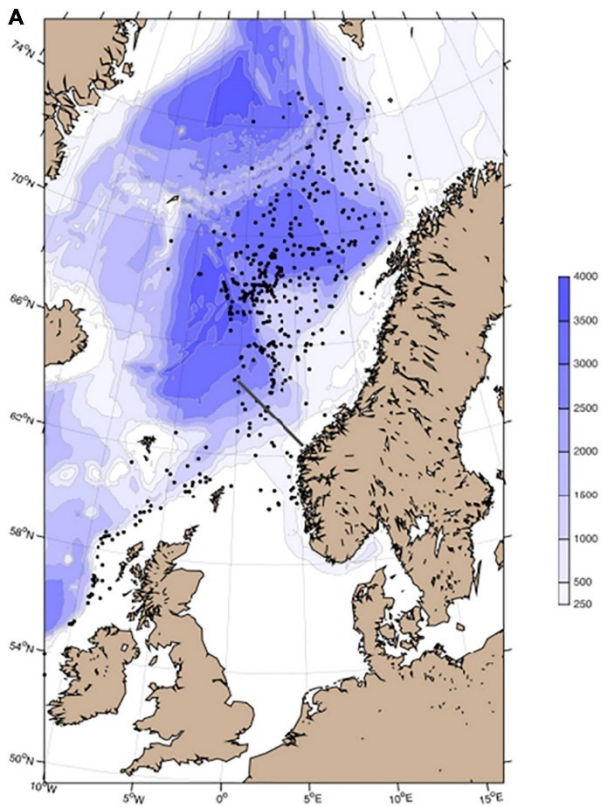
- **21%** of the among year variations

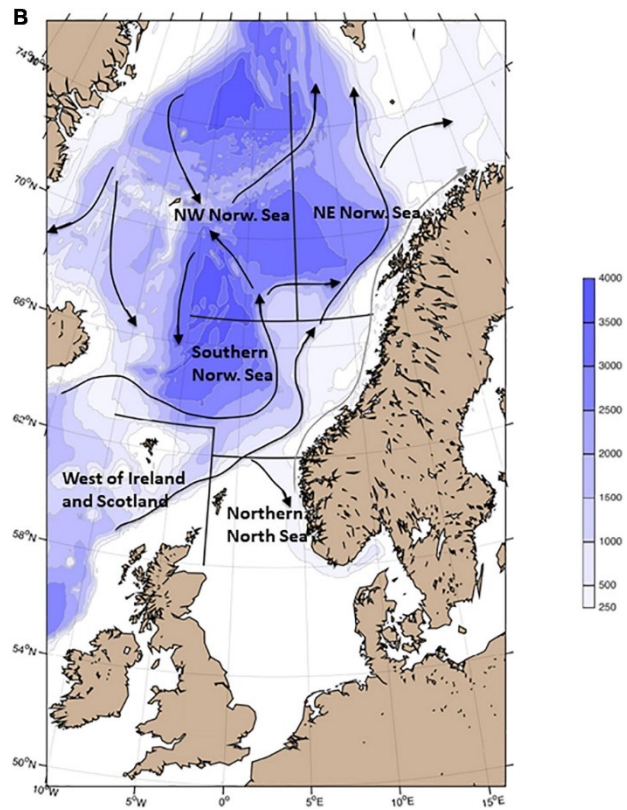
**Summer Growth** anomaly

- **29%** ♀
- **24%** ♂

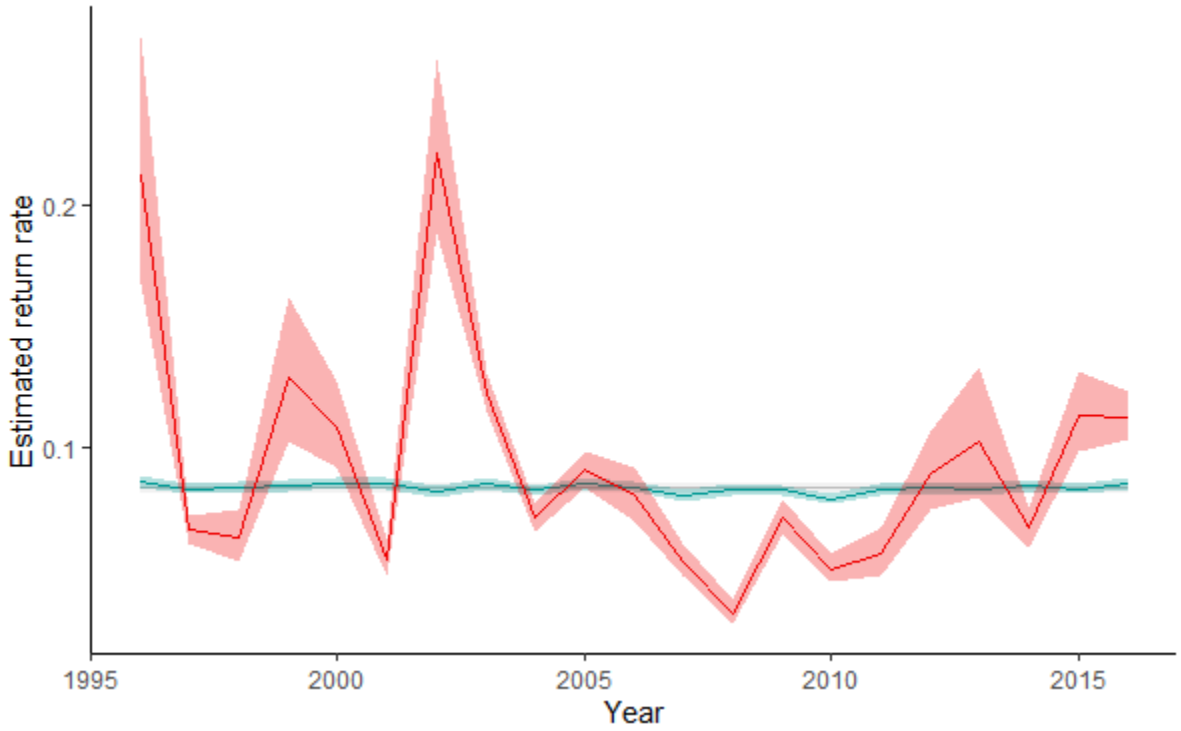
among year variations

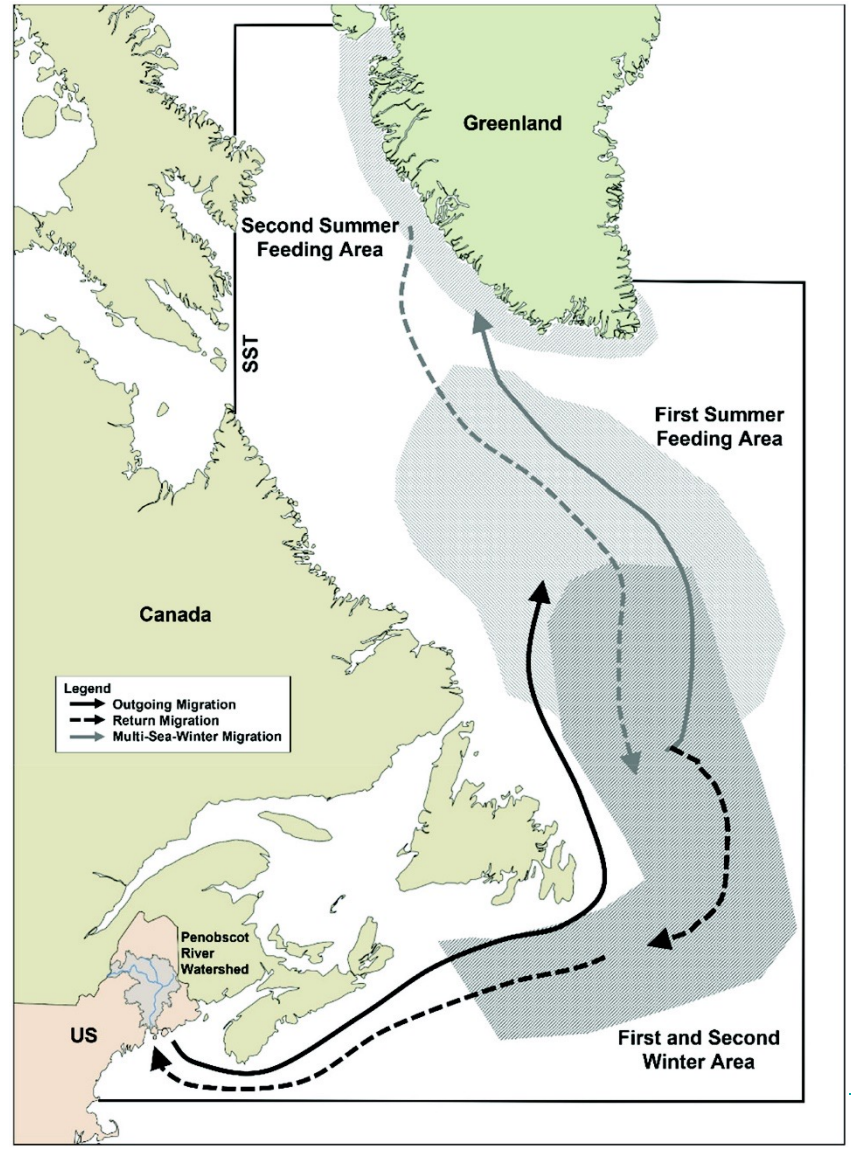

Gilbey et al. 2021

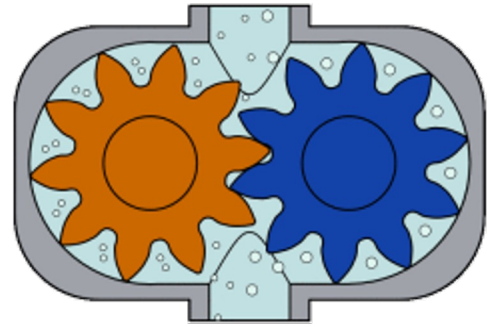



Utne et al. 2022



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