Embedding Atlantic salmon stock assessment within a Bayesian life cycle modeling framework:

a route toward ecosystem-based management

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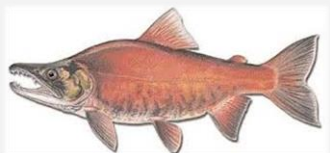
Rémi PATIN, Maxime OLMOS, Pierre-Yves HERNVANN, Marie NEVOUX, Stephen GREGORY, Etienne PREVOST, Gérald CHAPUT

& colleagues of ICES WGNAS

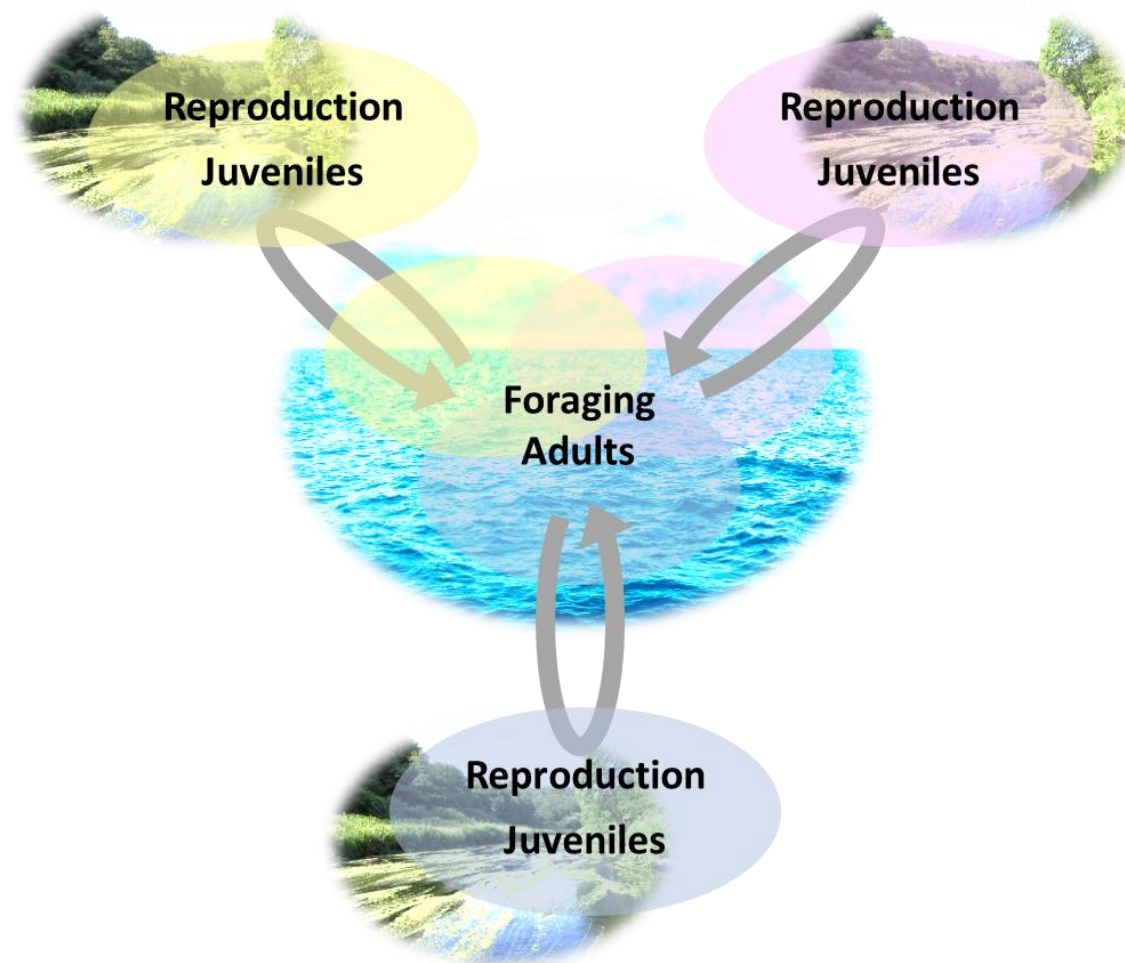*Oncorhynchus spp.*   *Salmonids spp.*   *Shads spp.*
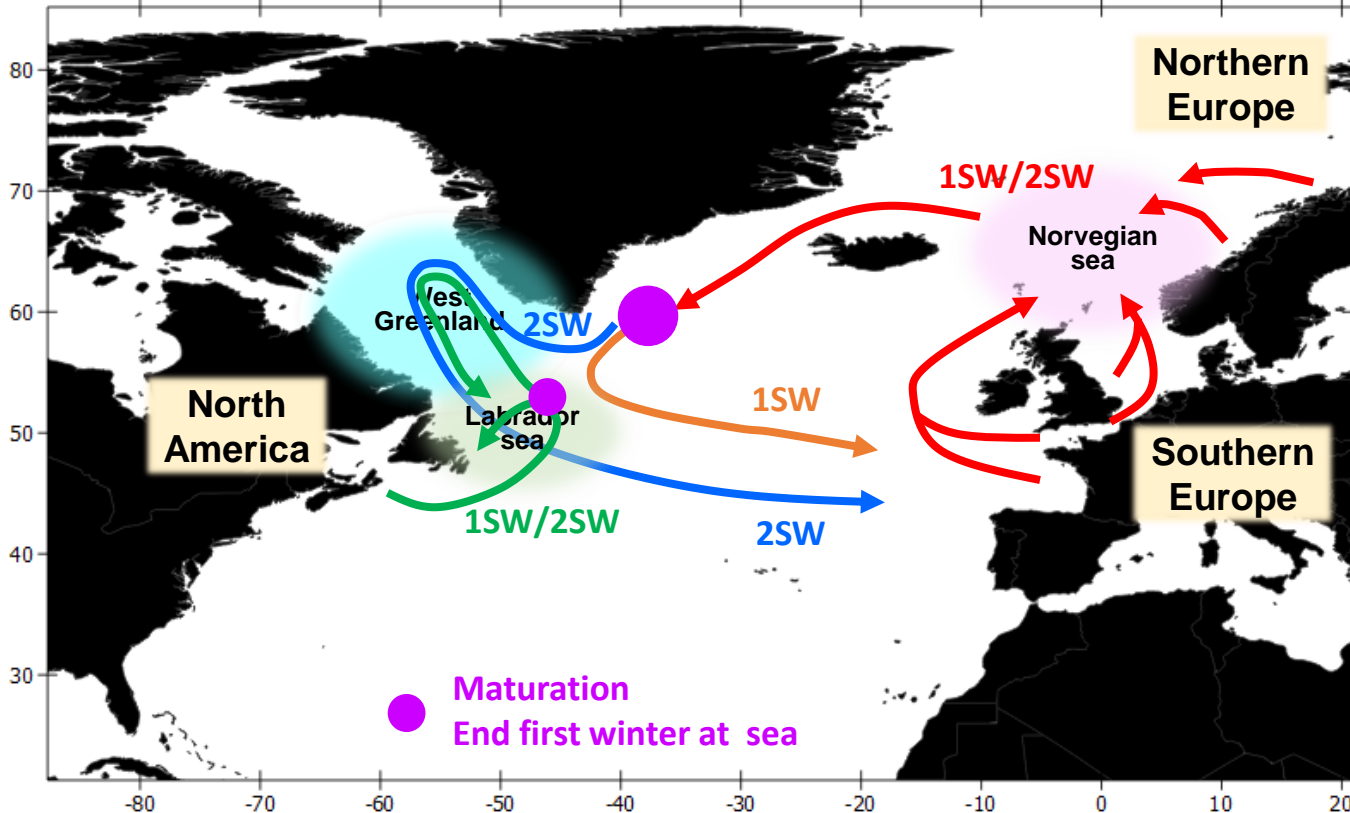
"Bio-complexity"

- Exposed to multiple stressors across wide range of ecosystems and scales

- Multiple reproductive strategies

"Data complexity"

- Dispersed

- Rarely cover the full range of scales and ecosystems

- Marine phase not easily accessible to observation

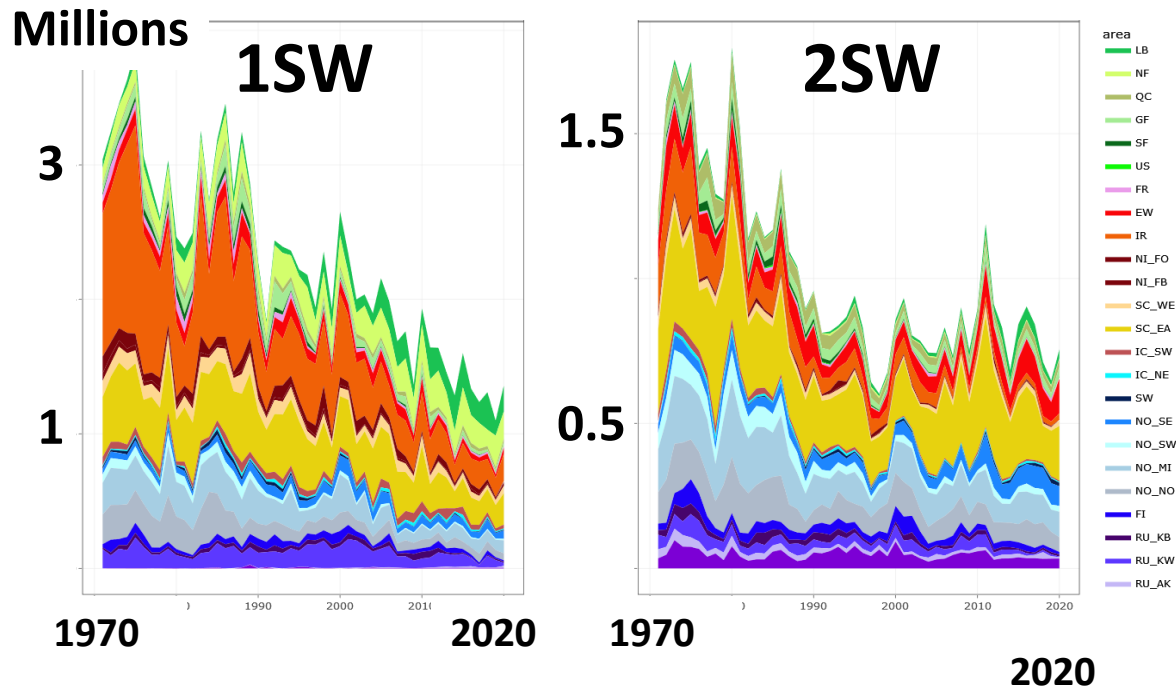# Atlantic salmon (*salmo salar*) in the North Atlantic basin

- **> 2500 rivers**

- **Diversity of life histories**
  - 1-6 years in freshwater
  - 1-4 years at sea (mainly 1SW & 2SW)

- **Migration routes depend upon fish origin & life histories**
  - Factors susceptible to affect large groups of populations simultaneously
  - Dynamics of 1SW/2SW fish may be partially disconnected

Mechanisms responsible for the decline in returns and for the changes in sea-age composition of returns ?

## Returns in coastal waters in 25 stock units

ICES WGNAS 2021

Millions

1SW

2SW

area
LB
NF
QC
GF
SF
US
FR
EW
IR
NI_FO
NI_FB
SC_WE
SC_EA
IC_SW
IC_NE
SW
NO_SE
NO_SW
NO_MI
NO_NO
FI
RU_KB
RU_KW
RU_AK

1970   2020   1970   2020

- ↘ in abundance of returns
- Changes in sea-age composition of returns

Models

- Separate out changes
  - survival (1st & 2nd year)
  - maturation

Smolt

survival 1st year

survival 2nd year

maturation

1SW

2SW
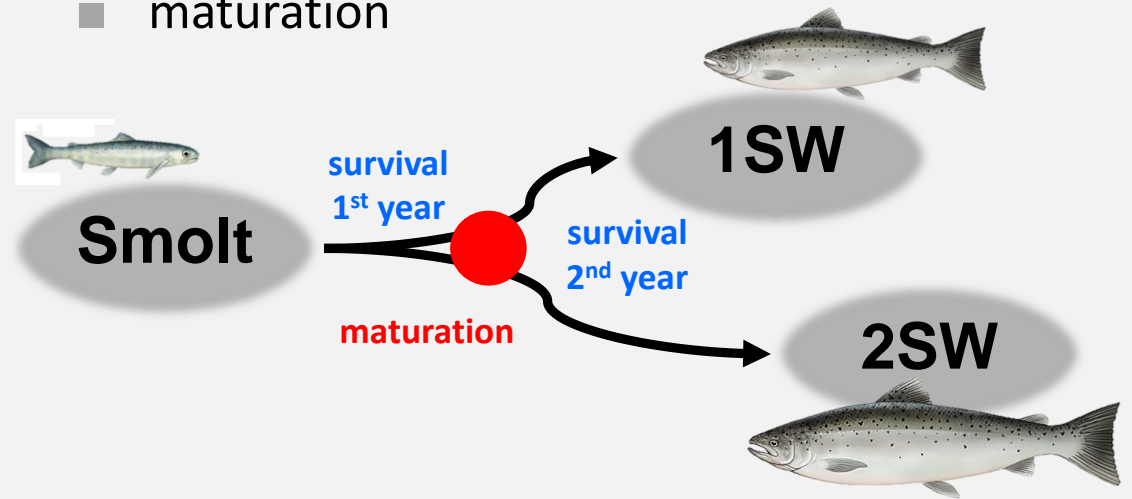
- Multi-population at basin scale to quantify the amount of signals shared between populations
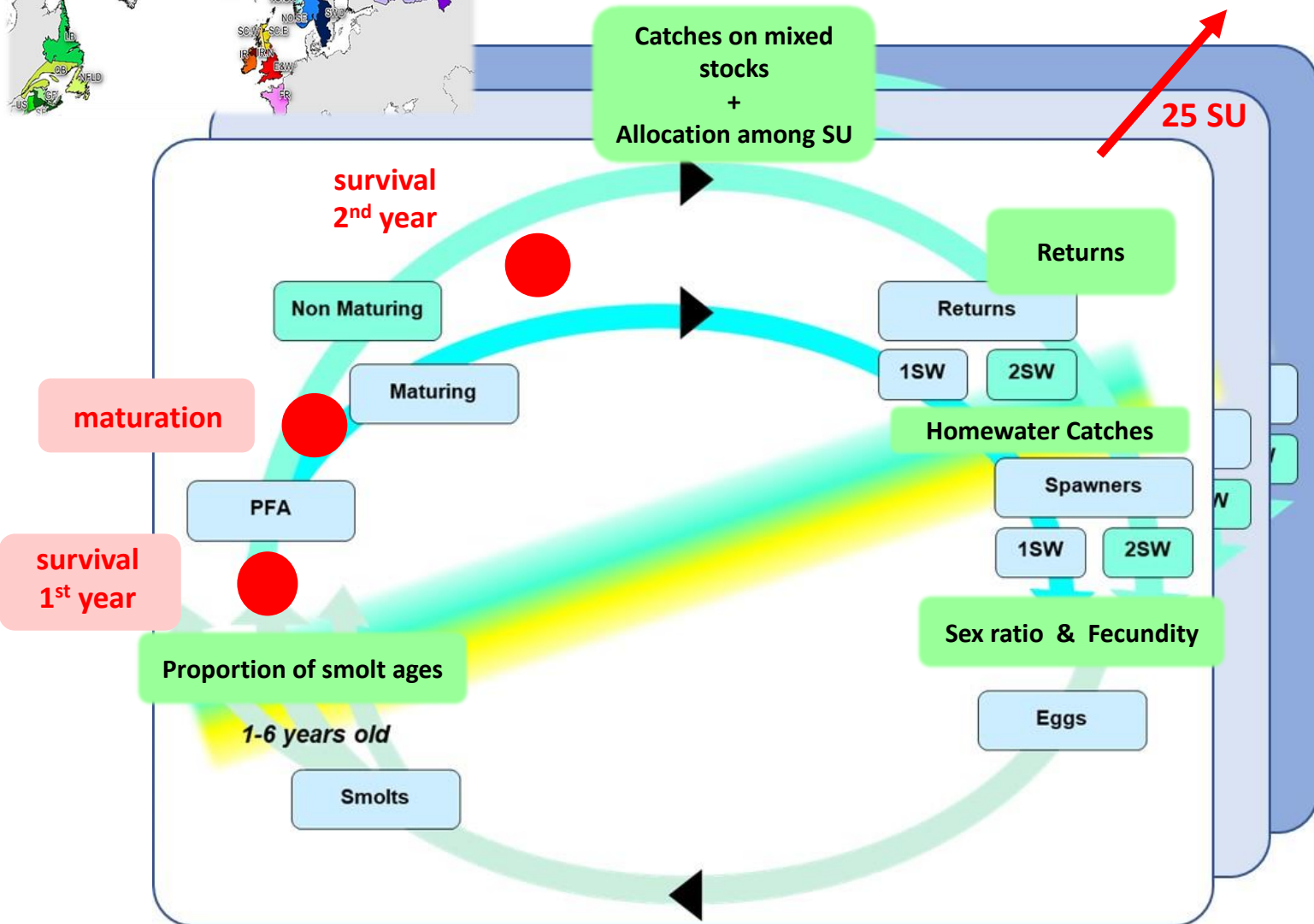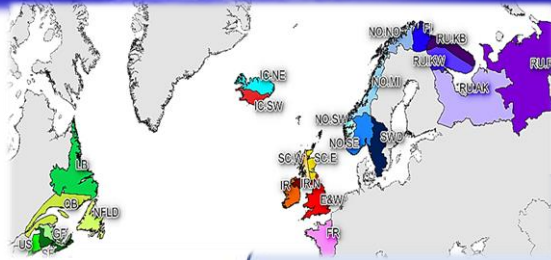
Olmos et al. 2019 ; Rivot, Patin, Olmos et al., 2021

25 SU
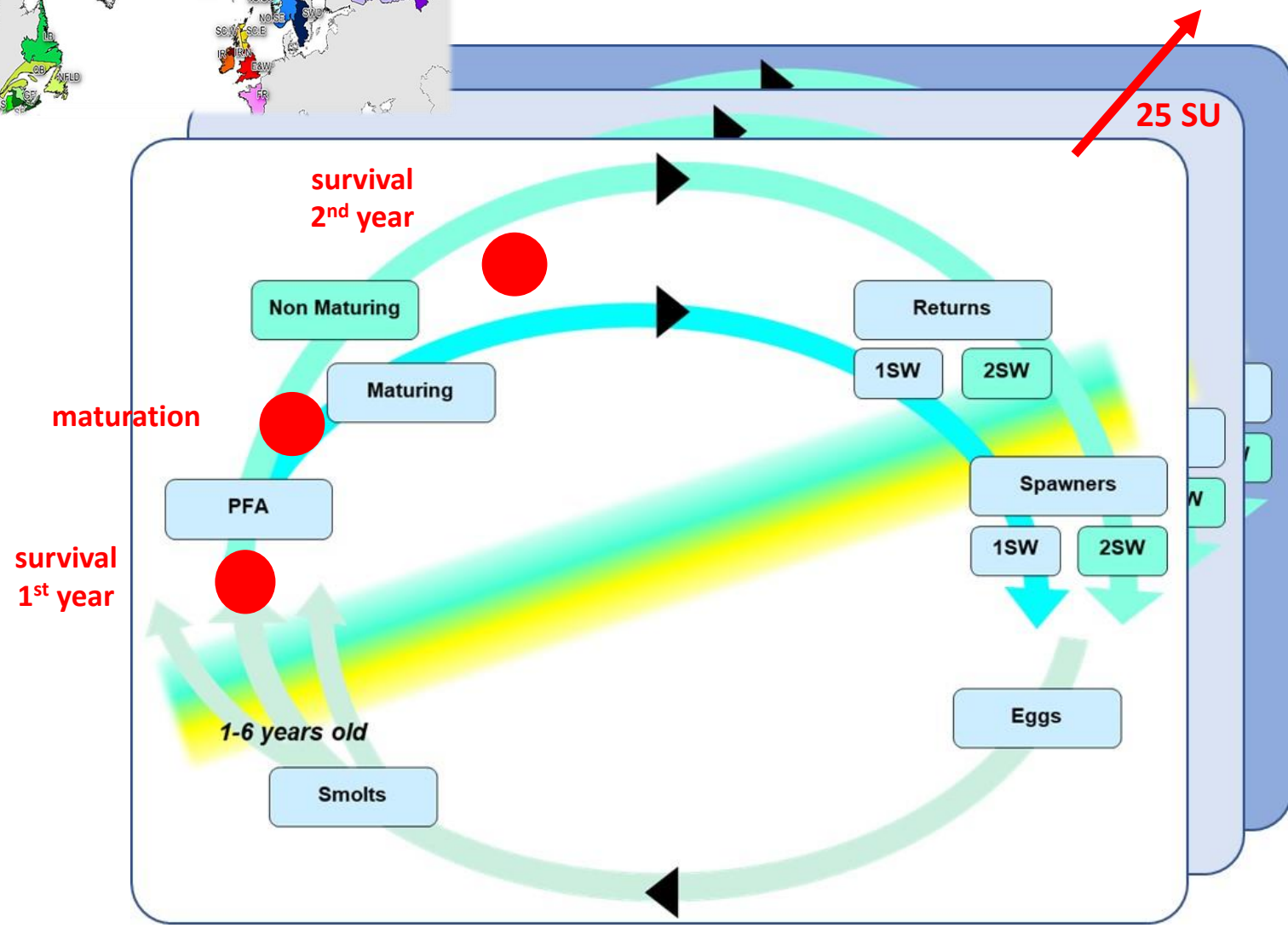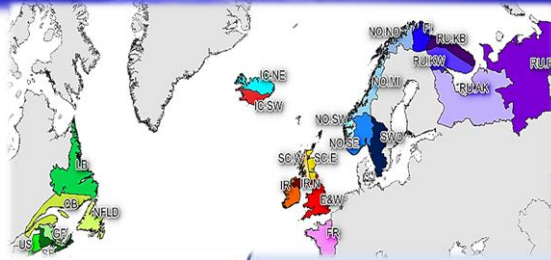
- **Joint dynamics of 25 stock units**

- **Overlap in cohorts dynamics (12 life histories)**
  - 6 smolt ages
  - 2 sea ages (1SW & 2SW)

- **Smolt return rates**
  - Survival 1st year
  - Maturation
  - Survival 2nd year (~ natural and fishing mortality)

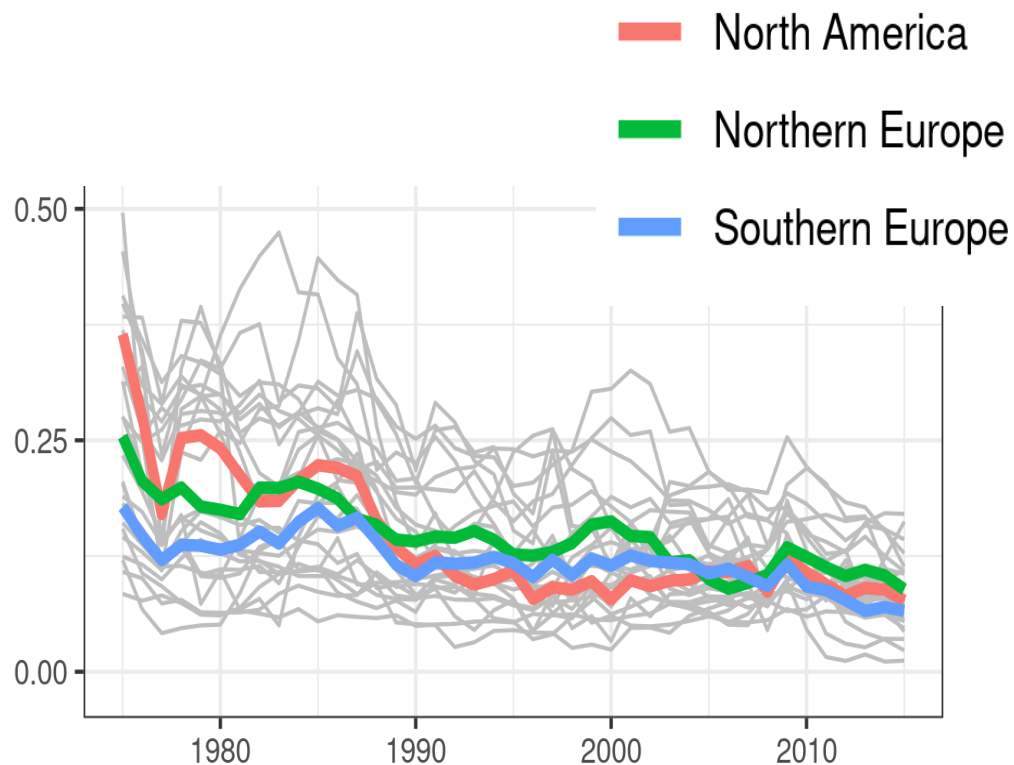Olmos et al. 2019 ; Rivot, Patin, Olmos et al., 2021

- **Bayesian stat. framework**

- **Data collated by ICES WGNAS experts for each SU**
  ~ 50 years [1971- [

- **High sea catches X allocation**

- **Bayesian estimates**
  - Survival 1st year & maturation
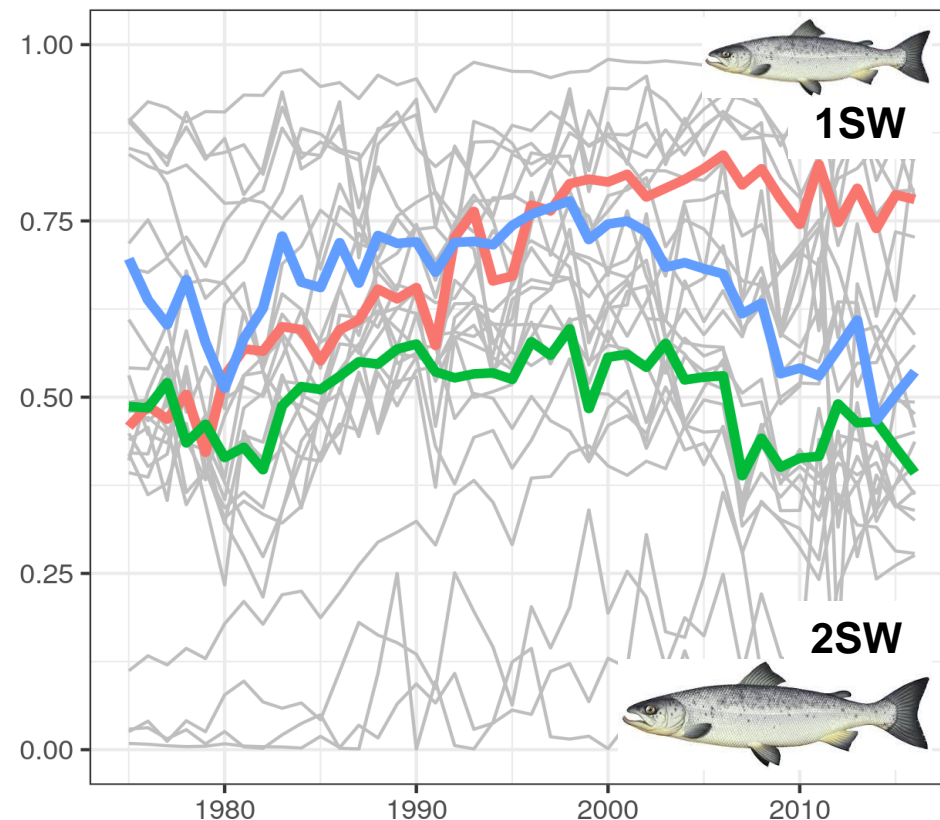 - Abundance at any stage

- **Probabilistic forecasts**

Rivot, Patin, Olmos et al., 2021

Survival 1st year at sea

Legend:
- North America
- Northern Europe
- Southern Europe

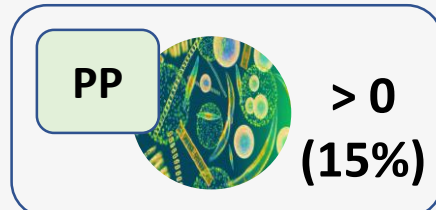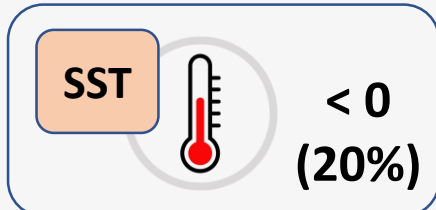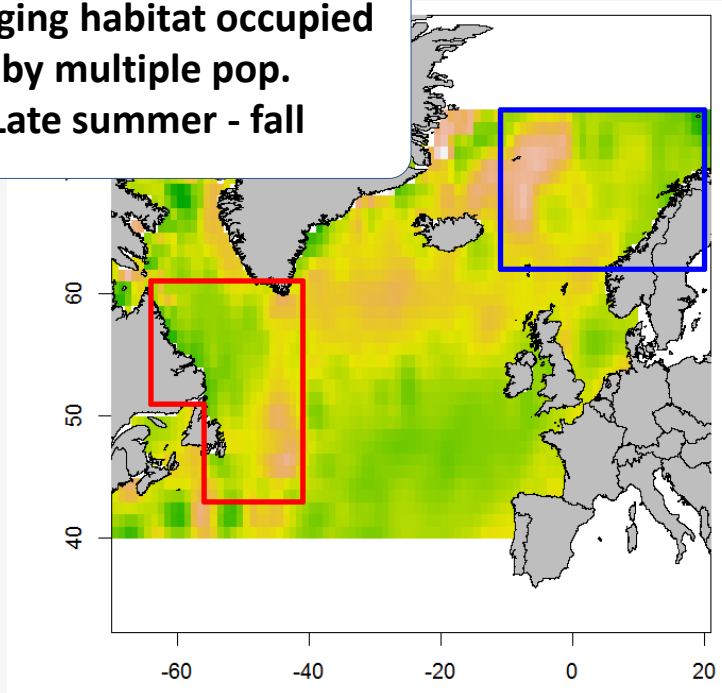## Probability to mature as 1SW

1SW

2SW

- ■ Shared signal explains **~ 40%** of the variability in marine survival and probability to mature as 1SW
- ■ Spatial covariation increases with the spatial proximity (Olmos et al., 2019)

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Olmos et al. 2020

Tillotson et al., 2021

Proxies of env. & trophic conditions

Does survival correlates

?

**Growth
North American fish**

Foraging habitat occupied
by multiple pop.
Late summer - fall

SST   < 0
(20%)

PP   > 0
(15%)

Survival first year
(logit)

1971-1989

All Years
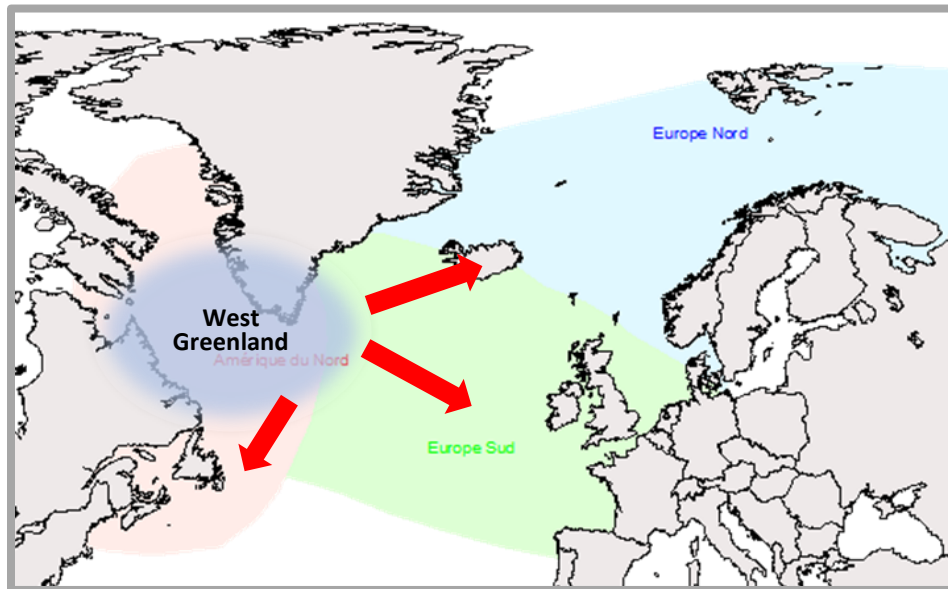
1990-2015

First summer growth increment

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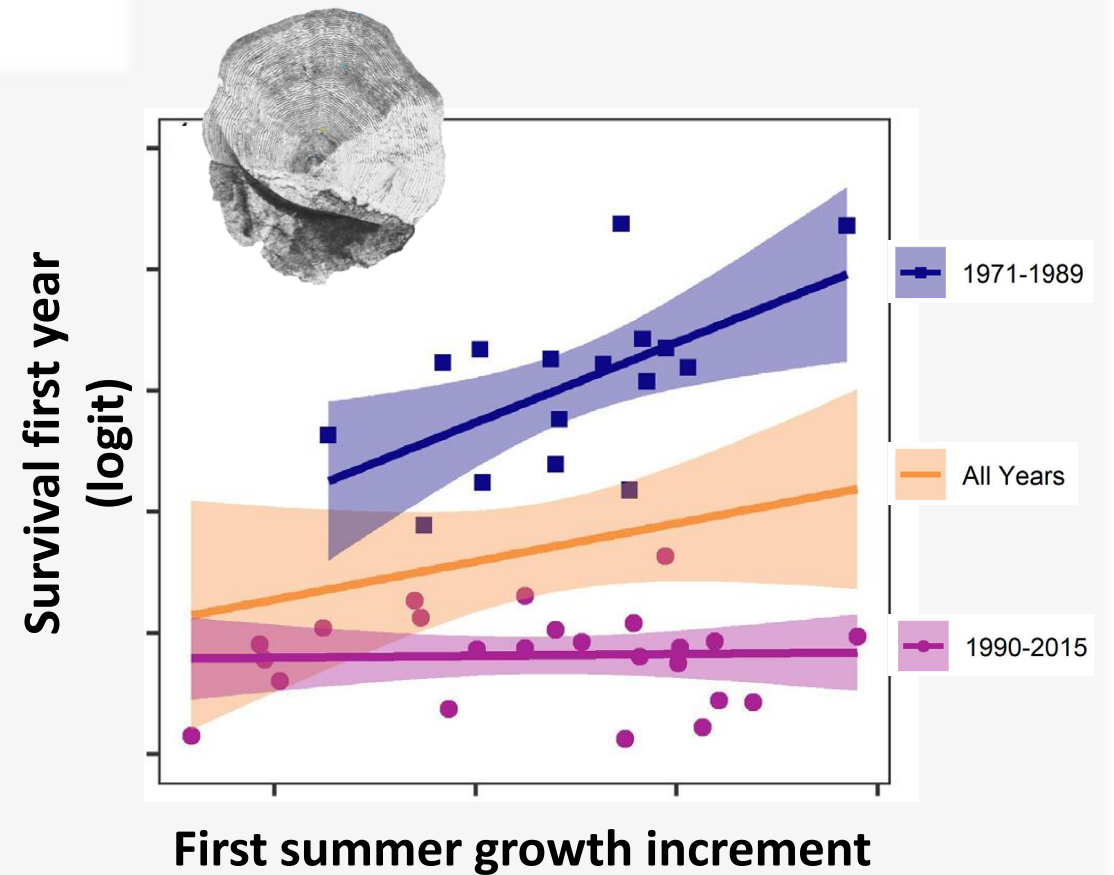
Evaluate management scenarios

Catch options

West Greenland fishery

P(eggs dep 2027 > CL)

2027 — **Northern Europe**

Legend: IC.NE, FI, SW, RU, NO

Norway

Finland

TAC in West Greenland (tons)

2027 — **North America**

Legend: LB, GF, NF, SF, QB, US

Quebec

USA

TAC in West Greenland (tons)

2027 — **Southern Europe**

Legend: FR, N.IR, EW, SC, IR, IC.SW

England&Wales

Ireland

TAC in West Greenland (tons)
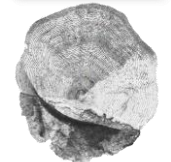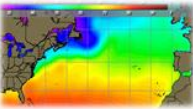
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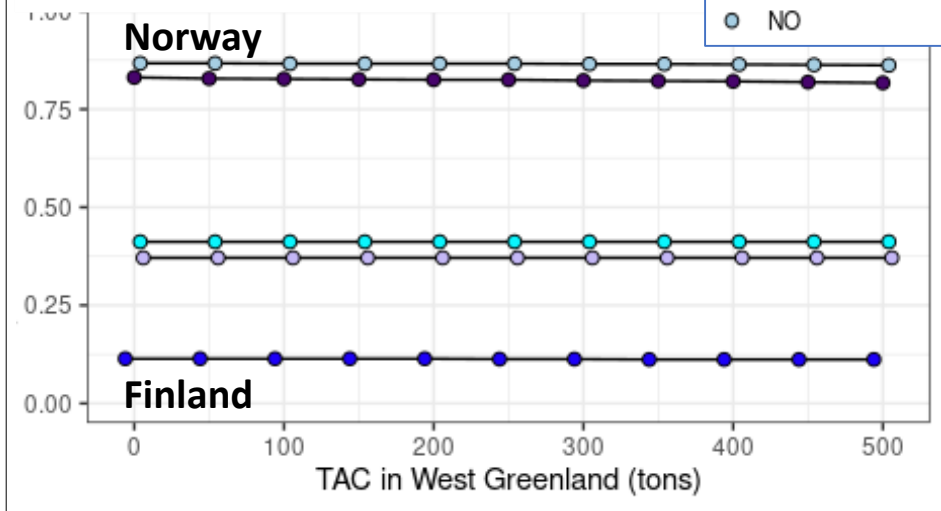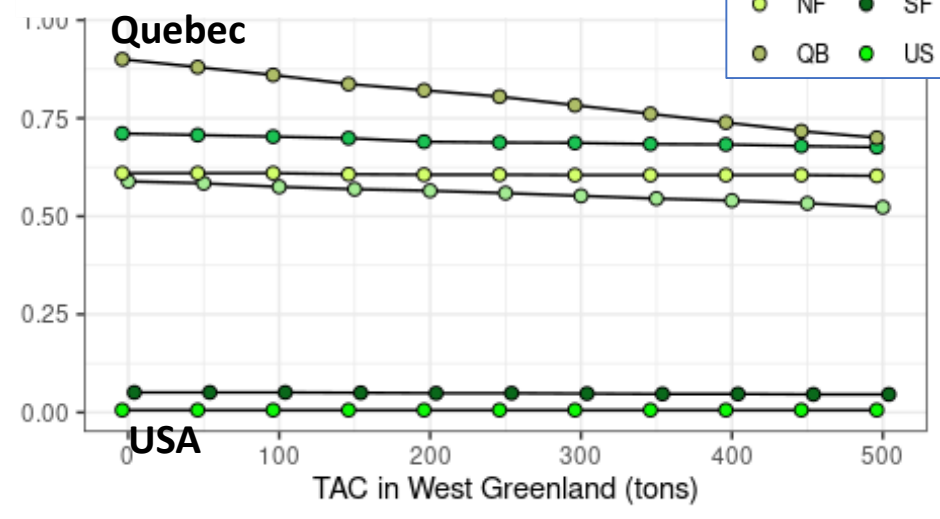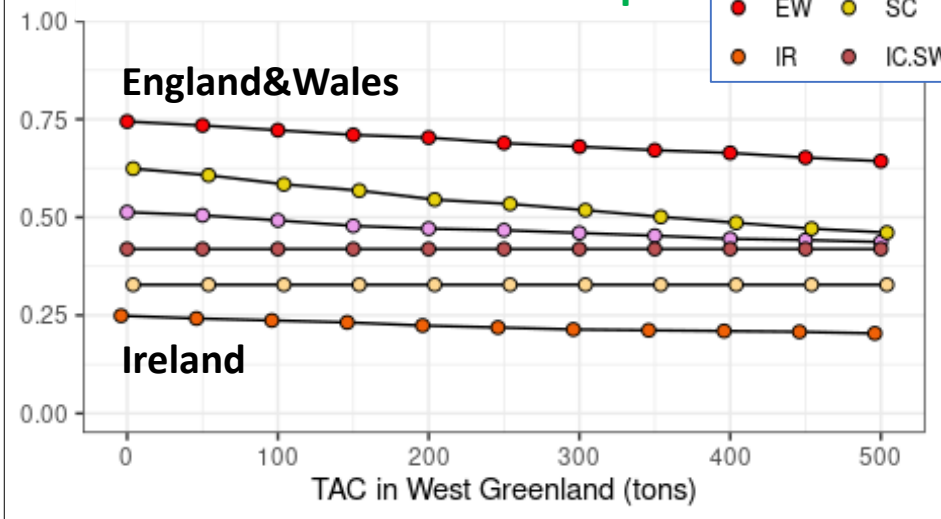
Take home messages

A life cycle model at the scale of the North Atlantic basin

- **A route toward embedding stock assessment within an ecosystem approach**
  → First ICES WGNAS Benchmark initiated in 2022

- **Basin scale and multi-population approach**
  → Integrating ecological process and data across scales

- **Stage-based life cycle model captures the complexity of life histories**
  → Go beyond "return rates" and unravel mechanisms of changes in demographic rates

- **Limits that help prioritizing future research**
  An expandable framework that allows additional information to be assimilated
  → Improving our understanding of the eco-evolutionary interactions

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Photo credit - INRAE U3E

Thank you !

SalmoGlob WGNAS ToolBox

A web application to support the workflow *data management* → *model* → *outputs*

https://sirs.agrocampus-ouest.fr/discardless_app/WGNAS-ToolBox/