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## Investigating the drivers of Atlantic salmon populations decline at the North Atlantic basin scale through a Bayesian life cycle modelling approach

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# Investigating the drivers of Atlantic salmon populations decline at the North Atlantic basin scale through a Bayesian life cycle modelling approach

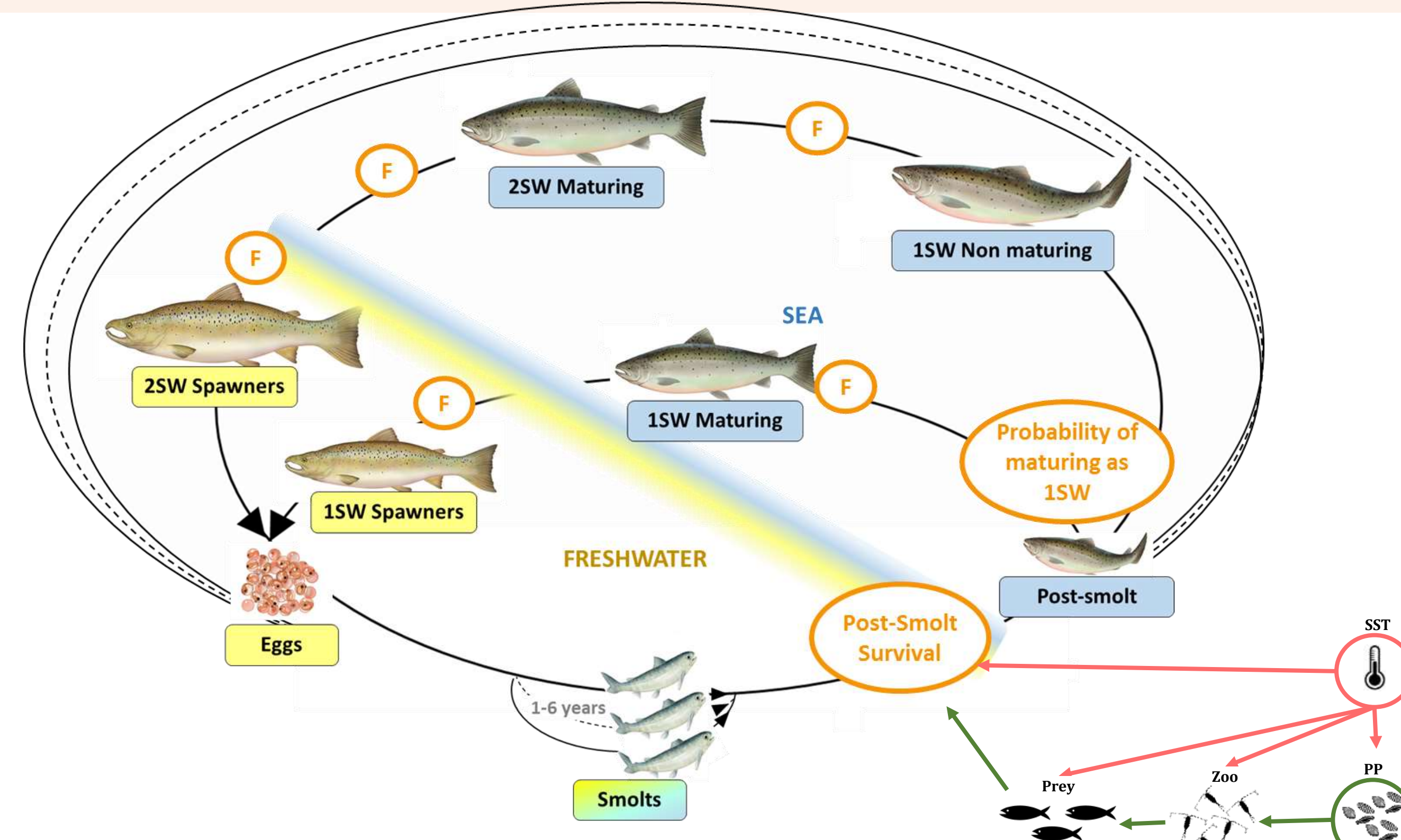
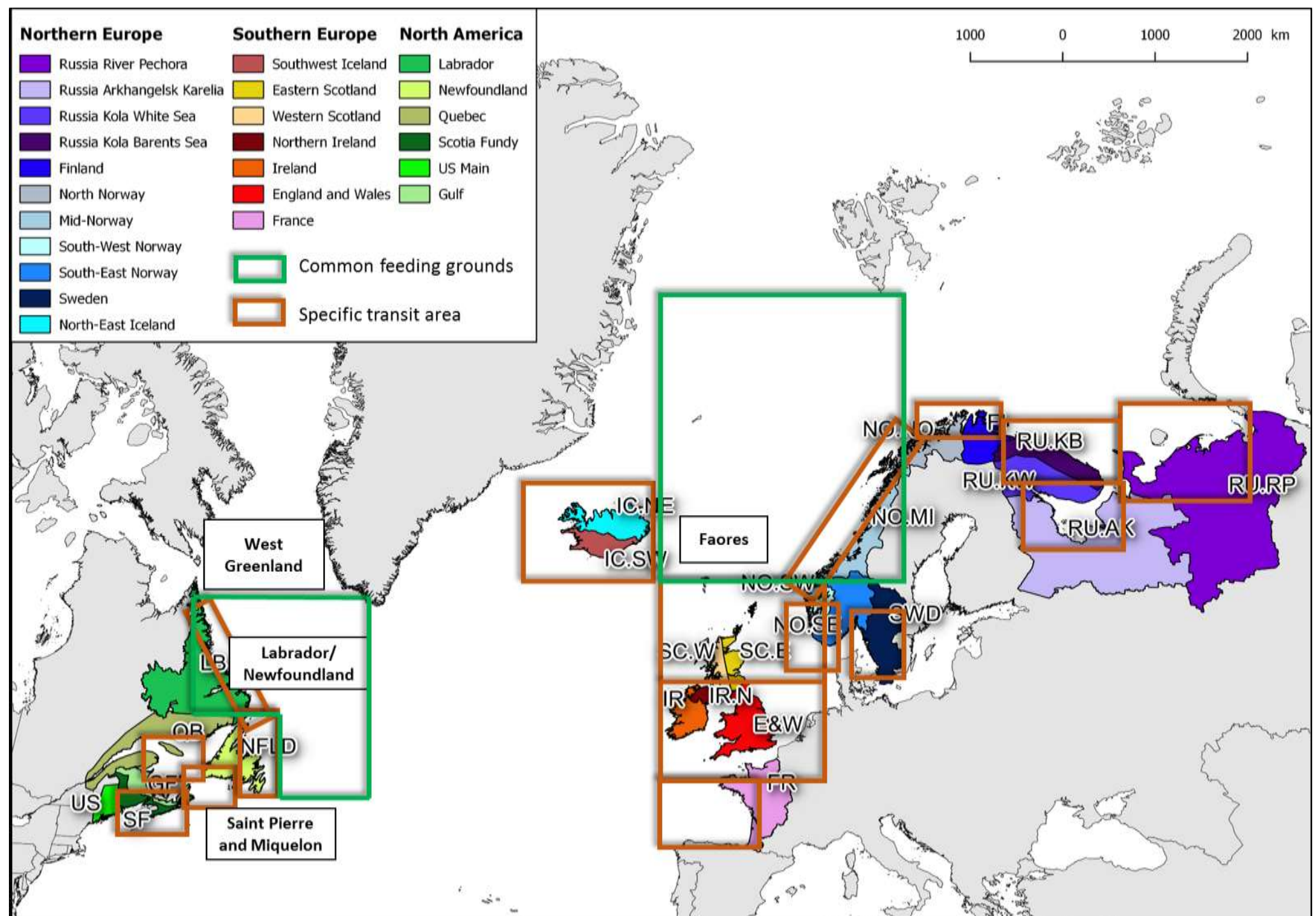
## CONTEXT & OBJECTIVES

- Context**
- A decline of Atlantic salmon (*Salmo salar*) populations across the North Atlantic basin
  - Identify the drivers and mechanisms of this decline ?
  - Develop a risk analysis framework to evaluate fisheries management strategies at the North Atlantic basin scale

- Objectives & Approaches**
- Develop a life cycle model to draw ecological inferences on the temporal and spatial variability of the processes
  - Use hierarchical models to separating out the effects of local from global pressures
  - Analyze scenarios through probabilistic forecasting

## MATERIAL & METHODS

A model working at the scale of all stock units in the North Atlantic



- Age- and stage based life cycle model
- Intra and inter-populations variability of life histories
- A hierarchical Bayesian model
  - Fitted to time series (1971-2014) of data available for each stock unit
  - A model designed to partition out the signal between common and local trends
- Synchrony : ICC Interclass Correlation Coefficient
 
$$ICC_r = \frac{Var}{Var_{tot,r}} \text{ or } \frac{Var+Var}{Var_{tot,r}}$$

**Hindcasting** Is the decline in post-smolt survival a response of populations to changes in the marine ecosystem (bottom-up processes)?

$$\left( \text{logit}(\theta_{t,r}) \right)_{\substack{r=1:24 \\ c=1:3}} = \delta_t + \alpha_{t,c} + \epsilon_{t,r} + \beta_r + \text{Effect of environmental variables}$$

$\delta_t$  : Global scale component common to the 24 SUs  
 $\alpha_{t,c}$  : Specific CSG component  
 $\epsilon_{t,r}$  : Specific SU component

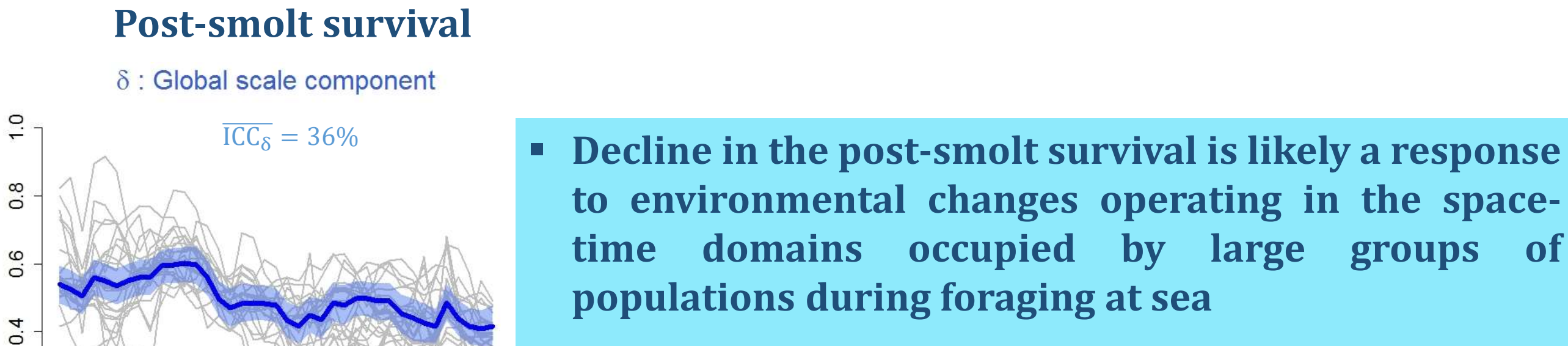
Environmental variables (PP or SST)

- H1 - Specific (transit) space-time domains (first 3 months of marine migration)
- H2 - Foraging space-time domains (late summer-beginning autumn)

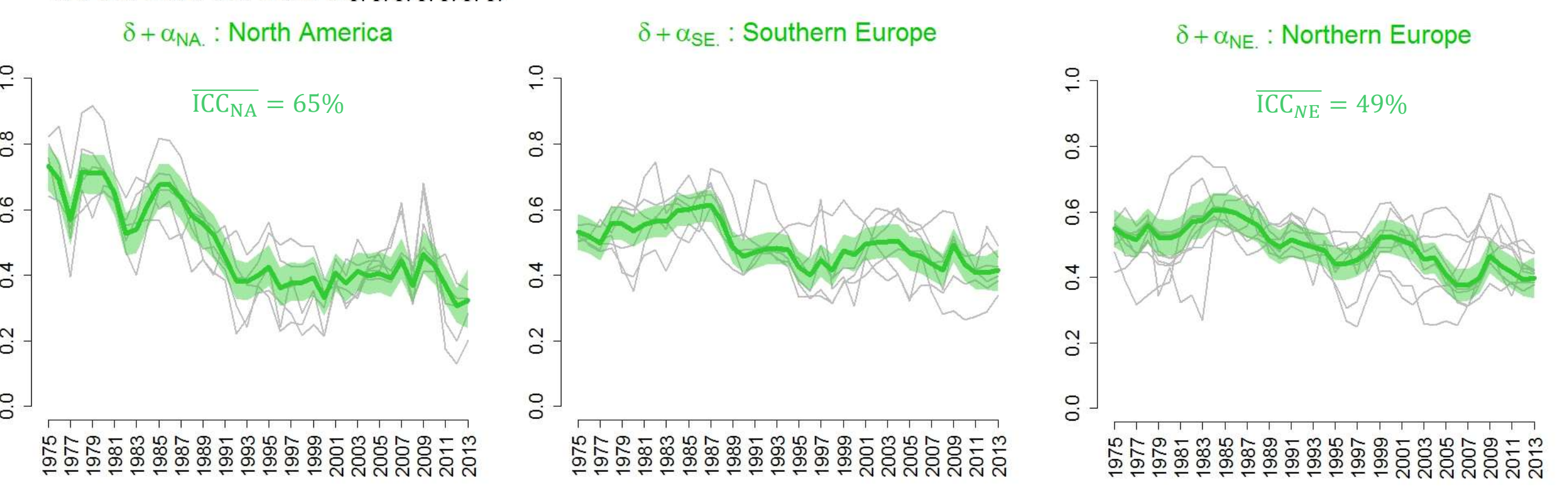
**Forecasting** What is the probability to reach Conservation Limits given management strategies of mixed stock fisheries (Greenland and Faroes)?

## RESULTS

### ECOLOGY



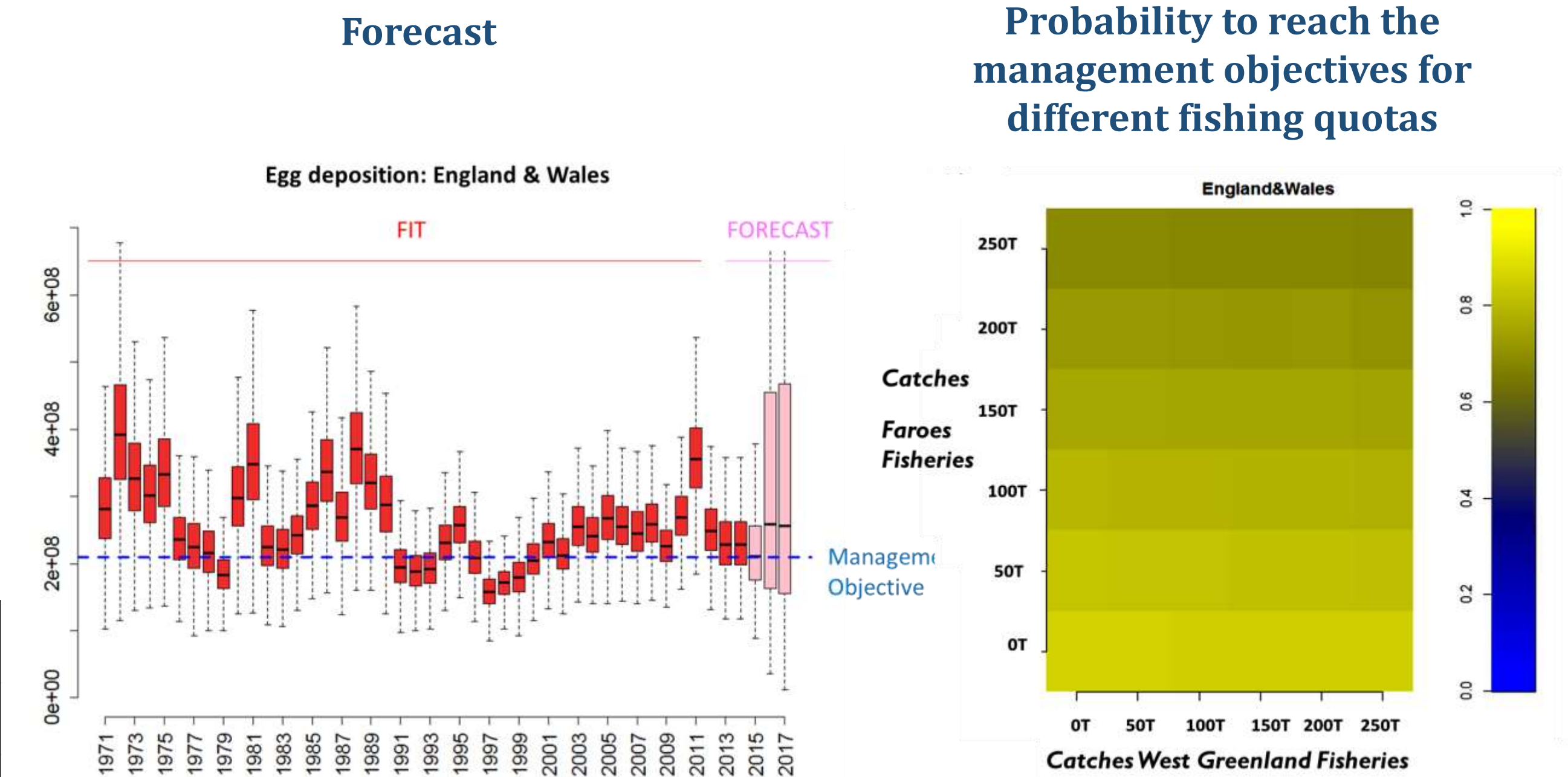
Decline in the post-smolt survival is likely a response to environmental changes operating in the space-time domains occupied by large groups of populations during foraging at sea



	% of variances explained by the covariate		
	Global component	CSG components	Specific components
PP	19%	12-26%	<11%
SST	43%	20-26%	<18%

### MANAGEMENT

- The probability to reach CL for a particular scenario is contrasted between SU
- But the probability to reach CL simultaneously for all SU for the same continental stock group is ~0 whatever the management scenarios



## CONCLUSIONS

- An unified framework to explore ecological mechanisms and forecast the response of populations to management strategies while accounting for the effect of environmental changes at the North Atlantic basin scale
  - Outperforms existing models
  - Highly expandable (incorporate new data and new ecological hypothesis)
- Decline of all populations is likely a synchronous response to large scale bottom up environmentally driven changes susceptible to synchronize post-smolt survival during the first year at sea
- Stock status is depressed - the probability to reach management objectives remains low whatever the fishing quotas (although it may be high for local populations)