Les modèles hiérarchiques : un outil pour gérer les emboitements d'échelles dans la modélisation intégrée des cycles de vie

Etienne Rivot, Félix Massiot-Granier, Benoit Archambault, Sébastien Rochette, Etienne Prévost, Olivier Le Pape

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Un outil pour gérer les emboîtements d’échelles dans la modélisation intégrée des cycles de vie

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UMR Ecologie et Santé des Ecosystèmes

Ecologie Halieutique

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Integrated life cycle models

- We still need population models!
  - Individuals $\leftrightarrow$ Populations $\leftrightarrow$ Ecosystem
  - The core of decision analysis
- Integrated life cycles models allow considering population models in an ecosystemic framework
- Raises challenges … classics of the old dichotomy between mechanistic and statistical models

  Levins, R. 1966. The strategy of model building in population biology. American Scientist, 54(4), 421–431.

Integrated life cycle models - Challenges

Challenge 1 - Understanding demographics

- **Integrate** various demographic processes and factors that control population dynamics at all life stages

  - with their associated sources of variability and uncertainty

  - within a hierarchy of spatial and temporal scales

    - Spatial — Local (~ site specific)

      Global (~ large geographical scale)

    - Temporal — Long term (~ decades)

      Short term (~ years)

Integrated life cycle models - Challenges

Challenge 2 - Data assimilation

- Assimilate various sources of data and information, with their associated sources of uncertainty, to extract an **integrated signal**
  - Survey methods are heterogeneous among life stages, in time/space
  - Observations errors are the rule, and must be accounted for
  - Data are incomplete

    Some key demographic transitions can not be directly observed

    → Borrowing strength (« Robin Hood Approach », Punt 2011)

    → Informative priors (« Standing on the shoulders of giants », Hilborn and Lierman, 1998)

Hierarchical Bayesian Models

(Clark, 2005 ; Buckland et al., 2007 ; Cressie et al., 2009 ; Kerry and Schaub, 2011 ; Parent and Rivot,2012)

Conditional probability distributions used for *cause* → *effect* relationships for process and observations

\+ (Informative) priors on parameters

→ Param. / Demographics / Observations are modeled in a **probabilistic** logic

→ Dependencies (Param → States → Obs.) are built in a **mechanistic** logic

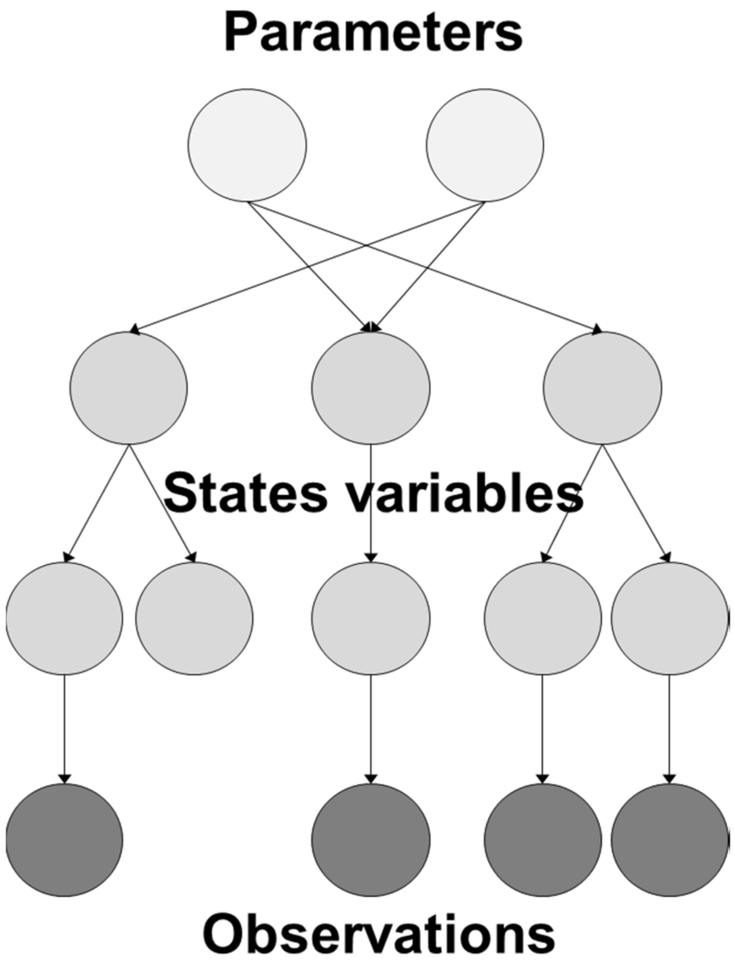
→ **Synthesis** between mechanistic and probabilistic approaches (~ data assimilation)

→ Allows for building complex network of dependencies, in a hierarchy of time and spatial scales

1. Demography

2. Data assimilation ("borrowing strength")

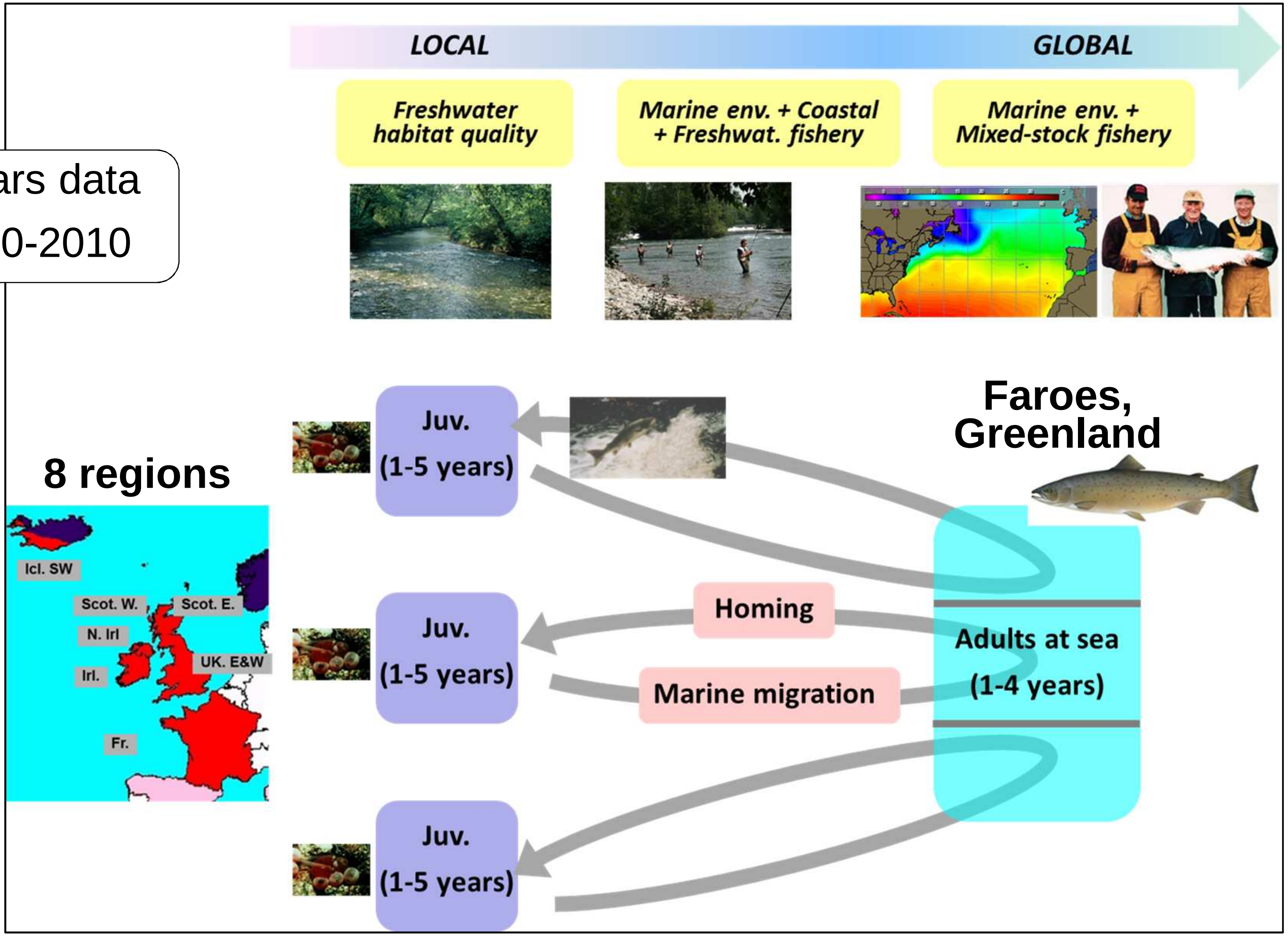
3. Informative Priors



Atlantic salmon *(Salmo salar)* in the North Atlantic Ocean

F. Massiot-Granier, V. Bret,
E. Prévost

40 years data
~ 1970-2010



Disentangling the different scales in the A. Salmon freshwater and marine survival

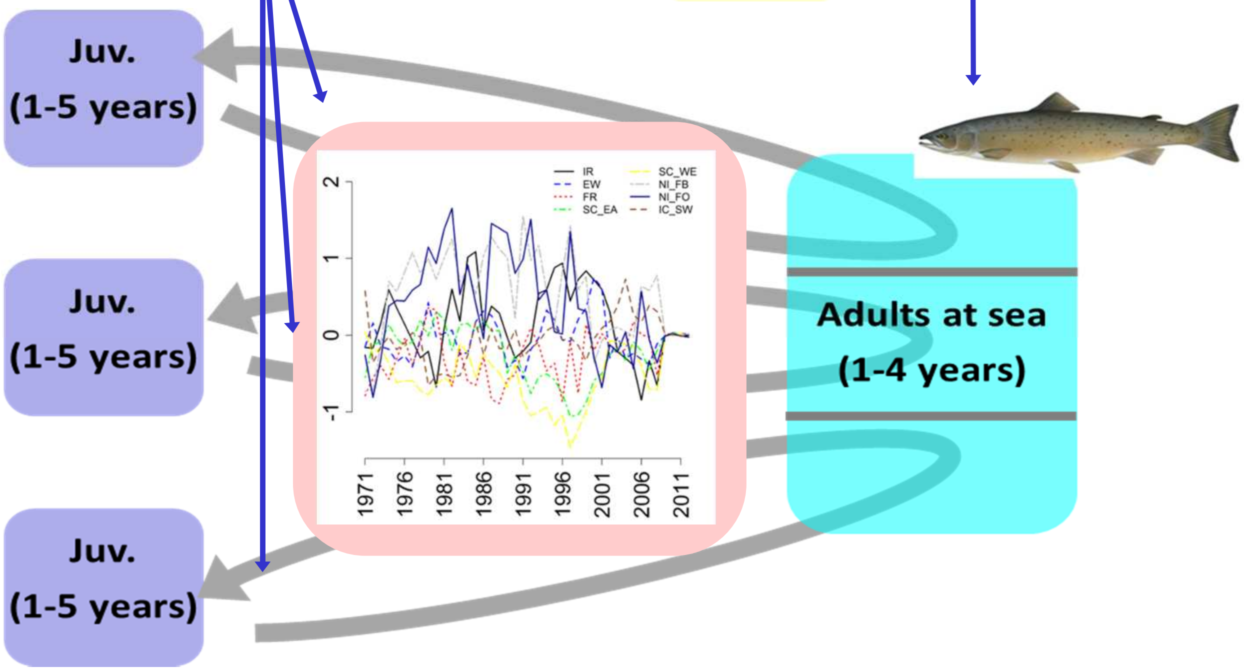
r = region (1,…,8)

t = years (1,…,40)

Marine survival

$$logit(\theta_{r,t}) = \alpha_t + \beta_{r,t}$$

Global	α_t	$=$	α_{t-1}	$+$	$\epsilon_t \sim \mathcal{N}(0, \sigma_\alpha)$
Local	$\beta_{r,t}$	$=$	$\beta_{r,t-1}$	$+$	$\omega_{t,r} \sim \mathcal{N}(0, \sigma_\beta)$
			Trends		Fluctuations



Disentangling the different scales in the A. Salmon freshwater and marine survival

r = region (1,…,8)

t = years (1,…,40)

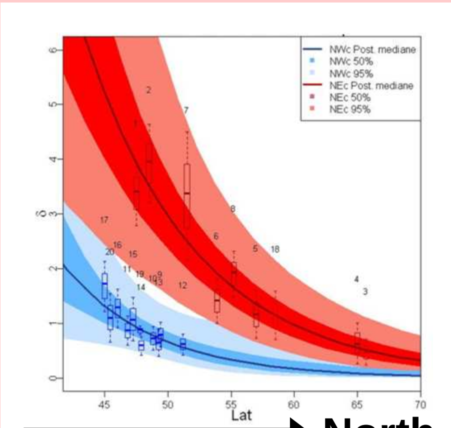
Eggs → Smolts survival

21 index rivers

HBM → Borrowing strength

"Data rich" → "data poor"

$$Mort_r = e^{\gamma_r + \lambda_r \cdot Latitude_r}$$



North

Latitude

Marine survival

$$logit(\theta_{r,t}) = \alpha_t + \beta_{r,t}$$

Global	α_t	=	α_{t-1}	+	$\epsilon_t \sim \mathcal{N}(0, \sigma_\alpha)$
Local	$\beta_{r,t}$	=	$\beta_{r,t-1}$	+	$\omega_{t,r} \sim \mathcal{N}(0, \sigma_\beta)$
			Trends		Fluctuations

Juv. (1-5 years)

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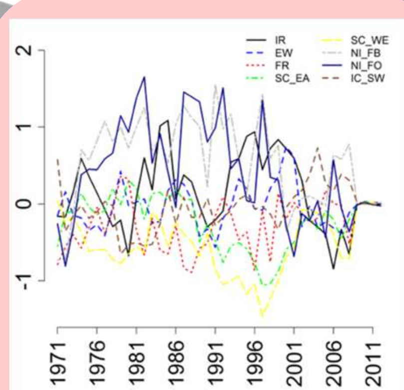


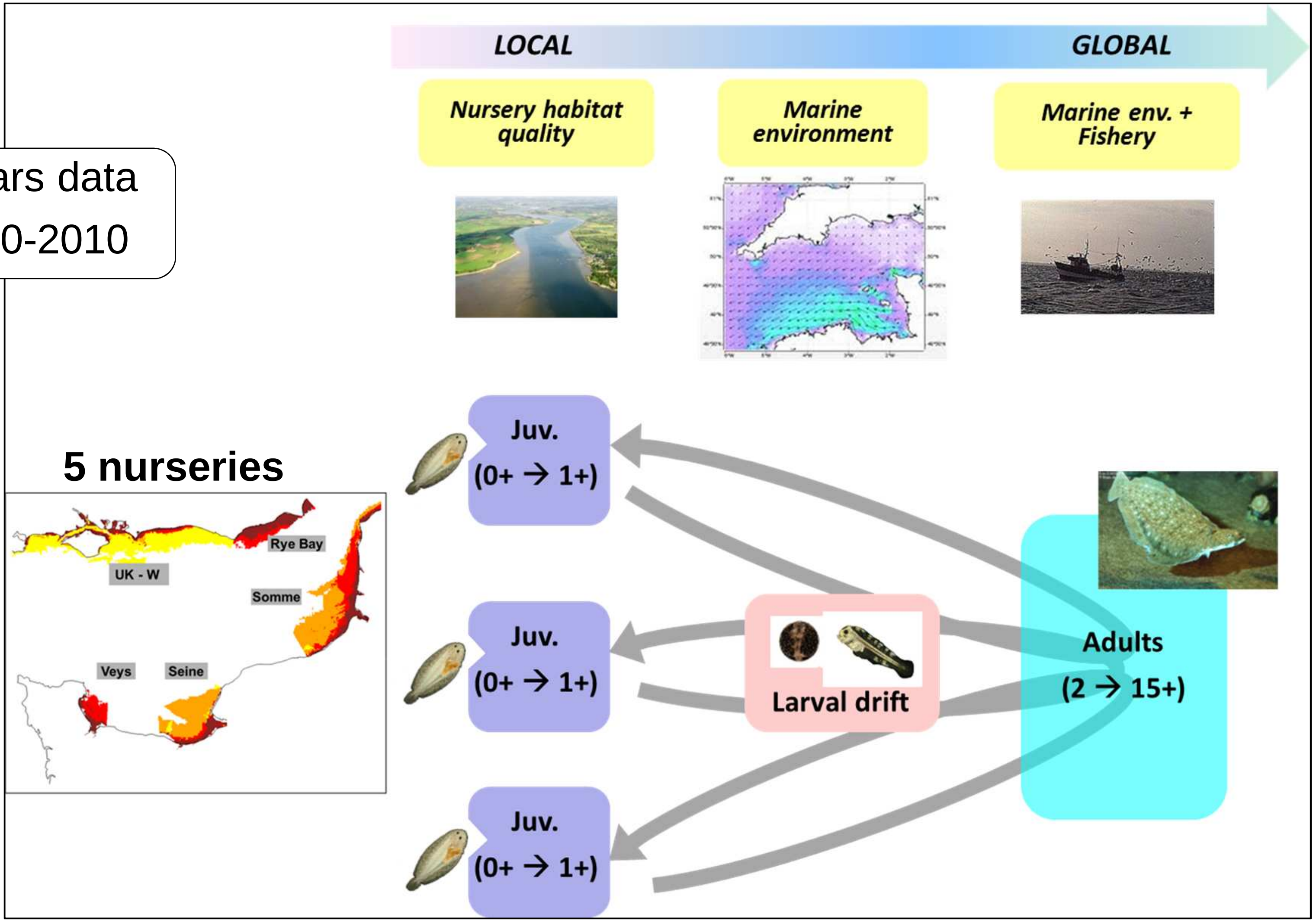
Adults at sea (1-4 years)

Common sole *(Solea solea)* in the Eastern Channel

S. Rochette, B. Archambault,
O. Le Pape, M. Huret

30 years data
~ 1980-2010

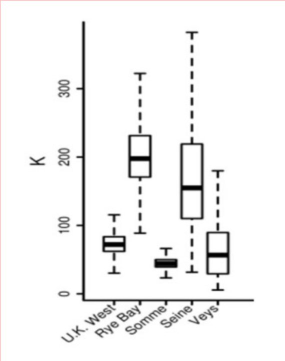
5 nurseries



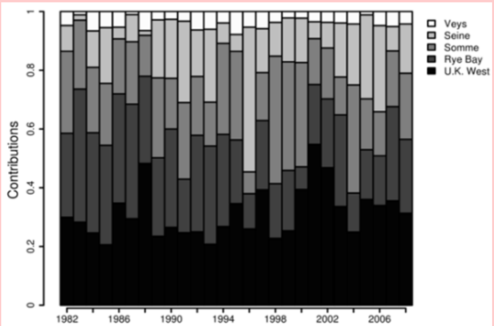
Merging Lagragian model for larval drift and survival within a life cycle of the common Sole in the E. Channel

Nursery-specific density-dependent mortality

Nursery-specific carrying capacity

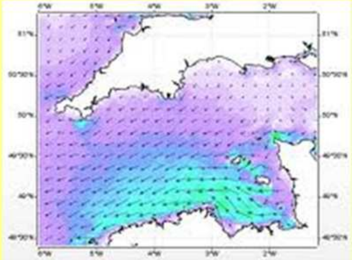


Contribution of each nursery to the total recruitment



Larval drift and survival

Lagragian model (MARS 3D)



X

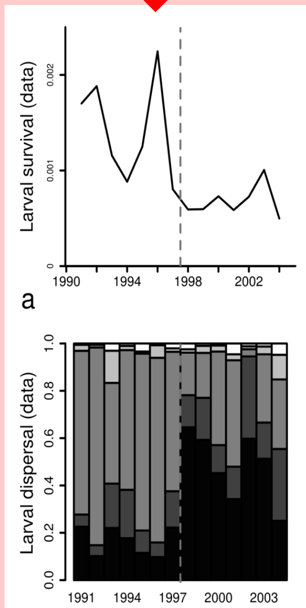
Biological hyp.

Informative prior

Juv. (0+ → 1+)

Juv. (0+ → 1+)

Juv. (0+ → 1+)



Adults (2 → 15+)

Conclusions

- HBMs are useful tools to move from simple population dynamics to integrated life cycle for an ecosystemic approach to population dynamics and demography

- Have the potential for stimulating collaborations and for a synthesis between different fields of science
  - Field ecology (data) and data assimilation
  - Demographics & pop. dynamics
  - Mechanistic models (IBMs …)
  - Maths. / Statistics / Comput. Sciences

- Provide insights to a better understanding of the factors controlling life cycles in a hierarchy of time and spatial scales

Thanks for your attention !

and welcome in the *Bayesounours World !*