



Coupling an age-structured population model for fish dynamics with a larval dispersal model within a Bayesian state-space modelling framework

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Outline

I. General context

- a. State-Space models
- b. Age-structured models
- c. Spatialization
- d. Integrated population model

II. Case study : *Solea solea* in the Eastern Channel

III. Population modelling

IV. Conclusions & Perspectives



I.a. State-Space models

- A key methodological framework for fisheries sciences

- Fish population dynamics (management)
 - High dimensional, non linear, stochastic
- State of the system not directly observed
 - Noisy, incomplete observations

Process equation:

$$X_{t+1} = f(X_t, \theta_1, \varepsilon_t)$$

Observation equation:

$$y_t = g(X_t, \theta_2, \omega_t)$$



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■ Bayesian framework coupled with Monte-Carlo method

- Easy-to-use quantification of uncertainty for risk analysis
- Various sources of information and expertise (data and prior)
- High dimension models, non linear SSM
- Software (MCMC methods, OpenBUGS / R)



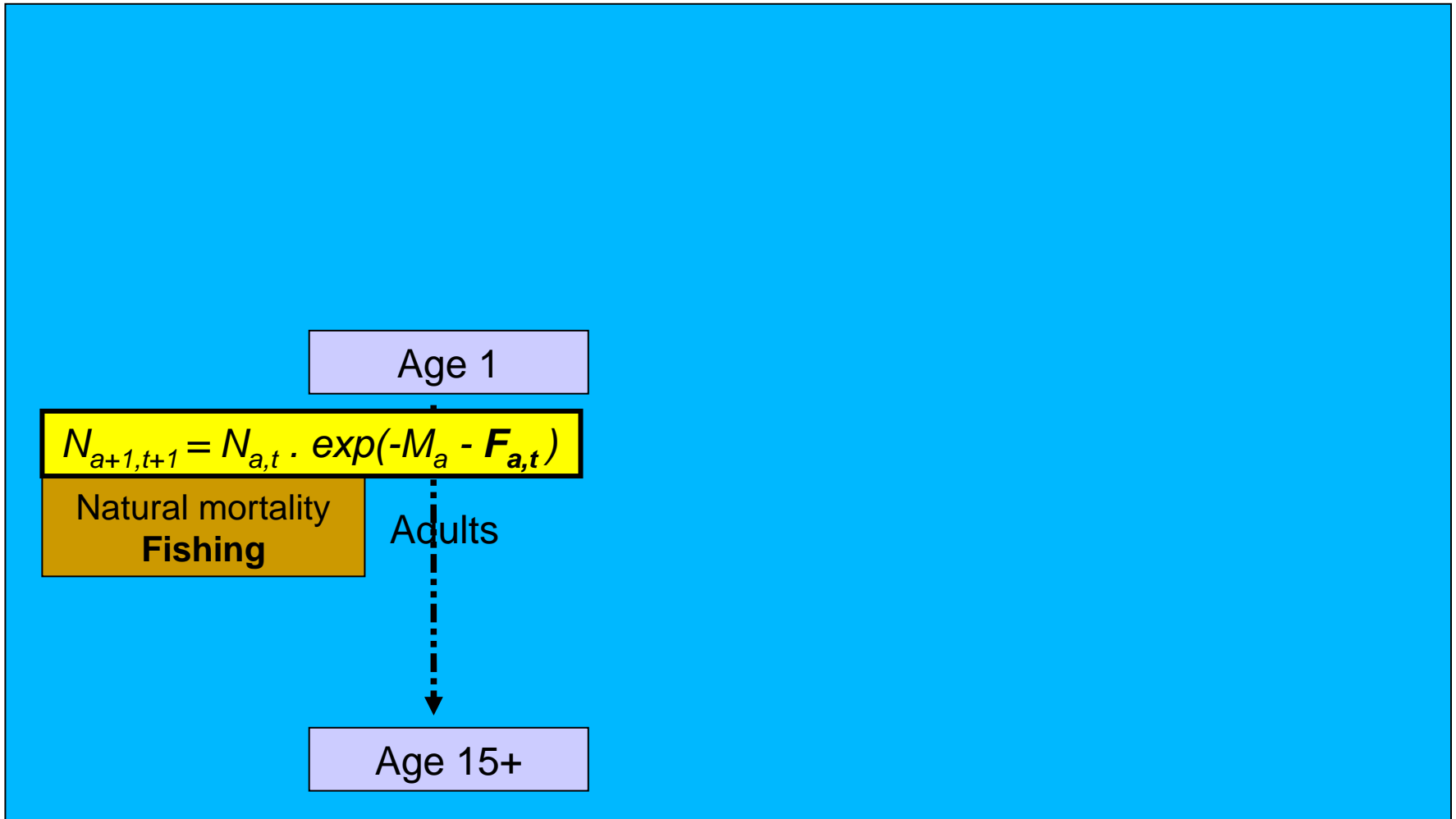
I.b. Age-structured models

- Extension of Leslie Matrix models



I.b. Age-structured models

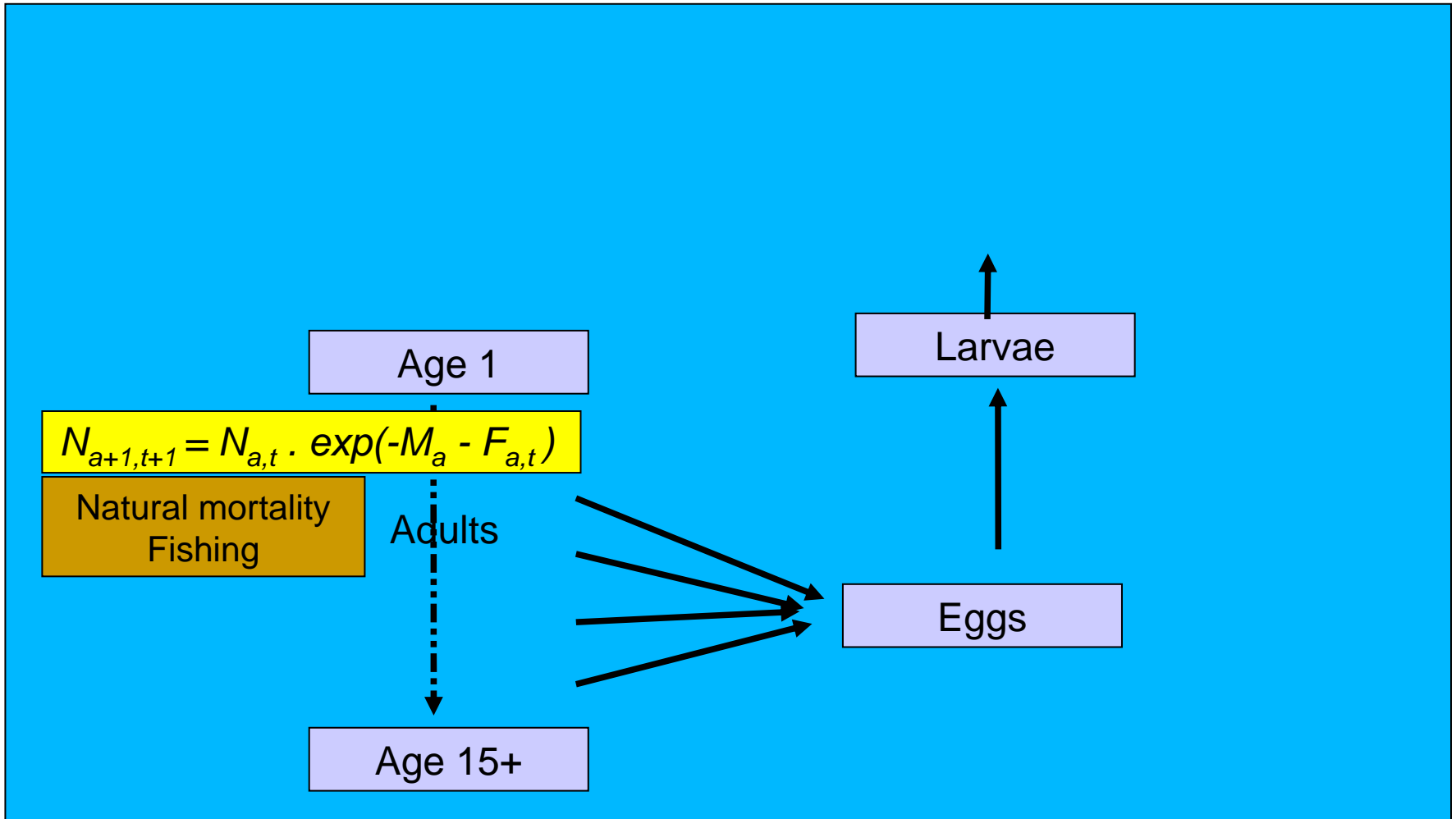
■ Process Equations





I.b. Age-structured models

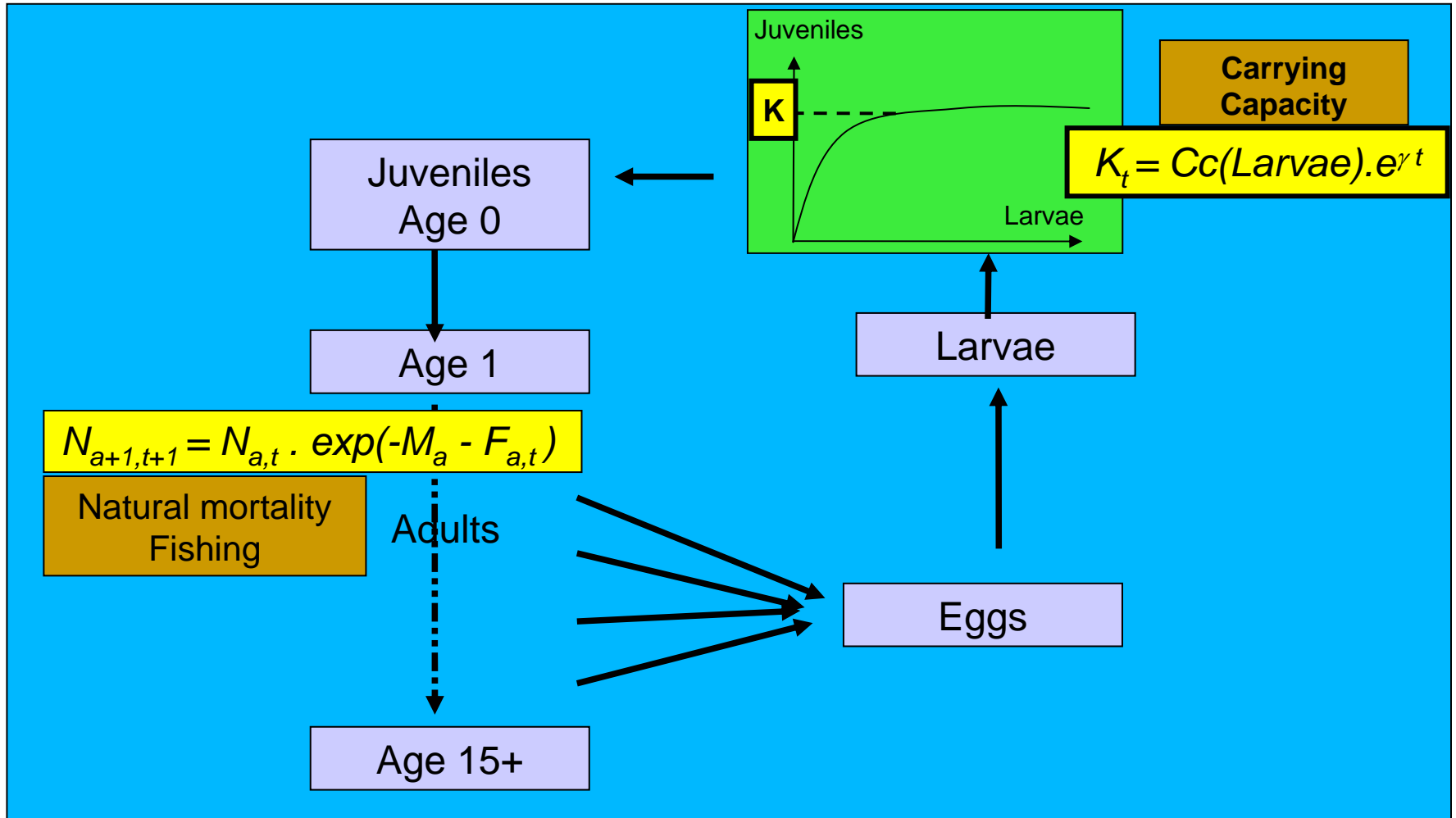
■ Process Equations





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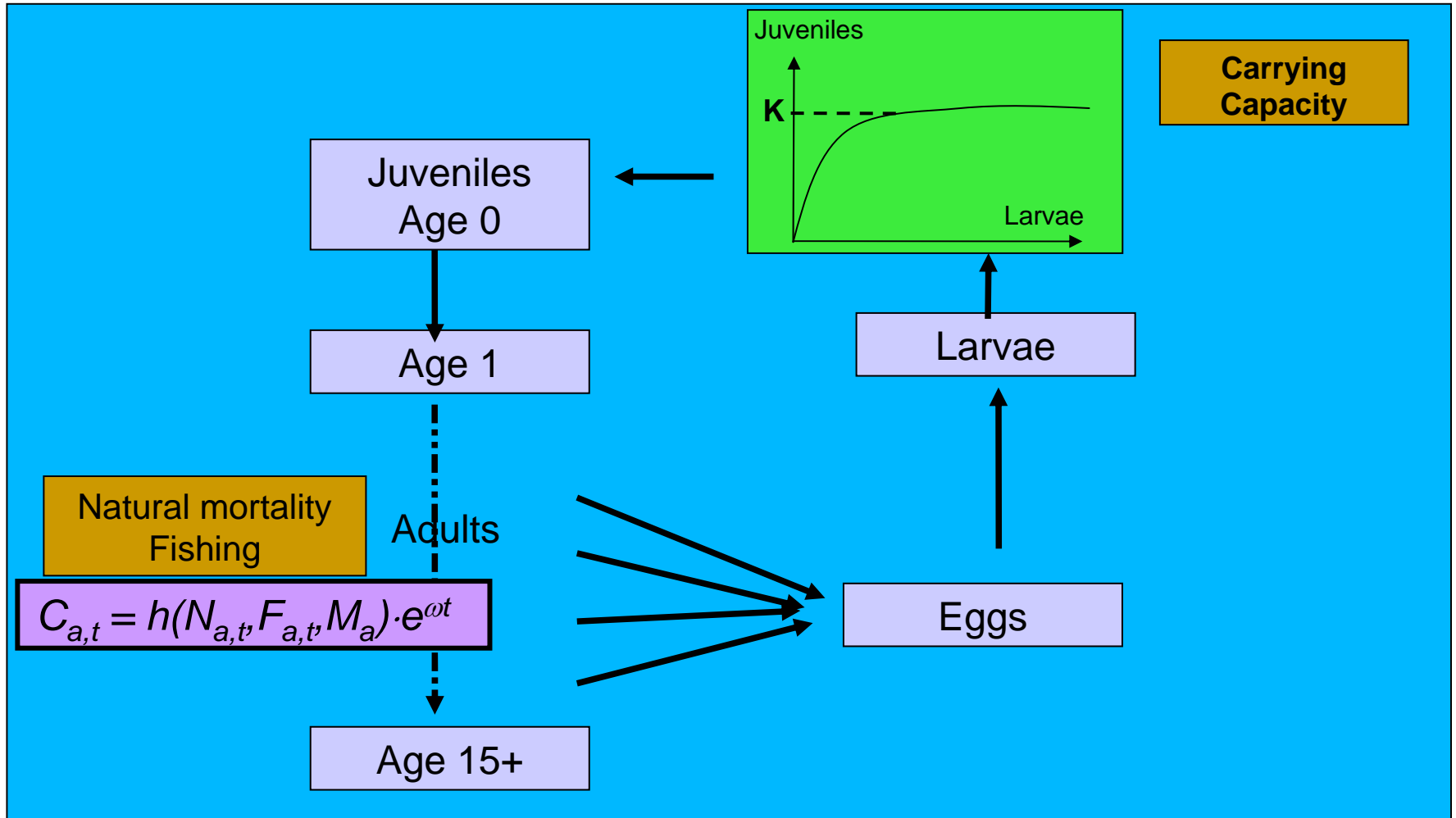
■ Process Equations with noise





I.b. Age-structured models

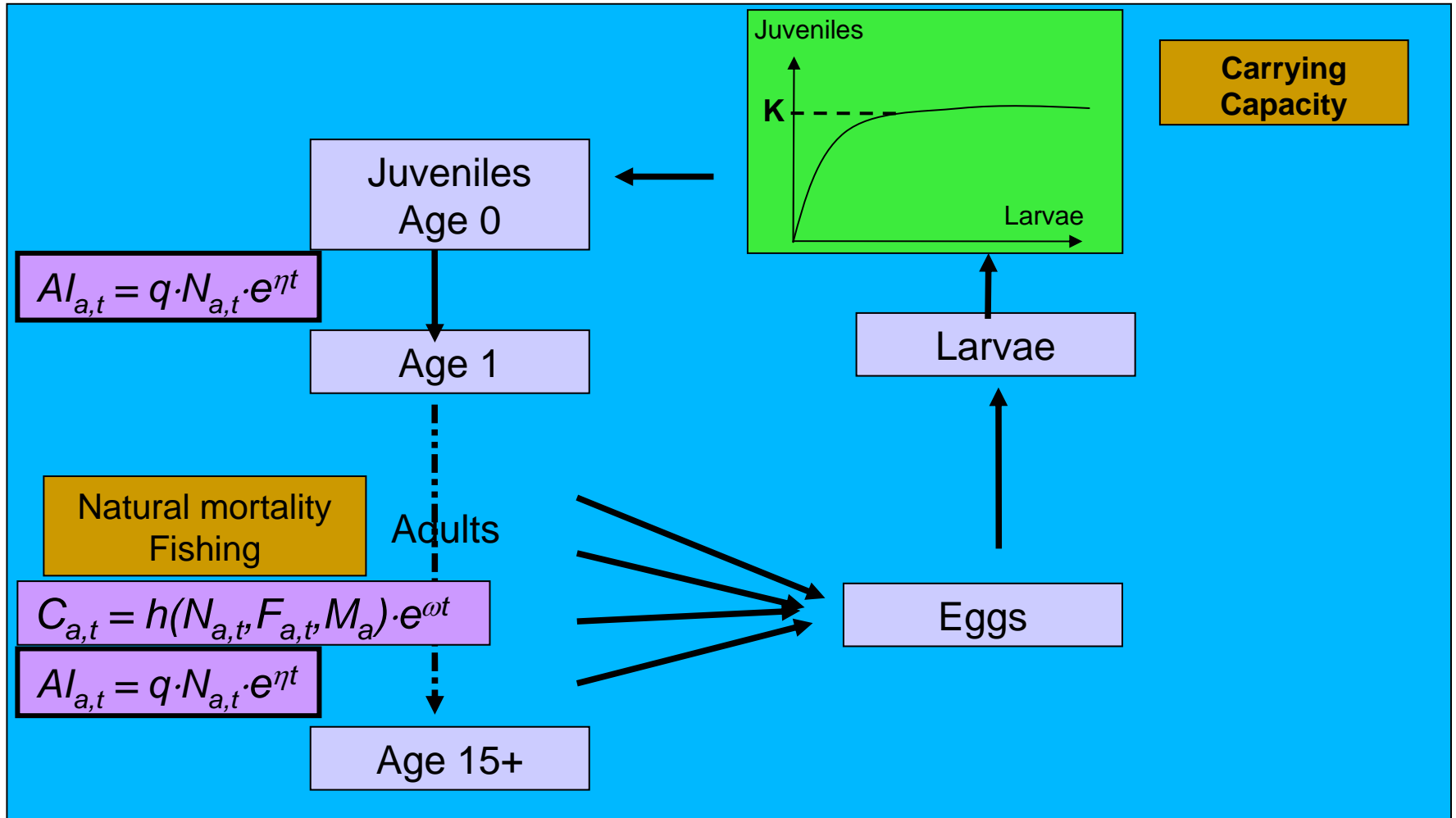
Observations with error





I.b. Age-structured models

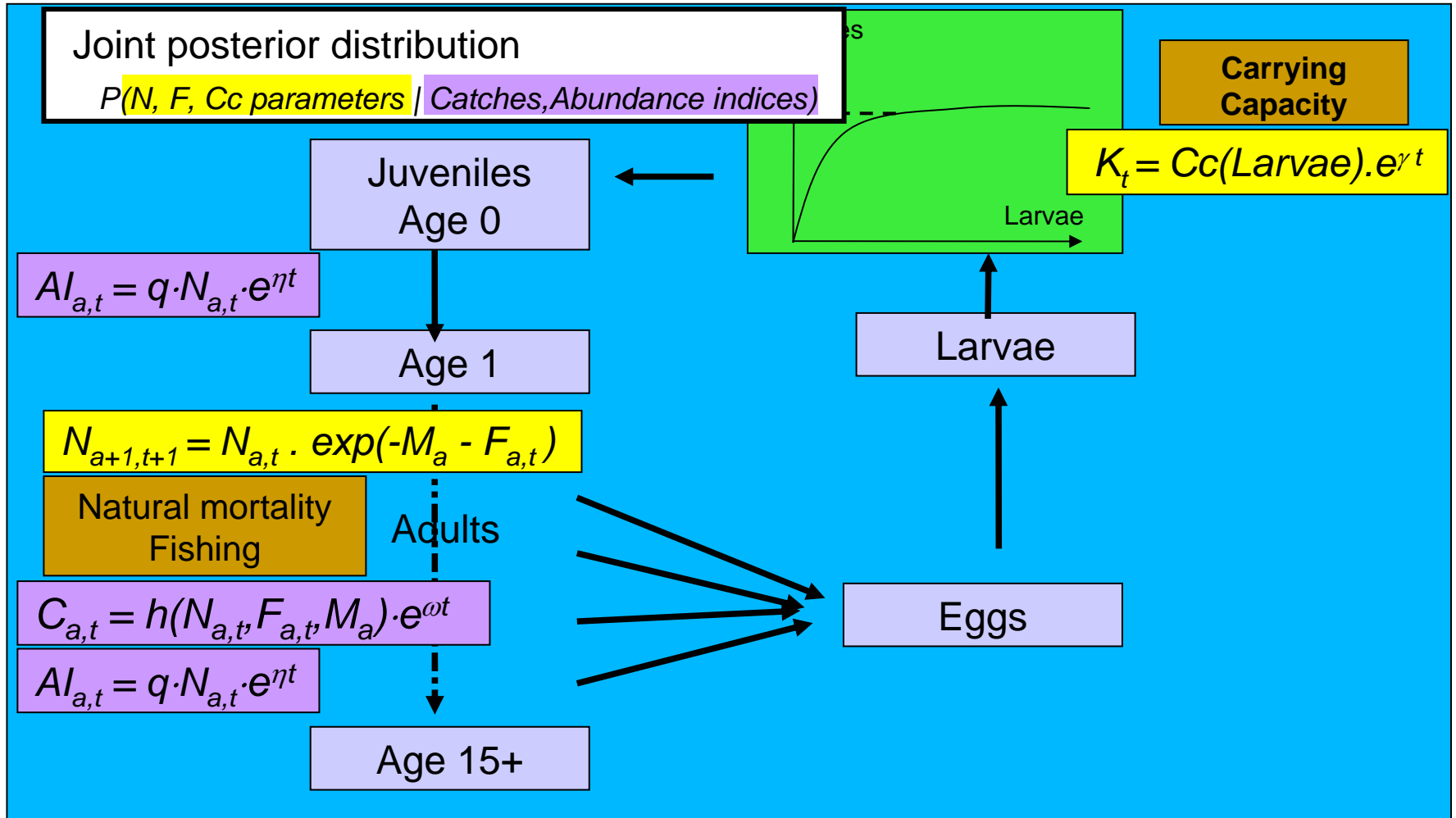
Observations with error





I.b. Age-structured models

Bayesian statistical catch-at-age analysis





I.c. Spatialization

- Recruitment governs populations renewal
 - Eggs → Juveniles: 6 months, survival $\approx 10^{-4}$
 - Adults survival : 15 years, $s \approx 5 \cdot 10^{-2}$



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 - Coastal (high productivity, low predation)
 - Variable quality and productivity (time & space)
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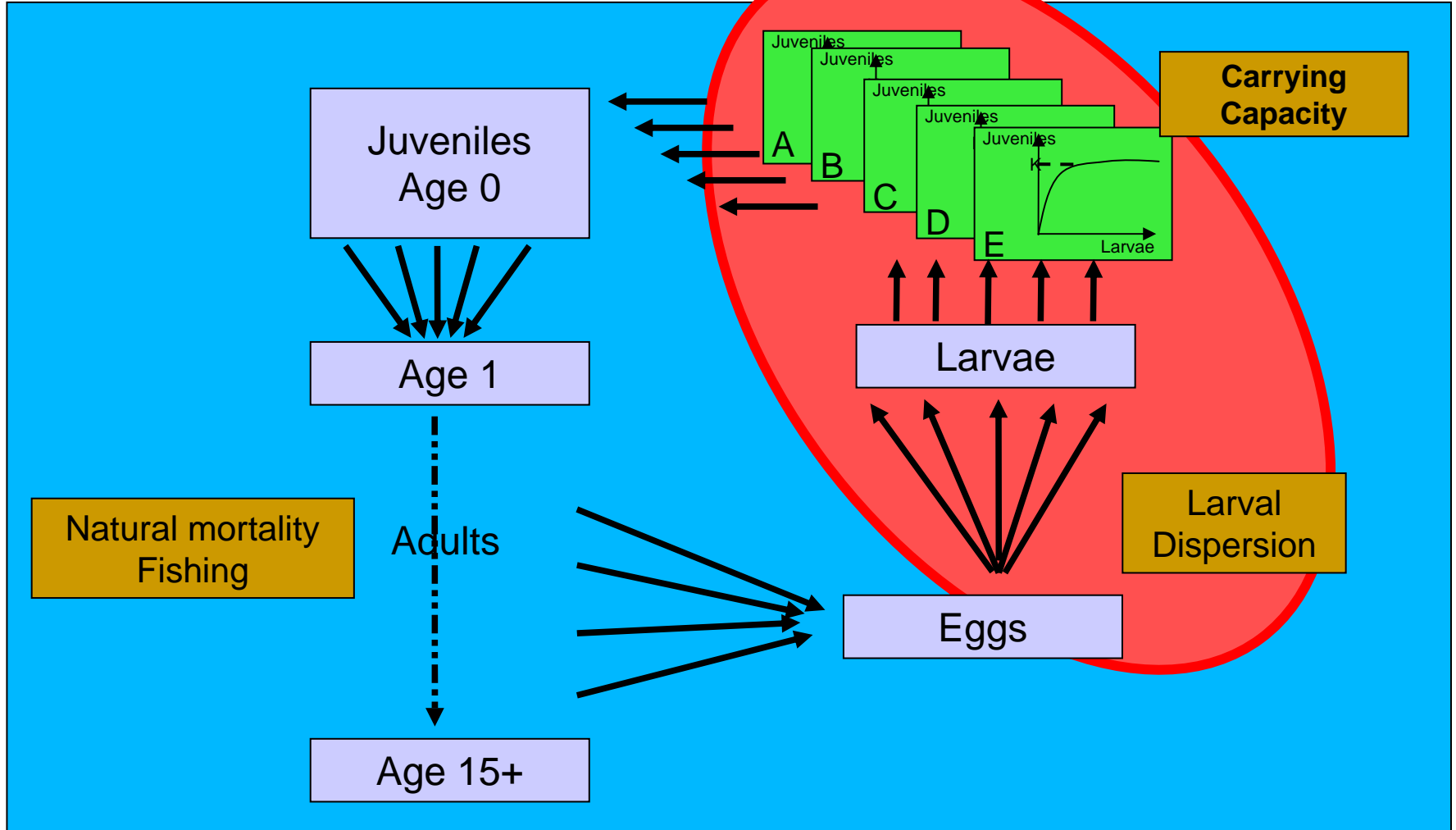
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- Amount of juveniles different in each nursery
 - Larval dispersal -> Larval supply
 - Habitat quality -> Carrying capacity



I.c. Spatialization

Population dynamic model





I.d. Integrated population model

- A framework for coupling models
 - Larval dispersion model
 - Oceanic circulation model
 - Lagrangian modelling
 - Spatialized age-structured population model
 - Fitted to commercial Catches and Abundance Indices
 - Fishing mortality included
 - Spatialization
 - Nurseries with contrasted productivities
 - Use larval dispersion model as an INPUT

- Application to sole population in the Eastern Channel



Outline

- I. General context

- II. Case study : *Solea solea* in the Eastern Channel
 - a. Data
 - b. Habitat suitability
 - c. Larval dispersion

- III. Population modelling

- IV. Conclusions & Perspectives

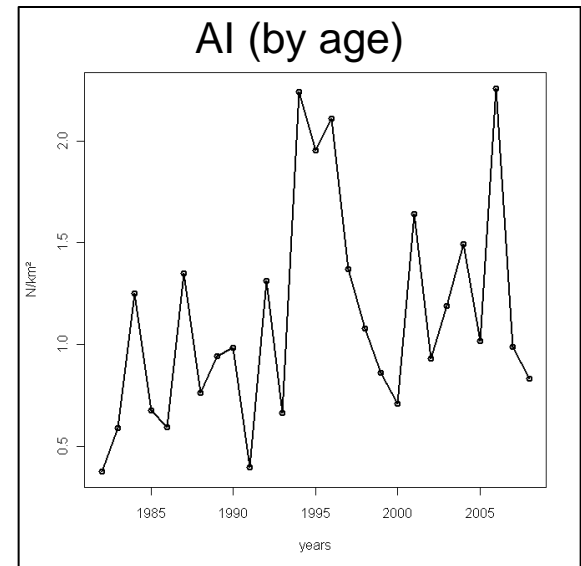
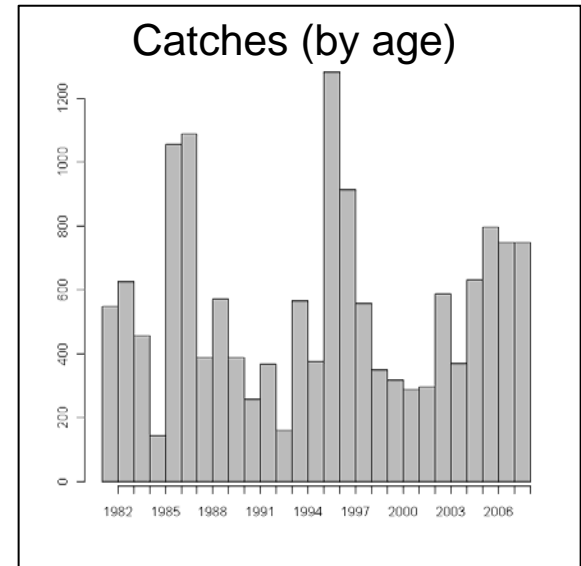


II.a. Data

- Adults (age ≥ 2) – not spatialized
 - Catches
 - Abundance indices
- (source : Sole stock assessment WG)



Eastern Channel

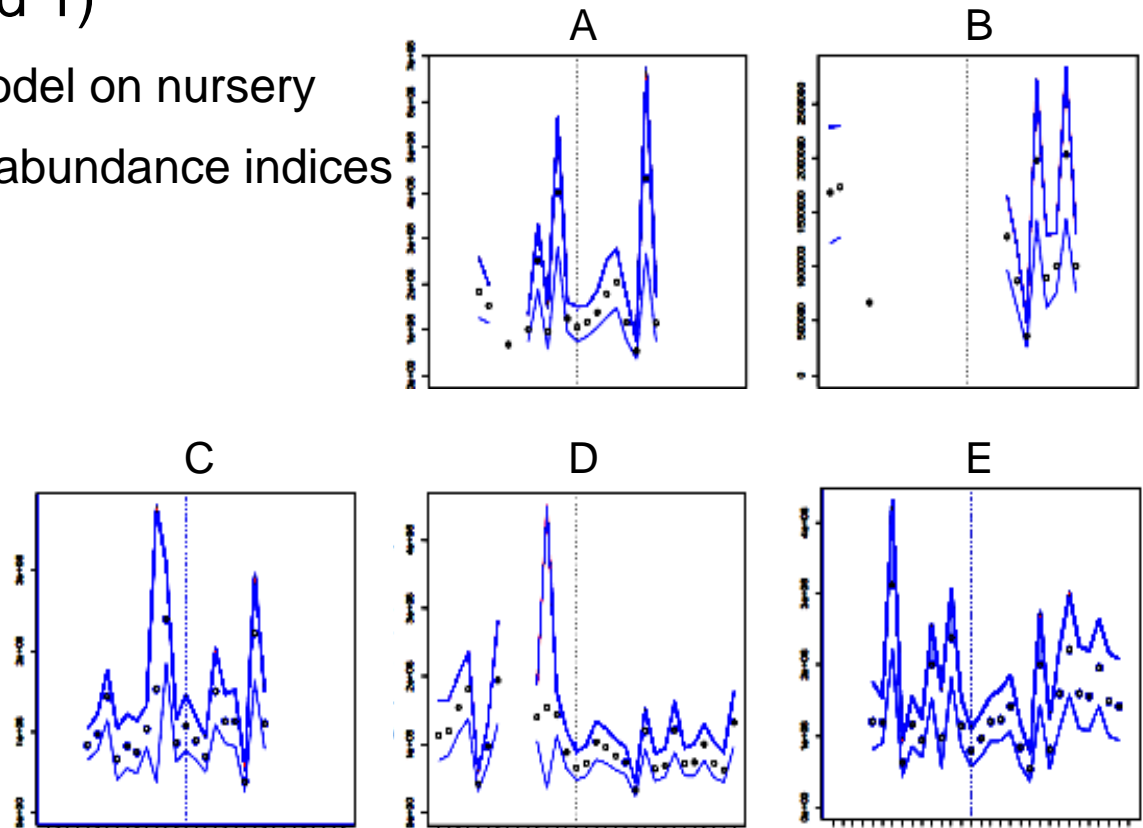




II.a. Data

- Adults (age ≥ 2)
- Juveniles (age 0 and 1)
 - Habitat suitability model on nursery
 - Spatialized juvenile abundance indices

Abundance indices
on nurseries

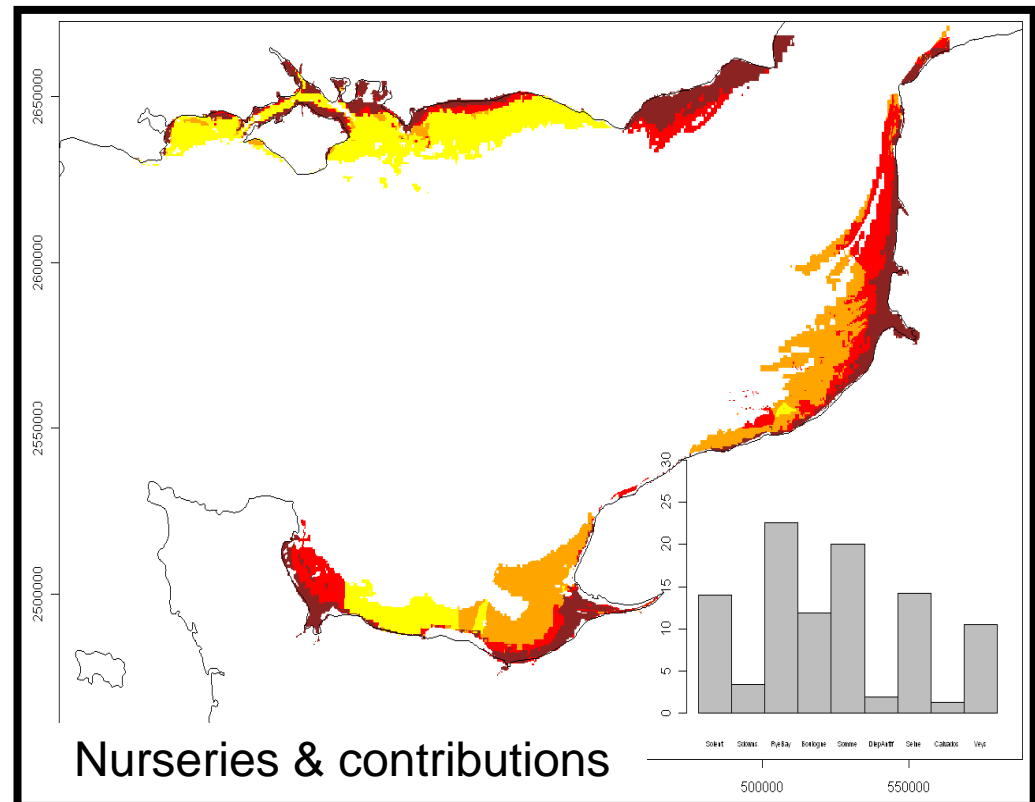




II.b. Habitat suitability

■ Mapping nurseries

- Juvenile densities = f (Depth, Sediment, Site)
- High contrast of densities (in time and space)
- Site effect :
 - Quality ?
 - Larval supply ?





II.c. Larval dispersion

- Larval dispersion model
 - Ocean circulation model (Mars3D)
 - Particle-tracking system (Lagrangian modelling)
 - Maps for spawning grounds
 - Individual based life traits (mortality, growth ...)



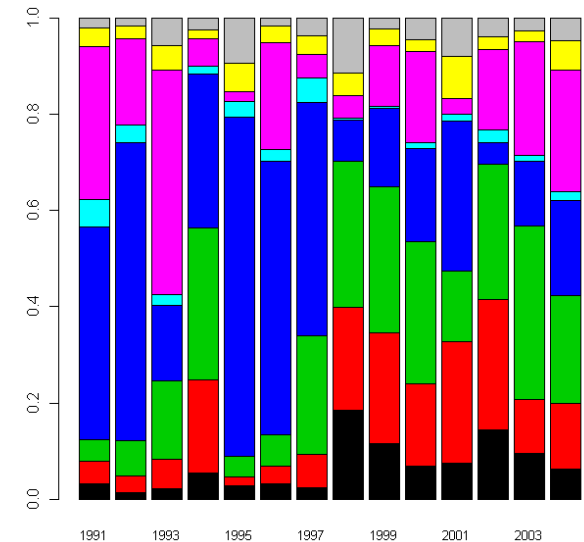
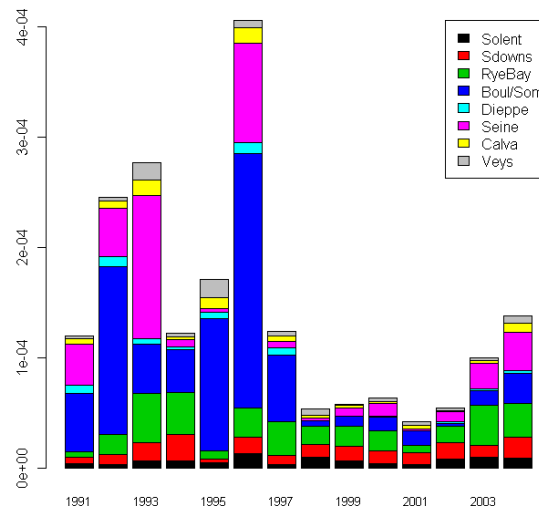
II.c. Larval dispersion

■ Larval dispersion model

- Ocean circulation model (Mars3D)
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■ Outputs

- Larval survival
- Larval repartition between nurseries





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- III. Population model
 - a. Simulation / Estimation
 - b. Results

- IV. Conclusions & Perspectives



III.a. Simulation / estimation

- Assess the performance of the estimation method
- Cycles of simulation – estimation



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- Assess the performance of the estimation method

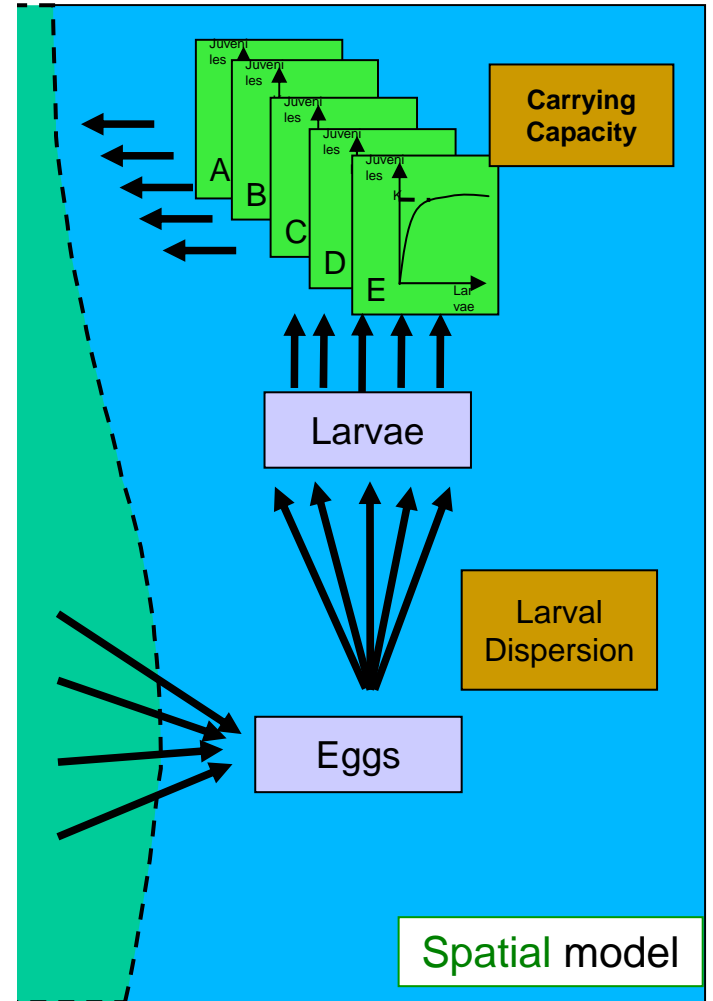
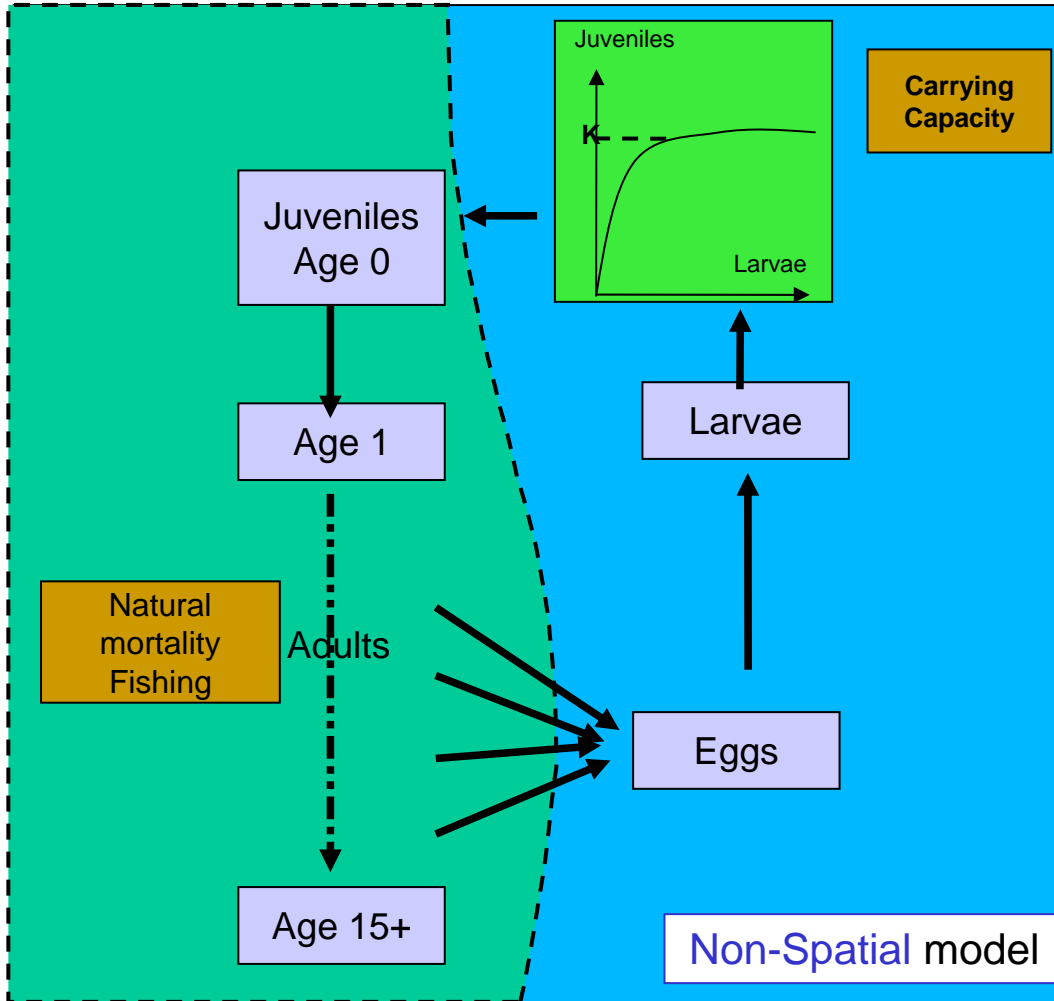
- Cycles of simulation – estimation

- Scaled to the Eastern Channel sole population case study
 - Population dynamics
 - Age-structured : 15 age classes – 27 years
 - Larval dispersal
 - Recruitment equation
 - 5 different nurseries ($K \approx$ habitat model)
 - Noisy recruitment over time
 - Noisy data
 - Abundances indices per age class
 - Catches per age class



III.a. Simulation / estimation

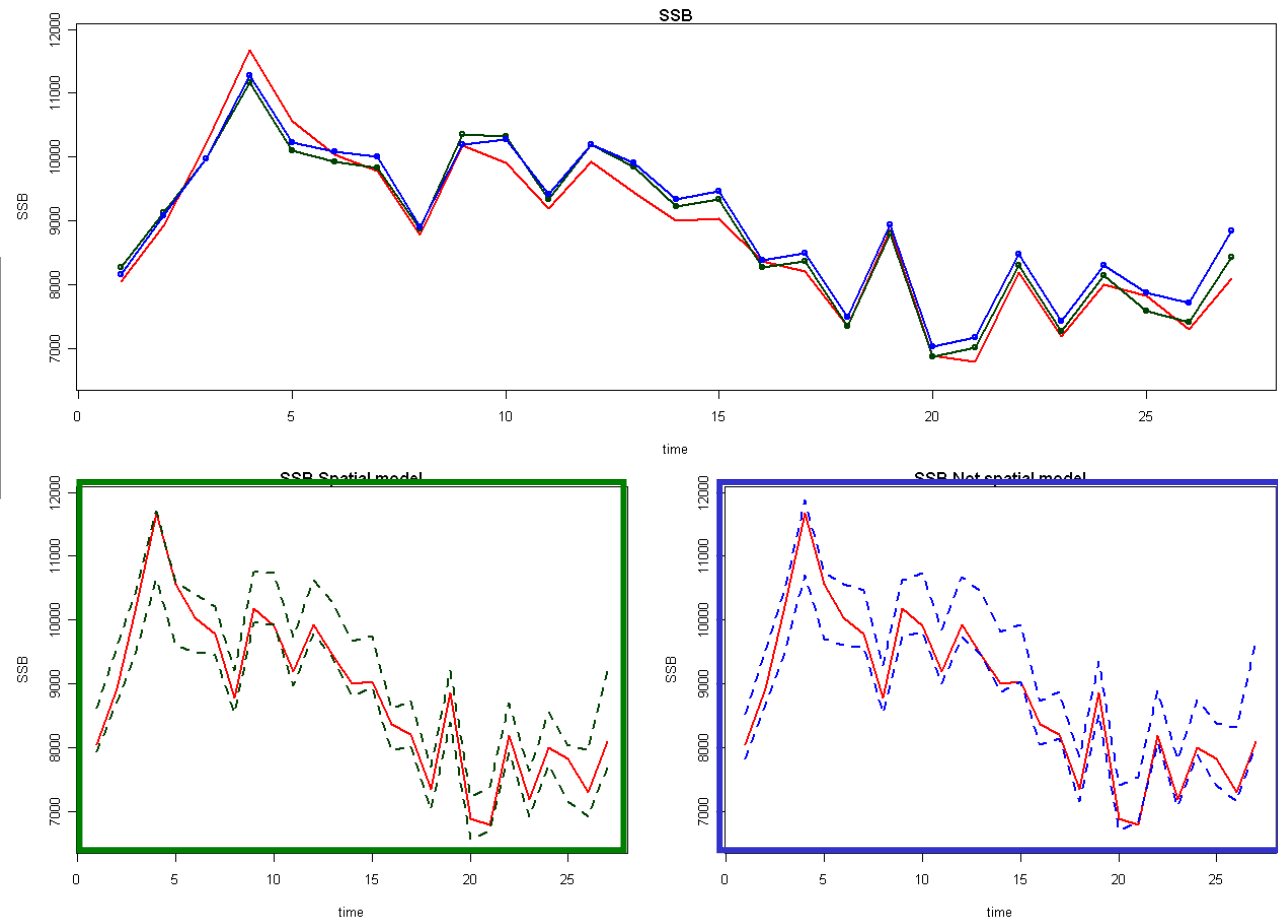
2 models





III.b. Results

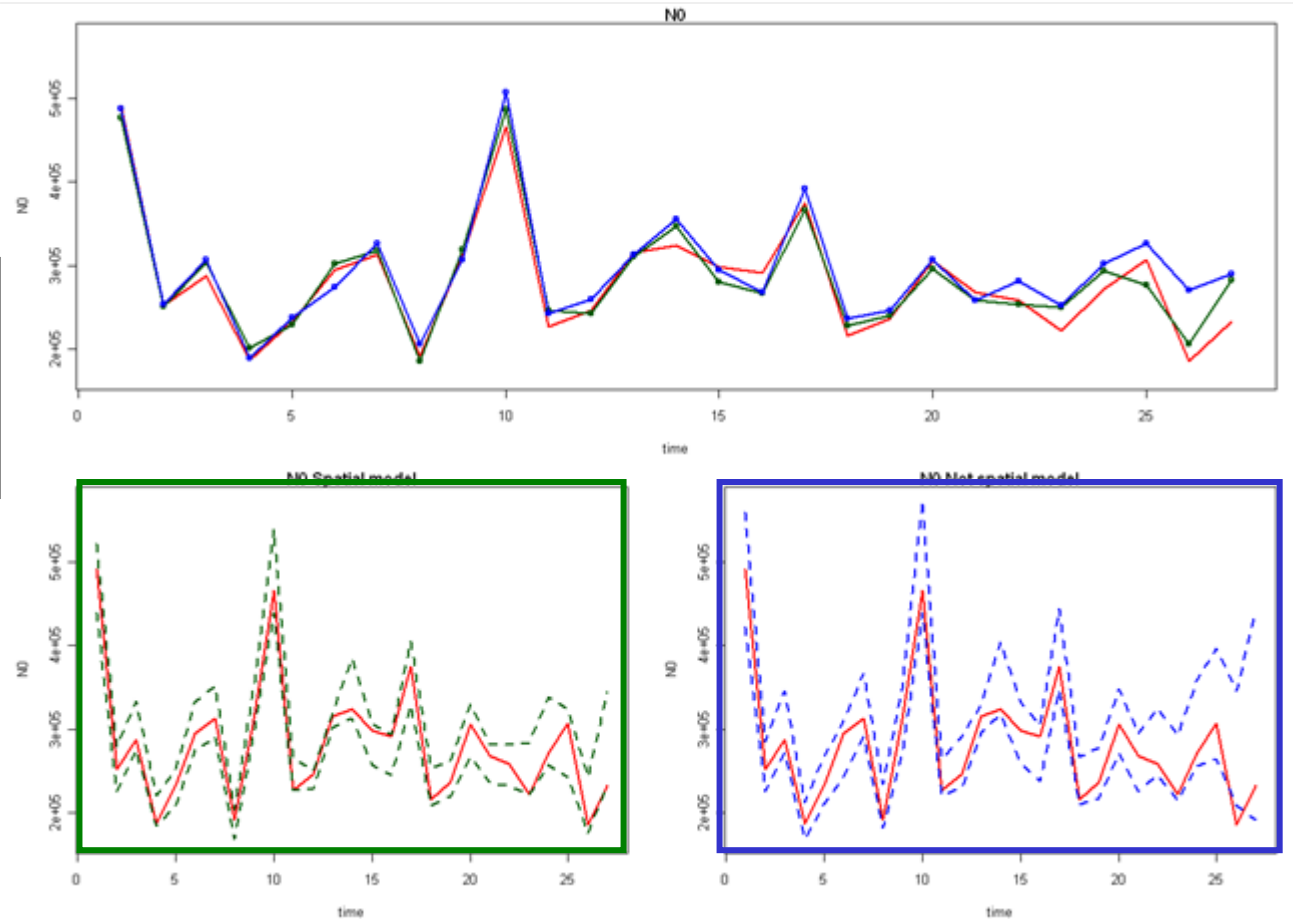
■ Spawning Stock Biomass (SSB)





III.b. Results

Juveniles (N0)



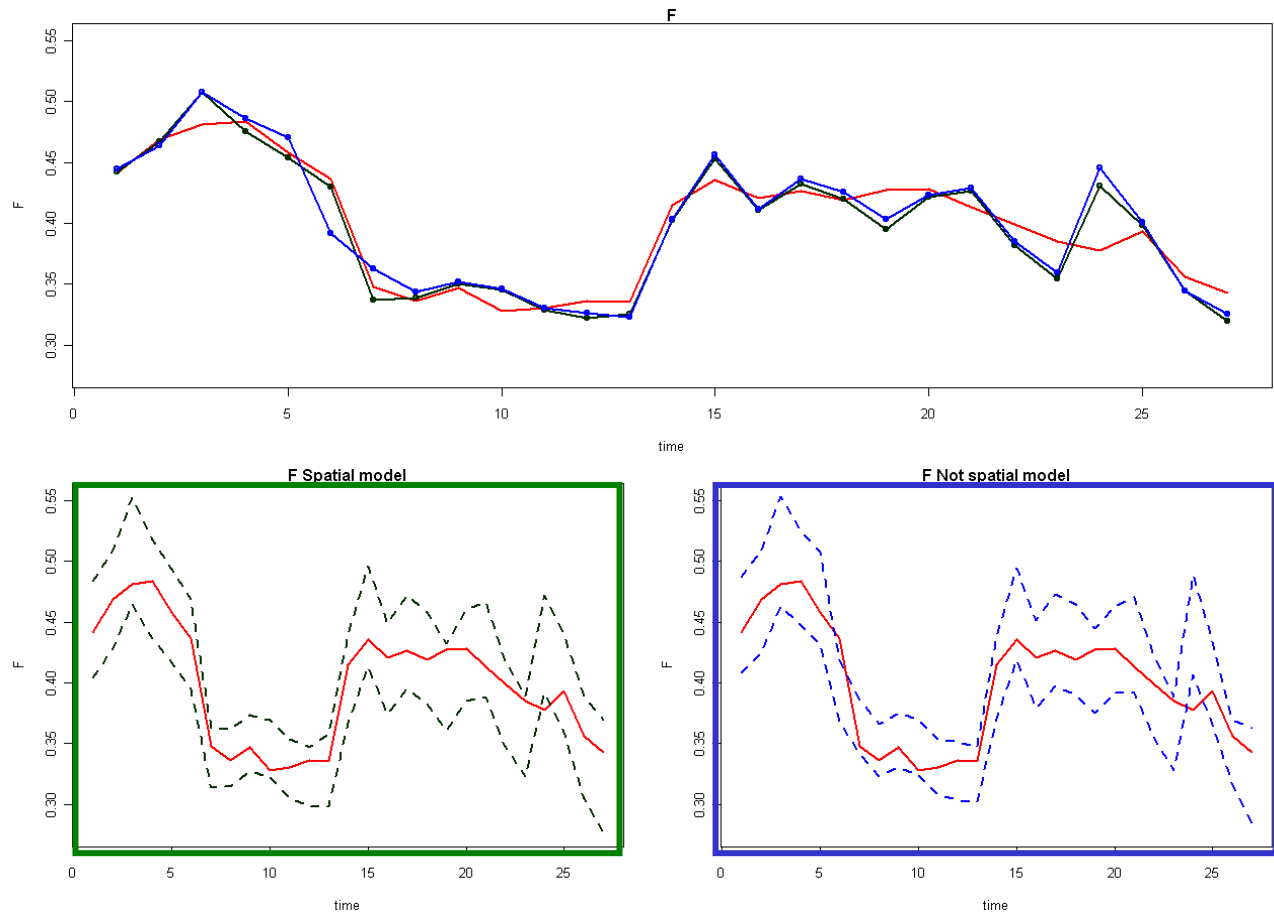
— Simulated value
— Spatial model
— Non-Spatial model



III.b. Results

■ Mean fishing mortality (F)

- Simulated value
- Spatial model
- Non-Spatial model



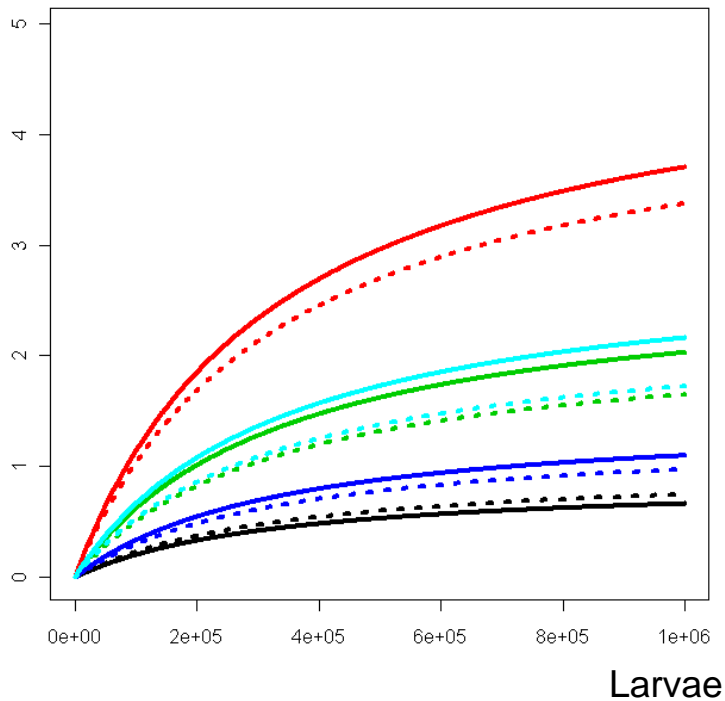


III.b. Results

- Productivity of each nursery
 - Density-dependent mortalities (Spatial model)

.....	Simulated
—	Fitted

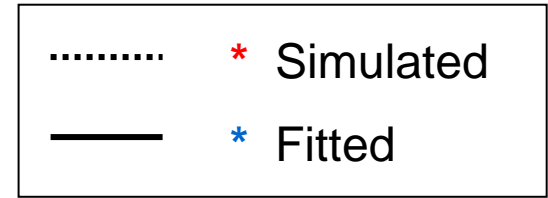
Juveniles



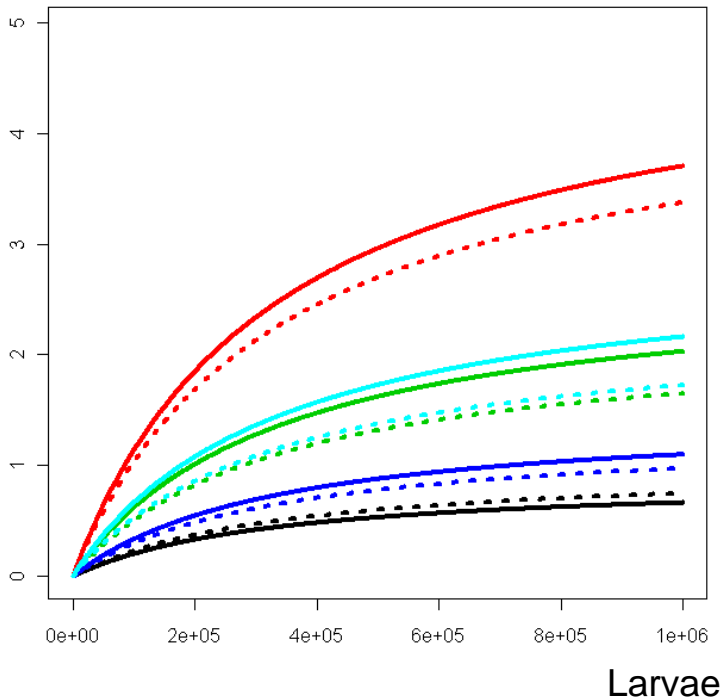


III.b. Results

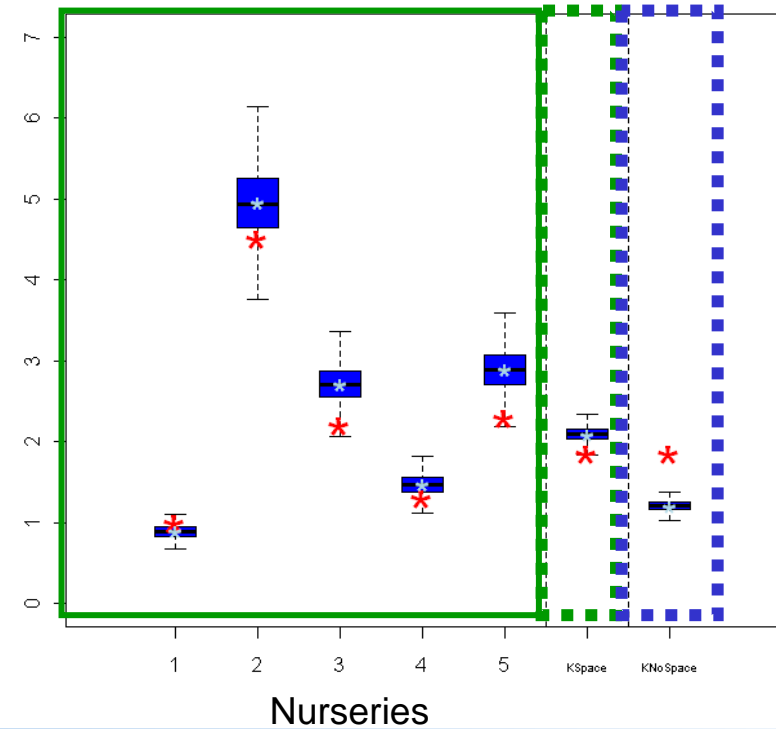
- Productivity of each nursery
 - Density-dependent mortalities (Spatial model)
 - Comparison of K



Juveniles



Carrying capacity





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IV. Conclusions & Perspectives

- Age-structured model and larval dispersion model were successfully coupled within the Bayesian SSM framework
 - Integration of various sources of data
 - several sources of uncertainty
 - The model simultaneously captures
 - Population dynamics with random variations
 - Fishing pressure
 - Contrasted level of productivity in the different nurseries
 - Effects of ocean circulation on larval supply



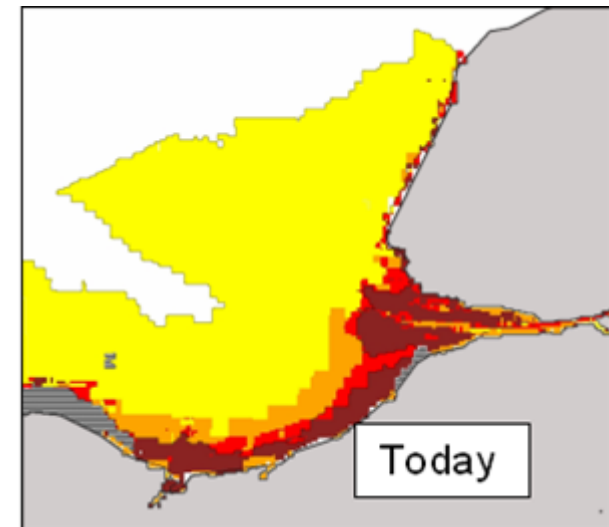
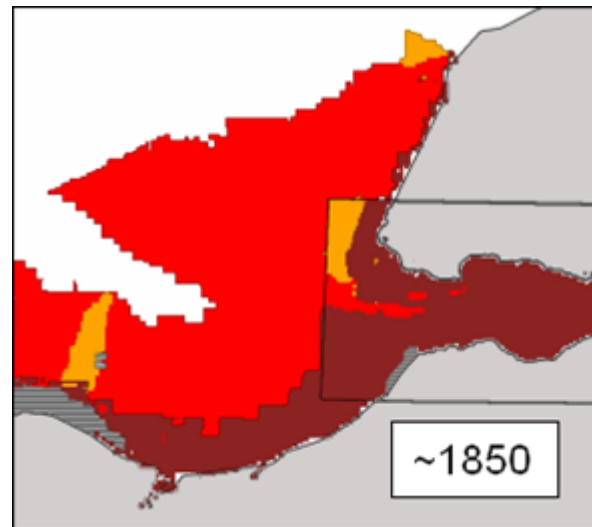
IV. Conclusions & Perspectives

- Applying to the Eastern Channel sole population
(work in progress)
 - Validation of the larval dispersion model
 - Influence of missing data (Juvenile abundance indices)



IV. Conclusions & Perspectives

- Applying to the Eastern Channel sole population (work in progress)
 - Validation of the larval dispersion model
 - Influence of missing data (Juvenile abundance indices)
- Simulating population under different scenarios
 - Habitat destruction
 - Pollution
 - Fishing pressure





Thanks for attention
