A Bayesian state-space model to merge larval drifting and habitat suitability models with spatially – explicit age-structured fish population dynamics model

The common sole (Solea solea) in the eastern Channel

Chapitre de thèse de S. Rochette à Agrocampus Ouest.  
Travail poursuivi par la thèse de B. Archambault.

1. Introduction

2. Assessing the quality of nursery habitats

3. Quantifying larval dispersal and survival

4. Modelling an integrated life cycle

5. Conclusion & perspectives
Outline

1. Introduction
2. Assessing the quality of nursery habitats
3. Quantifying larval dispersal and survival
4. Modelling an integrated life cycle
5. Conclusion & perspectives
1. Introduction

- The sole population life cycle in the eastern Channel

- Spawning
- Metamorphosis
- 2-3 years
- Eggs
- Larvae
- Nurseries
- Juveniles
- Adults
1. Introduction

- Pressures over nurseries of the eastern Channel
  - Habitat modifications (-75% of muddy grounds)
  - Chemical contamination (×10)

The Seine estuary

Polycyclic Aromatic Hydrocarbons
1. Introduction

How human pressures impact marine fish life cycle?

- Habitat degradation over nurseries
- Influence of larval supply
- Combination at the scale of the population
1. Introduction

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5. Conclusion & perspectives
2. Quality of nursery habitats

Method: Habitat suitability model

Scientific trawl surveys

Bathymetry

Sediment

Statistical model (Zero-inflated data: Delta model)

Juveniles densities ~ Sector + Bathymetry + Sediment

Effect of nursery habitat degradation on flatfish population: Application to Solea solea in the Eastern Channel (Western Europe).
Journal of Sea Research 64:34-44.
2. Quality of nursery habitats

Results: juvenile production

Map of juveniles densities

Contribution to the stock

Densities

% of contribution

Veys  Seine  Somme  Boulogne  RyeBay  Solent  Sdowns
2. Quality of nursery habitats

Discussion
1. Introduction

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3. Larval dispersal and survival

Material & Methods

Ocean circulation model & lagrangian particle tracking

(Lazure and Dumas, 2008)

Rochette, S., Huret, M., Rivot, E., Le Pape, O. (in prep.)
A biophysical model to analyse the influence of larval supply on fish recruitment: Application to a coastal and estuarine nursery dependent flatfish population.
Fisheries Oceanography.
3. Larval dispersal and survival

Material & Methods

Initial conditions
Spawning biomass (*1000t)

Ocean circulation model & lagrangian particle tracking

Eggs densities distribution

Spawning biomass (*1000t) (ICES, 2009)

Eggs densities distribution (Anon., 1992)

(Lazure and Dumas, 2008)
3. Larval dispersal and survival

Material & Methods

- Eggs
densities
distribution

Realistic estimation of larval supply
1991-2004

Ocean circulation model & lagrangian particle tracking

(ICES, 2009)

(Lazure and Dumas, 2008)

Initial conditions
Spawning biomass (*1000t)

Eggs
densities
distribution

(Anon., 1992)
3. Larval dispersal and survival

Results: interannual variability

- Yearly larval supply
- Larval allocation among nurseries

Interannual variability of larval supply
Outline

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4. The integrated life cycle

Material & Methods: the sole population life cycle

- Spatially-explicit structure

Spatialized recruitment

5 nursery sectors

Adults
4. The integrated life cycle

Material & Methods: the sole population life cycle

- Spatially-explicit structure

⇒ Density – dependent mortality specific to each nursery

Graph showing density-dependent mortality with K as the carrying capacity.
4. The integrated life cycle

Material & Methods: the sole population life cycle

- Spatially-explicit structure

Larval drift
14 years simulated
1991 - 2004

Hydrodynamical model
Drift survival
4. The integrated life cycle

Material & Methods: the sole population life cycle

- Spatially-explicit structure
- Age-structured population

Observations

Habitat Suitability Model
Spatial Abundance indices
Hydrodynamical model Drift survival

Catches
Abundance indices

5 nursery sectors
4. The integrated life cycle

Material & Methods: the sole population life cycle

- Spatially-explicit structure
- Age–structured population

⇒ Bayesian state-space model
  ⇒ Non-observed processes ↔ observations processes
  ⇒ Inferences on hidden states variables and parameters
    ⇒ Population dynamics and density-dependent mortalities
  ⇒ A fair quantification of uncertainties

Catches
Abundance indices
Hydrodynamical model
Drift survival
4. The integrated life cycle

Material & Methods: the sole population life cycle

- Spatially-explicit structure
- Age – structured population

Data poor context

5 nursery sectors

Habitat Suitability Model
Spatial Abundance indices
Hydrodynamical model
Drift survival

Catches
Abundance indices
4. The integrated life cycle

Material & Methods: the sole population life cycle

- Spatially-explicit structure
- Age – structured population

⇒ Assessing the ability of the model to estimate parameters with incomplete time series of data
  ⇒ Simulation – estimation approach
Assessing the ability of the model to estimate parameters with incomplete time series of data

**Simulation**
- Known parameters
  - Predictions
- Population dynamics
  - Predictions
- Simulated data

**Estimation**
- Estimated parameters
- Inferences
- Estimated population dynamics
- Inferences
- Simulated data

Comparison arrows connect simulation and estimation processes.
4. The integrated life cycle

Results: simulation - estimation

- Time series of states variables
- Site specific parameters

Spawning biomass (*1000t)

Carrying capacities

U.K. West
Rye Bay
Somme
Seine
Veys

* Simulation  Estimation  95% confidence
4. The integrated life cycle

Results: simulation - estimation

- Time series of states variables
- Site specific parameters

Spawning biomass (*1000t)

Carrying capacities

⇒ All parameters and state variables are identifiable
⇒ No bias and low uncertainty
⇒ Application to the real case
4. The integrated life cycle

Results: application to the real case

- Consistent with ICES estimations
- Spatially-explicit recruitment process

### Spawning biomass

<table>
<thead>
<tr>
<th>Year</th>
<th>ICES estimation</th>
<th>Estimation</th>
<th>95% confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>20,000t</td>
<td>15,000t</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>5,000t</td>
<td>10,000t</td>
<td></td>
</tr>
</tbody>
</table>

### Carrying capacity (K)

- Homogeneous sediment & bathymetry

- U.K. West
- Rye Bay
- Somme
- Seine
- Veys

- ICES estimation
- Estimation
- 95% confidence
Outline

1. Introduction
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5. Conclusion & perspectives

- A framework allowing for integrated life cycle modelling
  - Prior information of processes
  - Biological knowledge
  - Observations

- Layout foundations
  - Estimate hidden population dynamics under pressures
  - Detail effects of pressures on the recruitment process
5. Conclusion & perspectives

Importance of first life stages

N
(log scale)

0.06%

0.1%
5. Conclusion & perspectives

- Effect of connectivity on larval stage
  - Larval dispersal model suggest low young stage connectivity
5. Conclusion & perspectives

- Effect of connectivity on larval stage
  - Larval dispersal model suggest low young stage connectivity
  - What about the connectivity of the adult population?
5. Conclusion & perspectives

- The life cycle modelling framework offers interesting simulation perspectives
  - Past scenarios
    - Impact of fishing vs habitat degradation
  - Future scenarios
    - Stock assessment with reliable recruitment estimation
    - Effect of management scenarios (spatially-structured)
Thanks you for your attention
