Management Unit of the North Sea Mathematical Models
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SOLEMOD Project

Spatially-explicit model of sole larvae in the Southern North Sea: sensitivity of the dispersal to hydrodynamic/environment variability and biological parameters.

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Introduction

Sole (*Solea solea*) is one of the most valuable commercial species in the North Sea. The size of the spawning stock is above the level of sustainable exploitation, but fishing mortality is high. The stock is therefore at risk of being harvested unsustainably. Moreover, interannual recruitment variability is very high. It is crucial to understand the contribution of hydrodynamics, environment and biological parameters to recruitment variability in order to propose appropriate measures for the management of the North Sea stock. Here we use a particle-tracking transport model coupled to a 3D hydrodynamic model to study the relative effect of hydrodynamic variability, environment variability (throughout temperature) and biological parameters on the dispersal of sole larvae in the Southern North Sea.

Objectives

- To assess the impact of **hydrodynamics, environment and biology** on the **recruitment** of *Solea solea*
- To assess the possibility of **distinct subpopulations** in the North Sea despite the **high dispersal**
- To help **fisheries management** to ensure **sustainable exploitation** of North Sea sole stock

Methodology

The sole larvae transport model developed in the frame of the SOLEMOD project [1] couples the **3D hydrodynamic model COHERENS** with an **Individual Based Model (IBM)** of the sole larvae. It has been implemented in the area between 48.5°N-4°W and 57°N-10°E [Fig. 1]. Simulations are performed for the period 1995-2006.

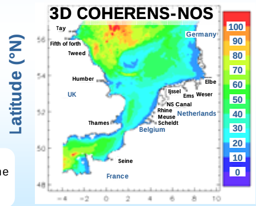

Fig. 1. Geographic implementation of the model, with bathymetry (m)

In the sole larvae IBM 4 stages are considered (eggs: L0, yolk larvae: L1, first-feeding larvae: L2 and metamorphosing larvae: L3) [Fig. 2]. Eggs are released within the 6 main spawning grounds of the North Sea [Fig. 3, left].
- The **impact of the hydrodynamics** is tested by simulating **different years (1995-2006)**.
- The **sensitivity to environment variability** is assessed by considering **a temperature-dependency** of the spawning period and the larvae stage duration.
- The **sensitivity to biological parameters** is assessed by considering (i) **diel and tidal vertical migration** and (ii) **larvae mortality**.

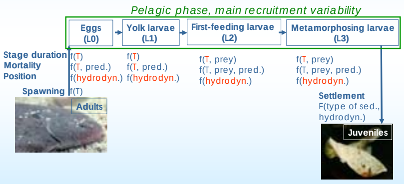

Fig. 2. Schematic representation of the sole larvae IBM. The parameters in red are already taken into account.

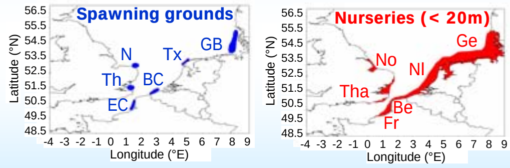

Fig. 3. Left: Main spawning grounds in the North sea. EC: Eastern Channel, BC: Belgian Coast, Tx: Texel, GB: German Bight, N: Norfolk and Th: Thames. Right: nurseries. Fr: France, Be: Belgium, Nl: Netherlands, Ge: Germany, No: Norfolk, Tha: Thames.

Results

Results are analyzed in terms of final **larvae distribution** [Figs. 4, 5 and 6], **larval retention in nurseries** [Figs. 3 right and Fig. 7] and **connectivity** [Fig. 7].

The **dispersal pattern** obtained 40 days after the egg release in the 6 main spawning grounds is shown in Fig. 4. in the case of a passive behavior (no vertical migration), constant mortality, fixed stage duration (L0+L1: 10 days, L2: 20 days & L3: 10 days) and a fixed date of spawning (15 April 1995).

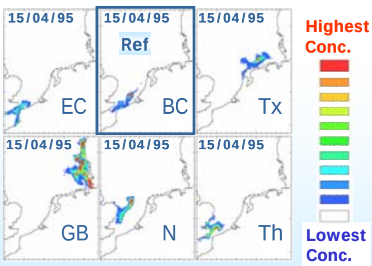

Fig. 4. Final distribution of larvae after 40 days for the 6 main spawning grounds (EC: Eastern Channel, BC: Belgian Coast, Tx: Texel, GB: German Bight, N: Norfolk and Th: Thames).

The impact of **interannual variability** and **spawning period** is assessed by comparing the dispersal patterns of eggs released in the Belgian Coast (BC) spawning ground at different spawning period (15 April and 1st May) and for 2 different years contrasted in term of meteorological forcing (1995 & 1996) [Fig. 5 & Fig. 4 Ref]. There is a significant impact of year-to-year variability and spawning period on the larvae dispersal.

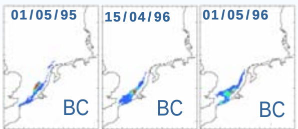

Fig. 5. Final distribution of larvae for eggs released in BC 1st May 1995, 15 April 1995 and 1st May 1996.

The impact of **vertical migration** is assessed by comparing dispersal patterns obtained with 3 different vertical behaviors schematized in Fig. 6. Active A: stage-related migration, active B: diel migration and active C: diel and tidal vertical migration. Vertical migration reduces the dispersal [Fig. 6 to compare with Fig. 4 Ref]. In case of diurnal and tidal migration (active C), the larvae are closer to the coast after 40 days.

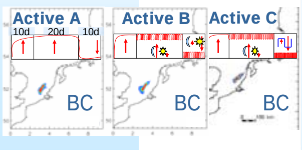

Fig. 6. Final distribution of larvae for eggs released the 15 April 1995 with different vertical migration behaviors (see text for description).

The **connectivity matrix**, representing the percentage of larvae originating from a spawning site [Fig. 3 left] and reaching a nursery area [Fig. 3 right] after completion of a 40 days pelagic stage is shown in Fig. 7. The **larval retention** corresponds to the **self-recruitment** (diagonal in Fig. 7). The other cases represent the possible exchanges between spawning grounds and nurseries (**connections**). For each case, the 2 different colours correspond to the minimum and maximum percentages obtained for the different scenarios: years 1995-1996, spawning periods 15 April and 1st May and the different vertical migration patterns (active A, B and C).

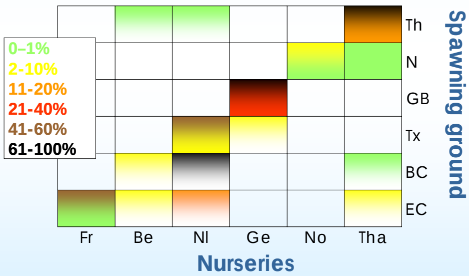

Fig. 7. Connectivity matrix. The colours correspond to the percentage of larvae originating from a spawning ground [Fig. 3 left] and reaching a nursery [Fig. 3 right].

The exchanges are quite moderate (9 exchanges found out of the 30 possible. The percentage of larvae exchanged are lower than the percentage of larvae retained.

Conclusions & Perspectives

CONCLUSIONS:

- There is a significant impact of hydrodynamics (year-to-year meteorological variability) and spawning period on the larvae dispersal.
- The vertical migration leads to a reduction of dispersal and the larvae are closer to the coast when tidal vertical migration is considered.
- From the connectivity matrix we found only quite moderate exchanges. This seems not incompatible with the possible existence of subpopulations of sole in the Eastern Channel and southern North Sea.

PERSPECTIVES:

- **Improvement of the IBM is in progress. (ex. Temperature-dependency of the sole spawning timing,…)**
- **The prey and predator fields must be added for the parameterization of mortality.**
- **The dispersal pattern of larvae will be compared with results from genetic markers & otolith microchemistry [2] (see also presentation ICES CM 2010/Q:16)**

Acknowledgements:
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References:
[1] Savina M., Lacroix G., Ruddick K., 2010. Modelling the transport of common sole larvae in the Southern North Sea: influence of hydrodynamics and larval vertical movements Journal of Marine Systems, 81: 86-98.
[2] Cuveliers E.L., Maes G.E., Geffen A.G., Volckaert F.A.M.J., 2010. Microchemical variation in juvenile *Solea solea* otoliths as a powerful tool for studying connectivity in the North Sea. Marine Ecological Progress Series, 401: 211-220.