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How is the connectivity of sole larvae affected by wind and temperature changes in the Southern North Sea? A modelling approach

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Introduction

Connectivity of flatfish remains an open question, especially at early life stages. The impact of anthropogenic factors, such as climate change on larval dispersal remains unknown. The case of sole (*Solea solea*) is of particular interest because sole is one of the most valuable commercial species in the North Sea. It is important to understand how the retention/dispersal of larvae would be affected by climate change in order to propose appropriate measures for the management of the North Sea stock.

Objective

To investigate the impact of climate change – temperature increase and wind magnitude/direction changes – on the recruitment and connectivity of sole larvae

Methodology

The sole larvae transport model couples the 3D hydrodynamic model COHERENS with an Individual Based Model (IBM) of the sole larvae [1][2]. It has been implemented in the North Sea [Fig. 1] for the period 1995-2006.

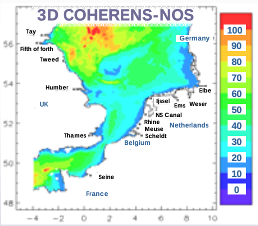


Fig. 1. Geographic implementation of the model, with bathymetry (m)

In the sole larvae IBM 4 stages are considered [Fig. 2]. Eggs are released within the 6 main spawning grounds of the North Sea [Fig. 3 left] during a 3-month period (peak of spawning at 10°C). The nurseries [Fig. 3 right] have been defined as coastal area with a depth of < 20 m and a high proportion of sand and/or mud (< 5 % gravel).

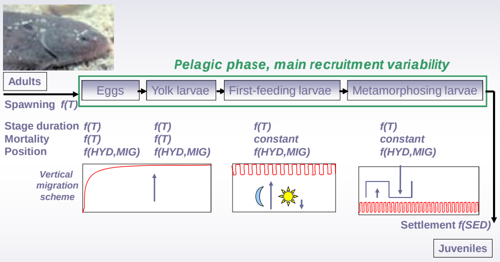


Fig. 2. Schematic representation of the sole larvae IBM. T: Temperature, HYD: hydrodynamics, MIG: vertical migration.

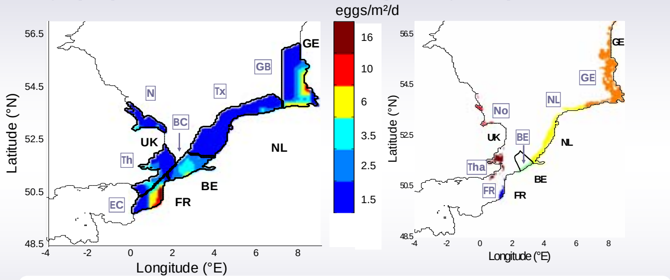


Fig. 3. Left: main spawning grounds in the North Sea and mean number of eggs spawned. Eastern Channel (EC), Belgian Coast (BC), Texel (Tx), German Bight (GB), Norfolk (N), and Thames (Th). Right: nurseries. France (FR), Belgium (BE), Netherlands (NL), Germany (GE), Norfolk (No), Thames (Tha).

The sensitivity of recruitment and connectivity to climate change is assessed by estimating the impact of a hypothetical (i) water temperature increase (+2°C) but no change of spawning period, (ii) increase of the wind intensity (+4 %) and (iii) increase of southwesterly wind (+10 % towards East and +20 % towards North).

Results

The dispersal pattern at the 6 main spawning grounds is shown in Fig. 4.

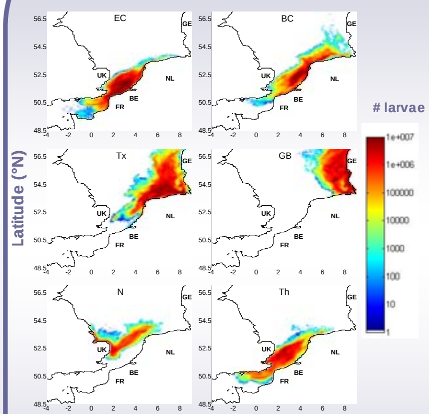


Fig. 4. Final distribution of larval abundance (# larvae) after the pelagic phase for the 6 main spawning grounds. Mean 1995-2006. STD run.

The impact of climate change scenarios is assessed by comparing the trajectories of the center of mass [Fig. 5], the transport success to the nurseries [Fig. 6] and the connectivity matrices [Fig. 7] obtained with the standard run and the perturbed simulations (for 4 contrasted years in term of wind and temperature: 1997, 1998, 2005 and 2006).

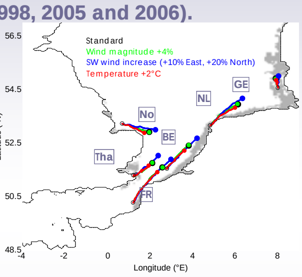
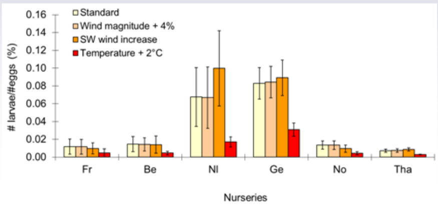


Fig. 5. Trajectories of the centre of mass (6 spawning grounds) for the 4 runs. Origin: empty circle. End of trajectories: full circles.



Relative difference (%)	FR	BE	NL	GE	No	Tha
Wind magnitude +4%	-0.6	-2.5	-0.9	1.8	-0.7	1.2
SW wind increase	-16.3	-4.5	47.7	7.4	-28.8	18.3
Temperature +2°C	-60.5	-68.7	-74.8	-62.7	-67.1	-60.1

Fig. 6. Recruitment in the 6 nurseries (mean 4 years). The error bars are the stdev due to interannual variability. The table gives the relative difference between perturbed and standard runs.

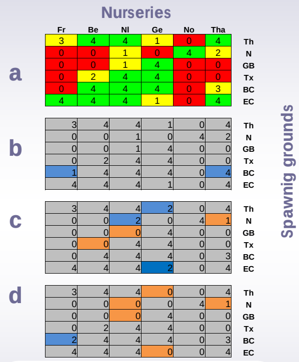


Fig. 7. Connectivity matrices. #years where connection or retention (self-recruitment) is predicted by the model. A: standard run, b: wind intensity increase, c: SW wind increase, d: temperature increase. A: Frequency of connections: never (red), sometimes or often (yellow), always (green). B-d: more connections (blue), less connections (orange).

- Larval retention in nurseries decreases significantly with temperature increase due to a combination of stage duration reduction and higher egg and yolk larvae mortality [Fig. 6]. The travel distance is reduced [Fig. 5].
- Recruitment decreases or increases when wind is perturbed [Fig 6]. The travel distance increases with SW wind increase [Fig. 5].
- New connections appear and others disappear according to the scenario and the area considered [Fig. 7].

Conclusions & Perspectives

- The impact of T° increase (without modification of spawning period) is a reduction of recruitment at all nurseries.
- A modification of the wind (intensity increase/southwesterly increase) gives either a reduction or an increase of recruitment according to the nurseries.
- The impact of climate change scenarios predicted by the model is significant (T°) and not negligible (wind) but interannual variability due to meteorological forcing is high.

PERSPECTIVES:
- The IBM is still under development. We will focus on mortality by including a prey/predator field.
- The dispersal pattern of larvae and recruitment must be validated.

REQUEST:
We are looking for life-history data of sole to validate the model

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 JMS, 81: 86-98.
[2] Lacroix G., Maes G.E., Bolle L.J., Volckaert F.A.M. 2012. Modelling dispersal dynamics of the early life stages of a marine flatfish (*Solea solea* L.). JSR, in press. 10.1016/j.seares.2012.07.010

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