Impact of projected wind and temperature changes on larval recruitment of sole in the Southern North Sea

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Summary

The impact of climate change on larval dispersal remains poorly known. The case of sole (_Solea solea_) is of particular interest because it is one of the most valuable commercial species in the North Sea. We compare scenarios of a particle-tracking transport model for sole larvae coupled to a 3D hydrodynamic model to investigate the impact of climate change on larval dispersal and recruitment at nurseries through hypothetical sea surface temperature increase and wind regime change for two years (2005 and 2006) in the North Sea.

Introduction

It is important to understand how the retention/dispersal of larvae would be affected by climate change in order to propose appropriate measures for stock management. The transport of sole larvae from the spawning grounds to the nurseries is driven by hydrodynamic processes but the final dispersal pattern and larval abundance may be modulated by behavioural and environmental factors. A water temperature increase might (i) move forward the spawning period, (ii) decrease the larval duration, (iii) increase the larval mortality and (iv) change the match-mismatch with prey fields. Modifications in the magnitude and direction of the wind regime might affect egg and larval retention and dispersal through changes in the hydrodynamics.

Materials and Methods

SOLEMOD, an individual-based model (IBM) for sole larval dispersal resulting from the coupling between a 3D hydrodynamical model (COHERENS) and a Lagrangian particle tracking module is used to simulate the scenarios (Lacroix et al., in press). The IBM includes four stages of development (eggs, yolk-sac, first-feeding and metamorphosing larvae) and considers temperature-dependant stage durations and stage-dependant vertical migrations. Mortality of egg and yolk larvae is temperature-dependant. The larval transport model covers the Eastern English Channel and the Southern and Central North Sea (48.5°N-4°W, 57°N-10°E.) at a resolution of 5′ (longitude) x 2.5′ (latitude) and 20 σ-coordinate vertical layers. It is forced by actual meteorological forcing, sea surface temperature (SST) and daily river runoff. Eggs are released in six main spawning grounds, during a 3 month-period (temperature-dependant). After their pelagic phase, larvae settle in the nursery areas defined according to depth and sediment type.

Sensitivity of larval dispersal and recruitment to climate change is assessed by estimating the impact of a hypothetical change in wind magnitude/direction and SST inspired from a 2040 IPCC scenario at the North Sea scale proposed in Van den Eynde et al. (2011). Five perturbed simulations have been tested and compared to a reference run: (1) Wind magnitude increase of 4%, (2) SW wind increase, (3) SST increase of 2°C, (4) SST increase of 2°C and early spawning and (5) all perturbations together (Climate change 'A').

Algal bloom (AB) onset/end is computed from the MERIS chlorophyll (CHL) time series (Park et al., 2010, http://www2.mumm.ac.be/marcoast/) by using piecewise linear regression (Muggeo, 2008) after linear interpolation in case of missing data.

Results and Discussion

The geographical position of the centre of mass of all particles released at a given spawning ground is recorded every 12 h. The trajectories represent the link between all positions recorded. A comparison between the trajectories obtained with the reference run and the scenario climate change 'A' for the six spawning grounds (mean 2005-2006) is shown in Fig. 1.

Larval recruitment (number of larvae arriving at nurseries at the end of their pelagic phase) computed for each perturbed simulation is compared to the reference run (mean 2005-2006) for the six nurseries (Fig. 2). It strongly depends on hydrodynamics, spawning period and pelagic duration. The SW wind increase has a significant impact on the larval recruitment in NL nursery. Overall a SST increase would reduce drastically recruitment as a consequence of the shortening of the larval duration which prevents the larvae from reaching the nursery. Combined with early spawning (resulting in a lower temperature during the pelagic phase and hence a lengthening of the pelagic phase), the recruitment would decrease except for Tha nursery. The recruitment predicted by the model combining all perturbations decreases in FR, BE and No nurseries, increases slightly in NL and significantly in Tha nursery.

Perspectives

The match-mismatch between the AB period and the larval food requirement period, defined as the period where first-feeding larvae are present in a given area, is shown in Fig. 3 (reference and climate change 'A'). The procedure used to produce satellite CHL time series (based on Park et al. (2010)) is being optimized and adapted to generate CHL time series for sole larvae during their travel between the spawning grounds and nurseries for the years 2003 to 2011. A parameterization of the larval mortality based on the overlap between AB and larval food requirement periods will be tested in the future.
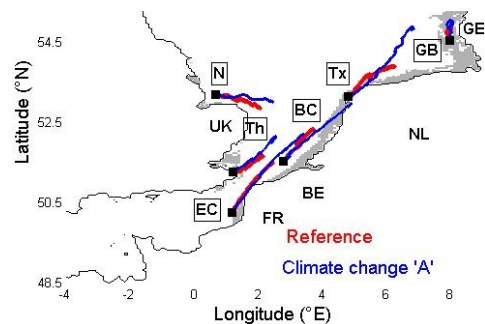

Figure 1. Trajectories of the centre of mass for the 6 spawning grounds (EC: eastern Channel, BC: Belgian coast, Tx: off Texel, GB: German Bight, N: Norfolk, Th: Thames). Black squares represent the origin of the trajectories. Nurseries are in grey.
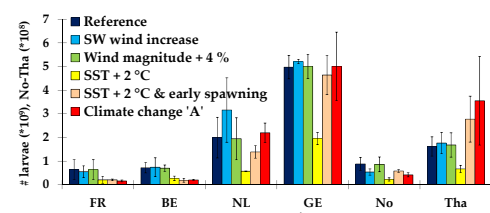
(2005-2006) for the reference run and the perturbed simulations. French (FR), Belgian (BE), Dutch (NL), German (GE), Norfolk (No) and Thames (Tha) nurseries.
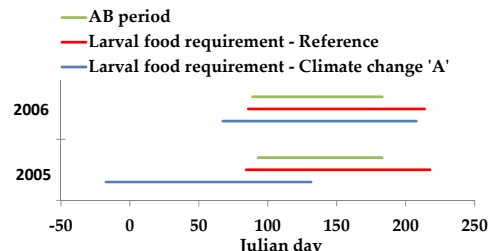
bloom period (green) and larval food requirement (larvae that reached the BE nursery). Red: reference run, blue: climate change scenario A (2005 and 2006).

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