Do man-made structures impact the connectivity patterns of hard substrate species in the North Sea?

Lacroix Geneviève[1], Barbut Léo[1], Vastenhoud Berthe[2], Kerckhof Francis[1], Vigin Laurence[1], **Degraer Steven**[1], De Mesel Ilse[1]

[1]Royal Belgian Institute of Natural Sciences (RBINS), Operational Directorate Natural Environment, Belgium
[2] National Institute of Aquatic resources (DTU Aqua), Denmark

Introduction

Man-made structures such as wind farms proliferate in the North Sea, possibly acting as stepping stones for fouling species and hence allowing species to expand their distribution range over large distances. Effective marine management requires the understanding of how (artificial) hard structures are ecologically connected and what processes influence larval retention and dispersal. The transport of marine organisms from the spawning grounds to settlement areas is driven by hydrodynamic processes. However, the final dispersal pattern, larval survival and successful settlement of the larvae are affected by environmental factors, physiology, behaviour and reproductive strategies (spawning period/areas). Biophysical models help assessing the dispersal potential of marine species during their pelagic phase.

Objectives

- **Assess the larval dispersal and connectivity patterns of blue mussel (*Mytilus edulis*), European flat oyster (*Ostrea edulis*) and common limpet (*Patella vulgata*) in the North Sea.**
- **Assess the stepping stone potential of spread due do wind farms for the three species.**

Methods

We use a larval transport model coupled to a 3D hydrodynamic model adapted from [1] for three species with different life traits: *Mytilus edulis*, *Ostrea edulis* and *Patella vulgata*.

Fig 1: Spawning period and pelagic larval duration (PLD) of the 3 species. Mean spawning period (blue line) and minimum and maximum were spawning occurred (dashed lines) over the period 2000-2010.

Simulations:

*1°) **Coastal release**: eggs are released from the coastal spawning grounds to assess the potential of wind farms to be colonised by coastal (natural) populations.*

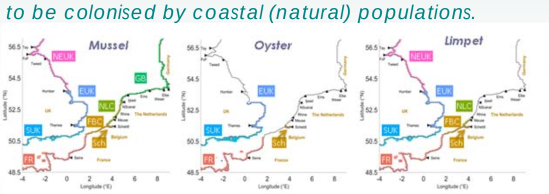

Fig 2: Spawning distribution in the eastern English Channel and the North Sea for the three species. The eight spawning grounds are: German Bight (GB), Dutch coast (NLC), Scheldt estuary (Sch), French-Belgian coast (FBC), French coast of the English Channel (FR), south coast of UK in the English Channel (SUK), east coast of UK (EUK) and north-east coast of UK (NEUK).

*2°) **Wind farm release**: eggs are released from the wind farm areas to assess the potential connectivity between them.*

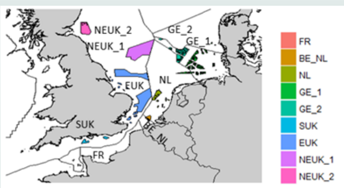

Fig 3: Wind farm zones (redrawn from [2]) aggregated into nine settlement areas (France: FR, Belgium-Dutch border: BE_NL, The Netherlands: NL, German coastal waters (including DK): GE_1, German offshore waters: GE_2, south UK: SUK, east UK: EUK, north-east UK offshore: NEUK_1, north-east UK coastal: NEUK_2). The black lines represent the national EEZ.

*By combining results from both, it is possible to test the **stepping stone** hypothesis.*

Results

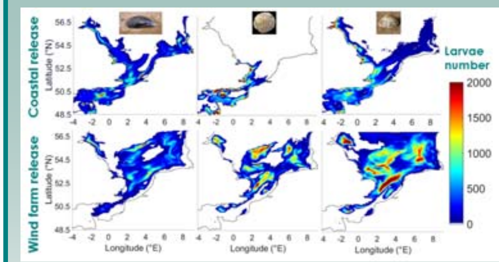

Fig 4: Mean Larval dispersal at the end of pelagic phase in 2000. from coastal release (upper panel) and wind farm release (bottom panel). From left to right: mussels, oysters and limpets.

Dispersal:

- For the coastal release, the oyster's larvae dispersed less than mussels and limpets, which dispersed into the whole area, except far offshore.
- Larvae issued from eggs spawned in wind farm areas dispersed over a great part of the domain, including offshore zones.

Connectivity:

- For mussels, all wind farm areas received larvae from the coastal areas. For oysters, only the wind farm areas close to the coastal areas where spawning occurred received larvae. For limpets, no larvae arrived in the GE_2 area. For the three species, in areas where larvae have a mixed origin, the relative contribution of the different spawning areas was different.
- All wind farm areas could exchange larvae. The BE-NL settlement area is isolated for oysters and limpets whereas no local retention was found for mussels in this area. In NL, GE_1 and GE_2, there was a mixed origin of the larvae.

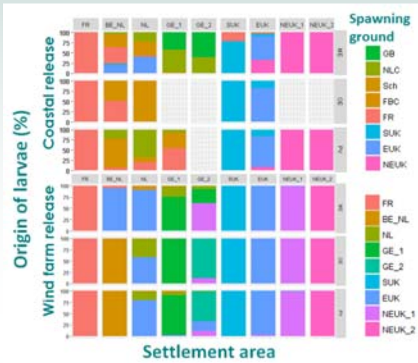

Fig 5: Proportion of larvae arriving in the wind farm areas from the coastal areas (upper panel) and from the wind farm areas (bottom panel) in 2000. For each panel, from top to bottom: mussels, oysters and limpets

Stepping stone:

- Larvae spawned in the coastal areas ("natural populations") reached all wind farm areas for mussels; all wind farm areas except GE_2 for limpets and reach NL, BE_NL, FR, SUK and EUK for oysters. Retention was high for the EUK area for the three species.
- When larvae are released from wind farm areas where larvae arrived first from the coastal areas, larval export would occur with 22, 6 and 19 connections out of the 64 possible for mussels, oysters and limpets respectively.

Fig 6: Transport success, that means the percentage of larvae arriving in the wind farm settlement areas divided by the number of larvae spawned in each area (%, 0 means < 0.5) in 2000 for the three species. Upper panel: from coastal areas to wind farm areas. Bottom panel: between wind farm areas considering only the larvae that arrived first from the coastal release.

Conclusions

- Artificial man-made structures could be settlement areas and could act as stepping-stone for the 3 species
- Significant differences of connectivity between species

Perspective

- Assess interannual variability (2000-2010)
- Improve parameterisation (T° dependent PLD)
- Consider 'realistic' number of larvae spawned and potential settlement surfaces for more ecological significance
- Testing stepping stone hypothesis on several generations
- Comparaison with genetic analysis

References

[1] Lacroix G., Maes G.E., Bolle L.J., Volckaert F.A.M., 2013. Modelling dispersal dynamics of the early life stages of a marine flatfish (Solea solea L.). Journal of Sea Research 84:13-25.
[2] OSPAR 2014. OSPAR database on offshore wind-farms 2013 UPDATE (revised in 2014). Biodiversity Series. OSPAR 627/2014.

Acknowledgements: This research has been conducted in the frame of the "UNDerstanding the INfluence of man-made structures on the Ecosystem functions of the North Sea (UNDINE)" project supported by the **INSITE programme [Foundation Phase, 2016-2017]**.