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Offshore wind farms – modelling tools for nature inclusive design in a dynamic sand wave area

Introduction

The North Sea is one of the busiest seas in the world. Biodiversity is impoverished due to overexploitation and several keystone species have nearly disappeared. This includes reef-building species such as the flat oyster *Ostrea edulis*. Offshore wind farms (Figure 1) are potentially suitable locations for such species as bottom-trawling is not allowed within their boundaries. However, in some areas of the North Sea environmental conditions are inhibitive to the establishment of reefs of such species. The project EcoFriend develops modelling tools and methods for site specific, effective Nature Inclusive Design (NID).

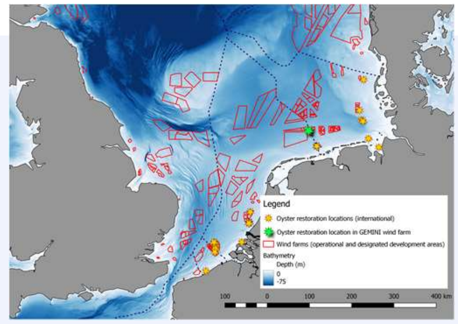

Figure 1: The southern North Sea with operational and planned wind farm developments.

Assessment of abiotic conditions

The state-of-the-art Dutch continental shelf model is used to assess and predict important local hydrodynamic parameters, such as temperature, bed shear stress .

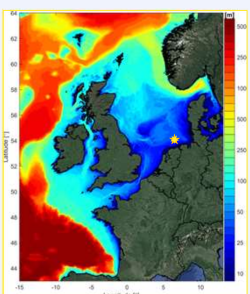

Figure 2: The domain of the DCSM-FM North Sea model. The yellow star indicates the pilot site in the GEMINI wind farm.

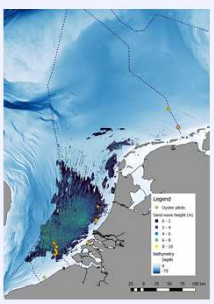

Figure 3: Area in the southern North Sea with large mobile bed forms (sand waves), denoted by the dark colors (sand wave heights).

Based on available monitoring data we construct maps of bed topography, indicating the presence of mobile sand waves inhibitive to the settlement of e.g. flat oysters (Figure 3). Numerical models and data analysis help with site selection.

Analysis of object stability

Oyster restoration often involved deploying live oysters in cages or gabions. In 2018 a number of cages were lost in wind Farm GEMINI (location indicated in Figure 2).

Figure 4: Cages used for deploying live oysters in the GEMINI Wind Farm.

A model was developed to determine the dislodgement and migration of such cages in such an event (Figure 5). Hindcast with the 3D DCSM-FM model indicated that in the deployment period a storm had occurred that would have dislodged such cages and moved them to the south. In future, such models can help ensuring that cages are designed sufficiently stable for specific areas.

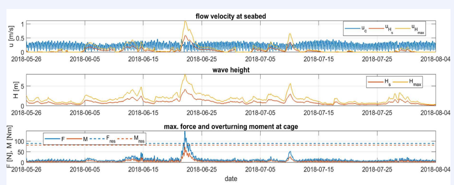

Figure 5: Analyses on local hydrodynamic conditions in GEMINI over the deployment period. The lower graph indicates a storm event on 25 June exceeding the forces required to overturn and move the cage

Analysis of oyster stability

Deploying loose oysters is much cheaper than deployment in gabions but they are much more mobile under hydrodynamic loads. Numerical models as well as physical model tests (Figure 6) were used to assess critical wave conditions under which oysters are dislodged from the seabed.

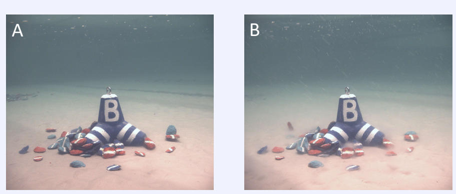

Figure 6: Tests with oysters under varying wave conditions: A: relatively calm, B: rough conditions

Using models to predict time of larval spawning

The time of year when flat oysters release their larvae is important for e.g. deployment of settlement substrate and the organization of monitoring campaigns. The timing can be predicted based on the temperature sum (Maathuis et al. 2018*):

$$T_{sum} = \sum_{1st\ of\ January}^{end\ date} (T_i - T_{th})\Delta d$$

where:

Tsum	=	temperature-sum [°Cd]
Ti	=	water temperature at day i in the timeseries [°C]
T_{th}	=	temperature above which gonad development occurs[°C]
Δd	=	time step [days]

Larvae start swarming at a temperature sum between 590 and 660 °Cd. The 3D DCSM-FM model can subsequently be used to assess the time of spawning at specific locations, including stratified locations. Figure 6 shows a hindcast of swarming periods in 15 years.

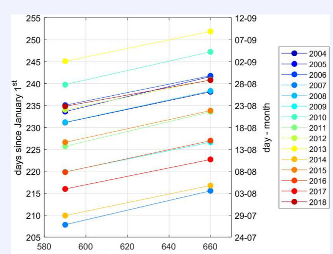

Figure 7: Days of the year where the temperature sum is between 590 and 660 °Cd.

Conclusions

Advancement and validation of these tools is essential for both regulators (setting tender criteria) and developers to tailor NID requirements and solutions to local conditions, to ensure optimal ecological benefits without wasting efforts on measures that nature renders ineffective in a few years' time.

*Maathuis et al. (2018): https://doi.org/10.1016/j.seares.2019.101828

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Funding
Joint Industry Project EOFRIEND is funded by TKI-Wind op Zee; project number TEWZ118017

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