Deltares

Deltares

WAGENINGEN
UNIVERSITY & RESEARCH

Deltares

Offshore infrastructure and its impact on marine biodiversity

Opportunities and risks

Luca van Duren, Luuk van der Heijden, Oscar Bos and Antonios Emmanouil

16 May 2024

The North Sea

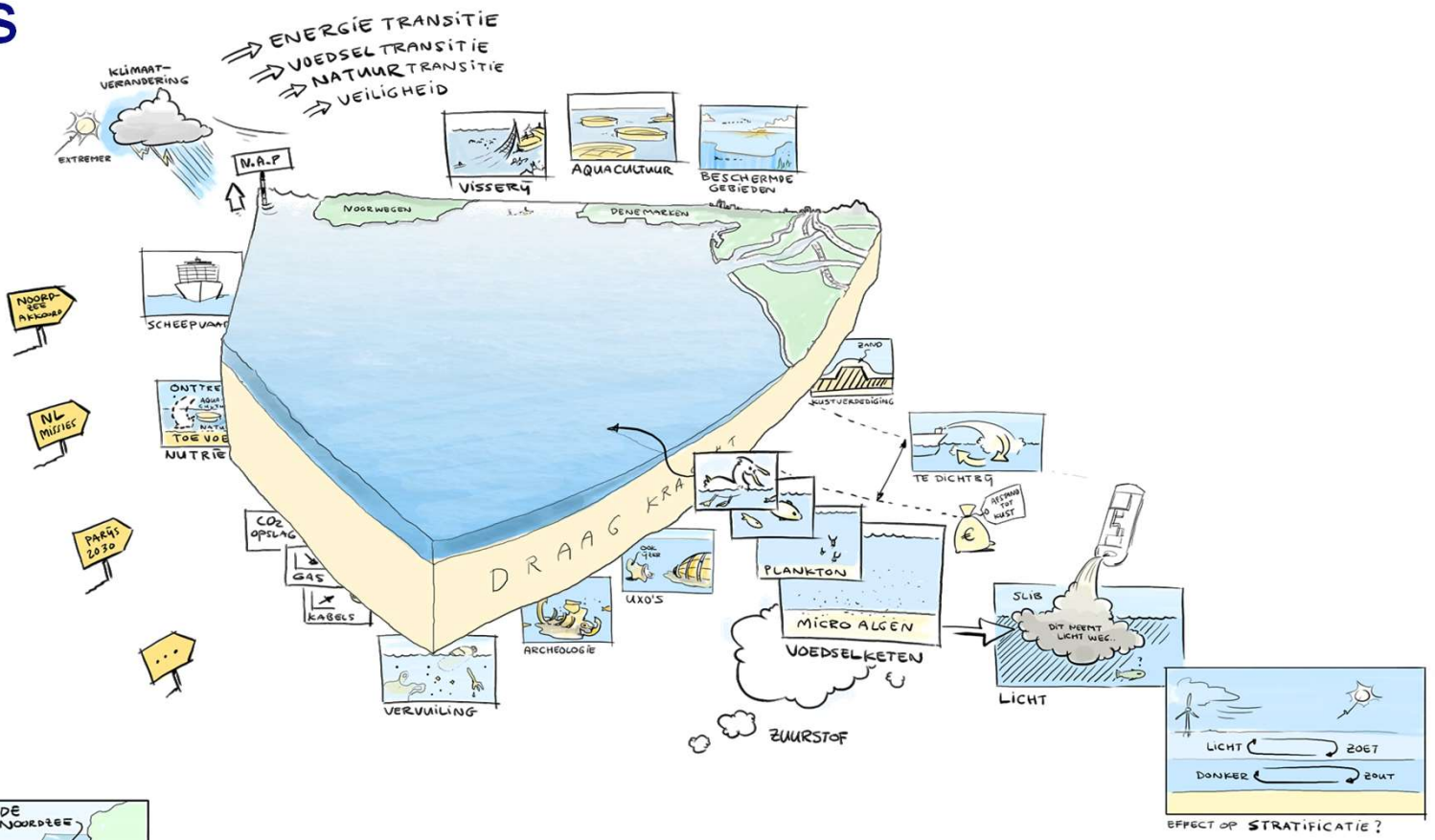






Photos: Oscar Bos, Luca van Duren

Challenges

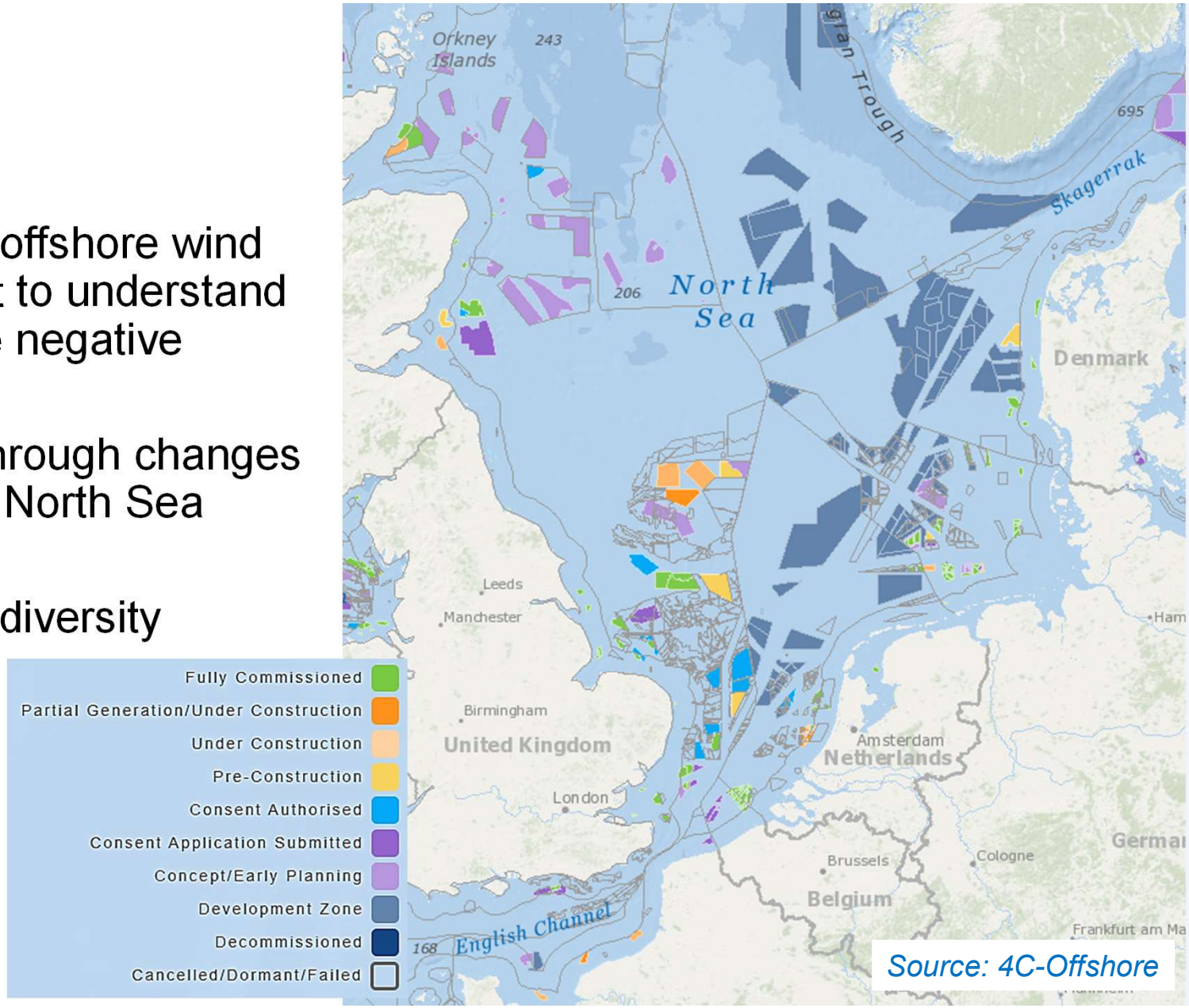


Deltares

WAGENINGEN UNIVERSITY & RESEARCH

Offshore wind

- Projected upscaling offshore wind very large; important to understand effects and minimise negative consequences
- Ecosystem effects through changes in the physics of the North Sea system
- Opportunities for biodiversity



Source: 4C-Offshore

Deltares WAGENINGEN UNIVERSITY & RESEARCH

Impacts of offshore wind on environment

Focus on ecosystem effects

The WOZEP programme

DUTCH GOVERNMENTAL OFFSHORE WIND ECOLOGICAL PROGRAMME

WOZEP assesses the impact of future OWF scenarios

- Cause – effect relations
- Development of models
- Long term monitoring data and model input
- Direct effects on protected species
- Indirect effects via habitat change
- Ecosystem effects

Knowledge gaps

Above water: collision/displacement



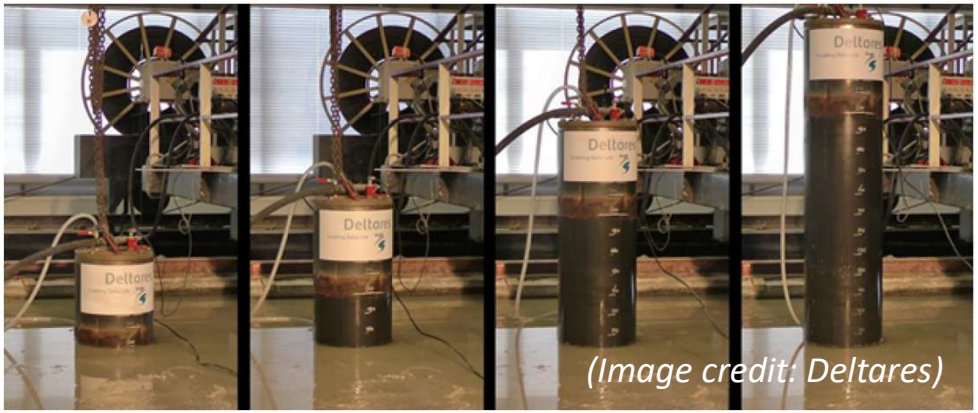
Under water: noise, habitat, EMF



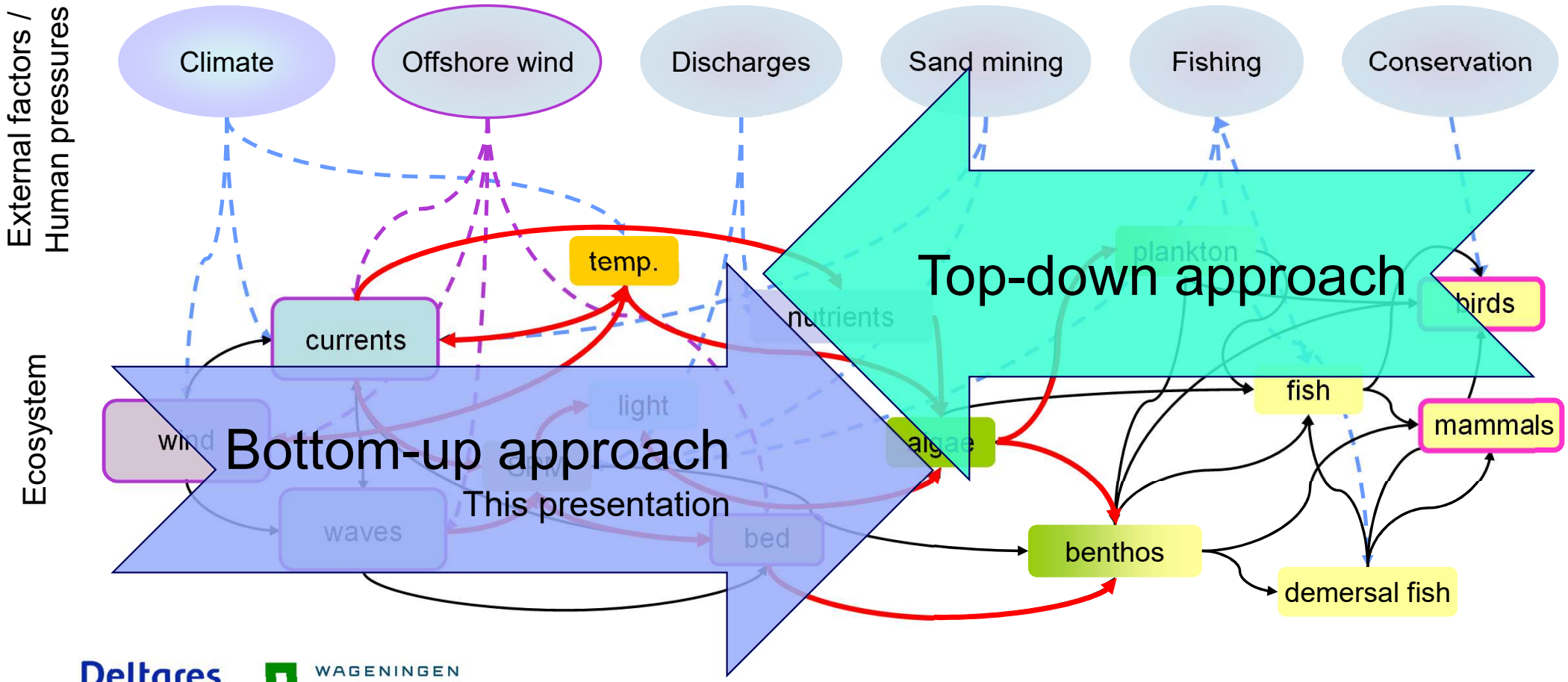
Deltares WAGENINGEN UNIVERSITY & RESEARCH

Phases

- Construction
- Operation
- Decommissioning



Effect chain



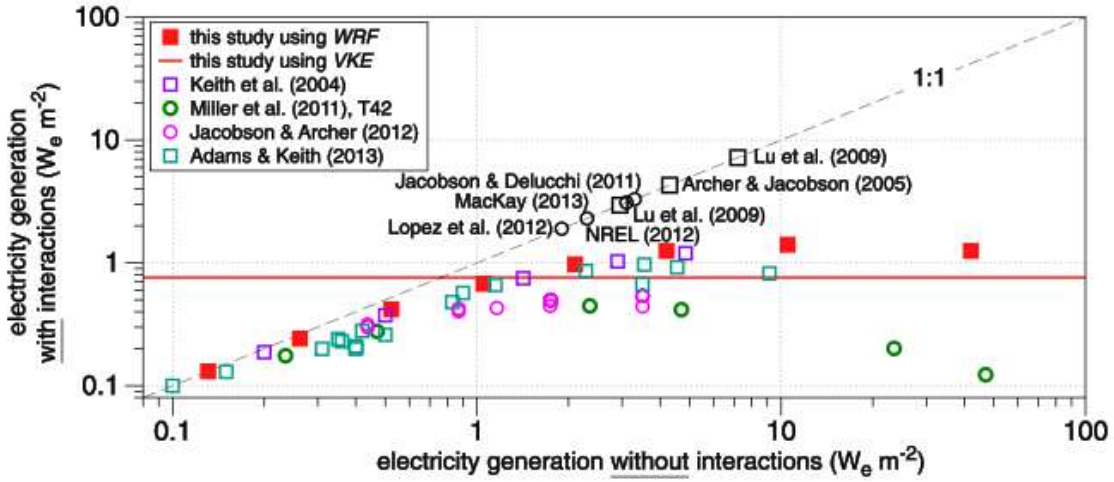
Deltares WAGENINGEN UNIVERSITY & RESEARCH

Effects on wind

- OWF's extract momentum from the wind – strongly depends on replenishment of energy from higher layers
- Globally the vertical flux of energy ranges around 2 W m^{-2}

Effects on wind

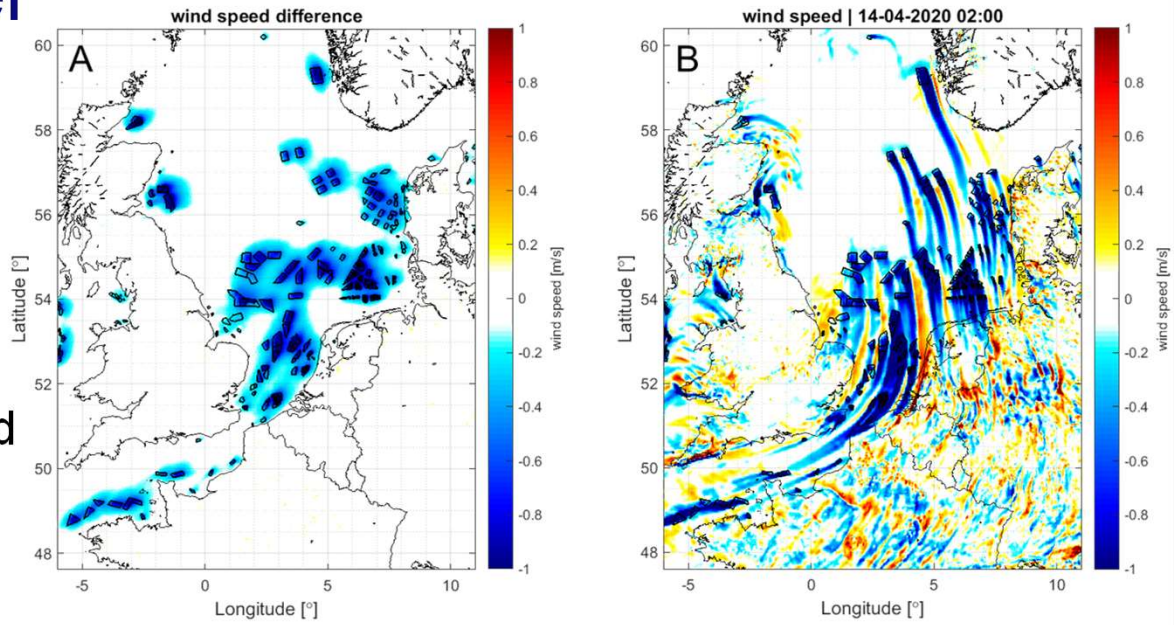
- OWF's extract momentum from the wind – strongly depends on replenishment of energy from higher layers
- Globally the vertical flux of energy ranges around 2 W m^{-2}
- Several papers estimate a maximum extractable energy due to turbine-wind interactions around 1 W m^{-2} – i.e. for Southern North Sea ± 100 GW
- Likely big effects on wind and weather patterns in NS countries



Limitation of maximal extractable energy due to turbine-wind interactions for large-scale wind parks and global studies. From Miller et al. (2015)

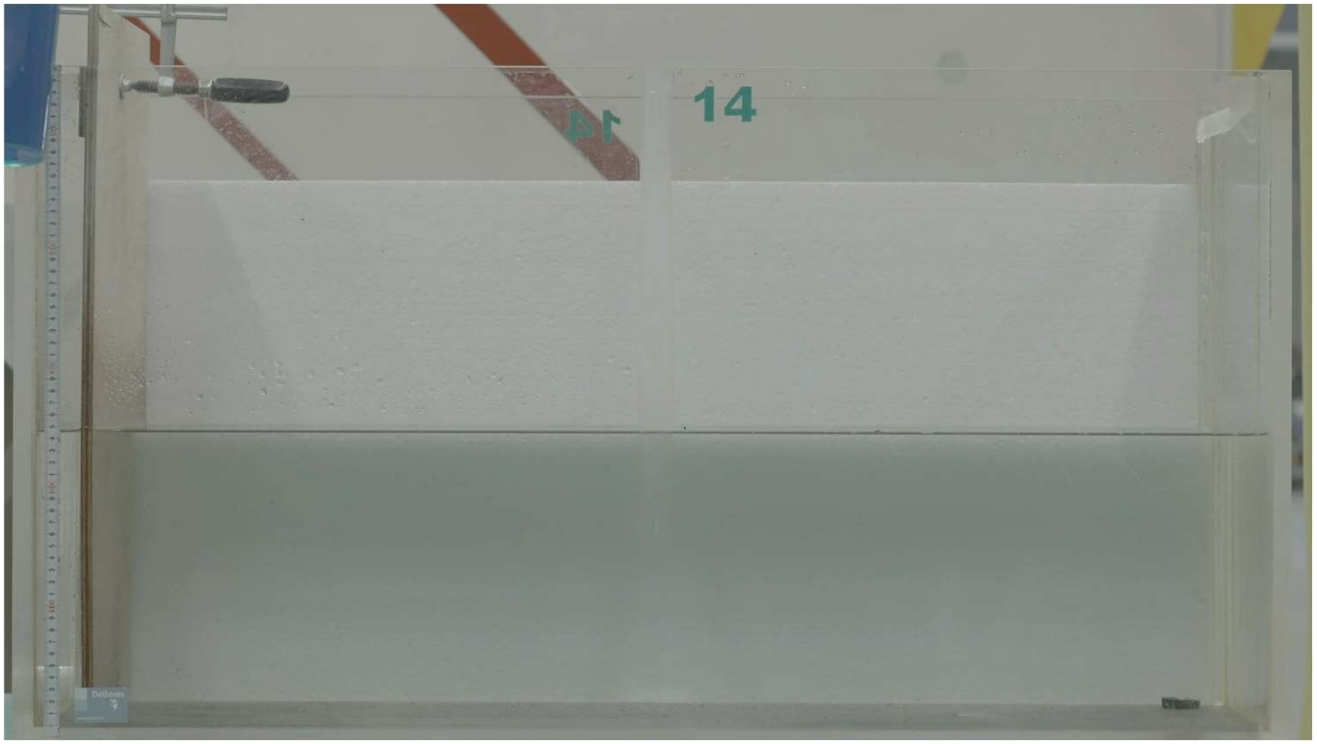
Effects in wind and water

- Processes around individual turbines and within wind farms reasonably well understood
- Large-scale processes (i.e. scale of southern North Sea) poorly understood – also by specialists.
- Instantaneous wakes can be visible over 100km
- Average effects more localised
- Wind drives waves
- Waves drive resuspension of sediment
- ➢ Potential for effects on the ecosystem – certainly with upscaling



Deltares WAGENINGEN UNIVERSITY & RESEARCH

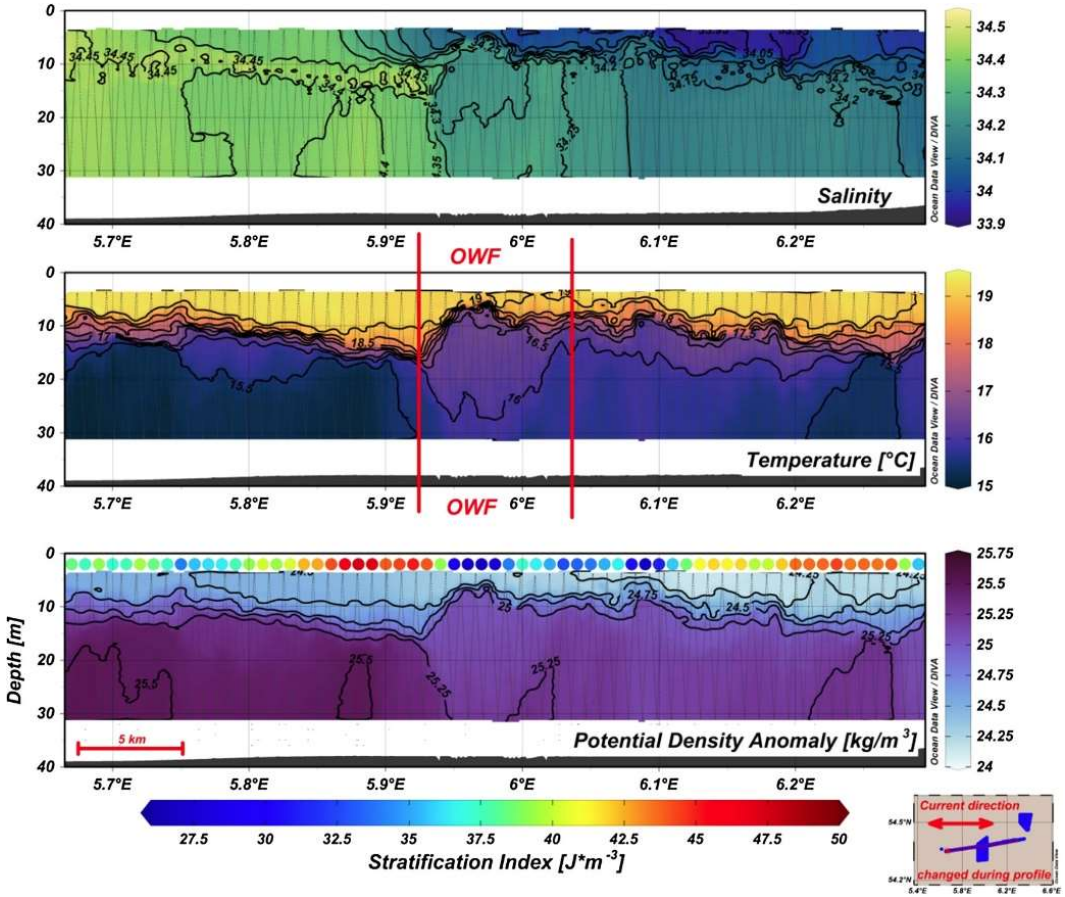
Stratification



© NTR Focus

- Salinity
- Temperature

Effects offshore wind stratification and mixing

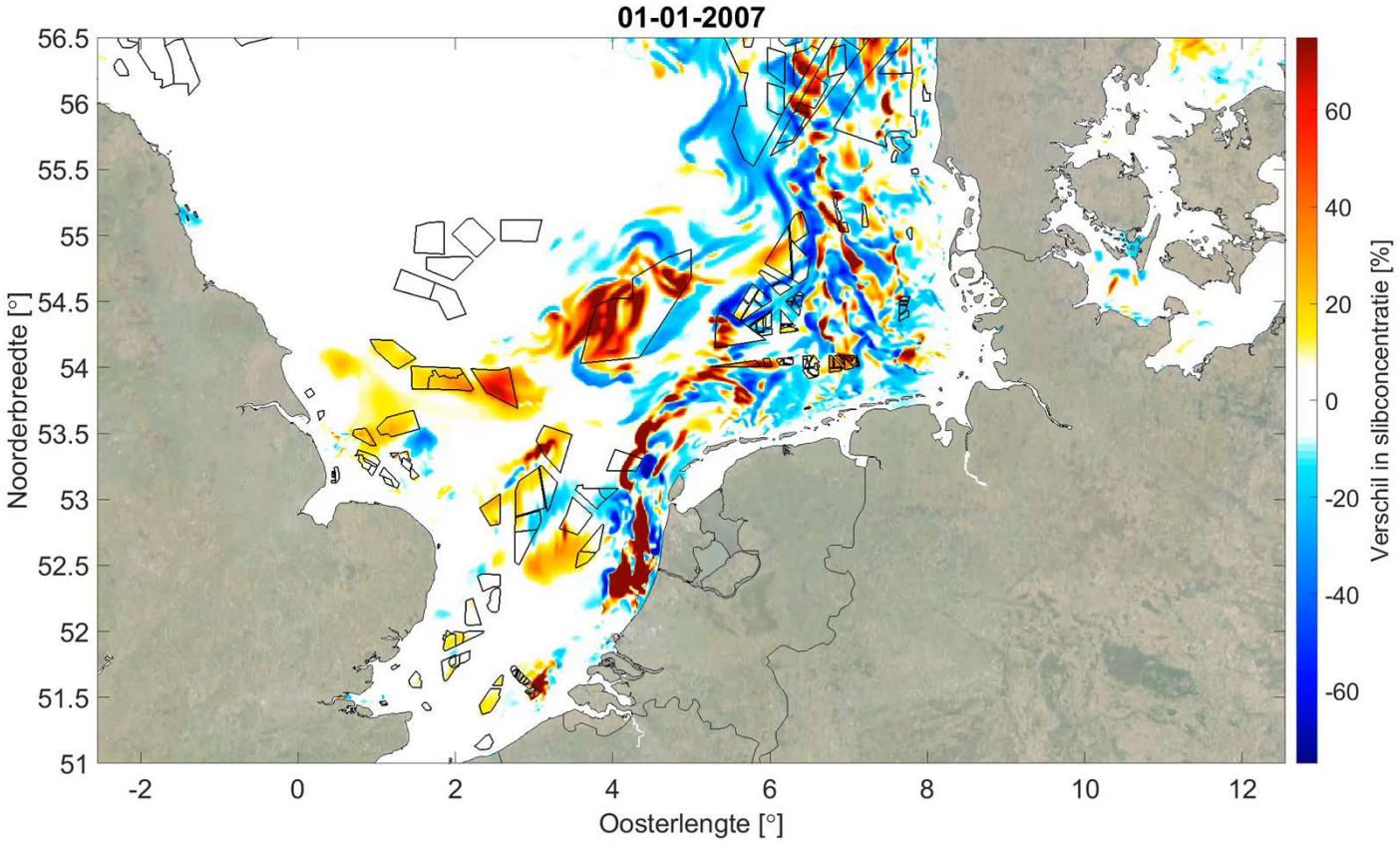


Floeter e.a. Progr. Oceanogr. 2017

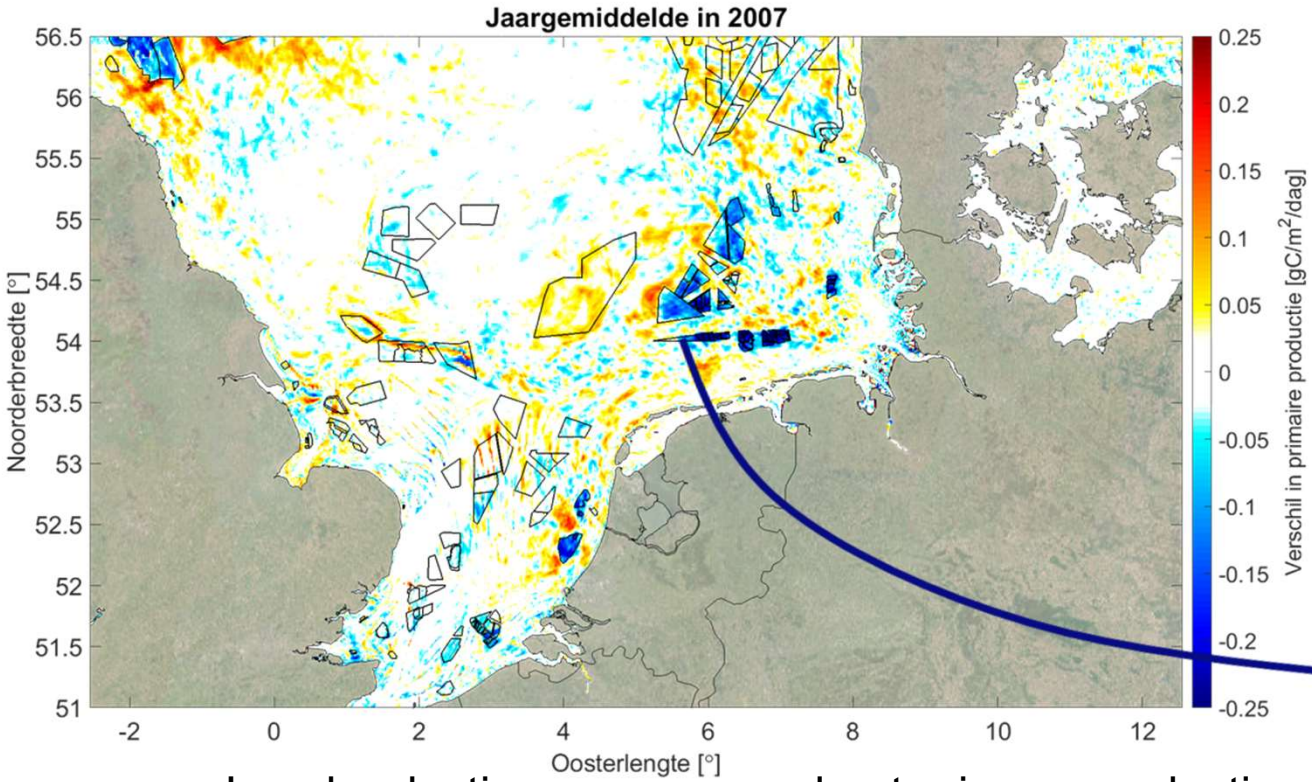
Effects offshore wind fine sediment

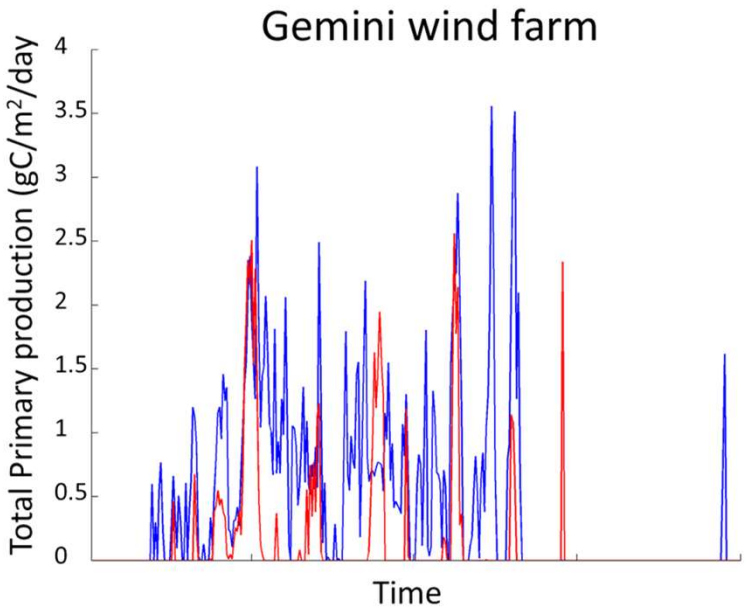
Effects offshore wind stratification and mixing

Difference in SPM concentration



Effects offshore wind primary production



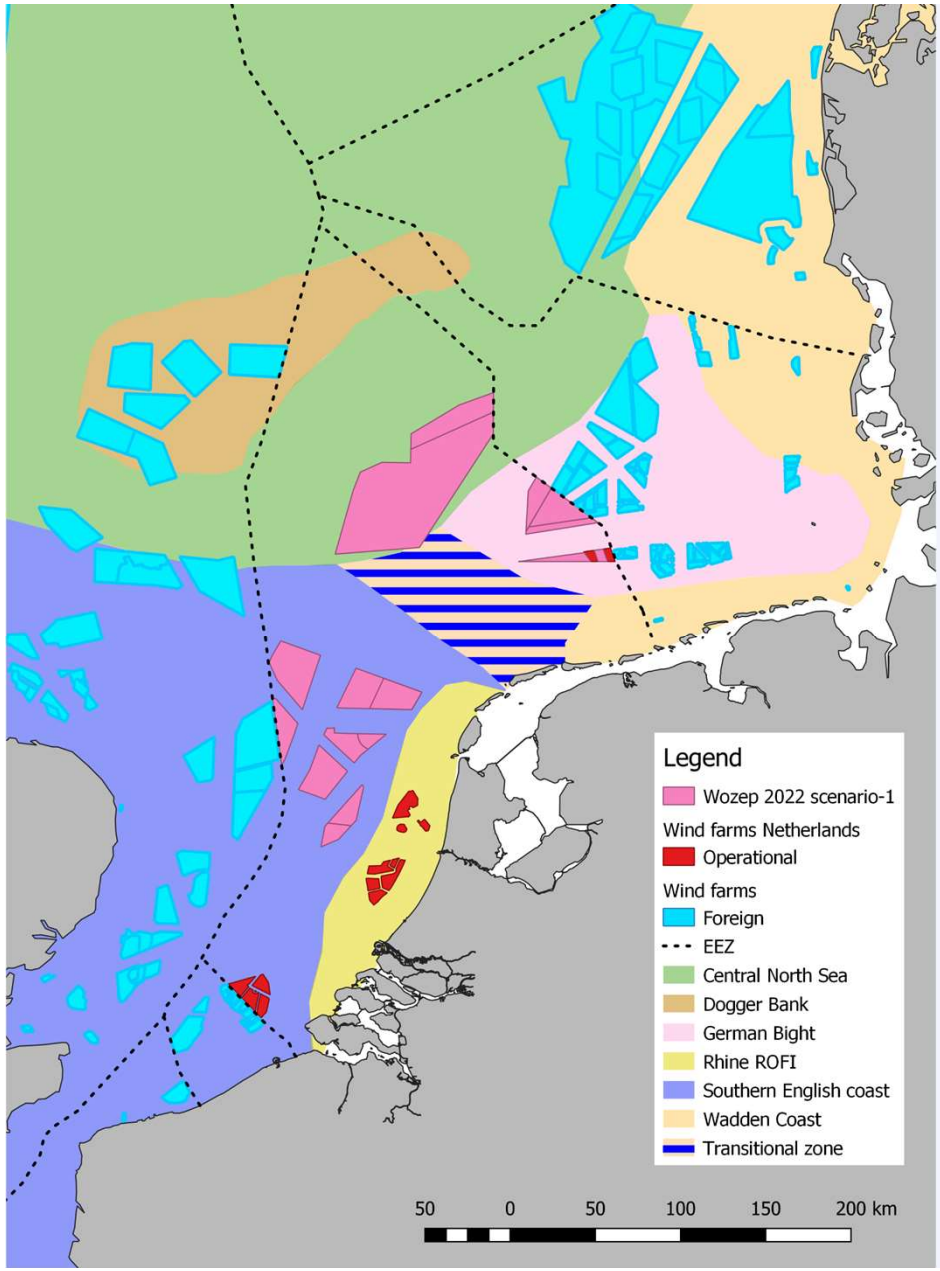


- Local reduction mean annual net primary production up to 60%
- Local increase (search area 6/7) >40%
- Delays in spring bloom

Deltares WAGENINGEN UNIVERSITY & RESEARCH

Regional differences

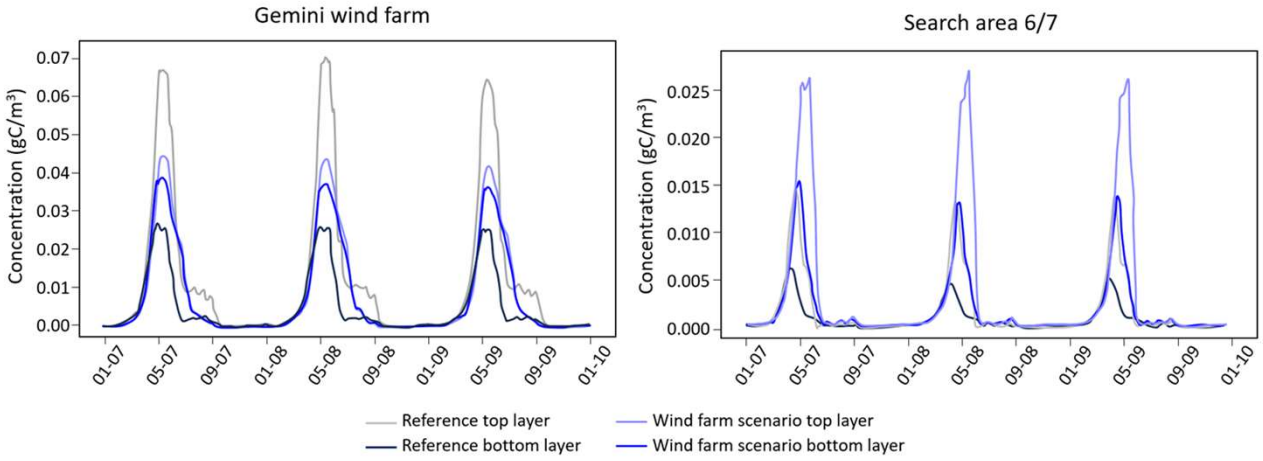
- Central southern North Sea: large effects due to relaxation of stratification. Limited effect of SPM, significant increase in productivity, delay spring bloom
- German Bight: regular but weak stratification. Opposing effects, net effect of increased turbidity appears to dominate, strong delay spring bloom
- UK coast and westernmost part of DCP: fully mixed some negative effects on primary production due to increased SPM
- German and Danish Wadden coast: similar to UK and western DCP, delineation unclear, effects limited in absolute terms
- Holland coast and Rhine ROFI: high nutrient availability, limited salinity stratification. Decrease of production due to increase in SPM
- Dogger Bank: limited, weak and variable stratification, coarse sediment, limited effect on productivity



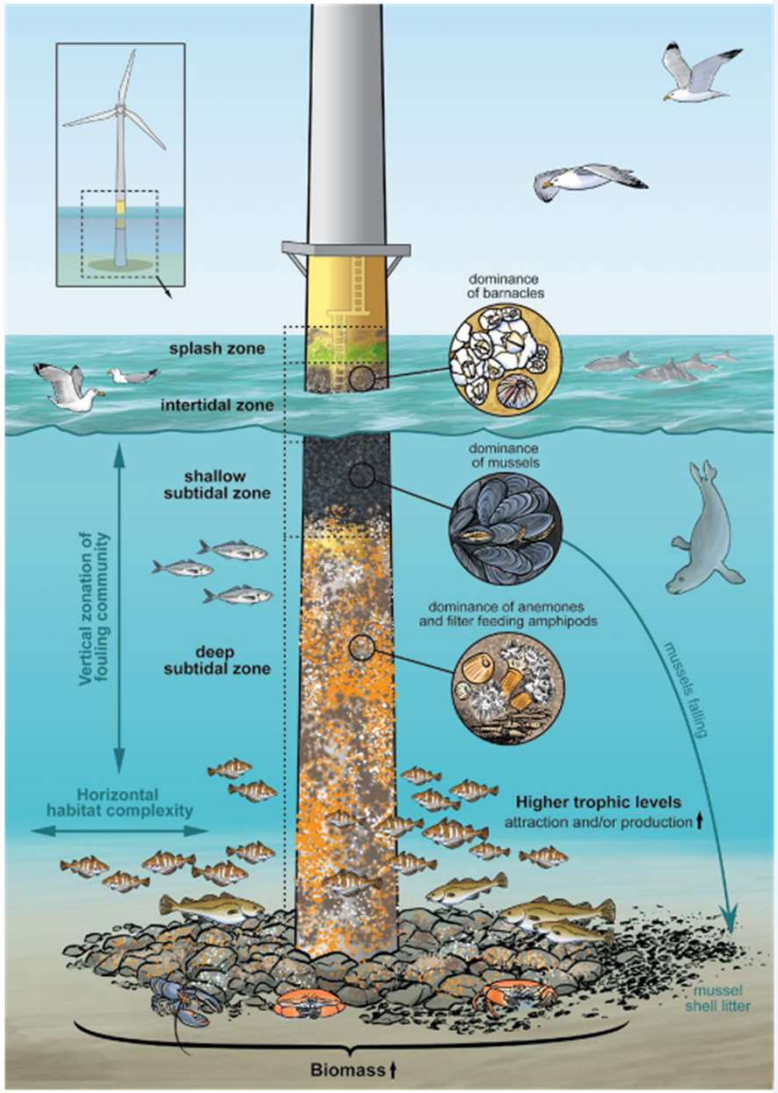
Deltares WAGENINGEN UNIVERSITY & RESEARCH

Effects offshore wind food web

Zooplankton concentrations



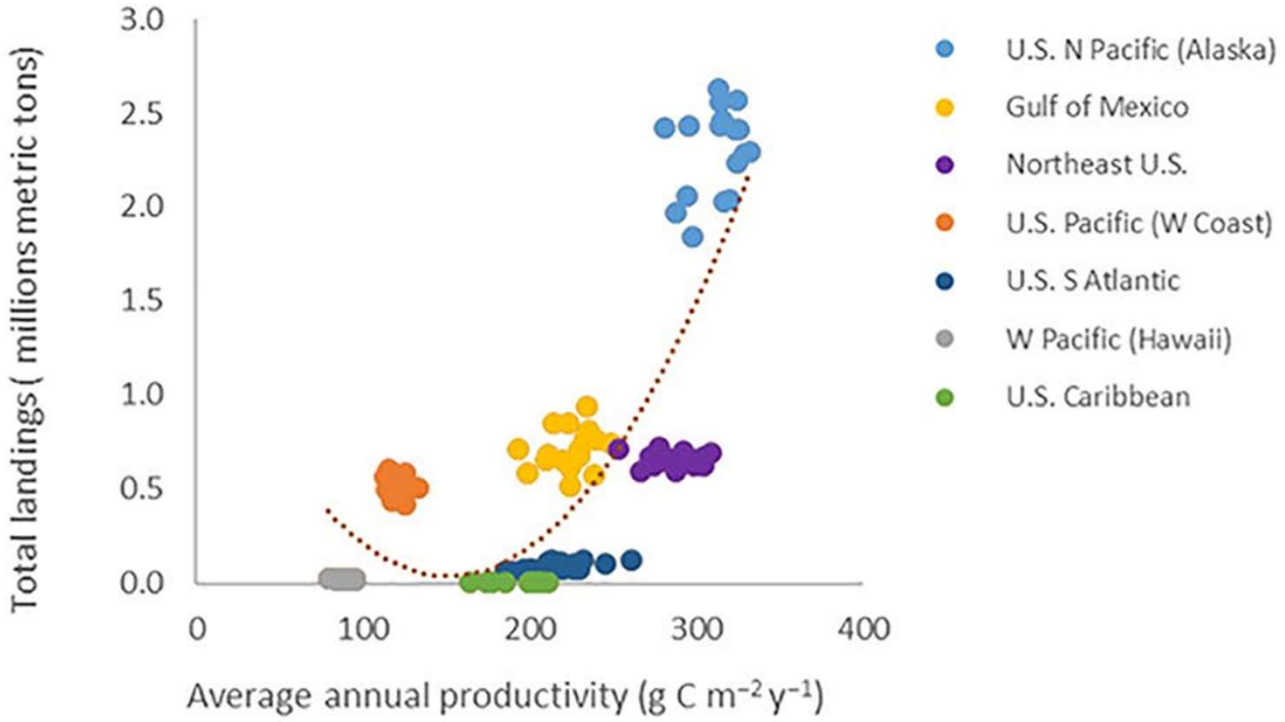
- Competition
- Primary Production



Degraer et al Oceanogr. 2020

Deltares WAGENINGEN UNIVERSITY & RESEARCH

Effects offshore wind cascade up the foodweb

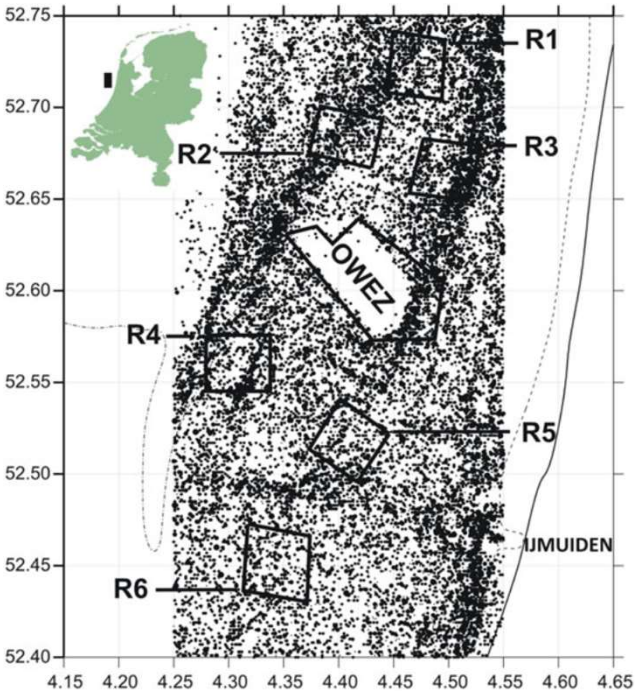


Marshak & Link 2021

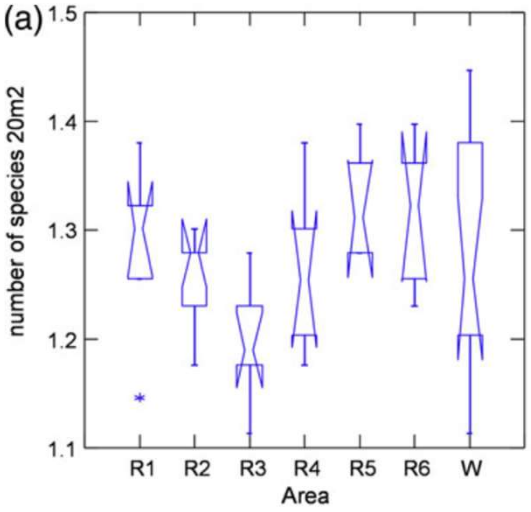
Effects sea bed

No detectible change in benthic species richness after 5 years of fishing exclusion

Fishing intensity



Bergman e.a. JMS 2015



- Slight increase in species diversity close to turbines (review paper several wind farms)

Coolen e.a. J. Env. Man. 2022

Effects offshore wind birds / mammals

Behaviour	Birds	Mammals
Attraction		
Inconsistent		
Avoidence		

Garthe e.a. 2023; Scheidat ea 2011; Vanermen e.a. 2015 and 2021; Dierschke e.a. 2016

Deltares WAGENINGEN UNIVERSITY & RESEARCH

Nature inclusive Design

Opportunities and Risks

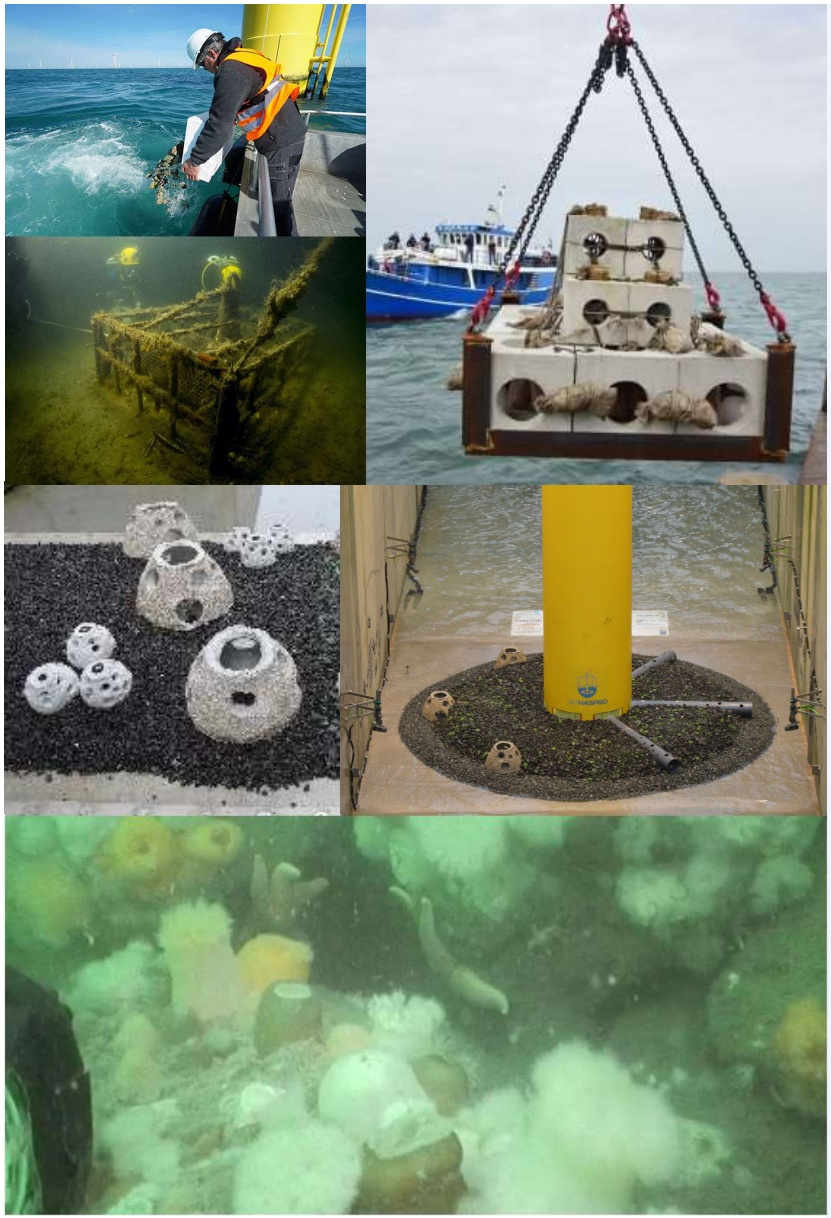
Opportunities

Nature Inclusive design

- Lots of unknowns (research opportunities)
- Large interest, especially in the Dutch North Sea due to regulations
- Deciding factor for the tender decision of HKW and IJmuiden Ver OWFs

Principles

- Nature restoration & enhancement of biodiversity
- Various measures exist, specific to certain “umbrella” species
- Design: Creating a more complex, 3D environment with shelter spaces
  - increases local biodiversity
  - effects from large-scale implementation are still Unknown



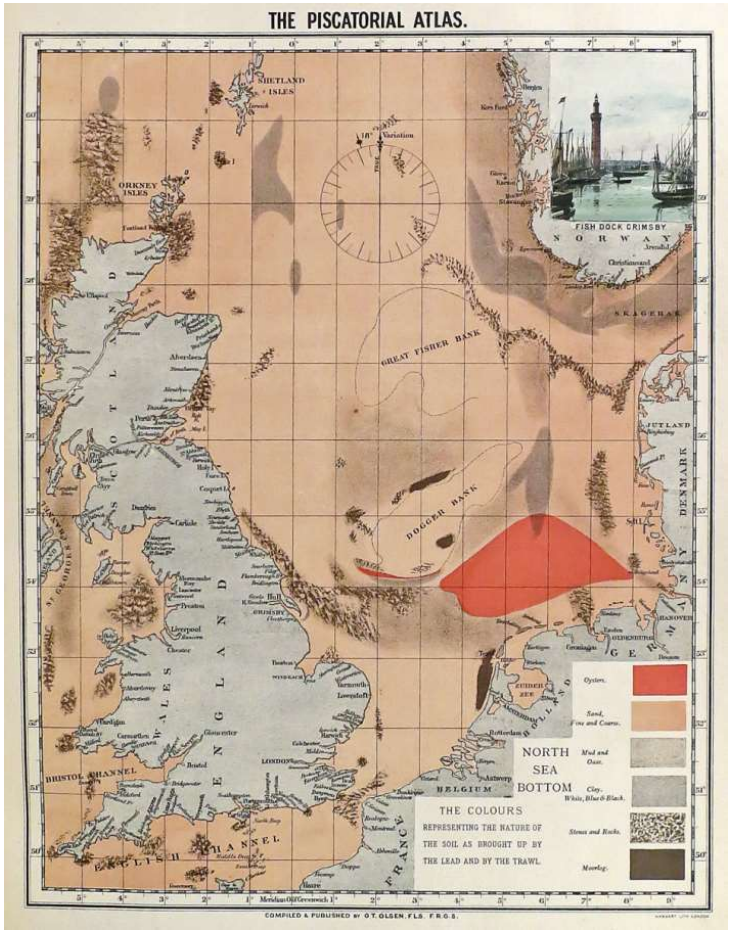
Deltares WAGENINGEN UNIVERSITY & RESEARCH

Industrial rationale

- Added value (either co-use fisheries, aquaculture or North Sea Nature) may help win bids. Currently deciding factor in NL.
- Decommissioning: current rules state that all defunct infrastructure has to be removed; current cautious move towards relaxation of these rules from international organisations (e.g. OSPAR) for sustainability

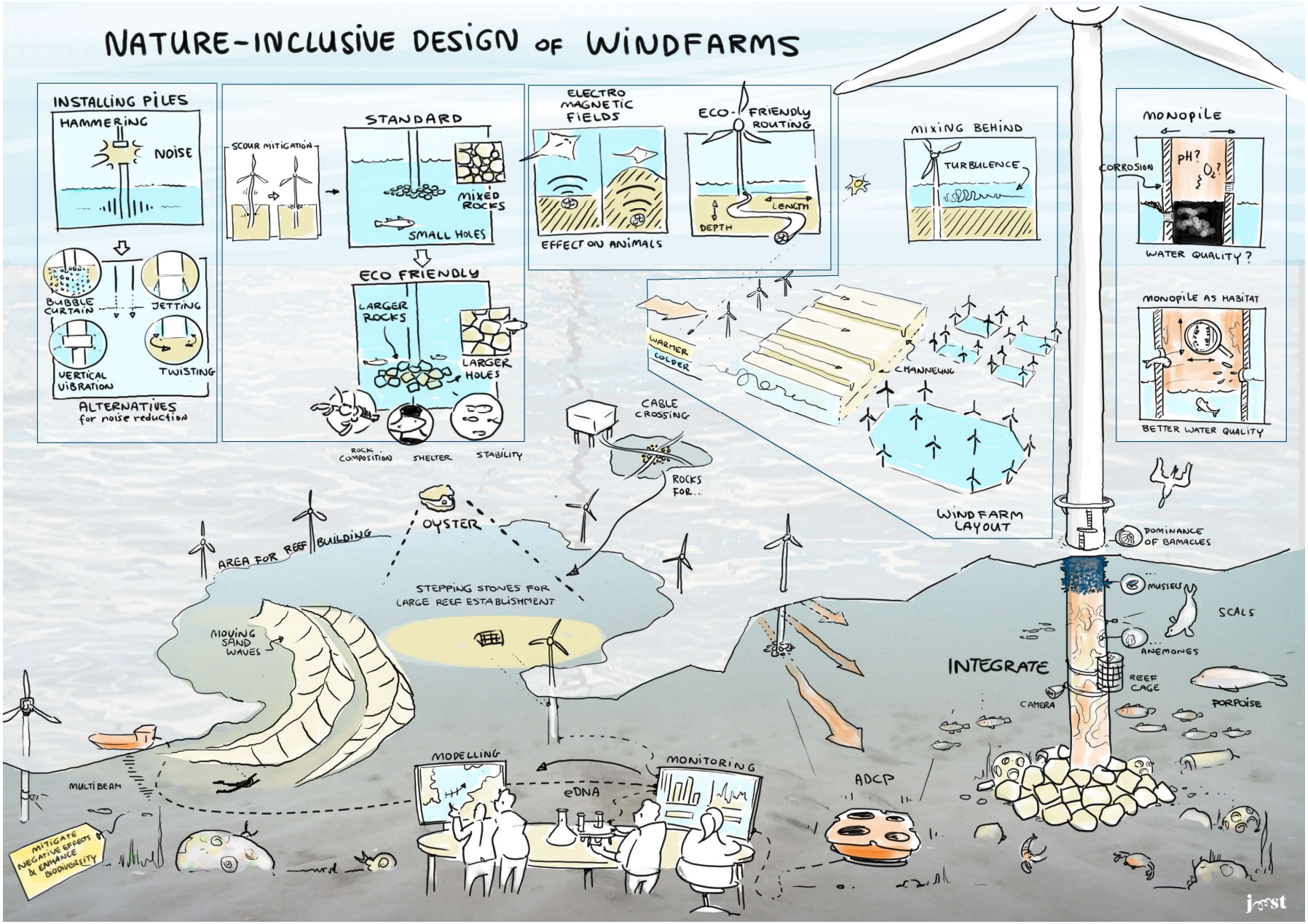
Societal / practical rationale

- North Sea is impoverished due to
  - Removal of large rocks and boulders
  - Disappearance of flat oysters (20000 km^2 from Dutch Continental Shelf)
  - Continuous bed disturbance (bottom trawling).



Societal / practical rationale

- North Sea is impoverished due to
  - Removal of large rocks and boulders
  - Disappearance of flat oysters (20000 km^2 from Dutch Continental Shelf)
  - Continuous bed disturbance (bottom trawling).
- Wind farms offer large area free from bottom trawling
- Wind farms have areas of hard substrate (scour protection, cable crossings)


NATURE-INCLUSIVE DESIGN OF WINDFARMS
INSTALLING PILES
HAMMERING
NOISE
BUBBLE CURTAIN
JETTING
VERTICAL VIBRATION
TWISTING
ALTERNATIVES for noise reduction
SCOUR MITIGATION
STANDARD
MIXED ROCKS
SMALL HOLES
ECO FRIENDLY
LARGER ROCKS
LARGER HOLES
ROCK COMPOSITION
SHELTER
STABILITY
ELECTRO MAGNETIC FIELDS
EFFECT ON ANIMALS
ECO-FRIENDLY ROUTING
LENGTH
DEPTH
MIXING BEHIND
TURBULENCE
WARMER
COLDER
CHANNELING
WIND FARM LAYOUT
MONOPILE
CORROSION
pH?
O_2?
WATER QUALITY?
MONOPILE AS HABITAT
BETTER WATER QUALITY
CABLE CROSSING
ROCKS FOR..
DOMINANCE OF BARNACLES
MUSSELS
SEALS
ANEMONES
REEF CAGE
PORPOISE
CAMERA
INTEGRATE
OYSTER
AREA FOR REEF BUILDING
STEPPING STONES FOR LARGE REEF ESTABLISHMENT
MOVING SAND WAVES
MODELLING
MONITORING
eDNA
ADCP
MULTIBEAM
MITIGATE NEGATIVE EFFECTS & ENHANCE BIODIVERSITY
jpost

Biodiversity – what do we want?

- Holland coast very dynamic
- Large mobile bed forms; by nature not conducive to e.g. reef builders

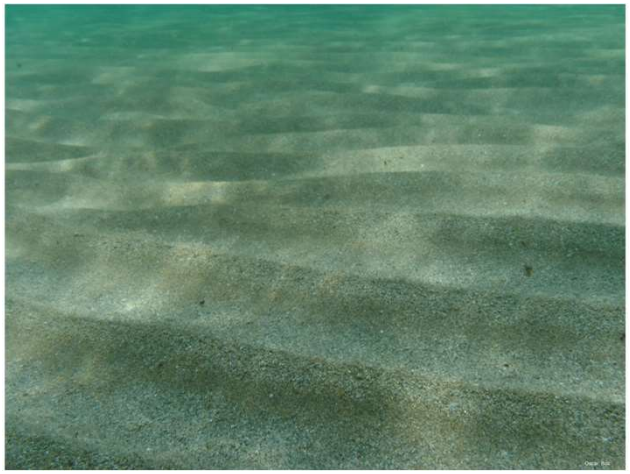
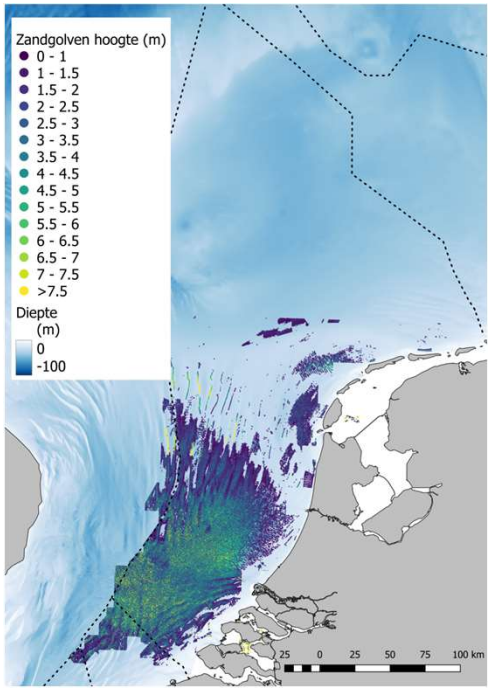
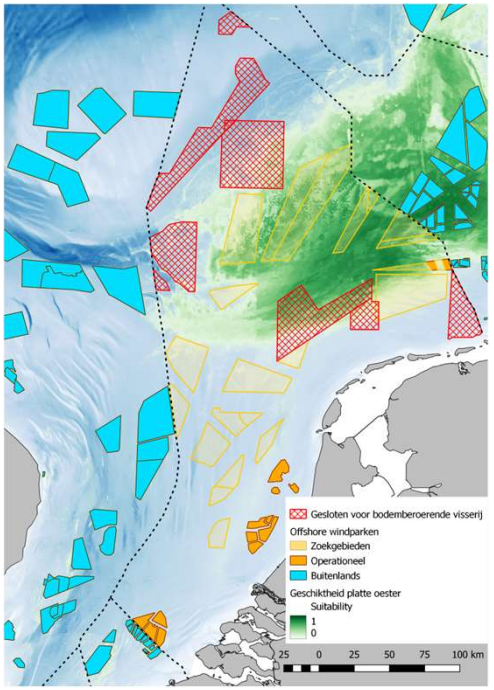


Photo: Oscar bos





Biodiversity – what do we want?

- Holland coast very dynamic
- Large mobile bed forms; by nature not conducive to e.g. reef builders
- Low in biodiversity macrobenthos
- Rich in meiobenthos (between 0.1 and 1mm)
- Holland Coast one of the largest sand wave systems in the world

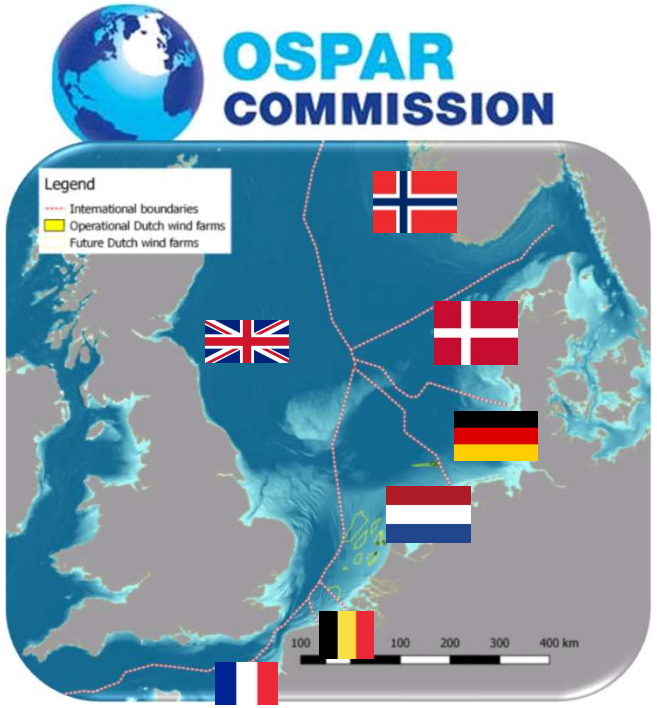
On land


Brabants Landschap
Natuurgebied
De Brabantse Alpen
Overigens verboden toegang artikel 461 W.v.Sr.


PLEASE NOTE
THIS BUILDING IS A BAT ROOST
All British bats are protected by the 1981 Wildlife & Countryside Act and listed on Schedule 2 of the Conservation of Habitats & Species Regulations 2017.
Access inside should only be undertaken by person(s) that hold a current Natural England bat licence to disturb.
Unauthorised entry by non-licenced person(s) whilst bats are present is an offence under the described legislation, punishable by fines and/or imprisonment.
If access is required for any reason then please contact the following number.
Tyrer Ecological Consultants Ltd
01704 875781

Artificial reefs – legal frame work

- OSPAR / HELCOM
  - mechanism by which fifteen national governments, together with the European Union, cooperate to protect the marine environment of the North-East Atlantic.
  - Advisory role for European legislation
  - Origin: dumping / pollution
- National governments
  - Legislative powers
  - Incorporate European guidelines
  - Interpretation and legislation re. liability may differ among countries



Deltares WAGENINGEN UNIVERSITY & RESEARCH JIP HASPRO Handbook Scour Protection Methods

Artificial reefs – legal frame work

- OSPAR / HELCOM
  - mechanism by which fifteen national governments, together with the European Union, cooperate to protect the marine environment of the North-East Atlantic.
  - Advisory role for European legislation
  - Origin: dumping / pollution
- National governments
  - Legislative powers
  - Incorporate European guidelines
  - Interpretation and legislation re. liability may differ among countries

North Sea Futures

The North Sea Futures Manifest 2017

THE NORTH SEA PRINCIPLES
"LIFE BETWEEN MAN-MADE OCEAN STRUCTURES"

10 Principles for making the North Sea thrive as an ecosystem during transition from fossil to renewable energy production

October 2017

This document manifests the challenges and opportunities for action during the current industrialisation and energy transition in the North Sea, and presents 10 principles for making the North Sea thrive as an ecosystem during – and after - the transition from fossil to renewable energy production.

It has been developed through a 6-month consultation process and an International Dialogue Meeting, held on 26th September 2017, in Denmark, involving science, green NGOs and industry representatives and is launched at the occasion of the ongoing review of derogation categories in Decision 98/3 and OSPAR meeting 2018. Its perspective, however, goes beyond this occasion as it addresses the wider challenge of protecting marine ecosystems during the transition and infrastructures development from fossil to renewable energy.

The purpose of launching The North Sea Futures Manifest 2017 is to provide a heads-up for decision makers, scientists and civil society organisations to (re-)consider and discuss how to achieve the most environmentally beneficial results from future offshore installation and decommissioning activities.

The North Sea is a sea of dilemmas: it is the largest nature area in North-Western Europe and one of the most intensively used marine areas in the world. It is also a very different ecosystem from what it used to be 200 years ago and probably just as different from what it will be like 200 years from now.

With the increasingly rapid transition from fossil to renewable energy resources and a vision of the North Sea as the so-called "Silicon Valley' for offshore wind energy, its ecosystem is confronted with an unprecedented challenge: adapting to further intensification of human activities and thousands of new man-made installations creating new habitats and conditions for marine life.

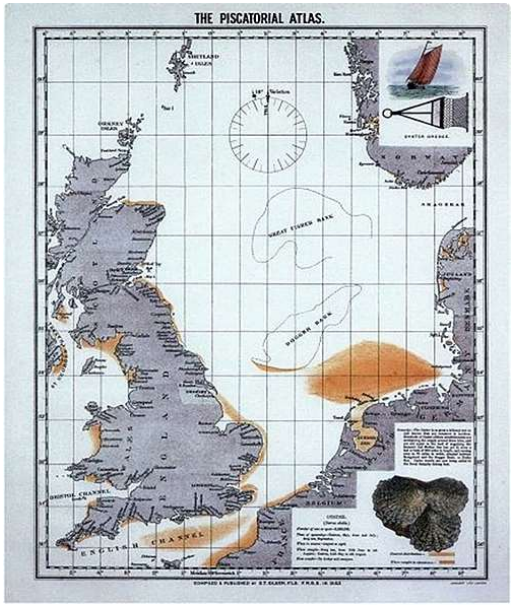
In this process, we need to find feasible solutions for how to protect and strengthen marine ecosystems during the phase-out and removal of existing installations, and through the placement, design and management of new types of offshore installations.

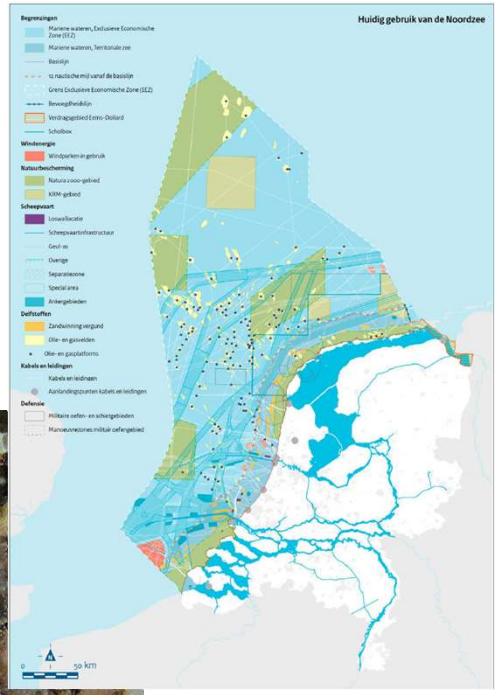
The North Sea Futures Manifest 2017
www.northseafutures.org

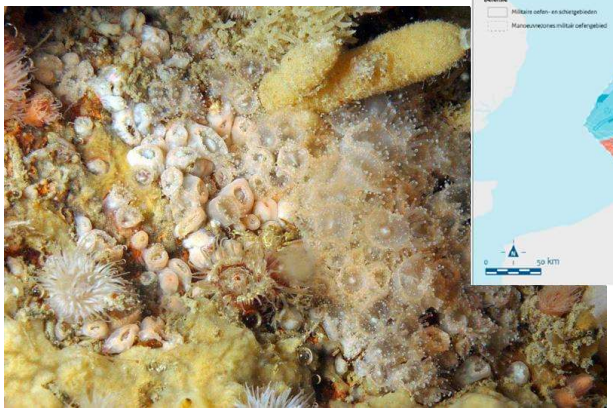
Deltares WAGENINGEN UNIVERSITY & RESEARCH JIP HASPRO Handbook Scour Protection Methods

What do we want with the North Sea?

- Return to historic situation not possible due to other changes (e.g. climate change, nutrient run-off, spatial planning)
- Historic situation can be an initial guideline
- It is valid attempting to try to restore habitats / populations that have disappeared due to human intervention
- Emphasis should be on ecosystem functions, but working with “umbrella species” is easier



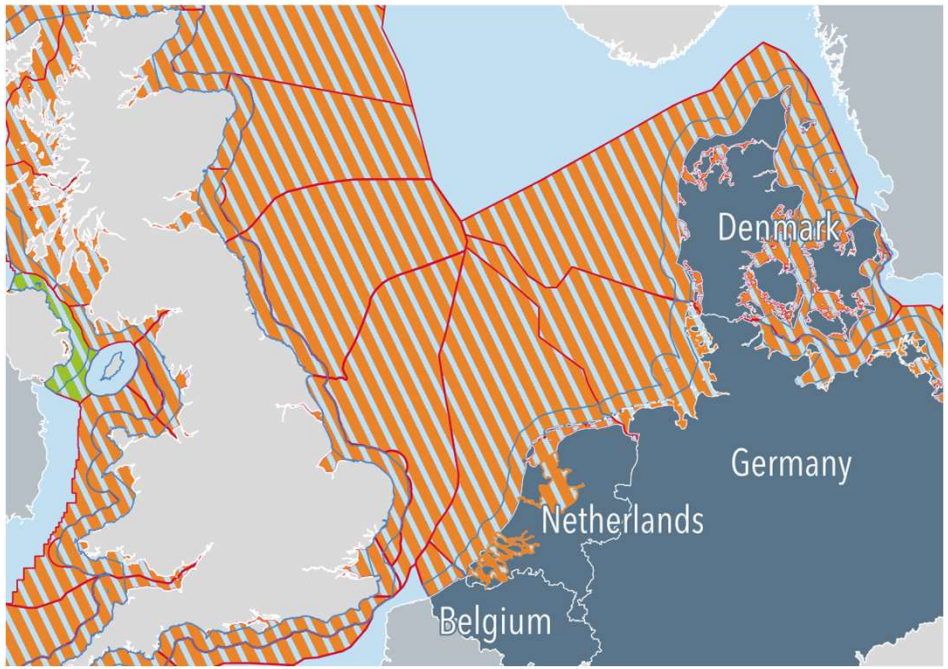




Deltares WAGENINGEN UNIVERSITY & RESEARCH JIP HASPRO Handbook Scour Protection Methods

What do we want with the North Sea?

- Return to historic situation not possible due to other changes (e.g. climate change, nutrient run-off, spatial planning)
- Historic situation can be an initial guideline
- It is valid attempting to try to restore habitats / populations that have disappeared due to human intervention
- Emphasis should be on ecosystem functions, but working with “umbrella species” is easier
- North Sea wide vision is required – for evaluation. Location specific circumstances should be taken into account (possible under GNSBI)



Deltares WAGENINGEN UNIVERSITY & RESEARCH JIP HASPRO Handbook Scour Protection Methods

Risks

Invasive species

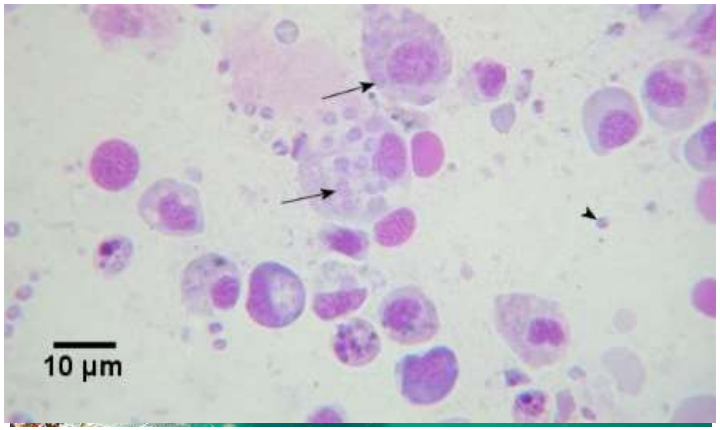
- High density on intertidal areas, buoys, stones and pillars near the surface
- Lower densities in deeper habitats
- Major vector: aquaculture → shifting live organisms, also for restoration purposes, entails a high risk

Spread of disease

- *Bonamia*

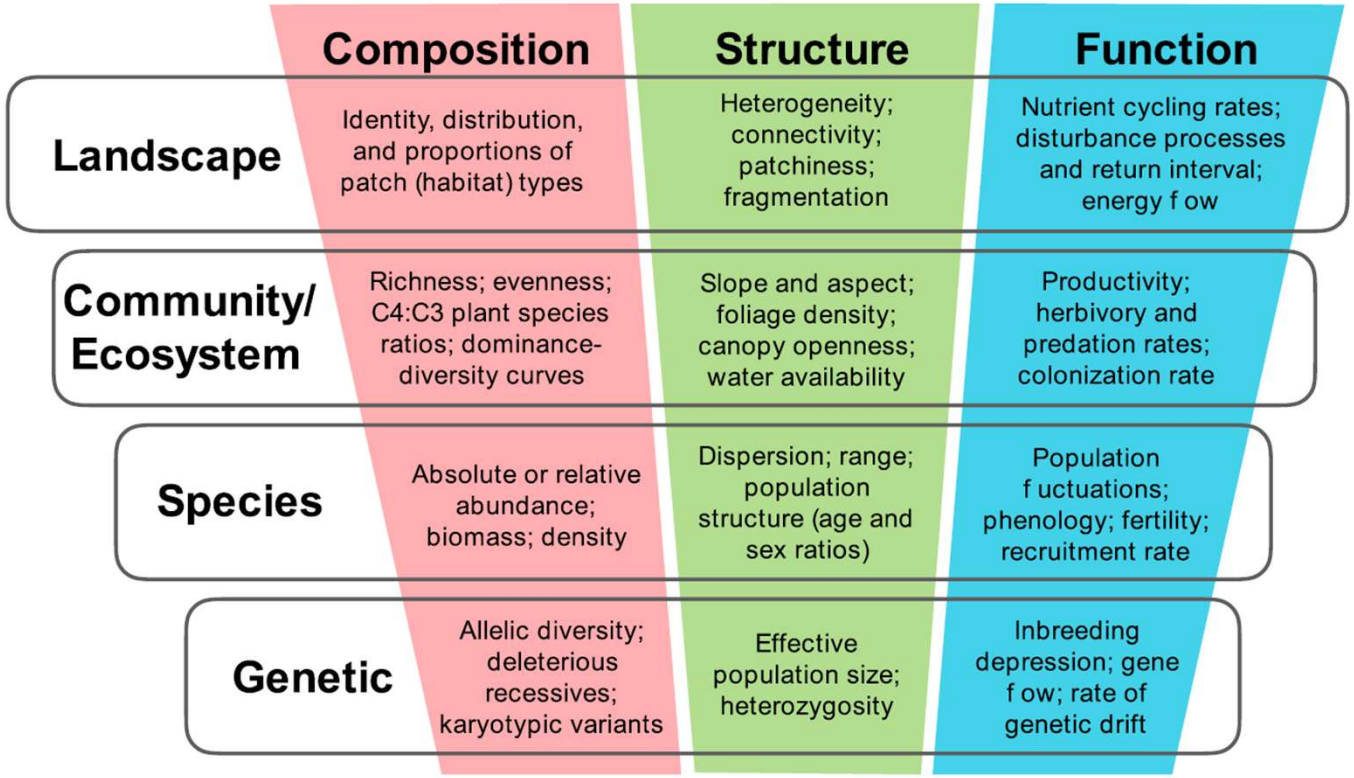
Stability

- Adverse effects on scour protection
- Stability of ecological structures (e.g. shell material



Deltares WAGENINGEN UNIVERSITY & RESEARCH JIP HASPRO Handbook Scour Protection Methods

Framework for evaluating biodiversity metrics



From: Bracy Knight, et al. 2020

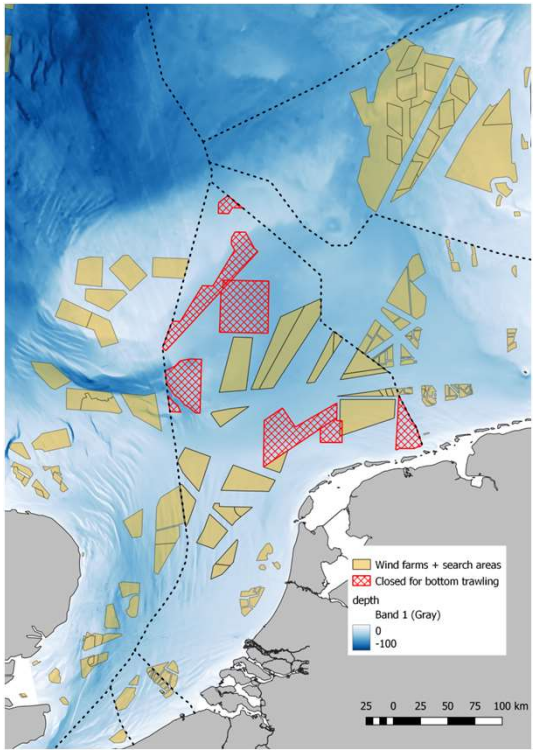
Reef restoration

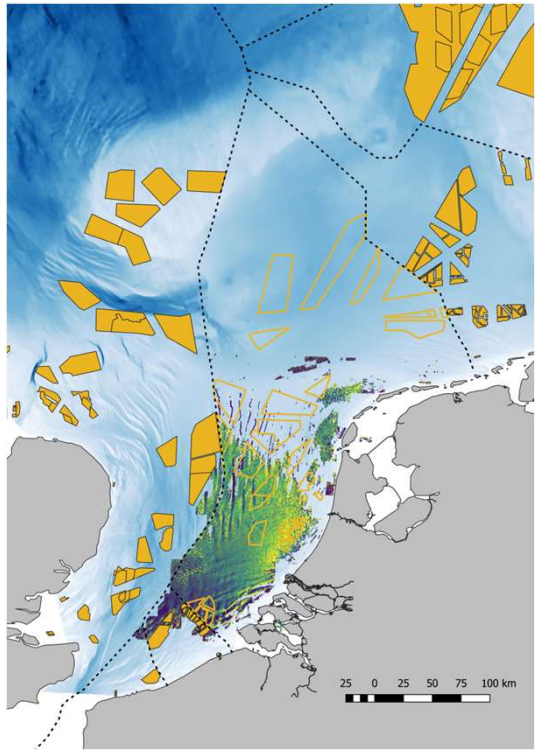
Flat oyster (*Ostrea edulis*)

- Historically characteristic key species, currently functionally extinct in the North Sea
- Nationally and internationally high priority
- Bed disturbance (bottom trawling) main threat
- Source population absent in the North Sea (present in e.g. Lake Grevelingen, Limfjorden)
- Pilot projects in “Voordelta region” using reef balls and gabions for settlement and desk studies available regarding habitat requirements and larval dispersal

Habitat requirements

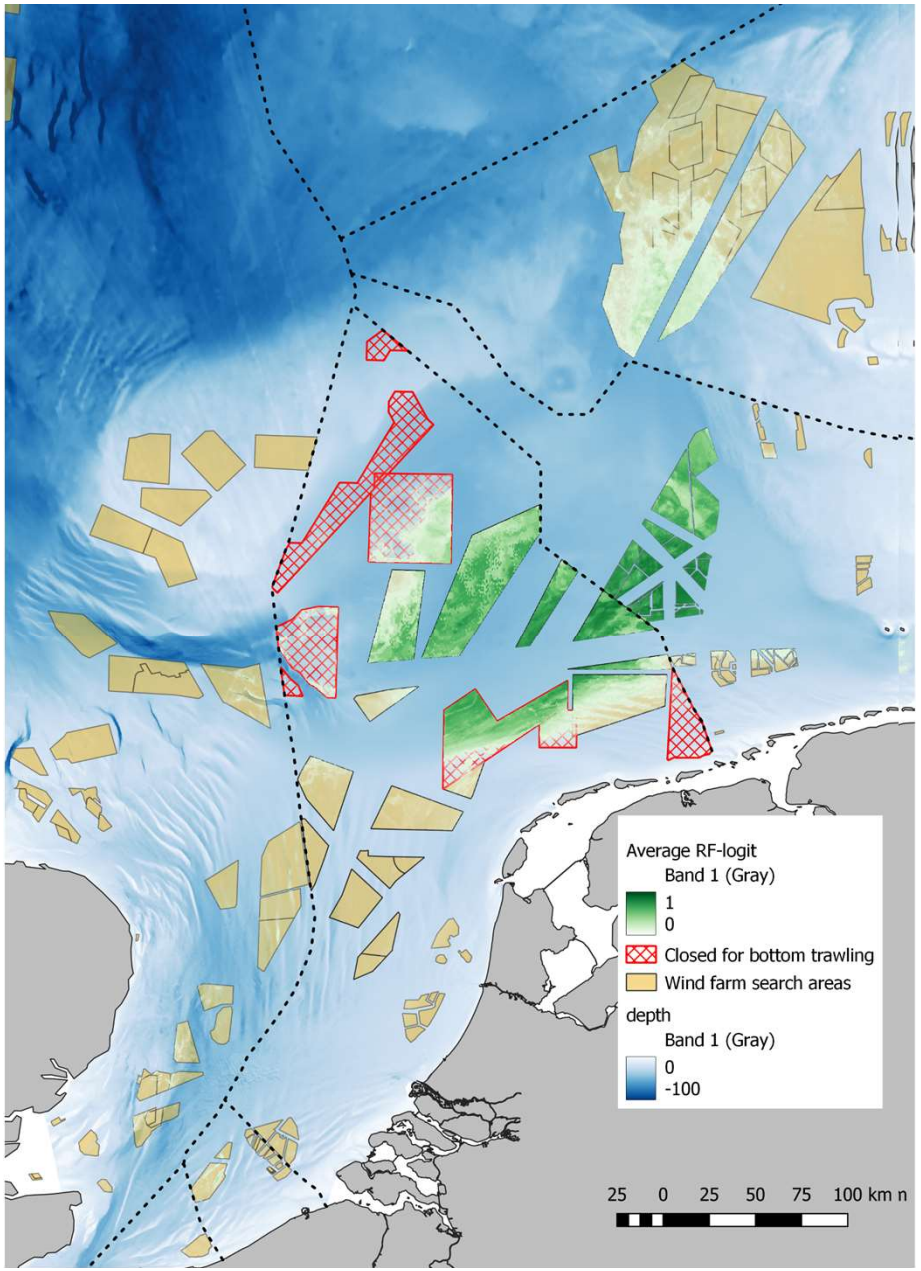
- No fishing
- Bed stability





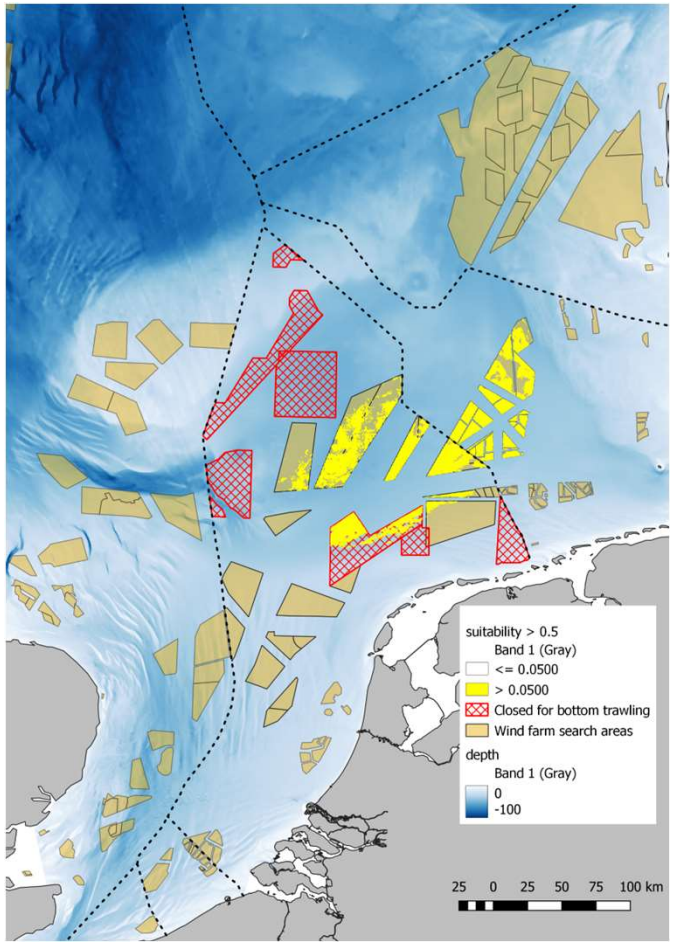
Habitat requirements

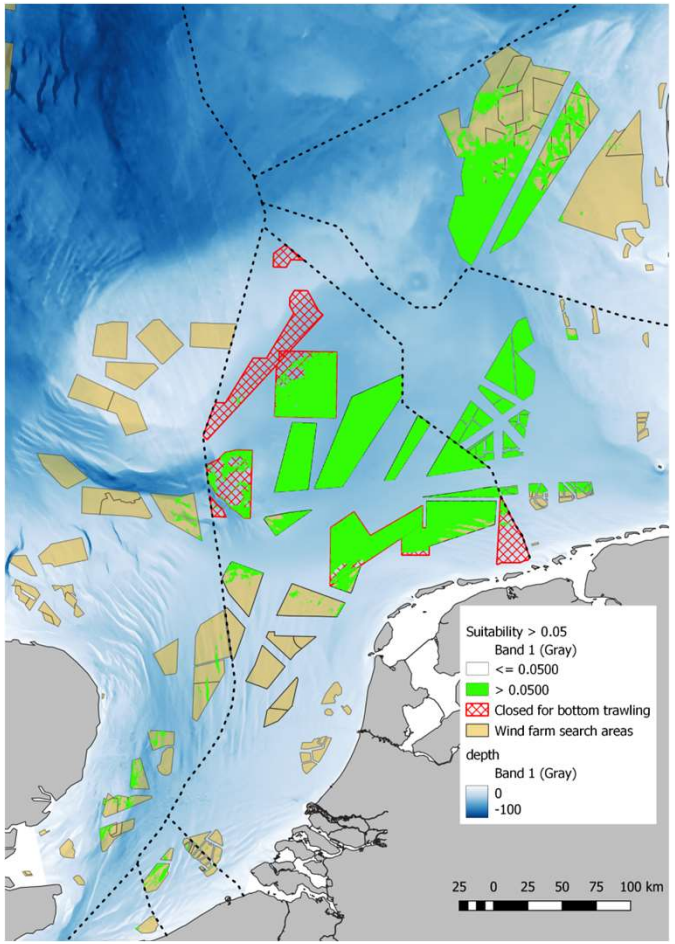
- No fishing
- Bed stability
- Low bed shear stress
- Medium mud content



Deltares WAGENINGEN UNIVERSITY & RESEARCH

Reality check: growth



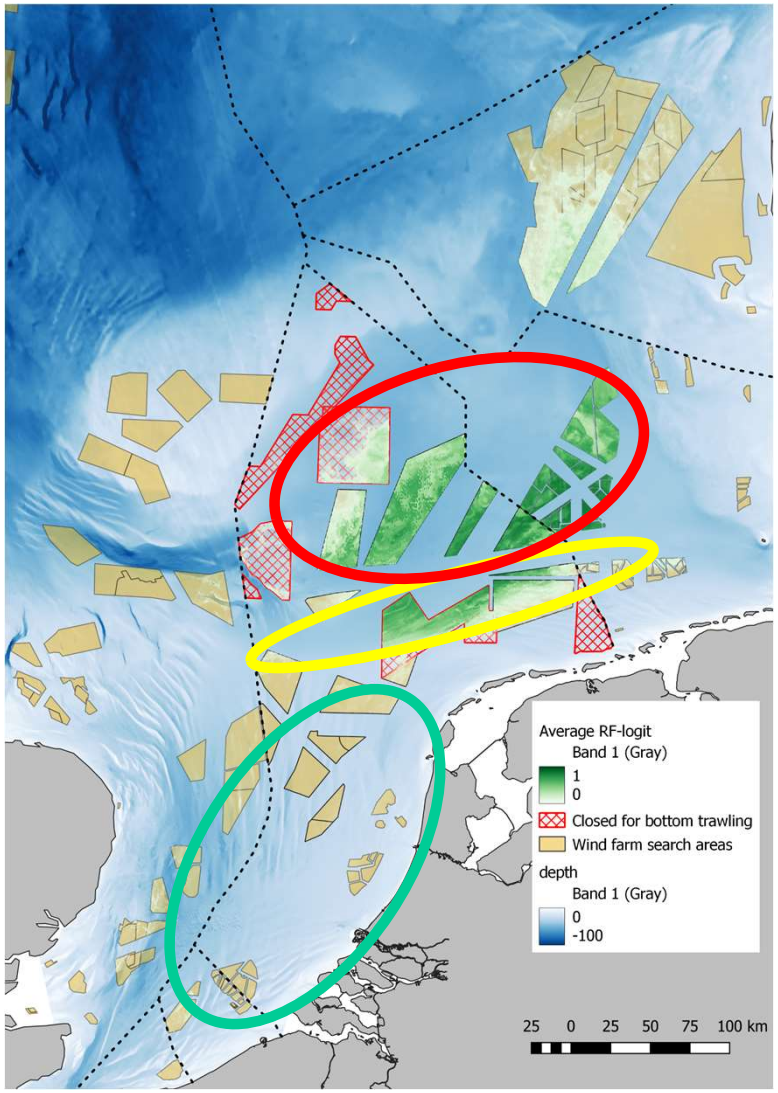


Deltares WAGENINGEN UNIVERSITY & RESEARCH

Results

- Hardly any growth in areas that are most suitable
- Reasonable growth on Frisian Front
- Good growth in areas that have limited suitability

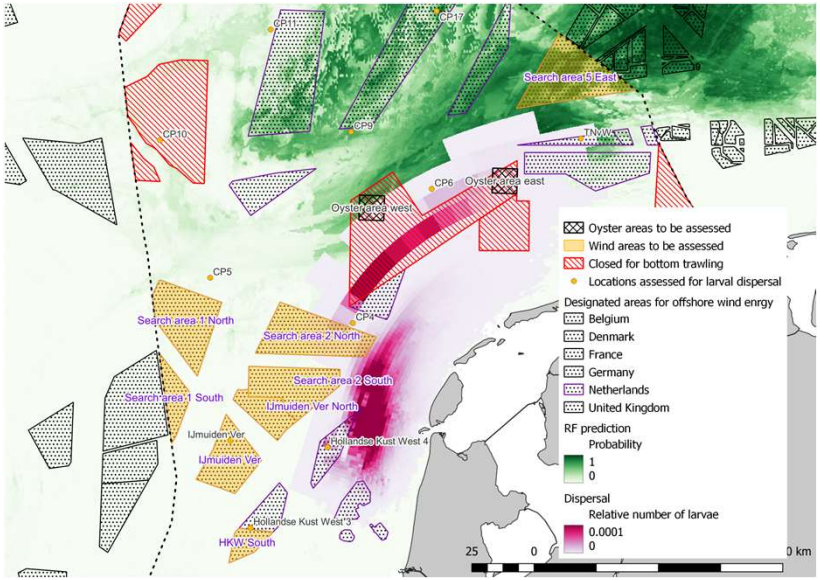
- ➢ Old oyster grounds were likely not all live oysters
- ➢ Old distribution of oysters likely built up over centuries
- ➢ Do not expect to get them back rapidly

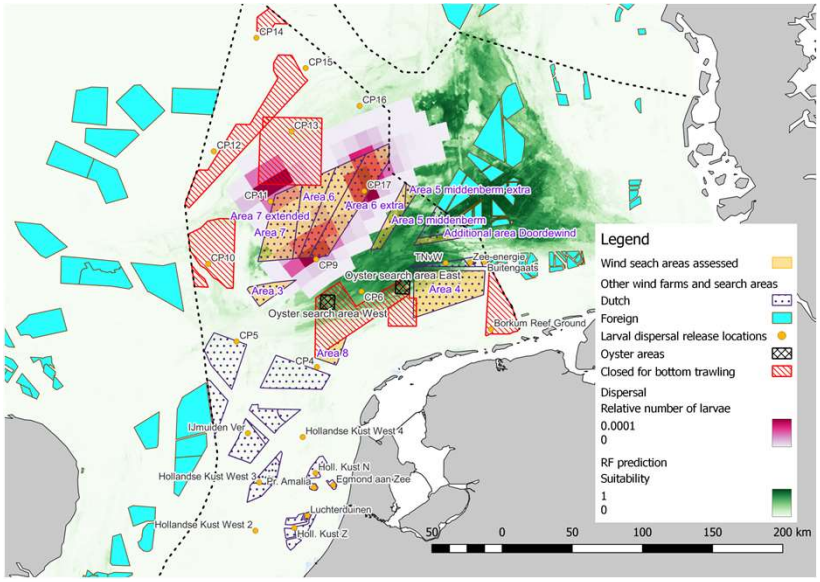


Deltares WAGENINGEN UNIVERSITY & RESEARCH

Larval dispersal

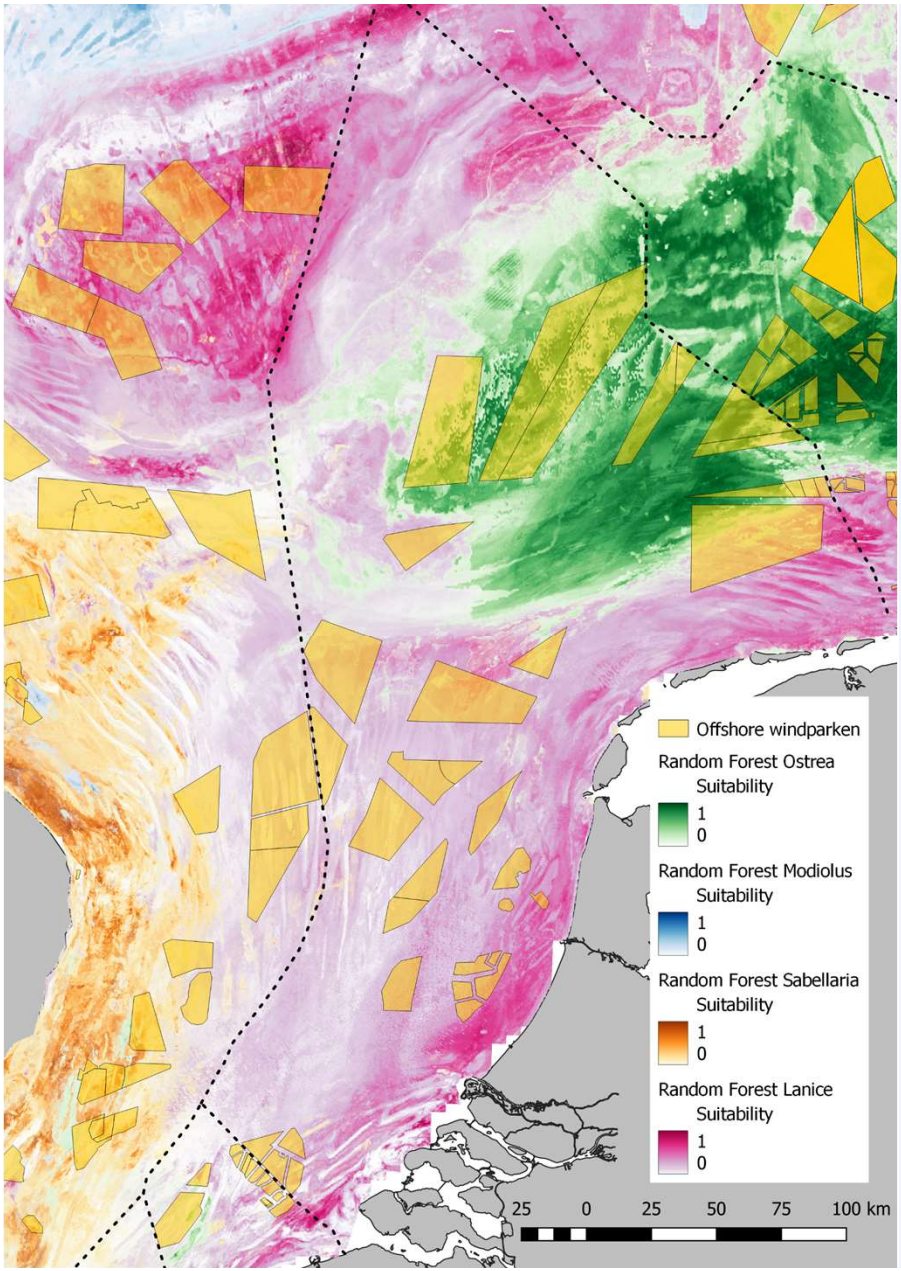
- Oysters are functionally extinct, so restoration will not happen by itself
- Oysters have pelagic larvae
- You want to kick start populations where larvae can reach suitable habitat
- Preferably become self-sustaining
- Note: this model is old!





Other reef forming species

- *Sabellaria spinulosa* (Ross worm)
  - Individuals not rare –reef forming is
  - Requires high suspended sediment
  - Reef formation accelerated by presence of adult reef
- *Lanice conchilega* (Sand mason worm)
  - Factors influencing reef formation not well understood
  - No measures known to stimulate reef formation
- *Modiolus modiolus* (Horse mussel)
  - No reefs known in the Netherlands
  - Reefs at depths >35 m



Deltares WAGENINGEN UNIVERSITY & RESEARCH

Wrap-up

Take home messages

- Offshore wind offers risks and opportunities to the environment
- The opportunities for Nature Inclusive Design are currently poorly understood
  - Biodiversity increase per sé should not be a target
  - Habitat, larval dispersal and carrying capacity for species should all be taken into account
  - Think before you start
- Passive restoration prefereable to active
- Define targets clearly
- Respect the under water landscape; also things you cannot see are valuable!

Photo: Ryo Minemizu

Figure: Christian Sardet

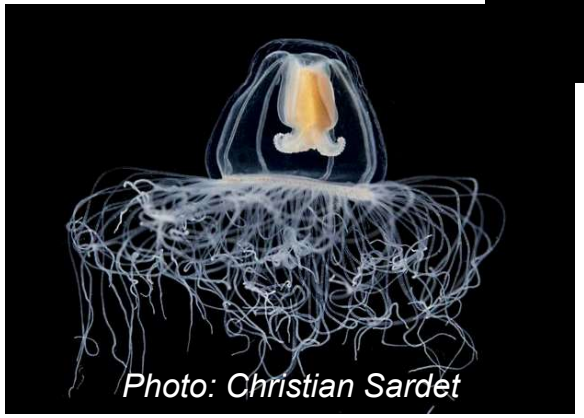


Photo: Christian Sardet

Deltares WAGENINGEN UNIVERSITY & RESEARCH

Contact

www.deltares.nl

@deltares

linkedin.com/company/deltares

luca.vanduren@deltares.nl

@deltares

facebook.com/deltaresNL