



Deltares

Consequences of the energy transition for the ecosystem; how is the North Sea going to change?

Luca van Duren and Johan van der Molen

17 January 2024

Energy transition



OSTEND DECLARATION OF ENERGY MINISTERS

ON

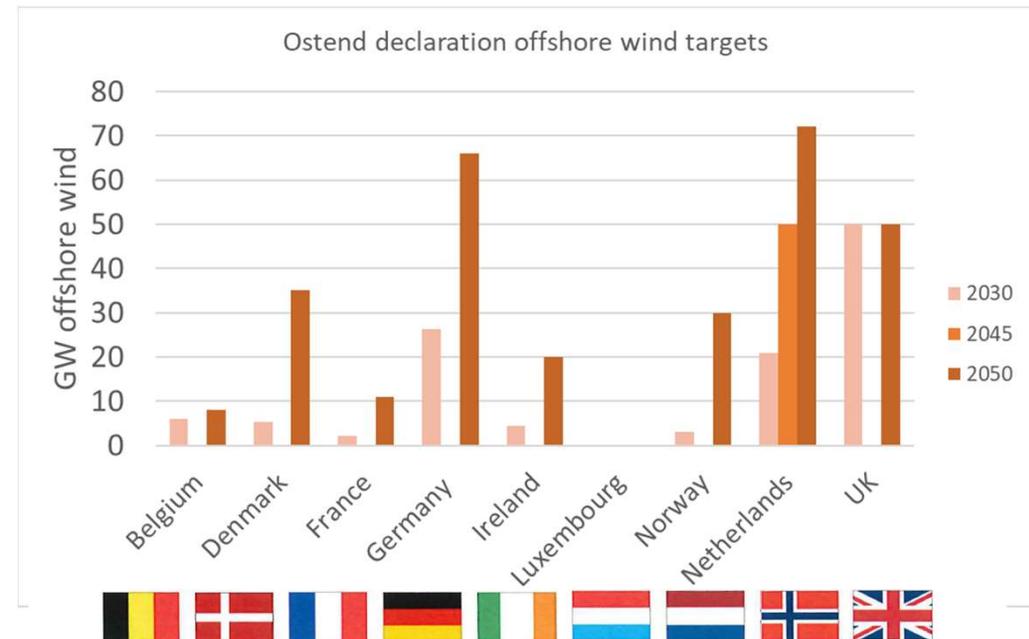
THE NORTH SEAS AS EUROPE'S GREEN POWER PLANT

DELIVERING CROSS-BORDER PROJECTS

AND ANCHORING THE RENEWABLE OFFSHORE INDUSTRY IN EUROPE

Recalling the declaration on the North Seas as a Green Power Plant of Europe in Esbjerg signed by the energy ministers of Belgium, Denmark, Germany and the Netherlands on 18 May 2022.

The energy ministers of France, Ireland, Luxembourg, Norway and the United Kingdom are joining this Ostend declaration.



Targets North Sea humongous

- Key issue North Sea
- Not adequately researched

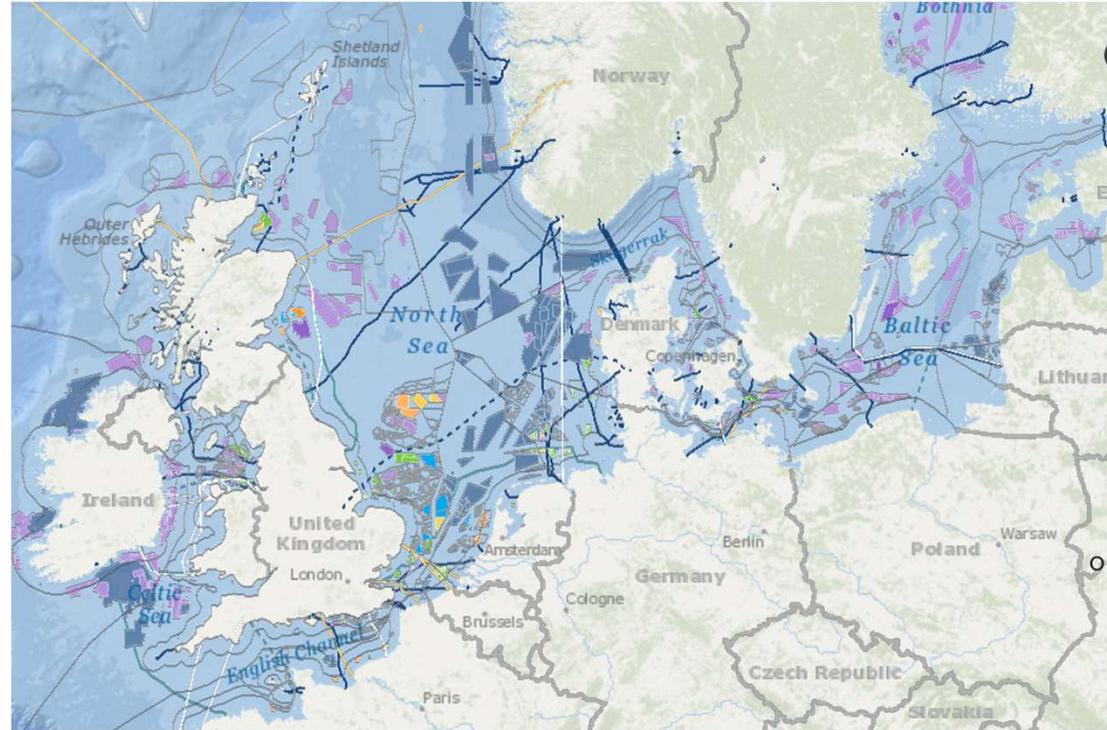
Energy transition



■ Wind, solar, hydrogen



- Winds and heat balance
- Currents and stratification
- Turbulence and turbidity
- Noise, shipping and cables
- Exclusion bottom trawling
- Plankton, fish, birds, mammals
- Benthos and biofouling communities
- Carbon and nutrient cycling
- Connectivity and non-native species
- Paints, chemicals and (heavy) metals

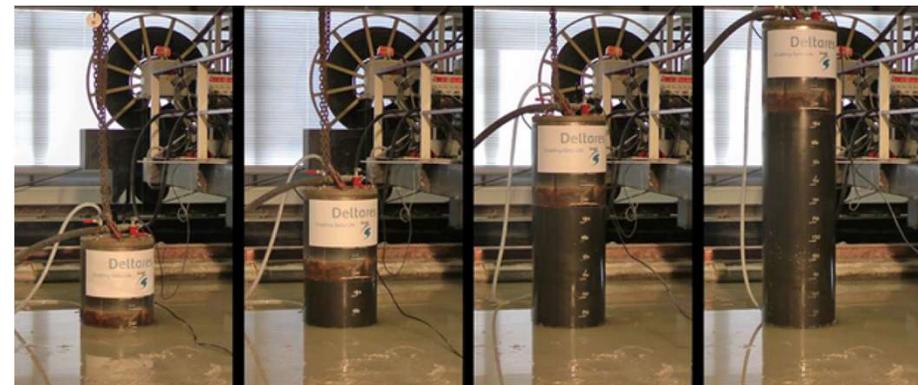


<https://map.4coffshore.com/offshorewind/>

Space, time and scale dependent

Phases

- Construction
- Operation
- Decommissioning



Effects on wind

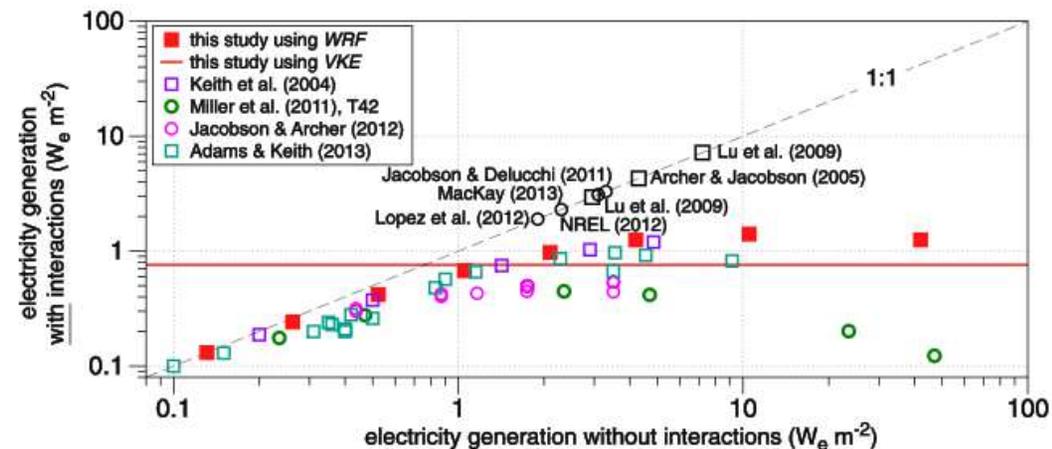
- OWF's extract momentum from the wind – strongly depends on replenishment of energy from higher layers
- Globally the vertical flux of energy ranges around 2 W m^{-2}

Image credits: London array



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 $\pm 100 \text{ GW}$
- Likely big effects on wind and weather patterns in NS countries

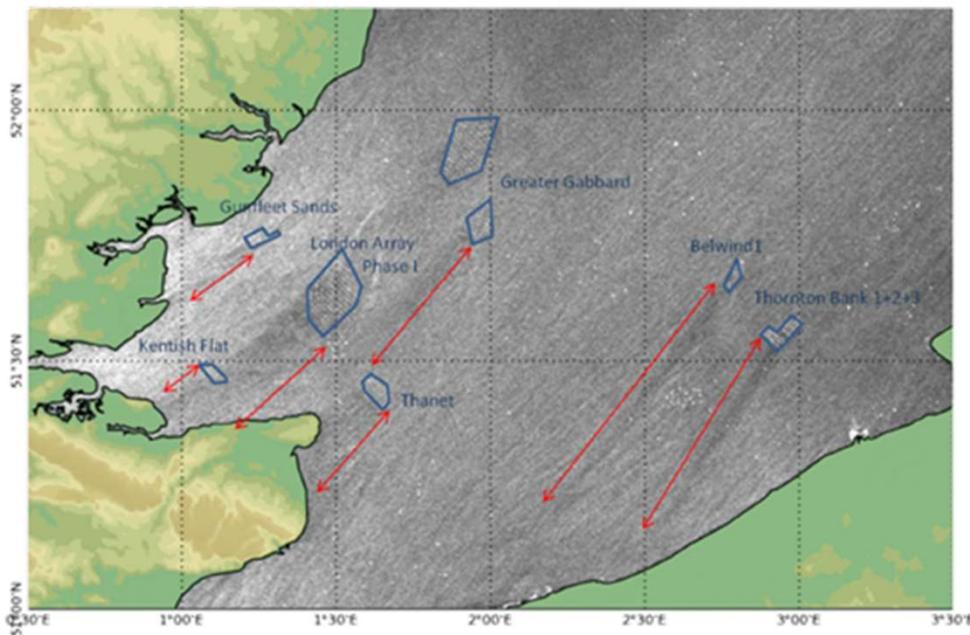


Limitation of maximal extractable energy due to turbine-wind interactions for large-scale wind parks and global studies. From Miller et al. (2015)

Effects offshore wind interaction with waves

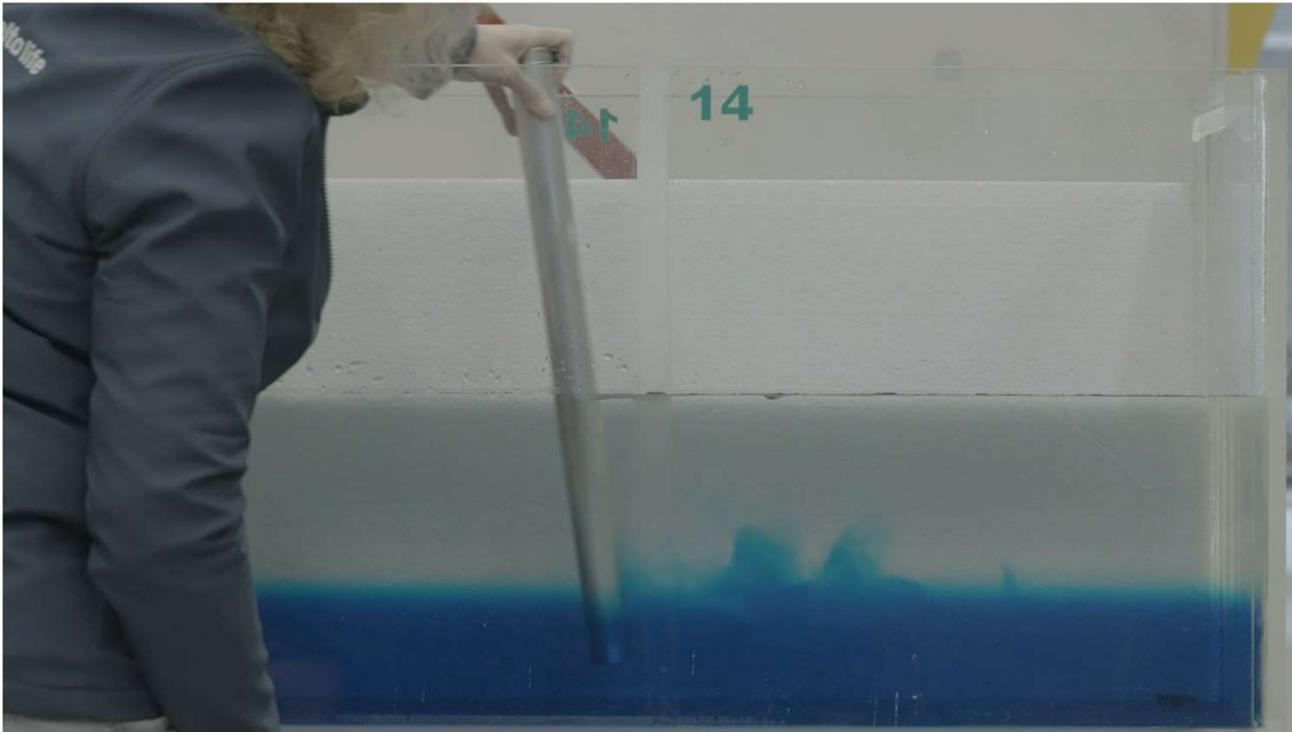


RS-2 20130430 17:41:53 UTC SAR intensity image



- Wind wakes up to hundreds of km, a few % reduction

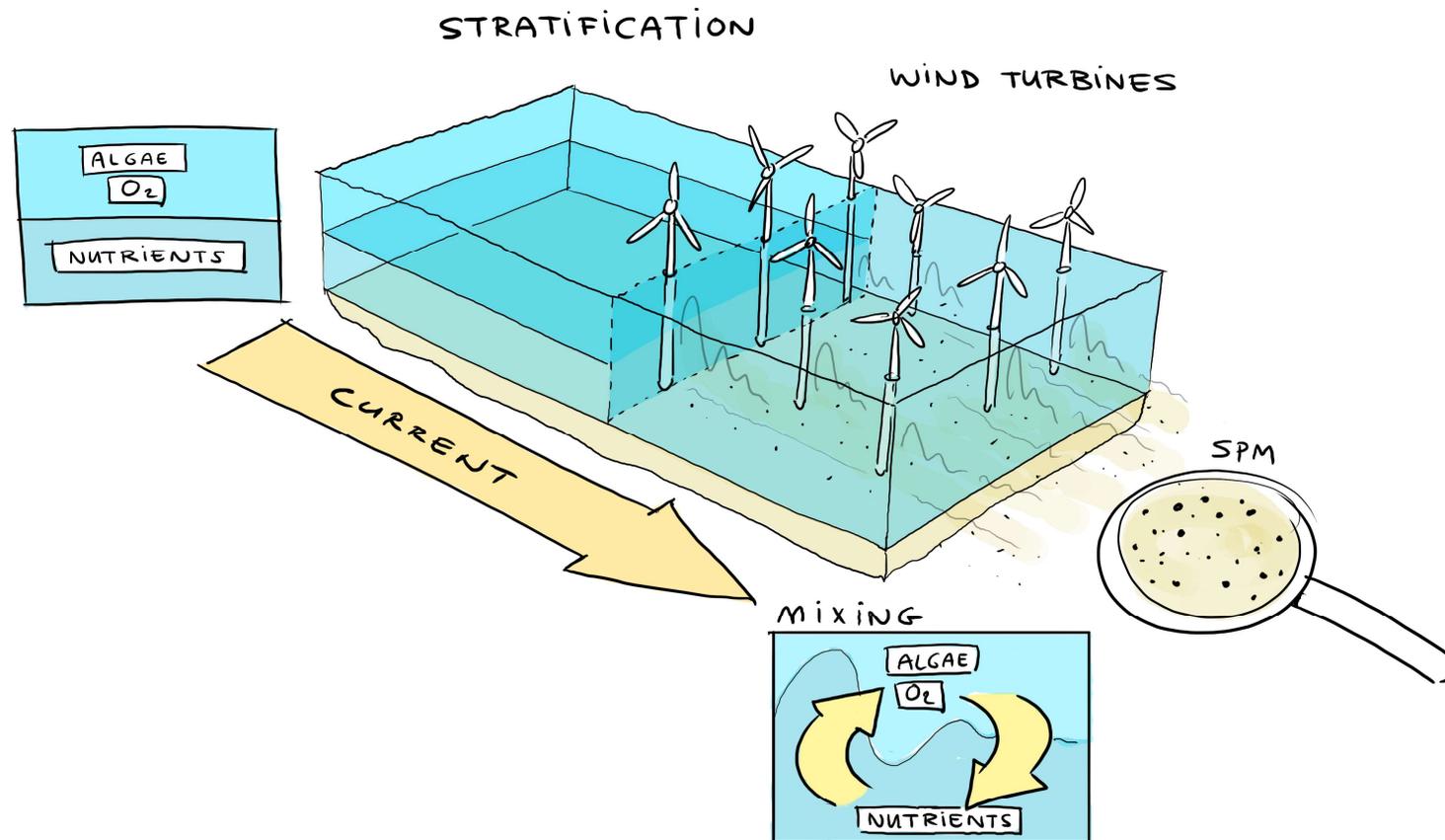
Stratification



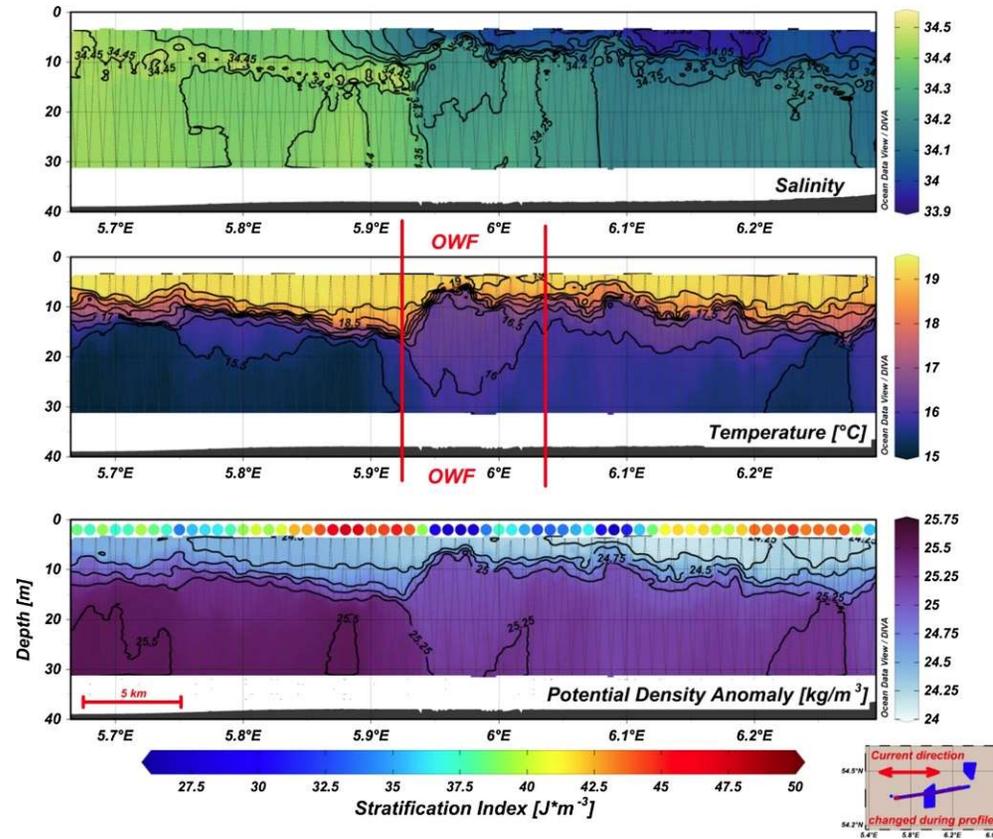
- Salinity
- Temperature

© NTR Focus

Effects offshore wind stratification and mixing



Effects offshore wind stratification and mixing



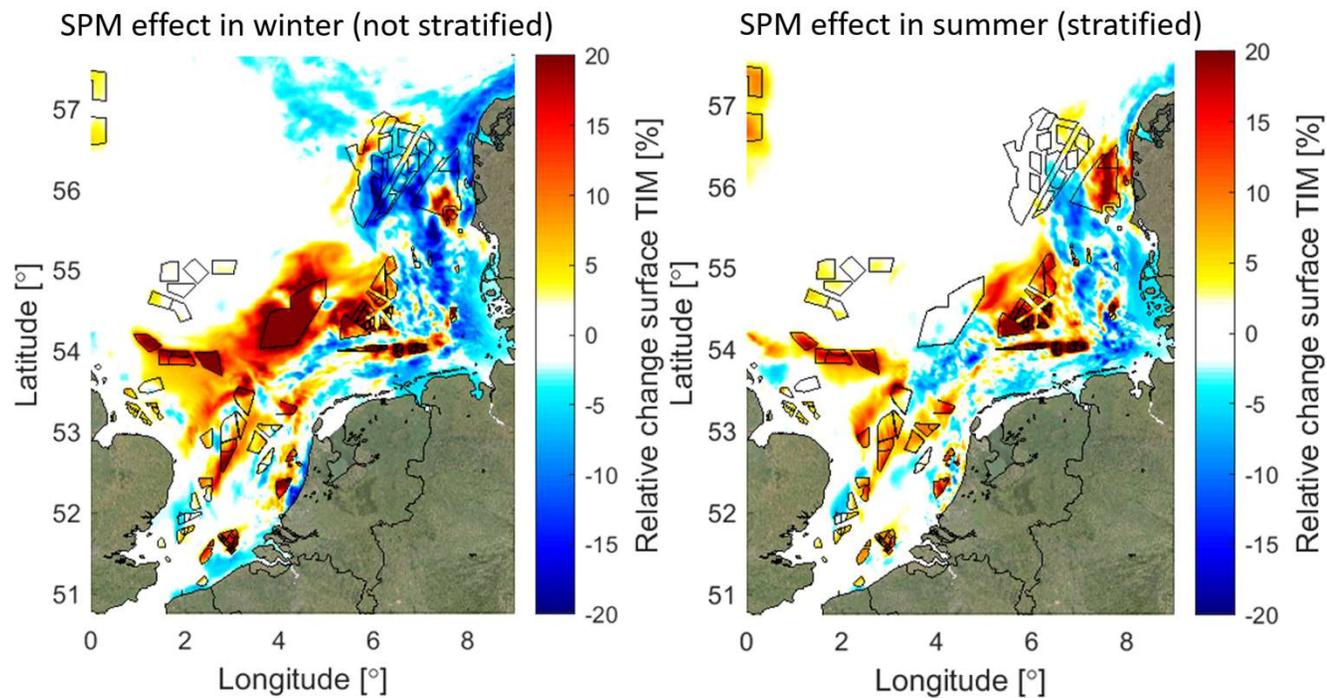
Floeter e.a. Progr. Oceanogr. 2017

Effects offshore wind fine sediment

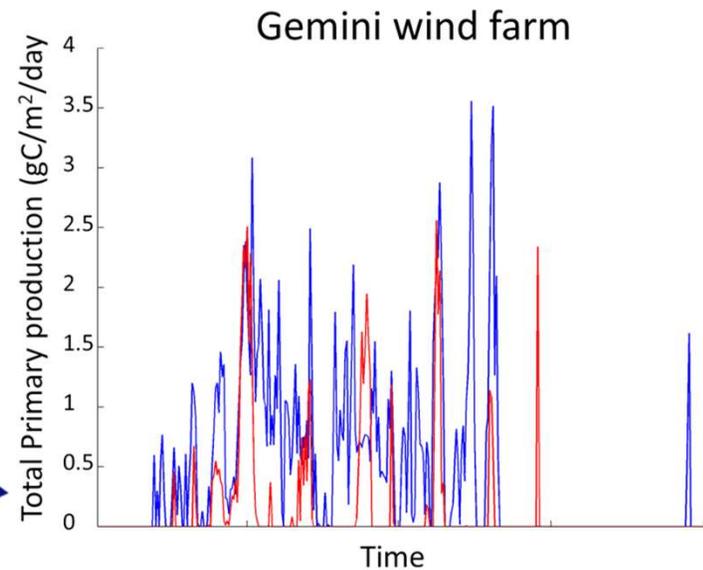
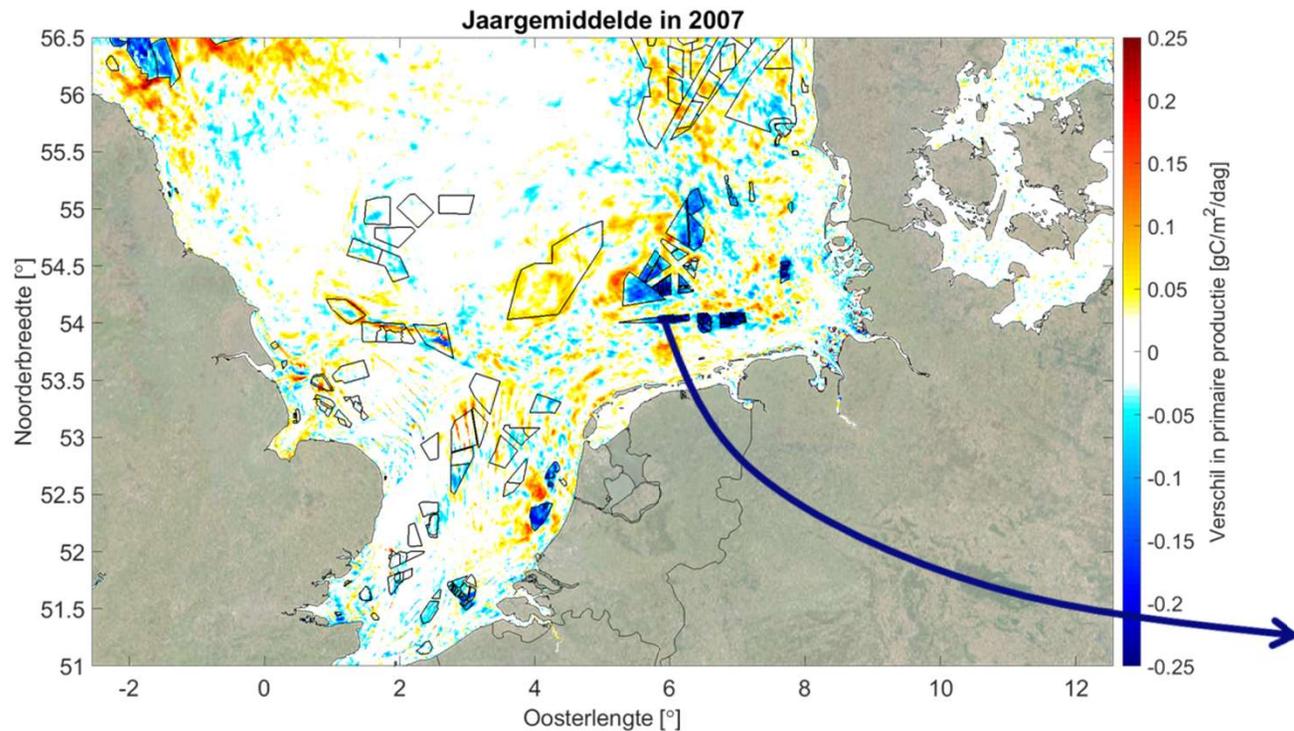


Effects offshore wind stratification and mixing

Difference in SPM concentration



Effects offshore wind primary production

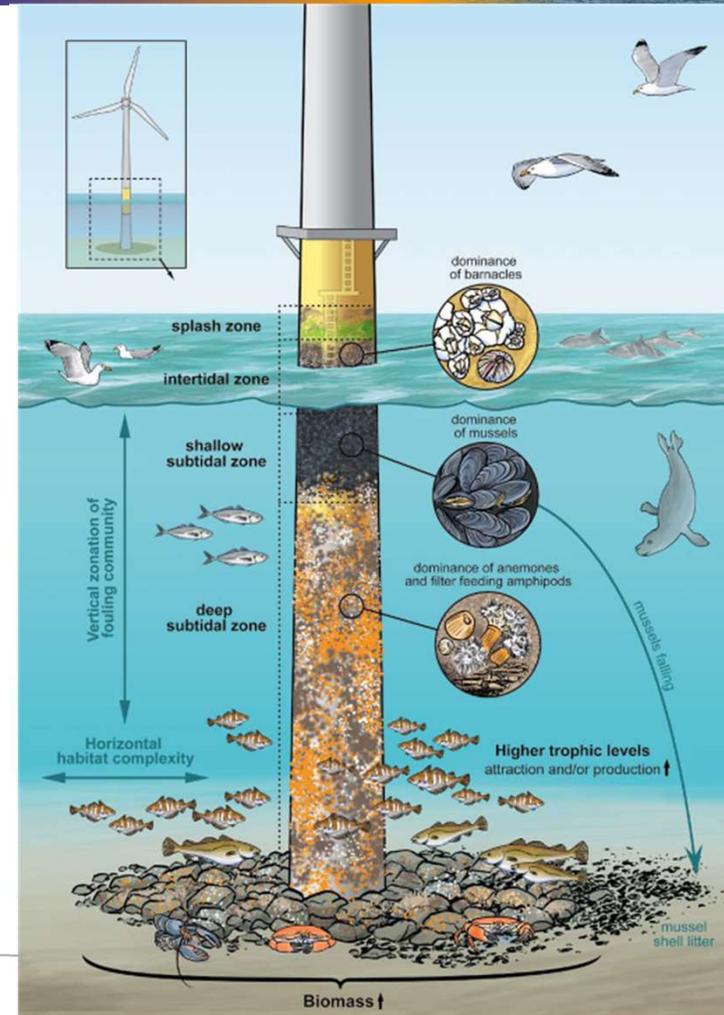
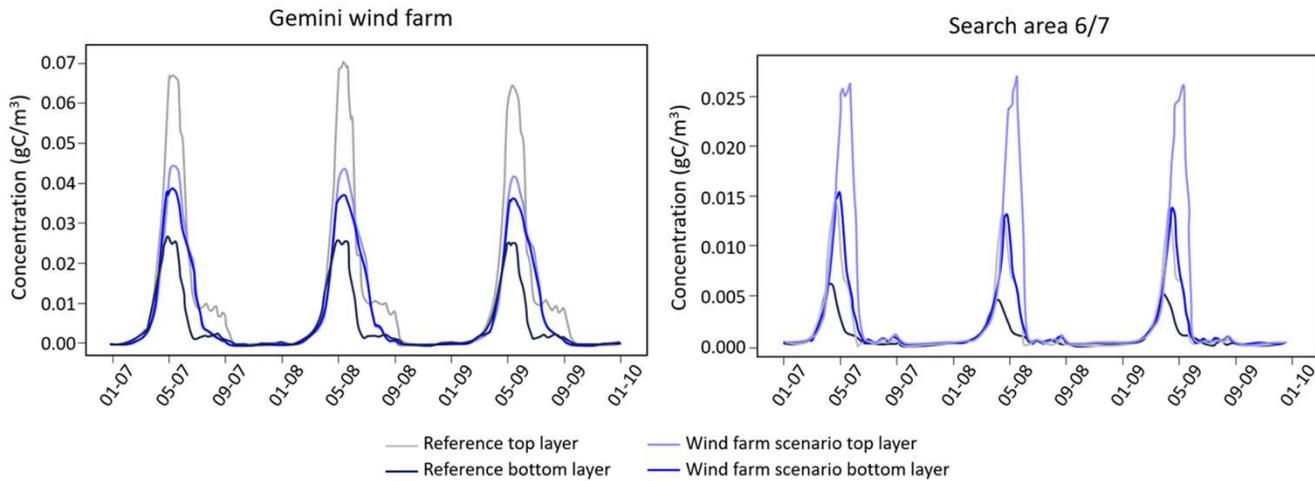


- Local reduction mean annual net primary production up to 60%
- Local increase (search area 6/7) >40%
- Delays in spring bloom

Effects offshore wind food web



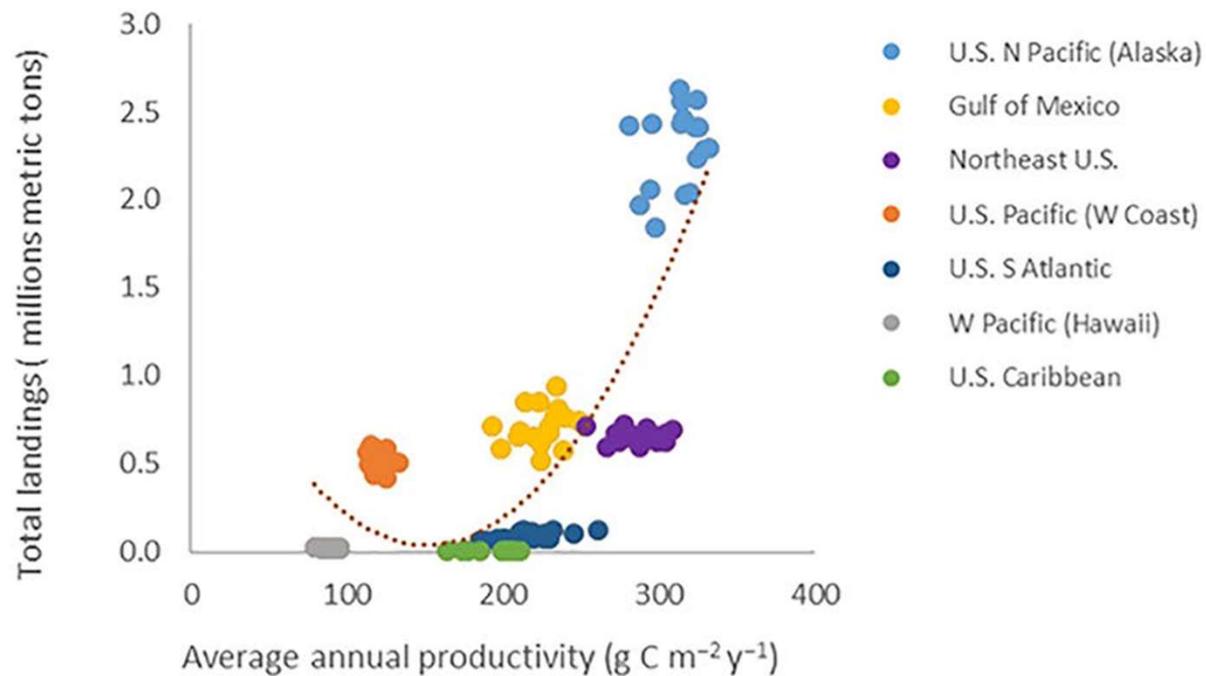
Zooplankton concentrations



- Competition
- Primary Production

Degraer et al Oceanogr. 2020

Effects offshore wind cascade up the foodweb

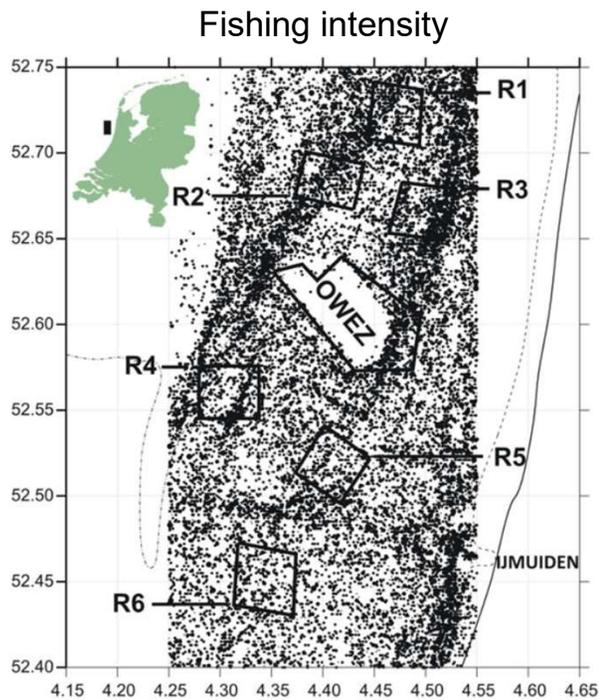


Marshak & Link 2021

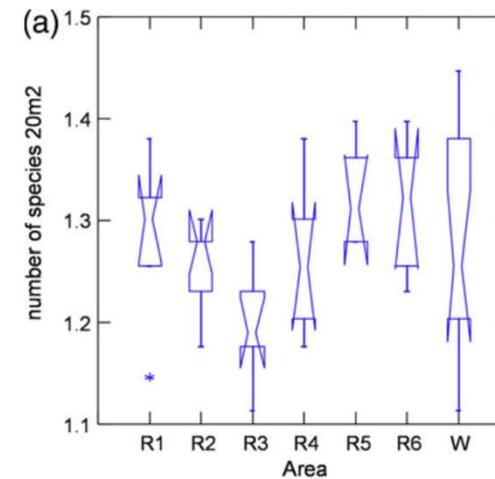
Effects sea bed



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



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		
Avoidance		

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

Effects offshore wind birds / mammals



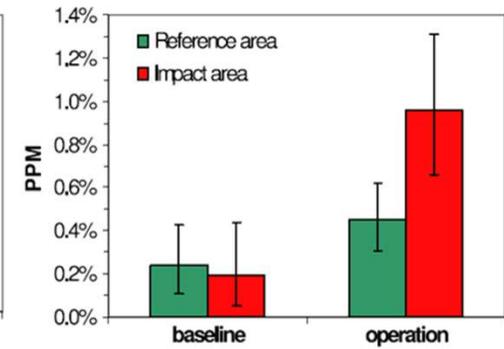
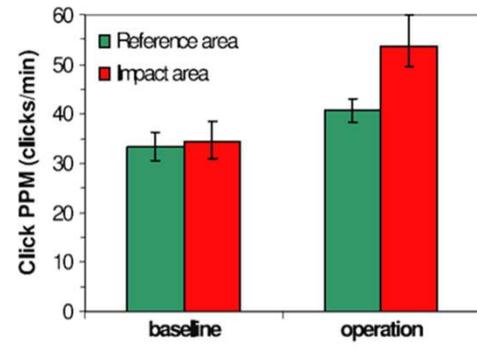
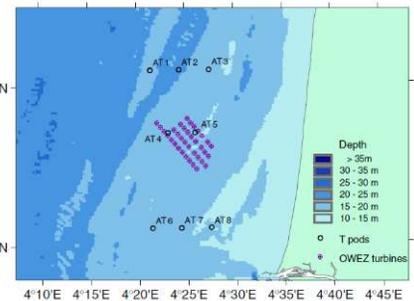
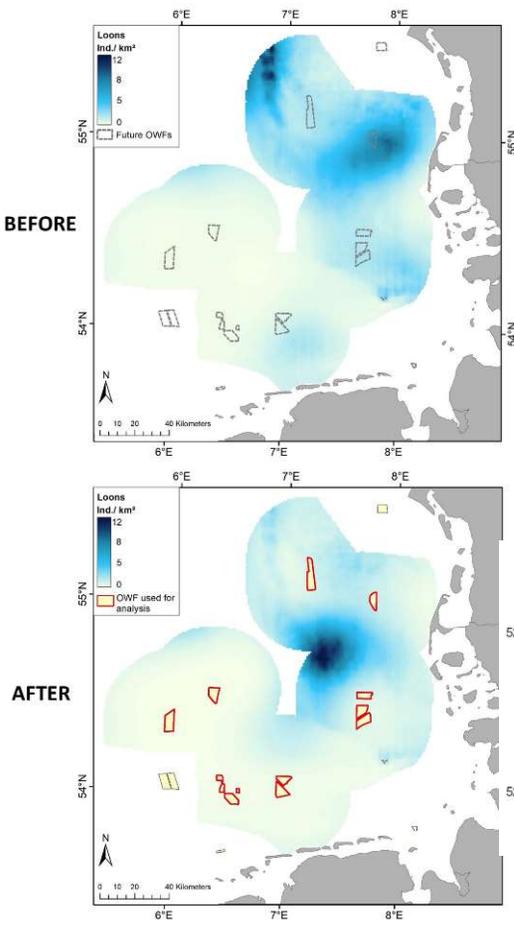
Loon (diver)

Garthe e.a. Sci Rep 2023



Porpoise

Scheidat e.a. Env Res Lett 2011



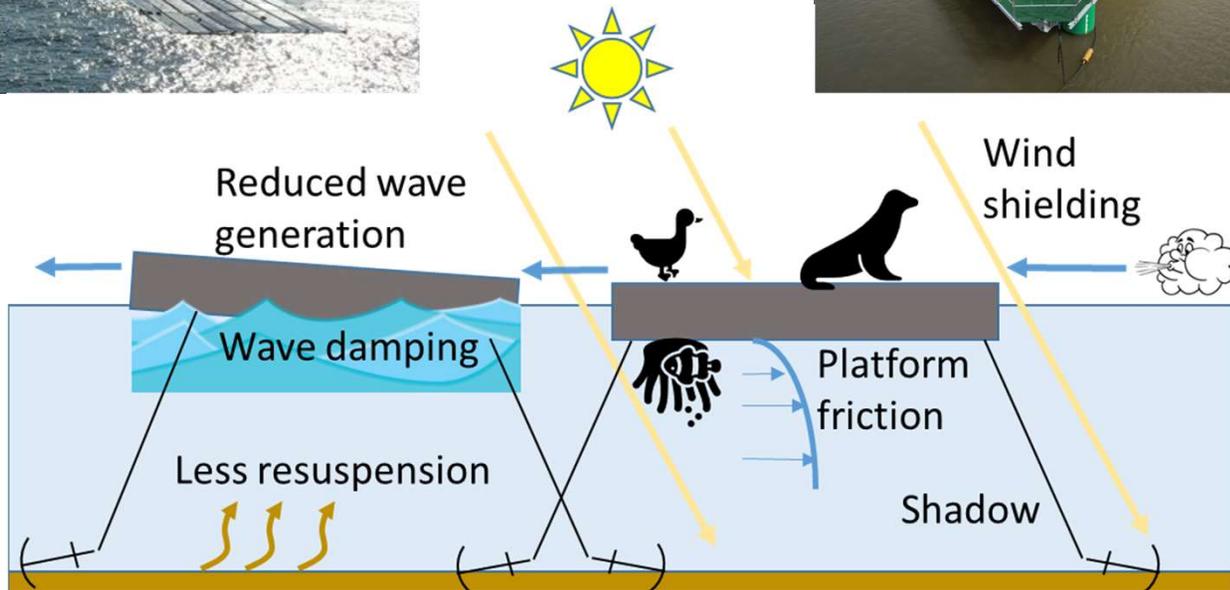
Effects offshore solar



Floating (Oceans of Energy)



Elevated (SOLARDUCK)



Solar vs Wind

- Footprint: 6 km² / GW = 600 x monopile footprint
- 100 x more substrate for fouling communities
- Blocking of light and primary production
- Unknown hydrodynamic effects
- 20 x smaller current blocking area

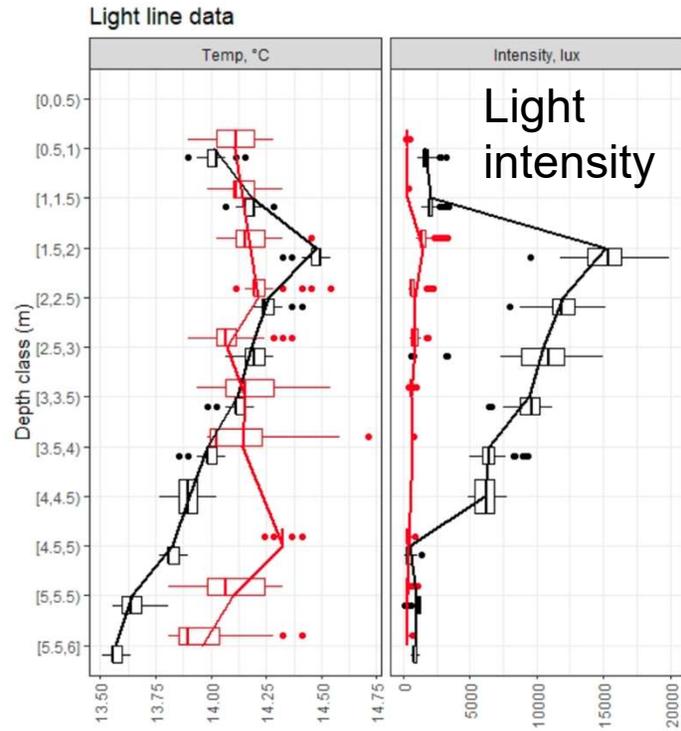
Effects offshore solar



Observations 400 m² platform, Oceans of Energy

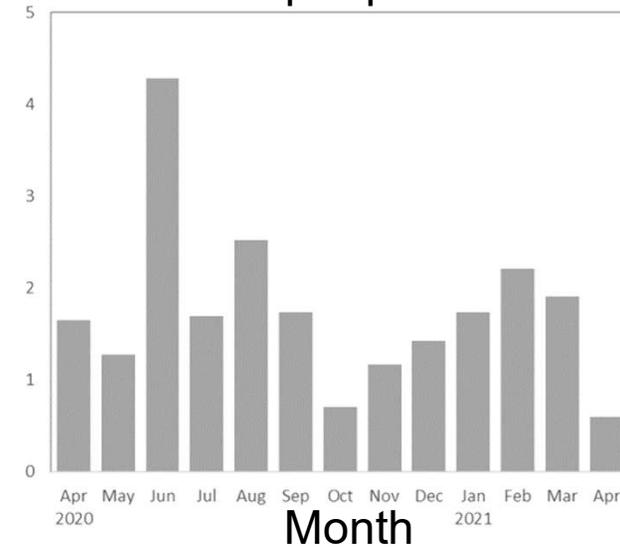


Vlaswinkel e.a. Sustainability 2023



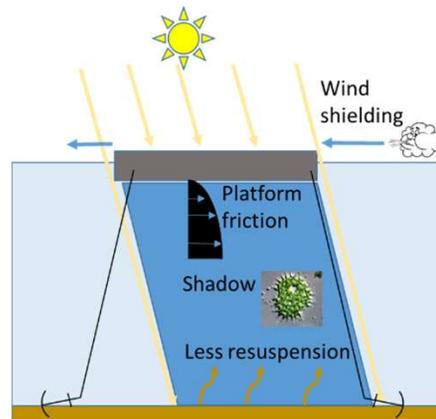
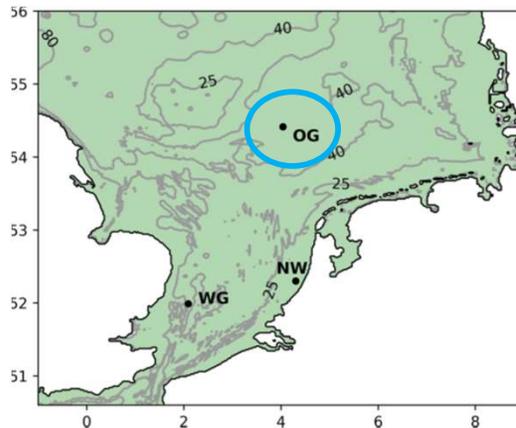
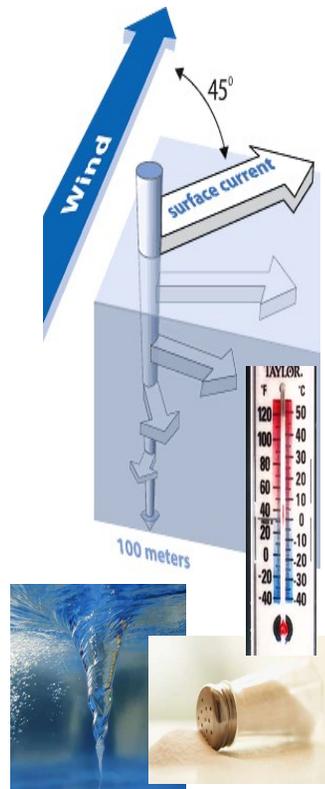
Ref
Farm

Birds per platform

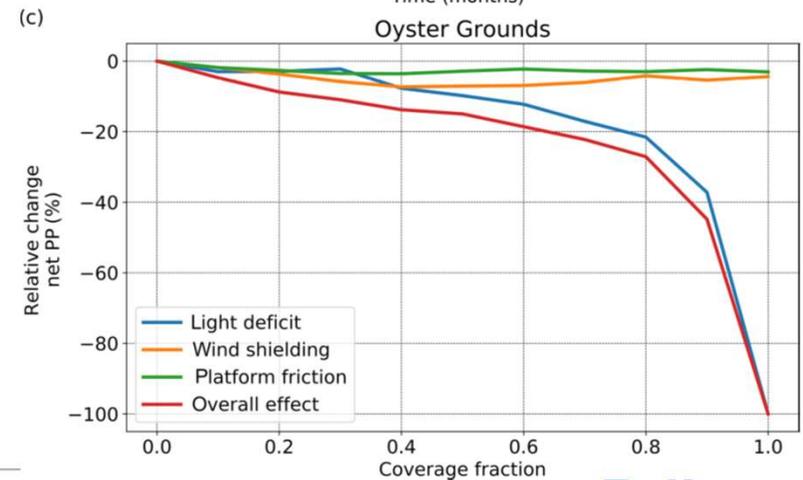
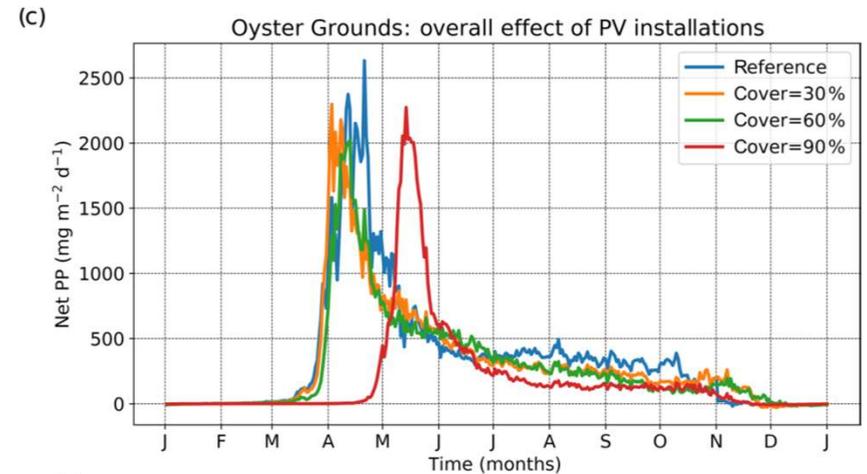


- Shadow confirmed
- Resting function birds

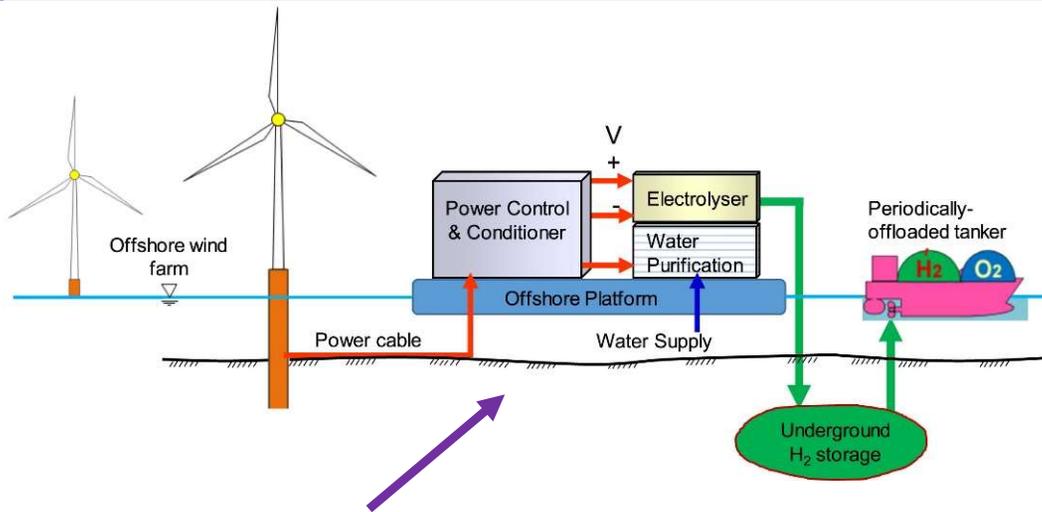
Effects offshore solar



Karpouzoglou et al. Ocean Science 2020



Effects H₂



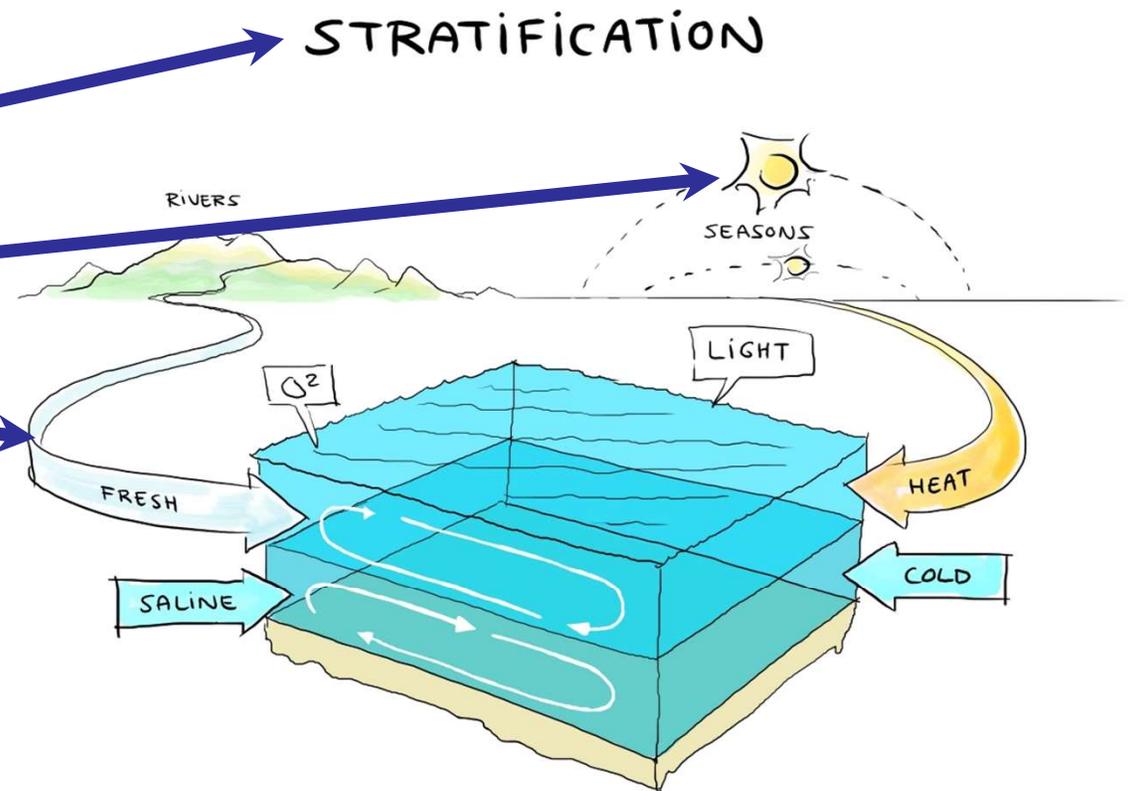
Van Nguyen e.a. *Int J Hydrogen Energy* 2021

- **Discharge:** brine, heat and chlorine
- Fate depends on:
 - Currents
 - Stability/mixing water column
 - Release depth?
 - Timing release wrt. max. tidal currents?
- Affects stratification and marine life?

Research & regulation needed!

Interactions

- Wind - solar
- With climate change
- With nutrient reductions (eutrophication)



Interactions

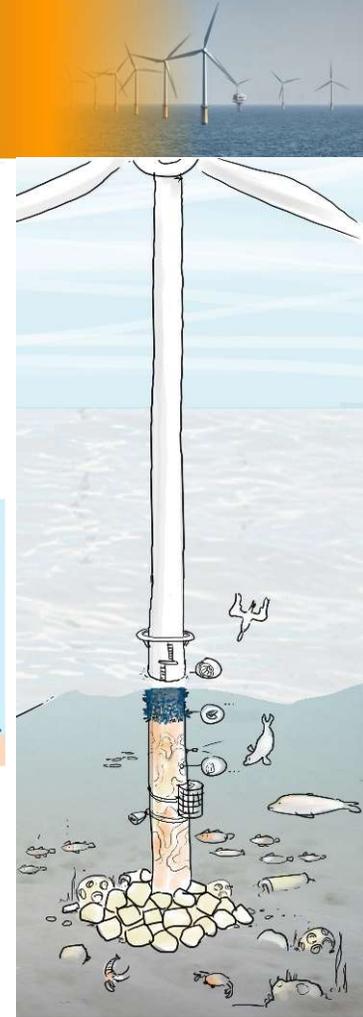
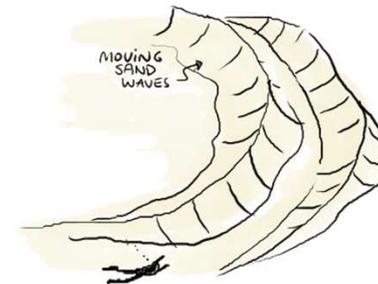
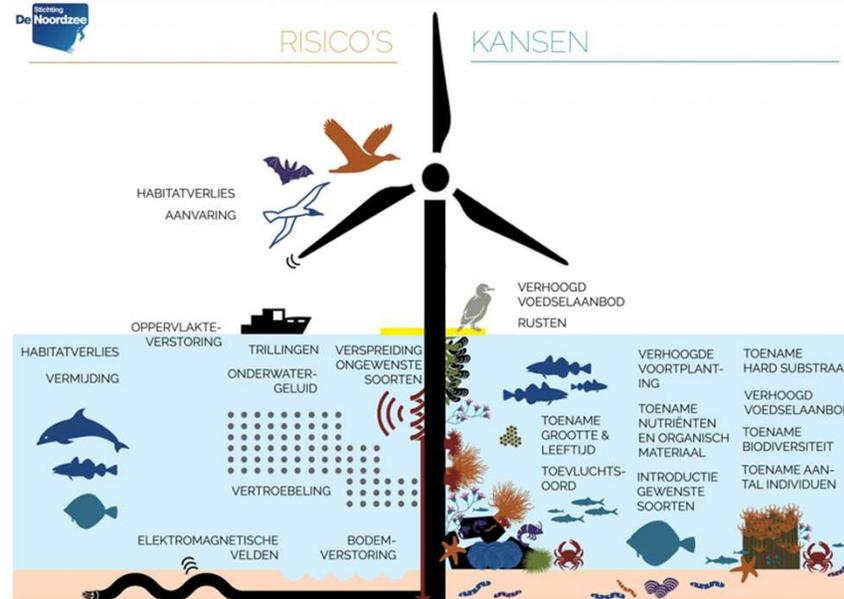
- Wind - solar
- With climate change
- With nutrient reductions (eutrophication)
- With (displaced) fishing



Image credits: Ardea

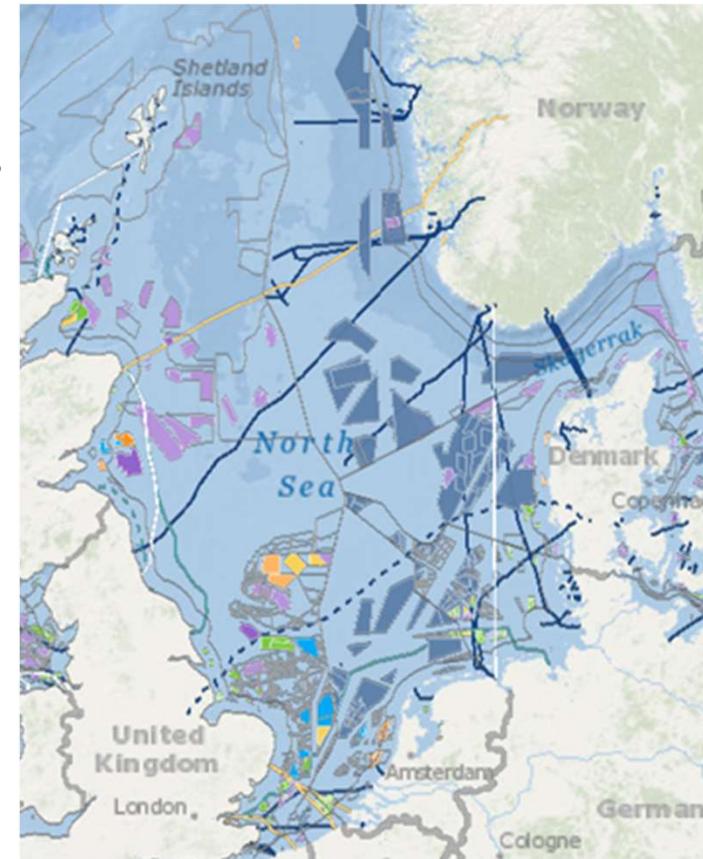
Nature Inclusive Design

- Nature Inclusive Design will increase biodiversity
 - Is costly – what level is enough?
 - Negative effects
 - Fundamental change of habitat (e.g. artificial reef vs. natural mobile sandwaves)
- What do we want and how do we ensure and verify this?
- Is net-positive really possible???



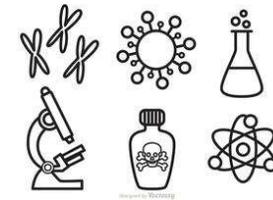
Discussion: What do we want?

- How will the North Sea change?
 - Almost everything will change by small to large amounts
 - Many spatial shifts, from currents through plankton to macrofauna
 - ↓ • Stratification: less wind vs. **structure friction**
 - ↑ • Mussels & hard substrate species: **MORE**
 - ↑ • Connectivity: **UP**
 - ↓ • Primary production: **less?** Priority for research?
- Mitigation measures
 - No solar in wind farms with significantly reduced PP?
 - Fewer, bigger turbines = good?
 - Avoid sensitive and high-production areas?



Discussion: Legal framework

- Scale of impact energy infrastructure – total often more than the sum of the constituents.
- Current evaluation basis: N2000, i.e species with conservation targets
- No inclusion yet of lower trophic levels – currently first discussion
- Challenges are
 - Scientific
 - Governance / policy
 - Legal



Discussion: Legal framework

- Scale of impact energy infrastructure – total often more than the sum of the constituents.
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- Challenges are
 - Scientific
 - Governance / policy
 - Legal
- NL target 2030: 21 GW Offshore wind!



Call NWO Sea of Turbines



NO-REGRETS – North Sea Renewable Energy: Gaining the Required Ecological Knowledge for the Transition



Prof. Myron A. Peck NIOZ (WUR)- myron.peck@nioz.nl



Photo credit: Erik Hendriks

Questions?

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