



Deltares

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

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29 september 2023

Energy transition



OSTEND DECLARATION OF ENERGY MINISTERS

ON

THE NORTH SEAS AS EUROPE'S GREEN POWER PLANT

DELIVERING CROSS-BORDER PROJECTS

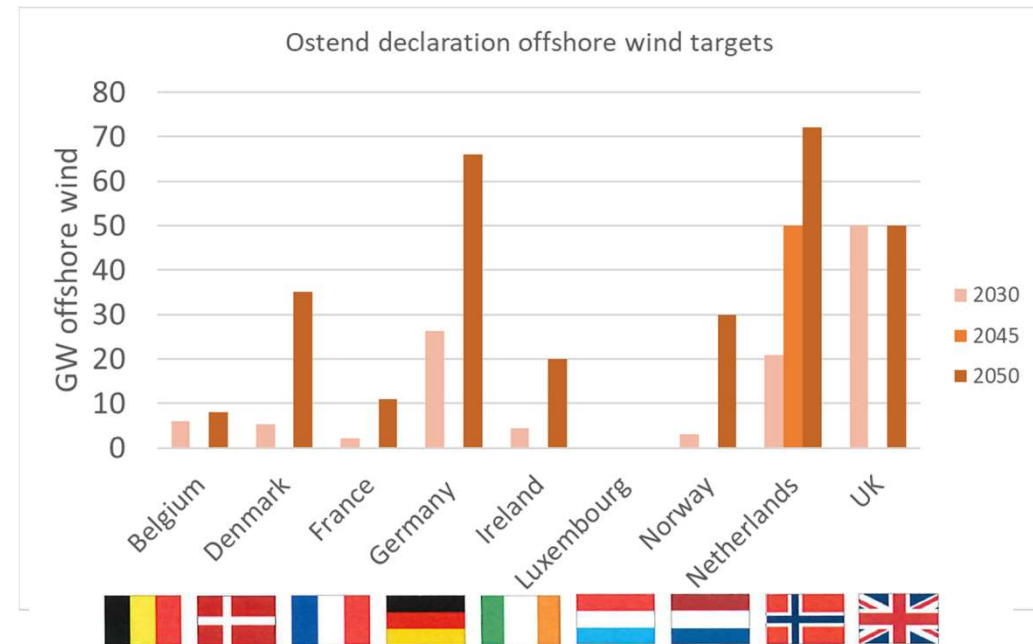
AND ANCHORING THE RENEWABLE OFFSHORE INDUSTRY IN EUROPE

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

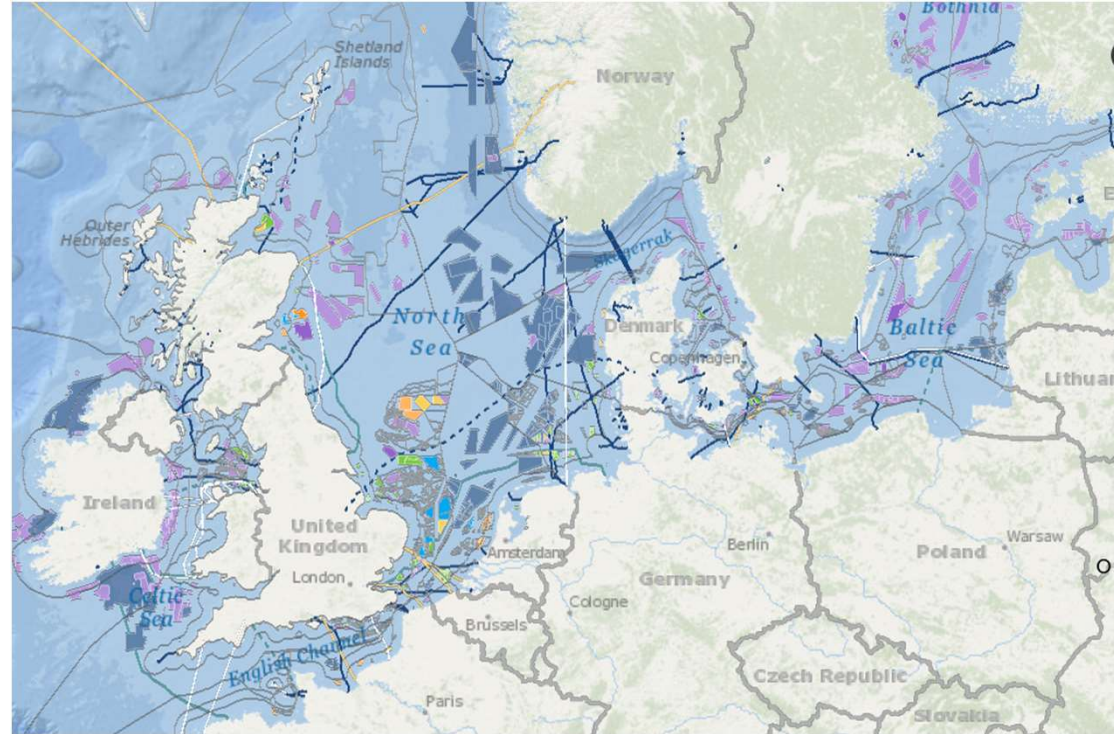


Energy transition

■ Wind, solar, hydrogen



- Winds and heat balance
- Atmosphere-Ocean exchange
- 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
- Pesticides, chemicals and (heavy) metals



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

Space, time and scale dependent

Effects on wind

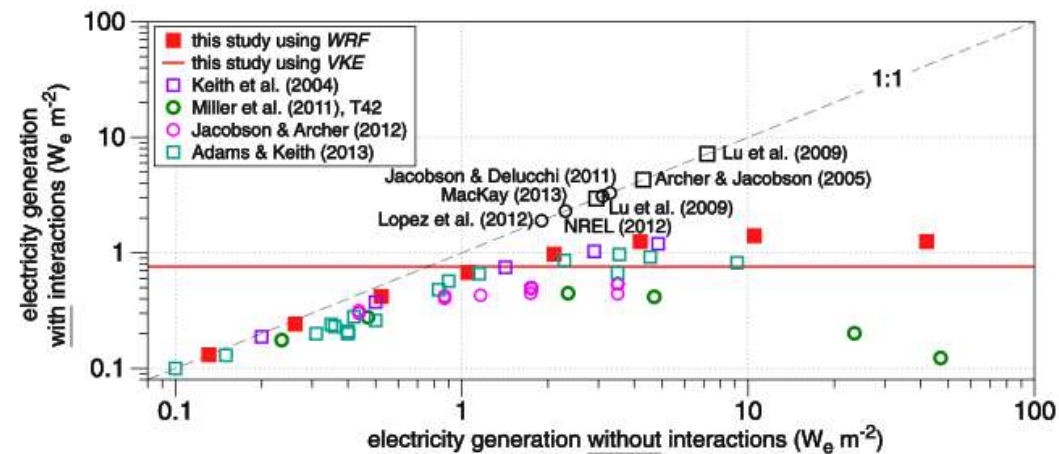
- OWF's extract momentum from the wind – strongly depends on replenishment of energy from higher layers
- Globally the vertical flux of energy ranges around 2 W m^{-2}

Image credits: London array



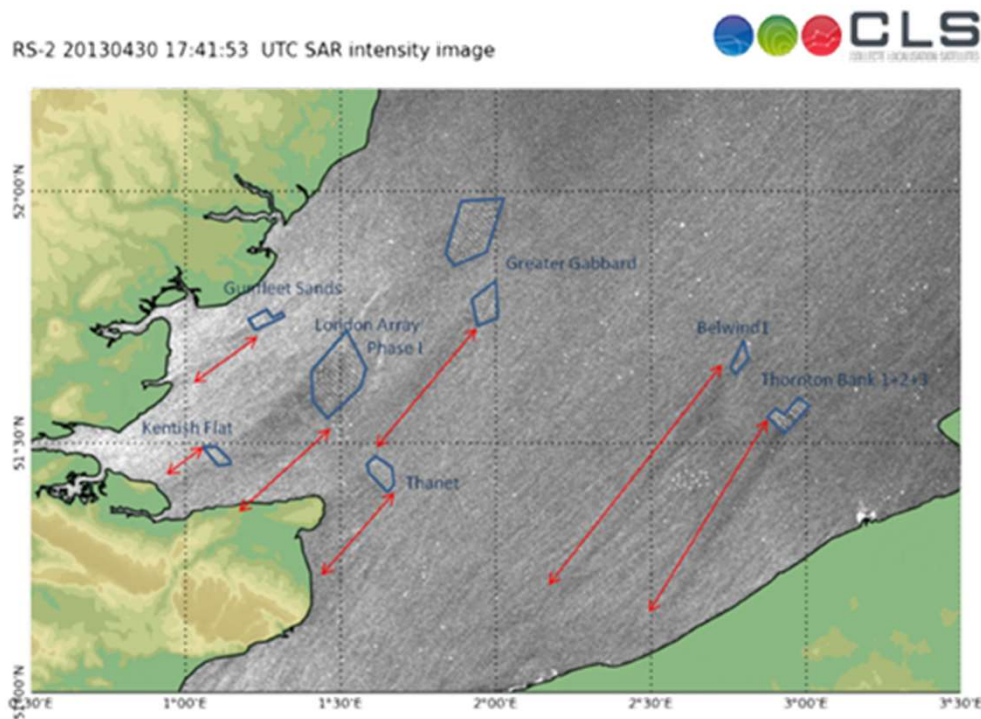
Effects on wind

- 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



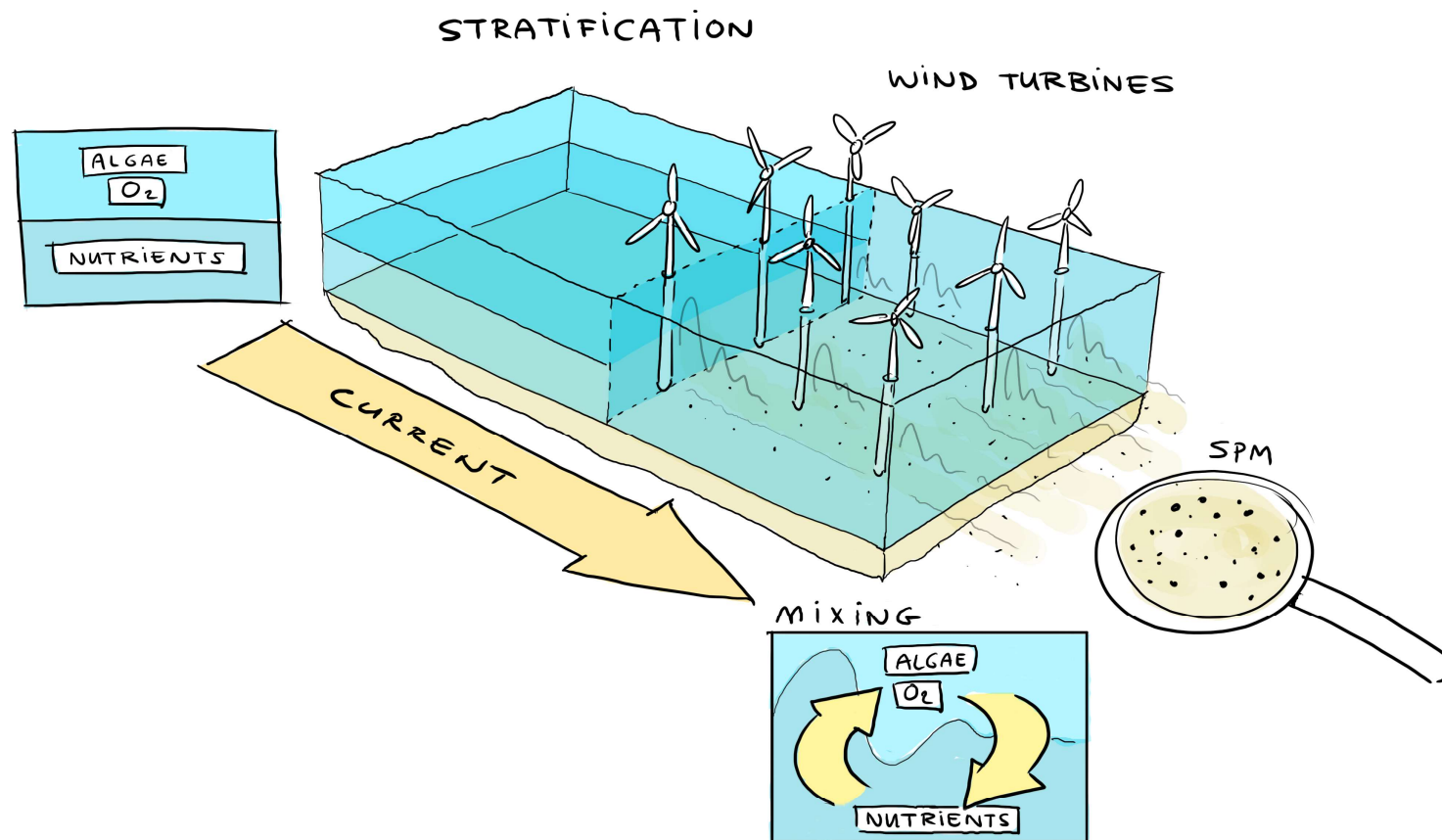
Hasager et al 2015



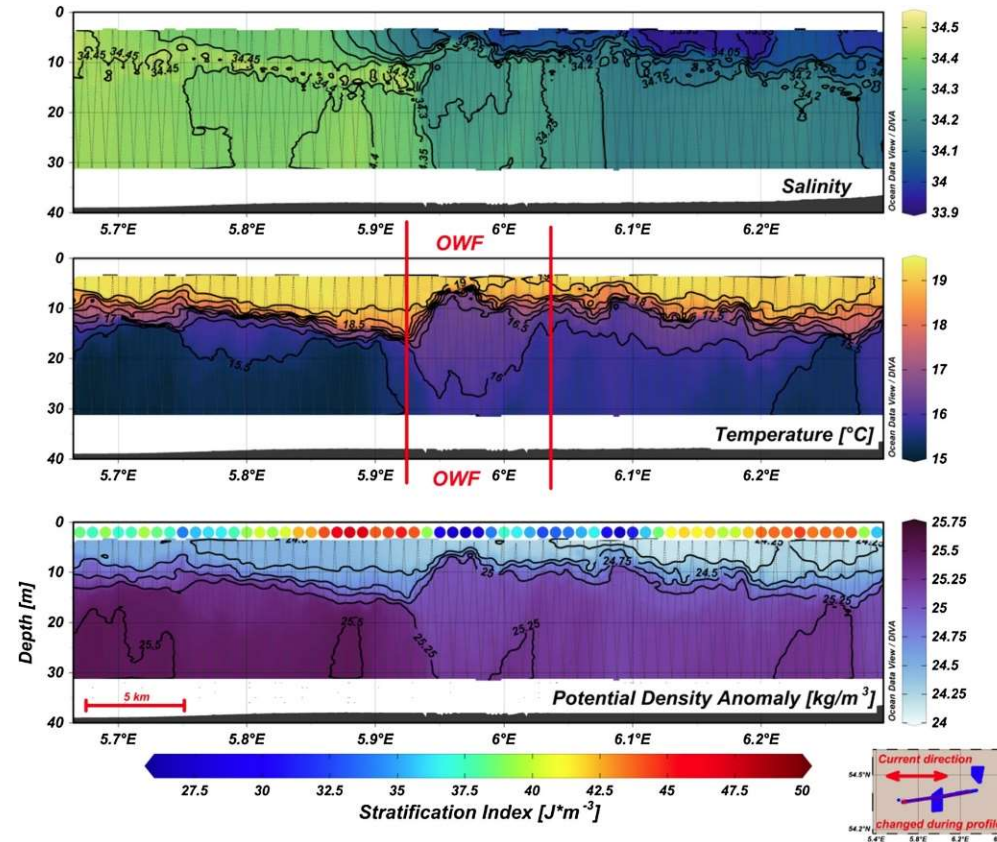
Image Credit: Arne Diercks, ECOGIG

- Wind wakes up to 70 km, a few % reduction

Effects offshore wind stratification and mixing



Effects offshore wind stratification and mixing



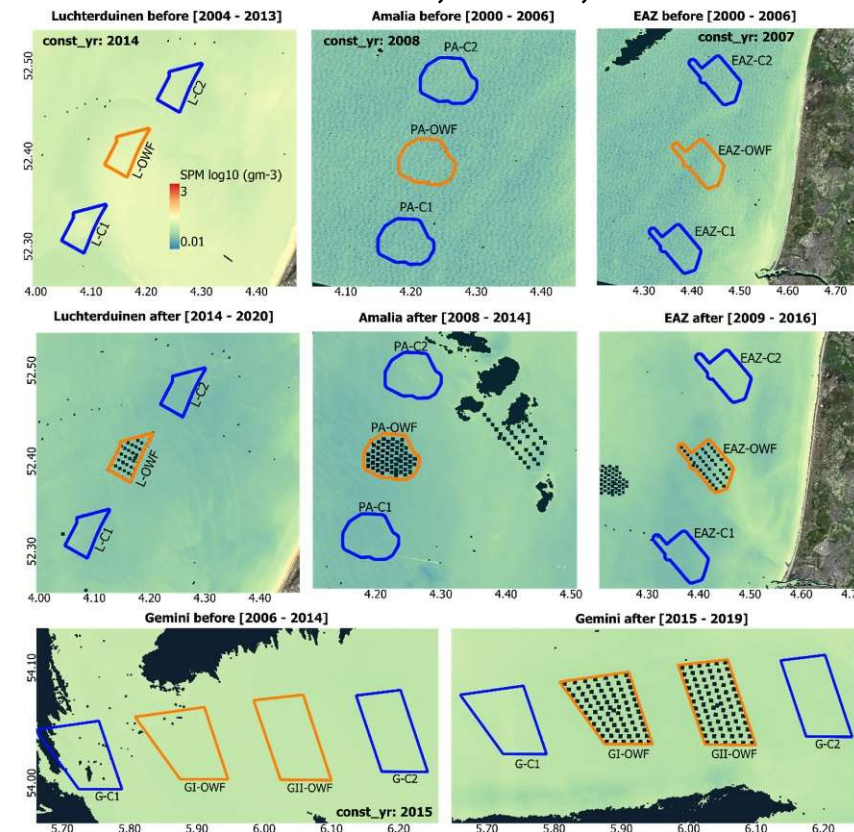
Floeter e.a. Progr. Oceanogr. 2017

Effects offshore wind fine sediment

Image credits: NASA Earth Observatory



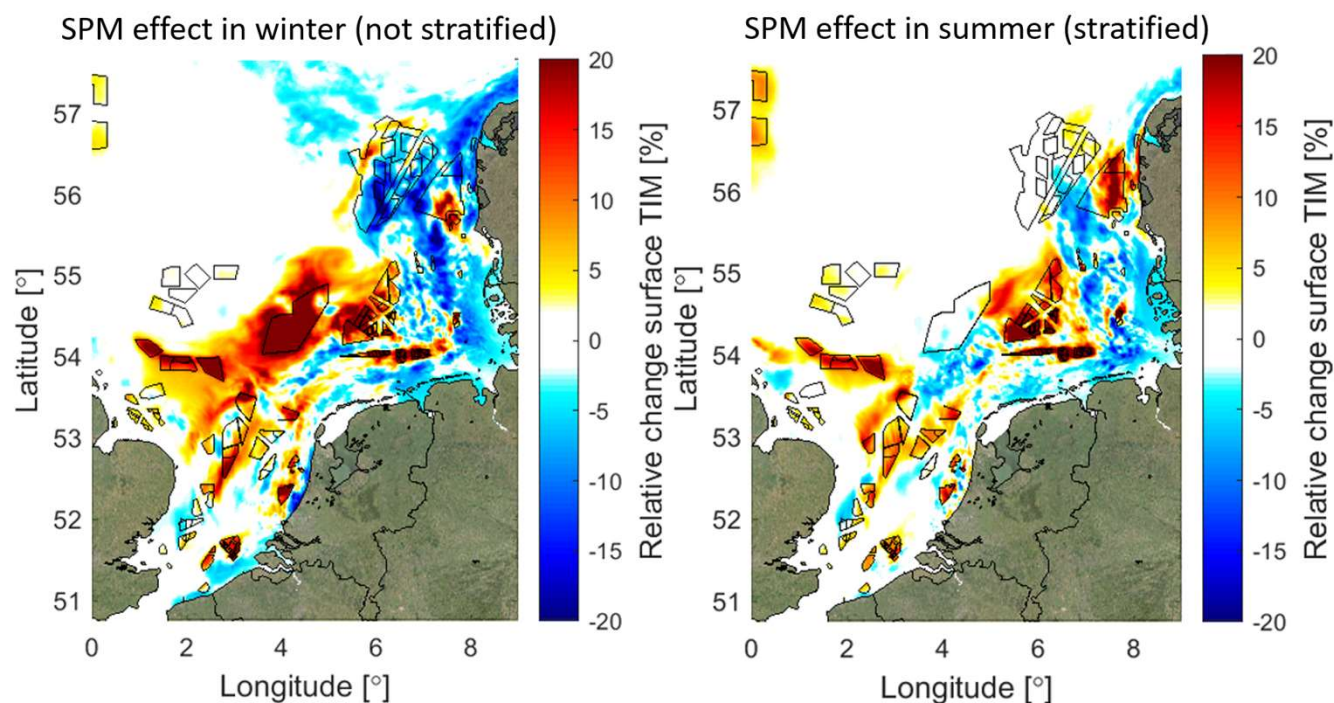
Satellite data, SPM, BACI



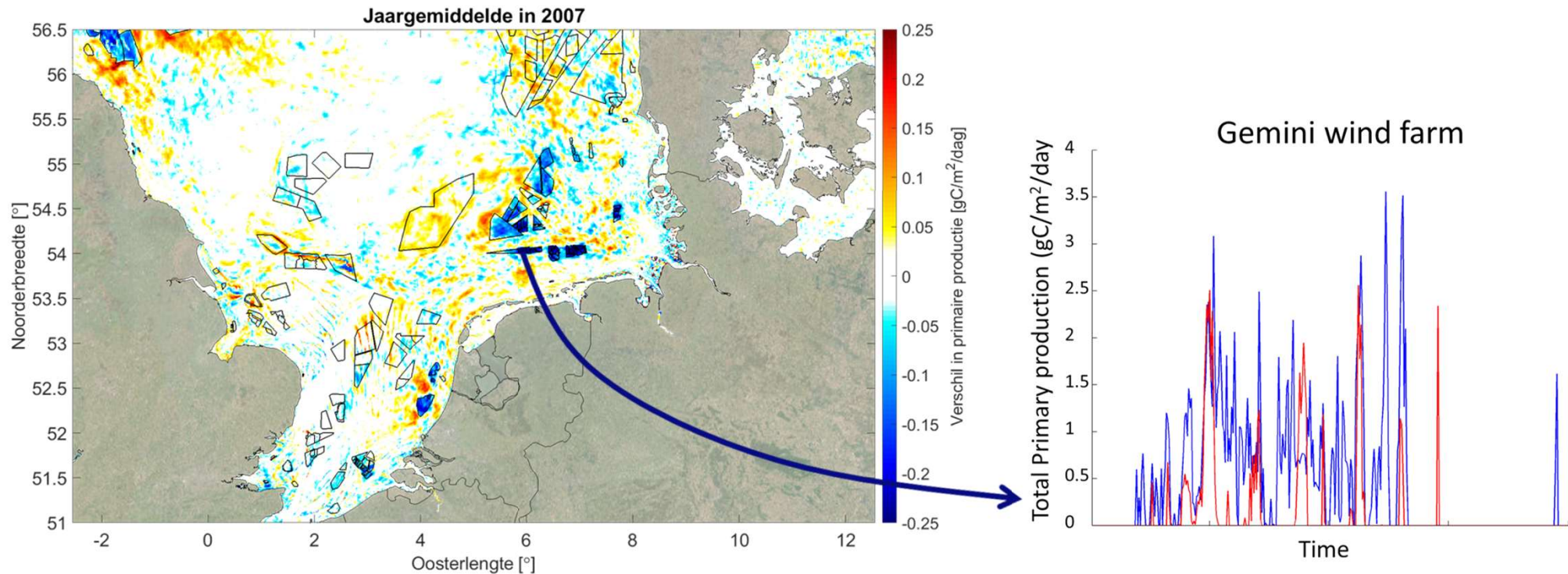
Brandao e.a. Sci Tot Env 2023

Effects offshore wind stratification and mixing

Difference in SPM concentration

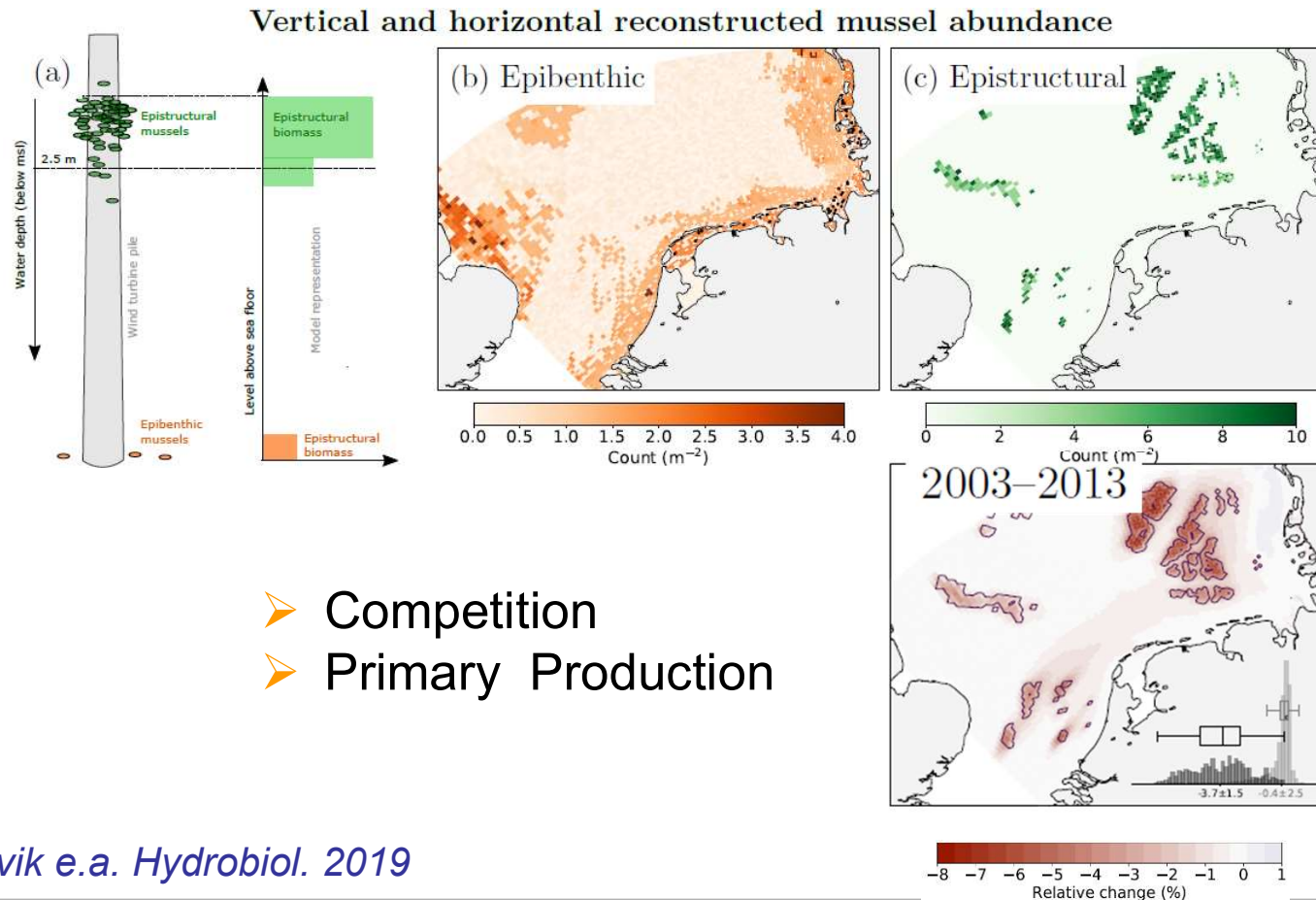


Effects offshore wind primary production

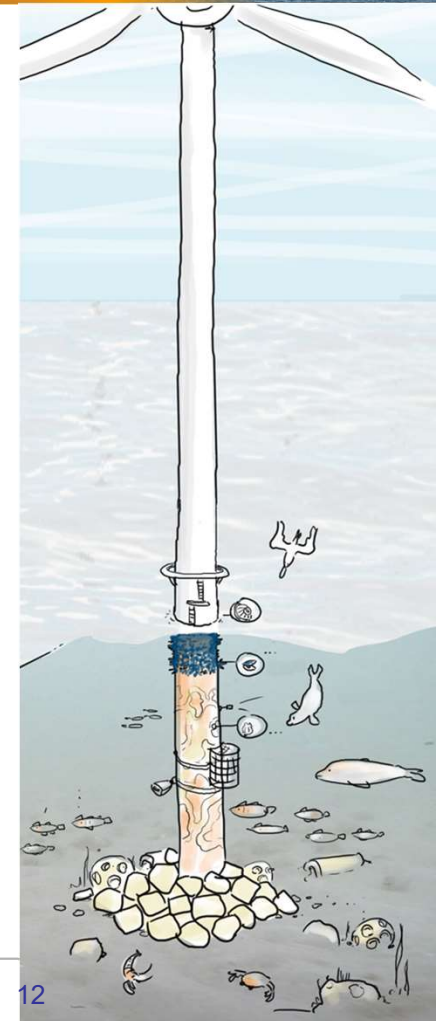


- Local reduction mean annual net primary production up to 60%
- Local increase (search area 6/7) >40%

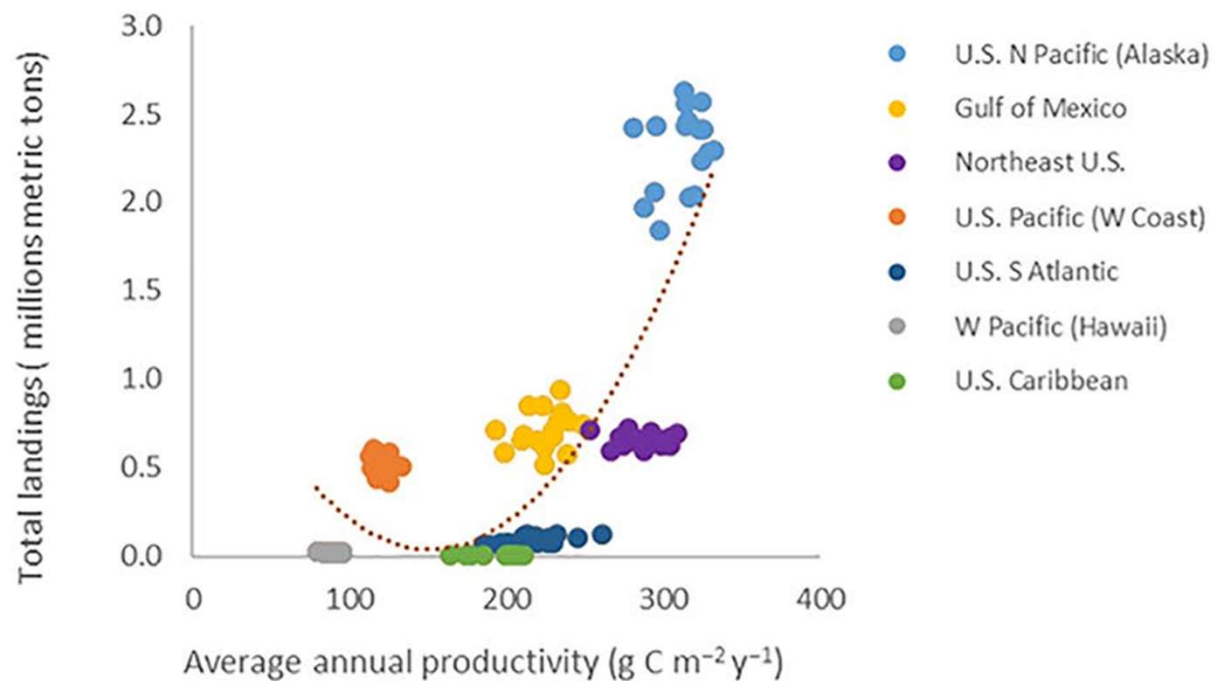
Effects offshore wind food web



Slavik e.a. *Hydrobiol.* 2019

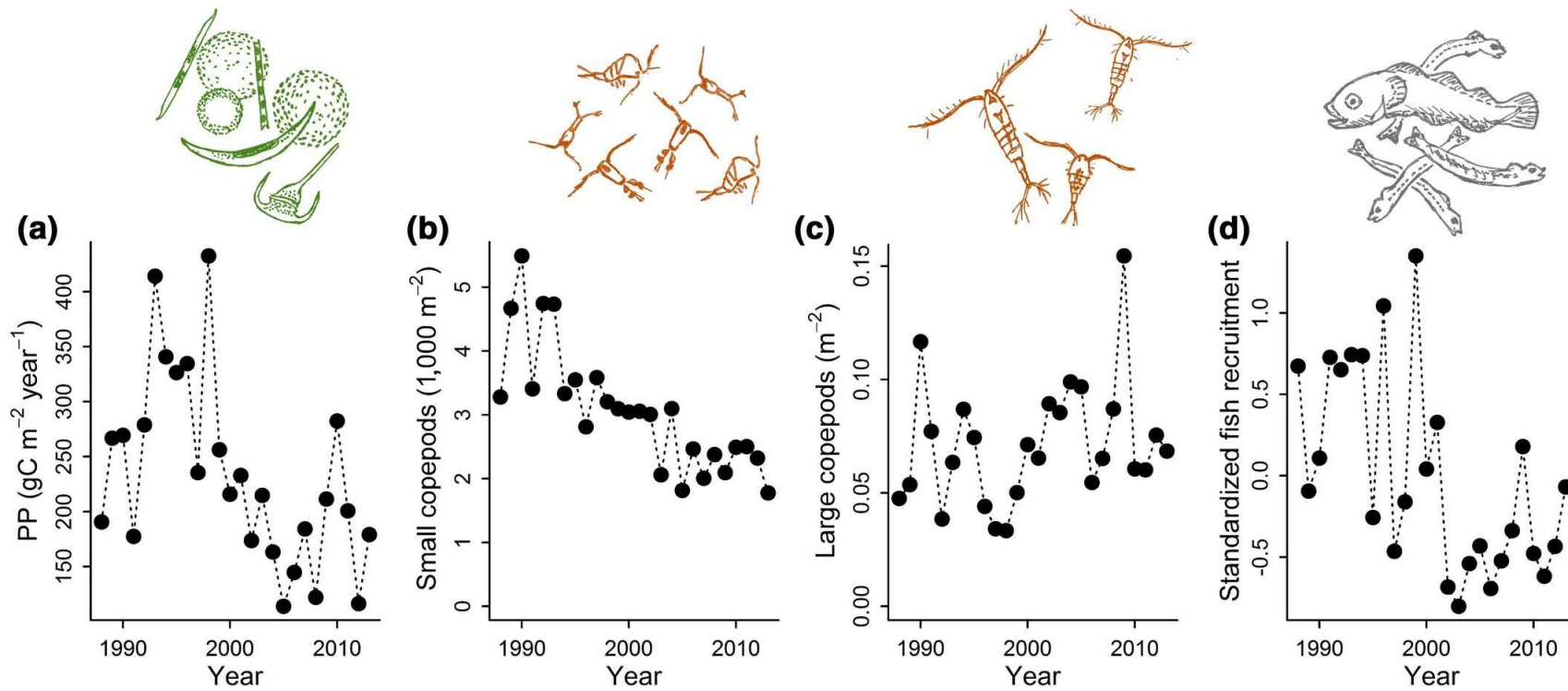


Effects offshore wind cascade up the foodweb



Marshak & Link 2021

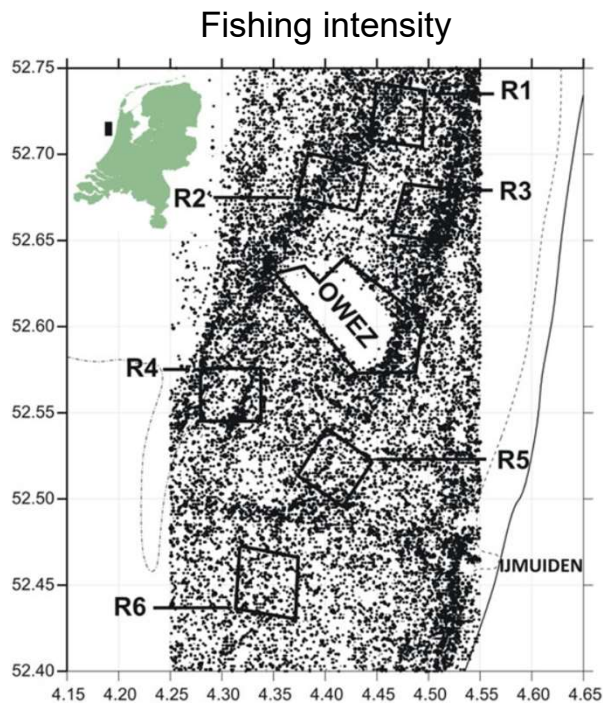
Effects offshore wind cascade up the foodweb



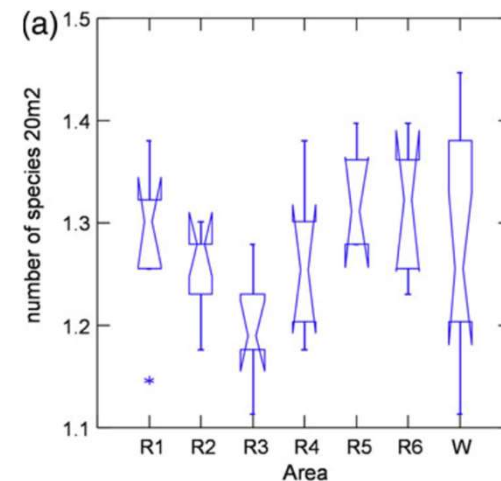
Capuzzo et al 2017

Effects sea bed

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



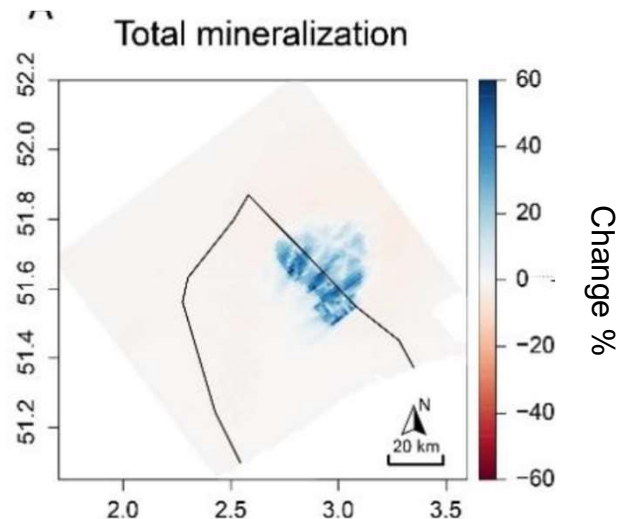
Bergman e.a. JMS 2015



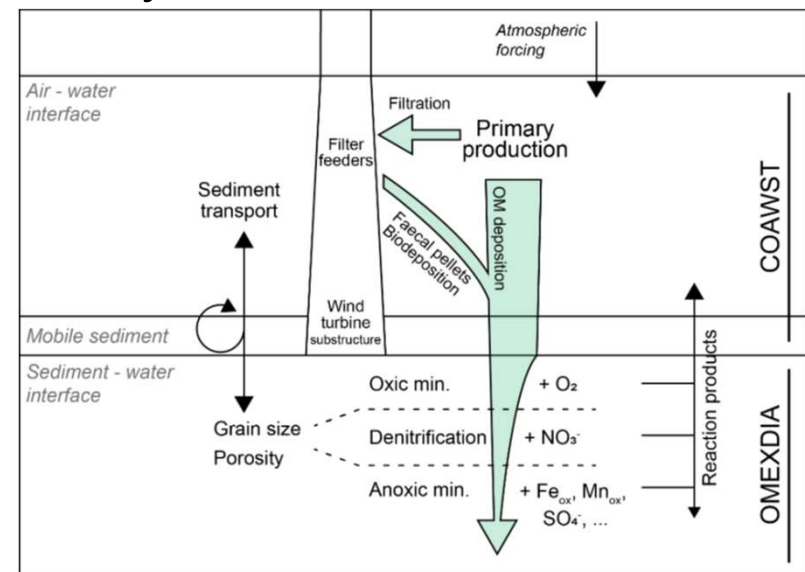
➤ Slight increase in species diversity close to turbines (review paper several wind farms)

Coolen e.a. J Env Man 2022

Effects sea bed



Increase in benthic biogeochemical activity in wind farm



De Borger e.a. Front. Mar. Sci 2021

Effects offshore wind birds / mammals



| Behaviour | Birds | Mammals |
|--------------|---|----------|
| Attraction | Black-backed gull, herring gull, red-breasted merganser, great cormorant, European shag | Porpoise |
| Inconsistent | Longtailed duck, common scoter, Manx shearwater, razorbill, common guillemot, little gull, sandwich tern, northern fulmar | |
| Avoidance | Northern gannet, divers, Black-legged Kittiwake | |

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

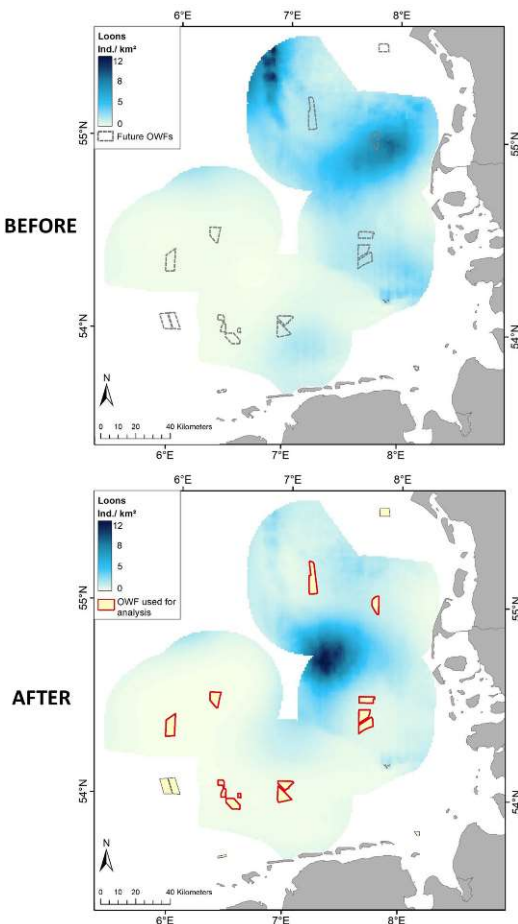
Effects offshore wind birds / mammals



Loon (diver)

Garthe e.a. Sci Rep 2023

Image credits Tyler Ficker



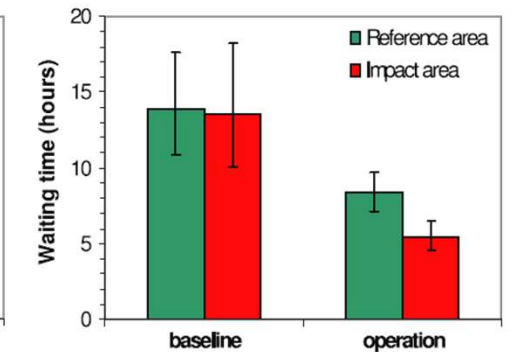
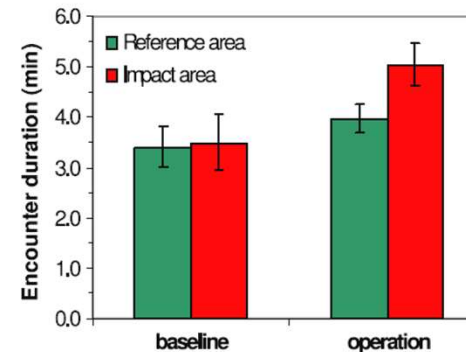
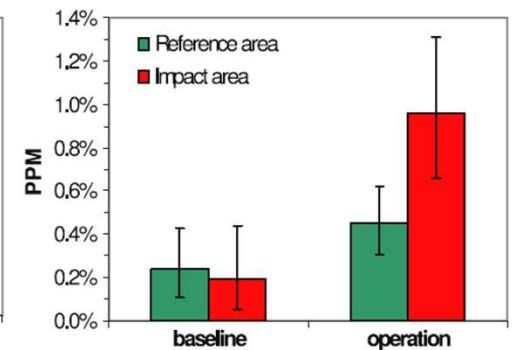
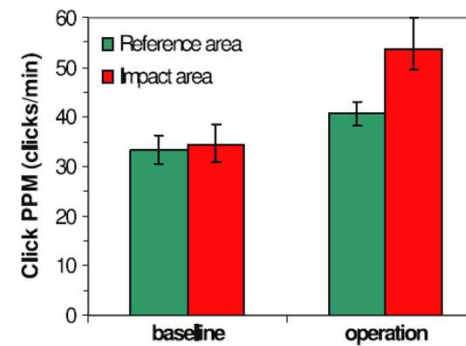
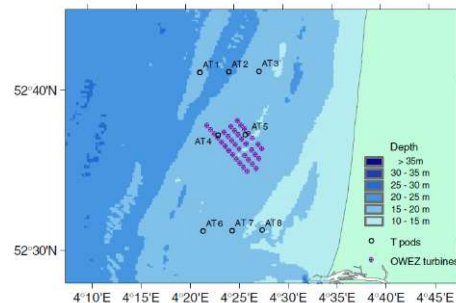
Effects offshore wind birds / mammals



Porpoise

Scheidat e.a. Env Res Lett 2011

Image credits: Wikipedia



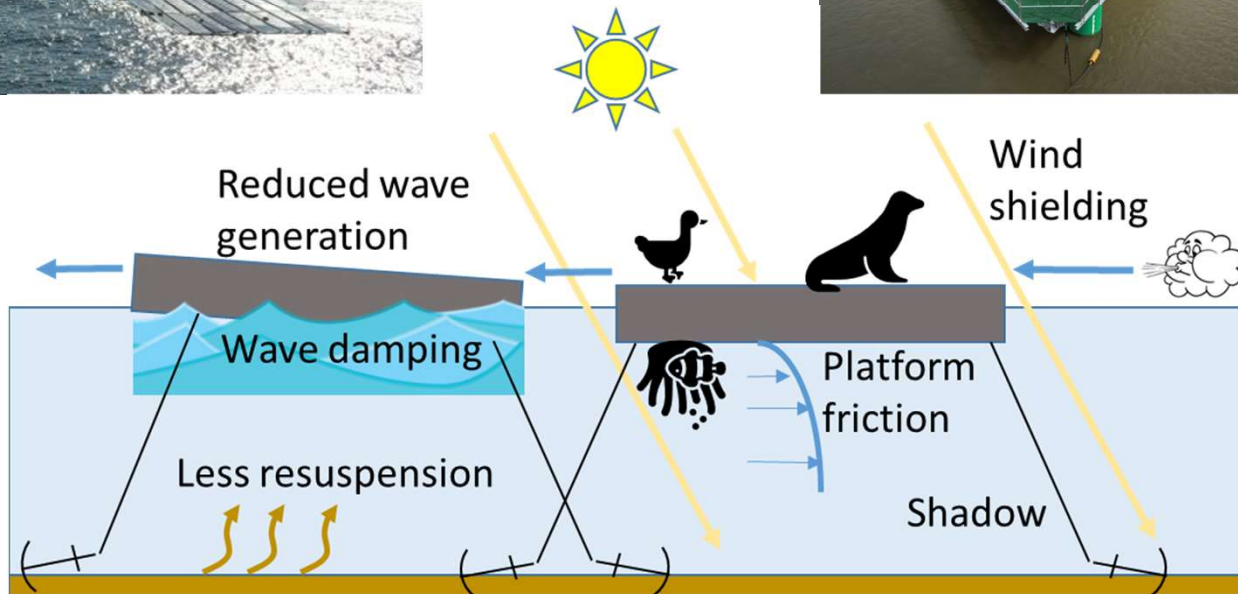
Effects offshore solar



Floating (Oceans of Energy)



Elevated (SOLARDUCK)



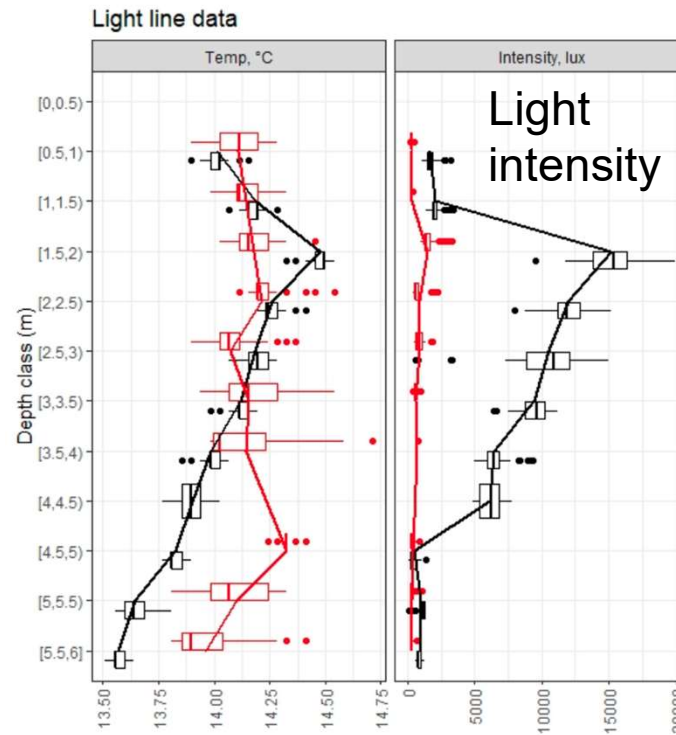
Solar vs Wind

- Footprint: $6 \text{ km}^2 / \text{GW}$
= 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

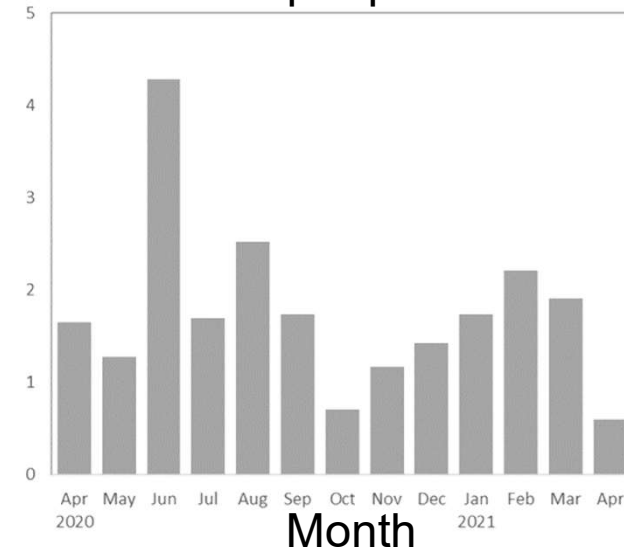


Observations 400 m²
platform, Oceans of Energy



Ref
Farm

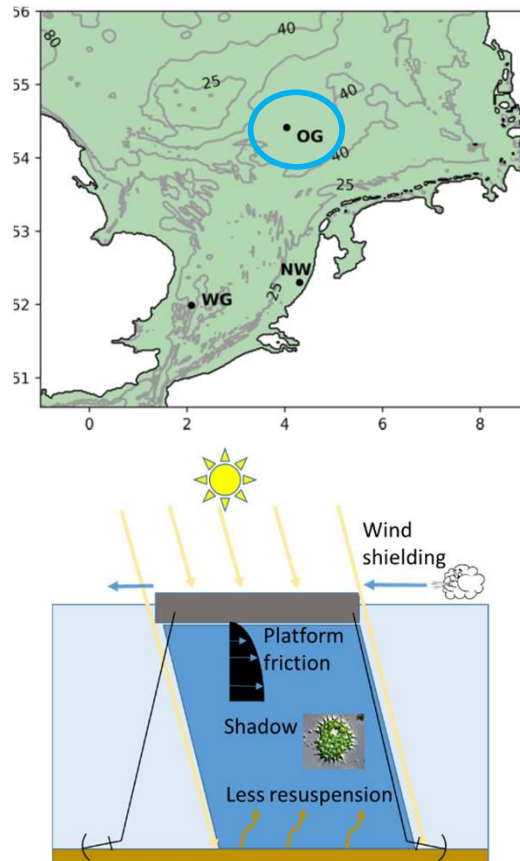
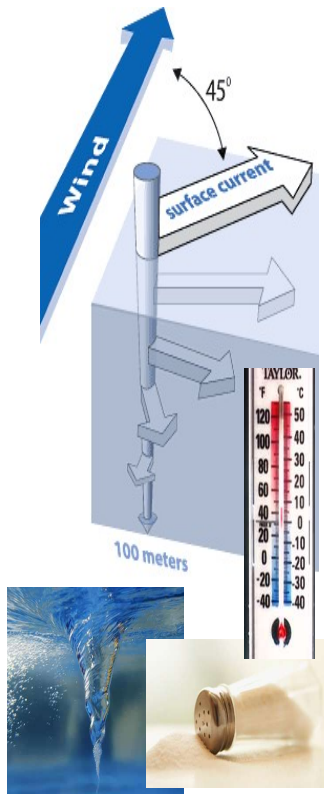
Birds per platform



Vlaswinkel e.a. Sustainability 2023

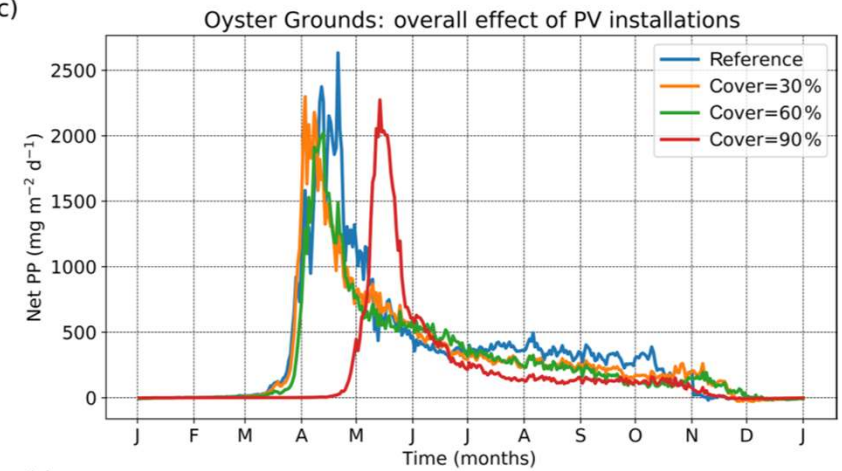
- Shadow confirmed
- Resting function birds

Effects offshore solar

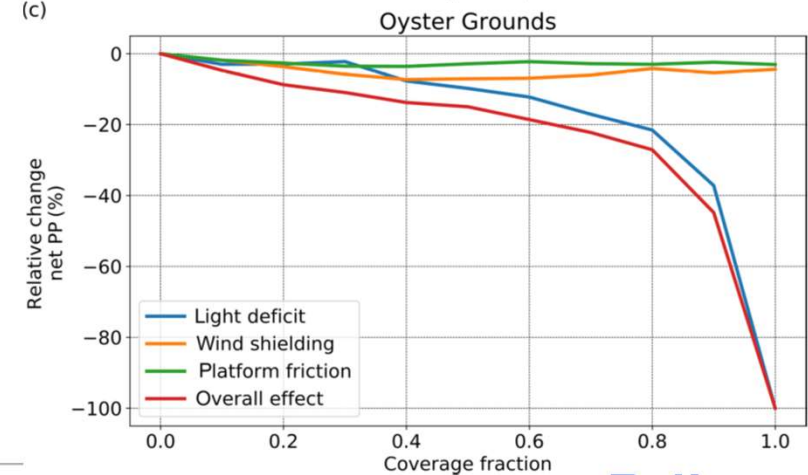


Karpouzoglou et al. Ocean Science 2020

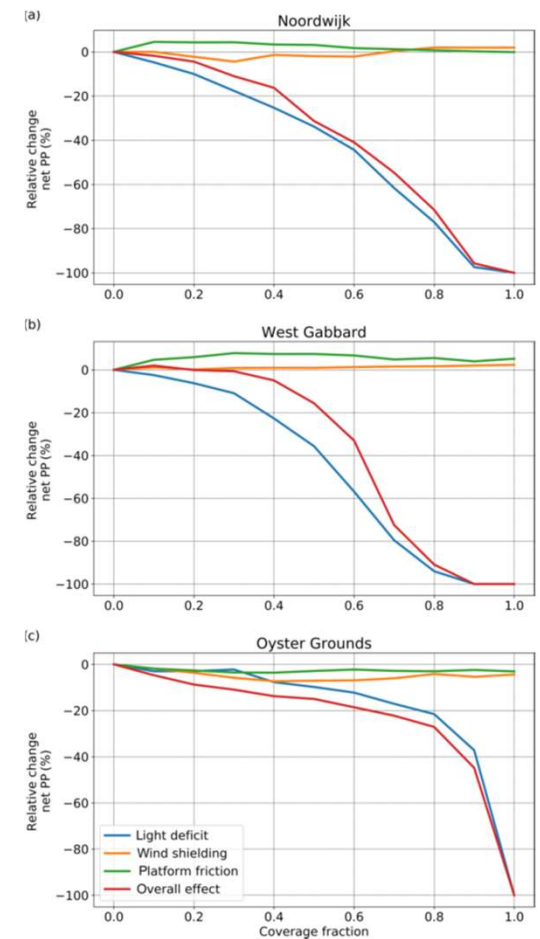
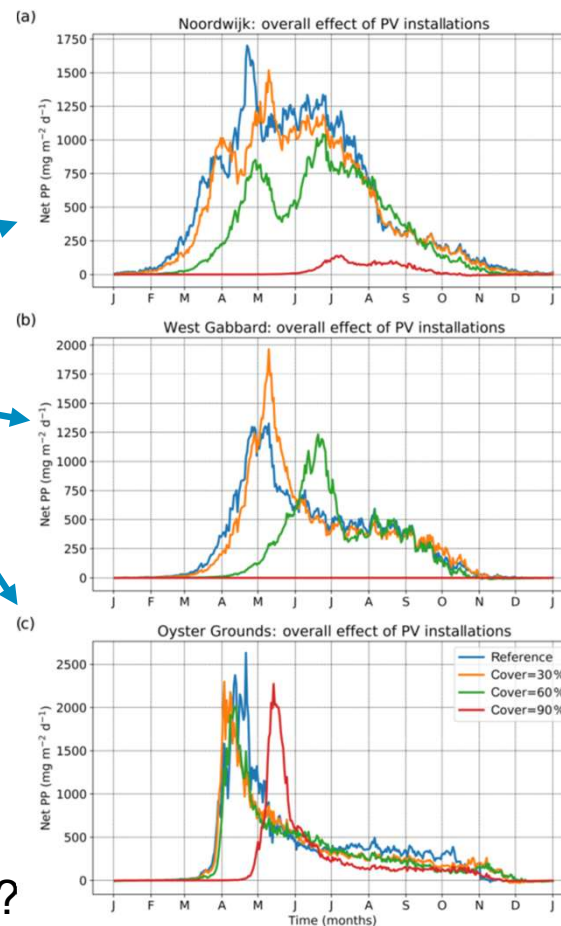
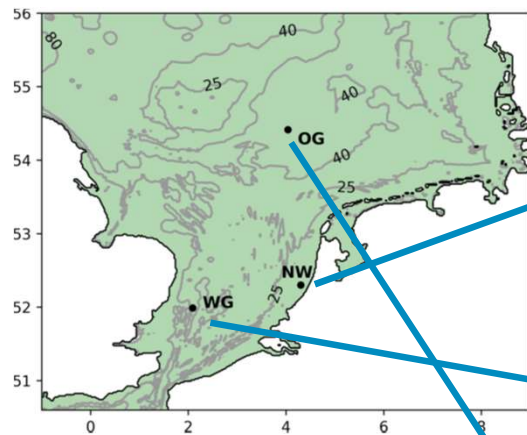
(c)



(c)



Effects offshore solar: spatial heterogeneity



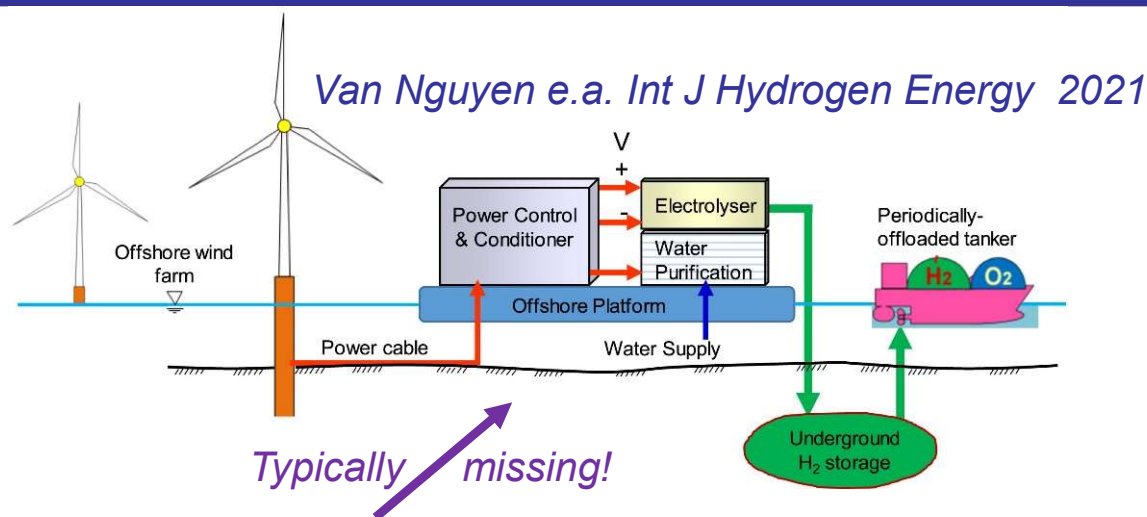
- Site-specific response
- Delay in spring bloom
- Reduction in primary production
- Shadow effect dominates
- Platform friction compensates in well-mixed areas
- Resilience increases with water depth?

Effects offshore solar



| Topic | Project |
|--|--|
| More and better observations | NS2, Sense-hubs, DEI Merganser, Naurical Sunrise |
| Model validation | Sense-hubs, Naurical Sunrise |
| Model 3D effects | Sense-hubs, Naurical Sunrise |
| Biofouling communities and ecosystem functioning | NS2, DEI Merganser, Naurical Sunrise |
| Model combined solar-wind farm ecosystem effects | Sense-hubs, |
| Understanding effects on birds and sea mammals | NS2, Nautical sunrise |
| Platform - waves - ecosystem interactions | Nautical sunrise |
| Comparison floating - elevated platforms | |
| Upscaling observations | Nautical sunrise |
| Combined solar-wind farm observations | Nautical sunrise |
| Connectivity & propagule transport | |
| Regulatory framework | Nautical sunrise |

Effects H₂



- **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?

Desalinisation: research to valorise solid salt by-products

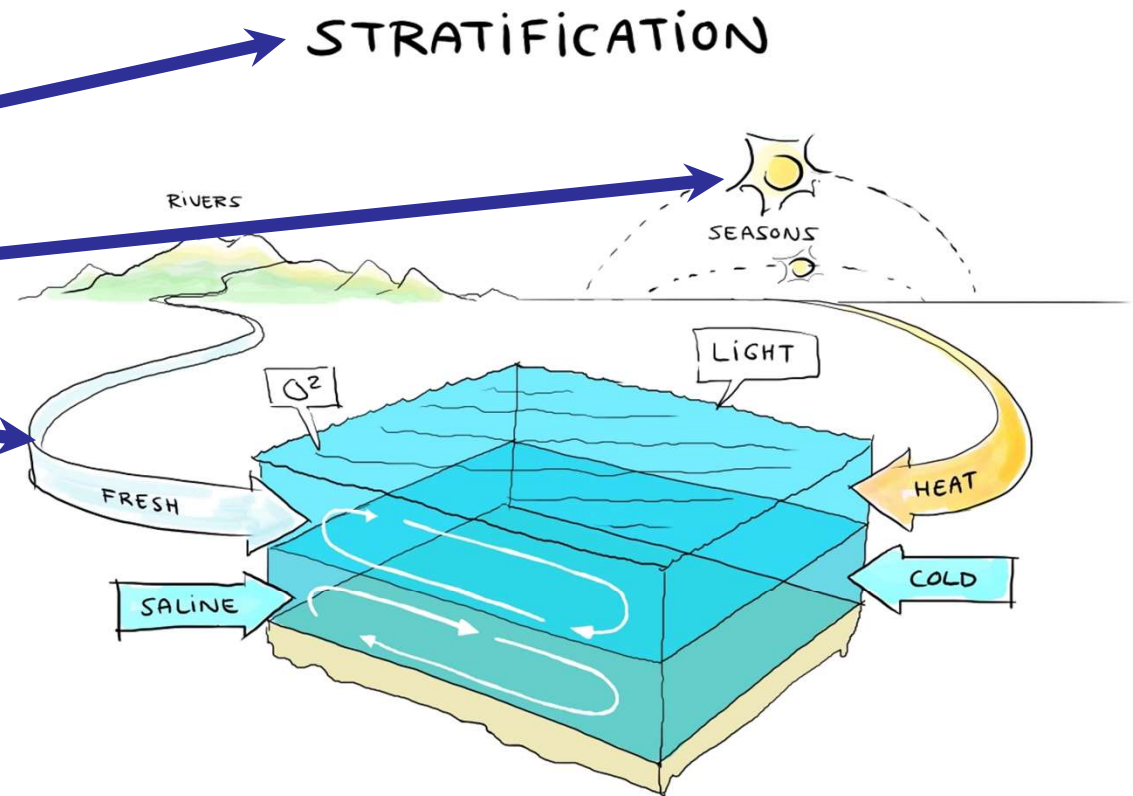


Zuo e.a. Membranes 2022

Research & regulation needed!

Interactions

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



Interactions

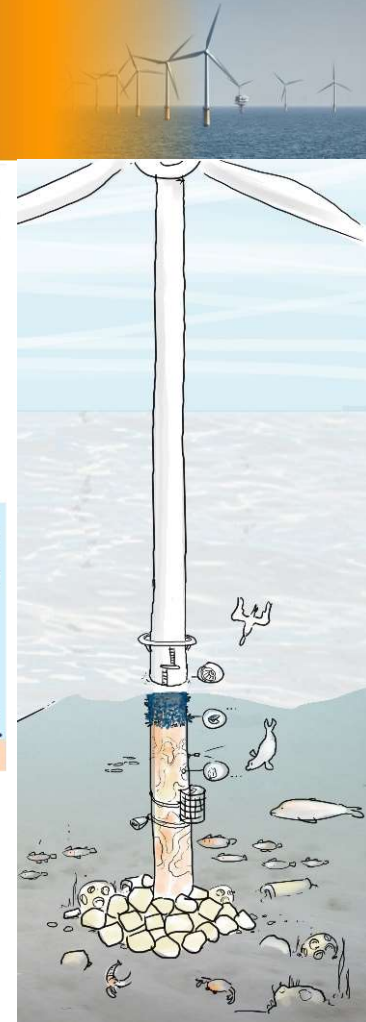
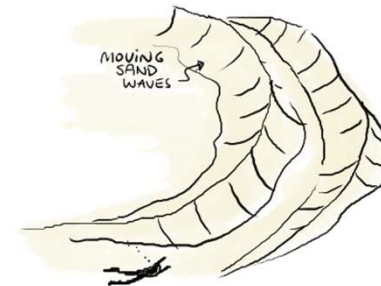
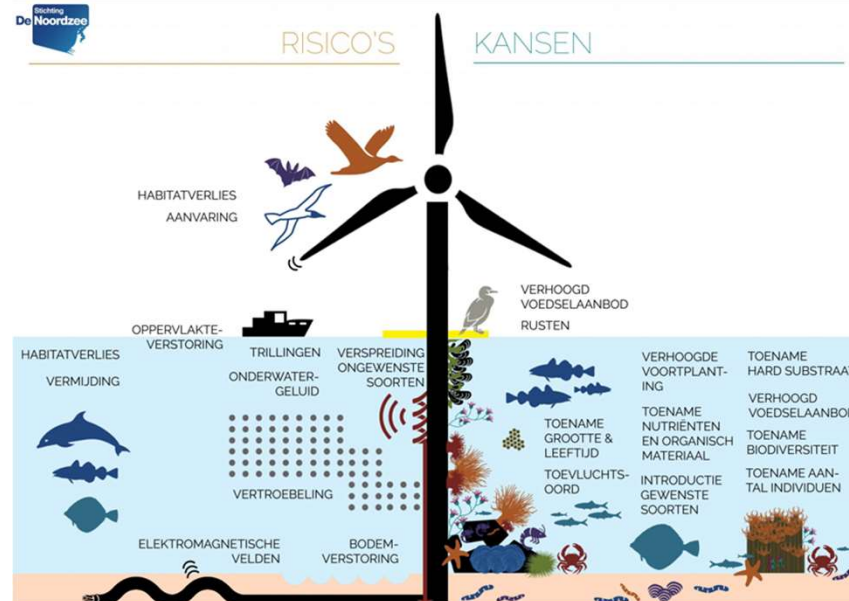
- Wind - solar
- With climate change
- With nutrient reductions (eutrophication)
- With (displaced) fishing



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???



Decommissioning

- Current regulations (OSPAR and London convention) everything needs to be removed above the seabed, unless
 - *Prior to building* infrastructure is designated as a reef – with clear targets
 - Or is proven that removal is doing more damage than not decommissioning

Image credit: Deltares

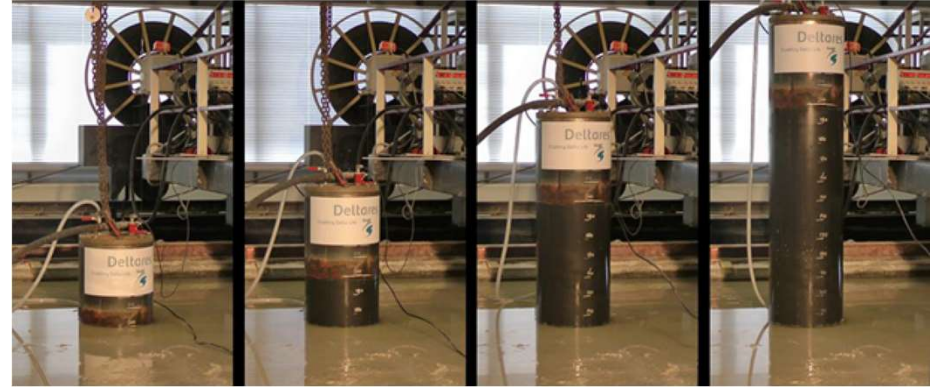
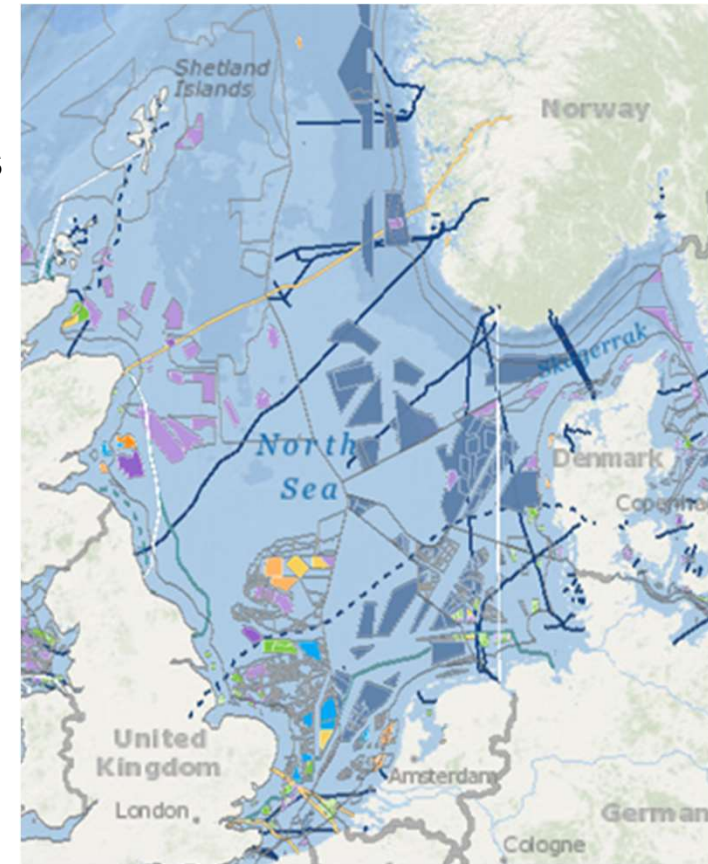


Image credit Milton Love



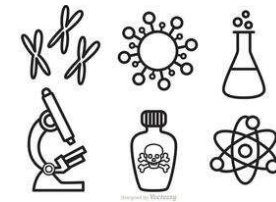
Discussion: What do we want?

- 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** ↓
 - Benthos: more muddy?
 - 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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 - Governance / policy
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- NL target 2030: 21 GW Offshore wind!



Upcoming Event

- Nationale Wetenschapsagenda L2 - NWA 2018 - **Ecologie & Noordzee final Programme Day**
- 3 projects on offshore wind farms & outlook
- **Tuesday 21 November *Places available!***
- www.nwo.nl/eindevenement-ecologie-noordzee



English



Dutch

Image credit: Erik Hendriks

Questions?

Deltares

