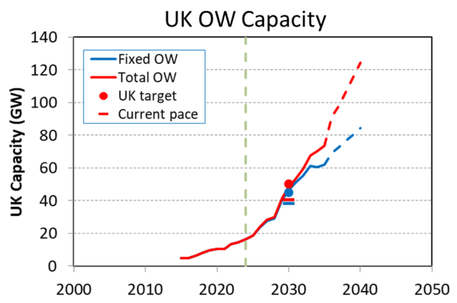
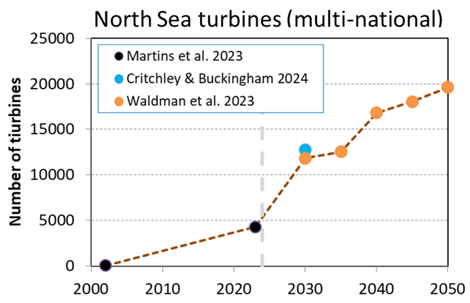
"Modelling the cumulative ecosystem effects of offshore wind and climate change in the North Sea: implications for strategic compensation and Marine Net Gain"

Expected future expansion of offshore wind in the North Sea





Assembled from:
- 2015-2035: (Rystad Energy & OEUK)[1]
- 2035-2040: extrapolated using cumulative capital investment estimates (OEUK, NSTA, Rystad) [1]

[1] OEUK Offshore Wind Insight (May 2024)
https://oeuk.org.uk/product/offshore-wind-insight-may-2024/

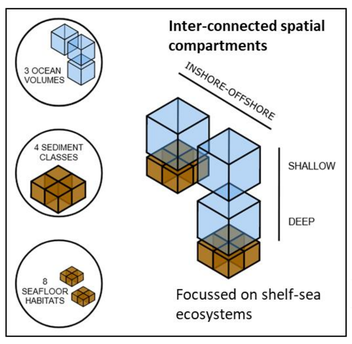
- Martins et al. 2023. Marine Policy 152, 105629
- Critchley & Buckingham 2024. Zenodo. https://doi.org/10.5281/zenodo.10478448
- Waldman et al. 2023. Zenodo. https://doi.org/10.5281/zenodo.1025906

- **What effects will the expansion of OW have on seabirds?**
  - *– Direct and indirect (food web) effects.*
- **How effective might proposed compensation measures be at alleviating effects on seabirds?**
- **How will climate change affect all this?**

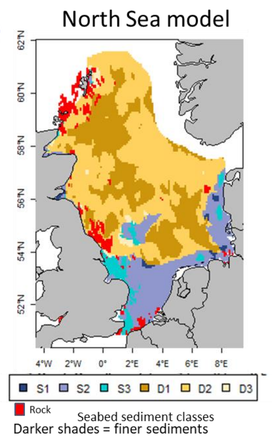
We used the StrathE2E ecosystem model to investigate the effects of OW, climate change and fishing

Simplifying space

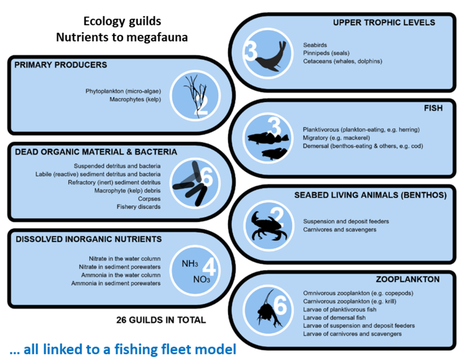
Minimalist discretisation of



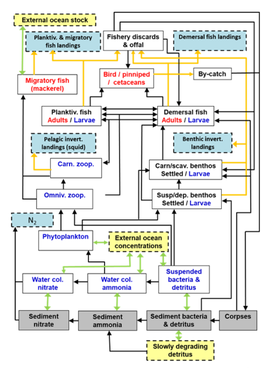
North Sea model



Simplifying taxonomy



… all linked to a fishing fleet model



Return flows from organisms to ammonia (excretion) and detritus (faeces and corpses) not shown here

All in nitrogen units – nitrate is usually the limiting inorganic nutrient in the shelf seas

StrathE2E is available as an R-package and an online web-app

https://outreach.mathstat.strath.ac.uk/apps/StrathE2EApp/

Mapping of OW pressures and seabird compensation measures onto changes in StrathE2E model parameters

Two stages 1) Direction of change in parameters 2) Magnitude of effect on parameters

Narratives for: - linking OW pressures to effects on individual guilds - the direction of change in model parameters

Pressure	Direction of change in model parameters
Scour protection	Replace a fraction of each sediment class with rock
Food aggregation	• Half-saturation coefficient for feeding ↘ • Feeding interference (where relevant) ↘
Shelter	• Density dependent mortality rate ↘
Noise	• Maximum uptake rate of food ↘
Barrier	• Maximum uptake rate of food ↘
Collision	• Additional density independent mortality ↘

Narratives for: - linking compensation to effects on the seabird guild - the direction of change in model parameters

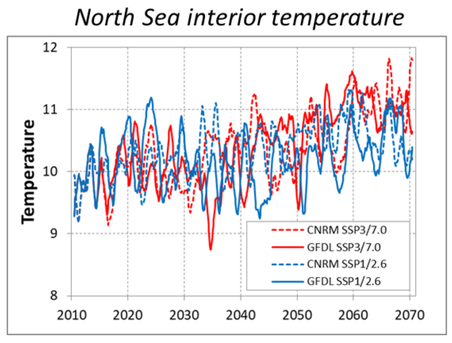
Compensatory measure	Direction of change in seabird parameters
Pollution reduction	• Density independent mortality ↘
New nesting habitats	• Density dependent mortality rate ↘
Nesting habitat management	• Density dependent mortality rate ↘
Predator management	• Density dependent mortality rate ↘
Supplementary feeding	• Half-saturation coefficient for feeding ↘ • Feeding interference ↘
Anthropogenic disturbance reduction	• Maximum uptake rate of food ↘

Linear scaling factors linking numbers of turbines in a given year to magnitudes of effects on baseline parameters treated as a random effect in a Monte Carlo scheme.

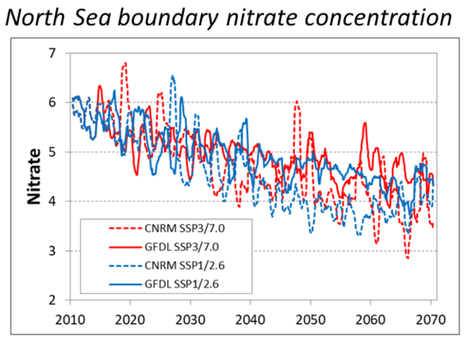
Climate projection data used to drive StrathE2E

Data from 4 combinations of Earth System Model and IPCC Shared Socioeconomic Pathway/RCP scenarios provided by the EU H2020 Mission Atlantic Project

North Sea interior temperature



North Sea boundary nitrate concentration



Data shown here are 12 month moving averages, bias corrected so as to coincide with empirical data during a baseline reference period 2003-2013.

Configuration of a baseline and 4 scenario model runs

- ***Baseline model*** **with environment & fishing conditions as in 2003-2013 & no OW**
- **Results from four *scenario models* compared with the baseline model results.**

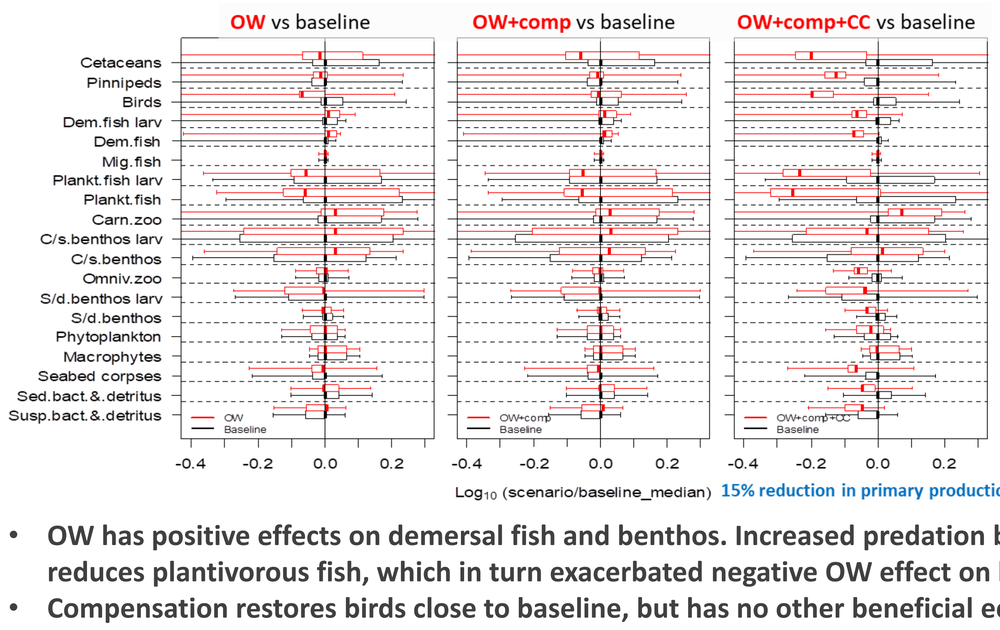
Scenario name	Effects of OW turbines	Effects of compensation	Effects of climate change	Fisheries management
OW	■			
OW+comp	■	■		
OW+comp+CC	■	■	■	
OW+comp+CC+FM	■	■	■	■

Each model run for 500 iterations in the Monte Carlo scheme

Baseline parameters drawn from posterior probability distributions arising from fitting the model to 2003-2013 observational data

Results : Monte Carlo distributions of annual averaged guild biomasses in 2050, normalised to the median of the baseline

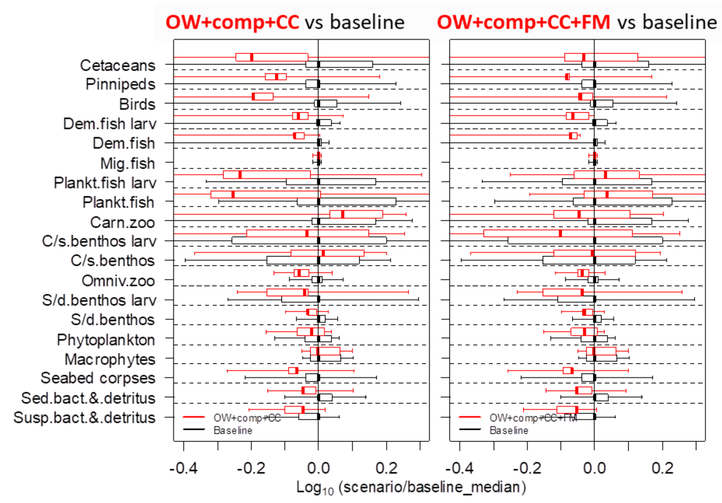
- **Boxes - quartiles and median, Whiskers – 5th and 95th centiles**
- **Black – baseline model, Red – Scenario model**



15% reduction in primary production

Fishing held at 2003-2013 baseline rates for all three of these scenarios

- **OW has positive effects on demersal fish and benthos. Increased predation by demersal fish reduces plantivorous fish, which in turn exacerbated negative OW effect on birds.**
- **Compensation restores birds close to baseline, but has no other beneficial ecosystem effects.**
- **Climate change causes a 15% reduction in primary production which overwhelms everything.**



For the FM scenario, sandeel trawling activity reduced to 50% of 2003-2013 baseline from 2024 onwards

Reduction in sandeel trawling alleviates some of the effects of climate change and OW on the ecosystem

Big questions arising from these results

- **What aspects of the ecosystem should we be trying to maintain?**
- **How do we measure net gain? This is about more than just birds**
- **How does society decide between ecological and economic objectives?**
- **How can fisheries management be drawn into this debate?**

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