Modelling the impact of wind turbines at sea on seabirds and marine mammals

An exploration of Individual-Based Models

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Questions so far within WOZEP

- What are the *direct* effects of offshore wind farms on the mortality (collisions) or health (noise) of seabirds and marine mammals?
- Do animals completely avoid offshore wind farms?
- What are the consequences of these effects on bird/mammal population distribution and abundance?

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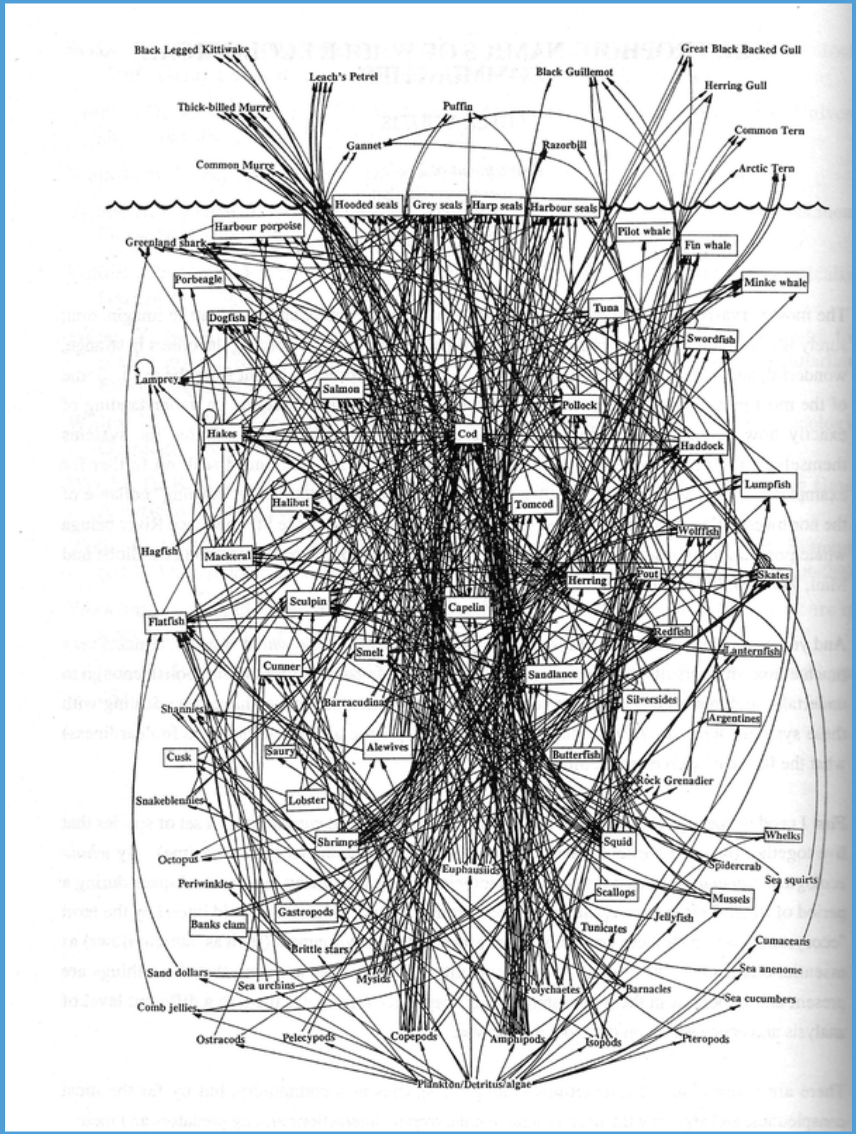
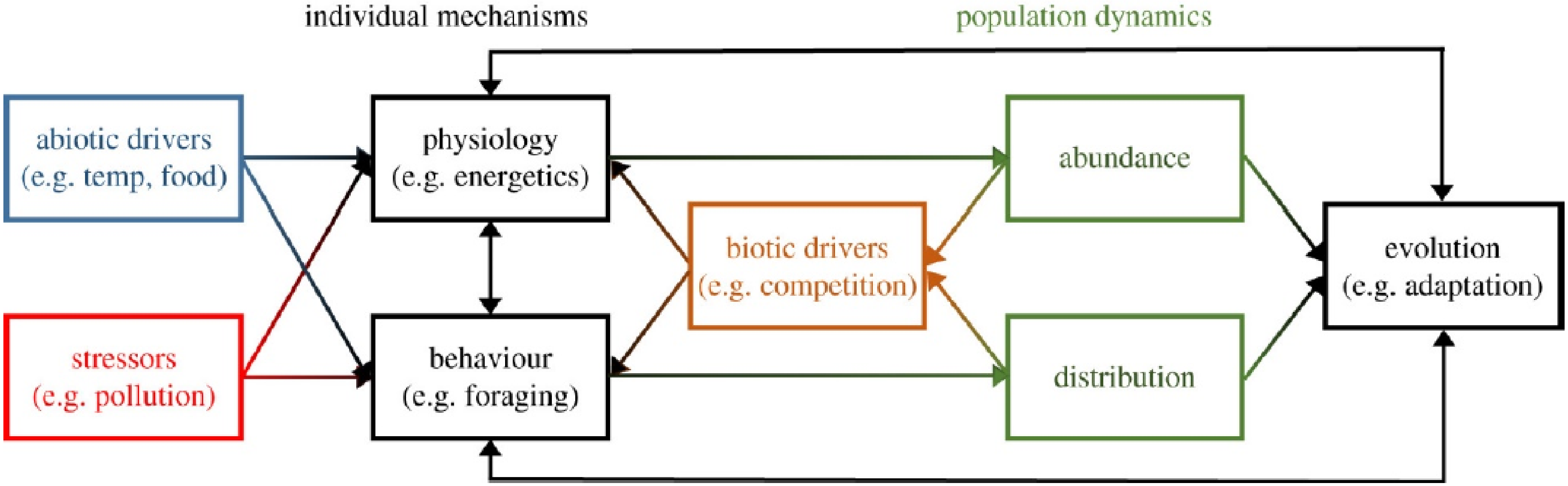
New question asks for a new approach

- How does the construction of large-scale offshore wind farms *indirectly* affect the distribution and abundance of seabird and marine mammal populations?
- Through changes in the physics and lower trophic levels (primary producers and herbivores)
- Physics and primary producers are modelled by Deltares
- What other models can be used to link output variables of the Deltares models to bird/mammal distribution and abundance?

Food webs are complex



Individual-Based Models (IBMs)



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Overview of IBMs

- Food landscape (0D, 1D, 2D)
- Physiology, energetics
- Behaviour, mainly movement
- Output: state (fat reserves), fitness (demographic variables like survival, reproduction), population size or dynamics

Overview of IBMs

Number	Species	Reference
1	Atlantic fur seal	Massardier-Galata et al. (2017)
2	Elephant seal	New et al. (2014)
3	Southern elephant seal	Goedegebuure et al. (2018)
4	Harbour seal	Steingass and Horning (2017)
5	Gray seal	Silva et al. (2020)
6	Weddell seal	Beltran et al. (2017)
7	Killer whale	Testa et al. (2012)
8	Harbour porpoise	Nabe-Nielsen et al. (2014)
9	Long-finned pilot whale	Hin et al. (2019)
10	Gray whale	Villegas-Amtmann et al. (2015)
11	Blue whale	Pirotta et al. (2018)
12	Common scoter	van de Wolfshaar et al. (2018)
13	Eider	Brinkman et al. (2003)
14	Common guillemot	Langton et al. (2014)
15	Red-throated diver	Topping and Petersen (2011)
16	Black petrel	Zhang et al. (2017)
17	Various seabirds	van Kooten et al. (2019)
18	Gannet	Warwick-Evans et al. (2018)

Overview of IBMs

Number	Purpose is to assess the impact of:
1	Climate-related change in food density and distribution on reproductive success
2	Environment-induced change in foraging behaviour on pup survival
3	Changes in resource availability
4	Hypoxia increases on energy balance
5	Food limitation, endocrine disrupting chemicals and infectious diseases
6	Change in food density on growth, reproduction and survival
7	Prey species composition on population size
8	Noise and by-catch on population size
9	Yearly recurrent period of no resource feeding
10	Disturbance on reproduction
11	Anthropogenic perturbations on reproductive success
12	Food availability and disturbance on carrying capacity
13	Food availability on carrying capacity
14	Change in food density and distribution on reproductive success
15	Removal of feeding area by wind farms on population size
16	Food distribution on movement patterns
17	Removal of feeding area by wind farms on mortality rate
18	Removal of feeding area by wind farms on mortality rate

Overview of IBMs

Number	Spatial	Food	Energetics	Output
1	2D	generated	I	F
2	n	intake generated	S	F
3	n	intake generated	I	F
4	1D	generated	I	S
5	n	intake generated	I	F
6	n	generated	D	F
7	n	simulated	I	P
8	2D	generated, dynamic	S	P
9	n	intake generated	I	F
10	n	intake generated	I	F
11	1D	upwelling index as proxy	S	F
12	2D	benthos survey	D	P
13	n	benthos survey	D	P
14	1D	generated	I	F
15	2D	water depth as proxy	S	P
16	2D	generated	S	S
17	2D	generated	S	F
18	2D	generated	I	F

Overview of IBMs

- Food landscape: for birds mostly a generated 2D food landscape
- Physiology, energetics: extremely variable, only a few used an established model based on e.g. Dynamic Energy Budget (DEB) theory
- Behaviour, mainly movement: correlated random walk (CRW) and memory
- Output: usually fitness (demographic variables like survival, reproduction)

Evaluation

- Food landscape: Baron von Münchhausen
- Food landscape tuned such that r=0 without human impact
- Consequently, (almost) always a negative impact of human activities

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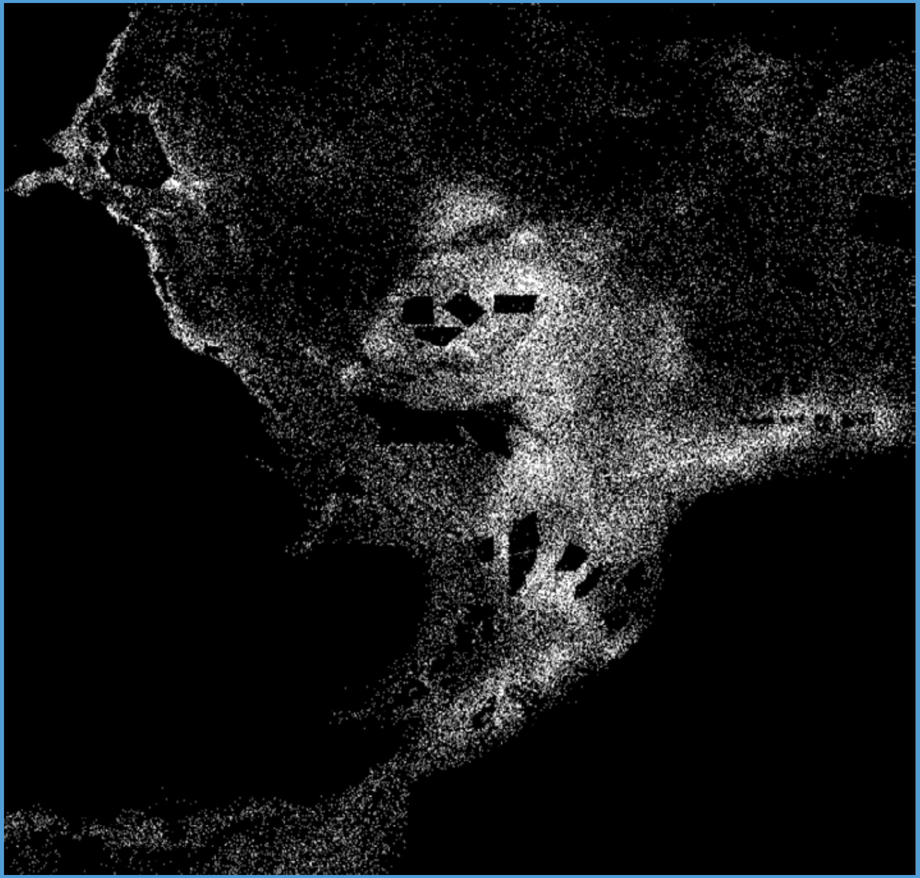
Evaluation

- Size of the effect very much dependent upon rules for movement and death: scramble versus contest competition



Conclusion

- For all models validation lacking
- Limited predictive value

(Long) way forward

- Apply a standardized approach for modelling energetics (DEB) and behaviour
- Choose species that occur in regions and periods with the greatest predicted change low in the food chain
- Link modelling to an observational program: sampling prey abundance at sea, behavioural studies at sea, tracking studies, diet studies in colonies
- Pay much more attention to the food landscape and changes therein
- Modelling zooplankton and fish as intermediate steps, IBMs or statistical modelling using CPR data
- Combine effort (MONS, NWA, WOZEP)