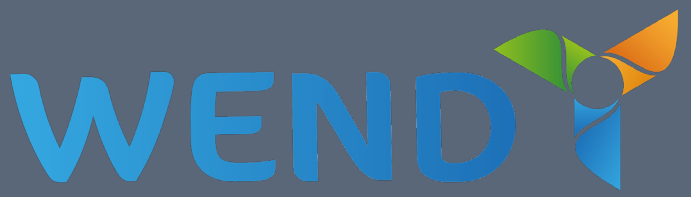
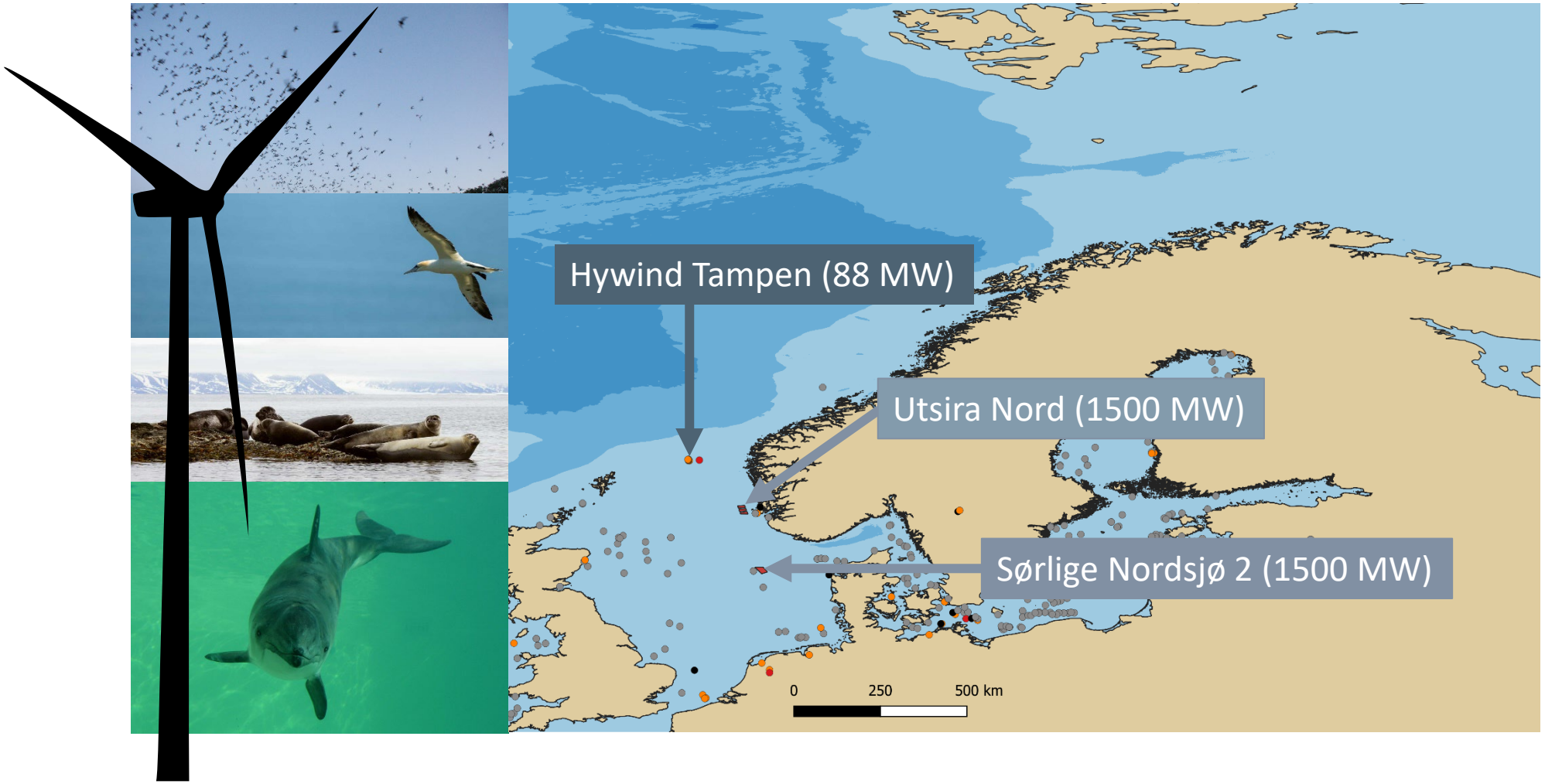
Life-cycle impacts of offshore wind energy development on marine mammals

Thomas Kvalnes, Reto Spielhofer, Evert J. Mul, Frank Hanssen and Roel May

January 19th, 2024



Wind farms: Constructed and planned



Harbour porpoise: Salko de Wolf.
Northern gannet: Olav Fossbakken.
Harbor seal: Per Harald Olsen. Bats: Daniel Spiess

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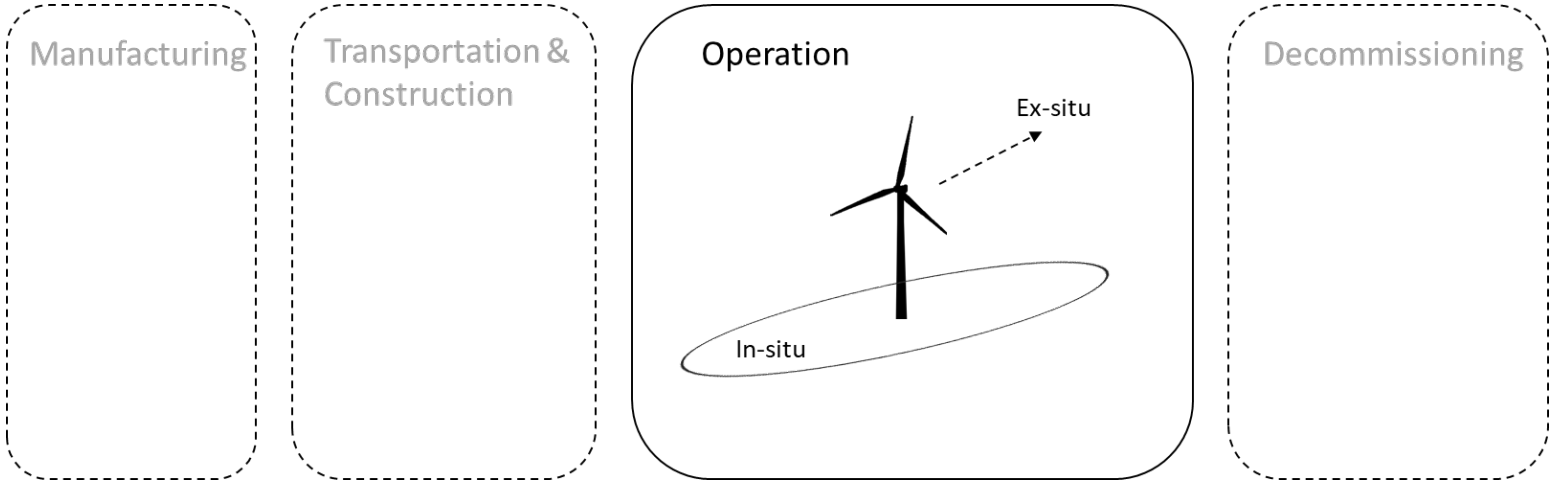
Life-cycle assessment (LCA) of wind power

- LCA
  - Standardized method
  - Life-cycle of wind farm
  - Focus on operational phase

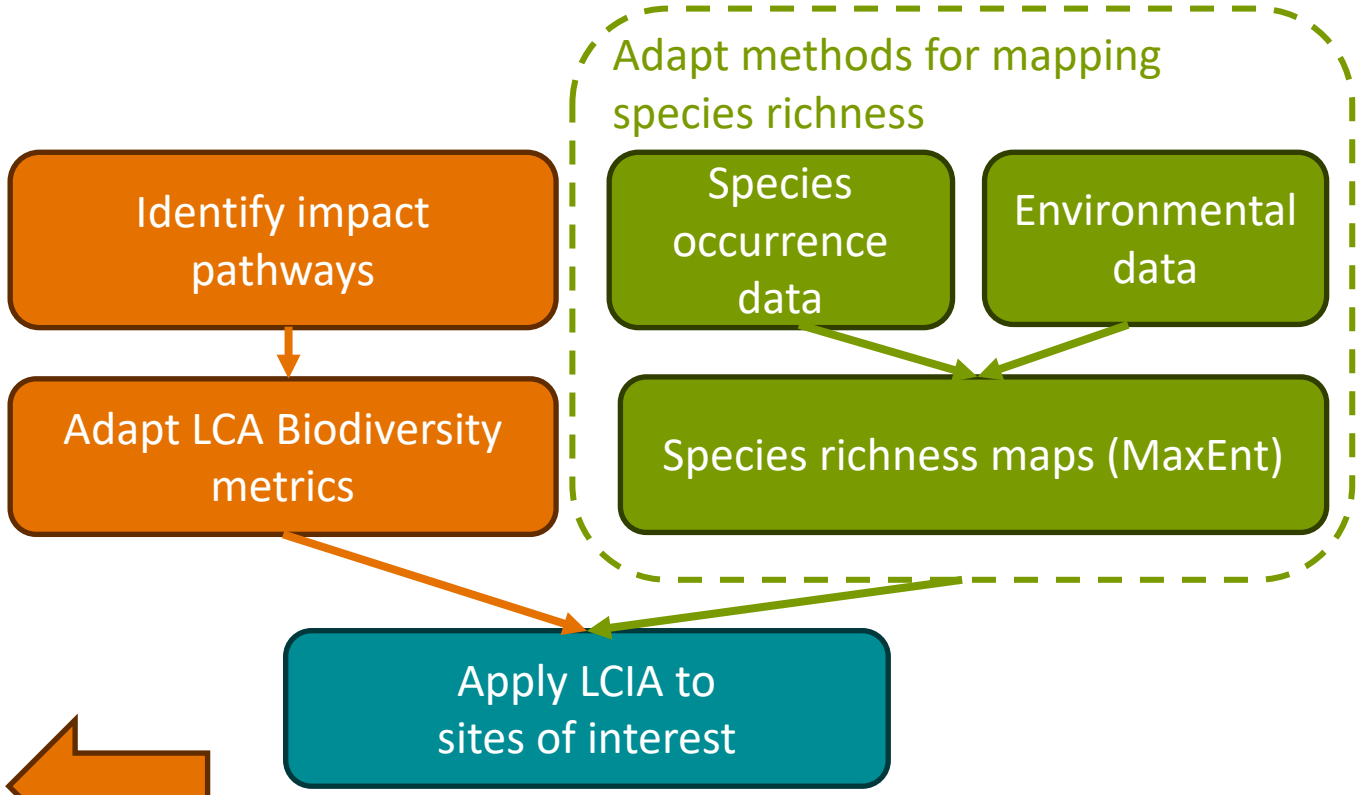


- Goal: Quantify the loss of species richness (endpoint)
  - Midpoint: Area loss → Impact pathways

LCA impacts from wind power on biodiversity

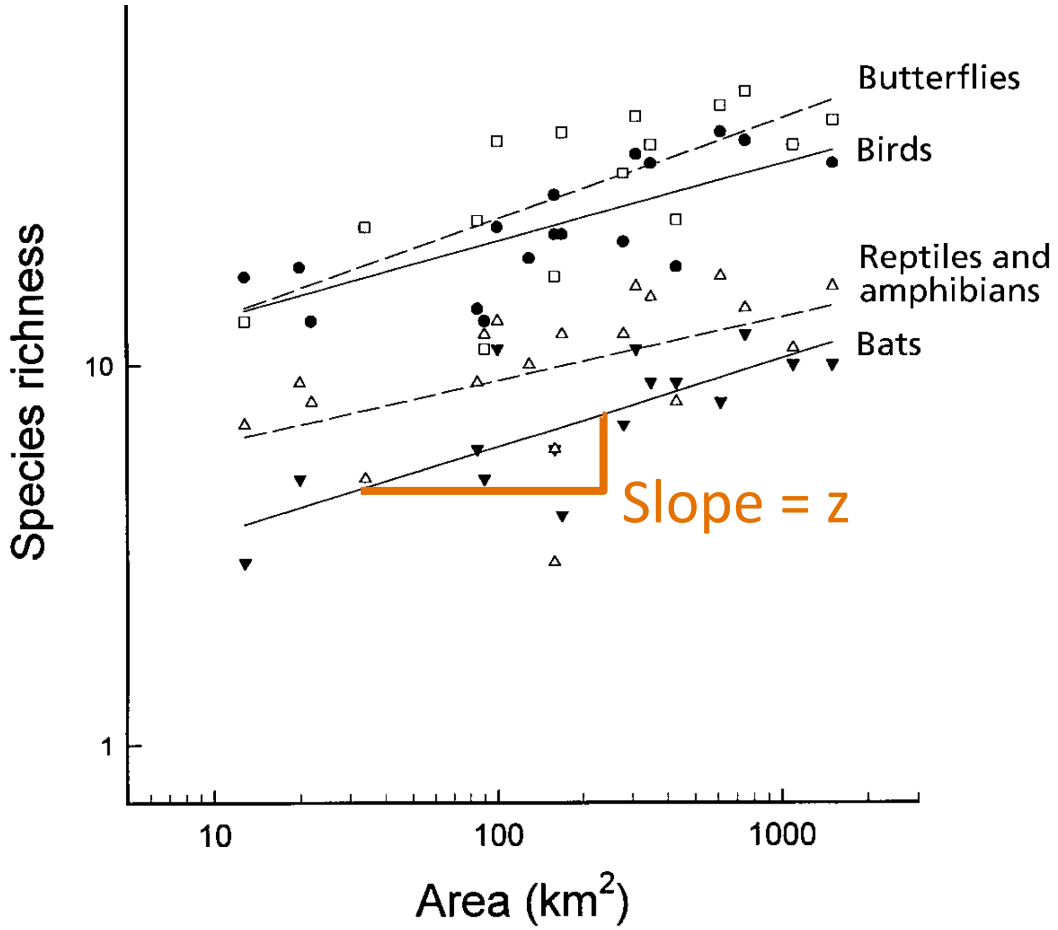
	Impact pathways	Habitat loss	Disturbance	Collision	Barrier
Onshore	Birds	+	+	+	+
	Bats	+	+	+	+
Offshore	Seabirds	+	+	+	+
	Marine mammals	+	+	-	+

Workflow for each group of species



Potentially disappeared fraction (PDF) of species

- Quantify the impact on species richness
- $$PDF = \frac{S_{lost}}{S_{org}} = \frac{S_{org} \cdot \left(1 - \left[\frac{A_{org} - A_{lost}}{A_{org}}\right]^{z}\right)}{S_{org}}$$



May et al. 2020, Ricklefs and Lovette 2001

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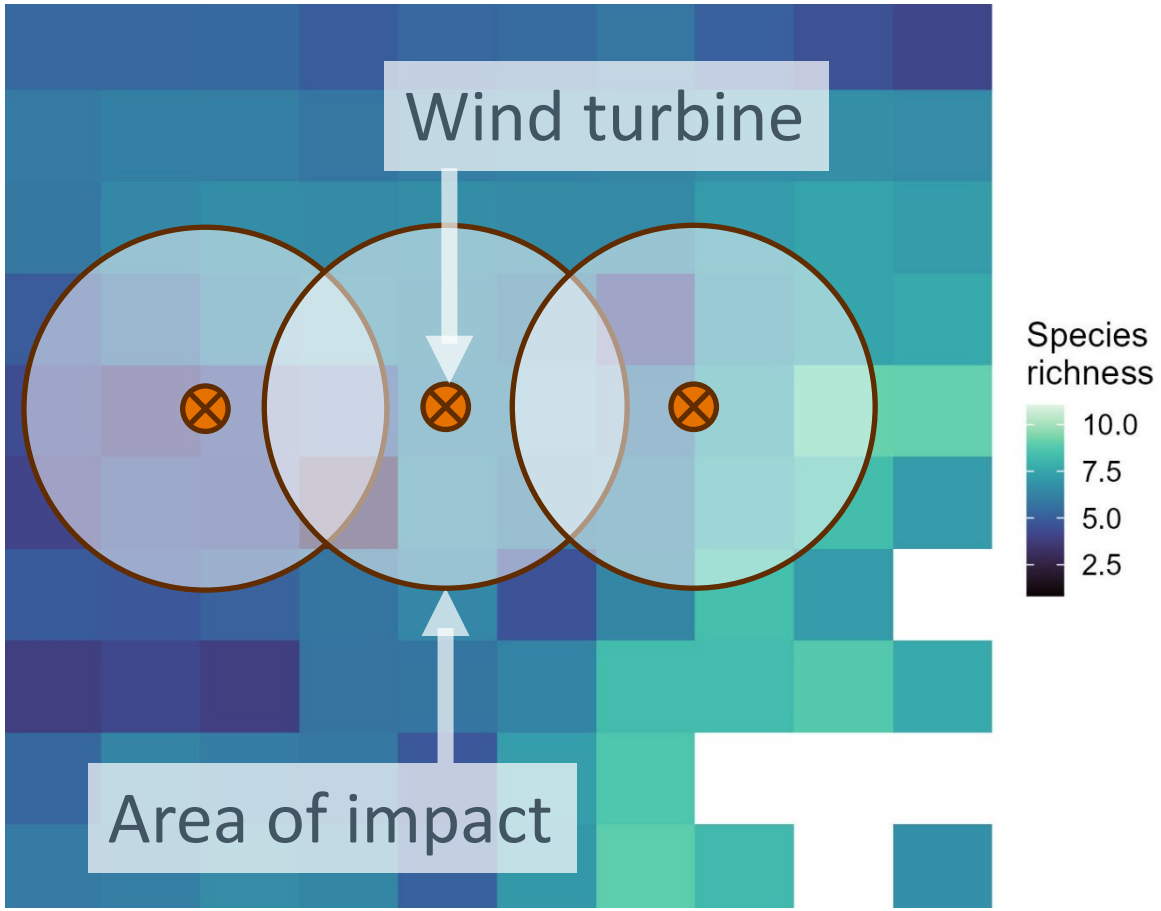
PDF of species for grids

- Account for spatial variation in occurrence probability

PDF for a wind farm

$$PDF(X)_{k,f} = \sum_i PDF(X)_{k,f,i}$$

- Functional groups (k)
  - 1) Baleen whales
    2) Toothed whales
    3) Seals



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Harbour porpoise

Photo: Salko de Wolf

Minke whale

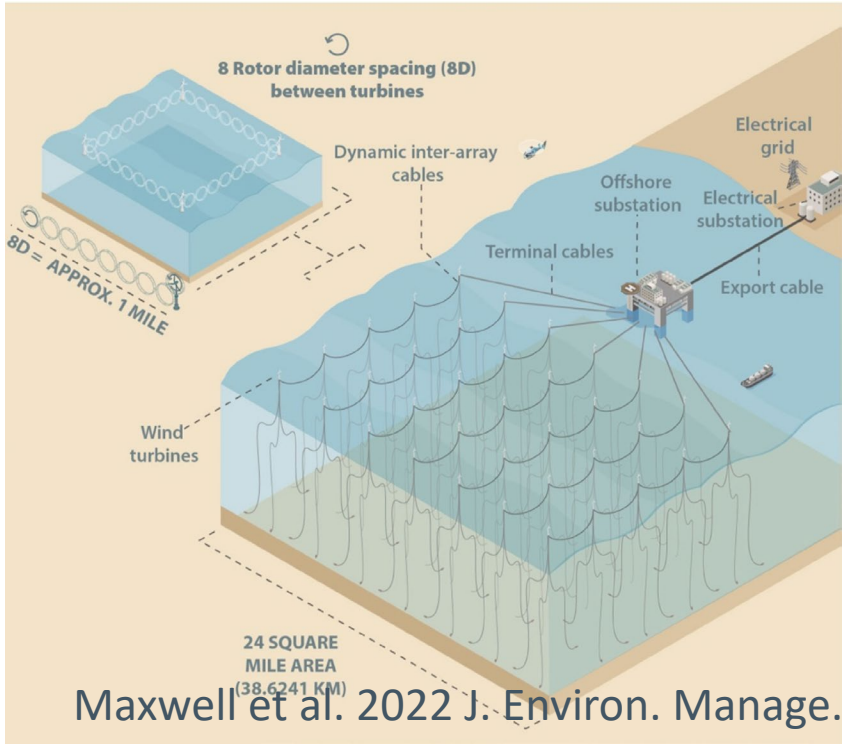
Photo: Len2040/Flickr (CC BY-ND 2.0)

Harbour seal

Photo: Brad Smith (CC BY-ND 2.0)

Habitat loss

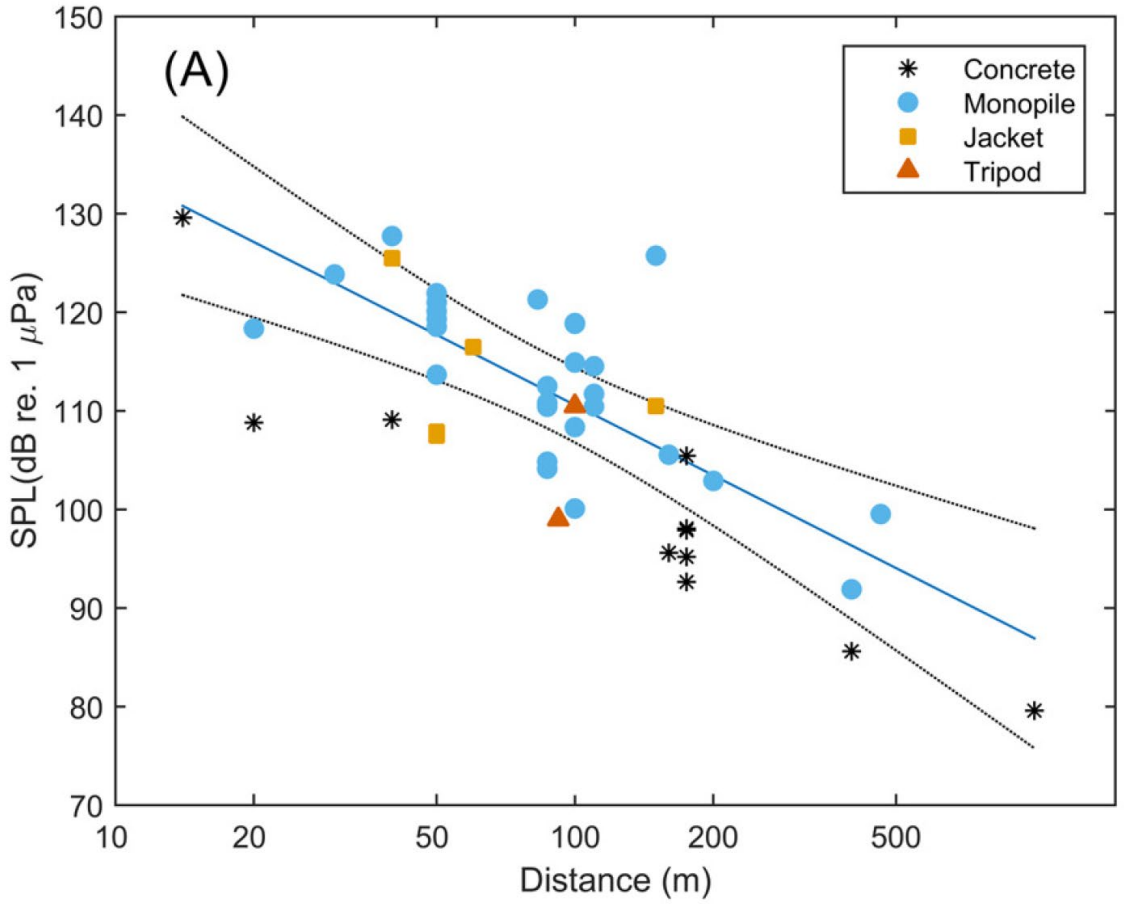
- Directly lost habitat area: transformation and occupation
- Includes
  - Wind turbine foundation
  - Scour protection
  - Anchors
  - Mooring lines
  - Electric cabels



Maxwell et al. 2022 J. Environ. Manage.

Disturbance: Operational noise

- Total sound pressure level (dB)
  - Increase with turbine MW
  - Decrease with distance
- Acoustic threshold for behavioural responses (NOAA): **120 dB re 1 µPa rms**
- Auditory sensitivity
  - Functional groups



Tougaard et al. 2020, Gomez et al. 2016, Southall et al. 2019

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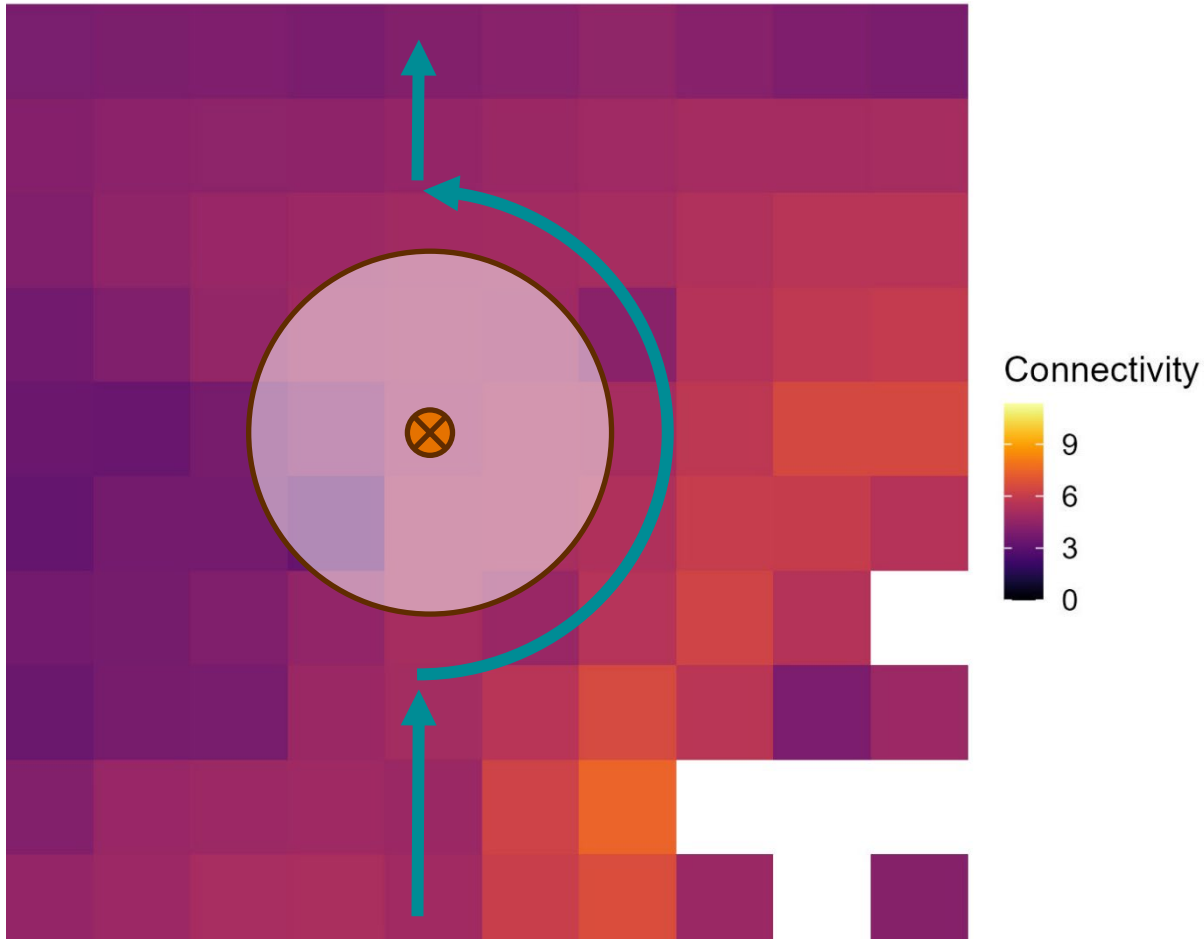
Barrier

- Quantifies the cost of travelling around a wind farm

- Barrier effect = Disturbance effect x M_k
  - M_k = The total energy requirement for migration



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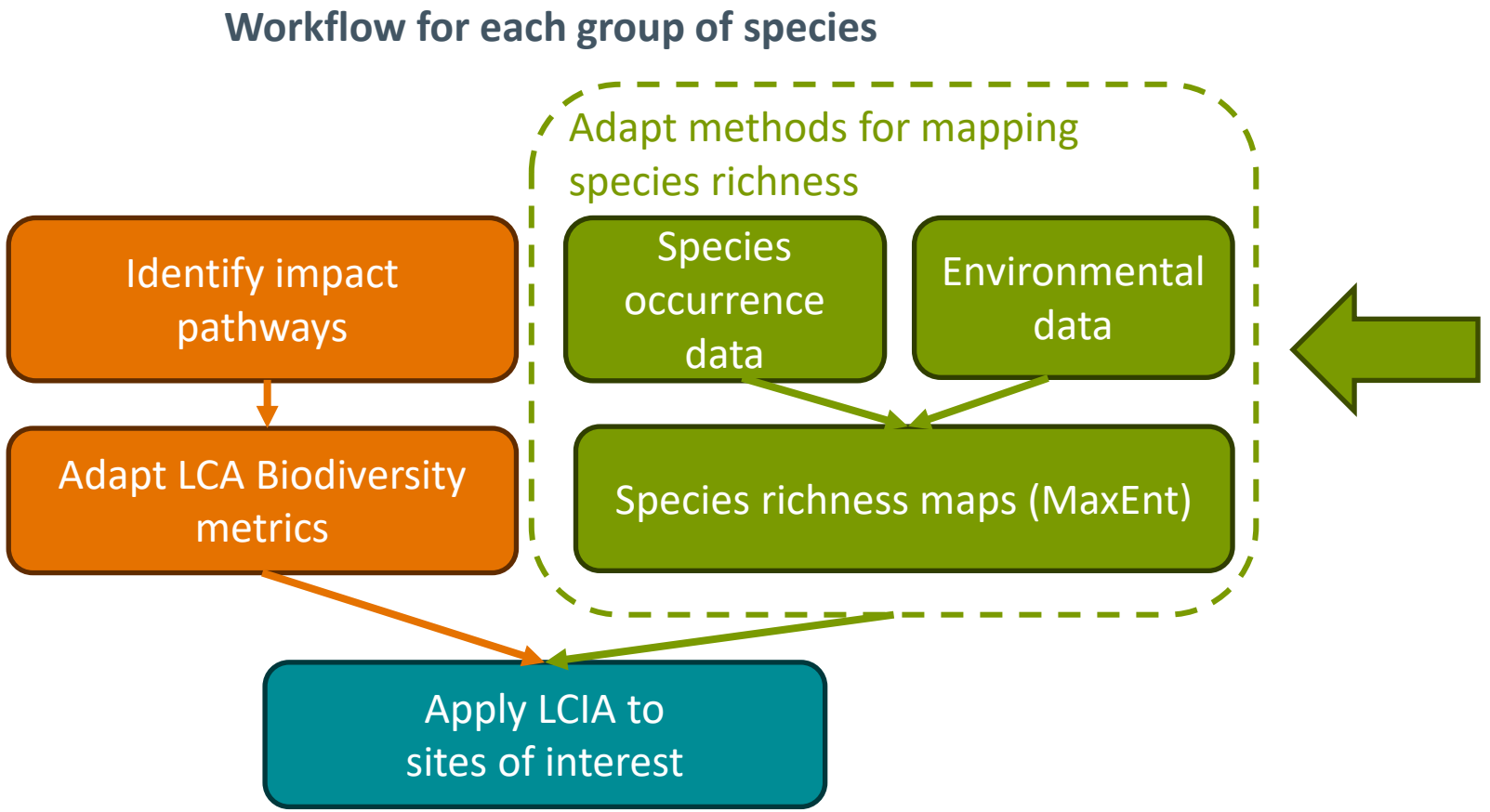
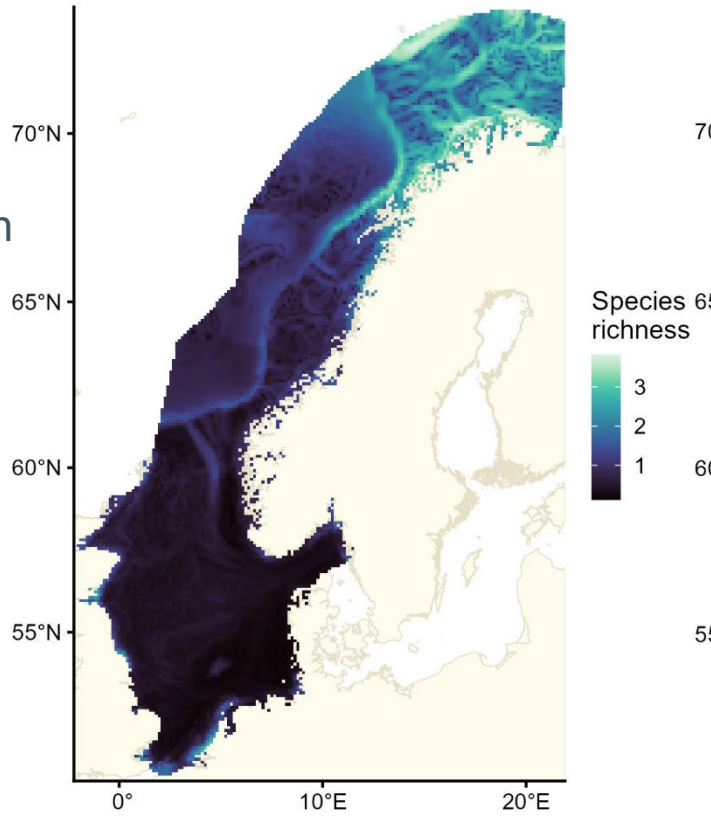
LCA impacts from wind power on biodiversity



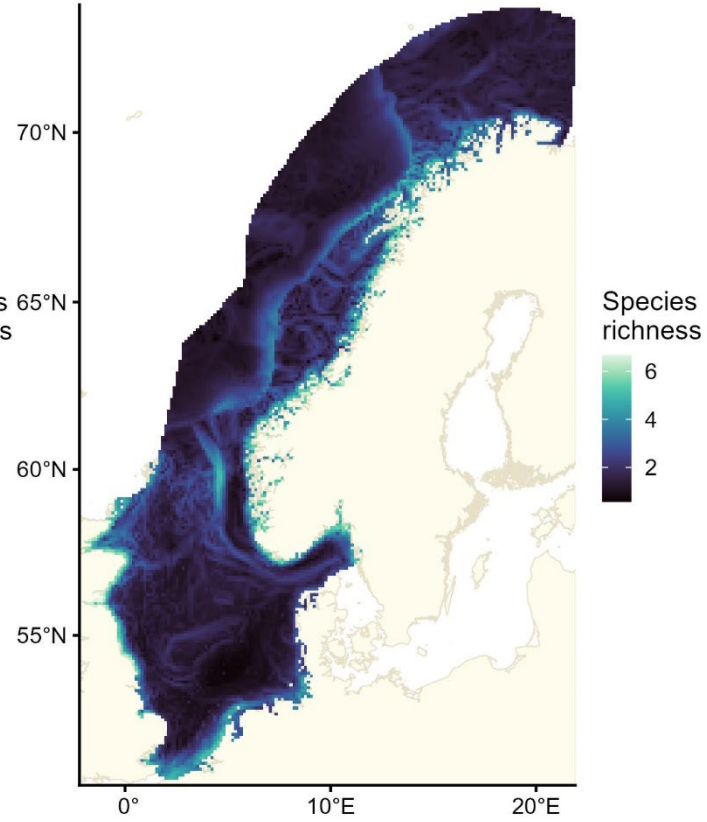
Species richness

- MaxEnt software
  - GBIF + OBIS
  - Bias correction
- Mean AUC
  - 0.842
- Range AUC
  - 0.705 - 0.915

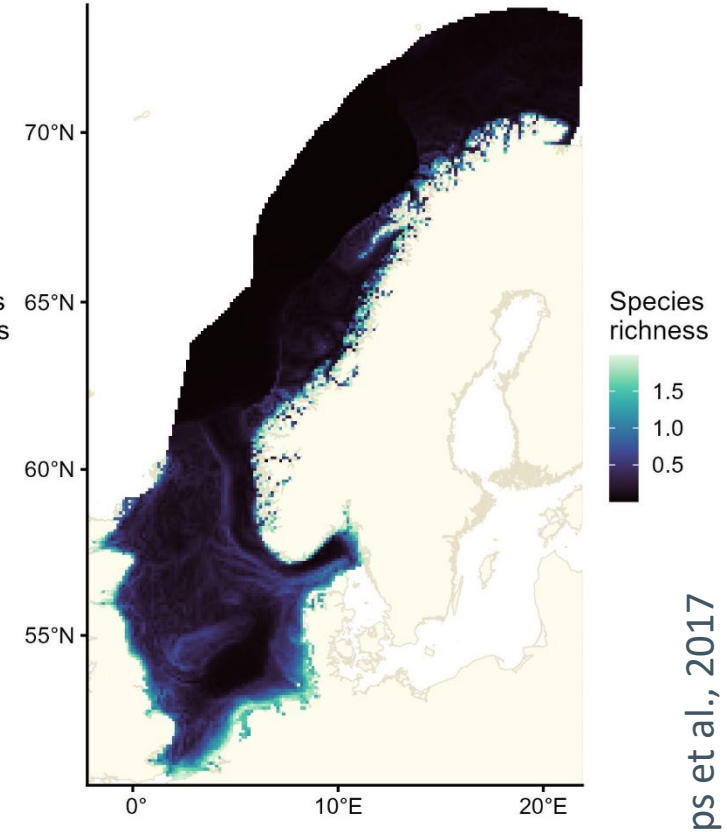
Baleen whales



Toothed whales



Seals



Phillips et al., 2017

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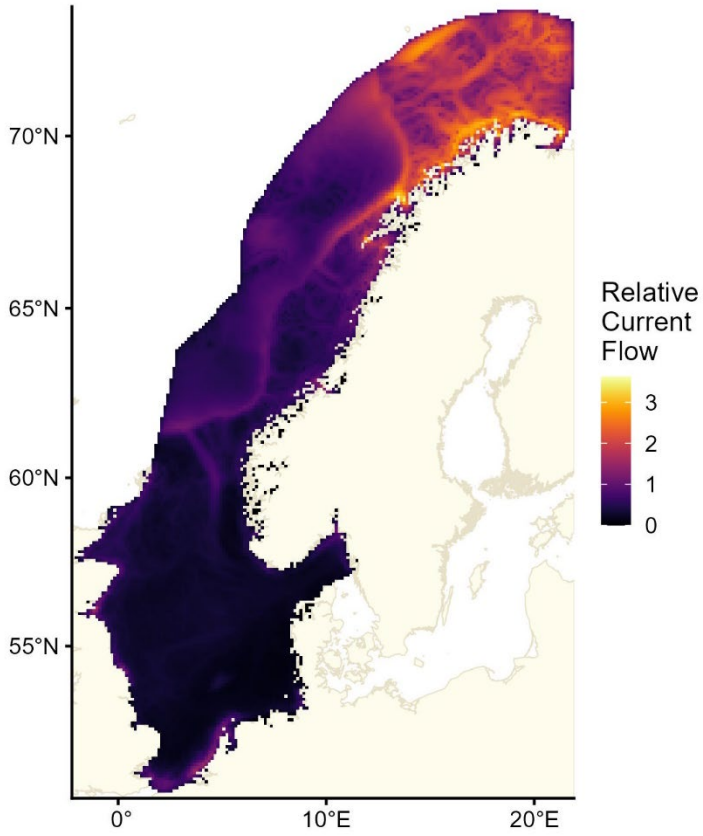
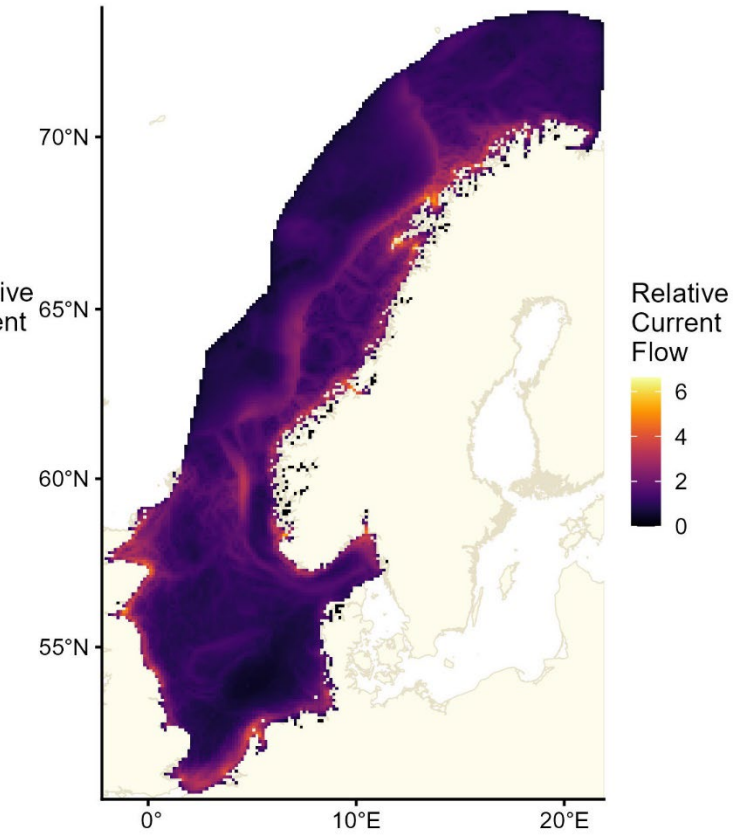
Connectivity

- Omniscape
  - Circuit theory
  - Omni-directional connectivity

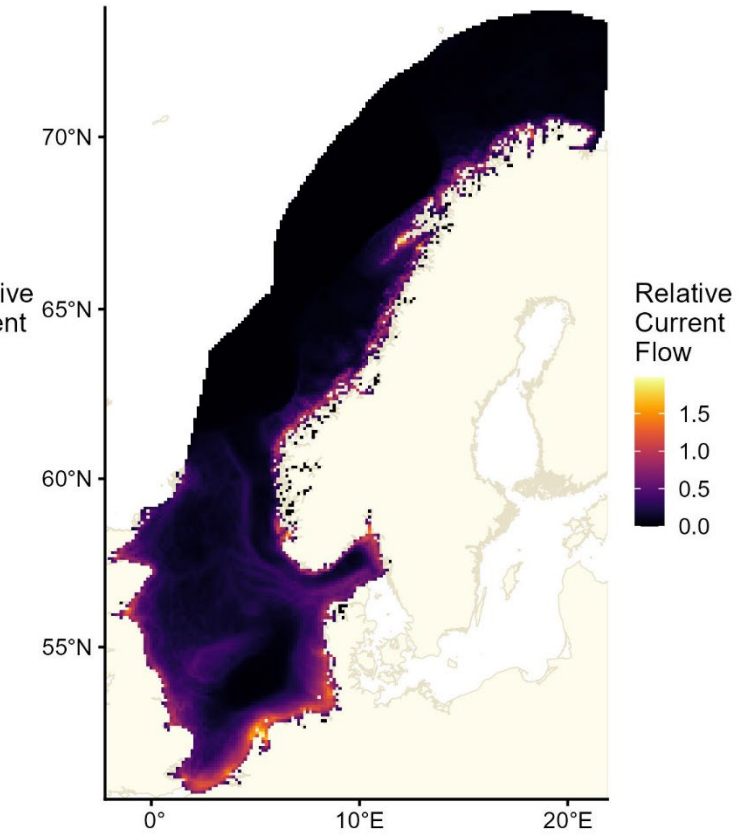
Baleen whales



Toothed whales



Seals



Landau et al., 2021; McRae et al., 2016

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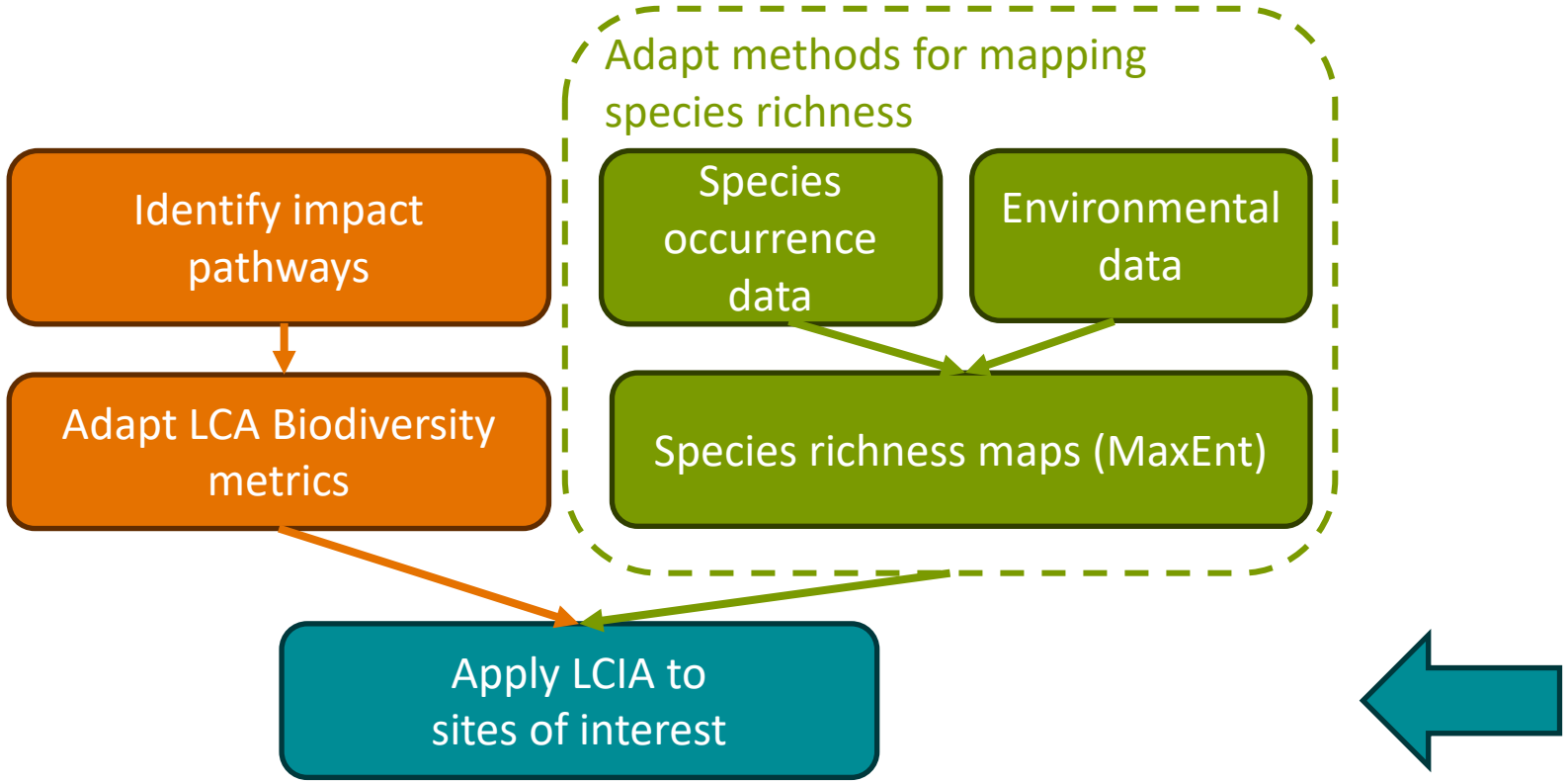
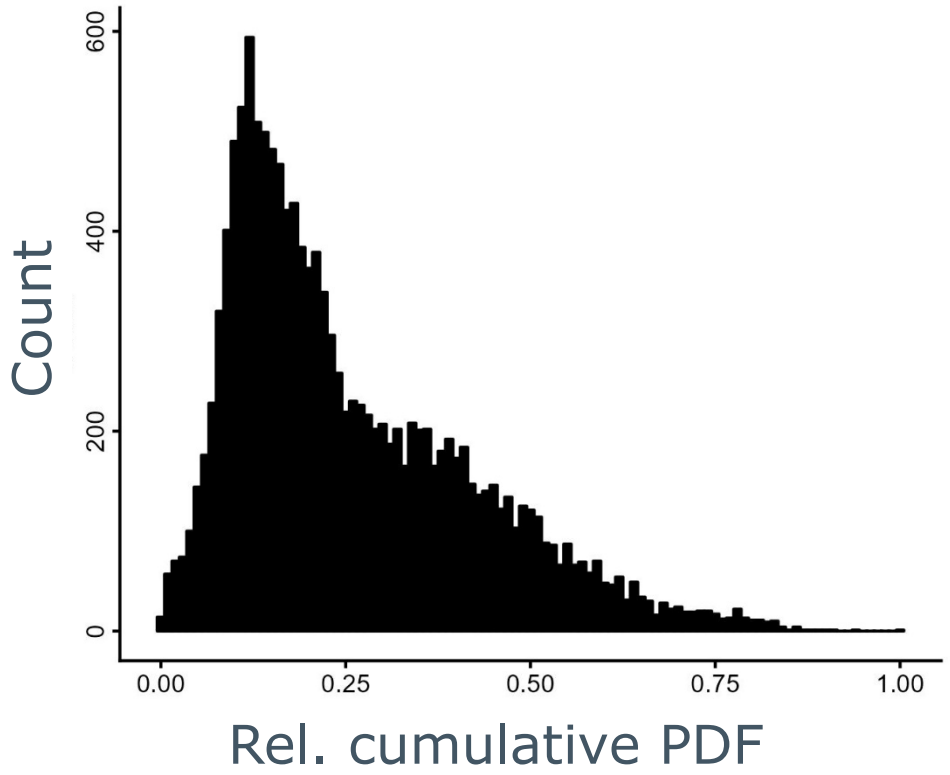
LCA impacts from wind power on biodiversity

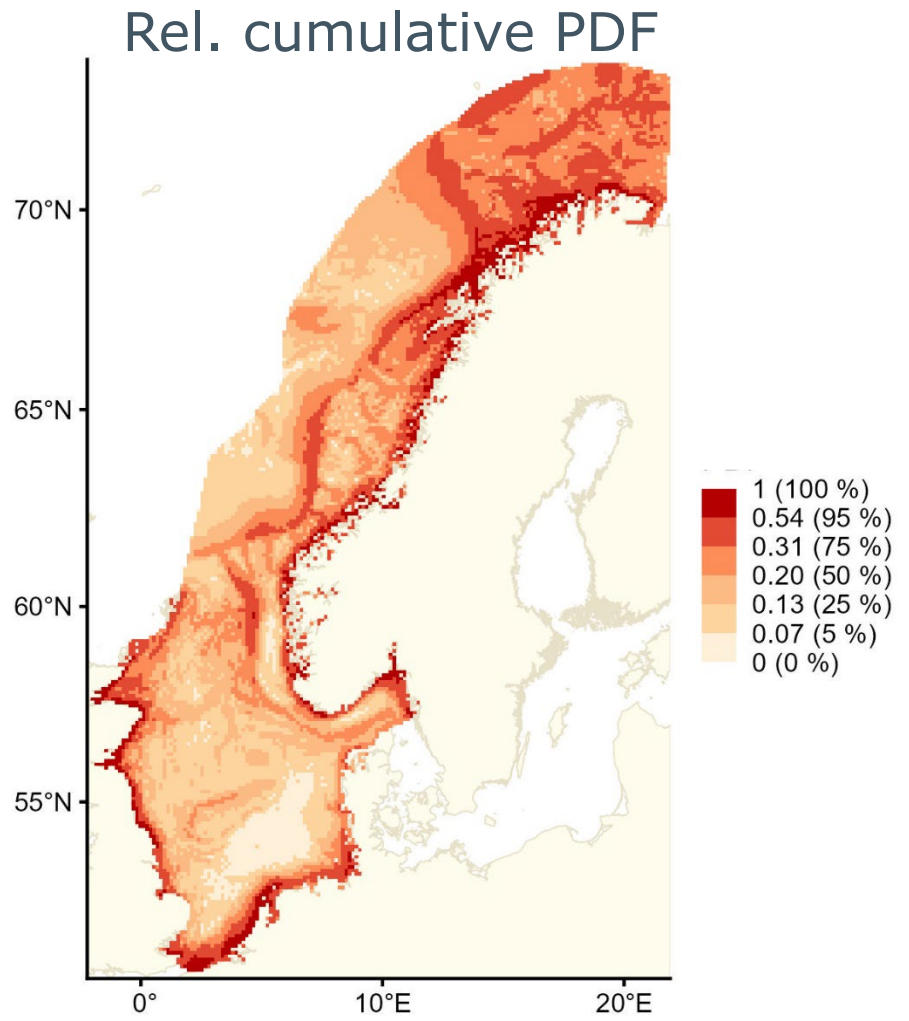
Workflow for each group of species



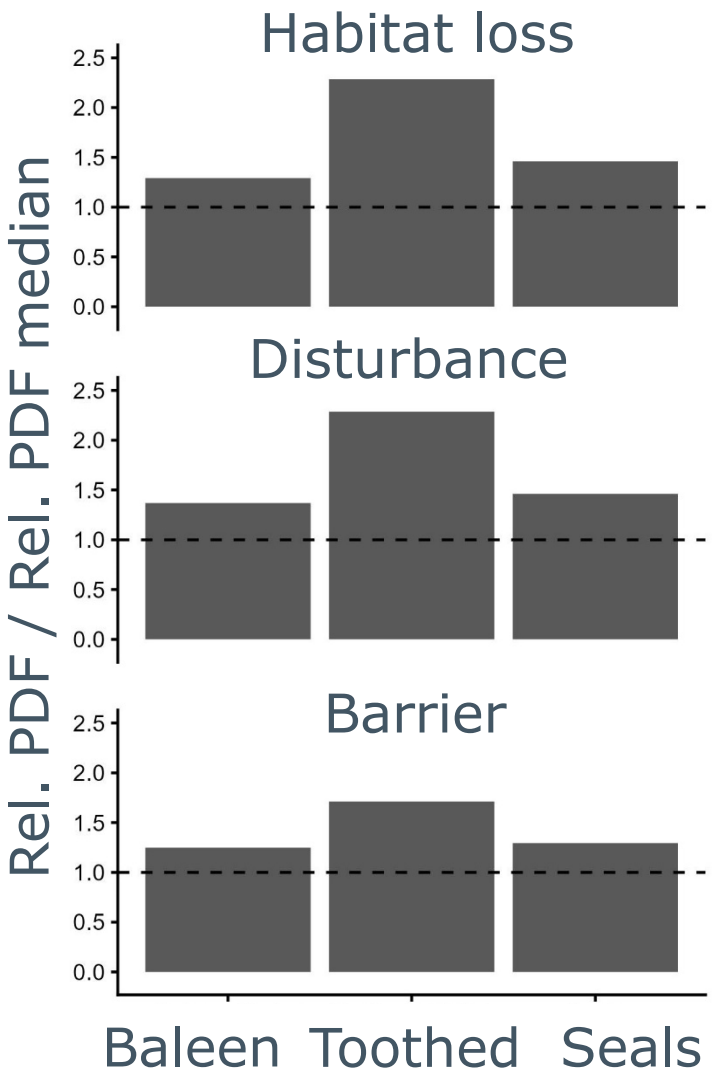
Relative cumulative PDF

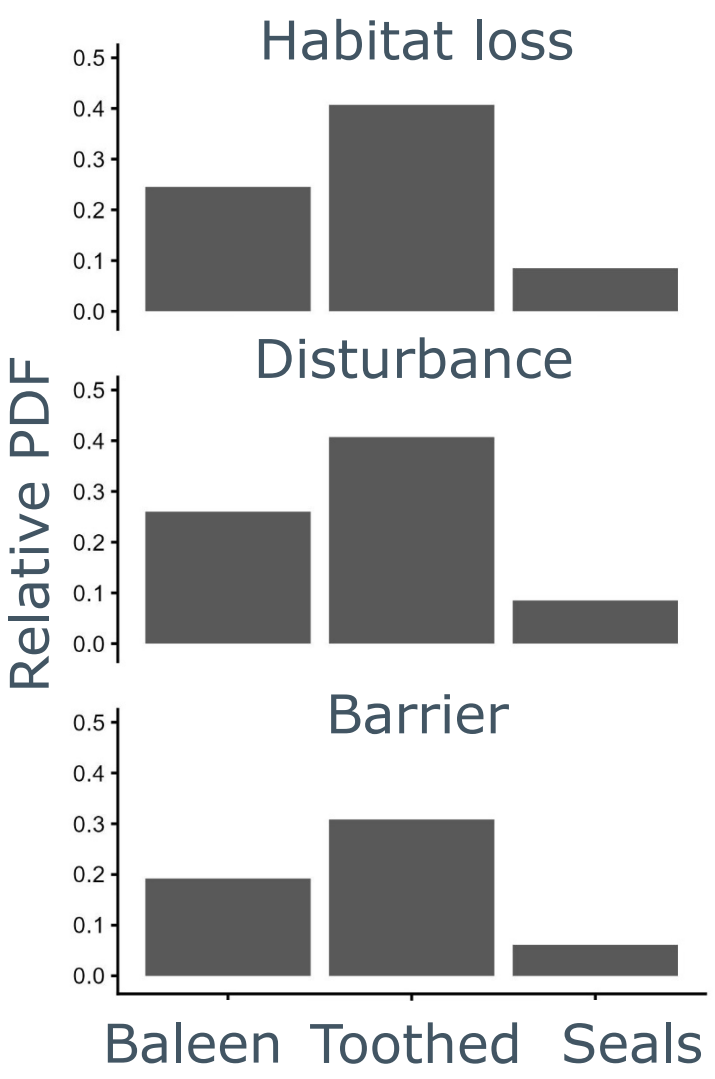
- High
  - Barents sea
  - Coastline
  - Continental slope

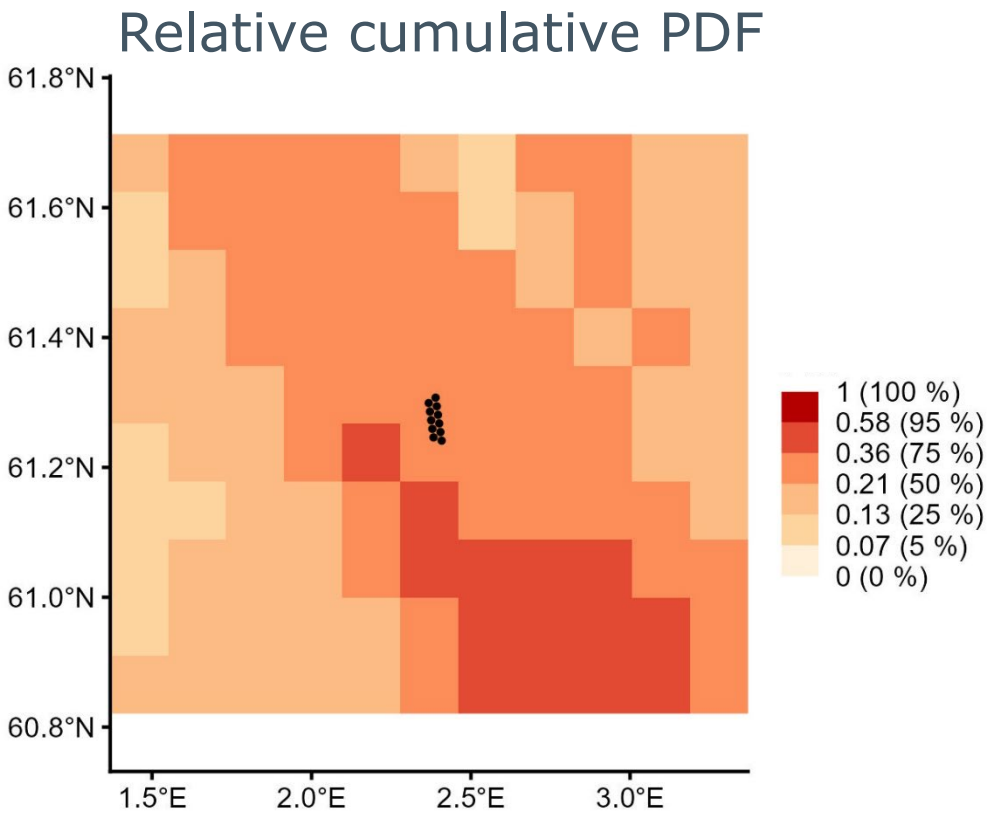




Hywind tampen







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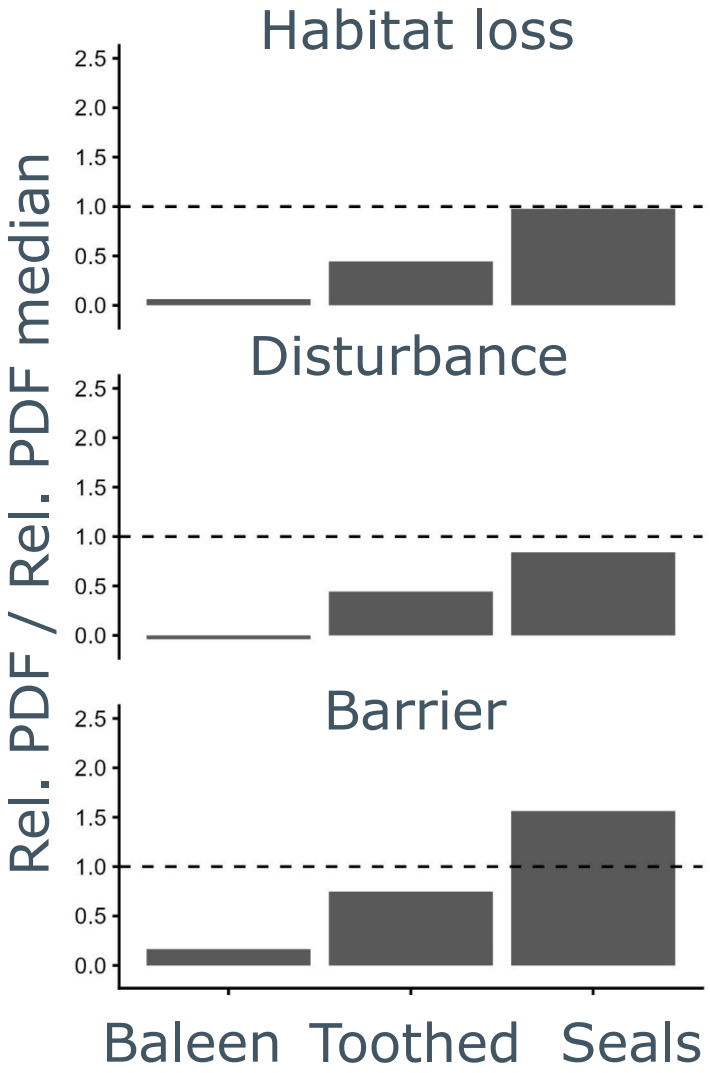
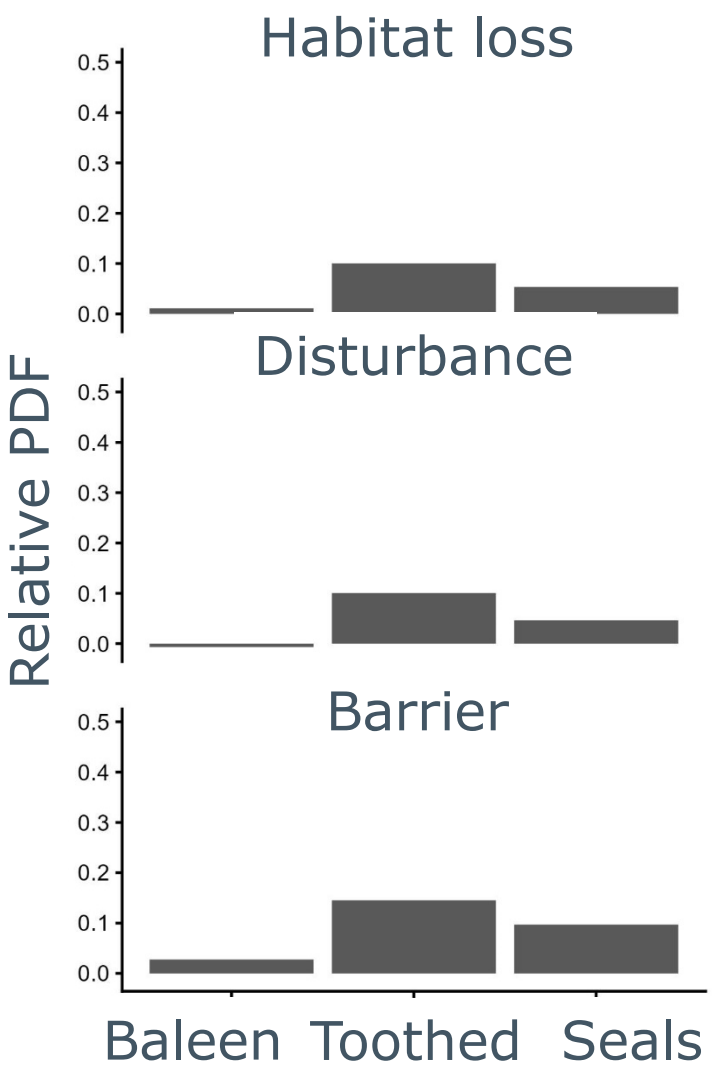
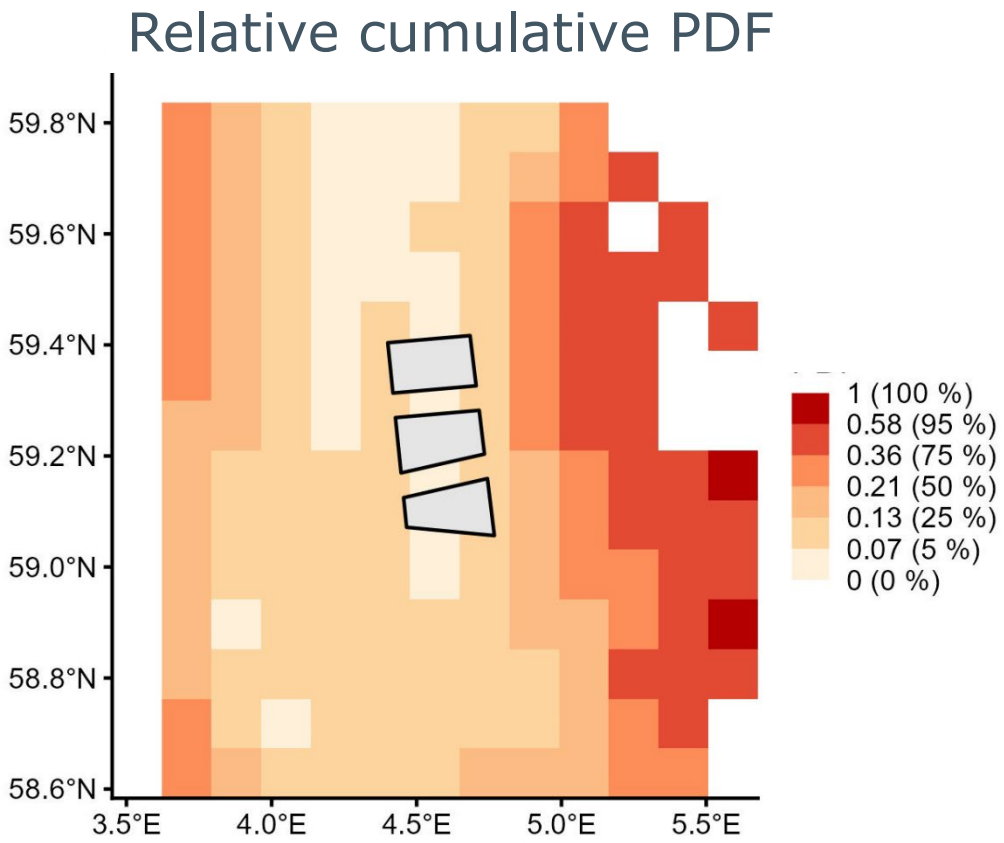
Utsira nord







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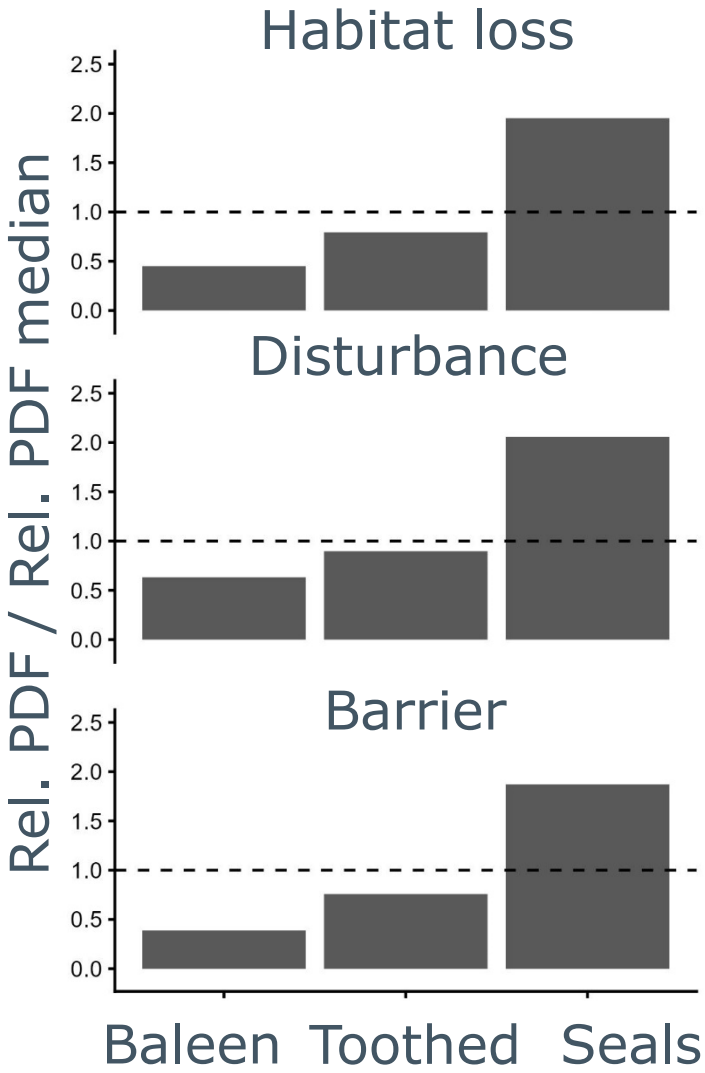
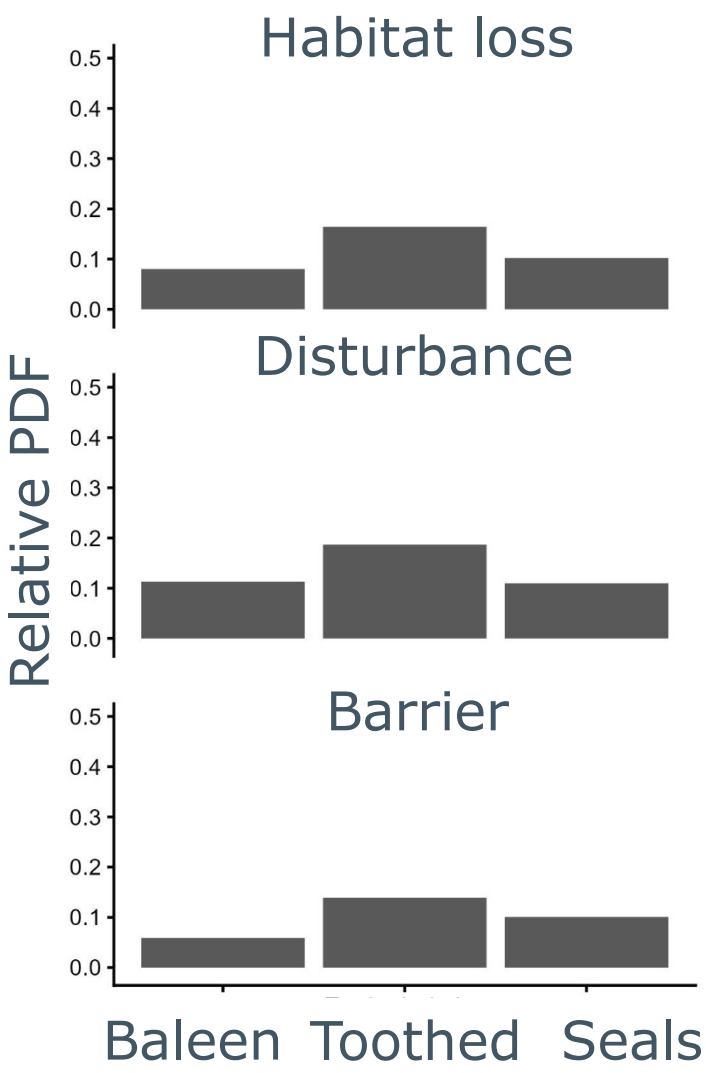
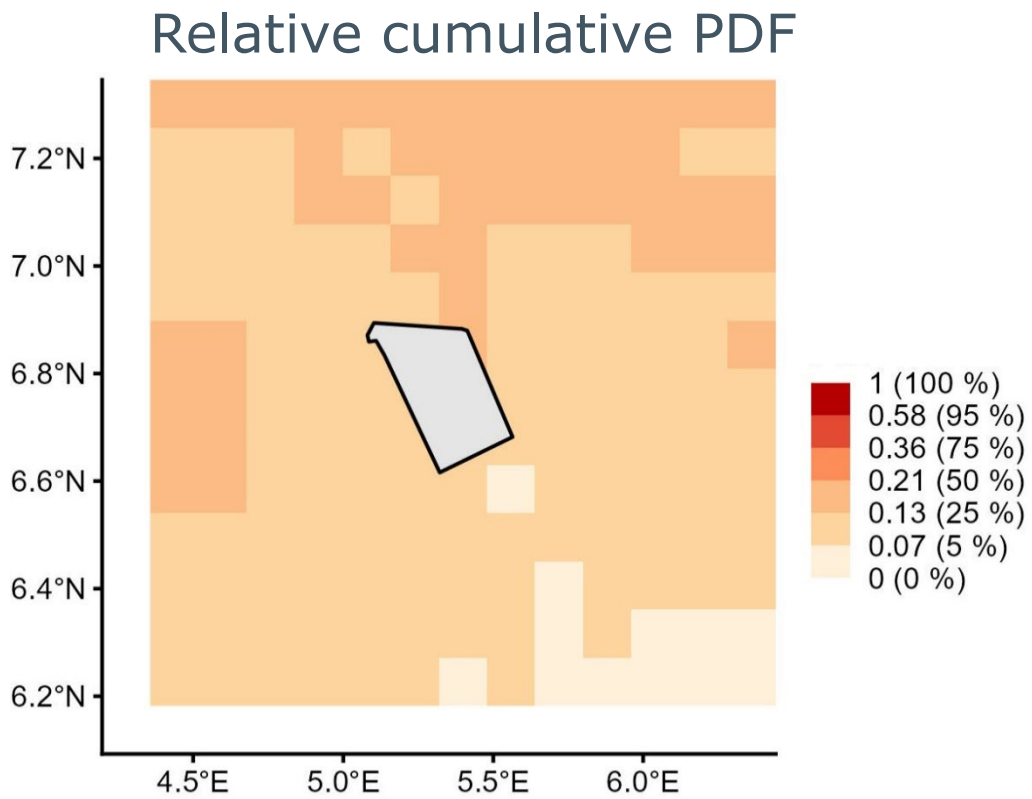
Sørlige nordsjø 2







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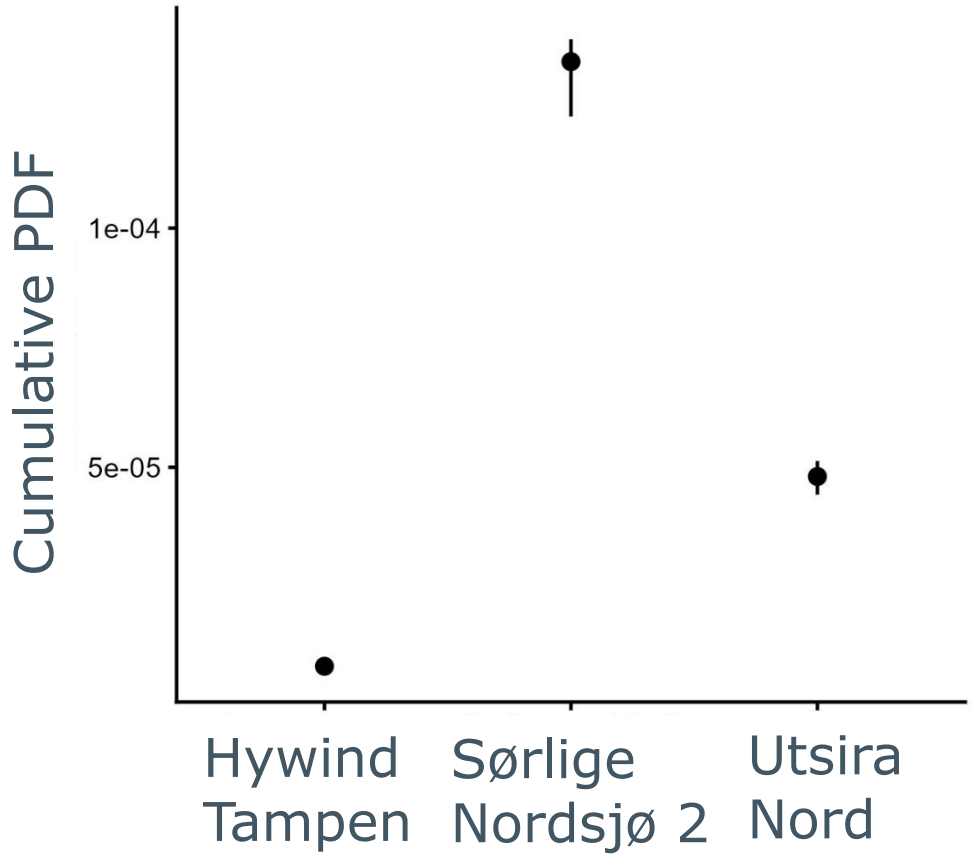
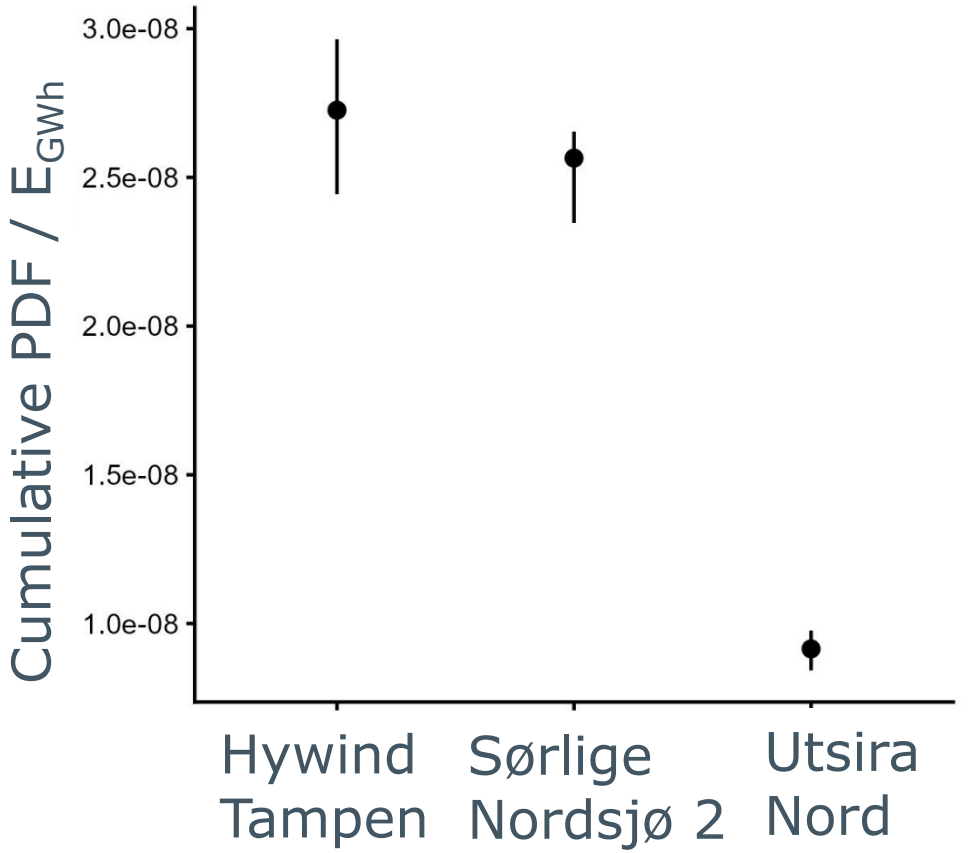
Case studies compared





- E_{GWh} = Annual energy production (GWh/year)

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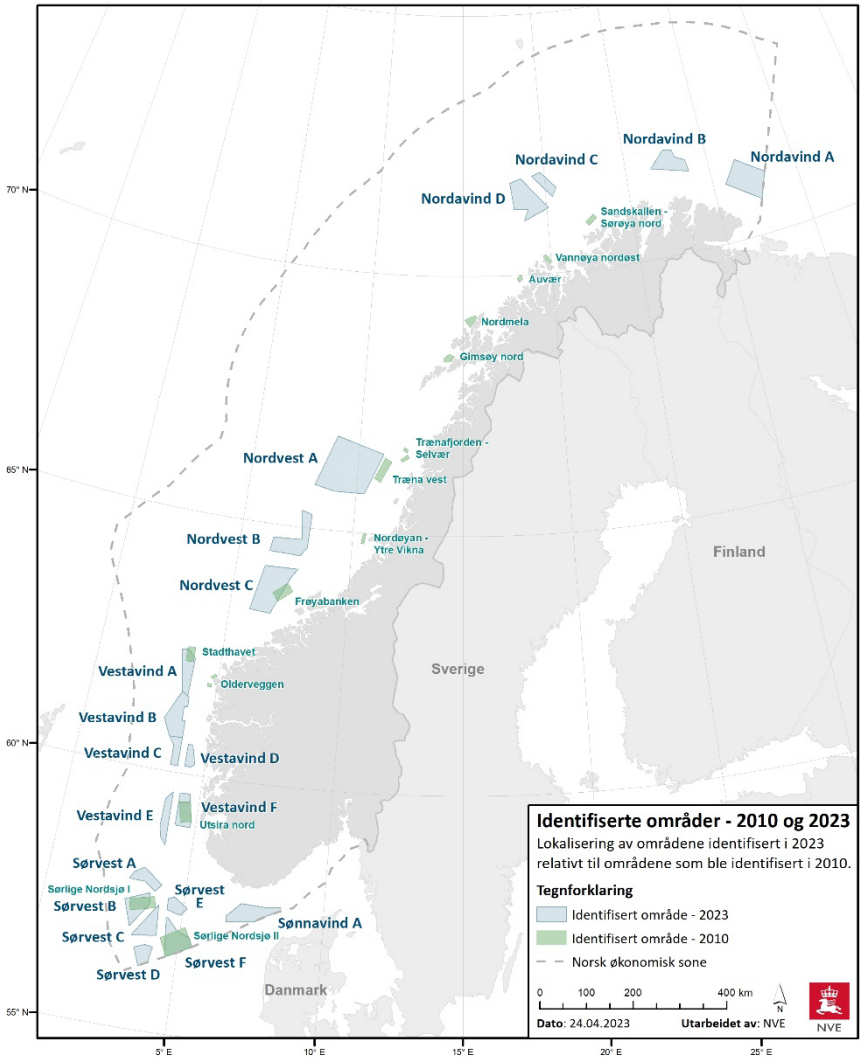
Whats next?

- **20 new offshore wind areas suggested in 2023**
  - Norwegian EEZ

- LCA can be a useful tool for initial assessments of the impact on biodiversity
  - Fast
  - Avoid the areas with highest impact



Questions?

Thanks for your attention

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