Life-cycle impacts of onshore wind-power plants on bird richness

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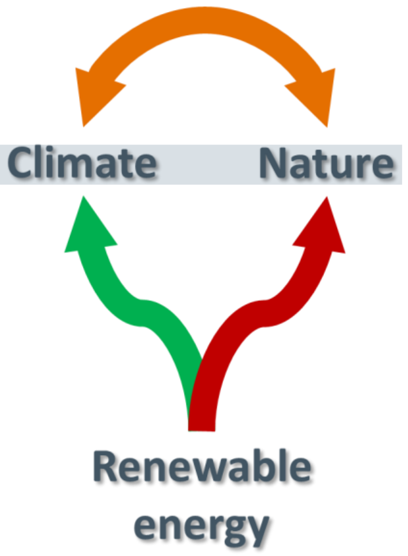
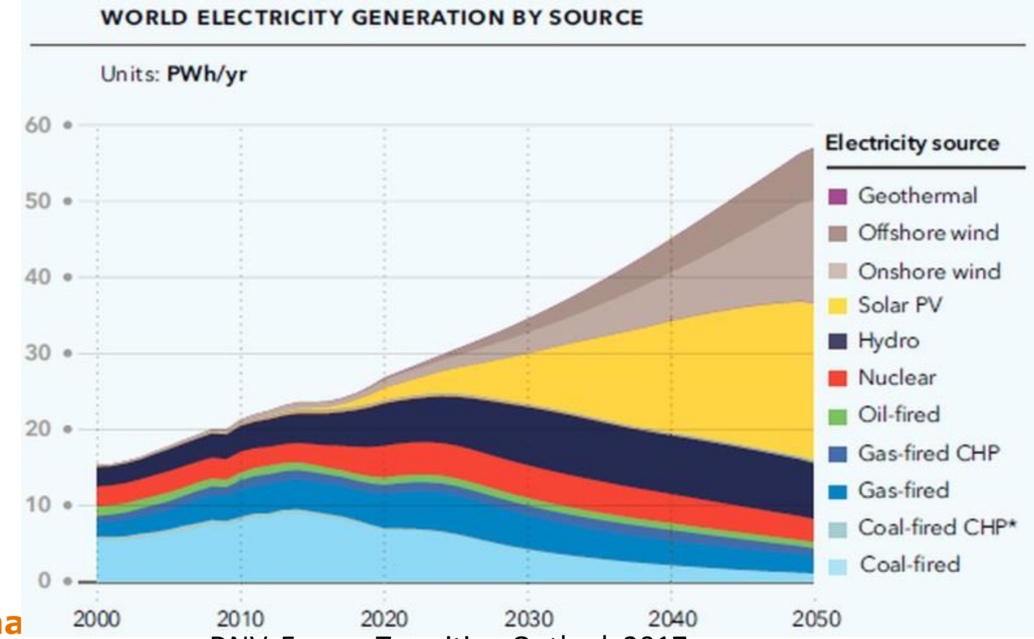
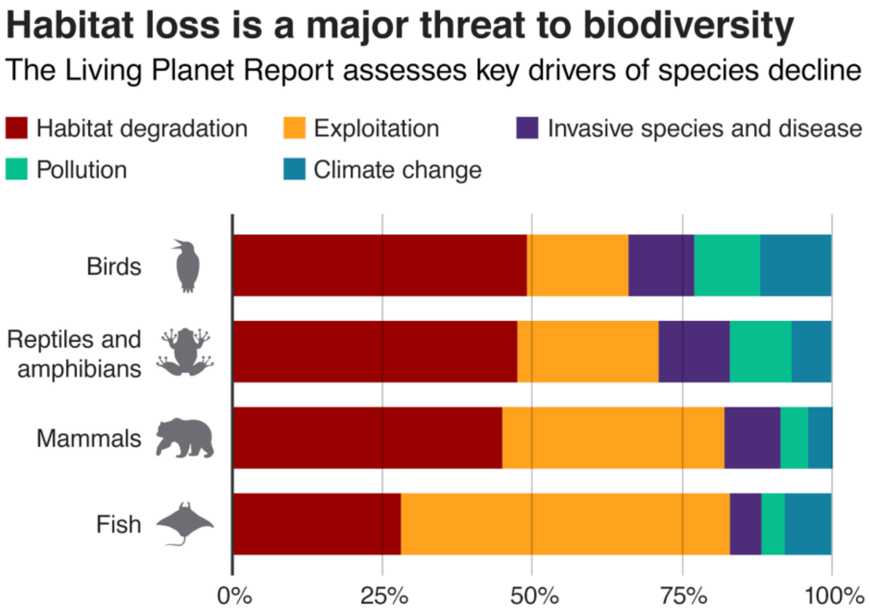
A renewable world



- Renewable energy contributes to lower CO_2 emissions
  - …but affects the natural environment
- Wind power potential is enormous
  - …but can landscapes withstand it on top of existing human activities?



DNV, Energy Transition Outlook 2017



WWF, Living Planet Report 2018

Cumulative effects of piecemeal development

- Environmental Impact Assessments (EIA) often fail to account for cumulative impacts at larger spatial scales
- Life cycle assessments (LCA) can provide a more holistic view, however models quantifying the main impact pathways on biodiversity are still lacking

- To address this gap, we present a methodology to quantify impacts of habitat loss, disturbance and collision at onshore wind power plants on bird biodiversity globally and regionally

Life-cycle impact assessment

- LCIA assesses the spatially explicit impacts occurring throughout a wind farm's life cycle, considering various impact pathways on avian biodiversity

Three impact pathways:

- Habitat loss
- Disturbance
- Collision

Two spatial scales:

- Global
- Norway

Life-cycle impact assessment

- Quantification of the impacts on bird richness
  - Assume impact occurs through direct or indirect loss of area
  - Based on the Species-Area Relationship (SAR)
  - Potentially Disappeared Fraction (PDF) of species (per bird order)
  - Characterization Factor (CF) of impact per GWh

$$\frac{S_{new}}{S_{org}} = \left[\frac{A_{new}}{A_{org}}\right]^z \Leftrightarrow S_{lost} = S_{org} - S_{org} \cdot \left[\frac{A_{new}}{A_{org}}\right]^z$$

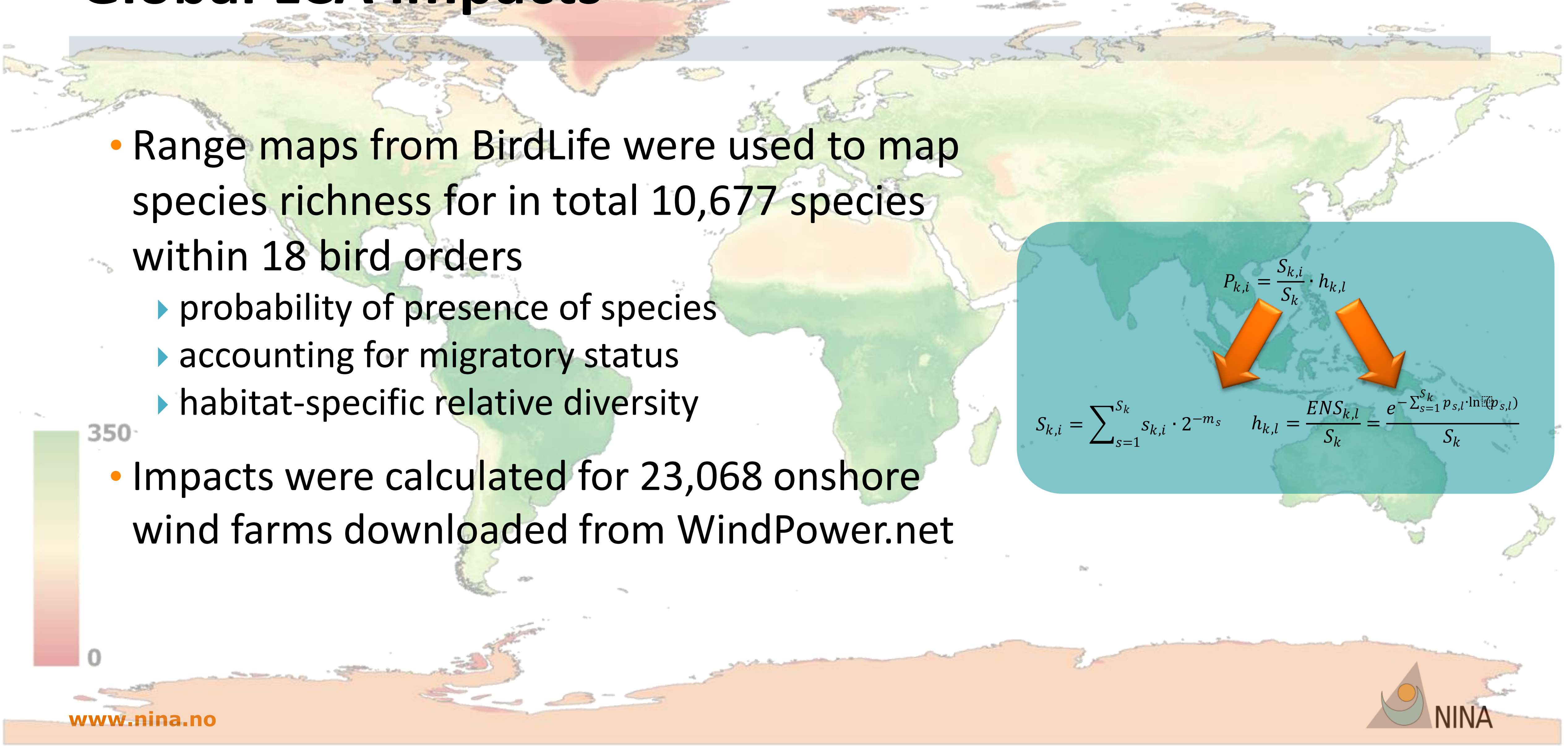
$$PDF_i = \frac{S_{lost}}{S_{org}} = \frac{S \cdot P_i \cdot \left(1 - \left(\frac{A_{org,i} - A_{lost,i}}{A_{org,i}}\right)^z\right)}{\sum_{i=1}^{I} S \cdot P_i}$$

$$CF(X)_w = \frac{\sum_{k=1}^{K} PDF(X)_{k,w}}{E_w}$$

Life-cycle impact assessment

Habitat loss (H)	Disturbance (D)	Collision (C)
structural area loss $$PDF(H)_{k,w} = \frac{S_k \cdot P_{k,i} \cdot \left(1 - \left(\frac{A_{org} - a_{EP} \cdot EP_w}{A_{org}}\right)^z\right)}{\sum_i^I S_k \cdot P_{k,i}}$$	**functional area loss** $$PDF(D)_{k,w} = \frac{S_k \cdot P_{k,i} \cdot \left(1 - \left(\frac{A_{org} - t_w \cdot (\pi \cdot (D_k \cdot d_{k,max})^2)}{A_{org}}\right)^z\right)}{\sum_i^I S_k \cdot P_{k,i}}$$	**loss of area use** $$PDF(C)_{k,w} = \frac{S_k \cdot P_{k,i} \cdot \left(1 - \left(\frac{A_{org} - R_k \cdot t_w \cdot (\pi \cdot r_w^2)}{A_{org}}\right)^z\right)}{\sum_i^I S \cdot P_{k,i}}$$
$S_k \cdot P_{k,i}$ = number of species locally present at cell i within group k A_{org} = 100 km^2 a_{EP} = 0.3 or 0.7 ha/MW EP_w = output (MW) of wind farm w	t_w = number of turbines D_k = proportion of species displaced over distance within group k $d_{k,max}$ = maximum flight initiation distance within group k	r_w = rotor blade length of turbine w R_k = probability of annual per-turbine collision within group k

Global LCA impacts



- Range maps from BirdLife were used to map species richness for in total 10,677 species within 18 bird orders
  - probability of presence of species
  - accounting for migratory status
  - habitat-specific relative diversity
- Impacts were calculated for 23,068 onshore wind farms downloaded from WindPower.net

$$P_{k,i} = \frac{S_{k,i}}{S_k} \cdot h_{k,l}$$

$$S_{k,i} = \sum_{s=1}^{S_k} s_{k,i} \cdot 2^{-m_s}$$

$$h_{k,l} = \frac{ENS_{k,l}}{S_k} = \frac{e^{-\sum_{s=1}^{S_k} p_{s,l} \cdot \ln(p_{s,l})}}{S_k}$$

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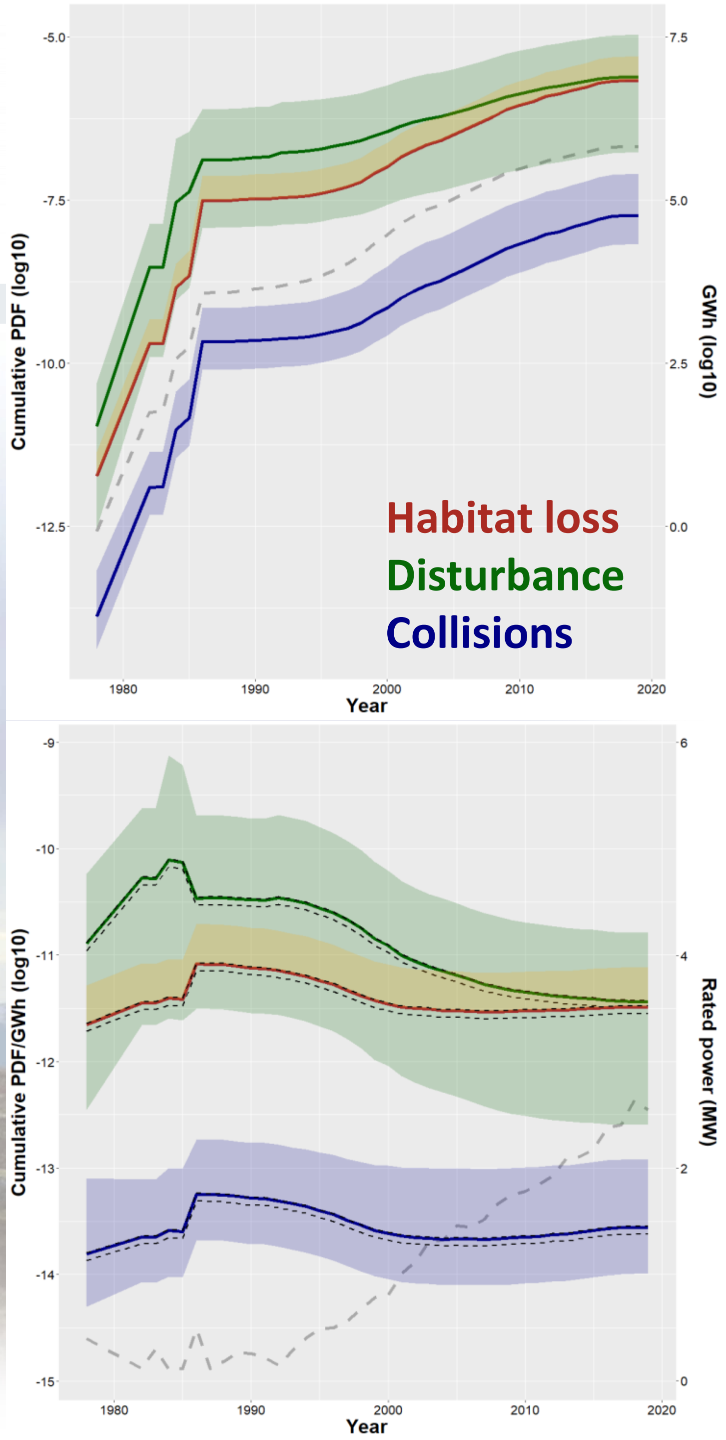
Global LCA impacts

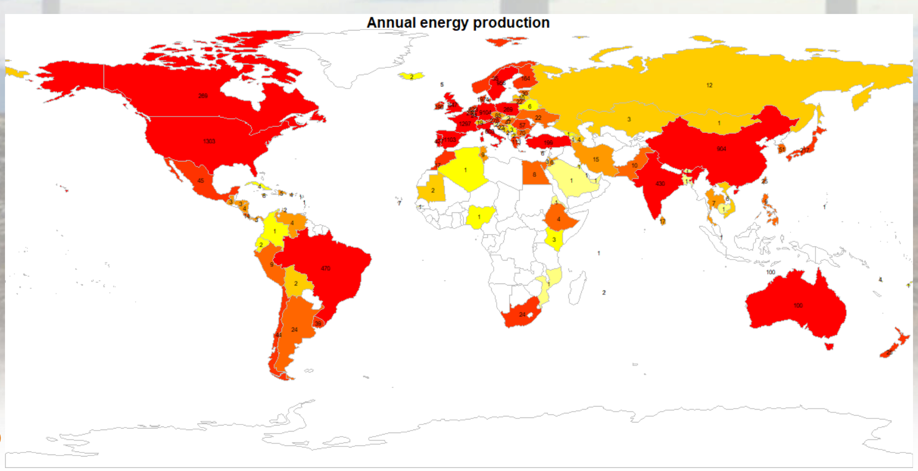
- Disturbance and habitat loss had a greater effect compared to collisions
- Impacts are highly influenced by annual energy production

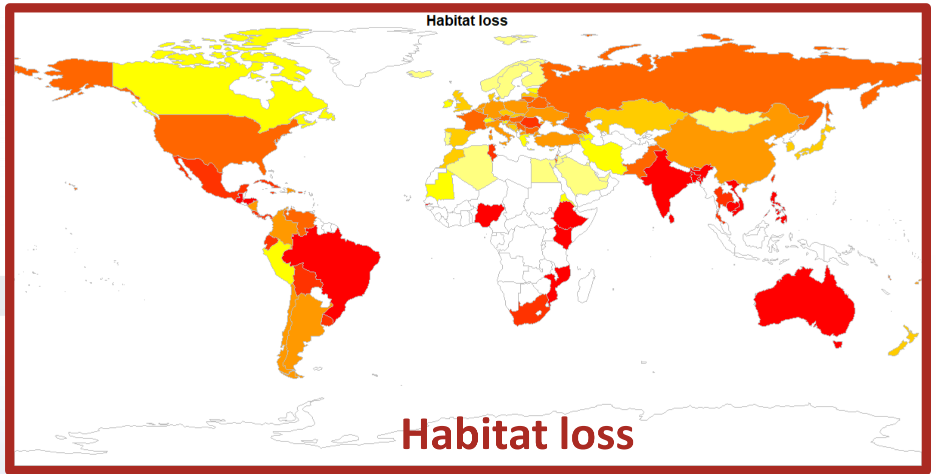


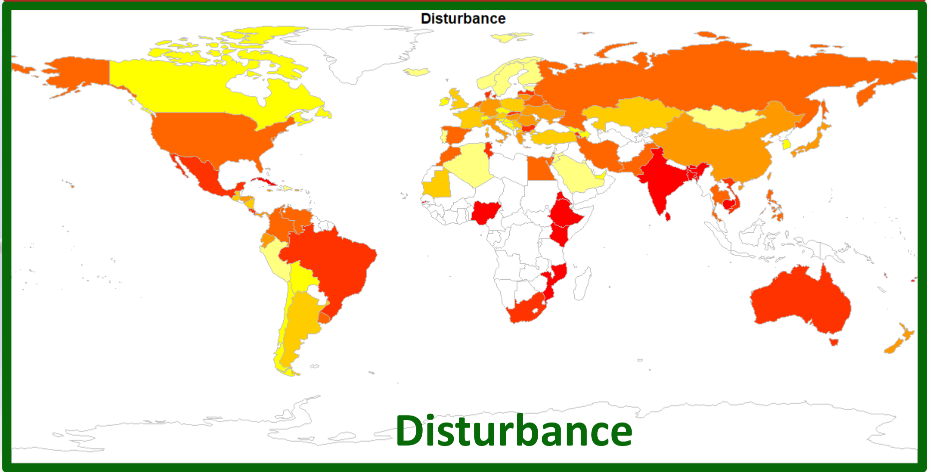
May et al. 2020 Env.Sust.Ind.

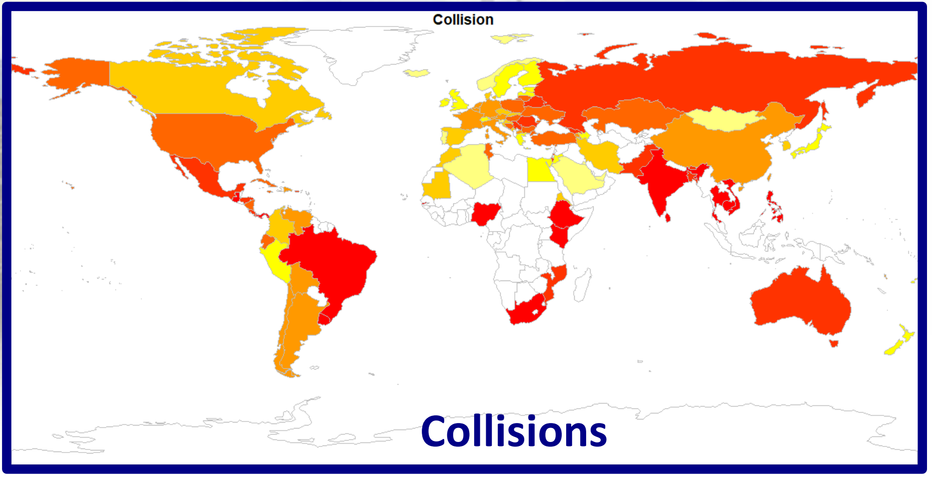
Global LCA impacts

- Globally, impacts were greatest in biodiverse tropical and subtropical regions





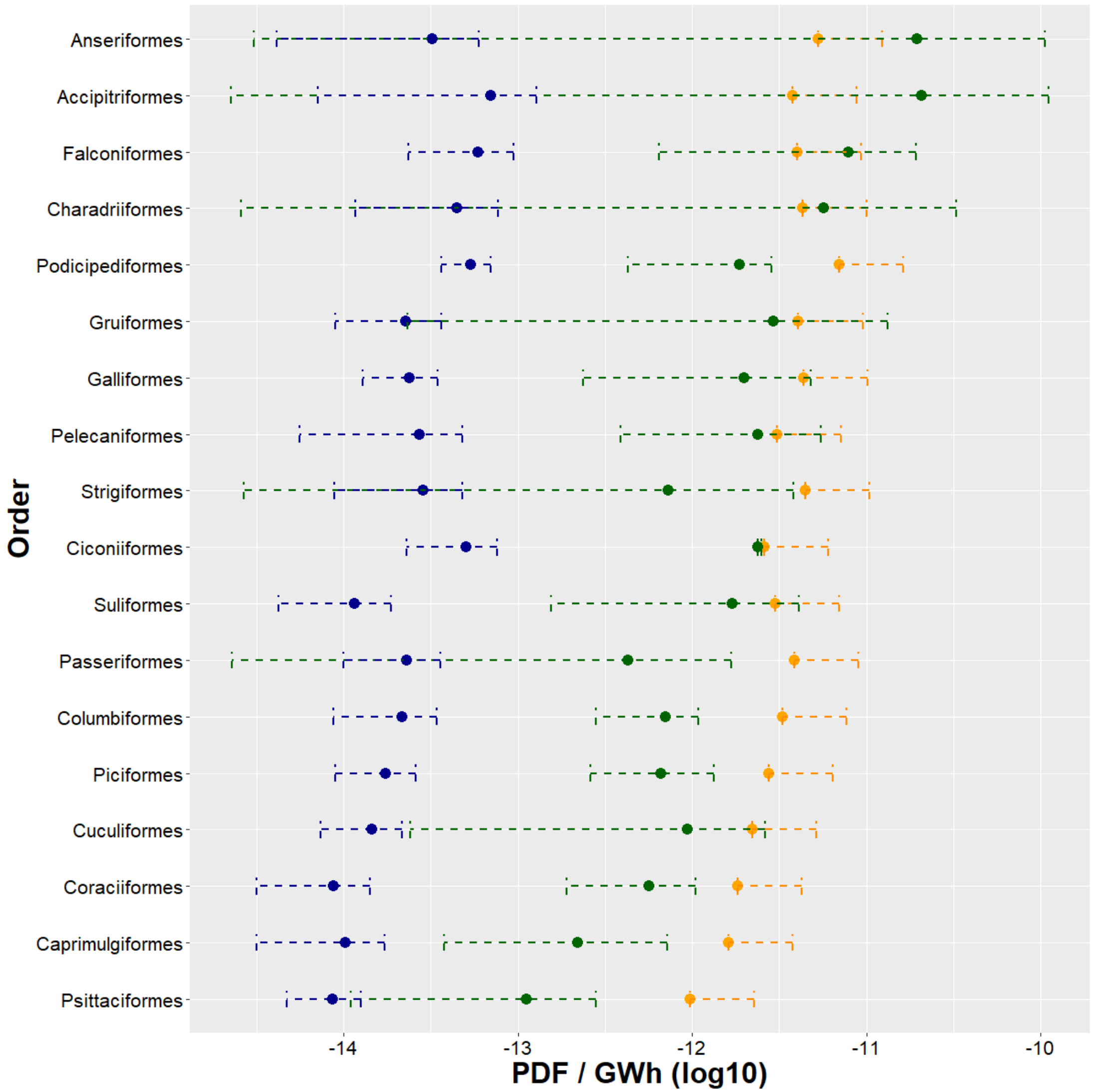




Global LCA impacts

- When controlling for continent, bird order rather than country more strongly influenced variation in the pathway-specific impact per GWh

- The highest affected bird orders:
  - Ducks & geese
  - Eagles & Falcons
  - Waders
  - Grebes



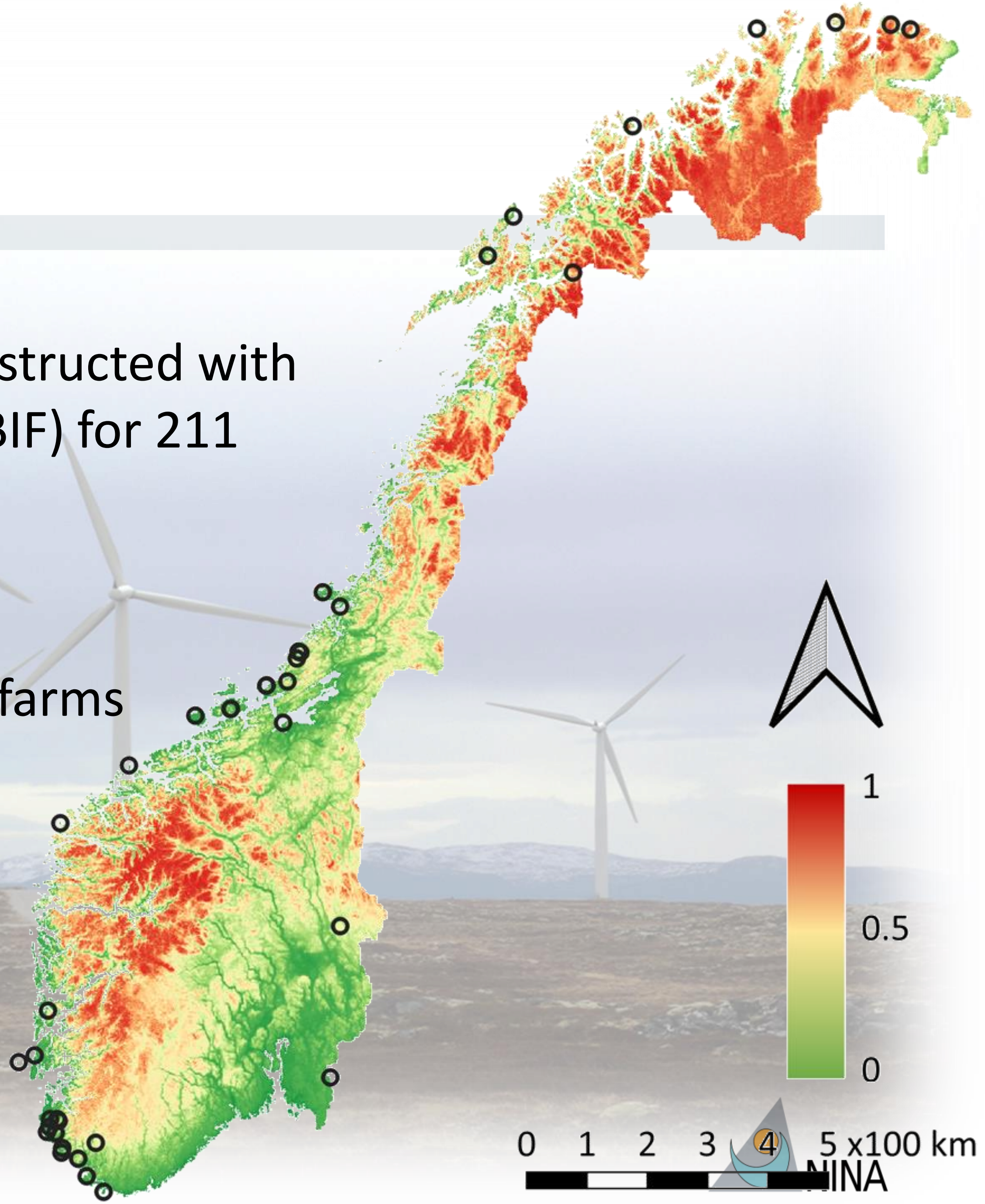
Regional LCA impacts

- Species-specific distribution models were constructed with MaxEnt using citizen science observations (GBIF) for 211 species
- Thereafter aggregated into 13 bird groups

- Impacts were calculated for 39 onshore wind farms

$$PDF_i = \frac{S \cdot P_i \cdot \left(1 - \left(\frac{A_{org,i} - A_{lost,i}}{A_{org,i}}\right)^z\right)}{\sum_{i=1}^{I} S \cdot P_i}$$

- Spatial resolution 1 km^2
- Quantified per turbine



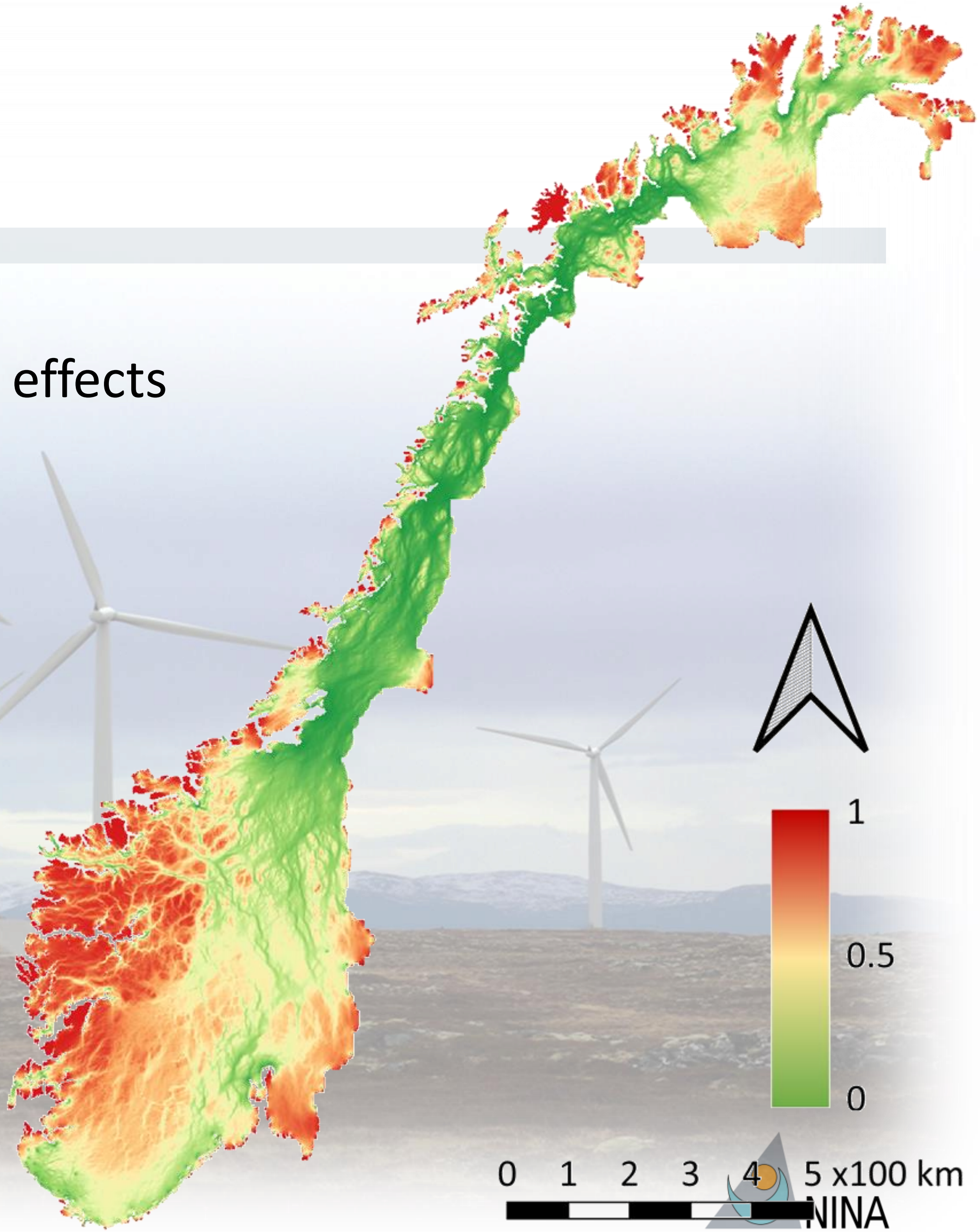
Regional LCA impacts

- In addition, a metric was developed for barrier effects

$$PDF(B)_{k,w} = \frac{S_k \cdot C_{k,i} \cdot \left(1 - \left(\frac{A_{org} - (\pi \cdot t_w \cdot M_k \cdot (D_k \cdot d_{k,max})^2)}{A_{org}}\right)^z\right)}{\sum_i^I S_k \cdot C_{k,i}}$$

relative conductance to movement across suitable habitat (Circuitscape)

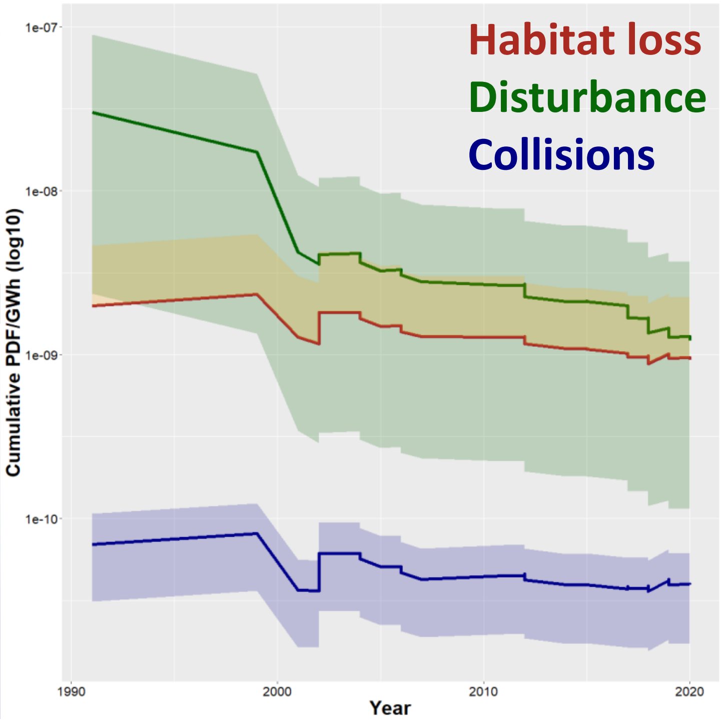
energetic impact of seasonal migration as a function of energy requirement and migration distance

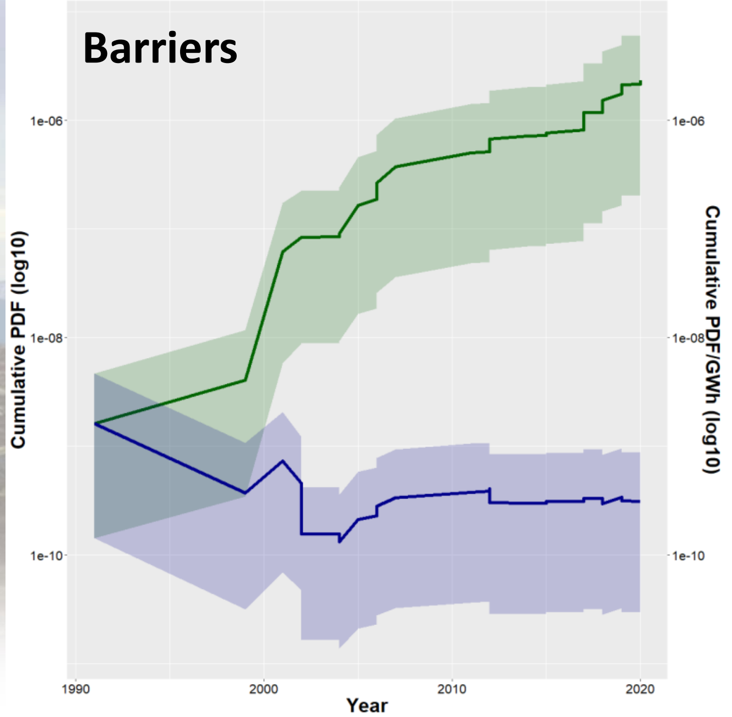


Regional LCA impacts

- In Norway, impacts increased with installed capacity, but smaller wind farms were less efficiently located with greater impacts per GWh

Covariate	Impact pathway			
	Habitat loss	Disturbance	Collision	Barrier
Turbine capacity (MW)	94.511***	9.857**	125.329***	5.465*
Number of turbines	66.151***	53.949***	77.239***	0.772
Interactive effect	-11.723**	-7.447*	-10.259**	6.466*
adjusted R^2	0.817	0.642	0.847	0.2034

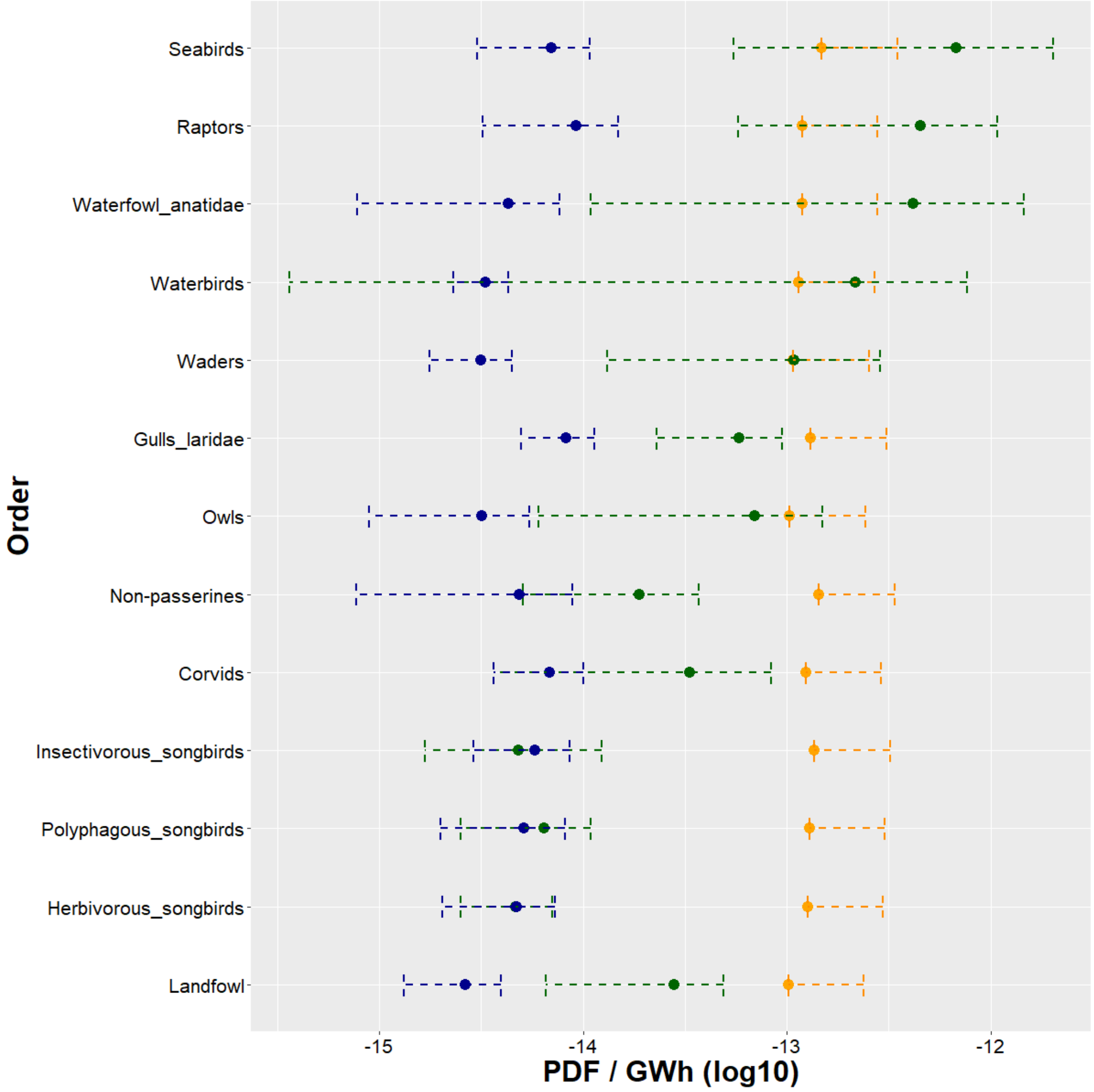




May et al. 2021 EIAR

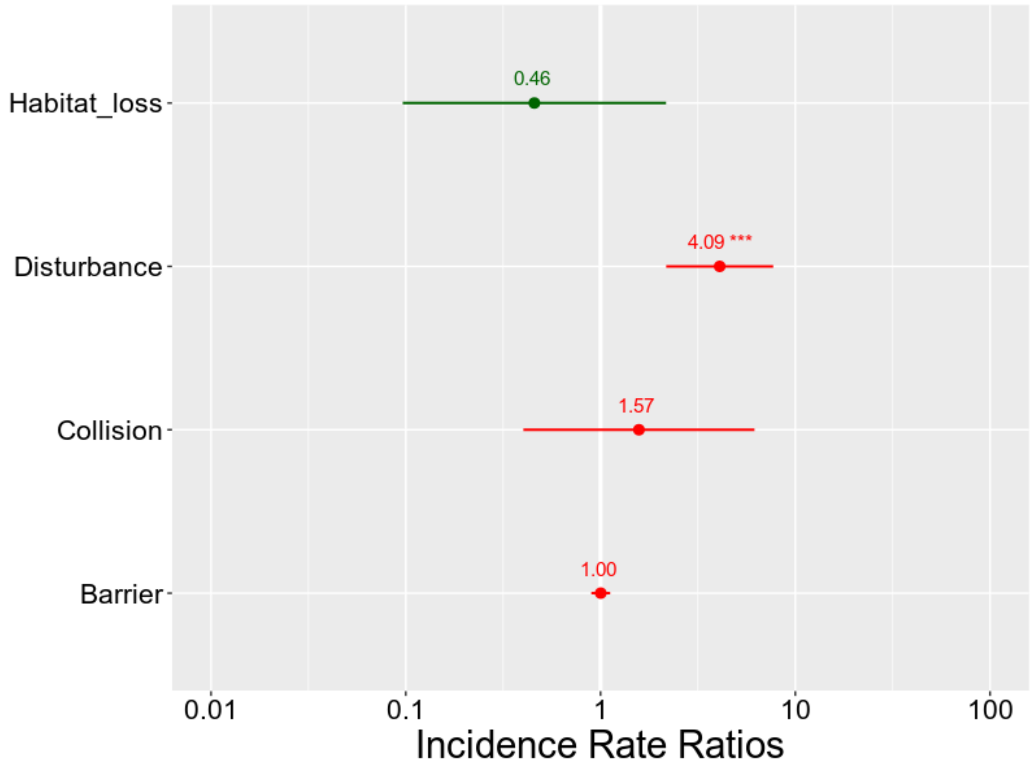
Regional LCA impacts

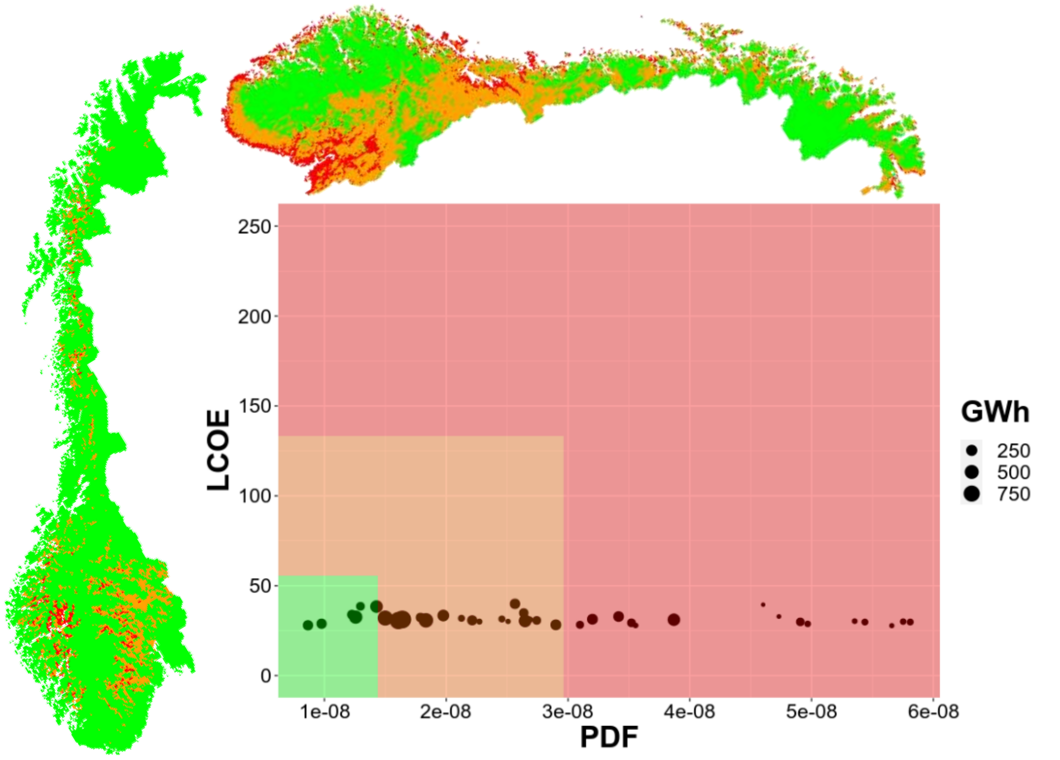
- Given the mostly coastal development, vulnerability was highest for seabirds, raptors and waterfowl



Regional LCA impacts

- Compared to random sites, wind farms did not seem to avoid conflicts with birds
- Although most parts of Norway are suitable for wind energy (LCOE),
- Current practice has not succeeded in avoiding sites with higher impacts for birds

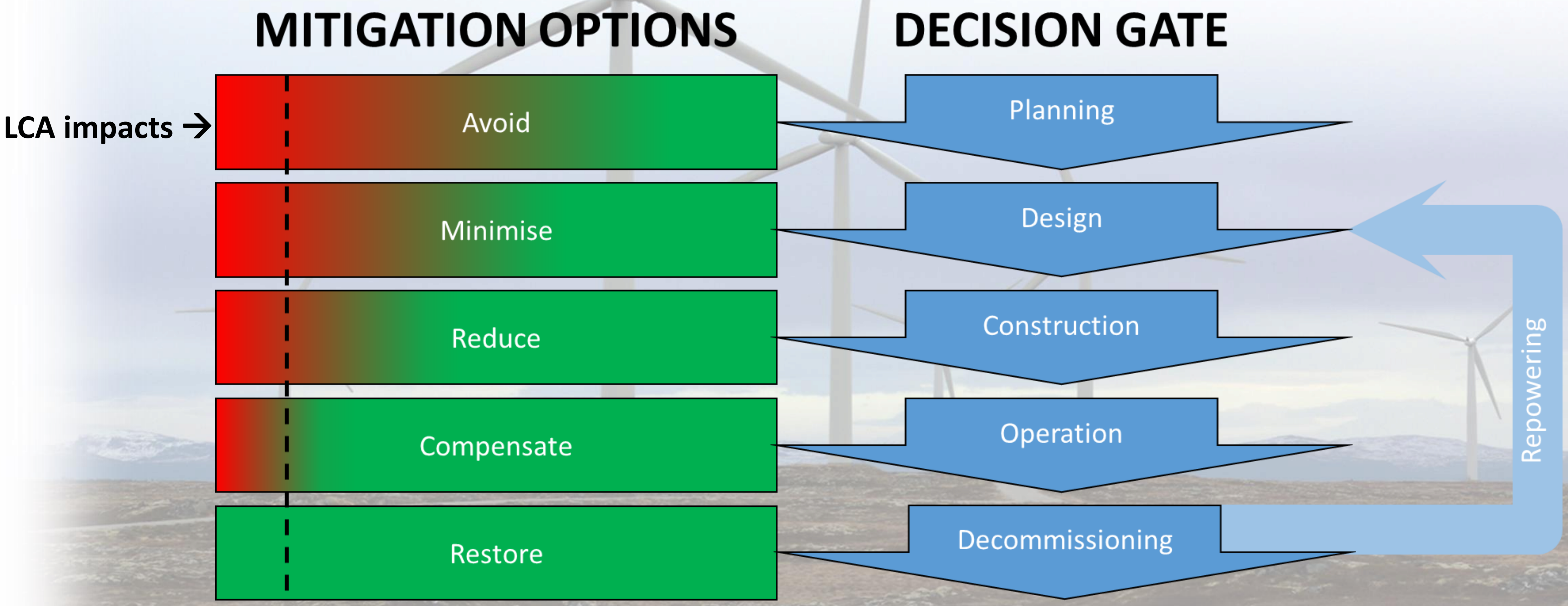




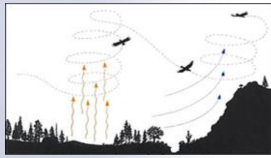
Implications

- Operative LCA models can help decision-makers by:
  - assessing localized life-cycle environmental impacts for environmental-friendly wind energy production in specific regions
  - assessing impacts of future renewable energy expansion scenarios to direct strategic planning or priority setting
  - evaluate consequences of renewable energy policy implementation to achieve a more sustainable wind energy development.
  - Improve EIA practice by picking the sites with the least impact on biodiversity,
- This will directly and significantly benefit technological performance: more wind energy projects will be realized with reduced environmental, and societal, impact per GWh

The Mitigation Hierarchy



ConSite Wind



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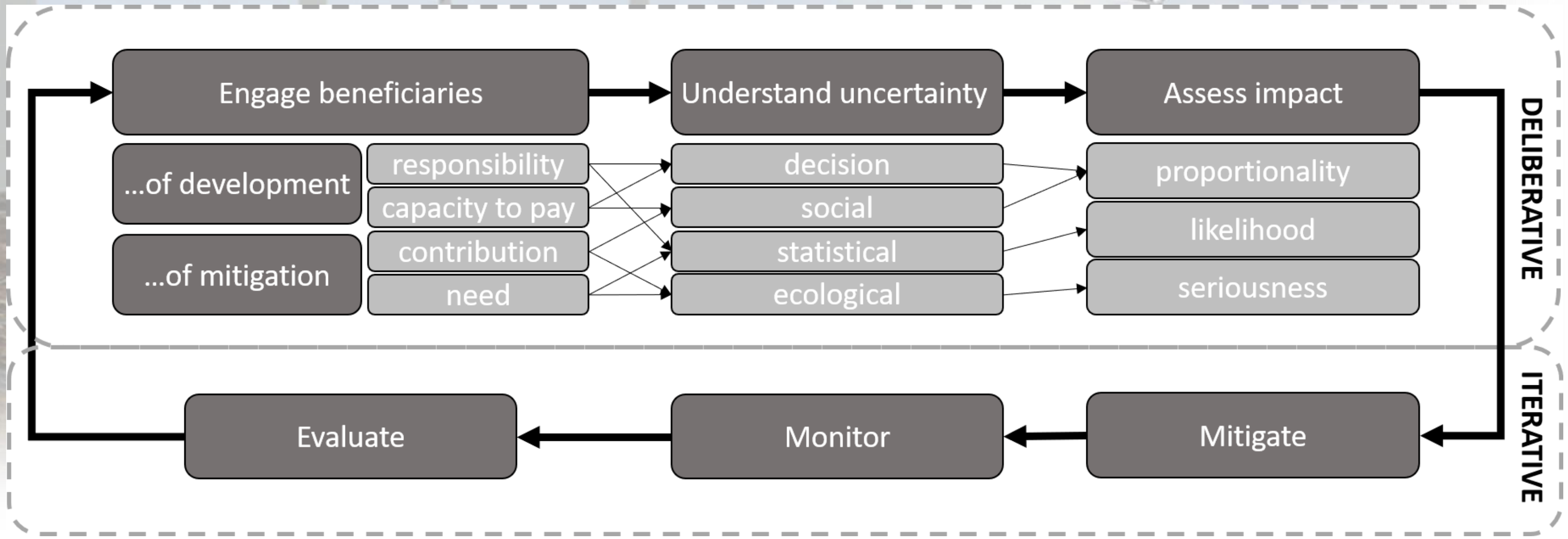
The Impact of Mitigation

- Wind energy with the least environmental impact per GWh requires to act upon:
  - acknowledgment that trouble never comes alone ('assess')
  - balancing interest trade-offs ('engage')
  - embracing uncertainty ('understand')
- Failing to mitigate these impacts negates an assessment of the trade-offs between biodiversity and energy production, and therefore the balancing of global sustainability goals.



Thank you for your attention

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