Balancing profitability of energy production, societal impacts and biodiversity in offshore wind farm design

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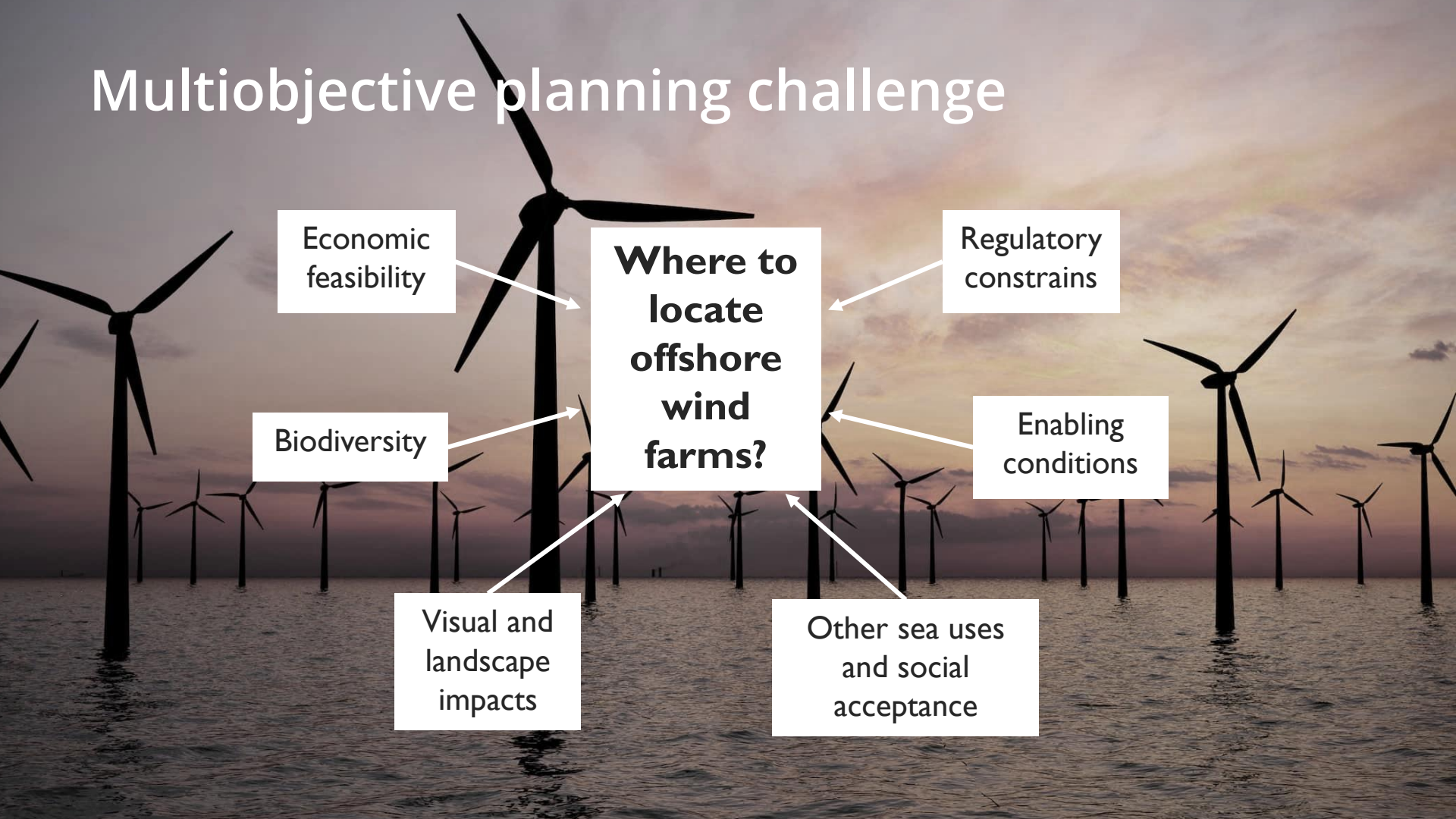
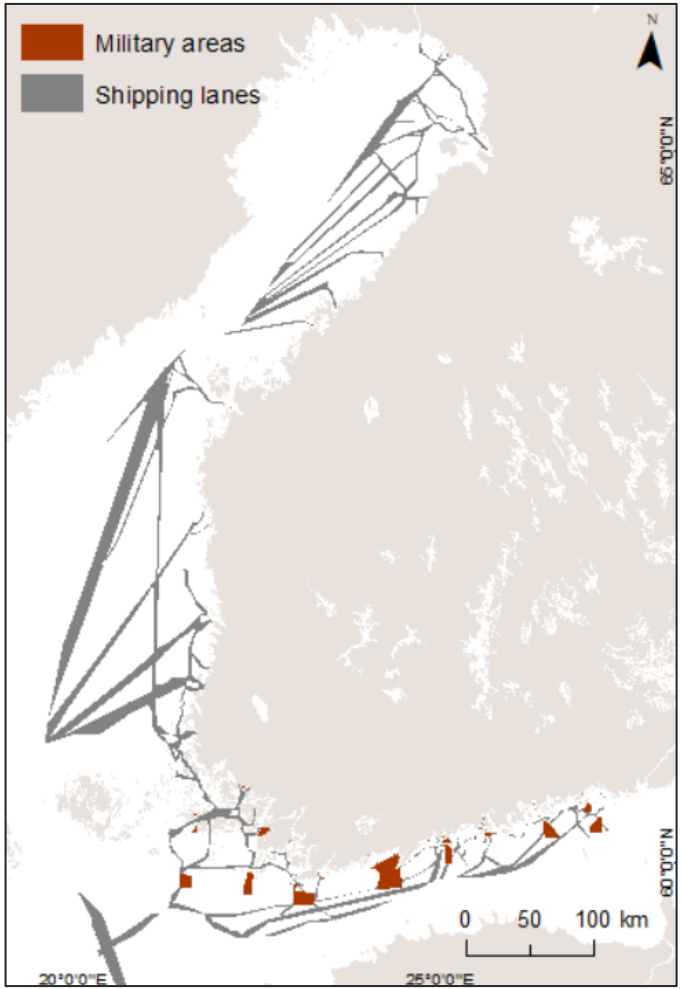
MSP4MORE
MeriTV

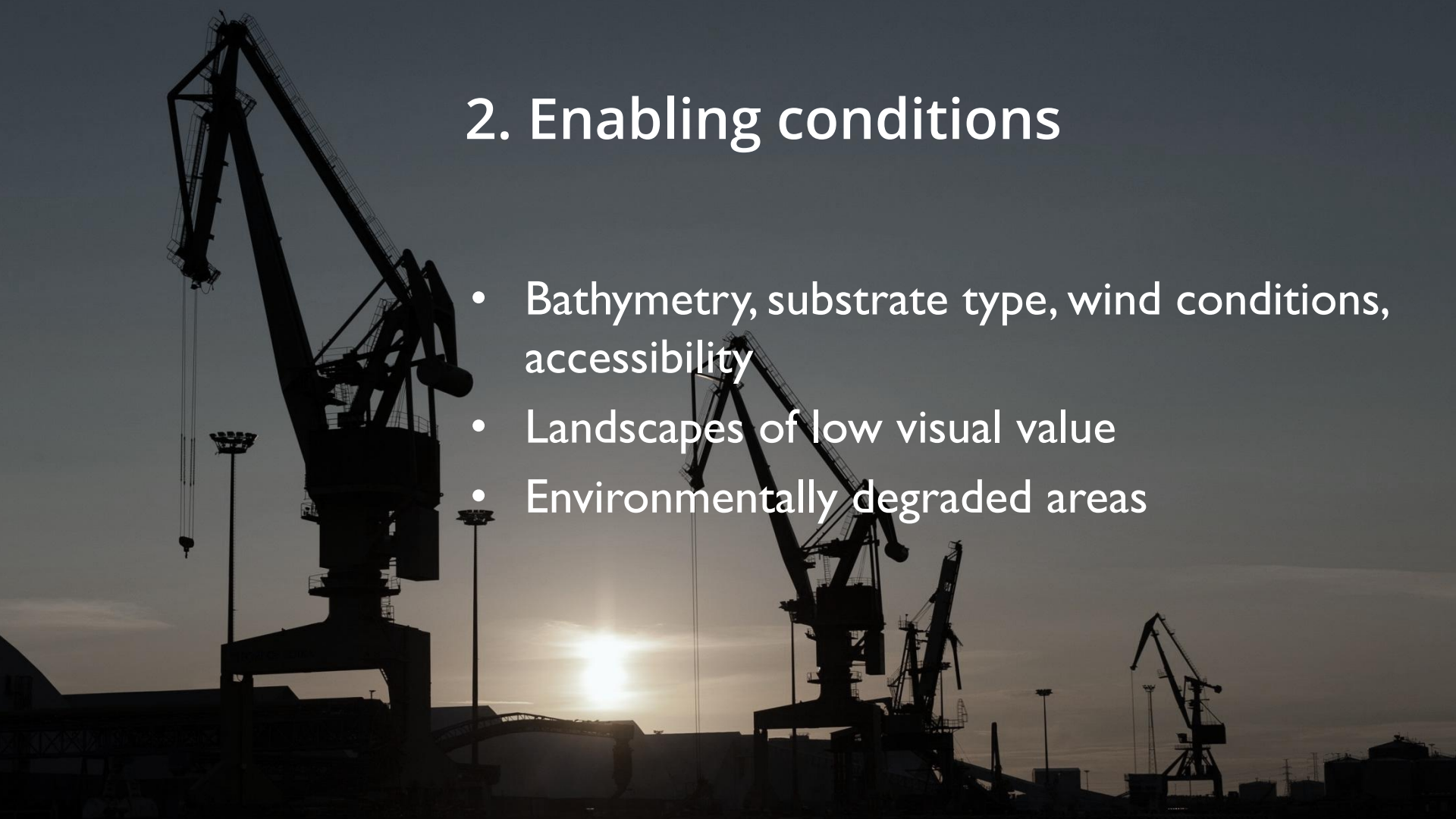
Multiobjective planning challenge



1. Regulatory constraints

- Protected areas
- Shipping lanes
- Anchoring areas
- Military areas
- Weather radars



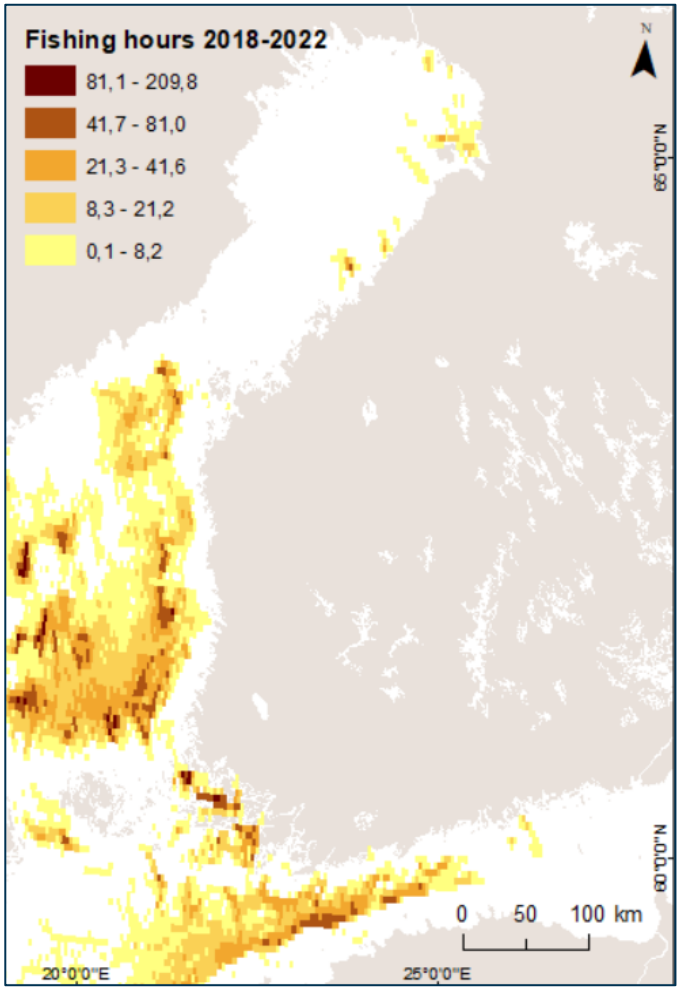


2. Enabling conditions

- Bathymetry, substrate type, wind conditions, accessibility
- Landscapes of low visual value
- Environmentally degraded areas

3. Other sea uses

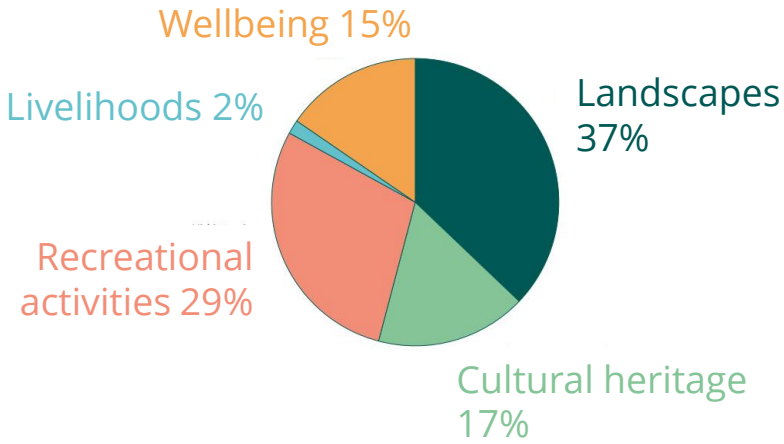
- Commercial fishing
- Aquaculture
- Recreational activities
- Tourism

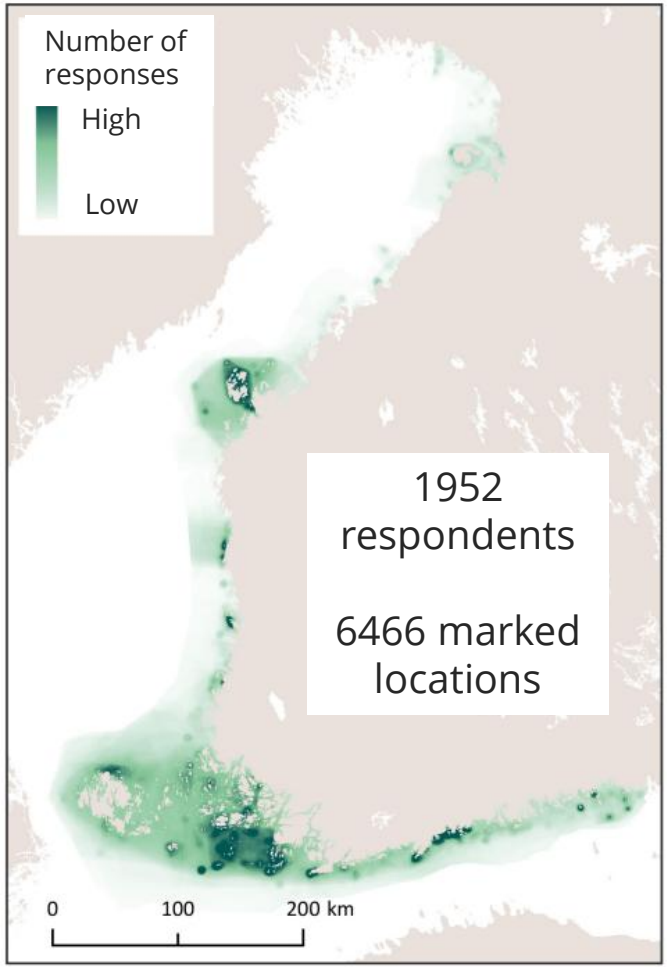


Lappalainen et al. 2023

3. Social acceptance

Participatory GIS survey: where are your meaningful places?



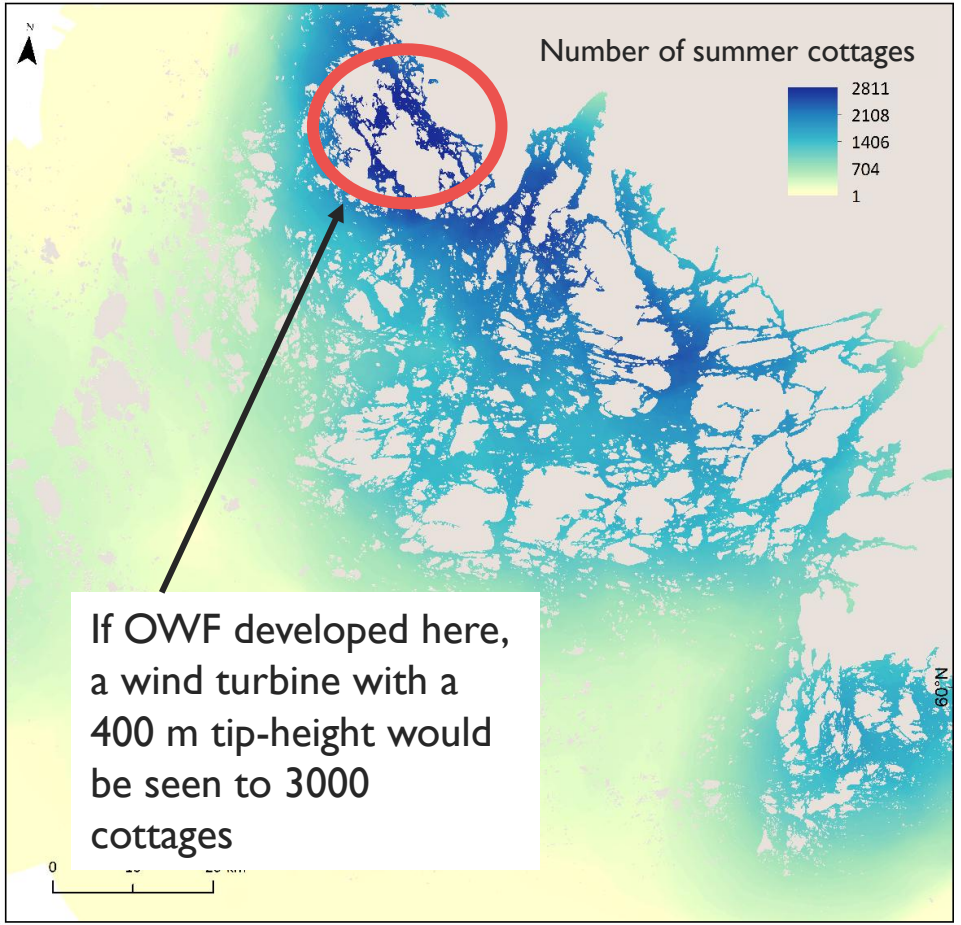


Paulus et al. 2024

4. Visual and landscape impacts

Visual impact modelling

→ Where offshore wind farms would be seen?



Virtanen et al. 2022

5. Biodiversity

Development of large-scale offshore wind farms impacts biodiversity both below and above water

→ habitat loss and disturbance

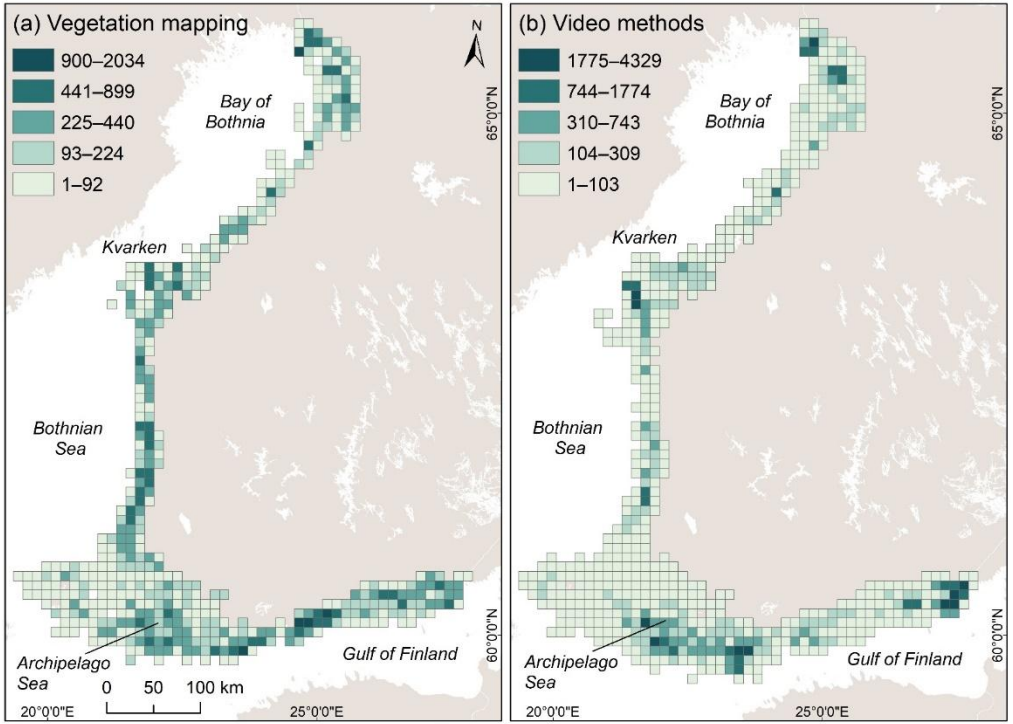
→ mobile and migratory species: disturbance, collision, displacement of nesting/breeding grounds

Finnish Inventory Programme for Underwater Marine Diversity

- Scientific diving
- Video observation methods
- Benthic fauna sampling

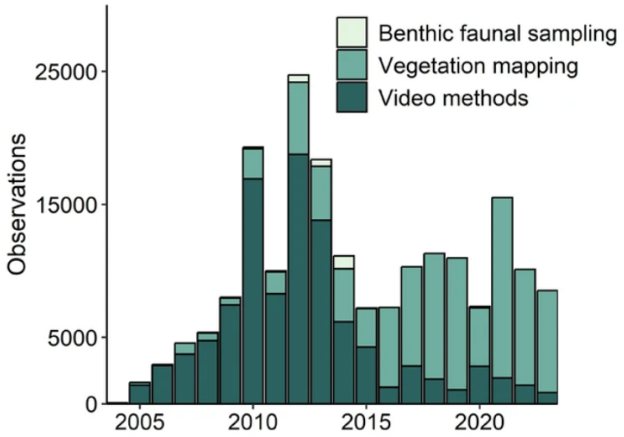
Photo: Jon Ögård / Parks & Wildlife Finland

Inventory data collected for over 20 years



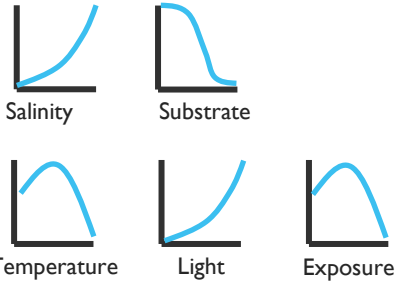
Forsblom et al. 2024

~190,000 sites surveyed

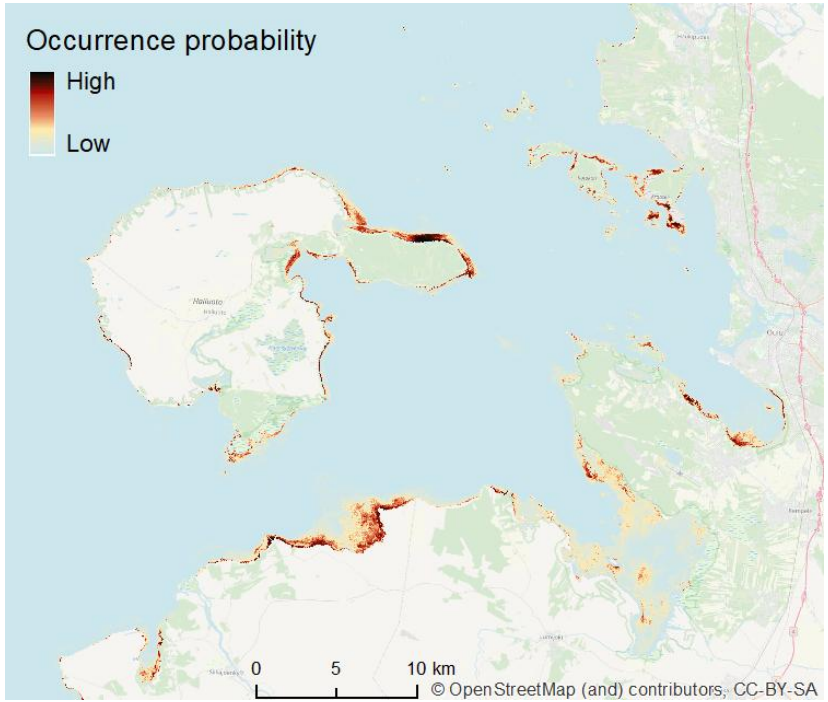


VELMU

Marine species distribution models



Macroplea pubipennis
-a rare leaf beetle occurring only in Finland



Virtanen et al. 2018

5. Biodiversity (above water)

- Bird migration areas
- Important areas for birds
- Migratory routes of bats

6. Economic feasibility

Spatial Life Cycle Cost analysis

Includes all costs during the project lifetime:

- Development and consenting
- Production and acquisition
- Installation and commissioning
- Operation and maintenance
- Decommissioning and disposal

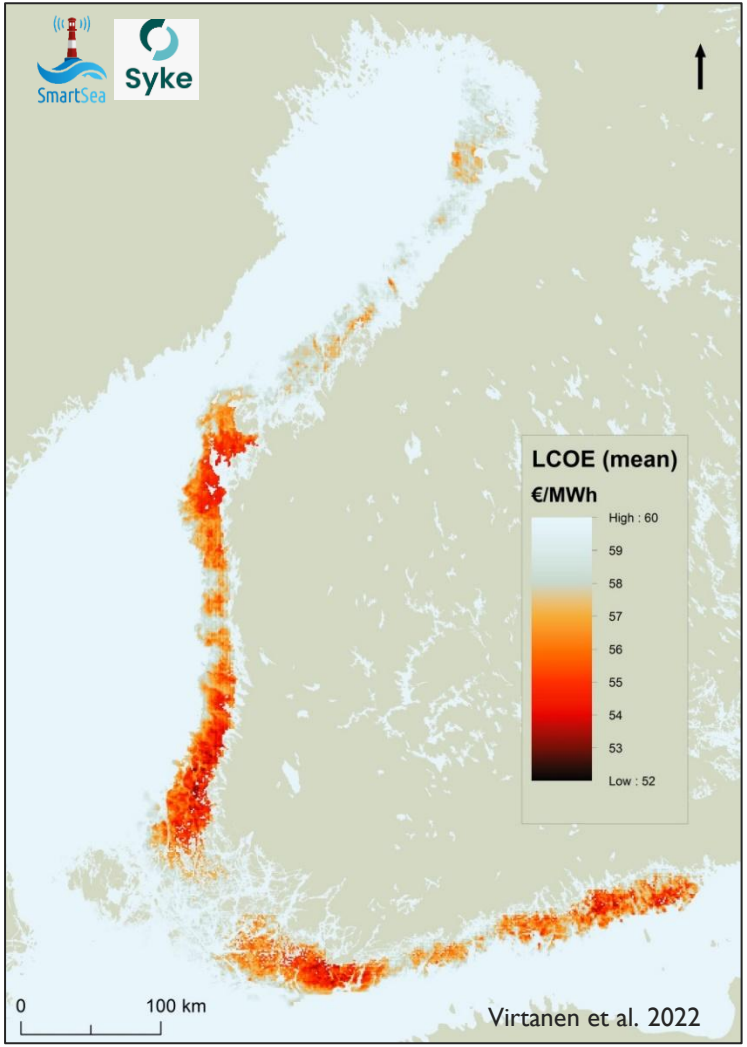
Levelised Cost of Energy (LCOE):

$$\mathrm{LCOE} = \frac{\sum_{t=0}^{T_{project}} \frac{LCC_t}{(1+WACC_{real})^t}}{\sum_{t=0}^{T_{project}} \frac{E_{annual}}{(1+WACC_{real})^t}}$$

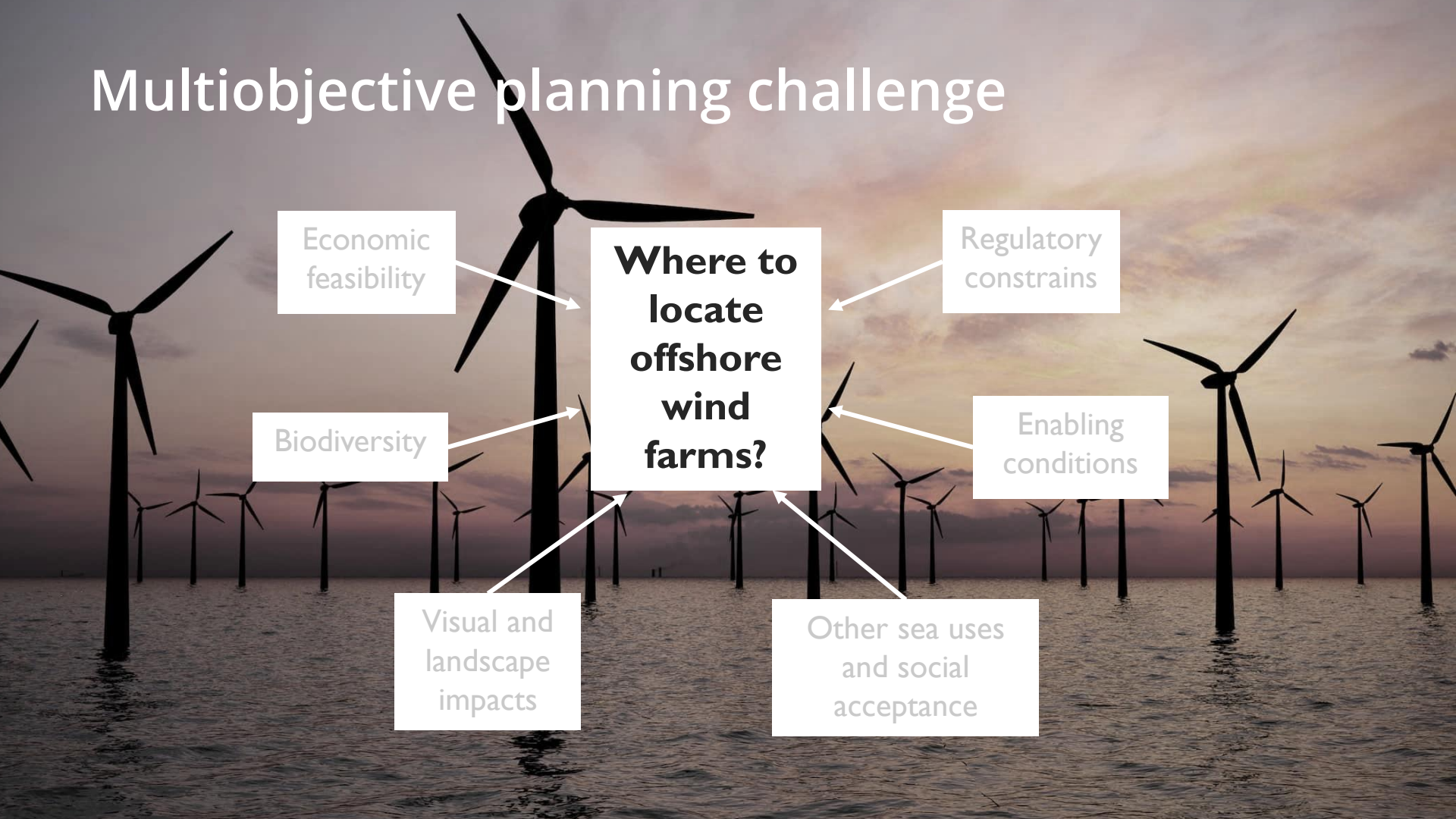
Spatial nature of costs: where affordable to produce offshore energy?

Spatial Life Cycle Cost analysis

- Sensitivity of LCOE: Monte Carlo simulations
- Most important drivers of cost: number of turbines, cost of capital

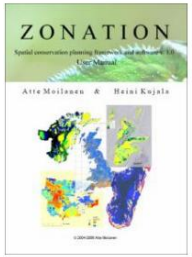


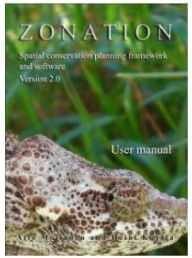
Multiobjective planning challenge

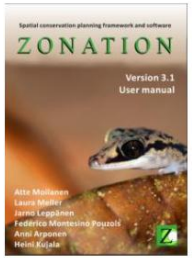


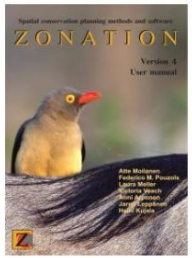
Zonation 5

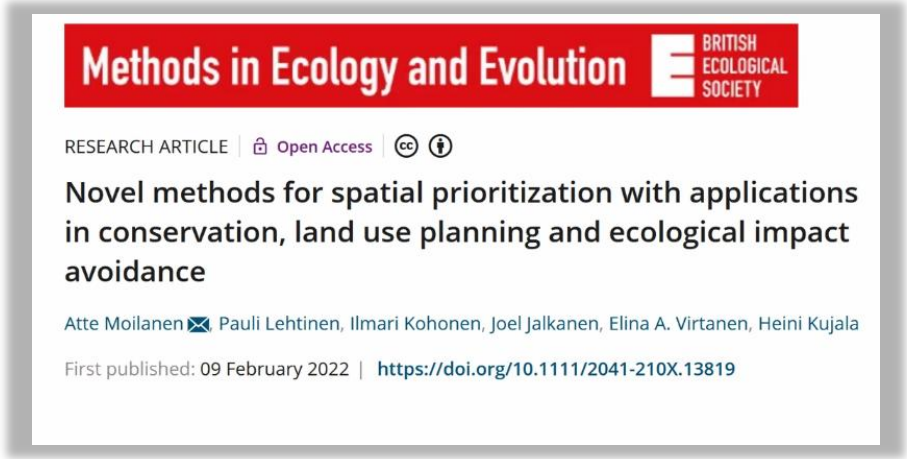
View the Project on GitHub
zonationteam/Zonation5











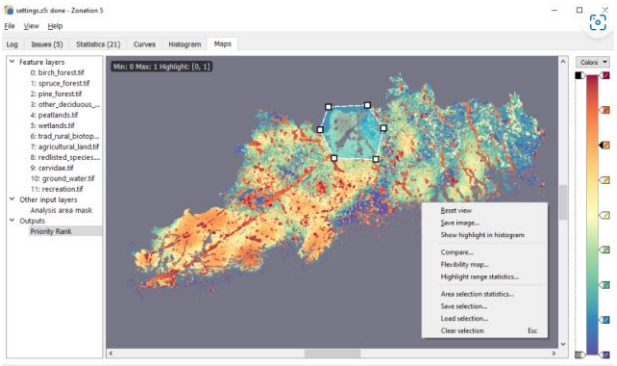
Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE | Open Access

Novel methods for spatial prioritization with applications in conservation, land use planning and ecological impact avoidance

Atte Moilanen, Pauli Lehtinen, Ilmari Kohonen, Joel Jalkanen, Elina A. Virtanen, Heini Kujala

First published: 09 February 2022 | https://doi.org/10.1111/2041-210X.13819



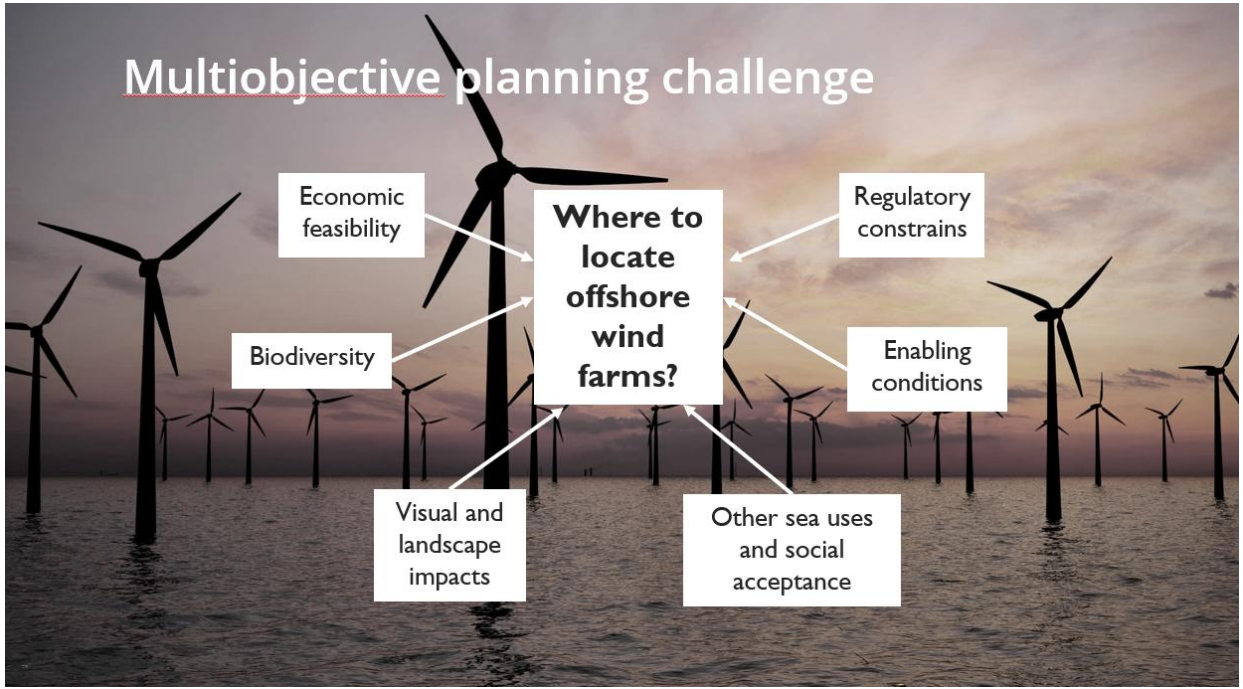
Zonation 5 user interface

- Produces a priority rank map + performance curves
- Maximizes benefit for each area: not based on setting targets
- Biodiversity, threats, costs, etc.

https://zonationteam.github.io/Zonation5/

In total 343 spatial layers

Some layers represent multiple features or synthesis of features



All included in spatial prioritization analysis

Zonation 5

1. Analysis version: only **sea uses and social aspects**

2. Analysis version: only **biodiversity**

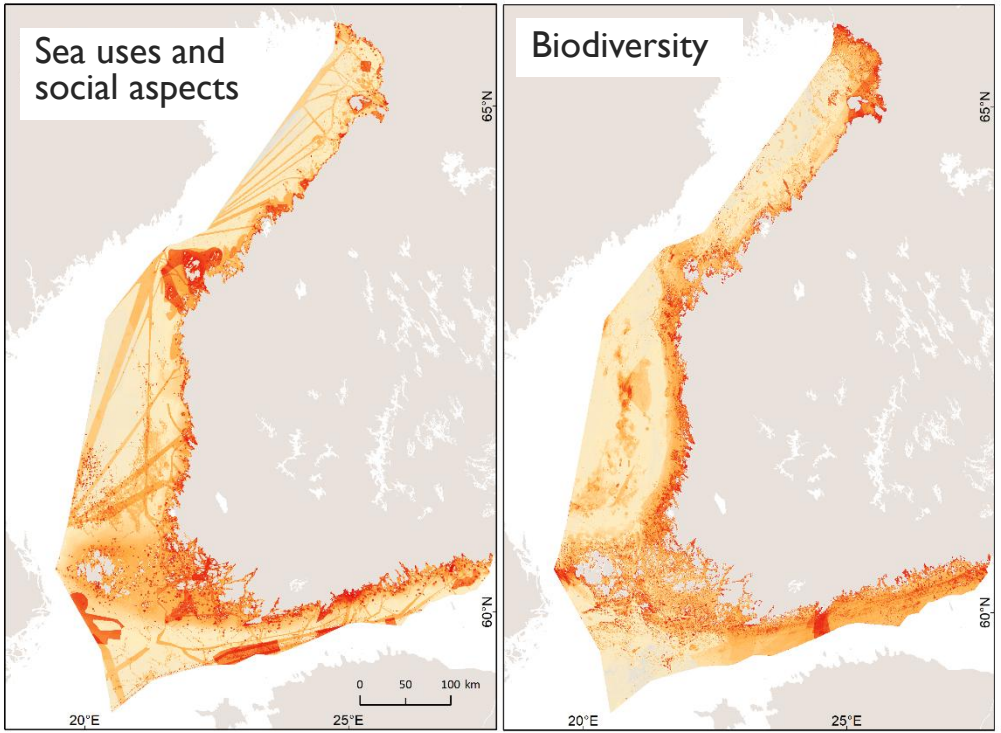
3. Analysis version: **all** integrated

Suitable areas for developing offshore wind energy

- Regulatory constraints
- Enabling conditions
- Other sea uses, social and visual aspects
- Biodiversity
- Economic feasibility

Zonation 5

(n=343)



Virtanen et al. 2022

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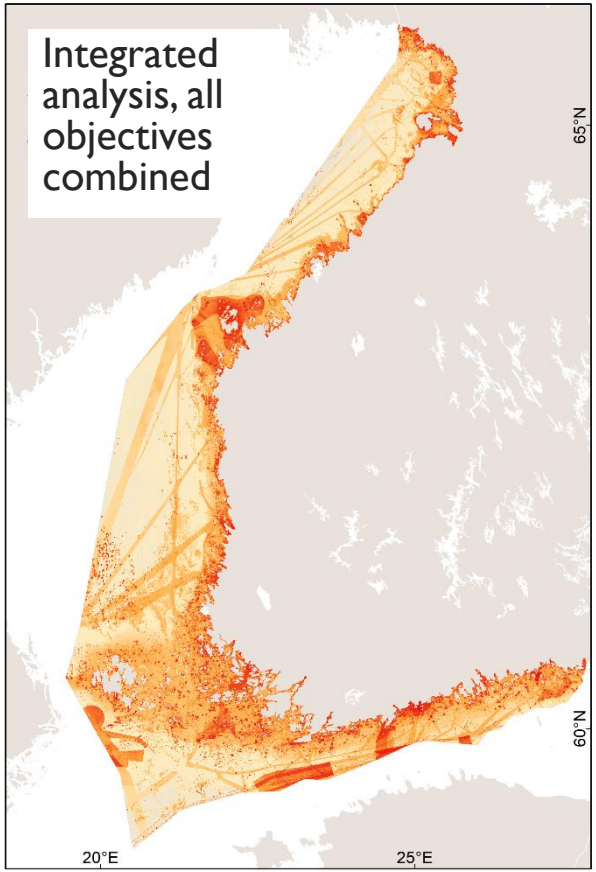
Zonation 5



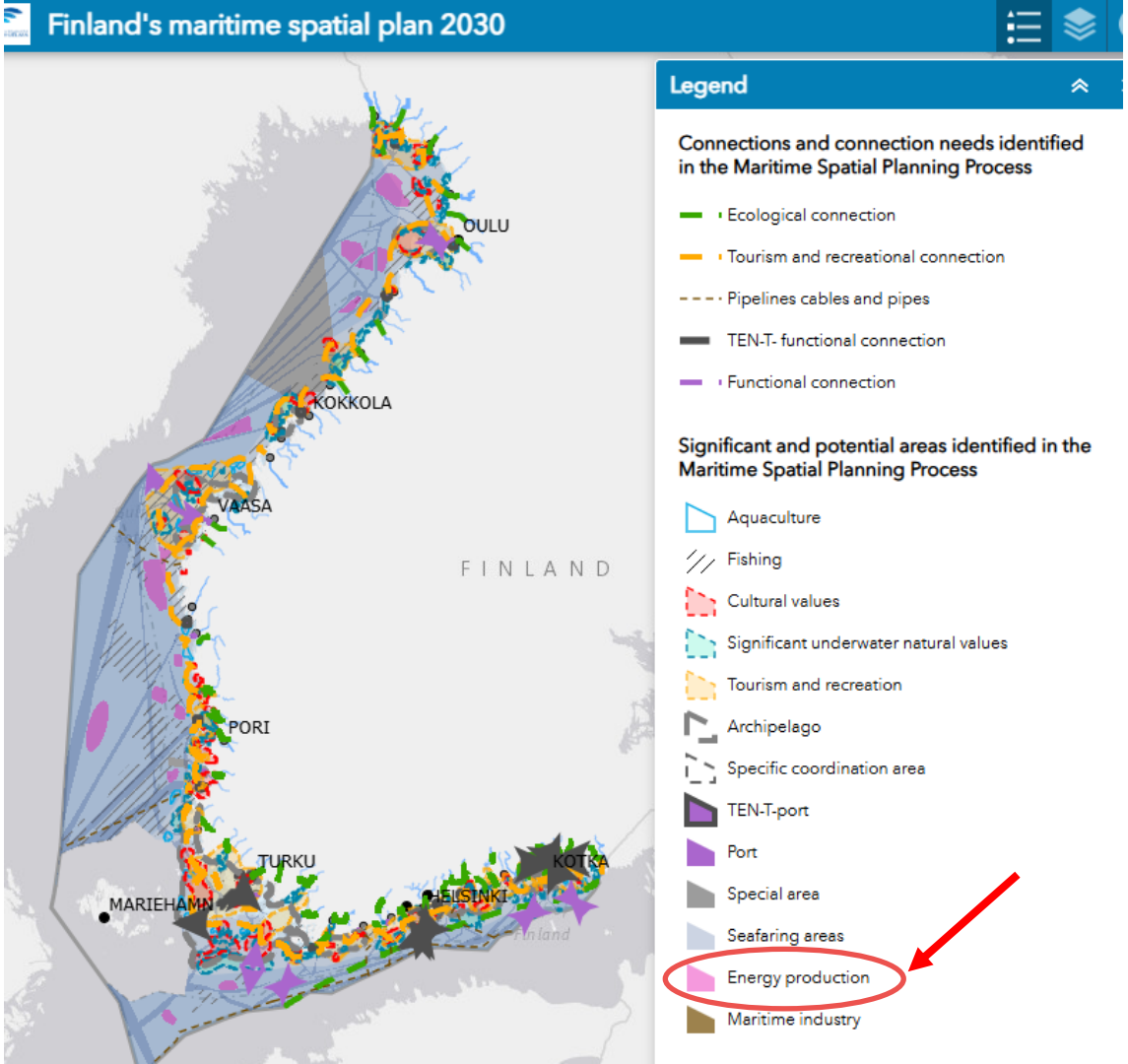
Impacts of offshore wind farms considerable

Impacts of offshore wind farms smaller

Virtanen et al. 2022

The results supported Finland´s first MSP

→ Energy production zones



ocean180

Development of basic technology for generalisation of marine biodiversity big data and applied technology to protect the richness of the oceans

Marine spatial planning analysis for balancing marine biodiversity conservation and sea uses in Japan: Virtanen, Kusumoto, Shiono, Ikari, & Kubota

Biodiversity features (Species distribution maps)

Coastline
11337 species
7 taxa

Off-shore surface
218 species
5 taxa

Deep sea
618 genera
30 taxa

Human sea uses (Pressures & protection)

Pressure
- Fishery
- Development
- Shipping
- Windpower plants
- Seabed mining

Protection
- Marine protected areas

Spatial prioritization analysis

Zonation 5

- Detect critically important biodiversity areas
- Evaluate the degree of current conflicts between conservation and use
- Evaluate the performance of existing marine protected areas
- Detect candidate areas for expanding MPAs & OECMs
- Suggest spatial design of sea use to mitigate conflicts
- Examine good balance between strict MPAs and OECMs

Thank you for your attention!

Photø: Essi Keskinen / Parks & Wildlife Finland