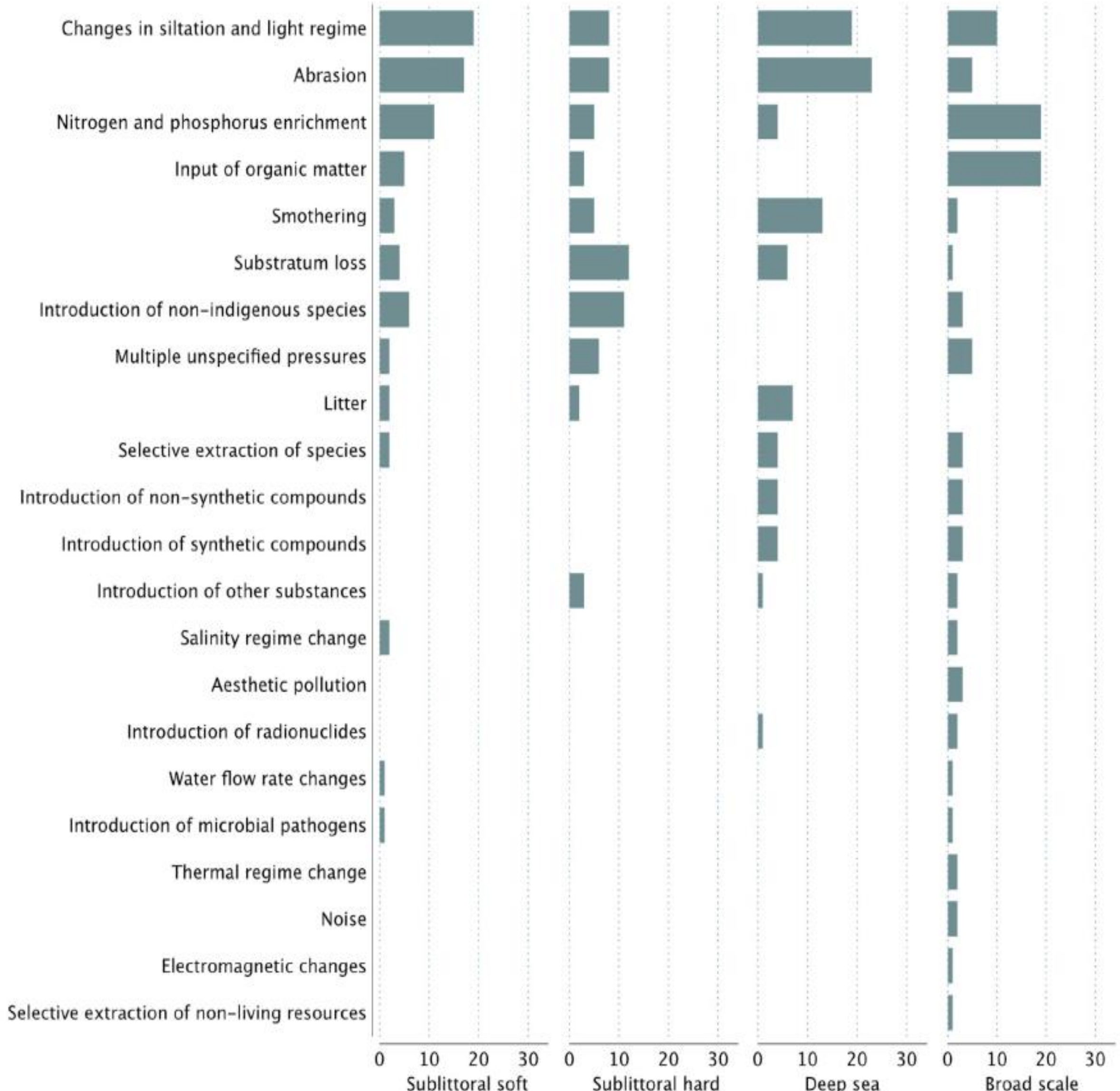
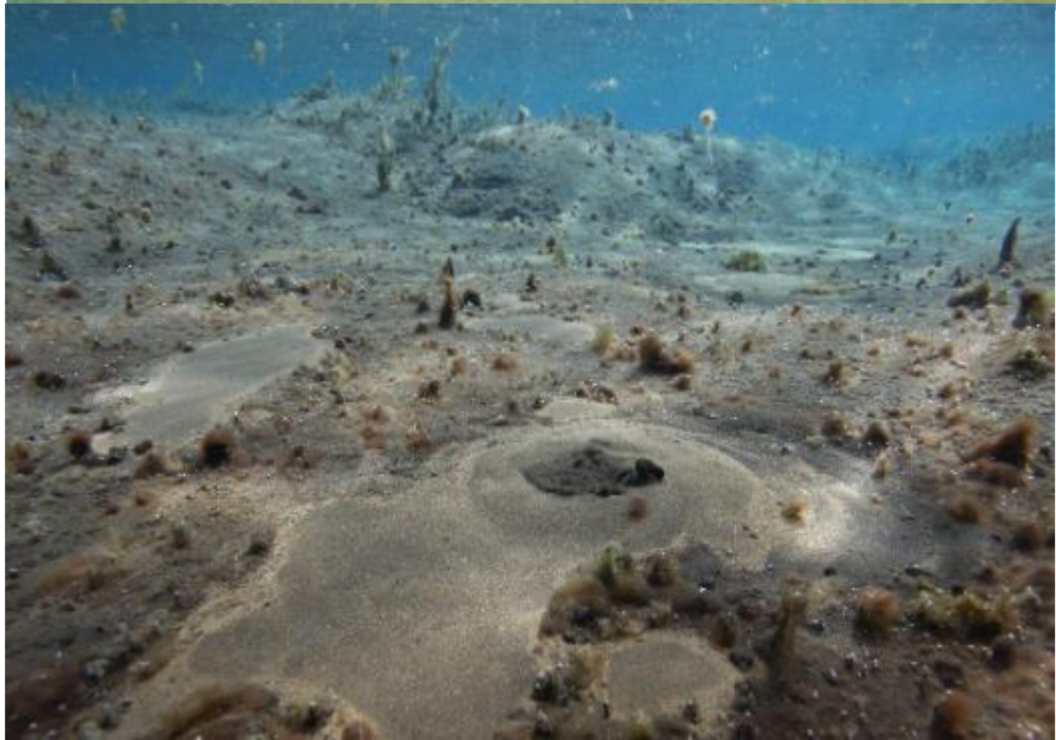
Modeling Marine Ecosystems to Address Societal Challenges

Jonne Kotta

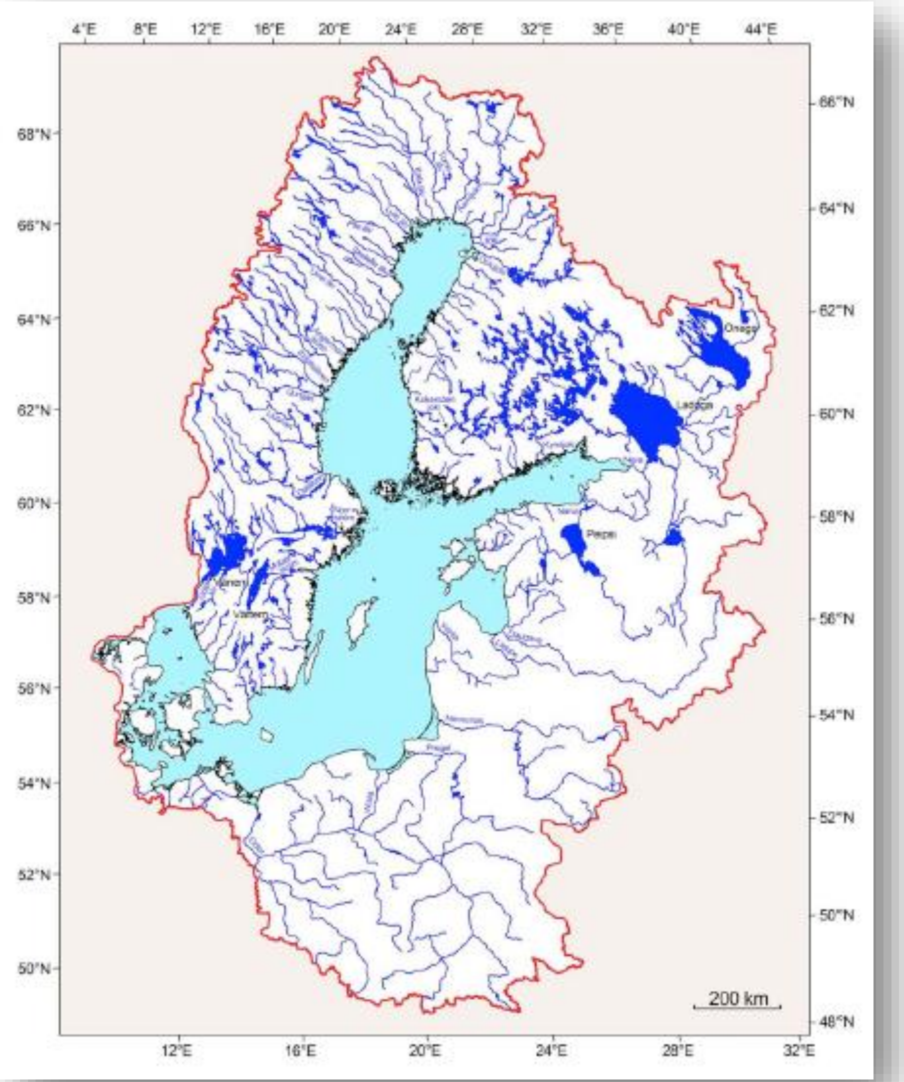
HUMAN ACTIVITIES HAVE IMPACTS

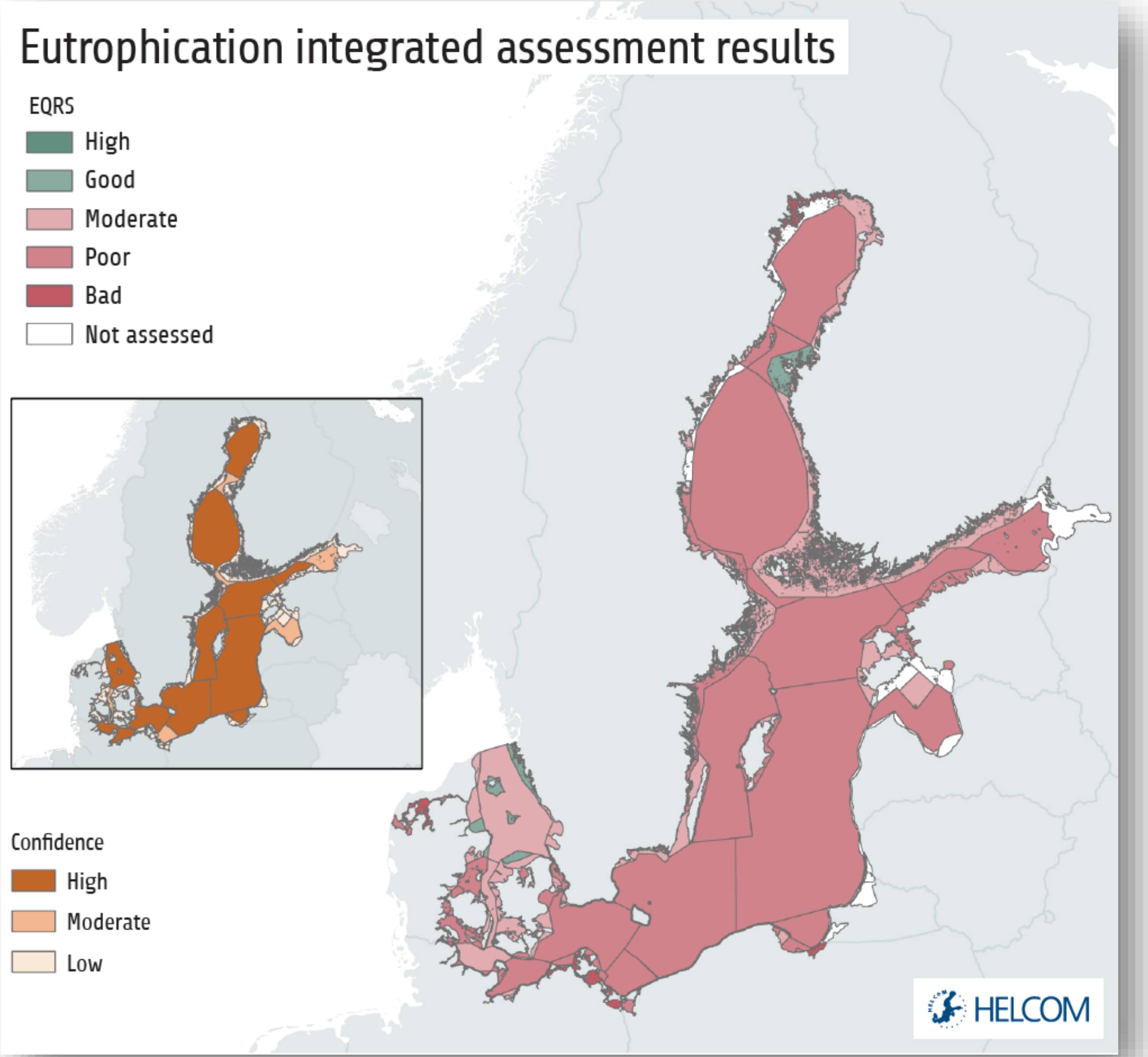
Human induced pressures become more intense and diverse and result in the loss of habitats





Baltic Sea is a transboundary ecosystem with large watershed area






Kattegat
Great Belt
The Sound
Kiel Bay
Bay of Mecklenburg
Arkona Basin
Bornholm Basin
Gdansk Basin
Eastern Gotland Basin
Western Gotland Basin
Gulf of Riga
Northern Baltic Proper
Gulf of Finland
Åland Sea
Bothnian Sea
The Quark
Bothnian Bay
Cadmium
Copper
Lead
Mercury
PBDE
PCB, dioxin and furan
HBCDD
PFOS
PAH and metabolites
TBT and imposex
Cs-137 in fish and seawater
White-tailed eagle productivity
l spills affecting marine environment
Trends in non-indigenous species
Macro litter on beaches
Low and mid frequency anthropogenic impulsive sounds*
Continuous low frequency anthropogenic sound**
Continuous low frequency anthropogenic sound***

HELCOM Baltic Sea action plan (BSAP) environmental targets

Eutrophication

Baltic Sea unaffected by eutrophication

- Clear water
- Natural level of algal blooms
- Natural distribution and occurrence of plants and animals
- Natural oxygen levels

Biodiversity

Favourable status of Baltic Sea biodiversity

- Natural marine and coastal landscapes
- Thriving and balanced communities of plants and animals
- Viable populations of species

Hazardous substances

Baltic Sea undisturbed by hazardous substances

- Concentrations of hazardous substances close to natural levels
- All fish are safe to eat
- Healthy wildlife
- Radioactivity at the pre-Chernobyl level

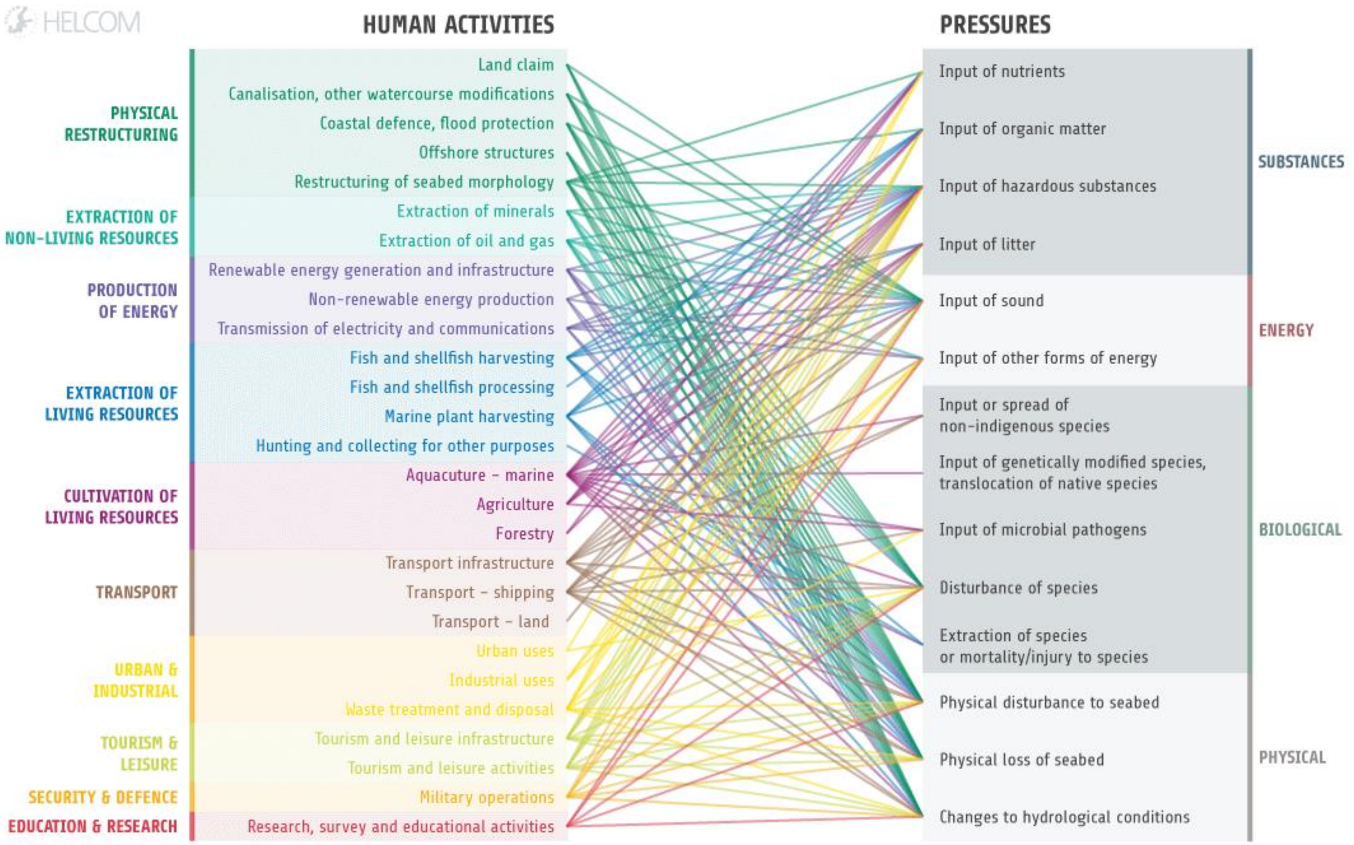
Maritime activities

Enviromentally friendly maritime activities

- Enforcement of international regulations – no illegal discharges
- Safe maritime traffic without accidental pollution
- Efficient emergency and response capabilities
- Minimum sewage pollution from ships
- No introductions of alien species from ships
- Minimum air pollution from ships
- Zero discharges from offshore platforms
- Minimum threats from offshore installations

But how?

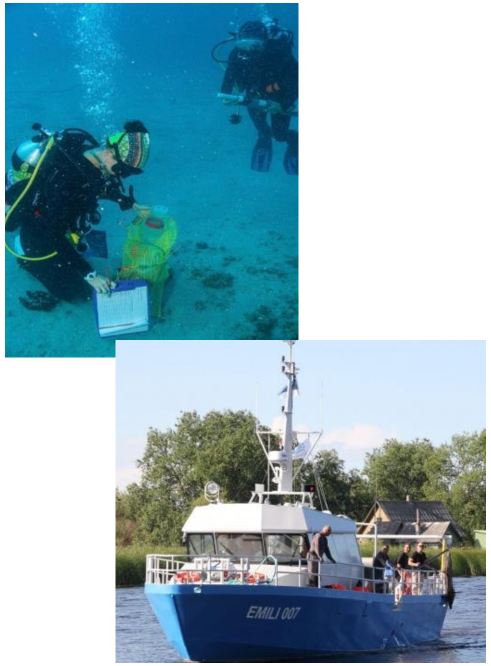
Complex system: human activities and related pressures in the Baltic Sea

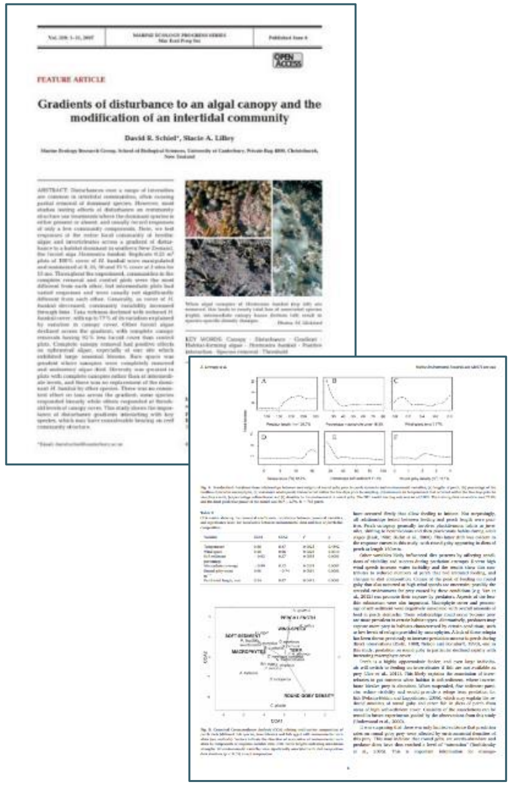


Complex ecosystems with multiple feedback loops

How to effectively bridge the gap between science and policy?

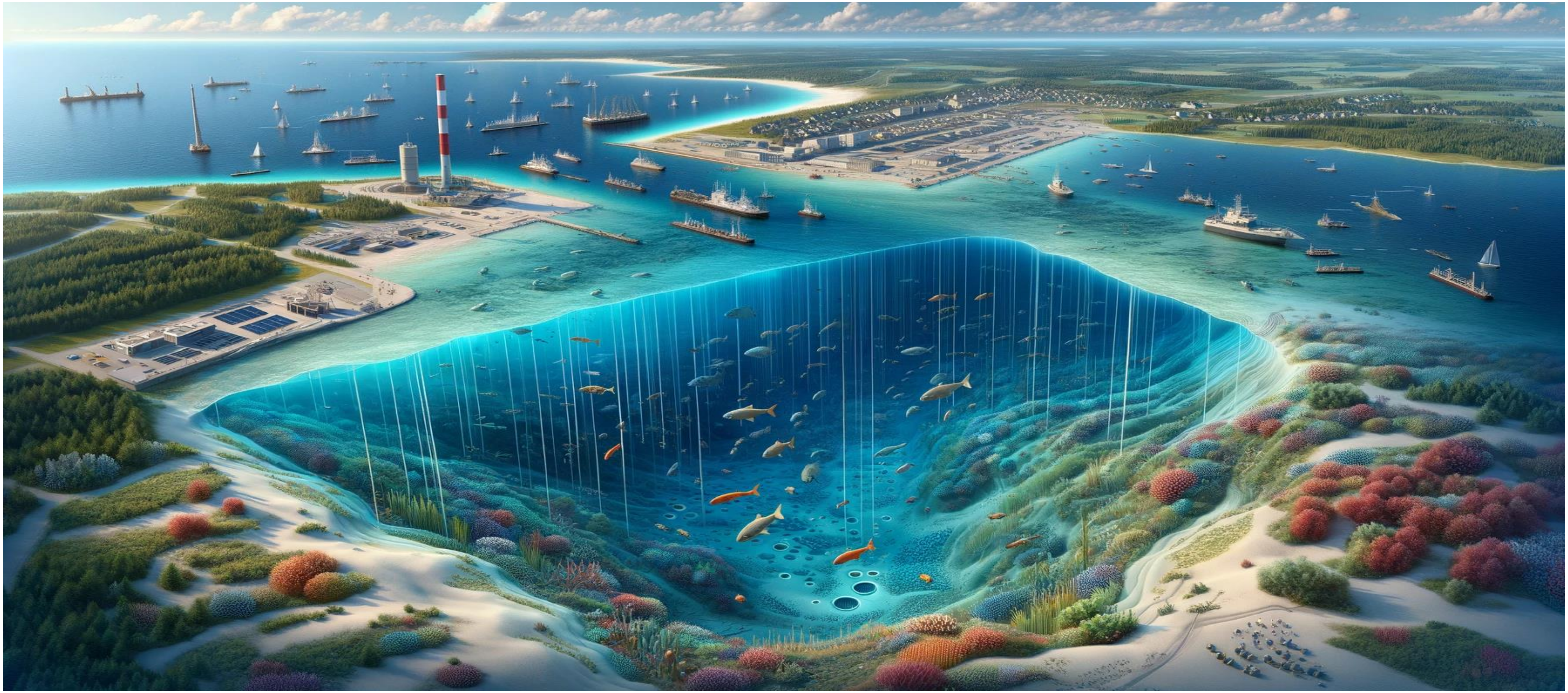
The structure and functioning of marine ecosystems is the result of myriads of components and processes acting simultaneously. Addressing this level of complexity ***requires data- and analysis-demanding schemes***.





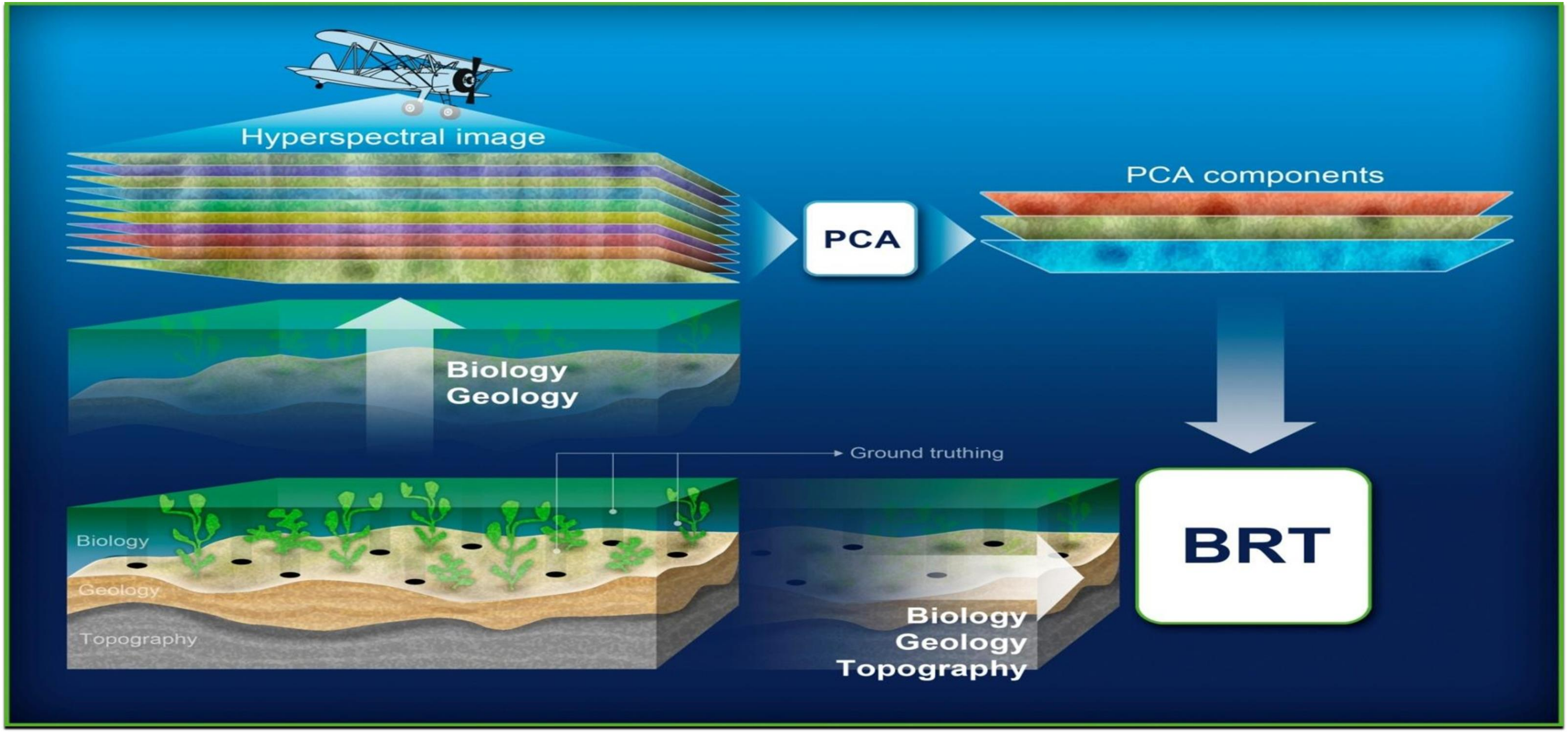
Disconnection in the flow of knowledge between science (specific/technical) ***and policy*** (general/layman approach).

Ecological digital twin for dynamic impact assessments and mitigation strategies

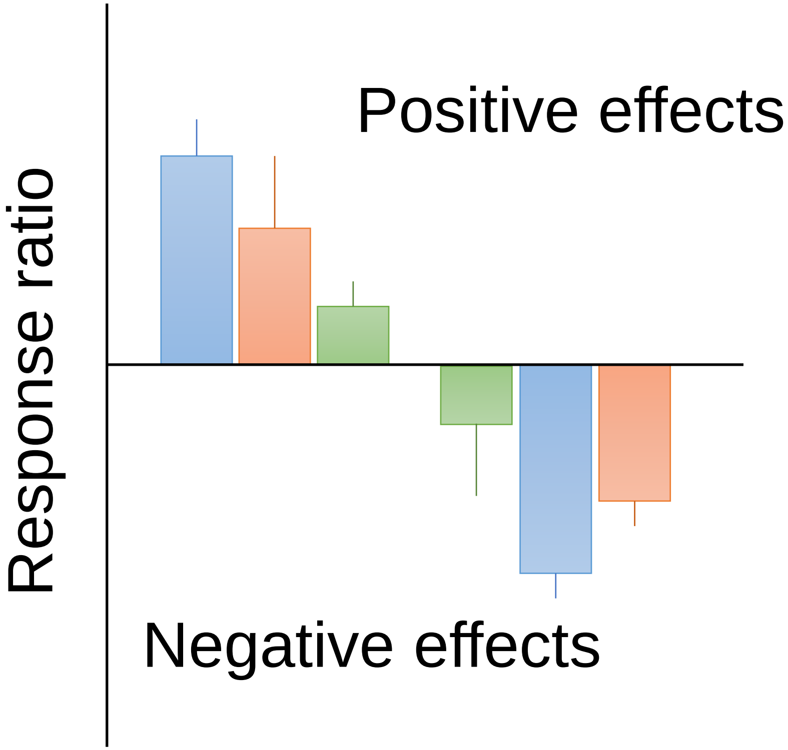


Ecological digital twin: New generation ecosystem models

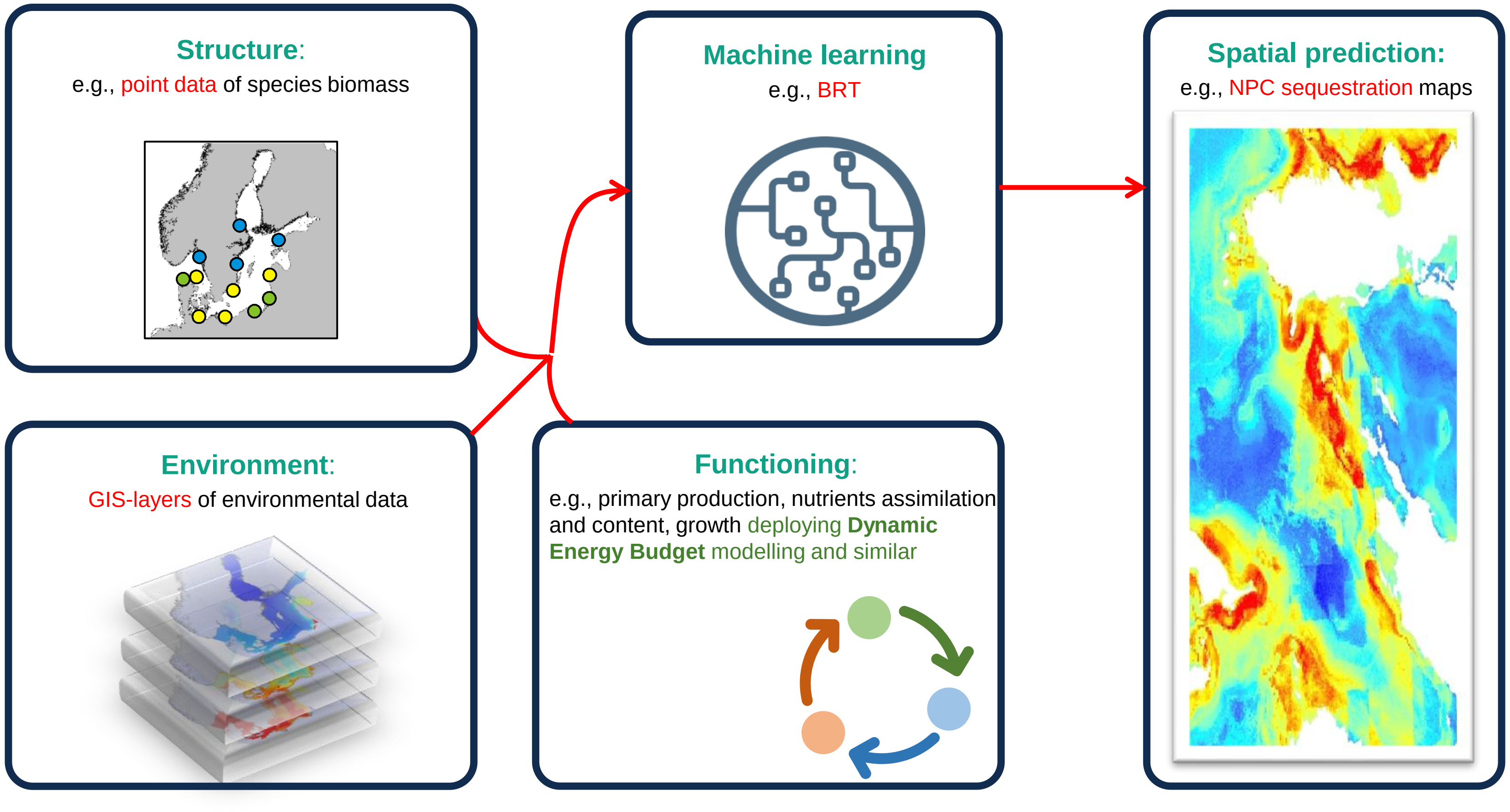
Ecological digital twin: Overcoming the challenges of data scarcity and quality



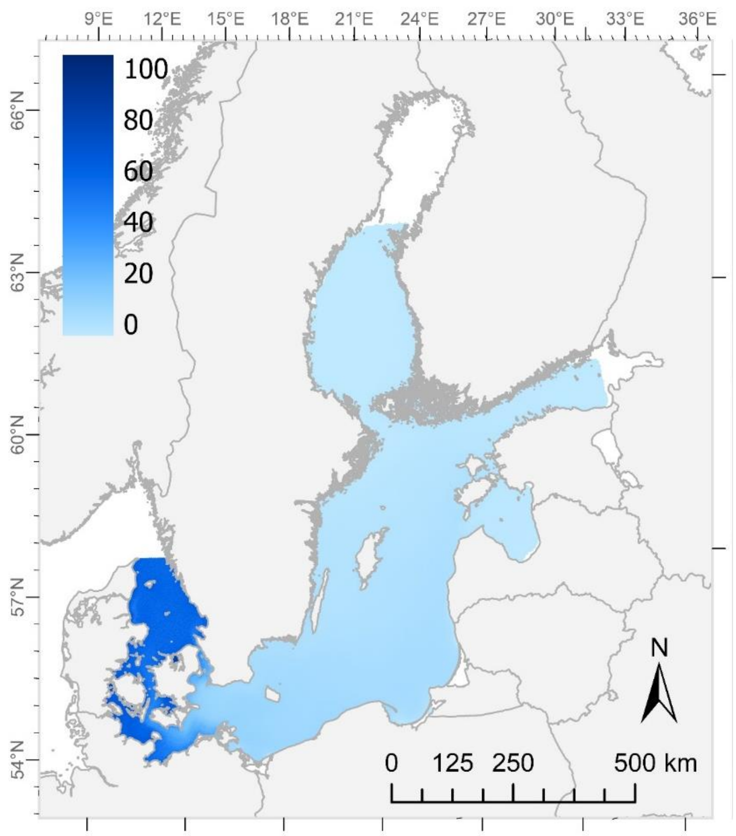
Ecological digital twin: Overcoming the challenges of data scarcity and quality

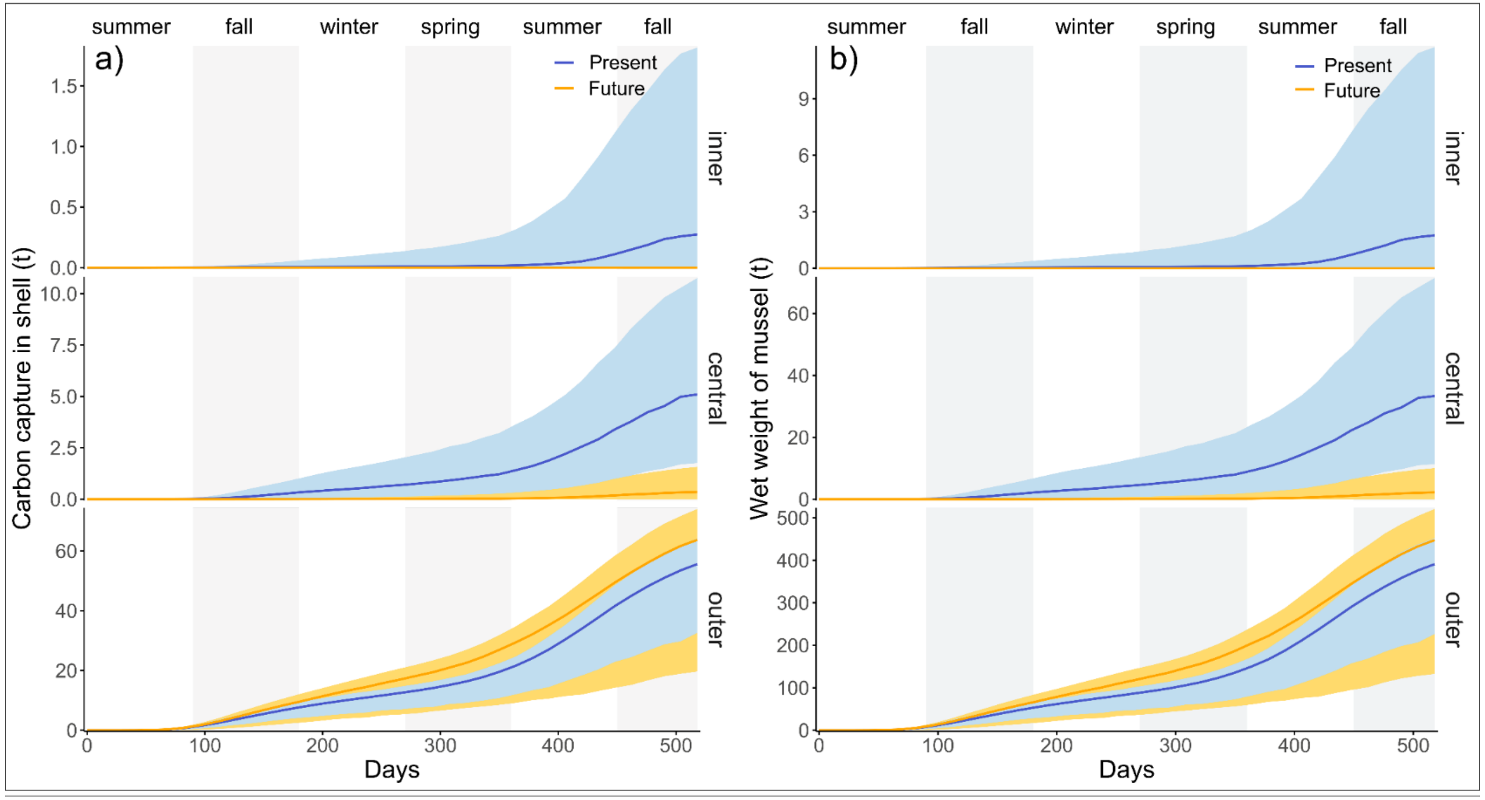


Communities and processes:
Single species and function modelling



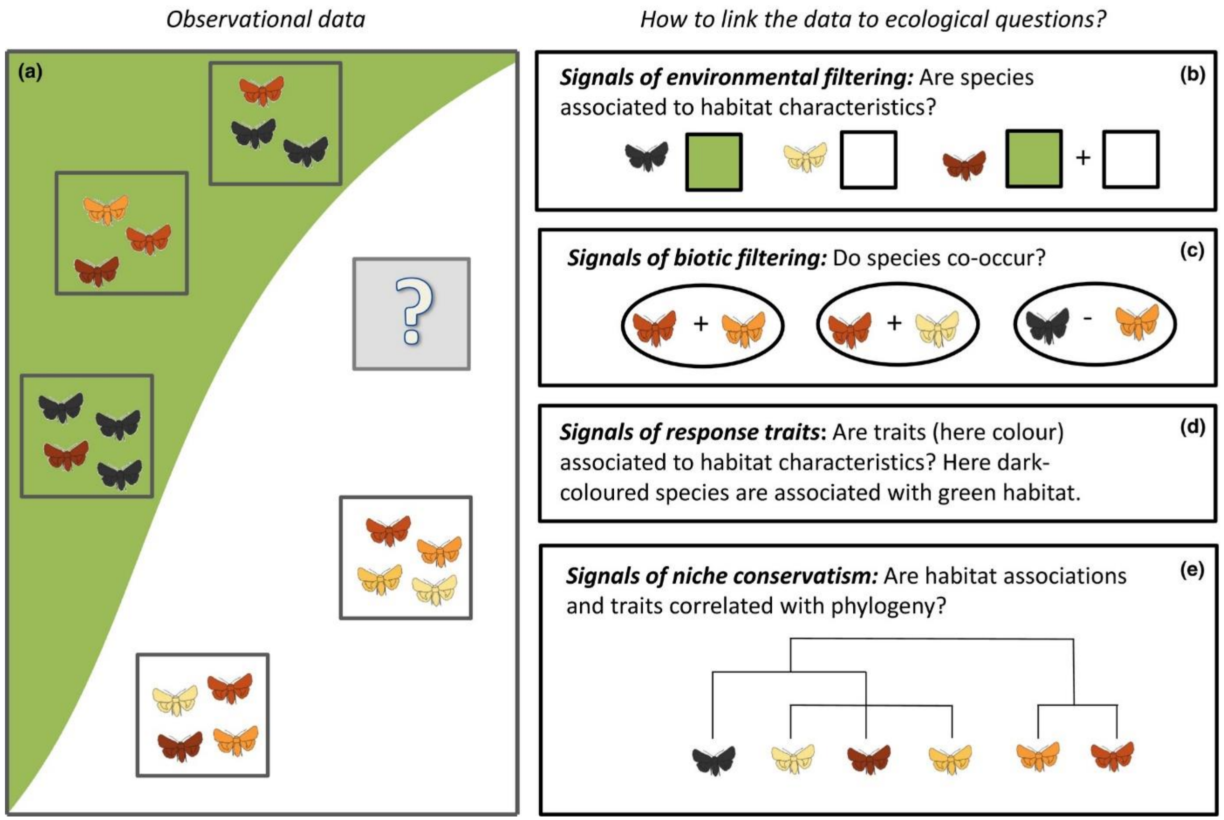
Communities and processes:
Measuring and modelling carbon capture

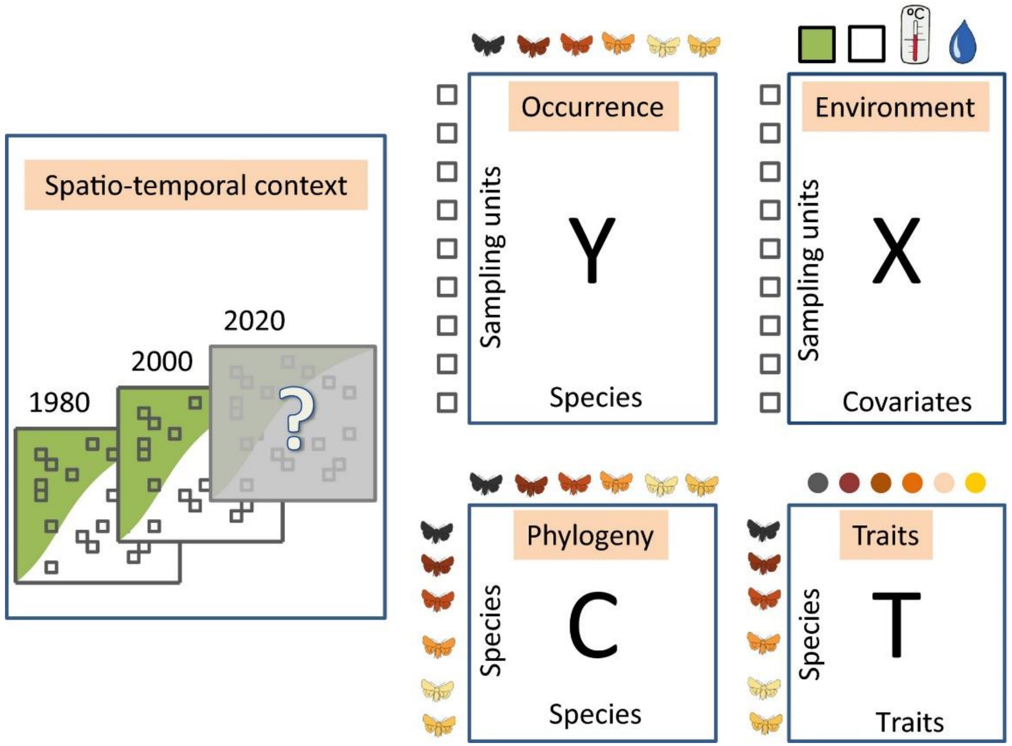




Quantifies the benefits of various nature assets in the context of future scenarios

Communities and processes:
Joint Species Distribution Modelling (HMSC)





Ovaskainen et al. 2017 Ecology Letters

Communities and processes:
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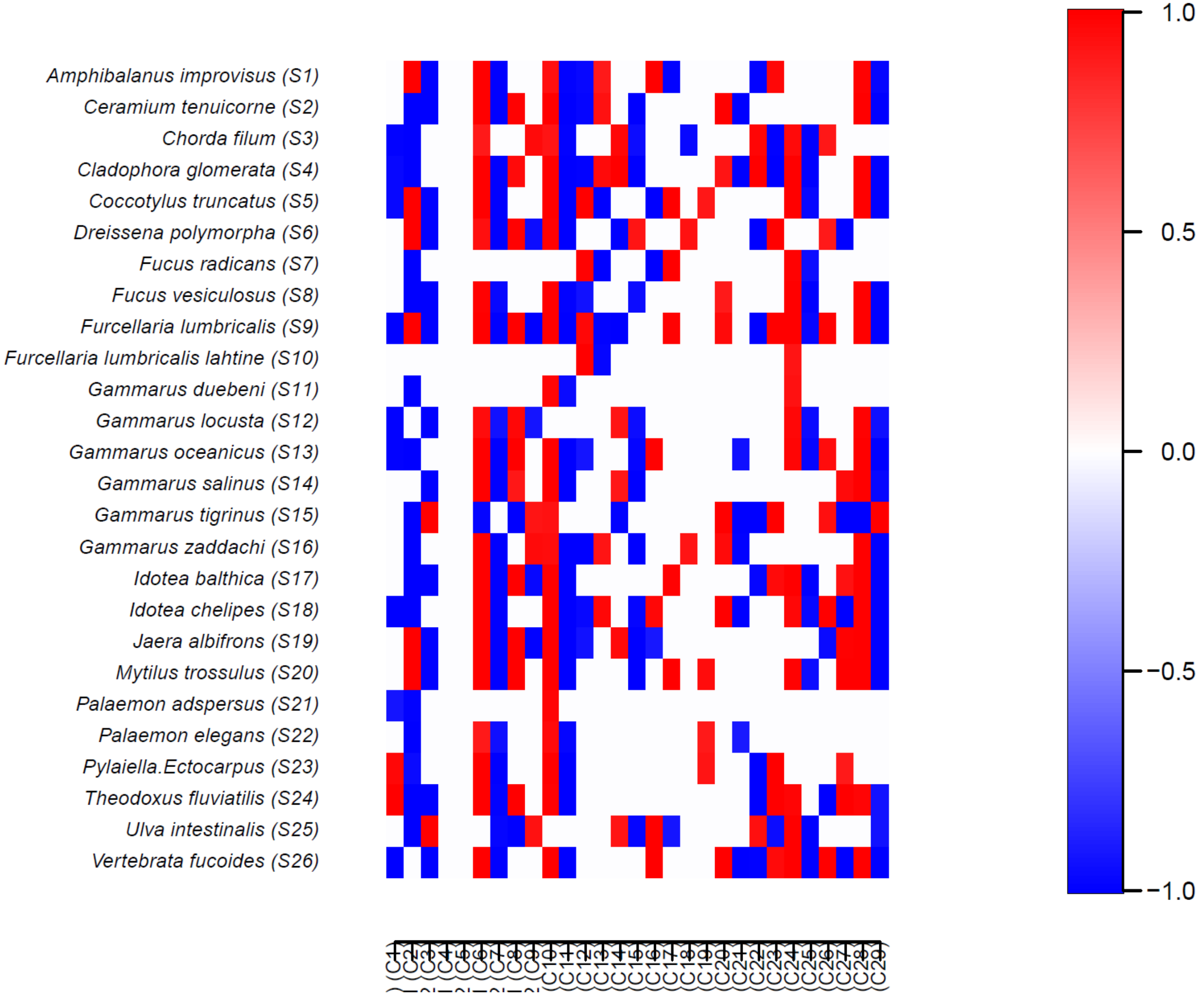
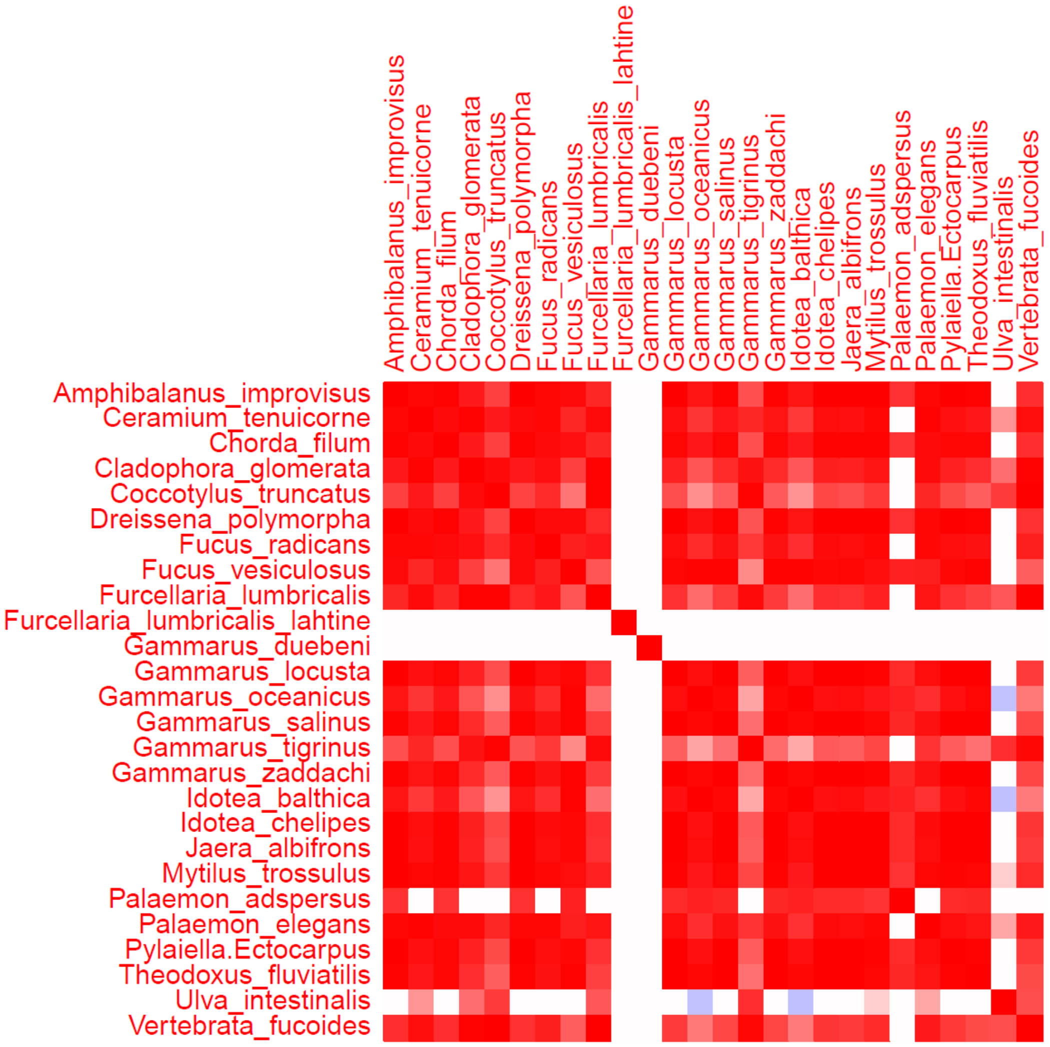
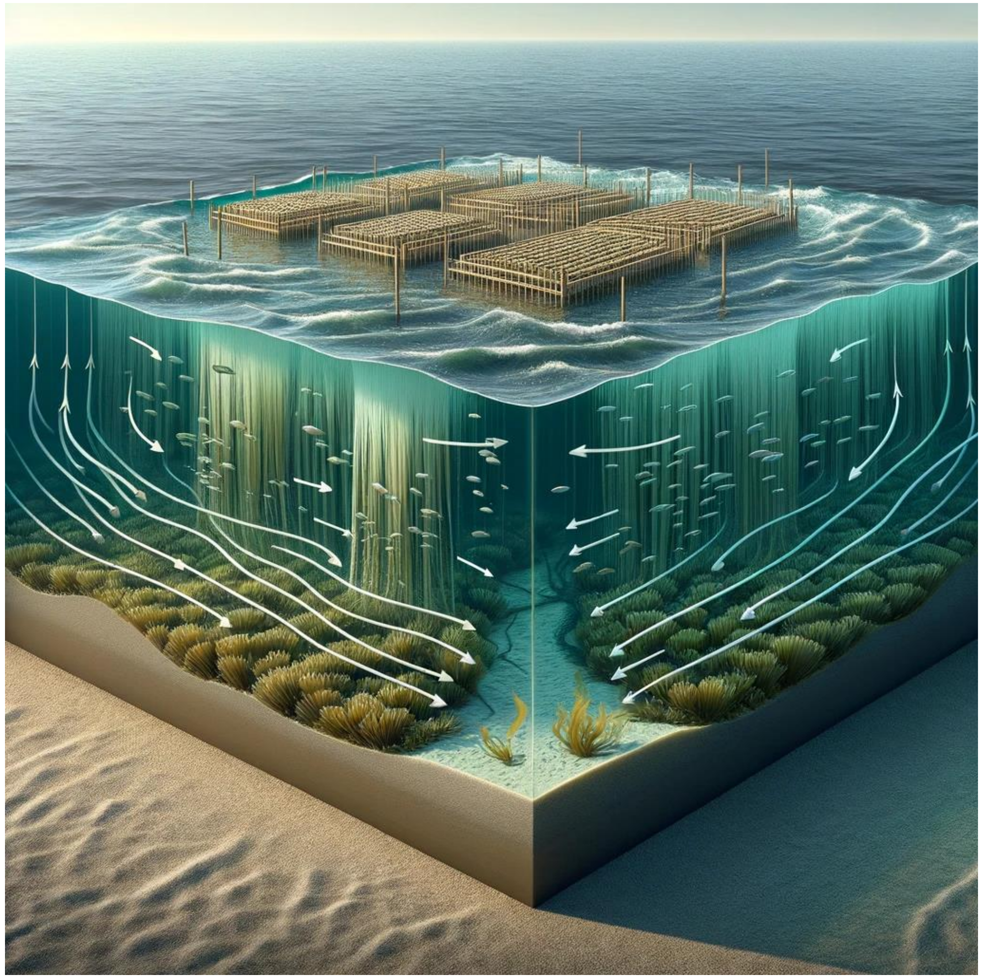


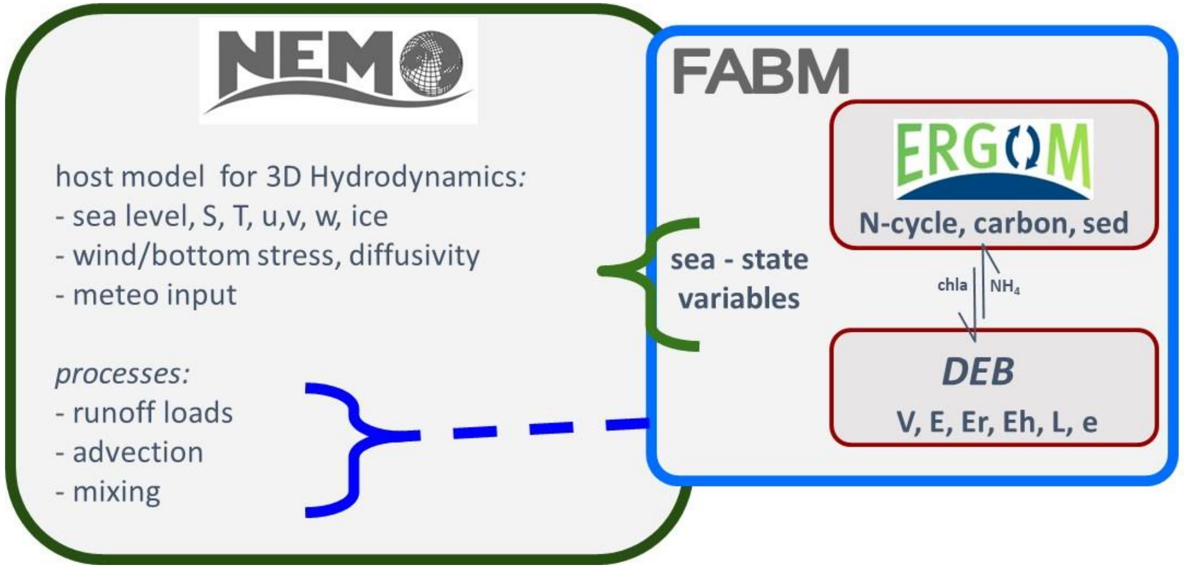


Incorporating non-linear responses and working with over 10,000 samples

Communities and processes:
Environmental carrying capacity modelling

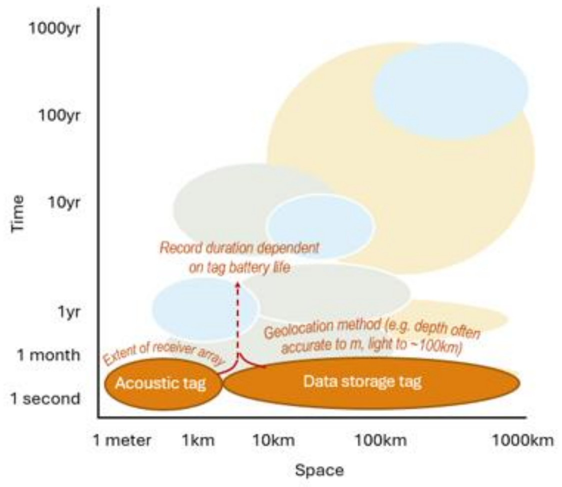


Integrating 3D hydrodynamics with biological process modeling, enabling dynamic feedback loops (e.g. dynamic energy budget models)

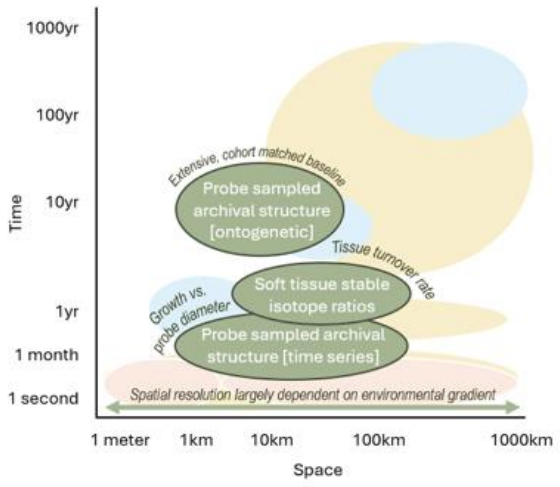


Connectivity

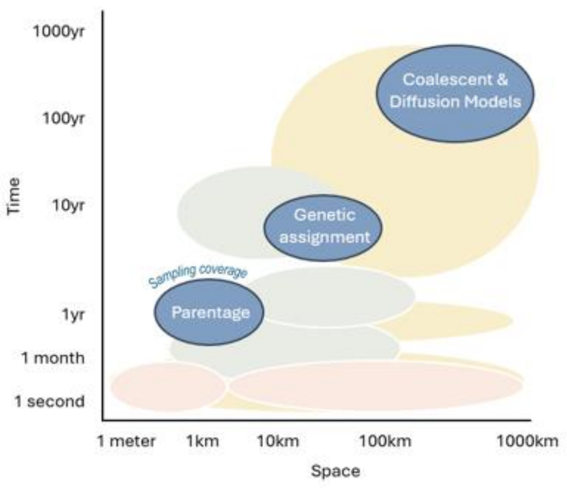
tagging and telemetry



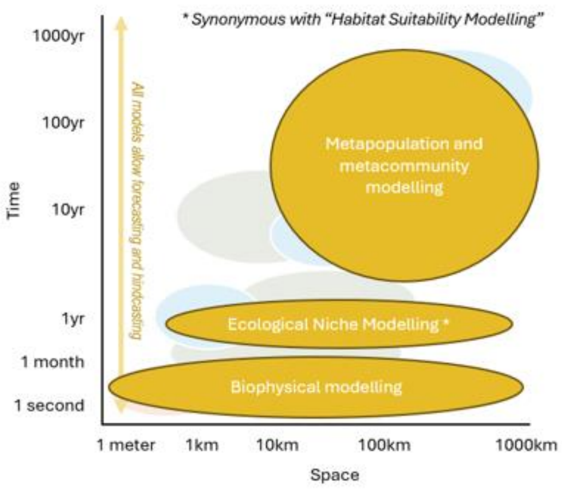
chemical markers



genetic approaches

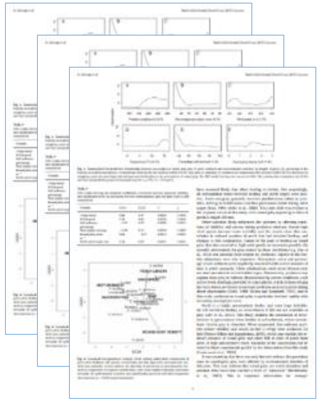


modelling

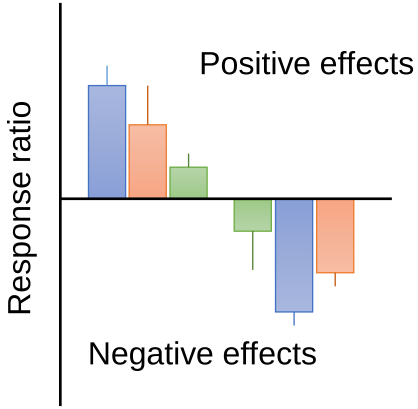


- Diverse, disconnected methods, each with unique assumptions, strengths, and weaknesses.
- Shift from single-species focus to community, metacommunity, and ecosystem-based approaches.
- Future direction: develop algorithms for integrating these methods.

Cumulative impacts: Knowledge inventory



Extract data from relevant publications



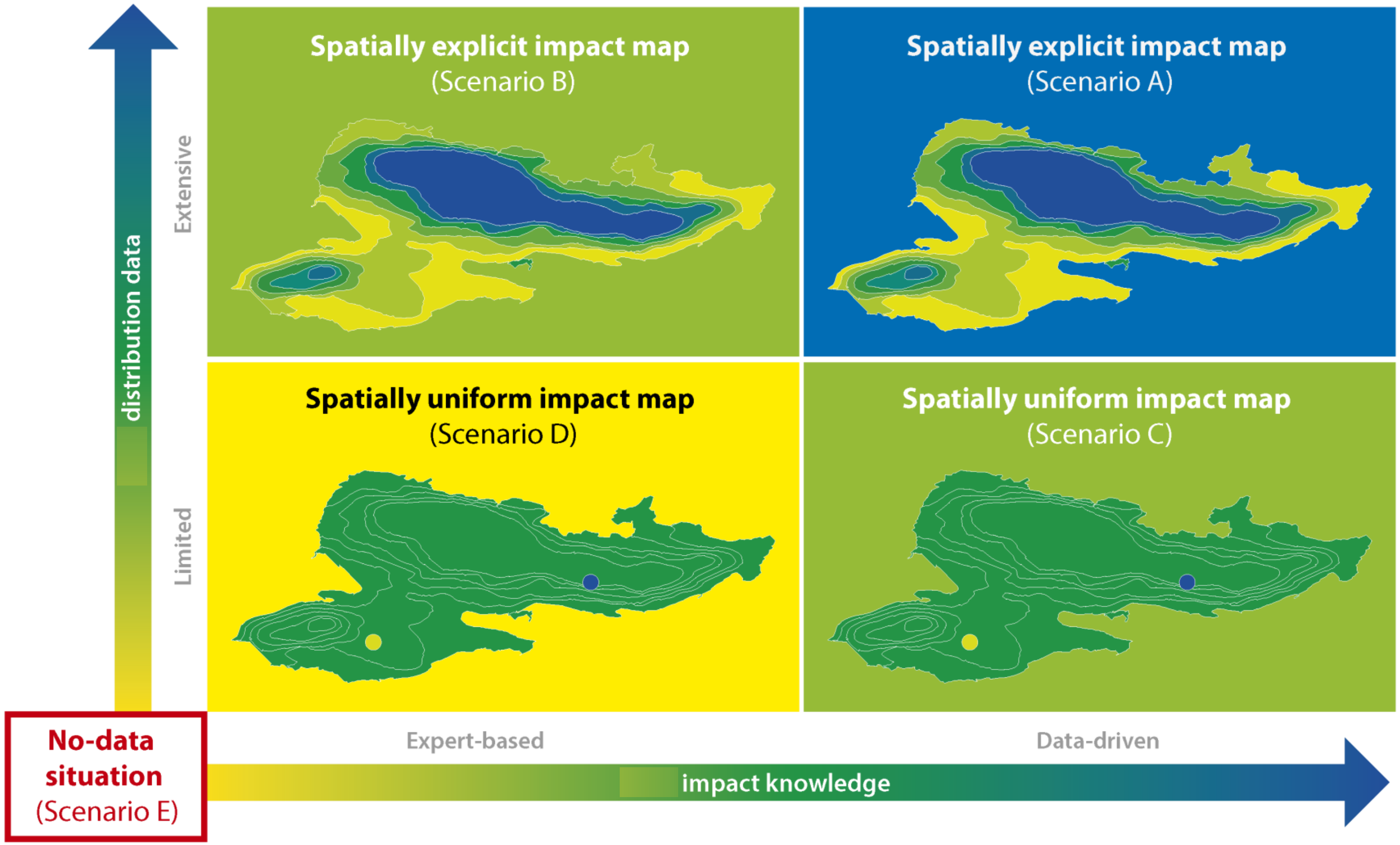
Meta-analyses and calculation of effect sizes

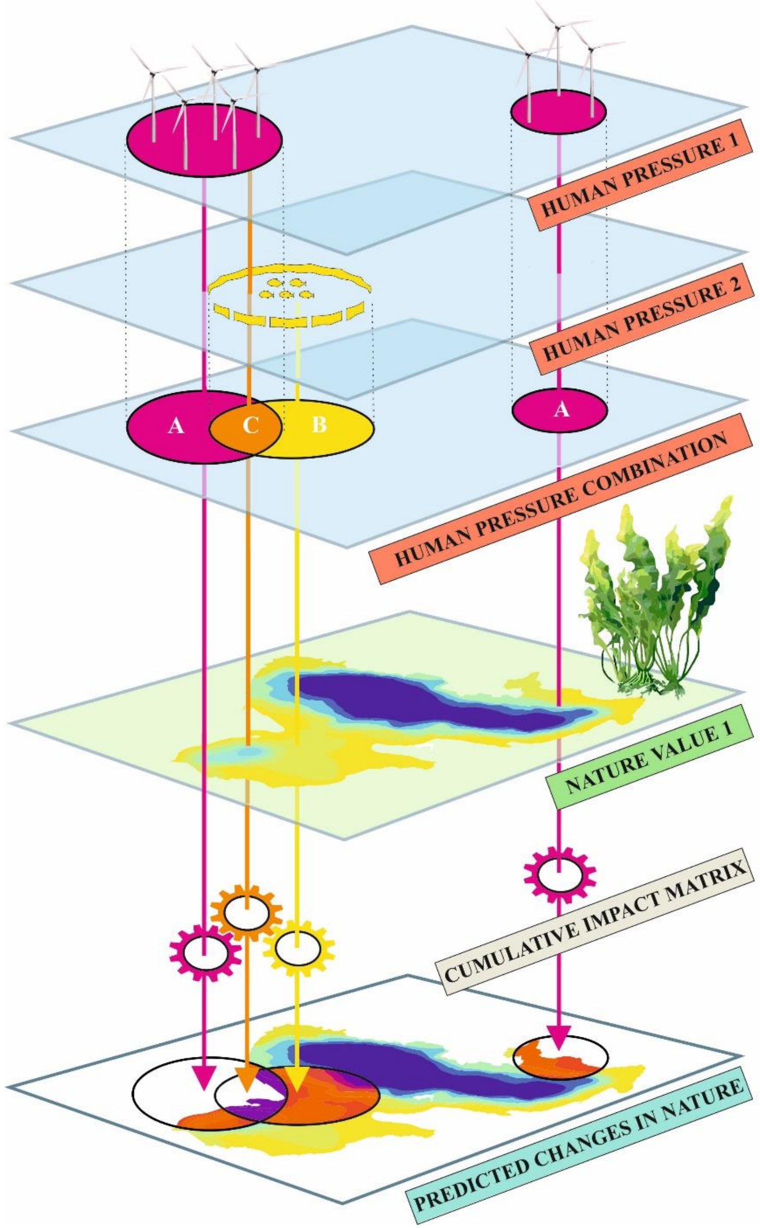
Nature value ID	env_layer_name	dredging	windpark	fish farming	shipping	underwater cable	commercial fishi	harbours
1	Bird - Benthos feeders	1	1	1	0.9	1	1	0.9
2	Bird - Fish feeders	0.75	1	0.9	0.9	1	0.9	0.9
3	Bird - Migration routes	1	0.75	1	0.9	1	1	1
4	Bird - Wintering areas	1	0.75	0.9	0.9	1	1	0.9
5	Bird - Herbivores	0.7	0.85	0.7	0.9	1	1	0.8
6	Fish - Herring spawning areas	0.75	1	0.9	1	1	1	0.9
7	Fish - Pikeperch spawning areas	0.75	0.9	0.9	1	1	1	0.9
8	Fish - Whitefish spawning areas	0.75	1	0.75	1	1	1	0.9
9	Habitat - Charophytes	0.5	1	0.5	1	0.9	1	0.75
10	Habitat - Fucus	0.9	1	0.9	1	1	1	0.9
11	Habitat - Furcellaria	0.75	1	0.75	1	1	1	0.9
12	Habitat - Higher plants	0.9	1	0.9	1	1	1	0.9
13	Habitat - Richness flora and fauna	0.5	1	0.9	1	1	1	0.9
14	Habitat - Suspension feeders	1	1.25	1	1	1	1	0.9
15	Habitat - Zostera	0.75	1	0.75	1	1	1	0.9
16	Seals - All species	0.9	0.75	0.9	0.9	1	0.9	0.9
17	HD - Sandbanks	0.66	1	0.76	1	0.98	1	0.86
18	HD - Mudflats and sandflats	0.63	1.06	0.89	1	1	1	0.9
19	HD - Reefs	0.79	1.06	0.89	1	1	1	0.9

Matrix of effects

Shift from expert judgment to data-driven analysis

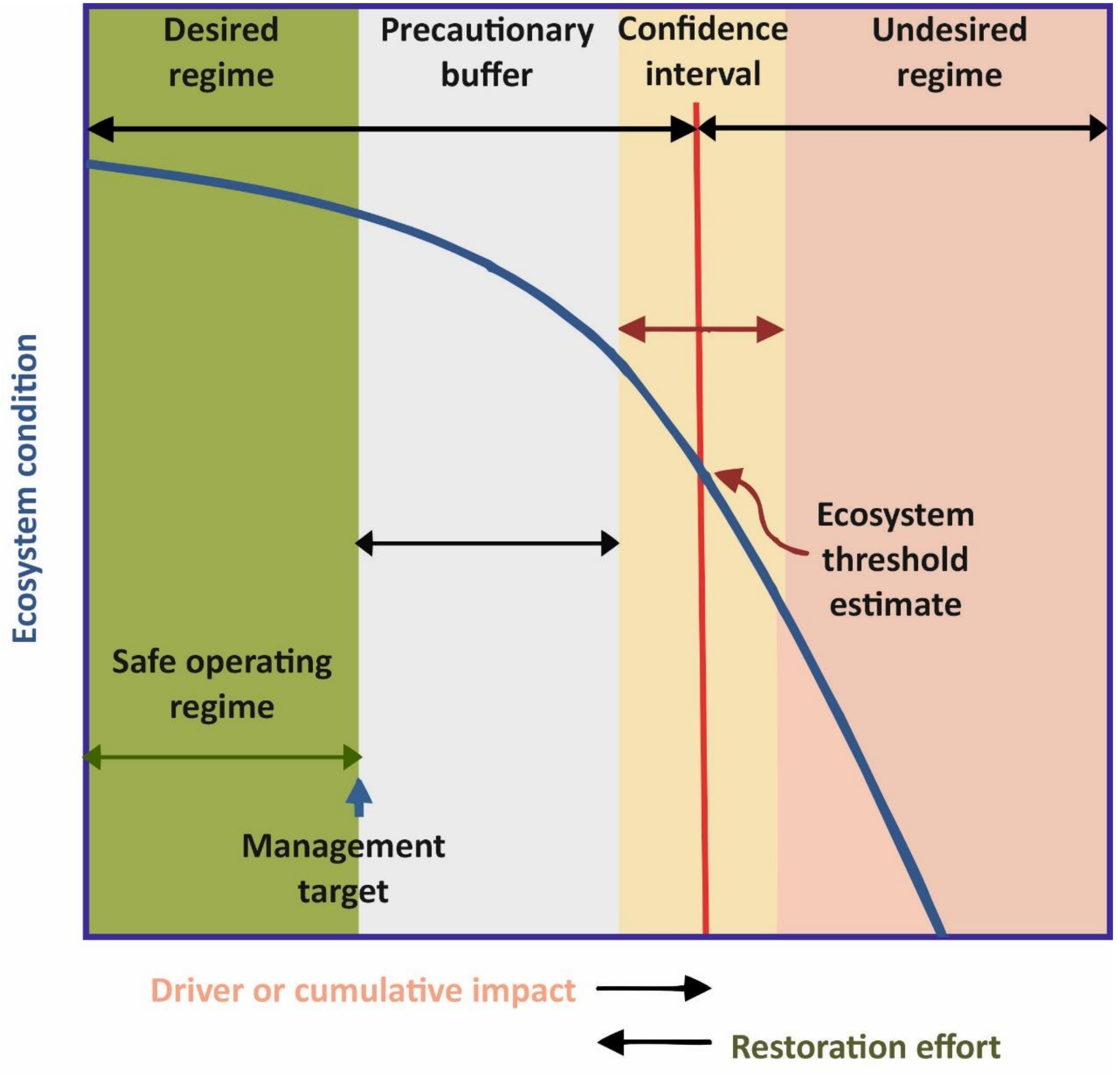
Calculating cumulative impacts

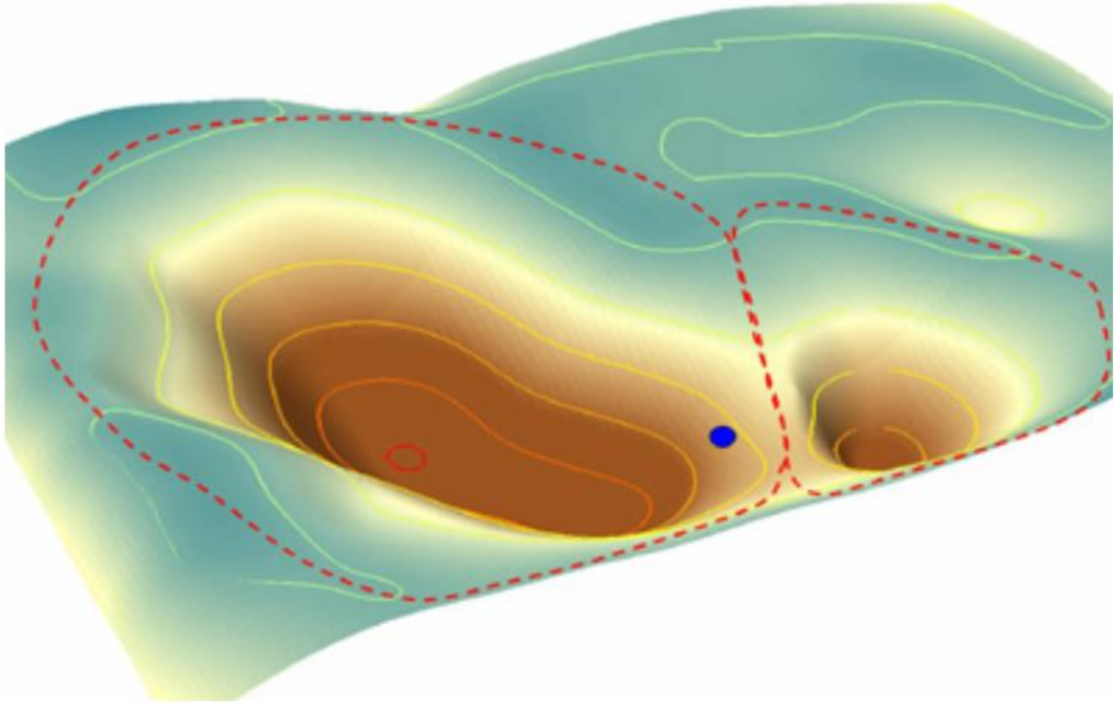




Presenting potential positive and negative outcomes of human impact scenarios and our restoration efforts

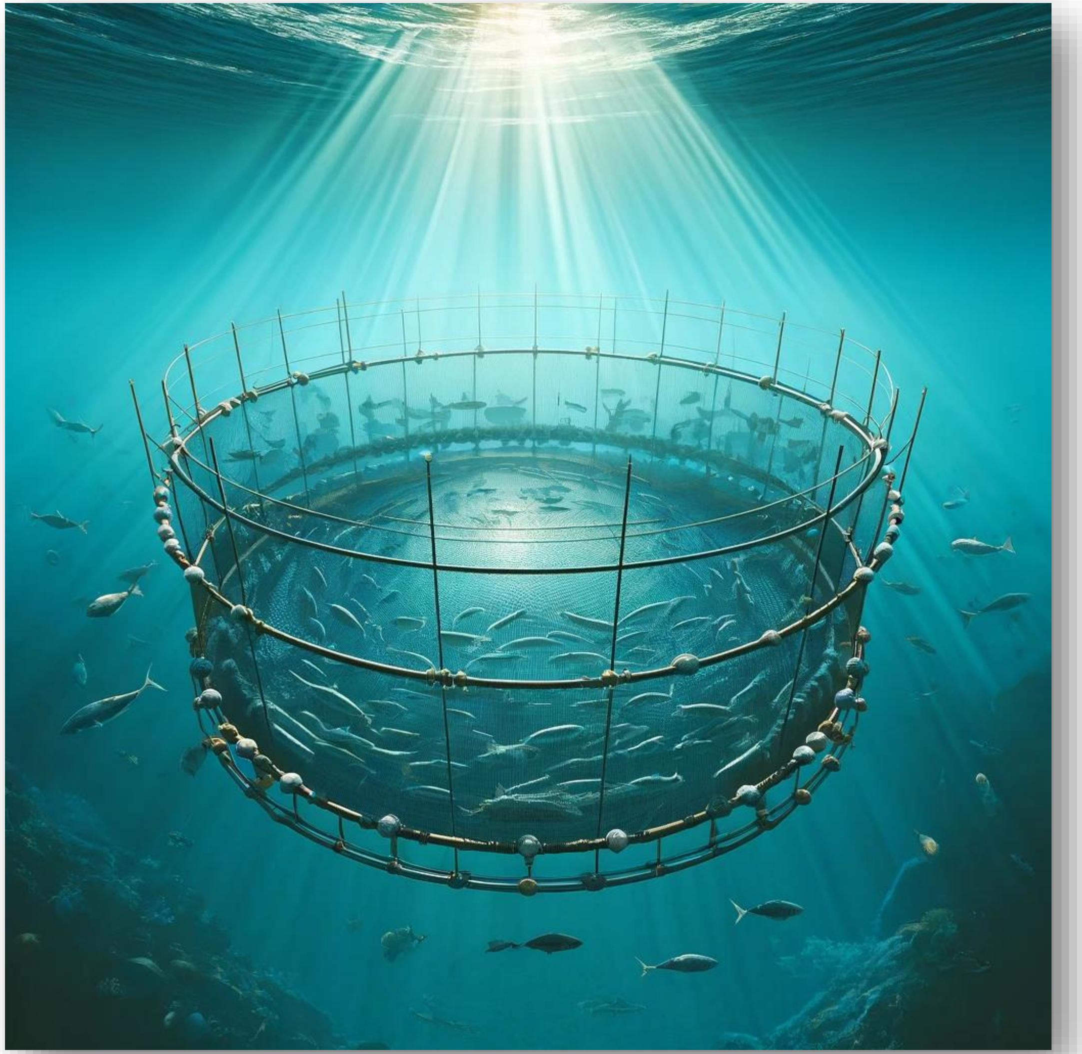
Ecological digital twin: Management model

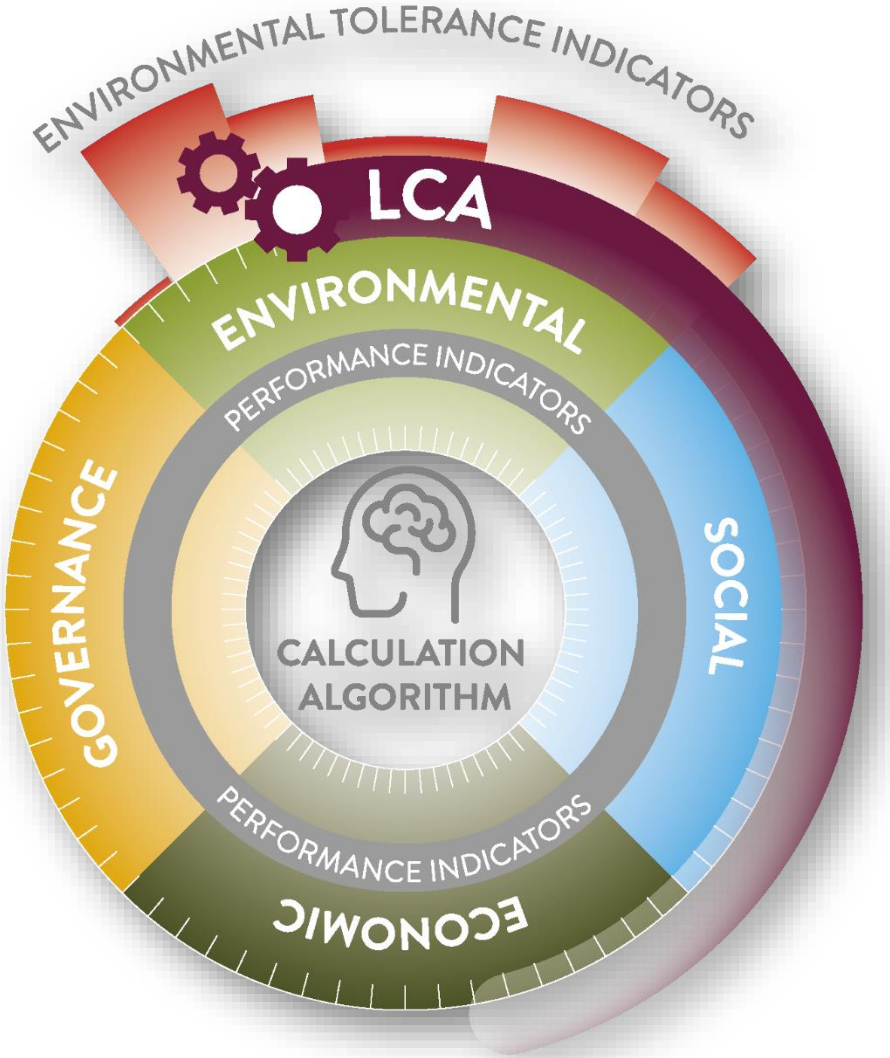


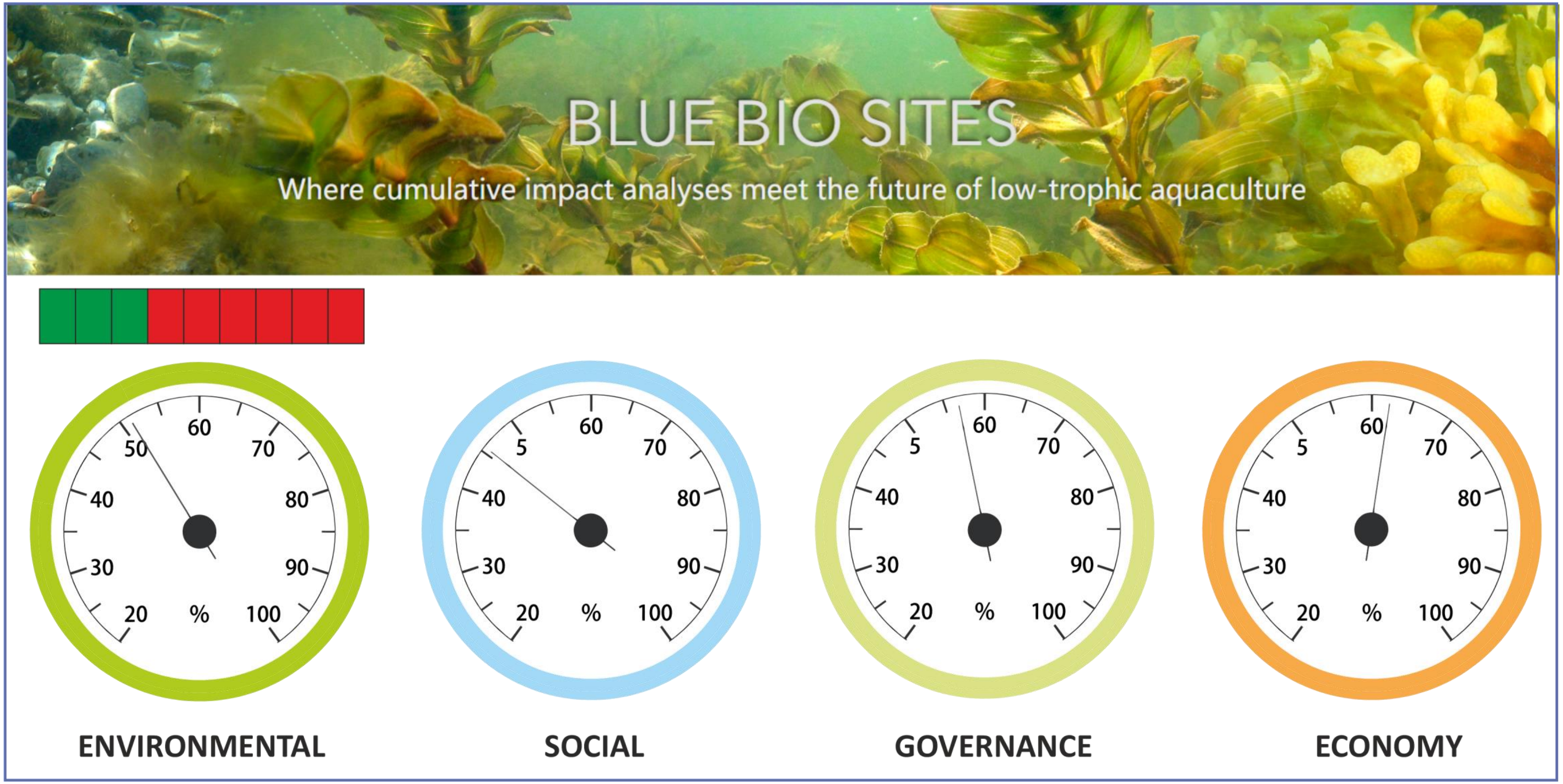


A transition from current management to true ecosystem-based management

Ecological digital twin: Sustainability assessment





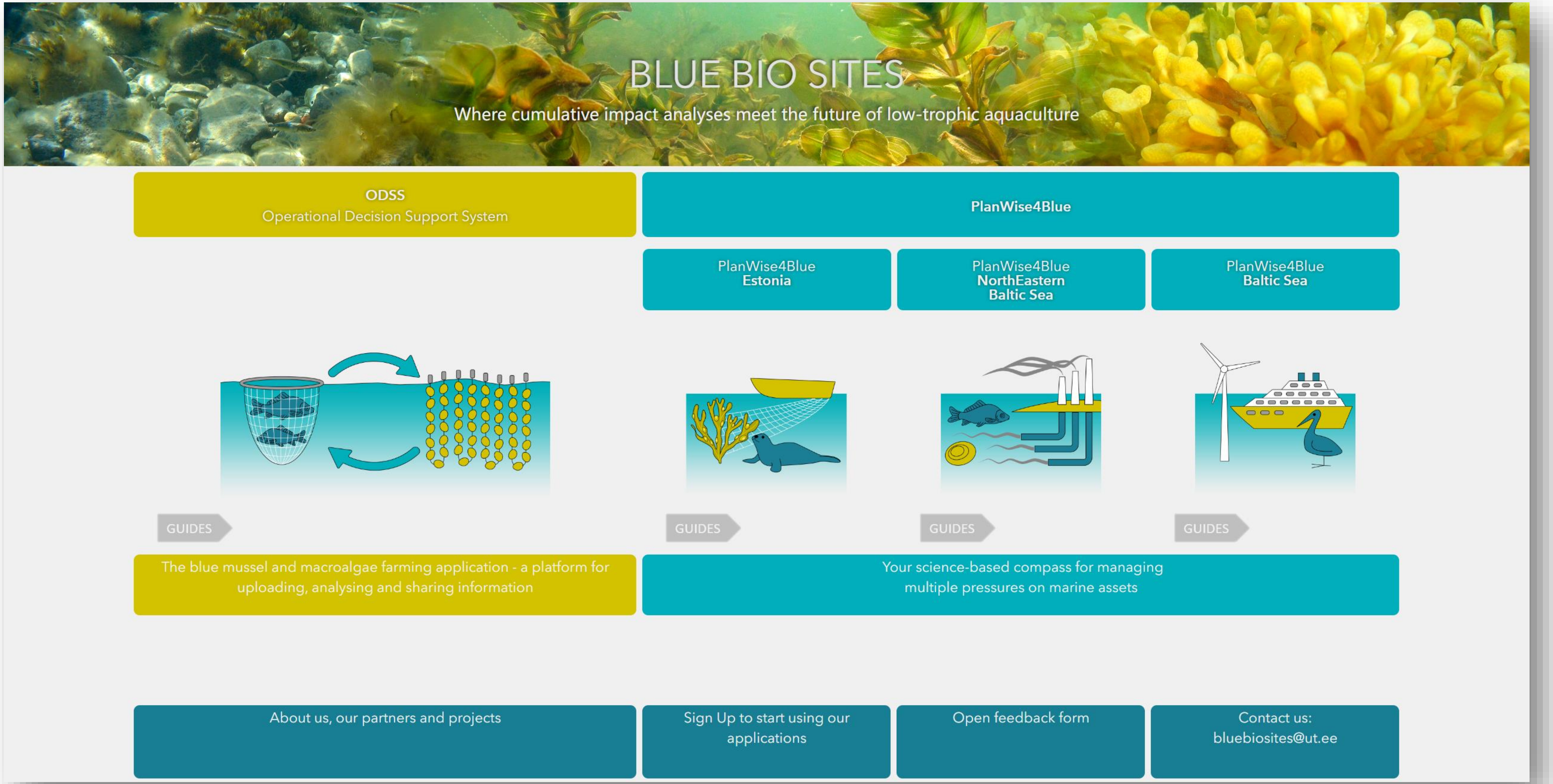


Conducting analyses across multiple dimensions while safeguarding the sustainability of natural systems


Creativity + Action
= Innovation

Ecological digital twin: Facilitating the creation of a shared vision

Ecological digital twin: Decision Support Tools



https://gis.sea.ee/bluebiosites/

developing novel foods

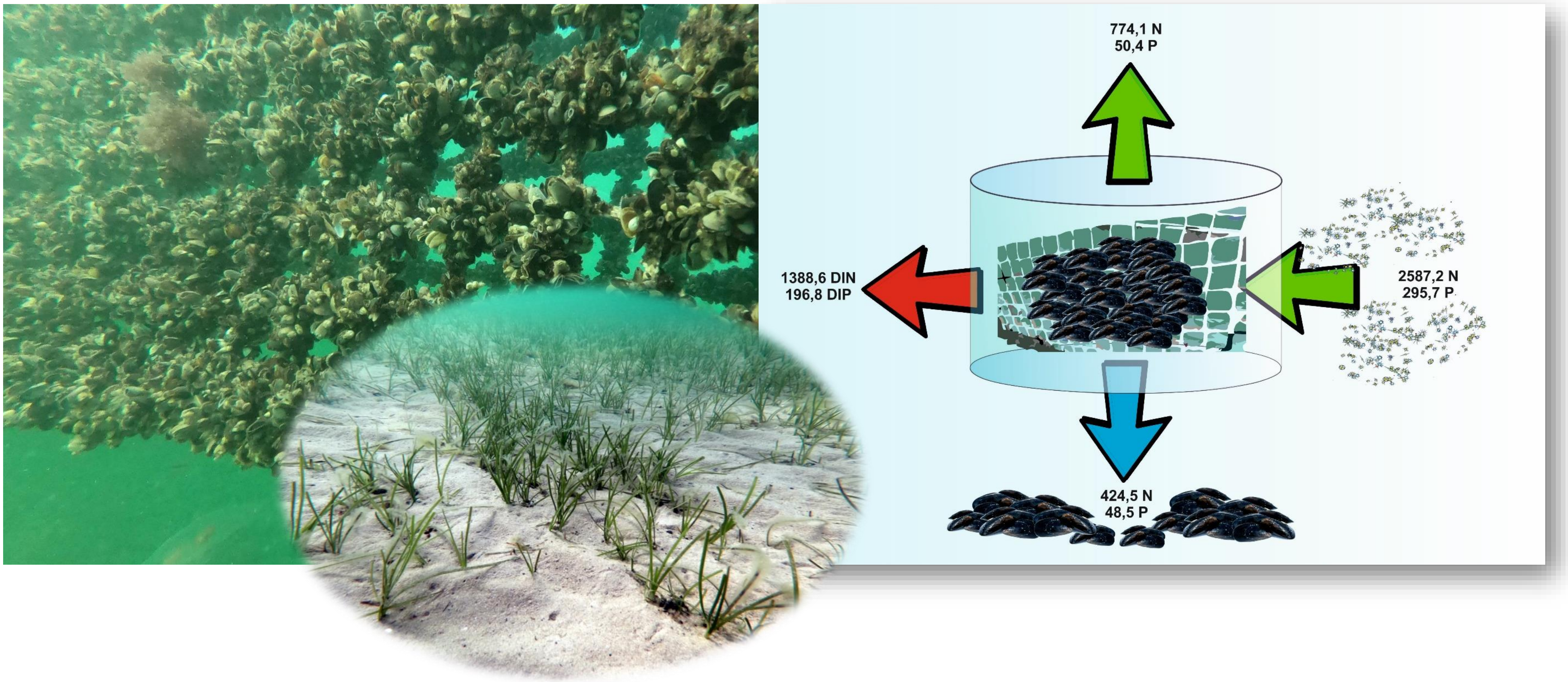
developing cultivation methods

NP

assessing environmental impacts (positive, negative)

A potential of algal and mussel farming

Mussel farming: Habitat restoration



Seaweed farming: Positive environmental impact

- Baltic Sea: Low salinity environment.
- Existing cultivation technologies from other seas are not viable.
- Necessity to utilize local species and forms.
- Potential for positive environmental impact.

Source: Ecopelag

Tiina
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TeraGel™
Natural Gelling Agent
Actera
CLEANSING MILK
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BERRICHI
FOR MEN
SMOOTHING AGE DEFENCE
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Epidermalny kwas hialuronowy
100%
NATURALNEGO NAWILŻENIA
Działa 3 razy szybciej niż kwas hialuronowy
PROFESSIONAL

There is nothing so practical as a good theory

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BlueGreen Governance

OLAMUR