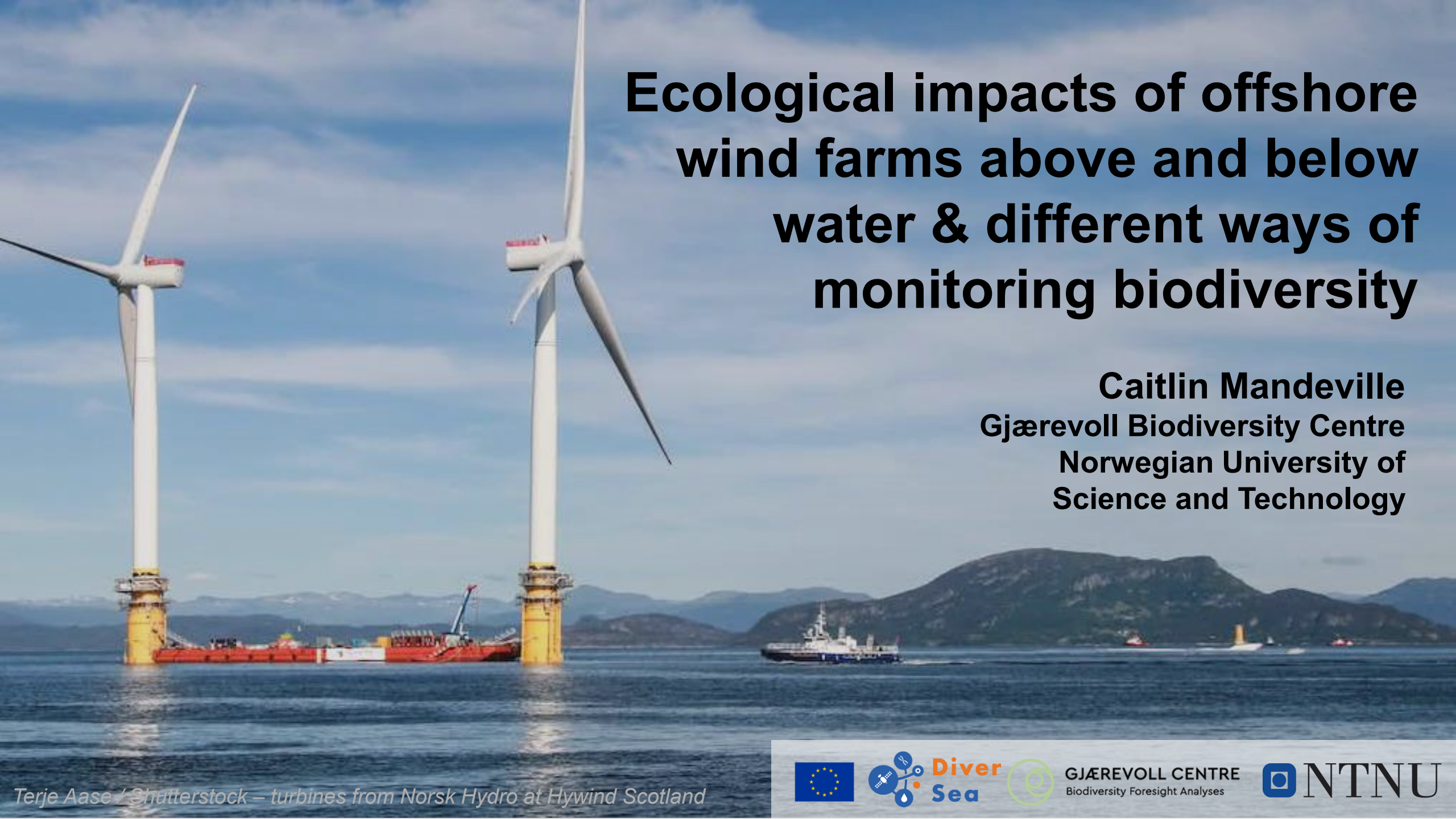

Ecological impacts of offshore wind farms above and below water & different ways of monitoring biodiversity

Caitlin Mandeville
Gjærevoll Biodiversity Centre
Norwegian University of Science and Technology

Terje Aase / Shutterstock – turbines from Norsk Hydro at Hywind Scotland

Diver Sea

GJÆREVOLL CENTRE
Biodiversity Foresight Analyses

NTNU

Inter Play

Integrated energy system models – RA1

- Integrated energy systems
- Demand and flexibility projections
- Power and sector markets
- Infrastructure investments and use
- Linking
- Uncertainty and stochasticity

Open energy system hub – RA4

- Data standardisation and accessibility
- Analysis tools
- Computational advancements

Case studies – RA5

- North Sea & Europe
- Norway
- Regions

Impact on biodiversity – RA2

- Digital twin of nature
- Cumulative impacts from energy system development
- Life cycle assessment-based revision to minimise loss

Markets and regulation – RA3

- Optimal market design across sectors
- Regulatory barriers and changes to overcome suboptimal solutions and practices
- Distributions of costs and benefits

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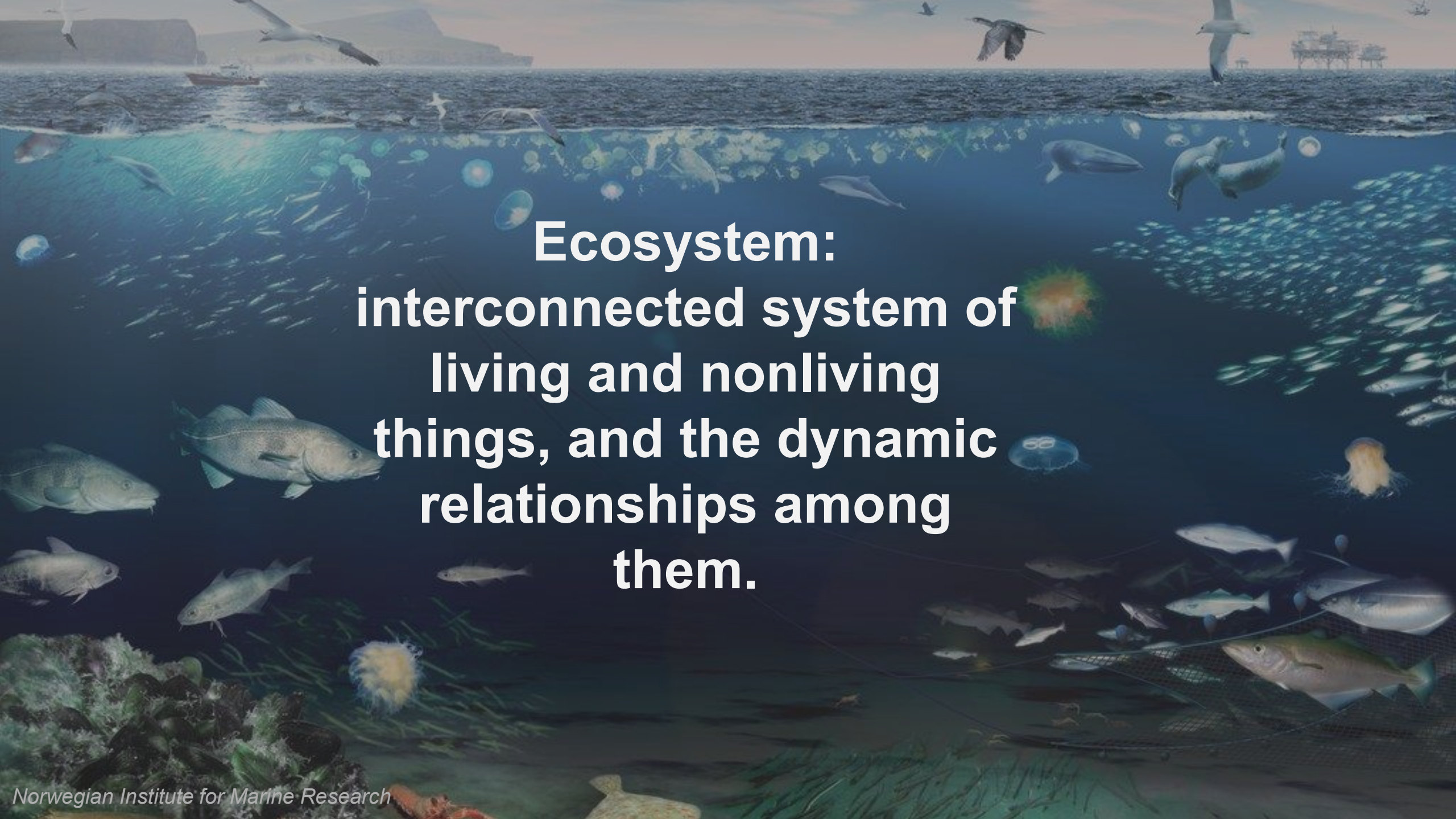
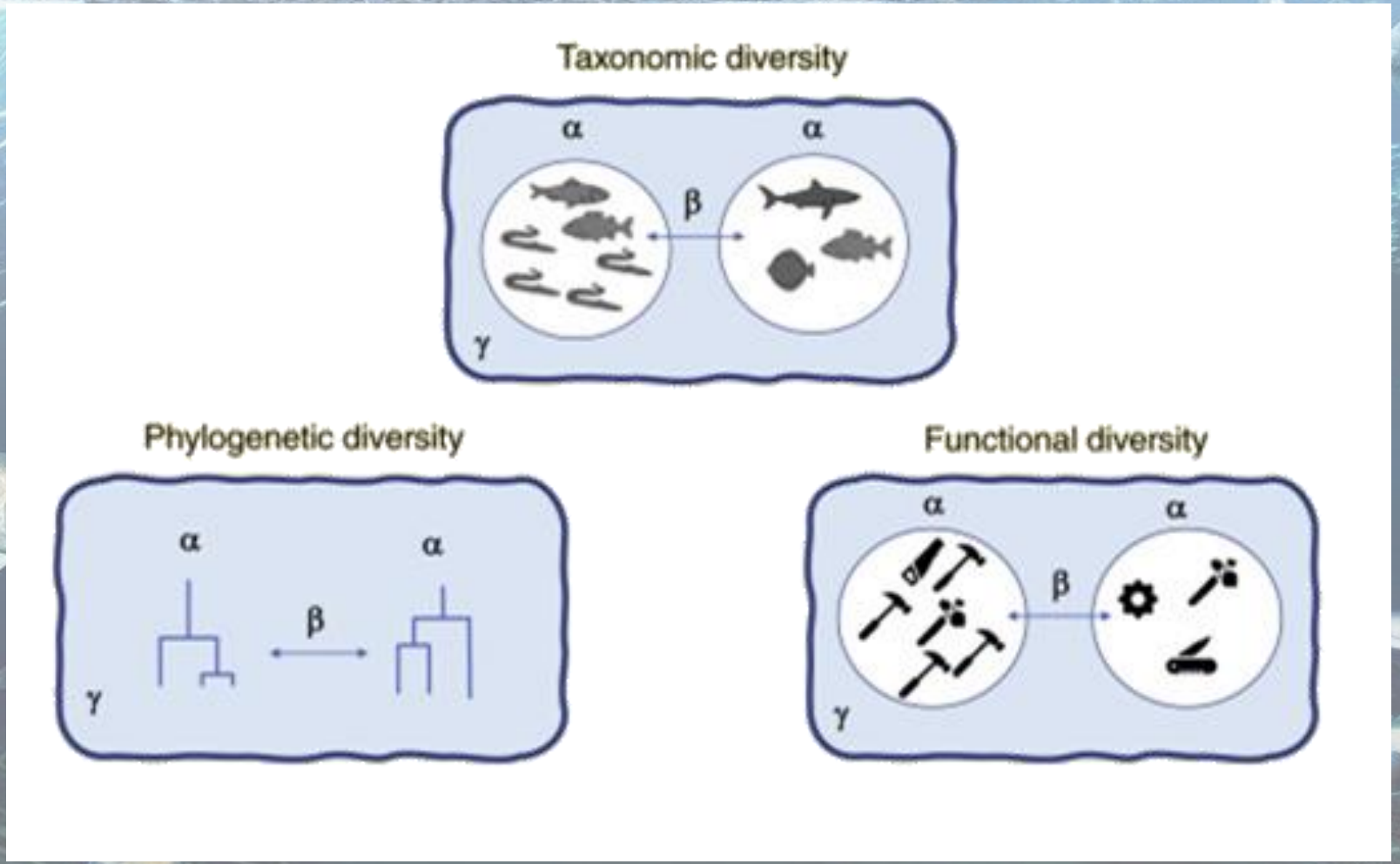
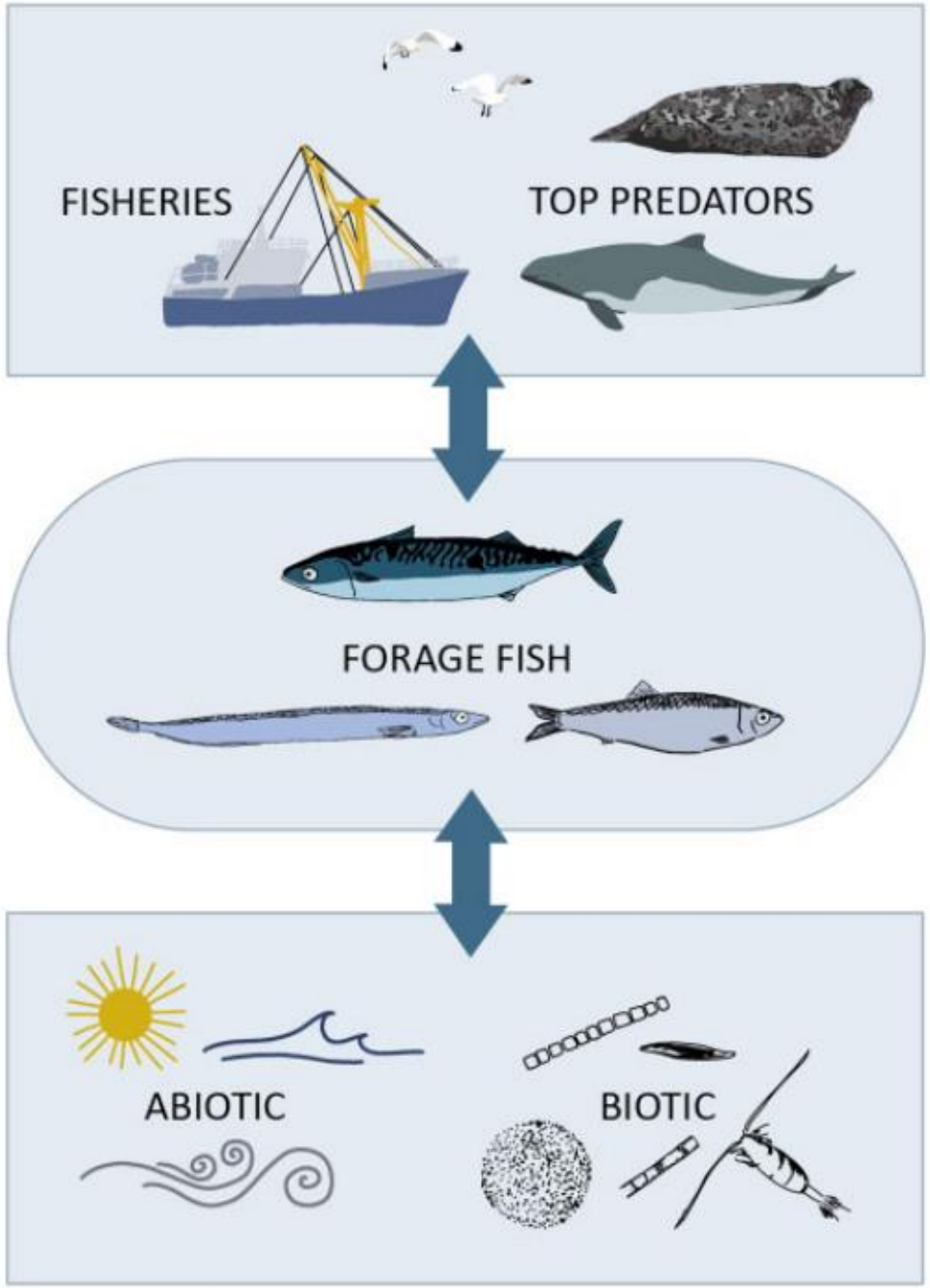
Topics for this session

- What do we mean when we talk about an ecosystem? About biodiversity?
- What do we know, and what do we NOT know, about ecological impacts of offshore wind?
- What are the methods used for studying and monitoring these impacts?

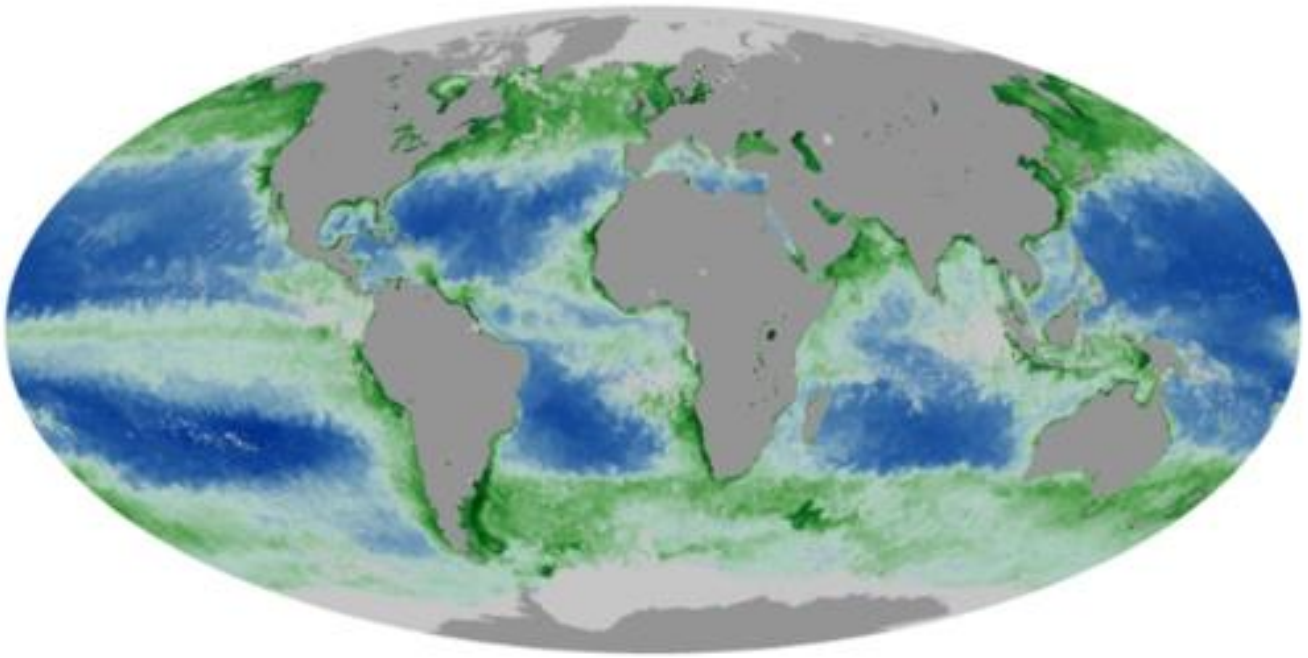

What do we mean
when we talk about an
ecosystem?
Norwegian Institute for Marine Research


Ecosystem:
interconnected system of living and nonliving things, and the dynamic relationships among them.
Norwegian Institute for Marine Research

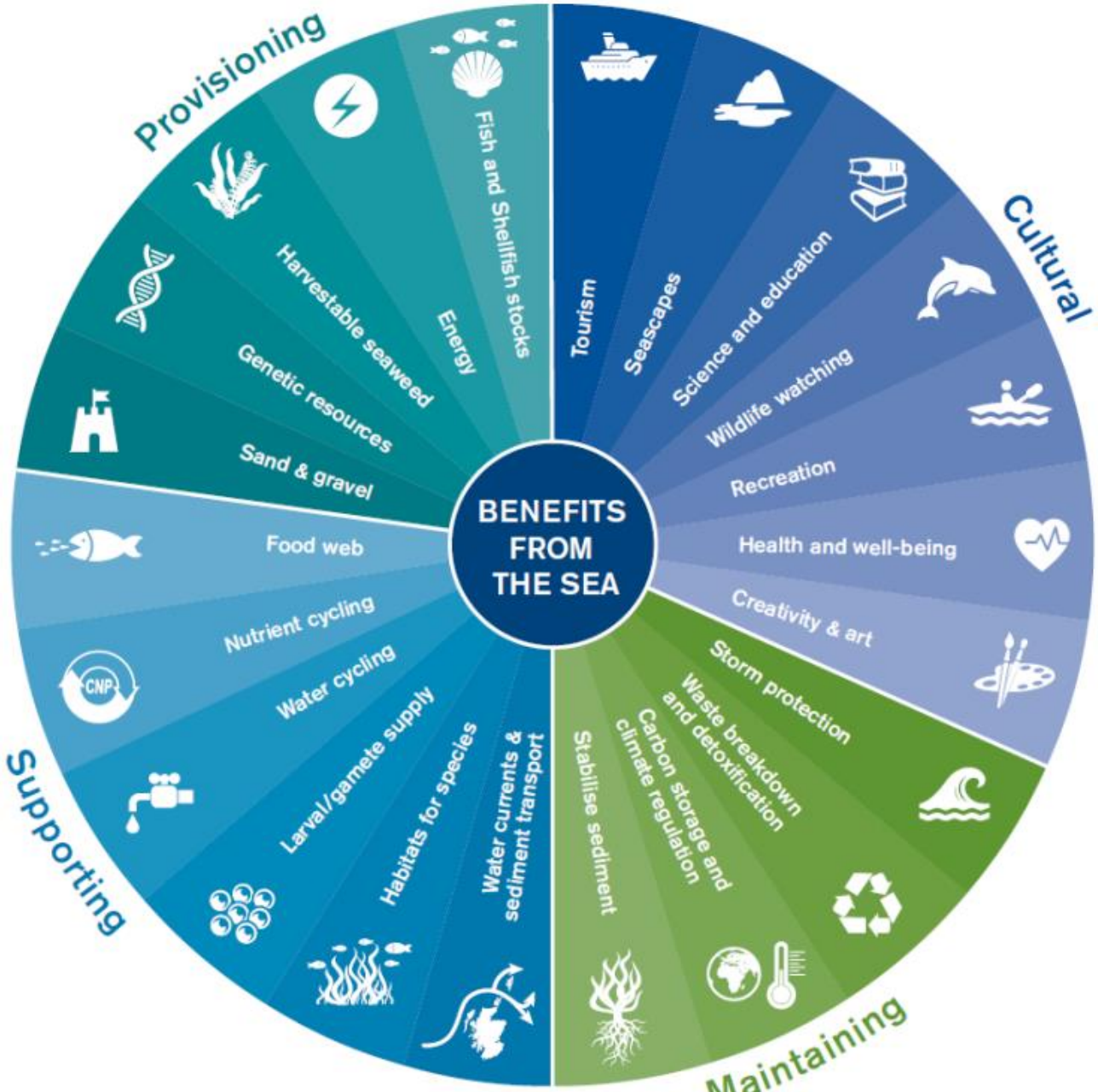

Taxonomic diversity
α
α
β
γ
Phylogenetic diversity
α
α
β
γ
Functional diversity
α
α
β
γ



Isaksson et al. 2023 ICES Journal of Marine Science



NASA Earth Observatory 2019


BENEFITS FROM THE SEA
Provisioning
Fish and Shellfish stocks
Energy
Harvestable seaweed
Genetic resources
Sand & gravel
Cultural
Tourism
Seascapes
Science and education
Wildlife watching
Recreation
Health and well-being
Creativity & art
Maintaining
Storm protection
Waste breakdown and detoxification
Carbon storage and climate regulation
Stabilise sediment
Supporting
Water currents & sediment transport
Habitats for species
Larval/gamete supply
Water cycling
Nutrient cycling
Food web
CNP

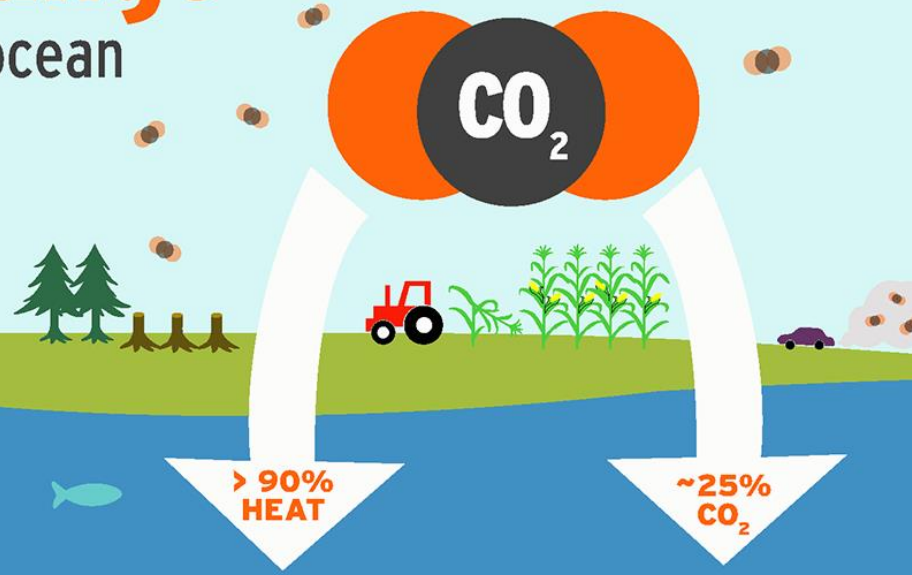
Nature Scot

Climate Change

A triple threat for the ocean

IPCC 2019 | Monterey Bay Aquarium

Burning fossil fuels, deforestation and industrial agriculture release carbon dioxide (CO_2) and other heat-trapping gases into our atmosphere, causing our planet to warm. The ocean has buffered us from the worst impacts of climate change by absorbing more than 90 percent of this excess heat and about 25 percent of the CO_2, but at the cost of causing significant harm to marine ecosystems.



WARMER **LESS OXYGEN** **MORE ACIDIC**

SEA LEVEL

Sea level rise is accelerating, flooding coastal communities and drowning wetland habitats.

BLEACHING

Warm-water coral reefs (marine biodiversity hotspots) could be lost if the planet warms by 2°C (3.6°F).

TOXIC ALGAE

Larger and more frequent blooms are making fish, birds, marine mammals and people sick.

HABITATS

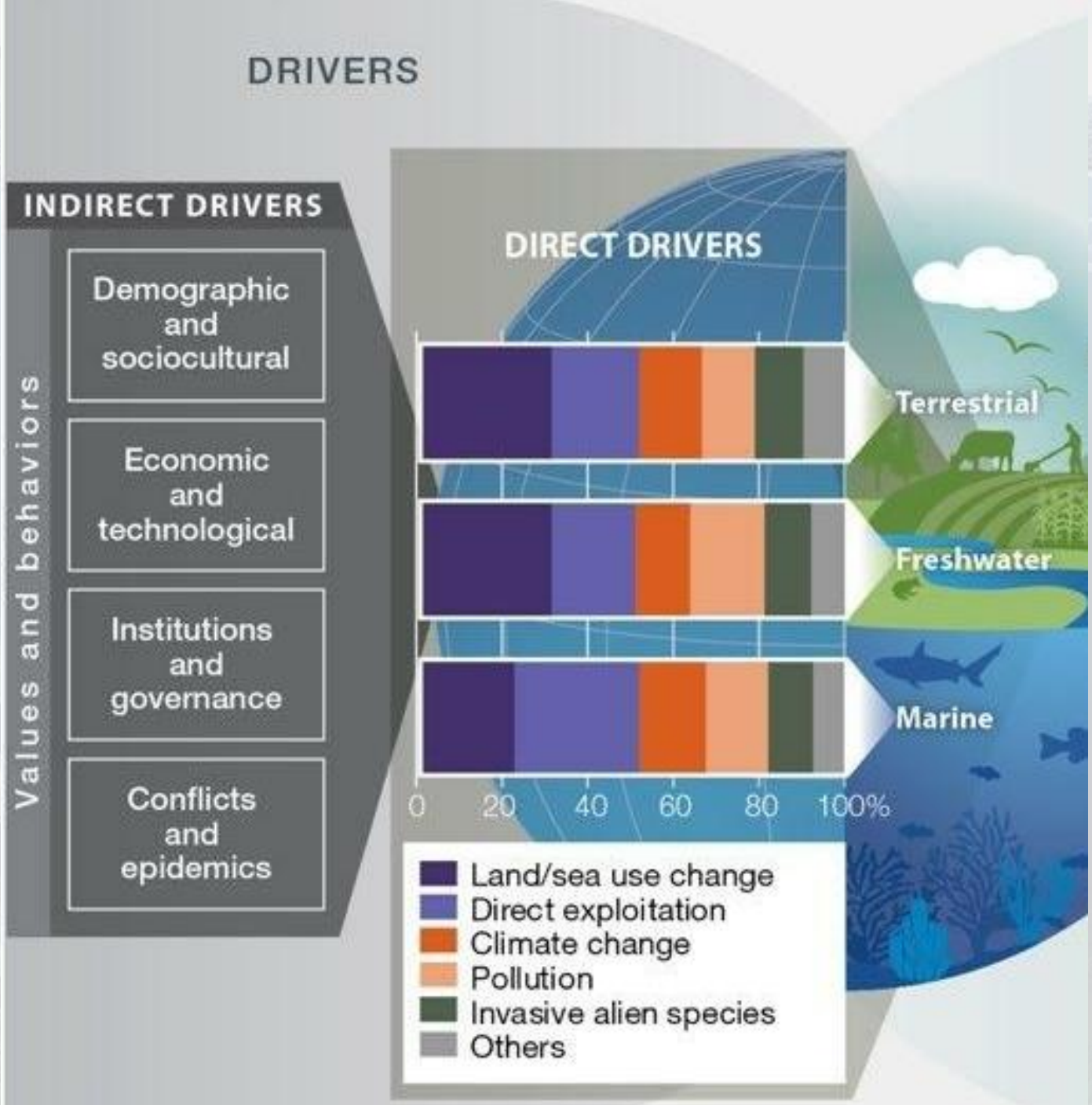
Lower oxygen levels are suffocating some marine animals and shrinking their habitats.

ACIDIFICATION

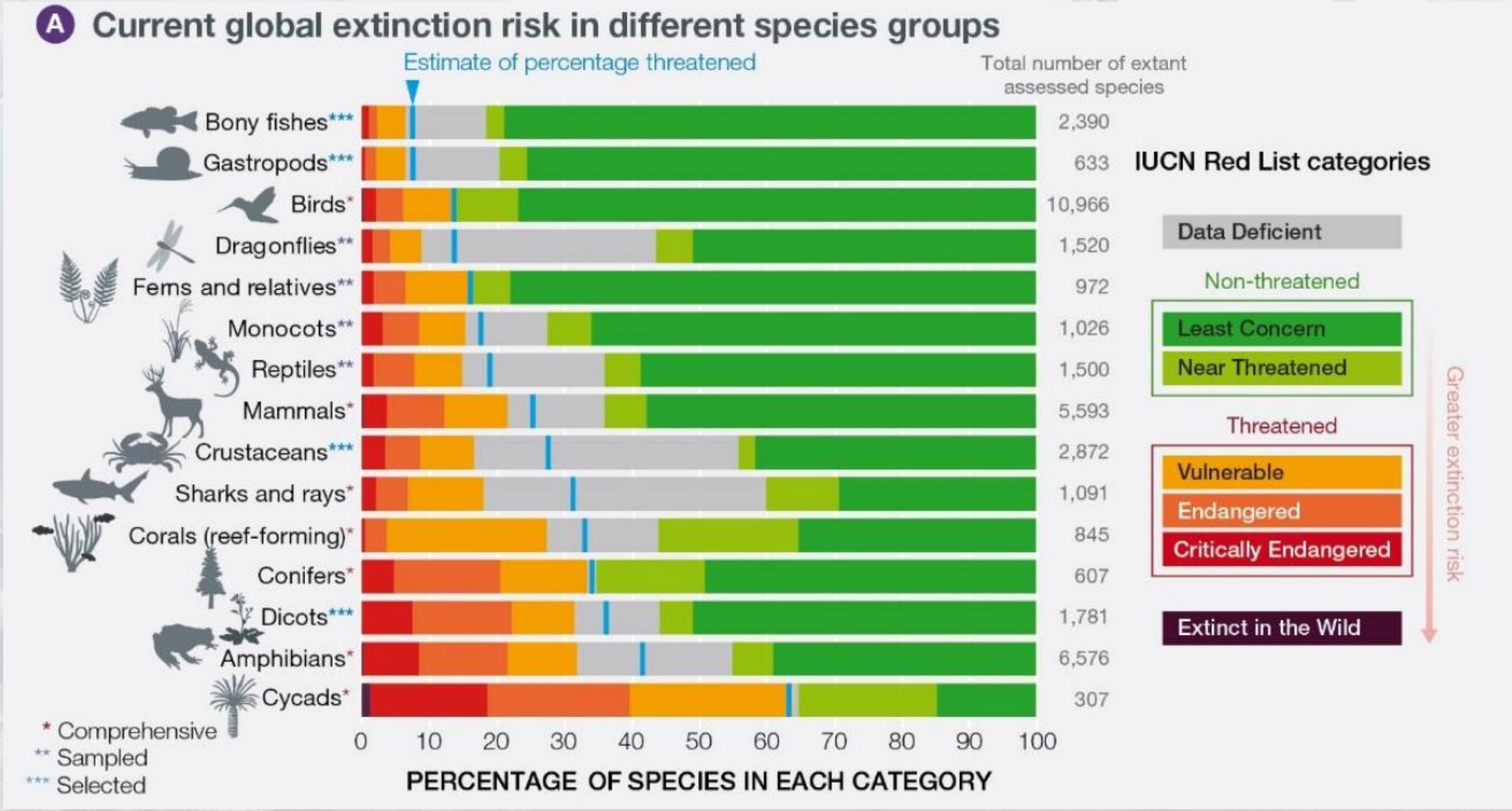
More acidic water harms animals that build shells, such as corals, clams, and oysters.

FISHERIES

Disruptions in fisheries affect the marine food web, local livelihoods, and global food security.



2019 IPBES Global Assessment Report on Biodiversity and Ecosystem Services



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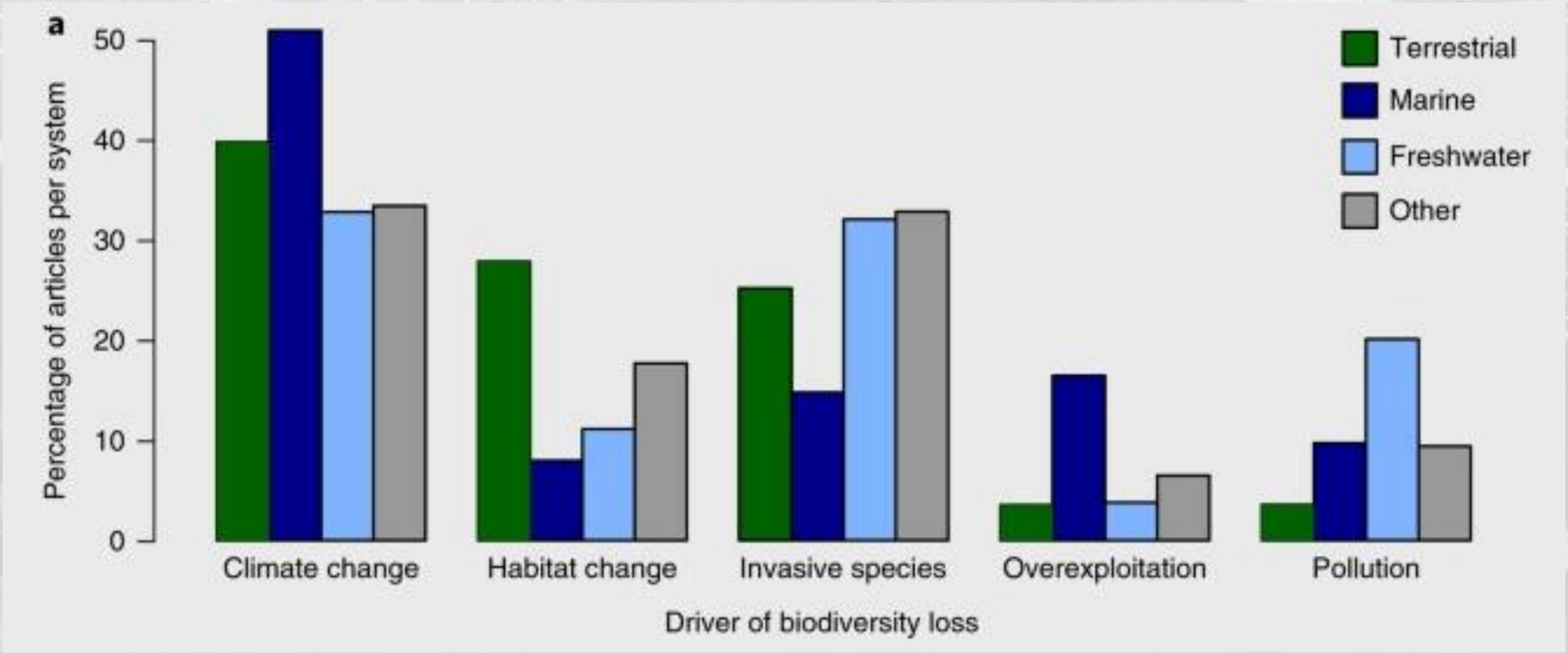
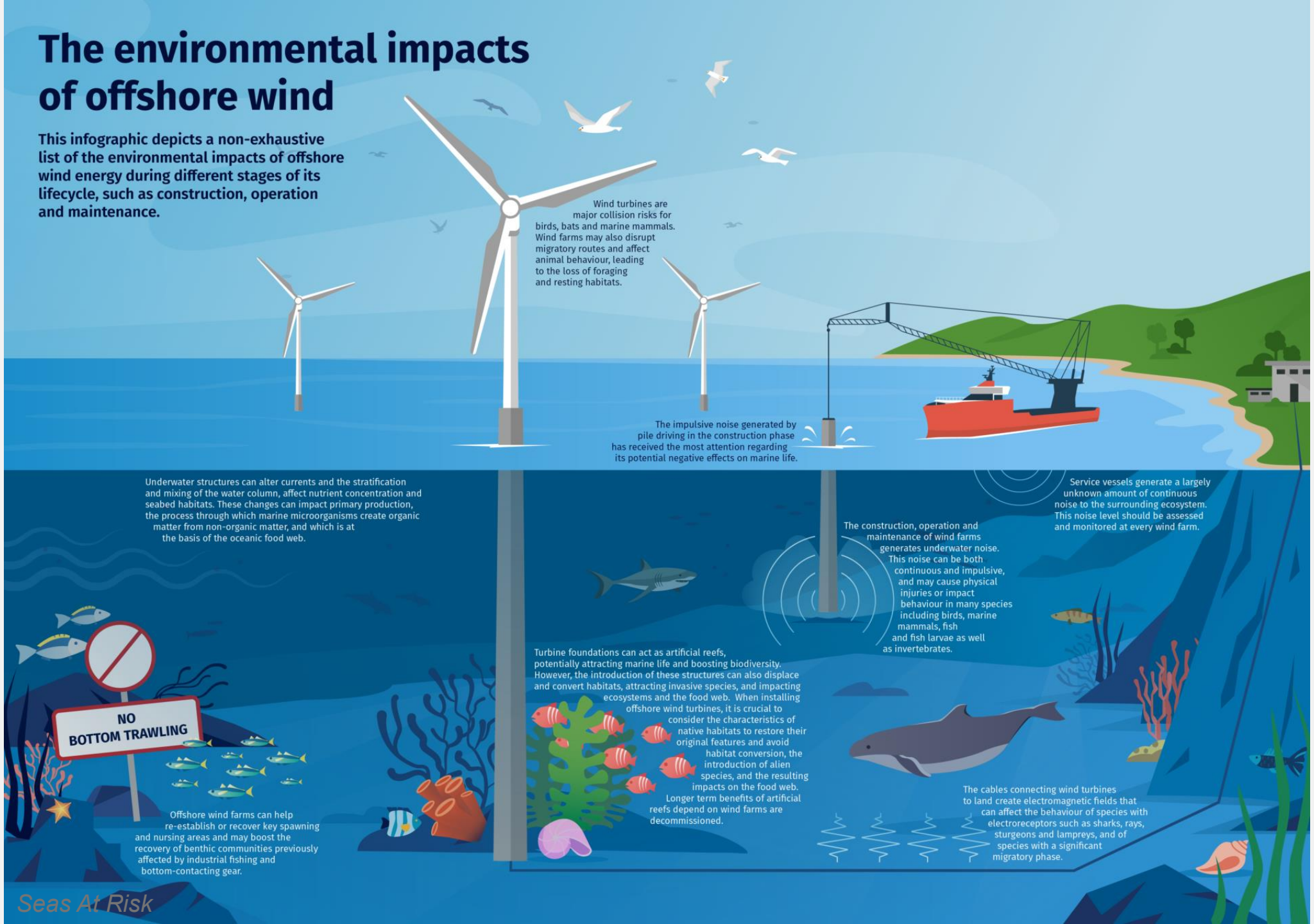


Mazor et al. 2018 Nature Ecology & Evolution

What ecological impacts do you associate with offshore wind?

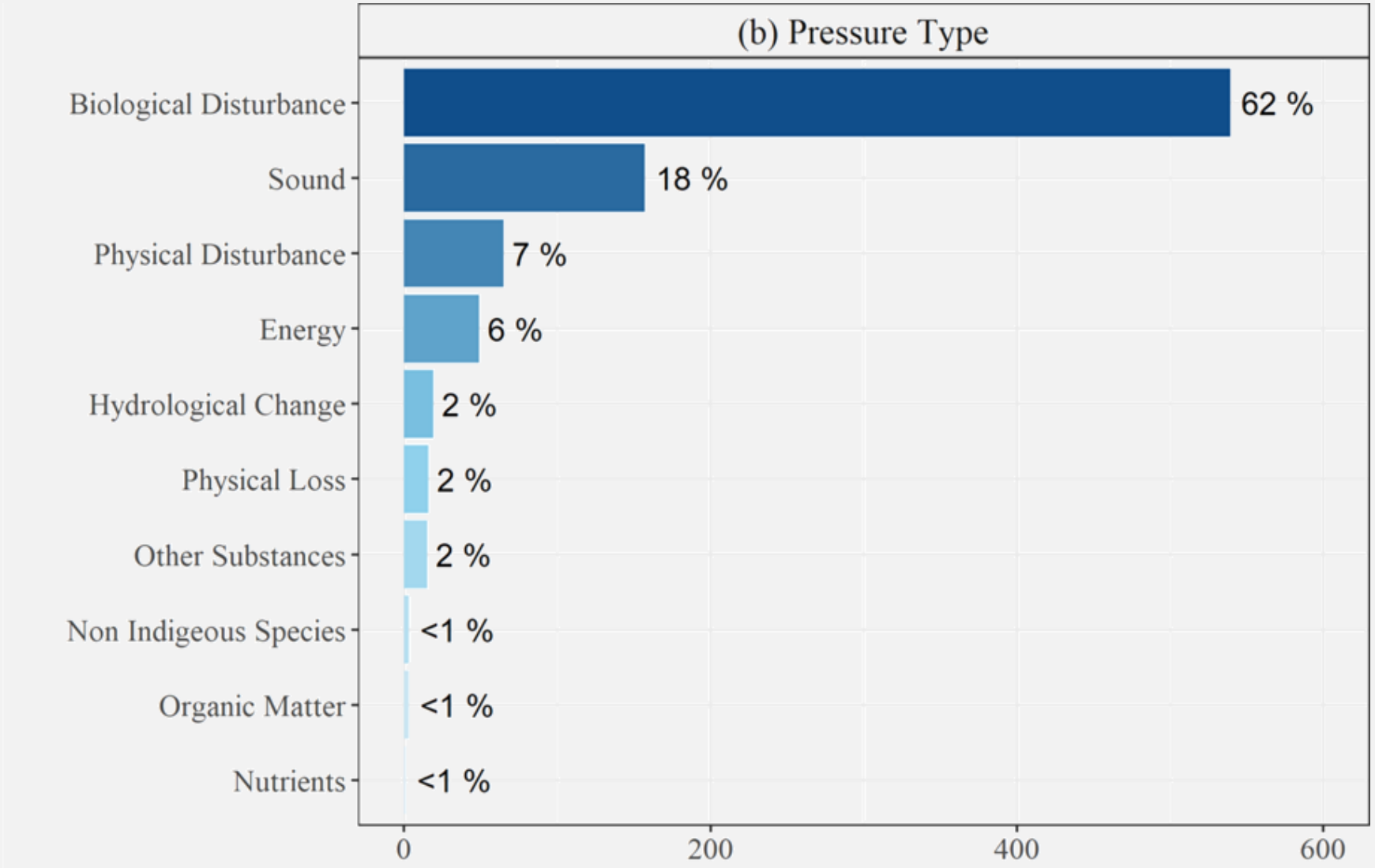
The environmental impacts of offshore wind

This infographic depicts a non-exhaustive list of the environmental impacts of offshore wind energy during different stages of its lifecycle, such as construction, operation and maintenance.



Seas At Risk

What types of pressures have been studied?



Galparsoro et al. 2022 npj Ocean Sustainability

→ Biological disturbance (62% of identified pressures)

- **Mortality**
- **Avoidance or attraction**
- **Behavioral change**
- **Change in interactions + predation pressure**
- **Spatial or temporal mismatch**

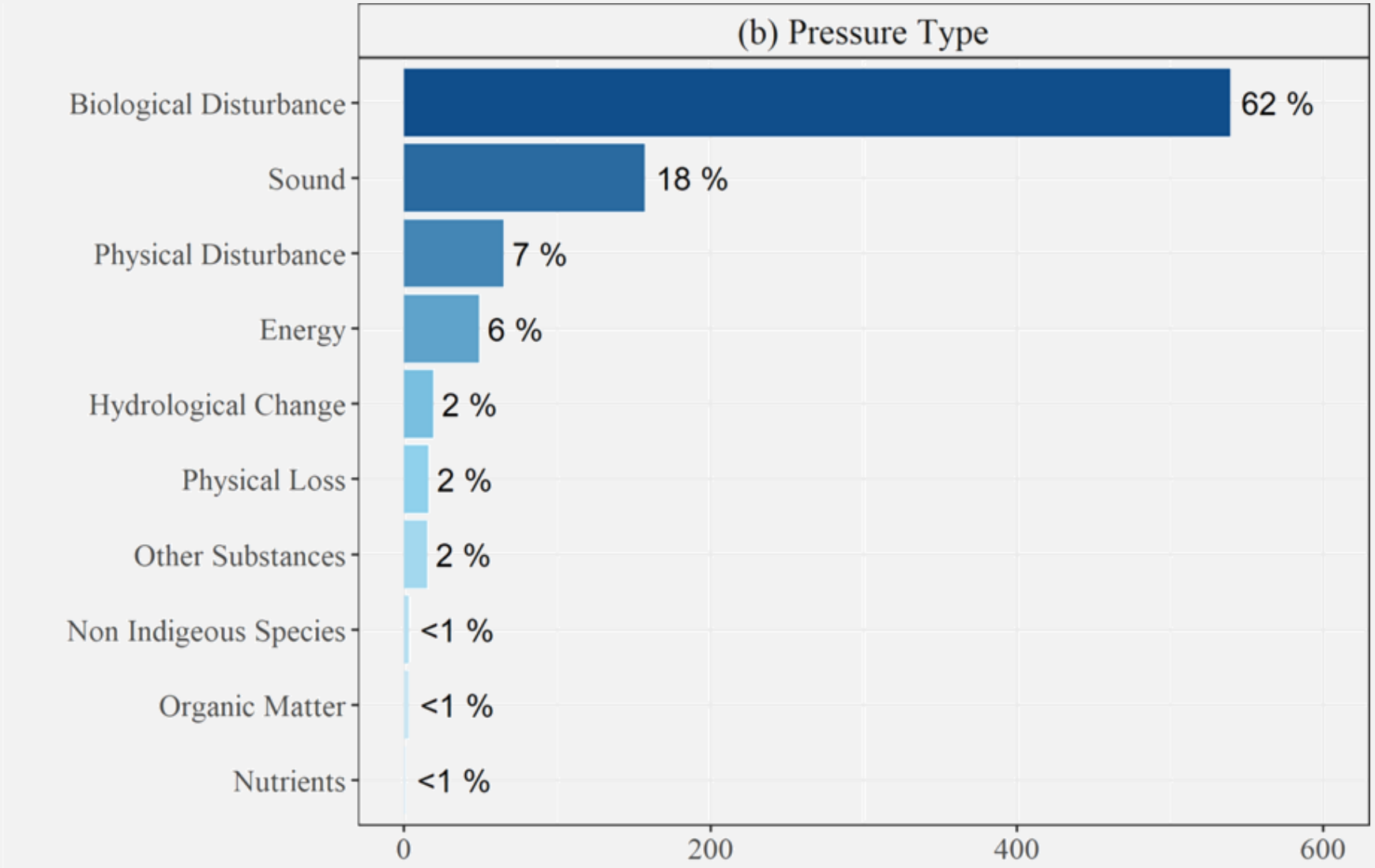
→ Sound (18% of identified pressures)

- **Avoidance and behavioral response**
- **Communication interference**
- **Recruitment response: e.g., in invertebrates**
- **Stress response: e.g., in copepods**

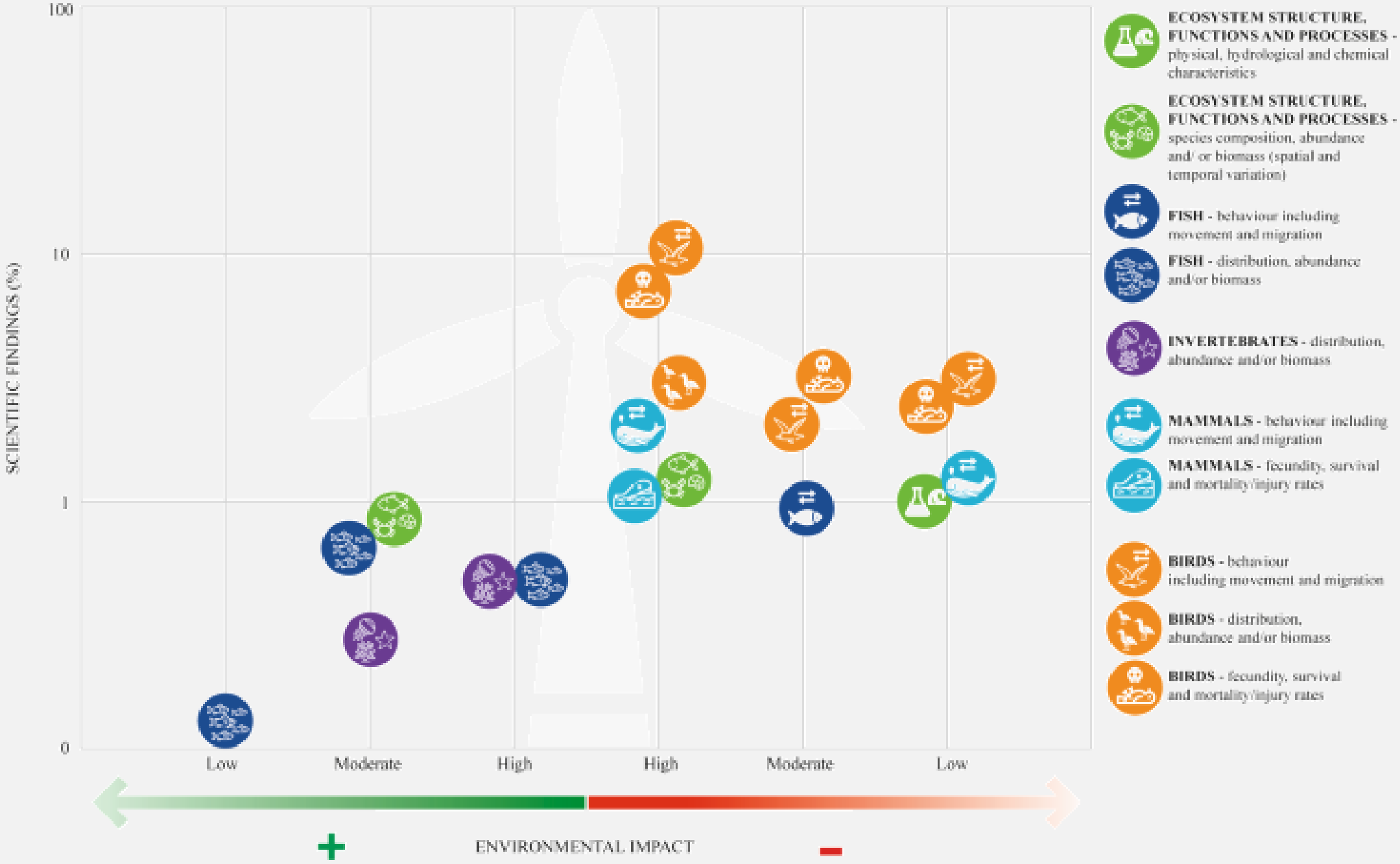
→ Physical, hydrological, energy disturbance (17% of identified pressures)

- **Alteration of physical seabed environment**
  - Impacts on species composition
- **Alteration of local topography, affecting tidal mixing and internal waves**
  - Impacts on distribution of primary productivity
- **Alteration of sediment scouring patterns, affecting turbidity**
  - Impacts on primary productivity & carbon storage

What types of pressures have been studied?



Galparsoro et al. 2022 npj Ocean Sustainability



Galparsoro et al. 2022 npj Ocean Sustainability

What is still unknown?

- Study contexts are not representative
- How do effects accumulate across space?
- How do effects accumulate over time?
- How to predict indirect and nonlinear effects?
- What are acceptable threshold values?

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- How to predict indirect and nonlinear effects?
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- Where are there opportunities for win-wins?

How do we study ecosystems and biodiversity?

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Research:

- Often hypothesis driven
- Investigates mechanisms

Monitoring:

- Consistent data collection over time
- Investigates trends

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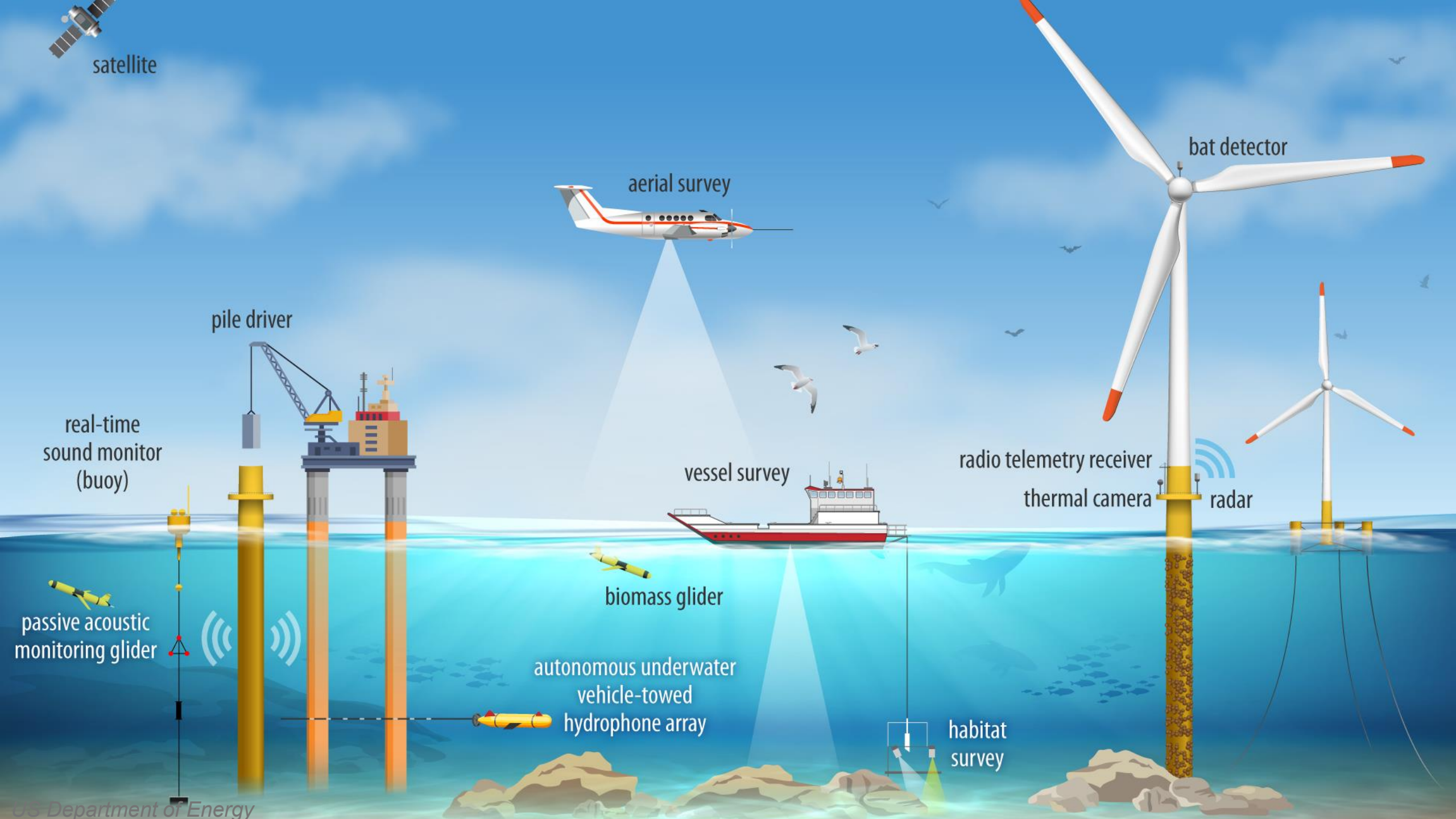
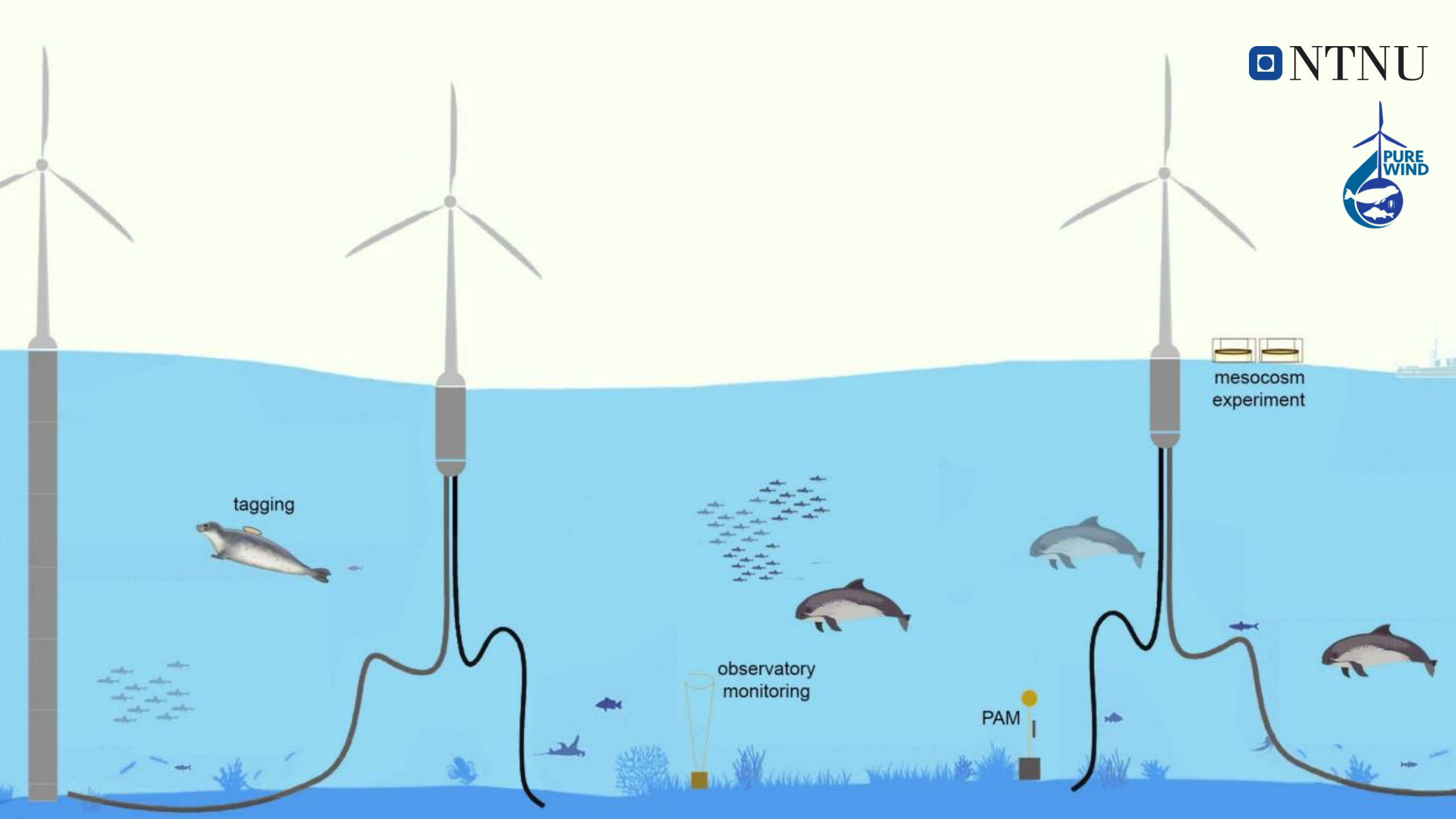
Observation:

- Data collection, often use-agnostic




tagging
observatory
monitoring
PAM
mesocosm
experiment

How do we use the collected data?

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→ Indicators towards international agreements

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How do we use the collected data?

→ Larger scale experimentation, modeling, synthesis

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→ Larger scale experimentation, modeling, synthesis

- Requires data to be shared and interoperable!
- (FAIR = Findable, Accessible, Interoperable, Reusable)
- Requires coordination among many actors

How do we use the collected data?

→ Larger scale experimentation, modeling, synthesis

Advancing eDNA/eRNA methods

Studying phytoplankton across scales using in situ sampling, AUVs, drones, and hyperspectral analysis of satellite imagery

DiverSea

NTNU

How do we use the collected data?

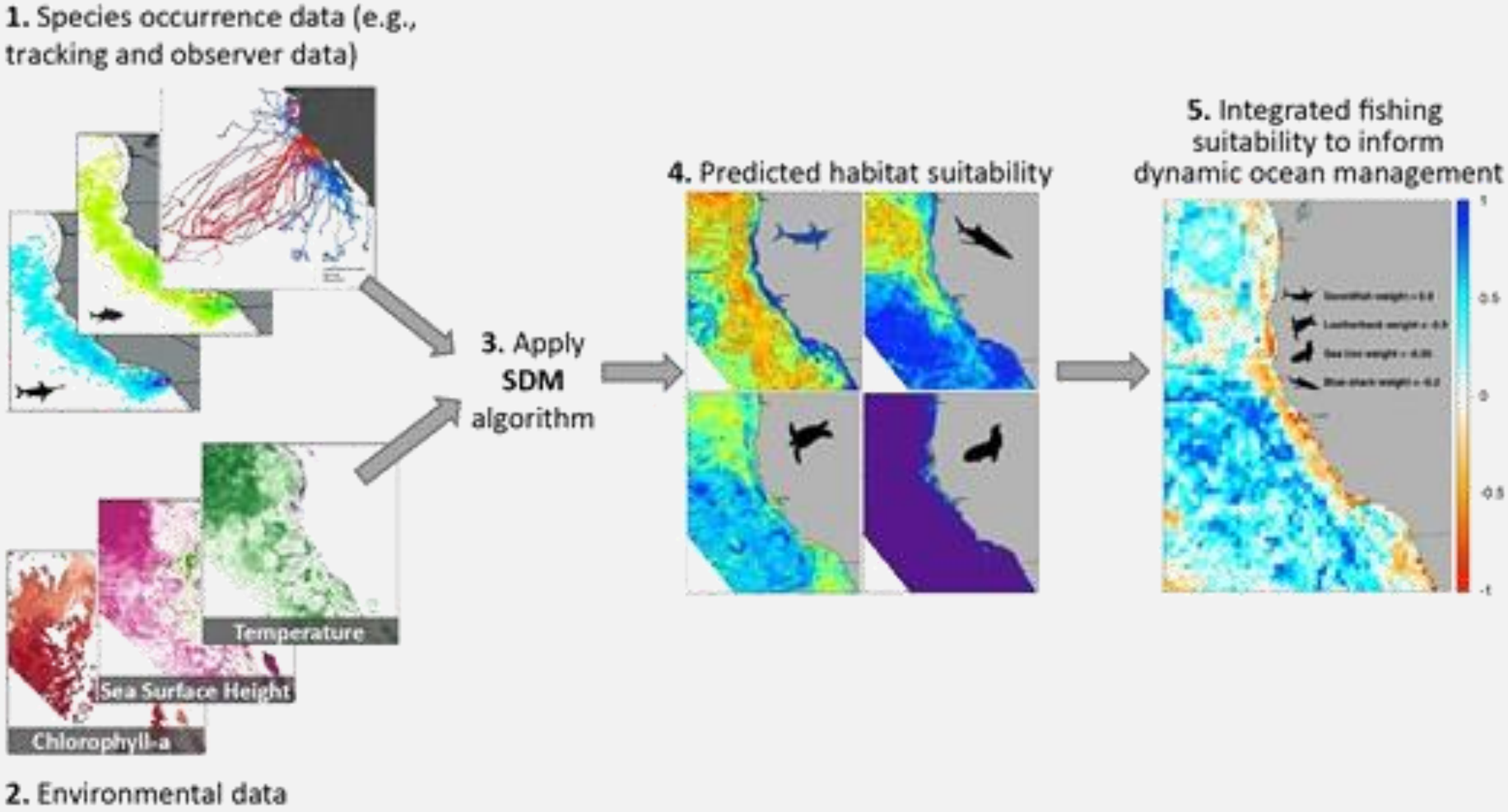
→ Larger scale experimentation, modeling, synthesis

- WP1 – Developing nucleic acid methods and field technologies through case studies
- WP2 – Data integration, harmonization, cataloguing, and compatibility with standards
- WP3 – AI, machine learning, and statistical methods for predictive scenario building
- WP4 – MARBIOSE dashboard for biodiversity and ecosystem goods and services
- WP5 – Consilience, public interface, communication, dissemination & exploitation

DiverSea NTNU

How do we use the collected data?

→ Larger scale experimentation, modeling, synthesis



Karp et al. 2025 ICES Journal of Marine Science

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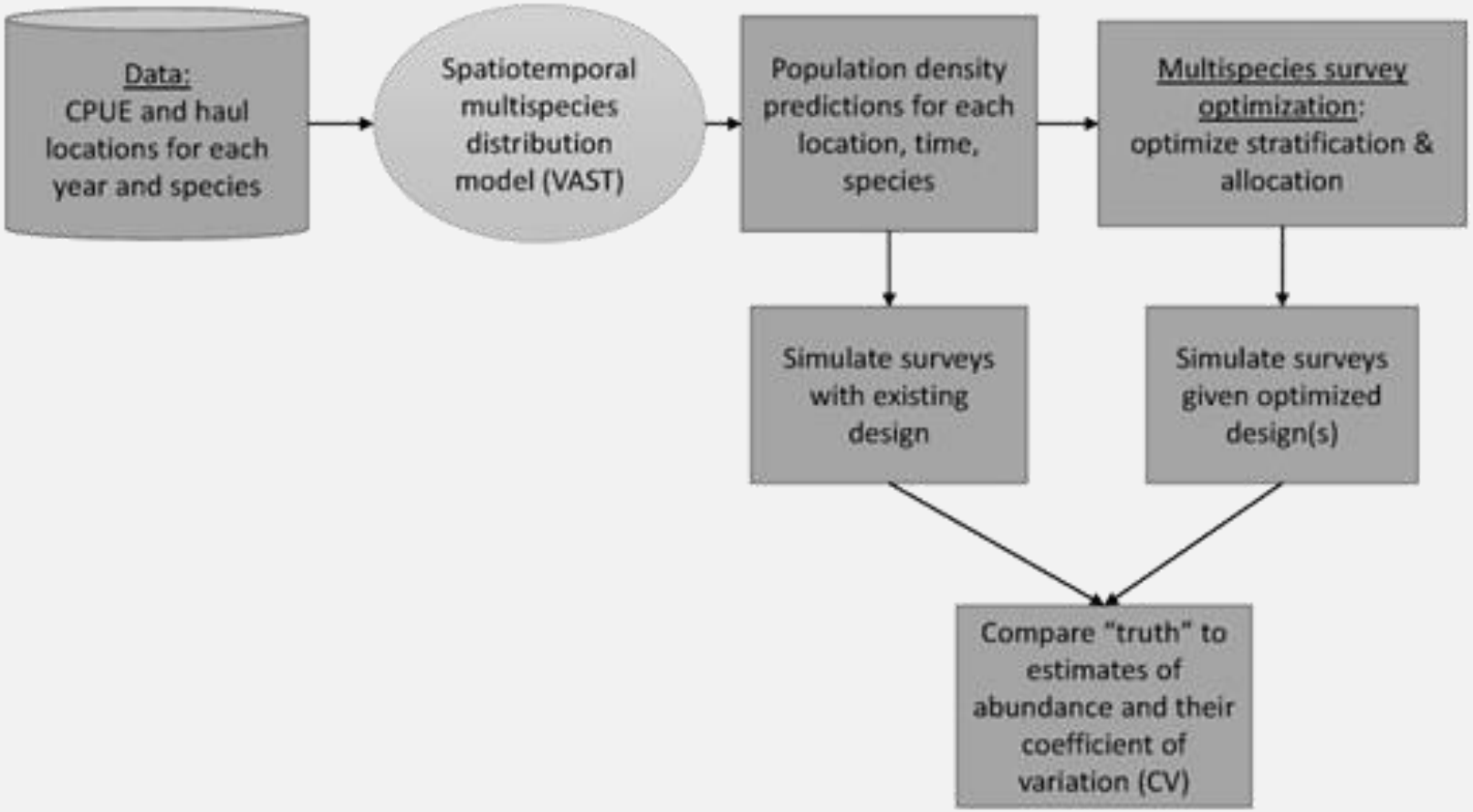

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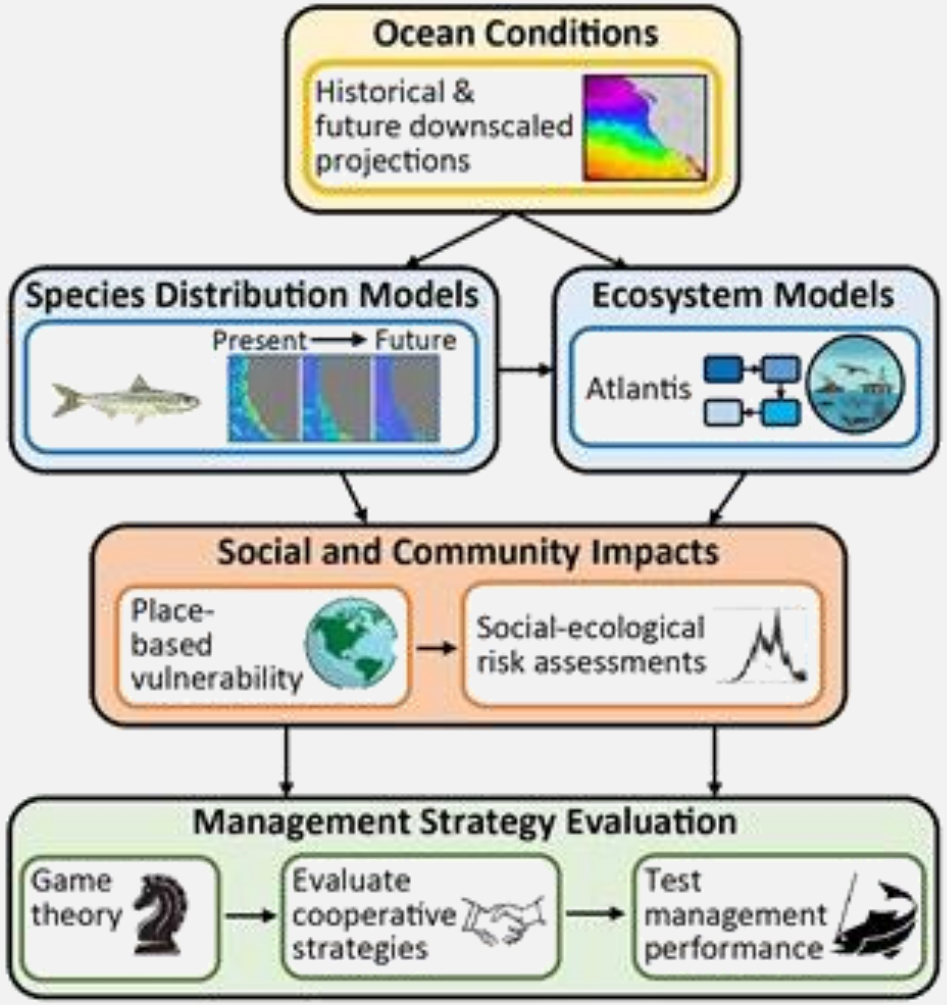

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Offshore Wind Farm Environmental Evidence Database

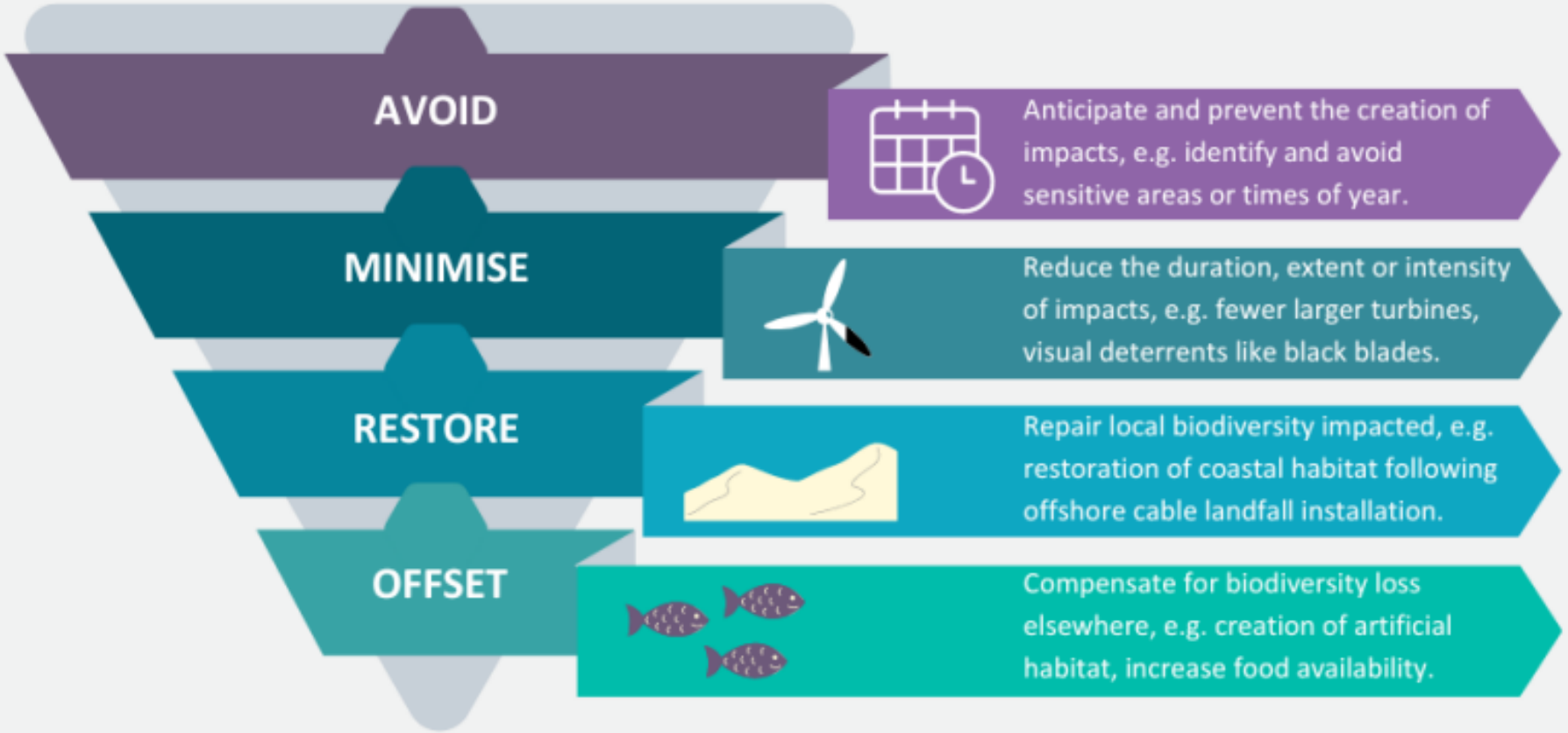
UKERC UK Energy Research Centre

PML | Plymouth Marine Laboratory

https://ories.pml.space/

How do we use the collected data?

→ Adaptive management of wind infrastructure



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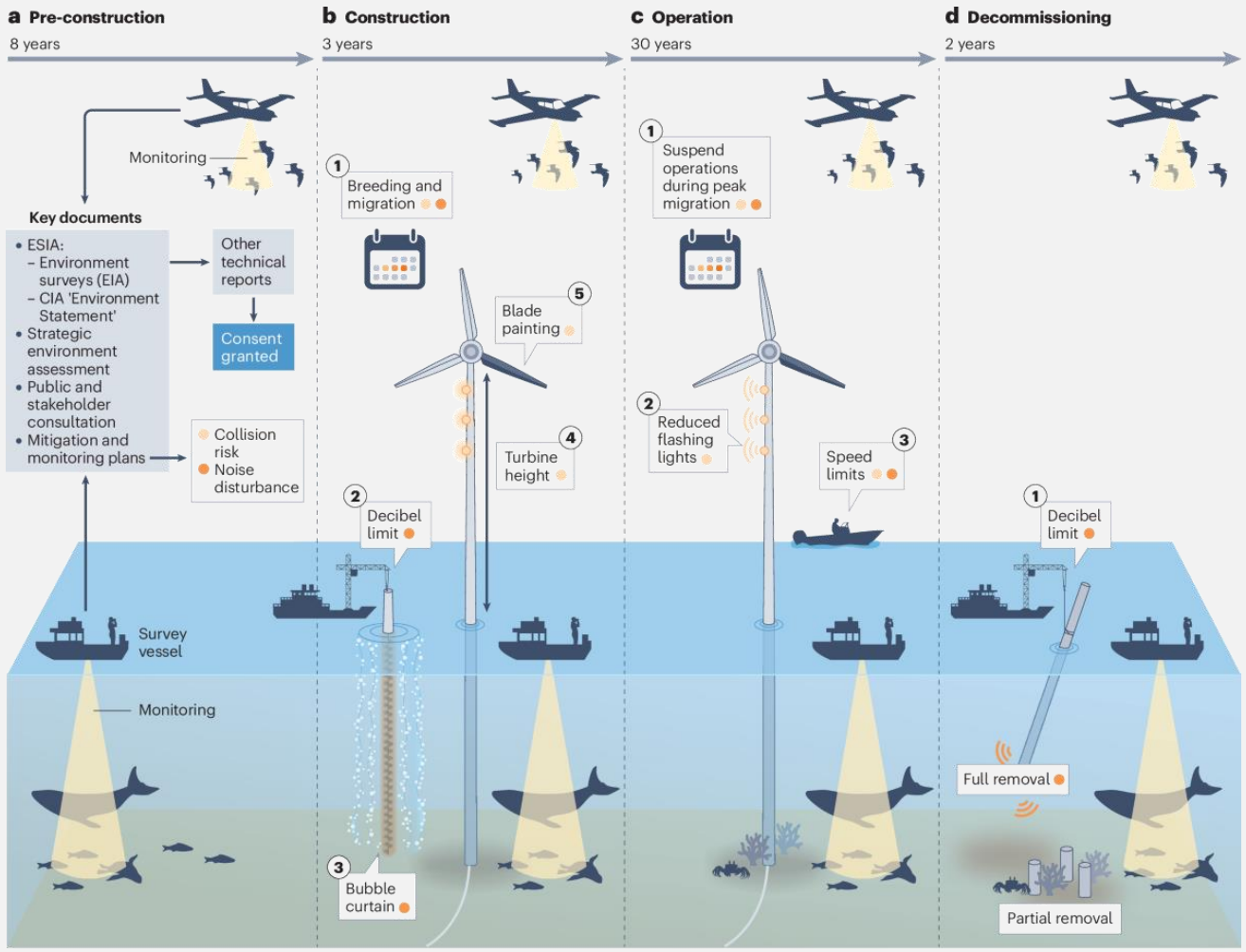


Some key questions to think about…

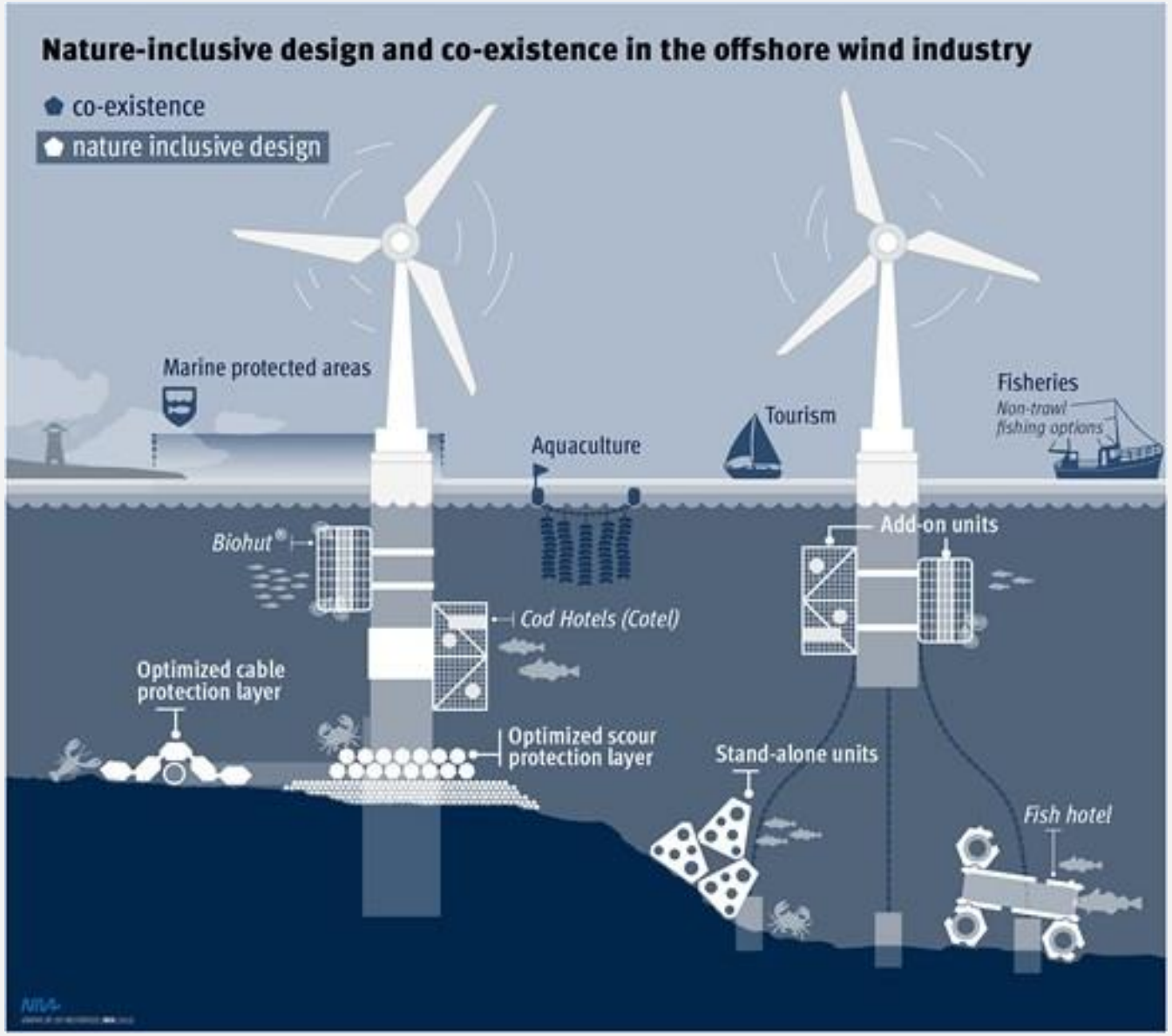
→ Where are the win-wins?

- Potential role as protected areas from fishing
- Reef effect (for which species, under what conditions?)
- Potential role in low-trophic aquaculture

→ Are there opportunities yet to be explored?

- Can wind infrastructure be combined with biodiversity monitoring tech to contribute to broader monitoring objectives?

Some key questions to think about…



Pardo et al. 2023
ICES Journal of Marine Science

Some key questions to think about…

→ How do we include the public in this issue?

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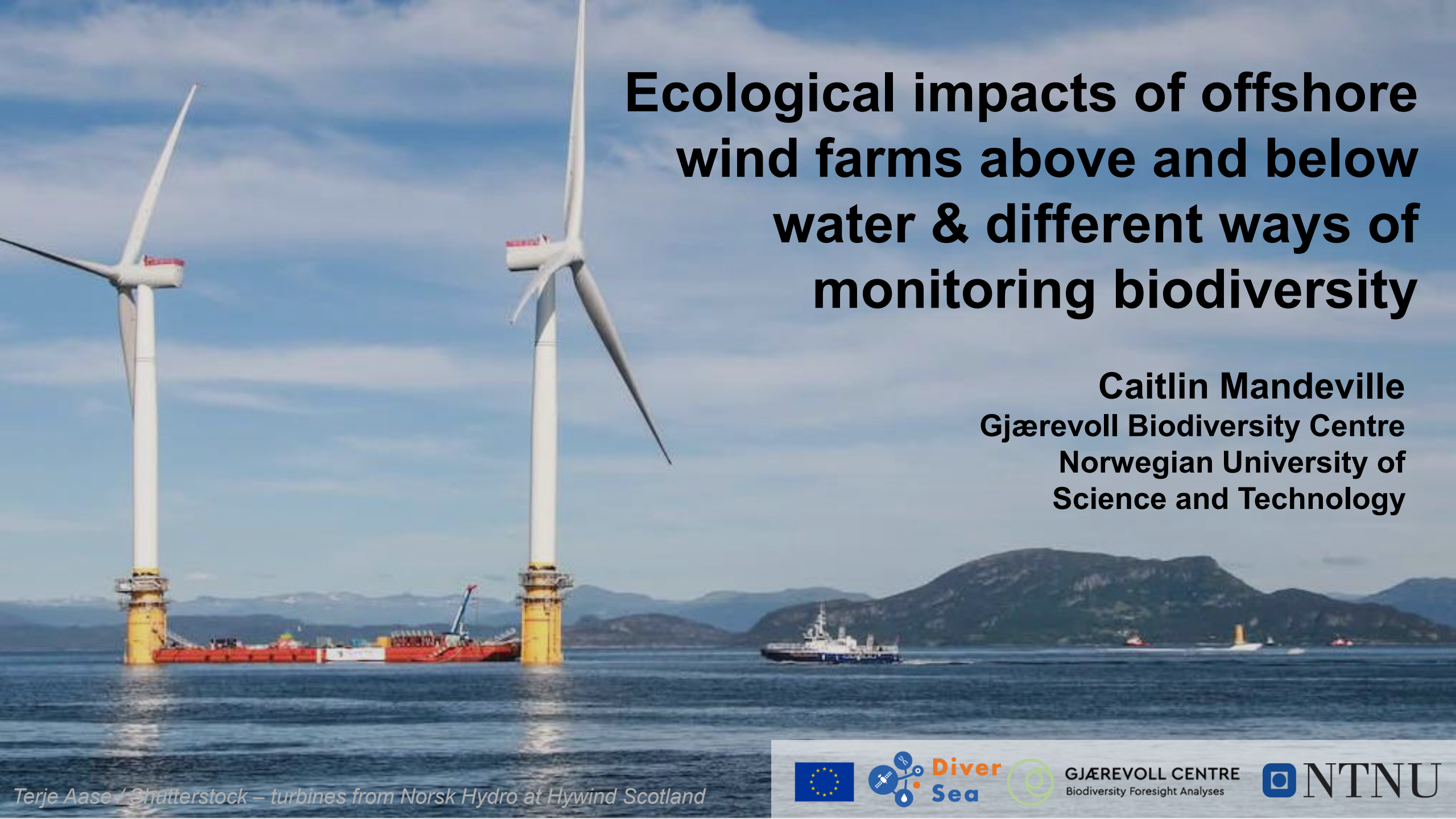
→ What does the offshore wind community know that biodiversity researchers should know too?



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