DTO-BioFlow
Integration of biodiversity monitoring data into the Digital Twin Ocean

EMBRC
EUROPEAN MARINE BIOLOGICAL RESOURCE CENTRE

SBDI
SWEDISH BIODIVERSITY DATA INFRASTRUCTURE

European Commission

UNIVERSITY OF GOTHENBURG

Digital Twin applications for dynamic assessments of marine biodiversity

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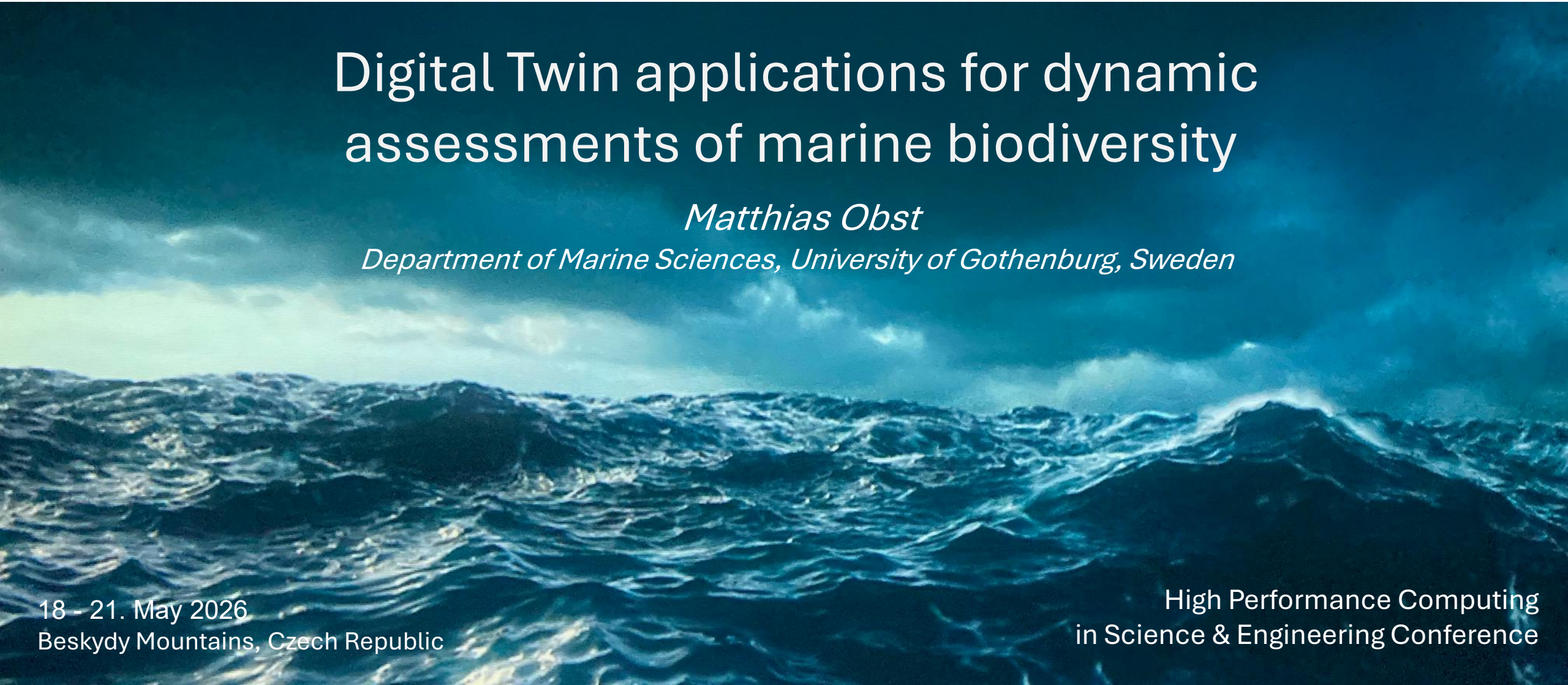


18 - 21. May 2026
Beskydy Mountains, Czech Republic

High Performance Computing
in Science & Engineering Conference

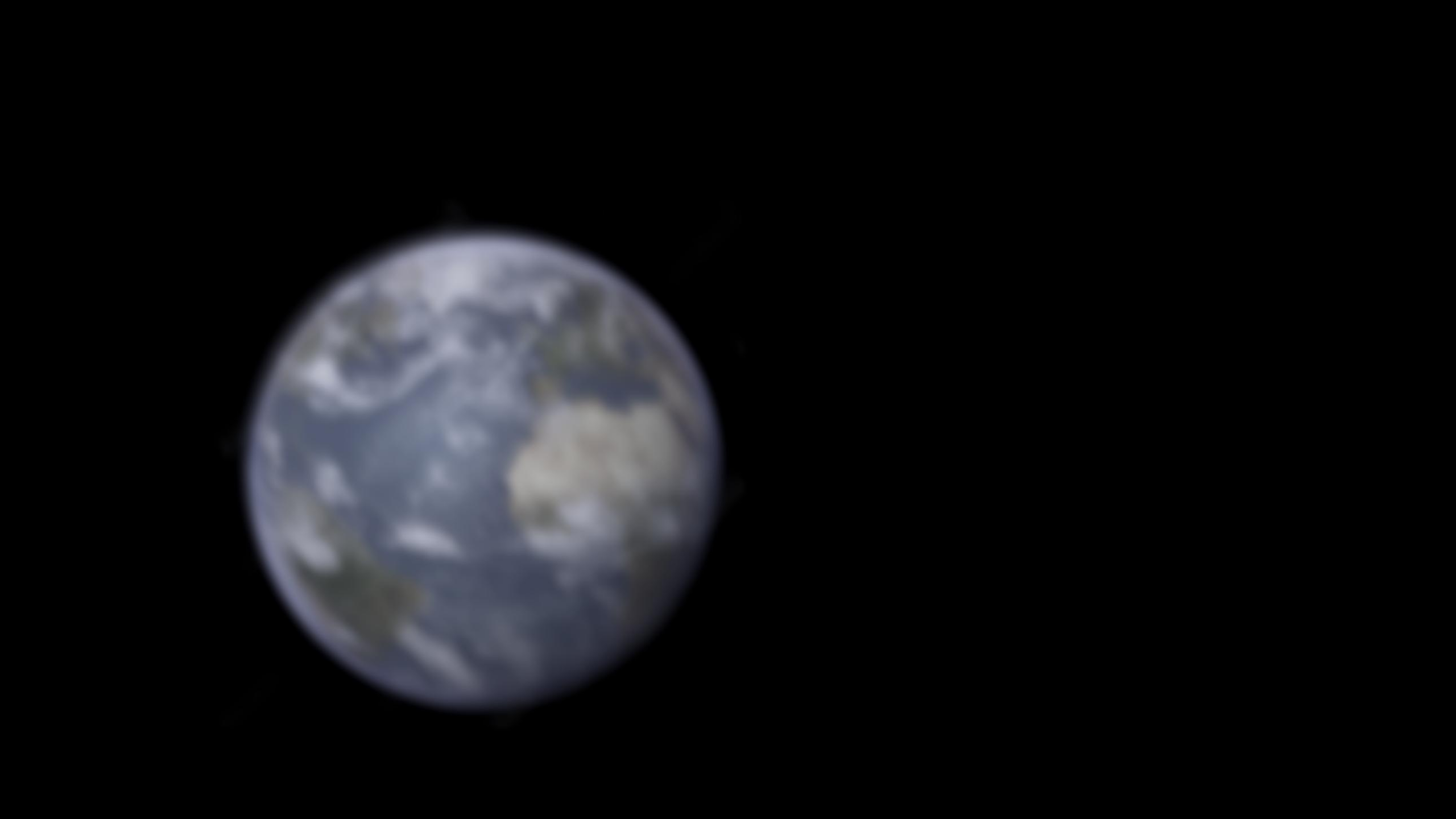
The “sea pig” (Scotoplanes sp.) belongs to the marine group of sea cucumbers and lives at 3,000 - 5,000 meters depth.

Overview

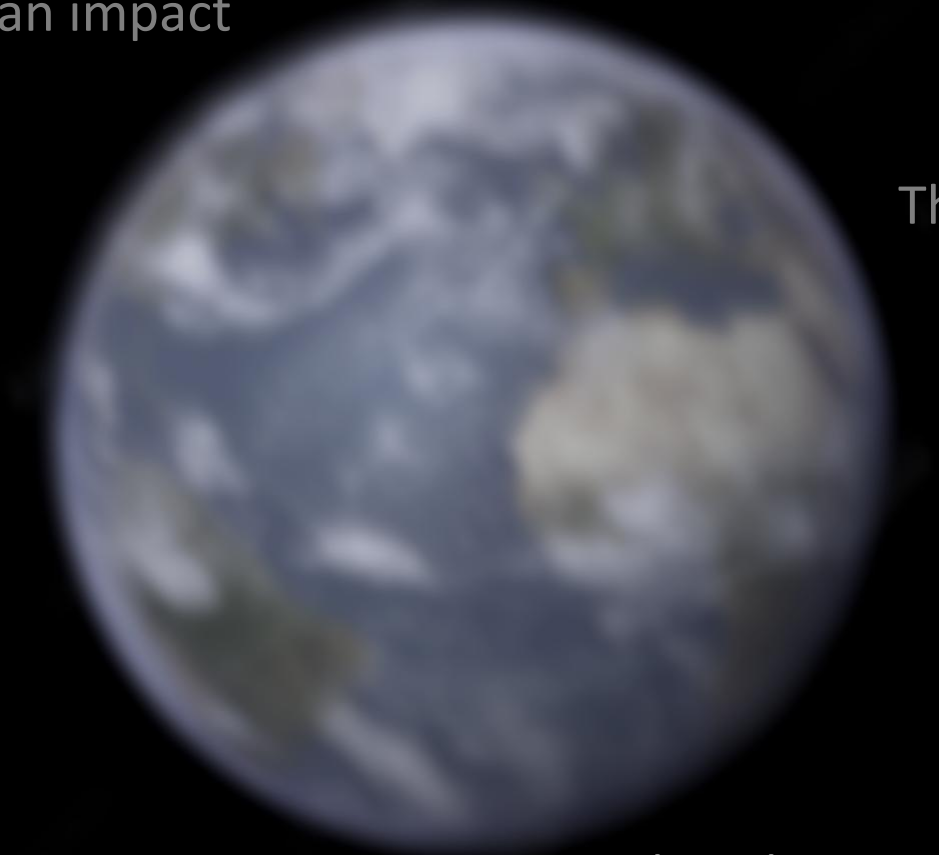
- On marine biodiversity
  - What is biological diversity
  - What is the problem with it
  - How to solve it
- Digital Twin of the Ocean (DTO)
  - Concept
  - Implementation
- Examples of DTO applications
  - Computer vision
  - “Biological weather forecasts”
- Conclusions

Their unending gaze helps us monitor the health of our world...

Taken by: Deep Space Climate Observatory (DSCOVR), on March 9, 2016



- Today there are 242,500 species registered in the World Registry of Marine Species (WoRMS)
- Experts estimate, only 10–25% of all marine species have been described…
- …and only <10% of the ocean has been explored
- IPBES estimates that 30% of mammals and corals are threatened and >66% of the ocean is under human impact



There are 3 basic levels of biological organisation

- Genetic diversity
- Species diversity
- Ecosystem diversity

- As most biodiversity can not be observed from space …
- We need to build a ”giant biodiversity telescope” from distributed in-situ sensor networks

Habitat destruction

Trawled seabed in Sweden with coral rubble

untrawled sea bed

trawled sea bed

Habitat destruction

Damage of habitat building species (eelgrass) by leisure boats.
Photo: The Pacific Salmon Foundation

Overfishing

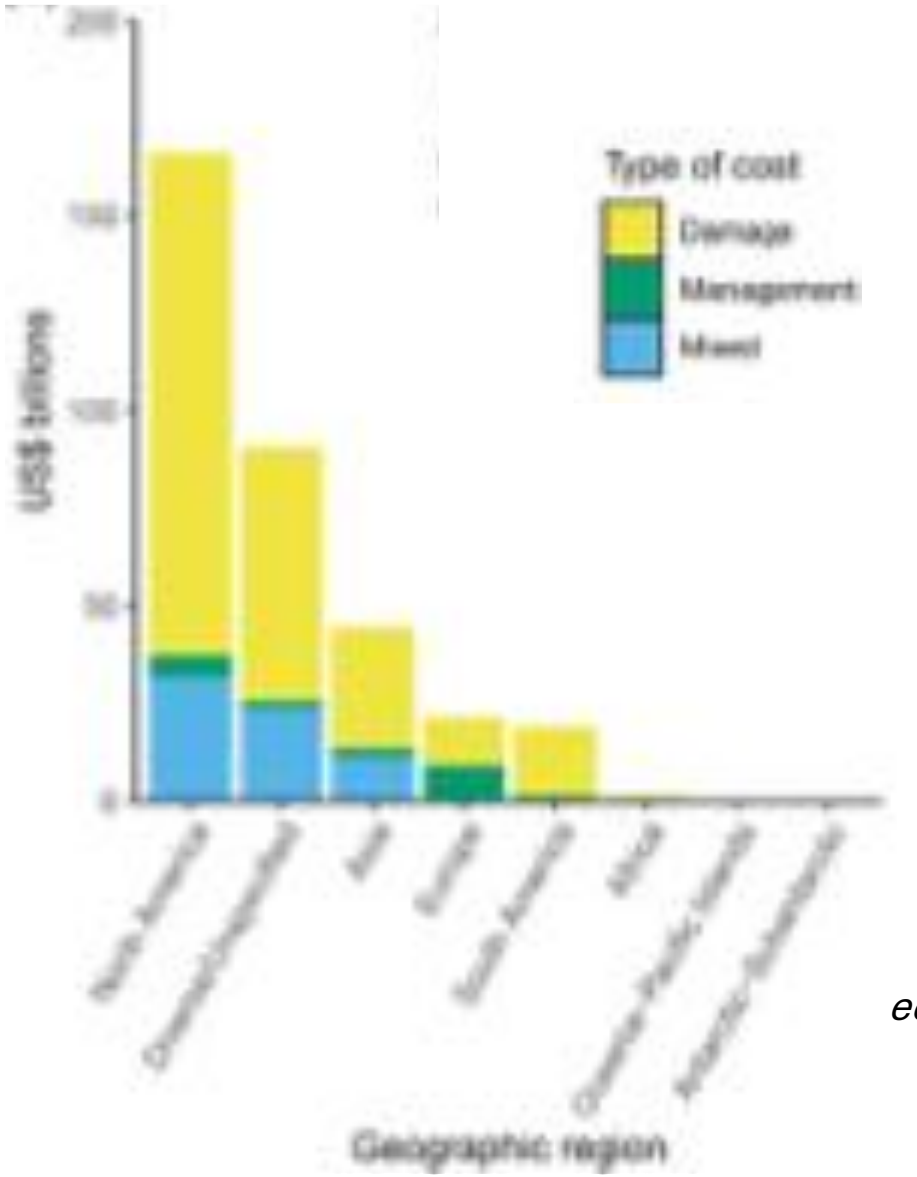
Bluefin tuna (*Thunnus thynnus*) caught in Denmark 1946 (MacKenzie & Myers 2007)

Climate change

Cumulative effects from climate change and epidemic pressure. *Middle European forests are affected by drought driven outbreaks of bark beetles. Hlásny et al (2021) Forest Ecology and Management. Photo: www.vulhm.cz.*

Cumulative effects from climate change and epidemic pressure. *Kelp forests are collapsing from a combination of abnormally warm water and epidemic outbreaks. Photo: Oregon Marine Reserves.*

Invasive alien species



Cuthbert et al (2021) Global economic costs of aquatic invasive alien species

European green crab (*Carcinus maenas*), also called "cockroaches of the sea" eat juvenile salmon and king crab, threatening multi-billion dollar fisheries. Photo: Amanda Beland

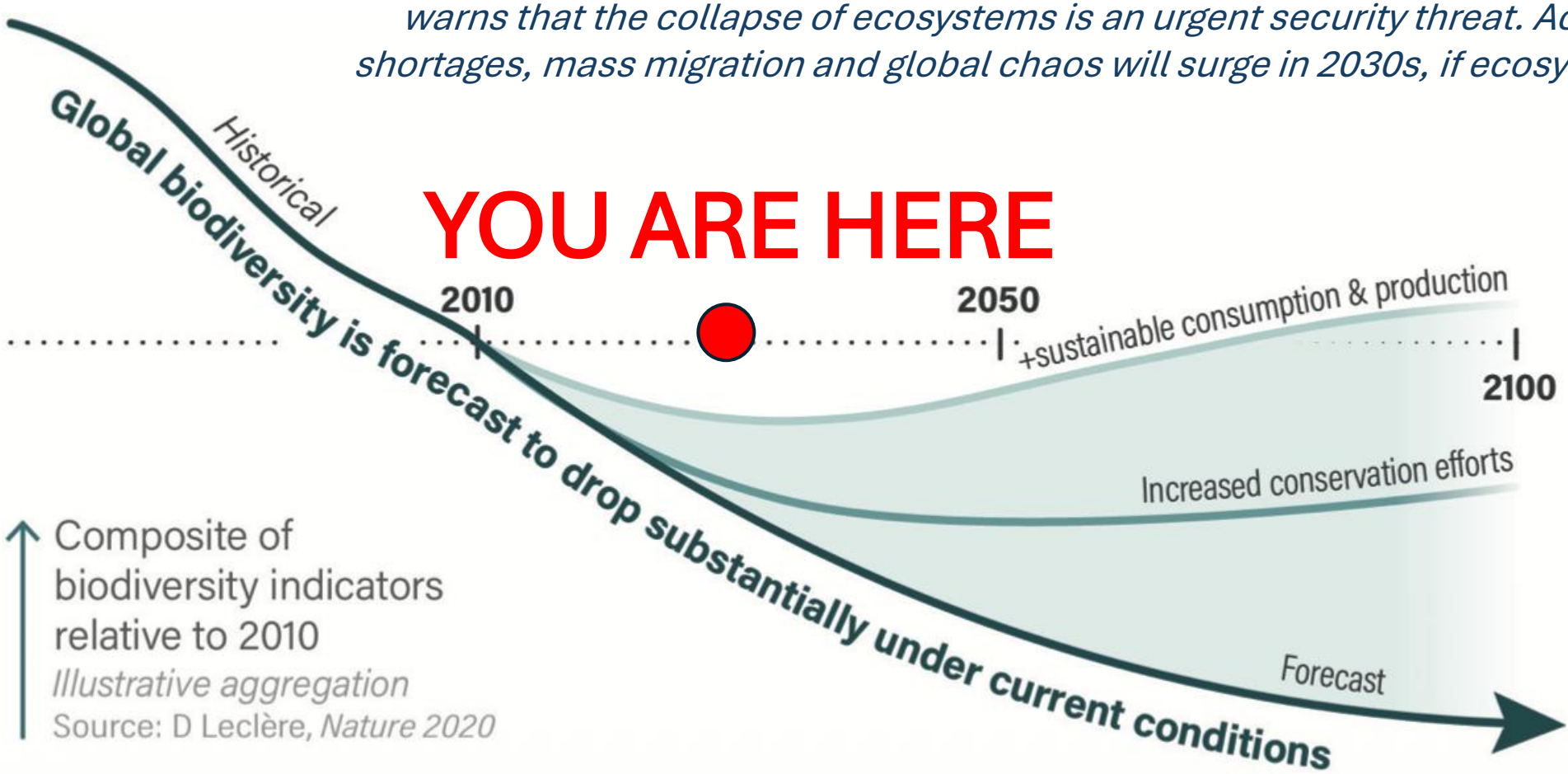
Preventing the collapse of ecosystems

HM Government

Global biodiversity loss, ecosystem collapse and national security

A national security assessment

*A recent reported issued by the **British Joint Intelligence Committee** (overseeing MI5 & MI6) warns that the collapse of ecosystems is an urgent security threat. According to the report, food shortages, mass migration and global chaos will surge in 2030s, if ecosystems continue to decline.*



Source: www.gov.uk

Towards is nature positivity

Nature positivity **means enhancing and restoring the natural environment** while securing the supply of food, medicine, and raw materials

It is about **leaving nature in a better condition than we found it.**

That means that nature restoration has become **our most important science and engineering task**

The concept of the Digital Twin of the Ocean

What’s a Digital Twin

- Digital twins are **virtual representations** of physical objects or systems
- They are **used for modelling and design** purposes. These virtual models are used to digitally represent performance, identify inefficiencies, and design solutions to improve their physical counterparts.

What’s new about Digital Twins

- Digital twin vs. simulation. Digital twins ”model specific real-world assets”. In contrast to simulations, which operate in entirely virtual environments the **Digital twins are outfitted with sensors** that continuously update their virtual counterparts in real time with high-quality data.
- **New assets** include the Internet of Things (IoT), Artificial Intelligence (AI), Virtual Reality (VR), Extended Reality (ER), and Cloud computing

Digital Twin concept

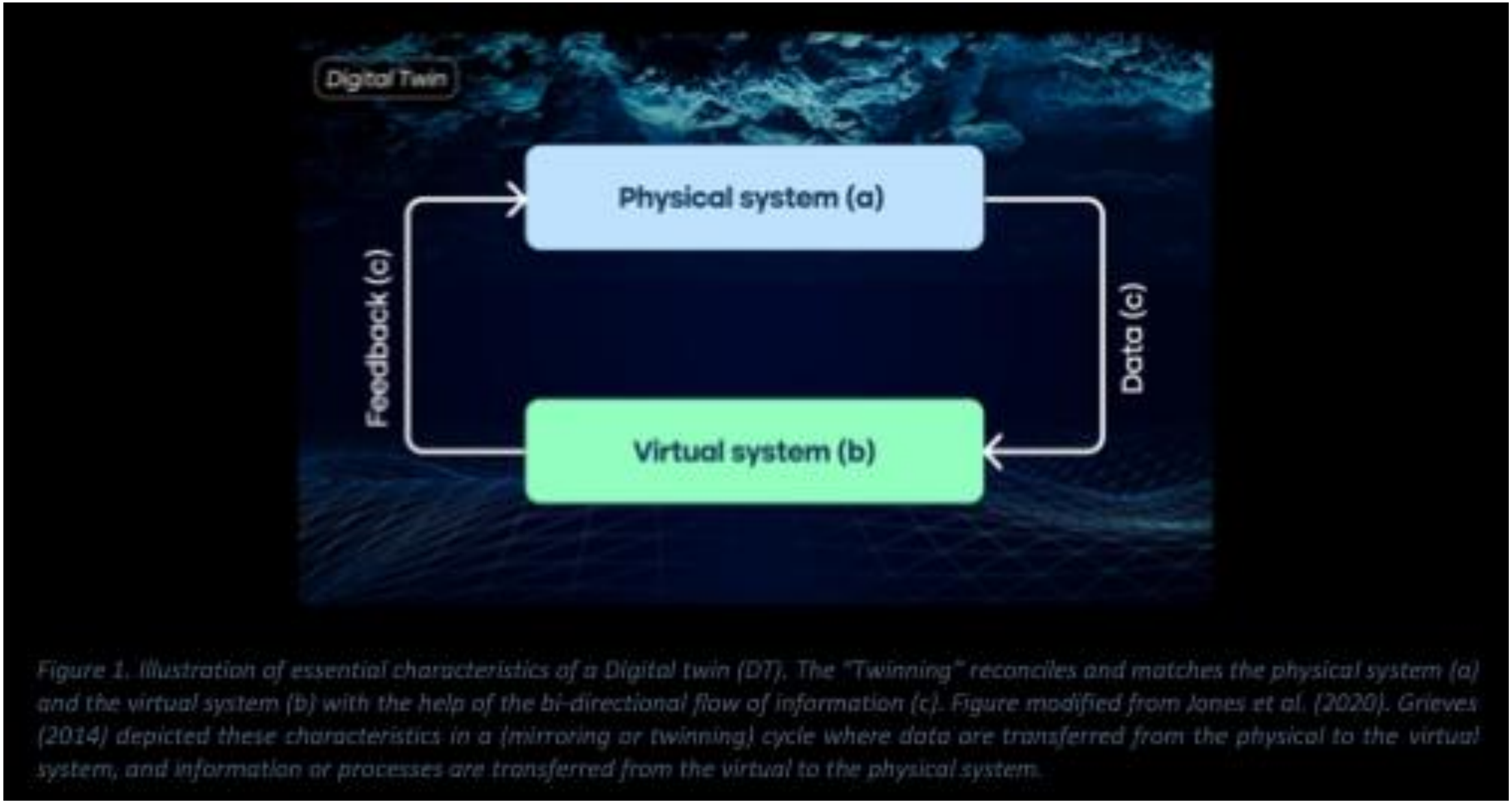
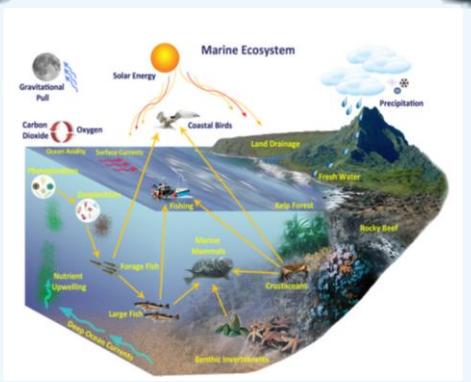


Figure 1. Illustration of essential characteristics of a Digital twin (DT). The "Twinning" reconciles and matches the physical system (a) and the virtual system (b) with the help of the bi-directional flow of information (c). Figure modified from Jones et al. (2020). Grieves (2014) depicted these characteristics in a (mirroring or twinning) cycle where data are transferred from the physical to the virtual system, and information or processes are transferred from the virtual to the physical system.

Stakeholders

System engineering

(e.g., decision, action, optimisation, intervention, engineering)



DTO-WP2

Observation & data collection

(e.g., sensors, monitoring)

Physical system

DTO-WP4

Virtual experiments

(e.g., modelling, scientific analyses)

DTO-WP3

Data systems

(e.g., data management, publication, archiving)

DTO-WP5

Analysis system / eLabs

(workflows, tools)

Virtual system

European Digital Twin of the Ocean

A leap in ocean knowledge and sustainable action

EU MISSIONS RESTORE OUR OCEAN & WATERS

MERCATOR OCEAN INTERNATIONAL

VLIZ

SUBSIM

VSB TECHNICAL UNIVERSITY OF OSTRAVA | IT4INNOVATIONS NATIONAL SUPERCOMPUTING CENTER

LUMI AI Factory

Welcome to SUBSIM

- the Swedish national platform for analysis of subsea images

The quickly rising demand to monitor the ocean with autonomous techniques and computer vision methods led to the development of SUBSIM, a platform for efficient management and processing of underwater image and video data. SUBSIM provides essential functions to conduct research and automated monitoring using image and video data, including data management, machine learning, digital collaboration, citizen science, and high-performance computing.

www.subsim.se

Component name	Function	Description
Zooniverse (ZU) Biigle	Annotation	Online workbenches for experts and the public to annotate videos and images
Koster Seafloor Observatory (KSO)	AI/ML	Workspace for importing, training and testing computer vision models
Cloudina	Data management	Infrastructure for temporary data storage, authentication-authorisation (AAI), scaling operations, high performance computing (HPC), provenance, data federation, and interoperability with external systems
Integrated Publication Toolkit (IPT)	Publication of models and outputs	Individual script-based functions to publish models (e.g., on Zenodo) and species observations (e.g., on GBIF)

SUBSIM – at a glance

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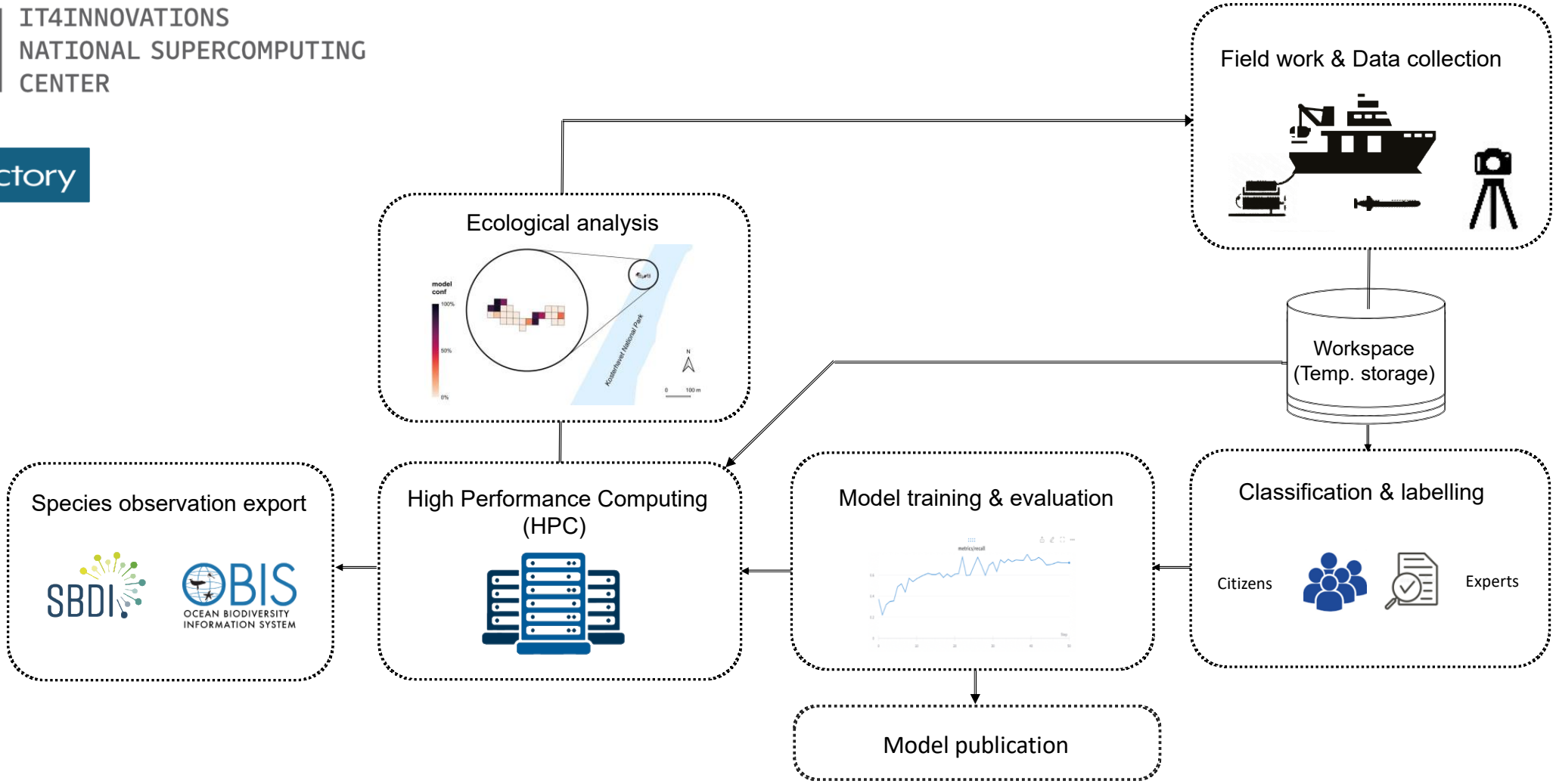
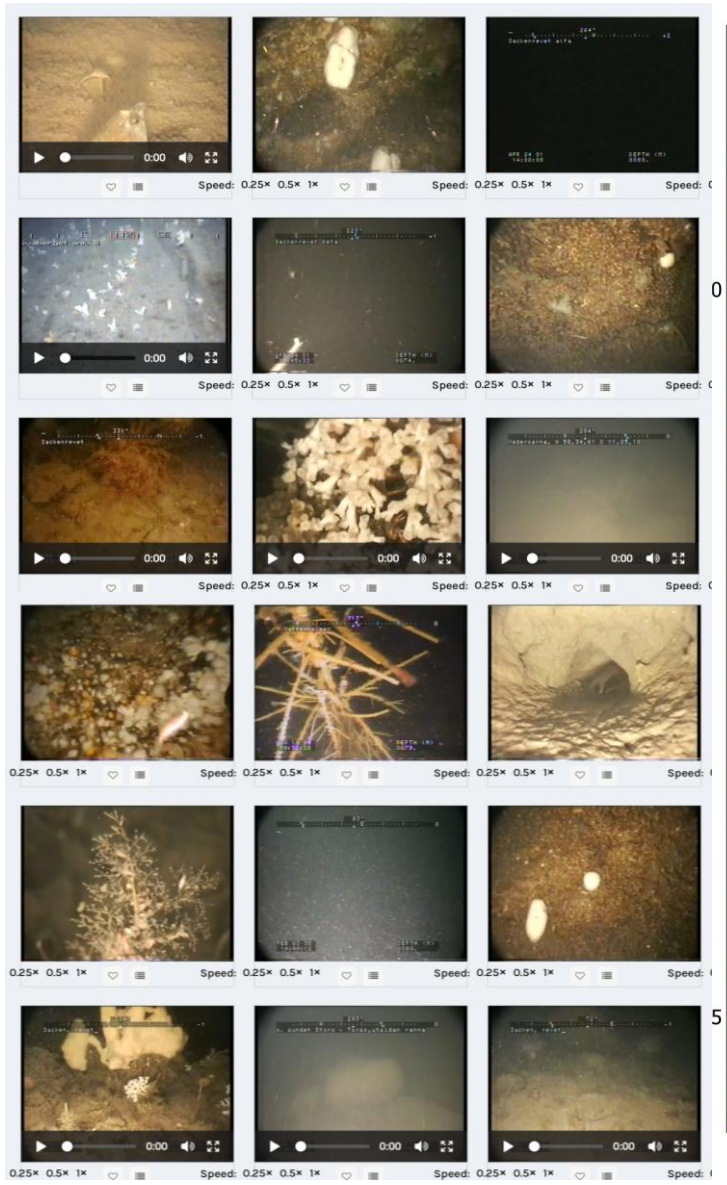
LUMI AI Factory

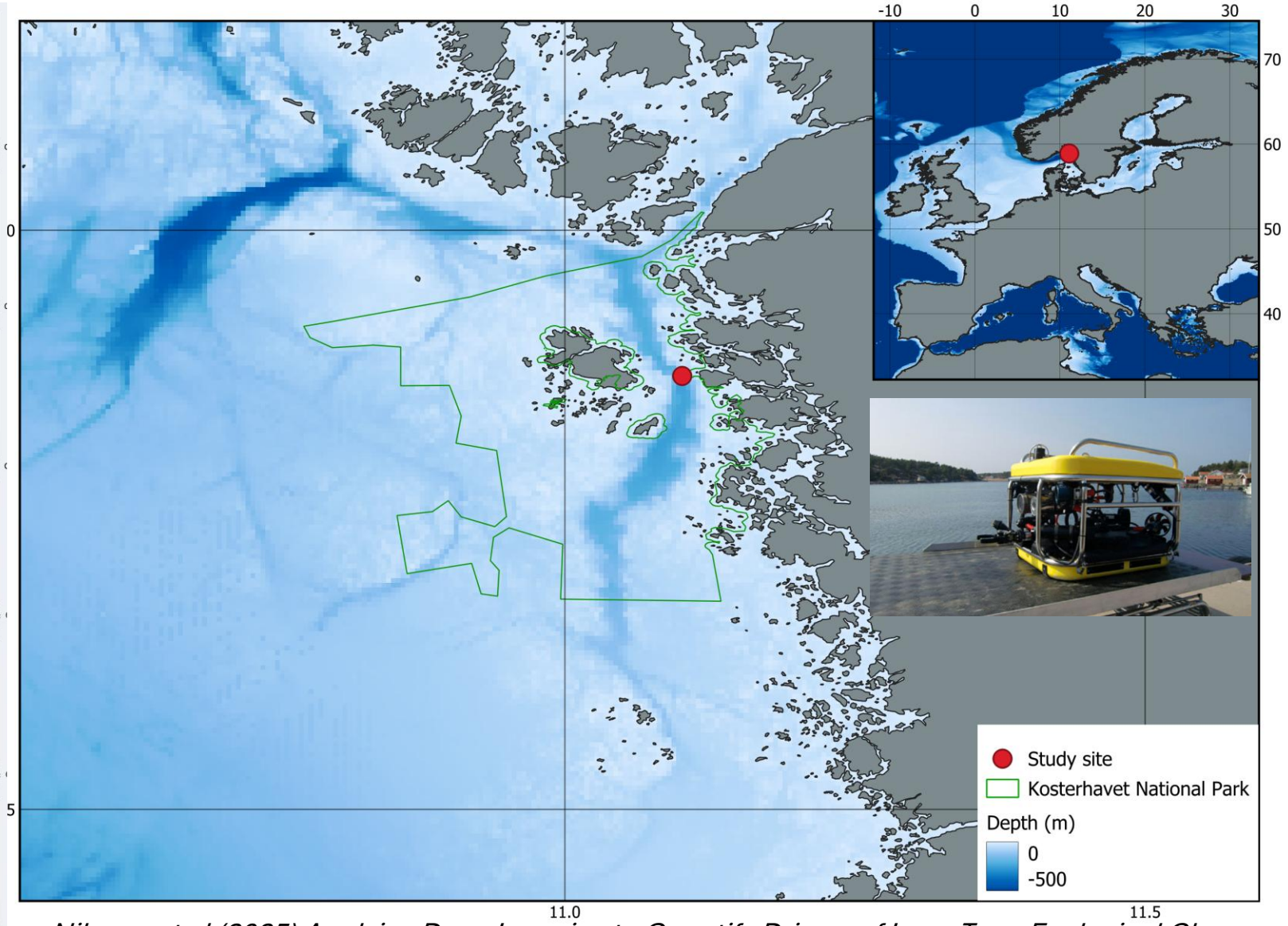
UNIVERSITY OF GOTHENBURG



Anton et al (2021) An open-source, citizen science and machine learning approach to analyse subsea movies. Biodiversity Data Journal

Sweden’s first marine National park





Nilsson et al (2025) Applying Deep Learning to Quantify Drivers of Long-Term Ecological Change in a Swedish Marine Protected Area. Ecol Evol

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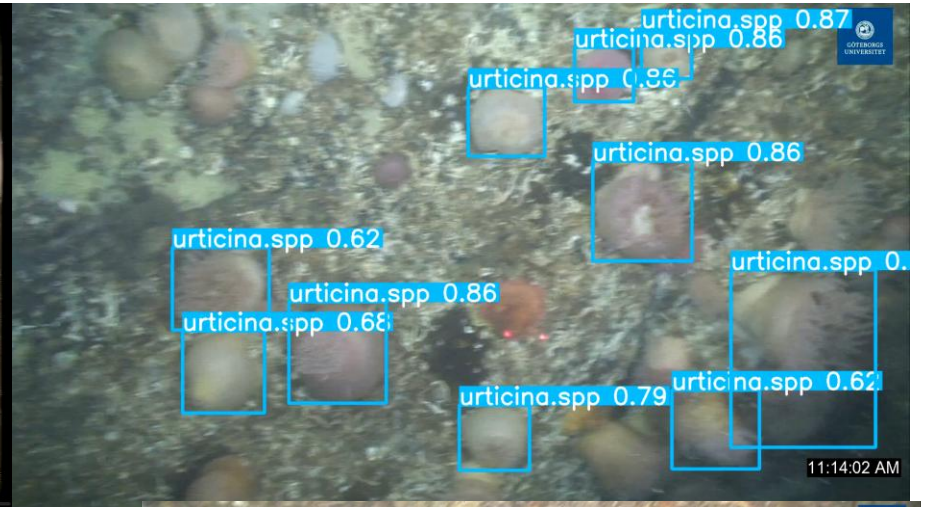
Model training and prediction

Old footage

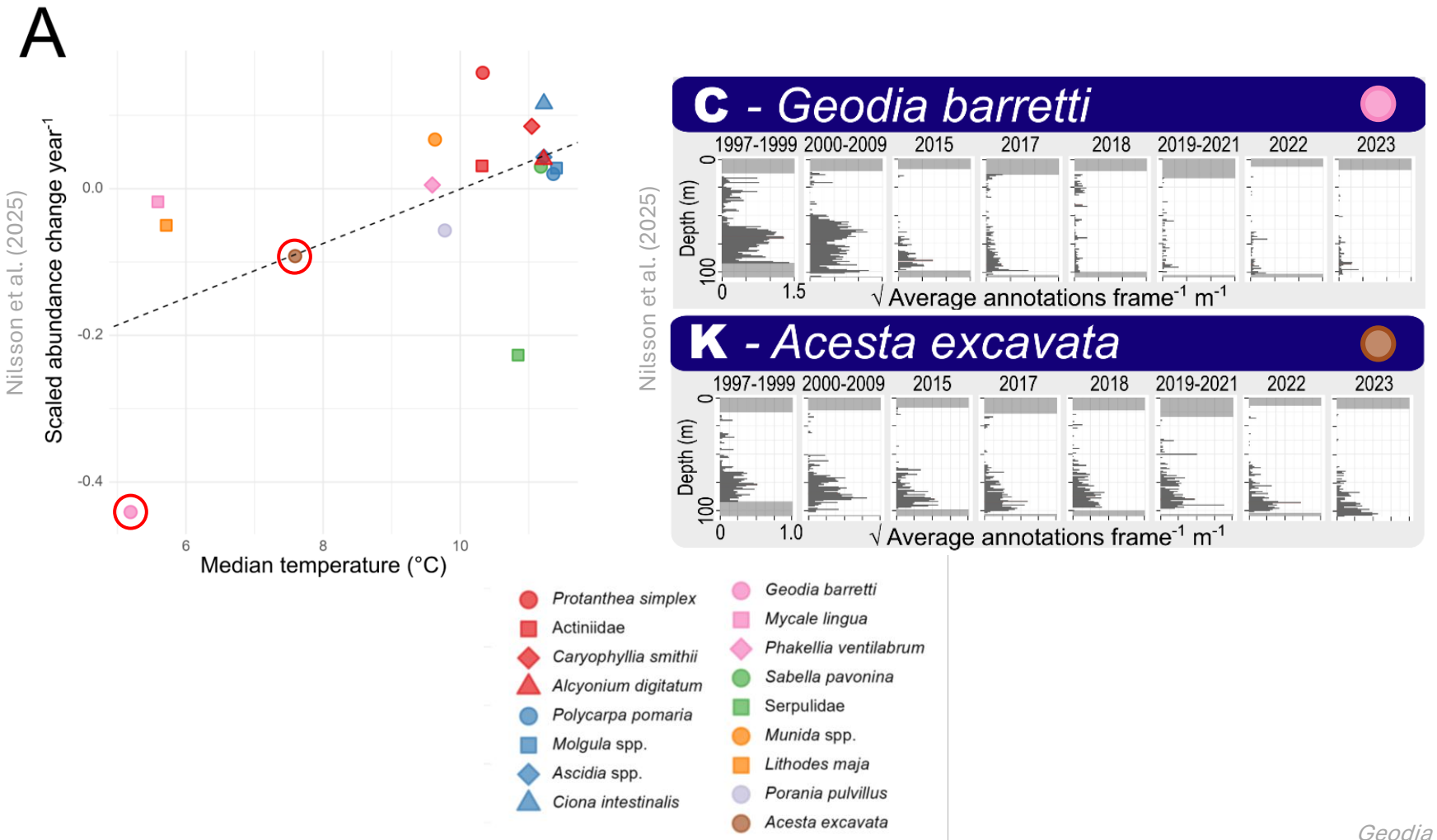


New footage

Shallow water

Rare classes

Cold-loving species decline



Nilsson et al. (2025)

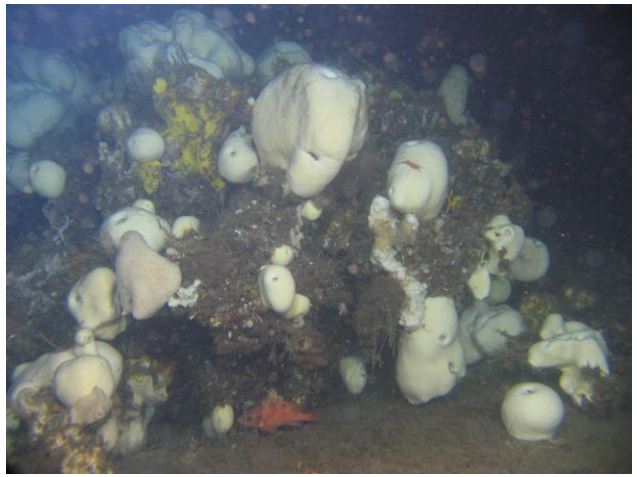
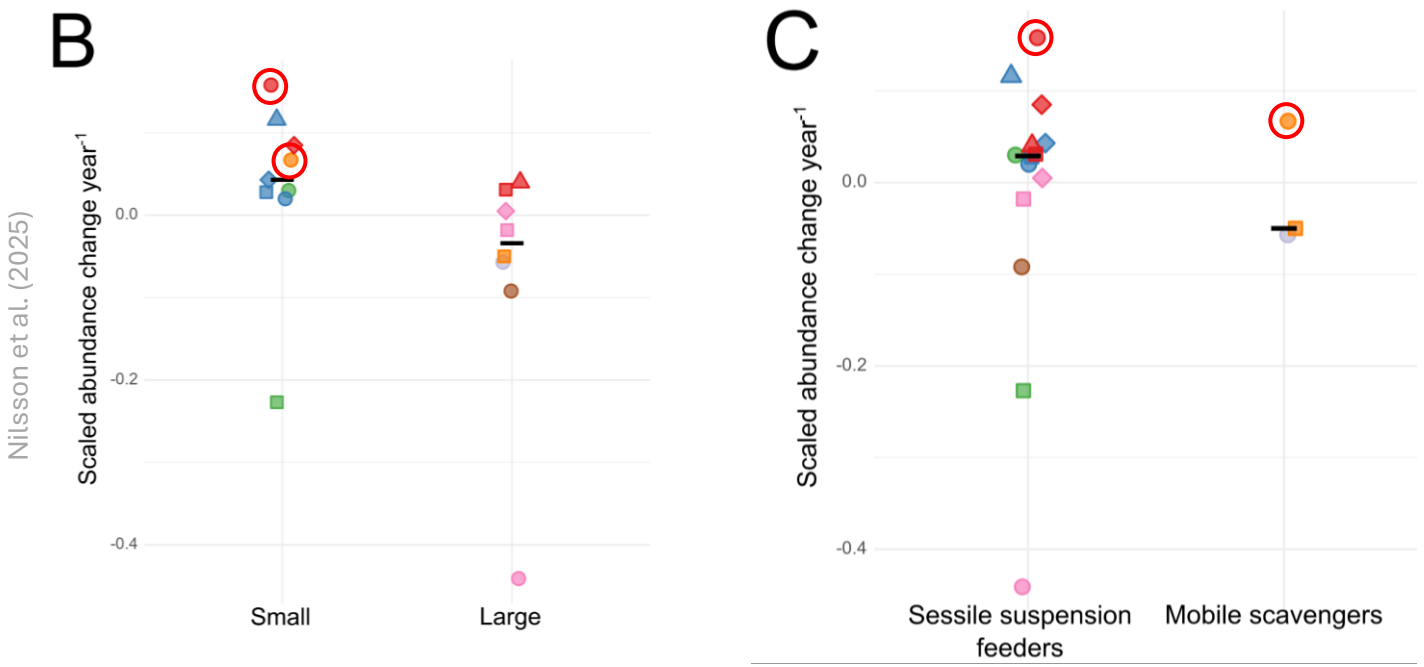


Photo: Vanderbilt University

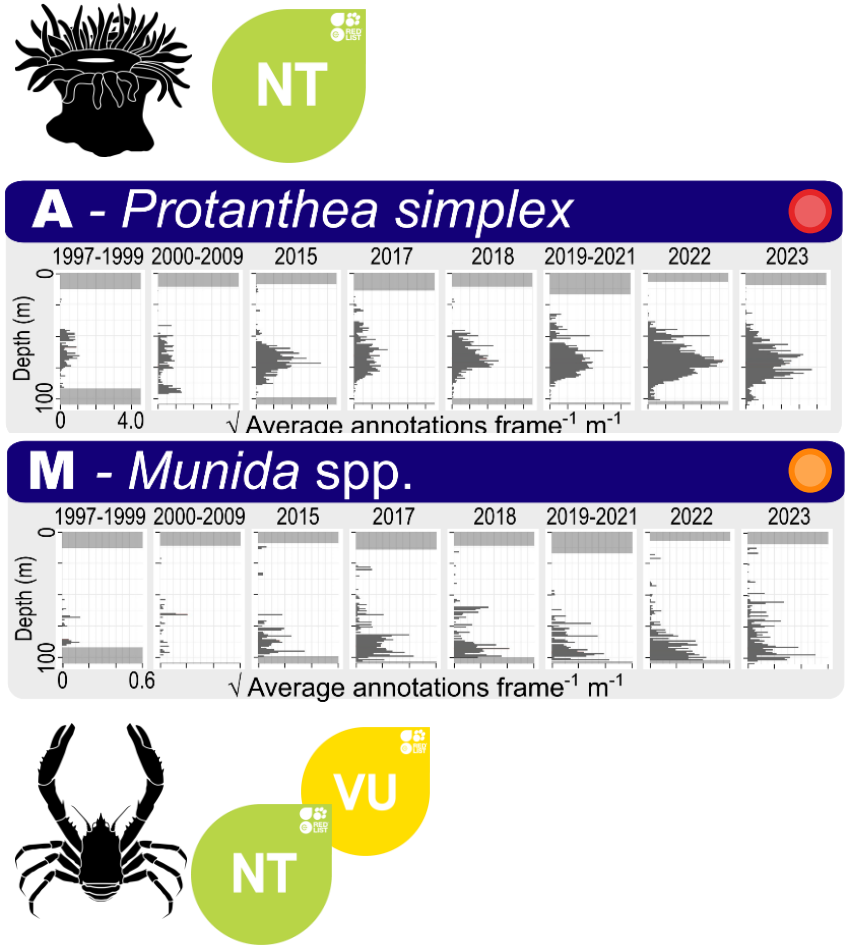
Photo: Westfal et al. (2010)

Geodia barrettil Acesta excavata temperature sensitivity sources – Guihen et al. (2012)/Scanes et al. (2024)

Recovery of trawl-sensitive species



Nilsson et al. (2025)

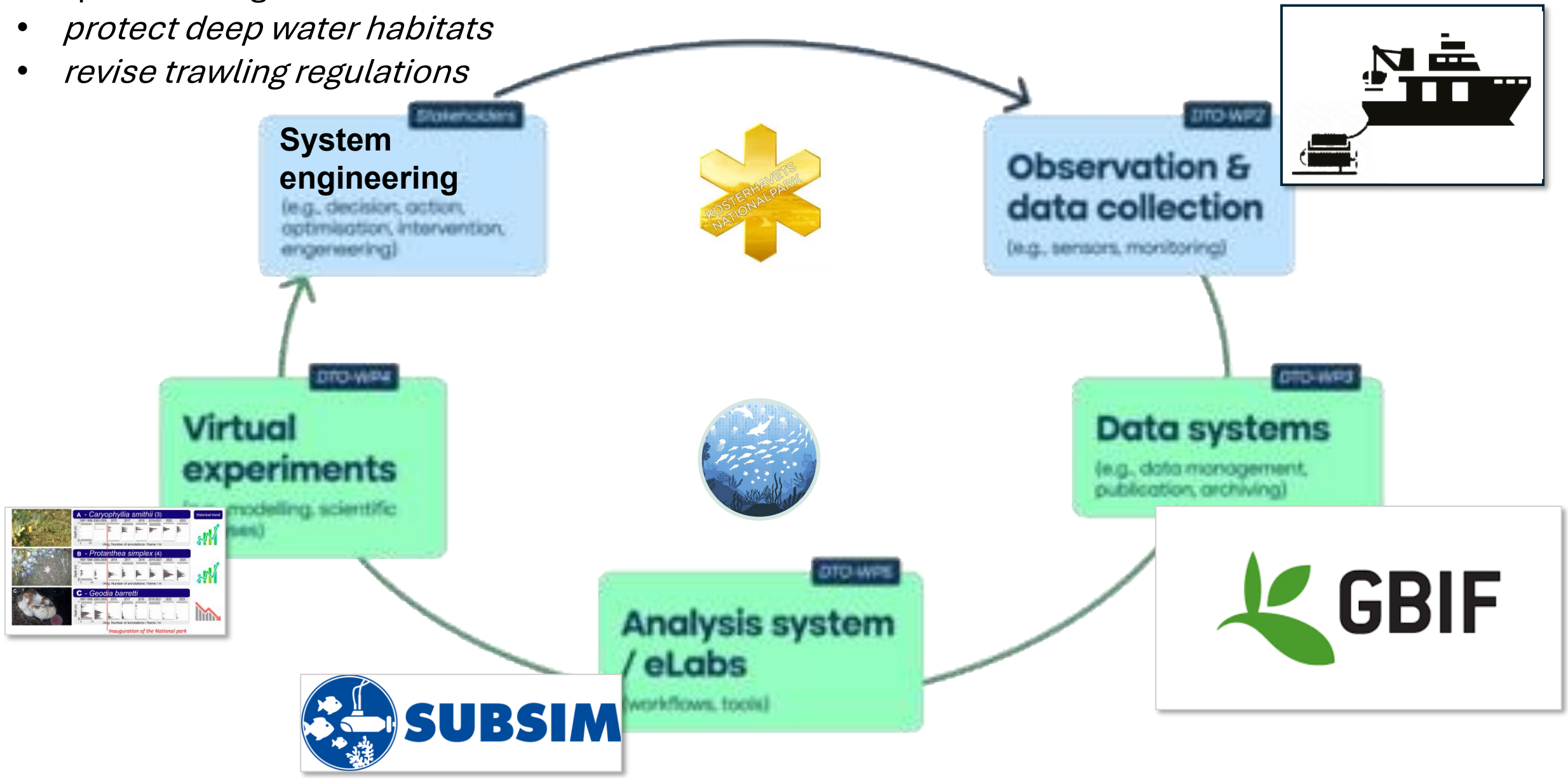


Nilsson et al. (2025)

Protanthea simplex & *Munida* spp. trawling sensitivity sources – Artdatabanken (Swedish species information portal, artfakta.se)

Adaptive management

- *protect deep water habitats*
- *revise trawling regulations*

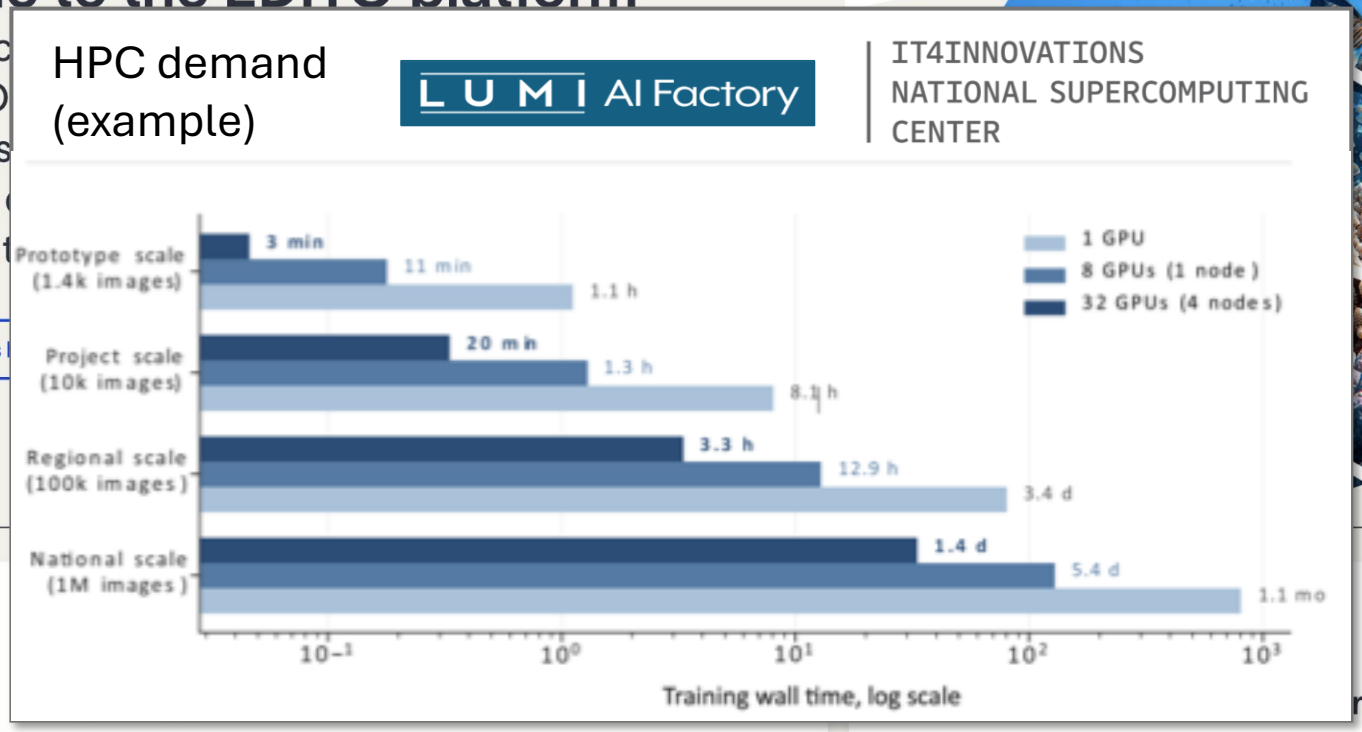


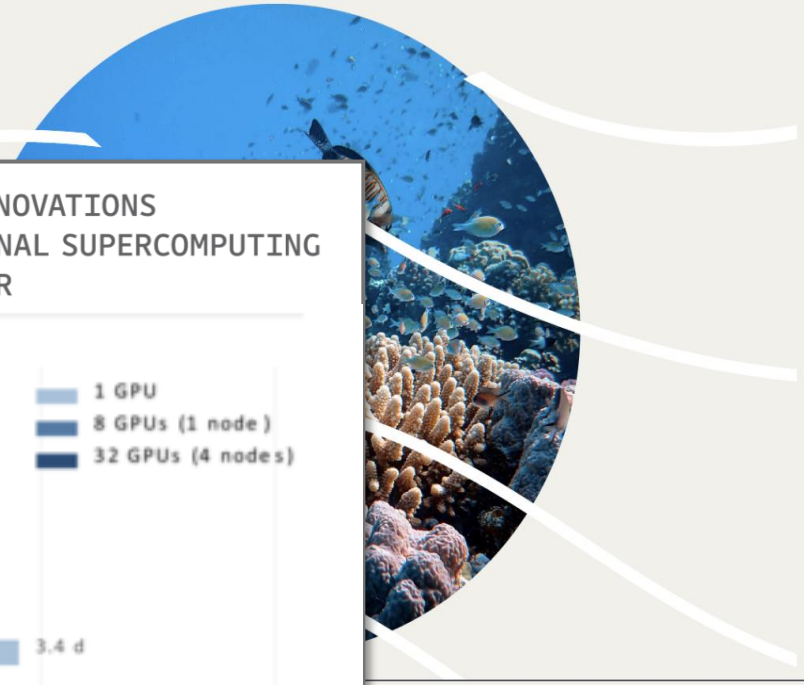
Reduce
Home
My account
Project settings
Service catalog
My Services
Process catalog
My processes
My Secrets
File Explorer
Data Explorer

Welcome to the EDITO platform

EDITO is the c
Digital Twin O
marine data, s
run your own
contribute to t

Access guidelines





nd processes

Tune and deploy your application to provide it as a service to your community. Analyze data interactively, benefit from a growing catalog of services, create your own tools, What-If applications and focus applications. Work with the languages and environments you prefer and reserve the resources you need.

Browse the service catalog

Execute and configure remote functions to compute scientific processes, such as data transformation, pre/post-processing, reanalysis, forecasts, detections, What-If scenarios, quality controls. Configure runtime inputs to generate data that have never been generated before within the data storage of your choice.

Browse the process catalog

Towards biological weather forecasts

Preventing invasive outbreaks with sensor-to-modelling systems

Preventing invasive outbreaks with sensor-to-modelling systems

Preventive actions

Biological weather forecasts

System engineering

(e.g., decision, action, optimisation, intervention, engineering)

Observation & data collection

(e.g., sensors, monitoring)

Virtual experiments

(e.g., modelling, scientific analyses)

Data systems

(e.g., data management, publication, archiving)

Analysis system / eLabs

(workflows, tools)

GBIF

EDITO

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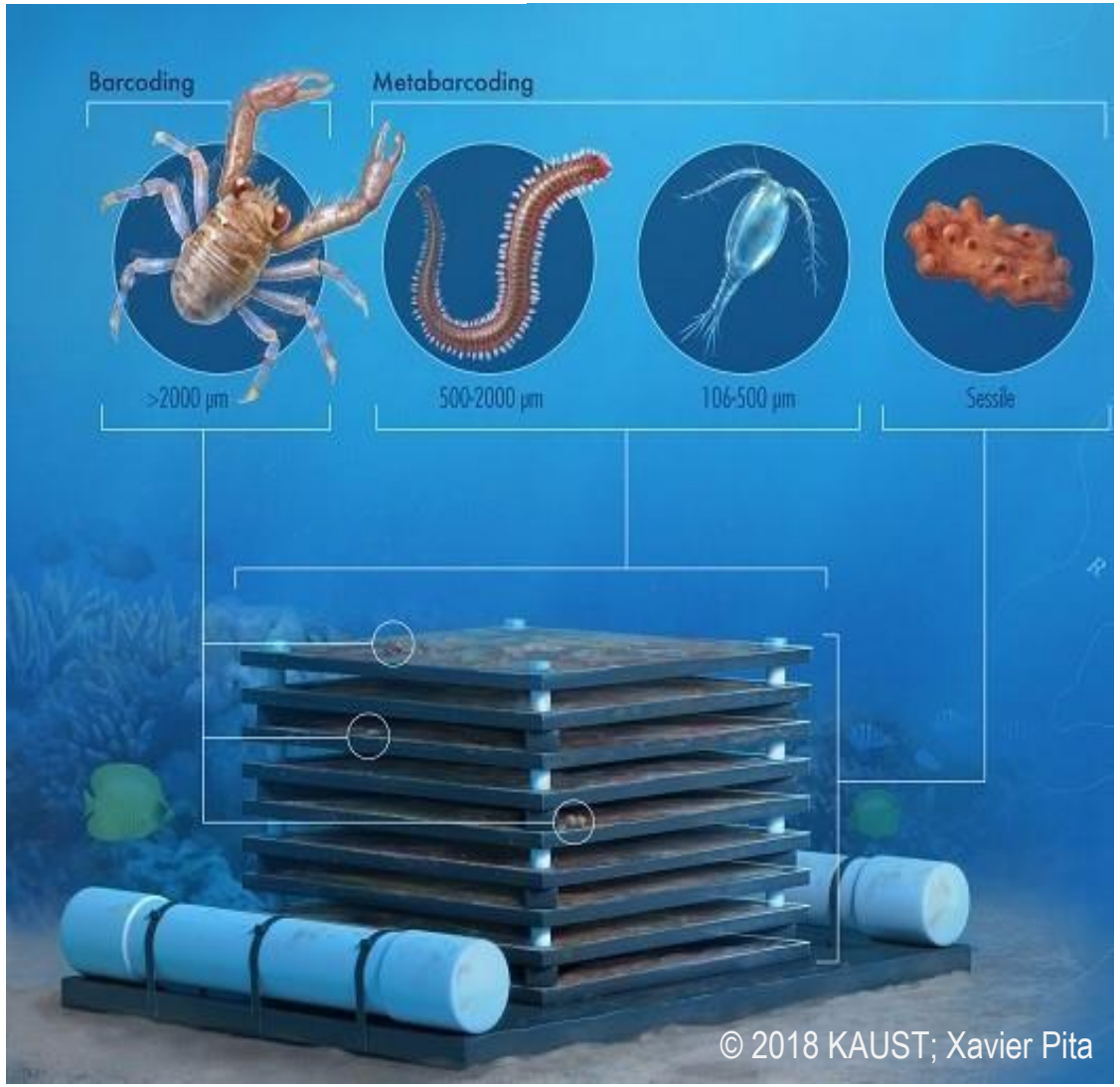
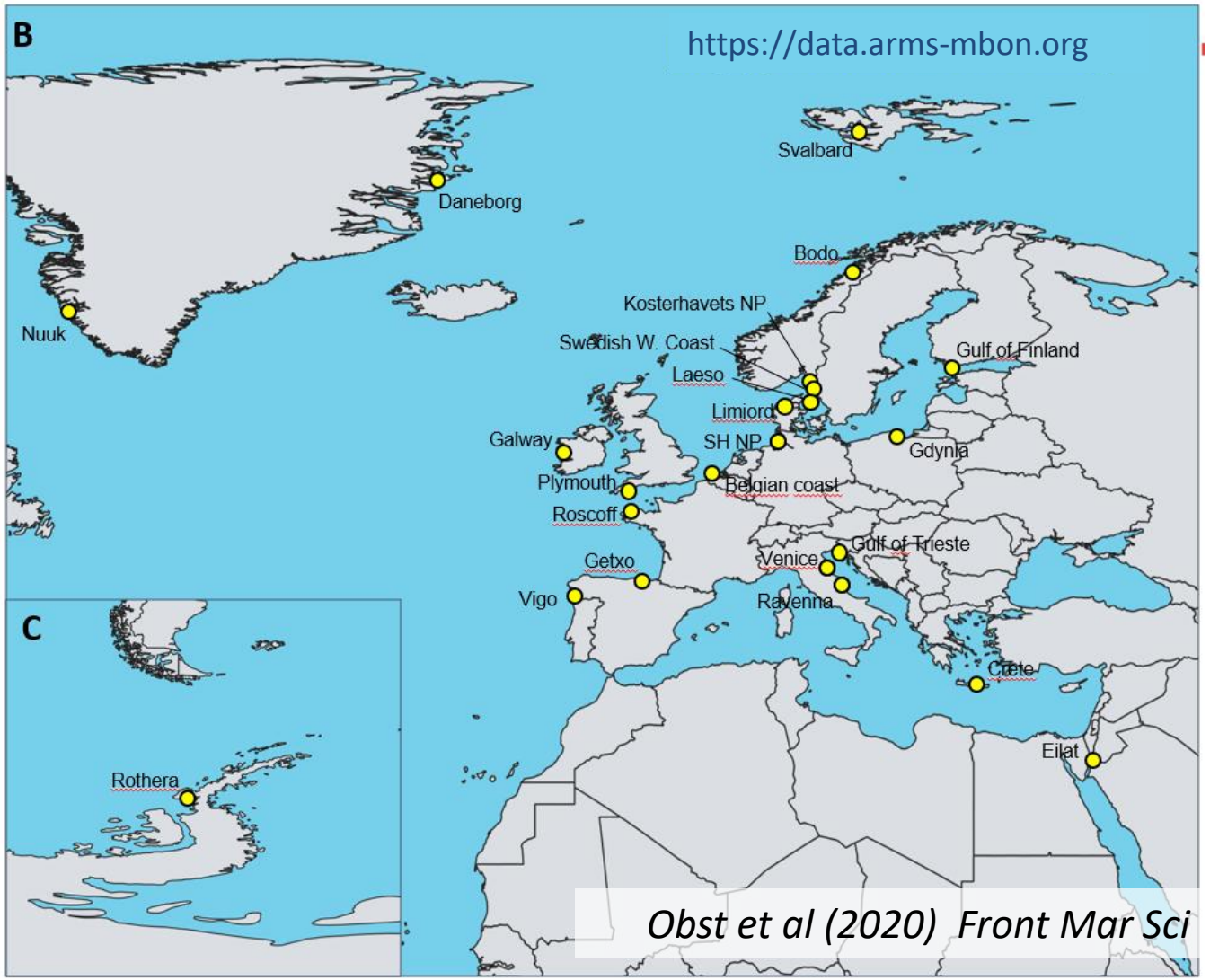
Genetic Sensor Network

EMOBON
EUROPEAN MARINE OMICS
BIODIVERSITY OBSERVATION NETWORK



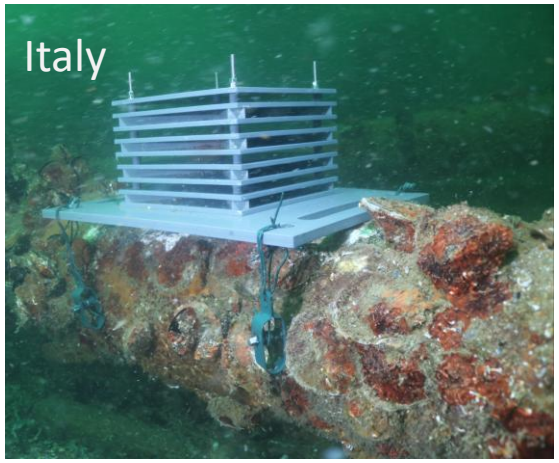



Slovenia

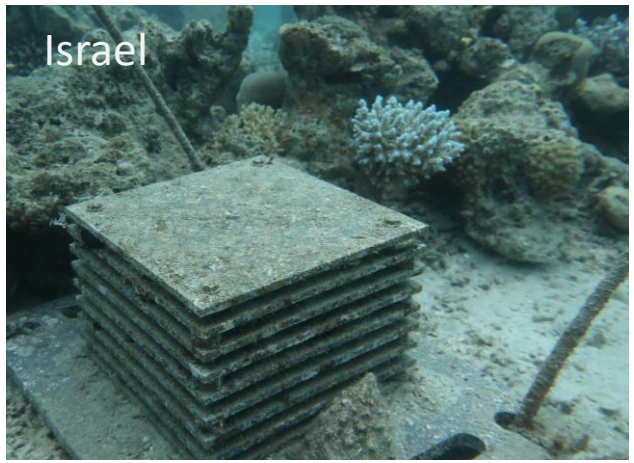

Denmark


Antarctica

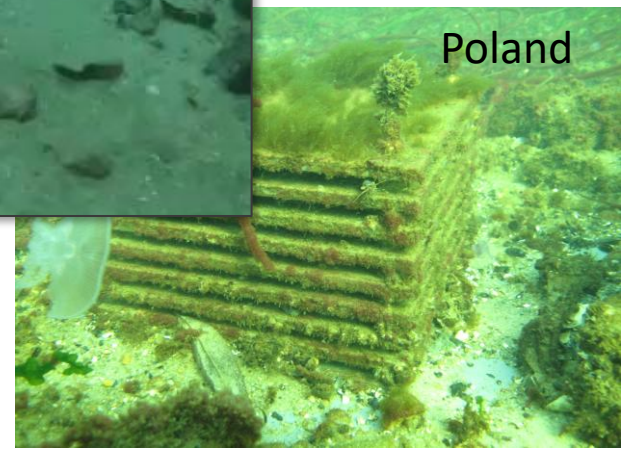

Sweden


Italy


Ireland


Israel


Finland


Poland

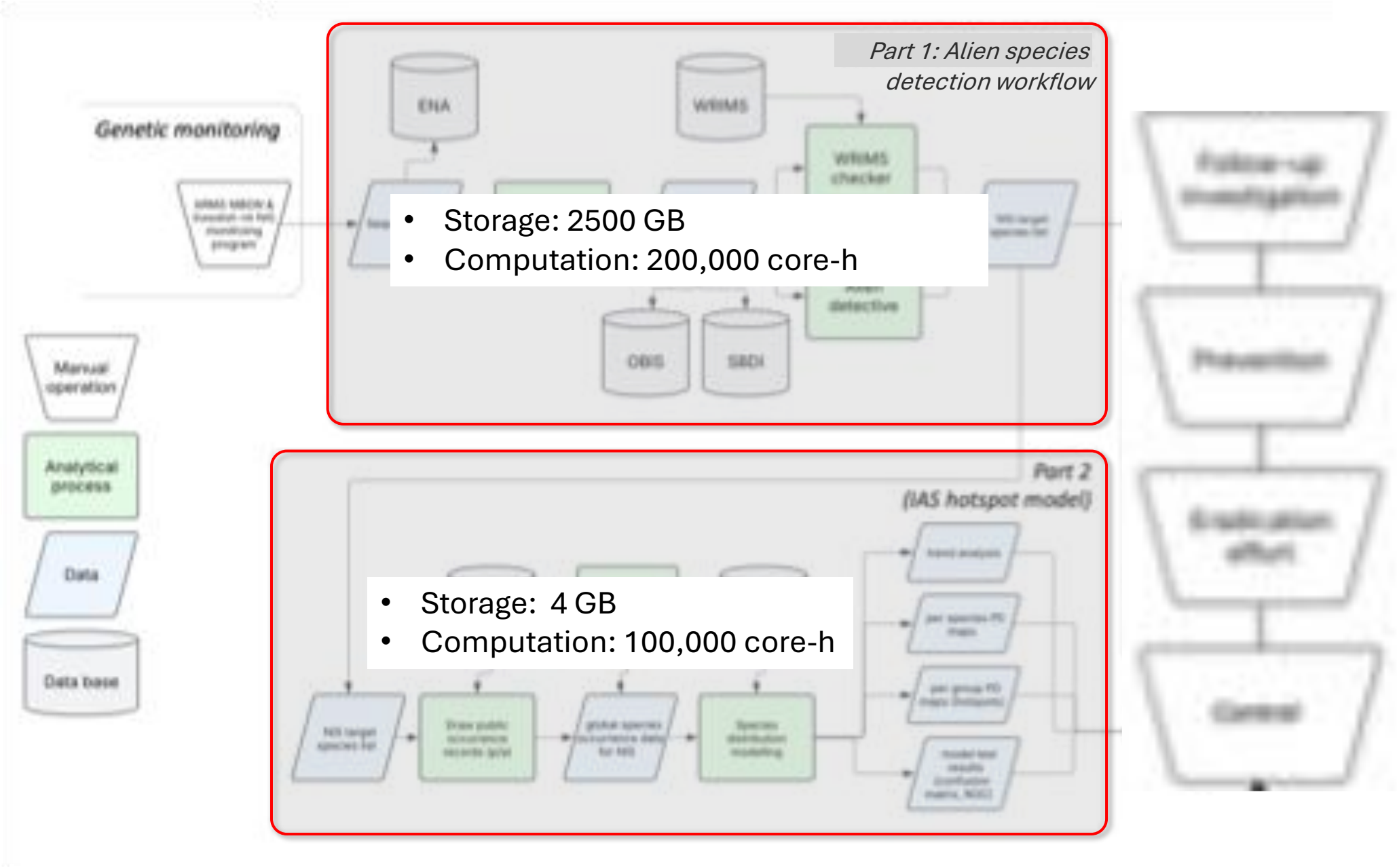


Figure 2. Genetic workflow and IAS hotspot model for DUC analysis.

Biological weather forecasts

Pseudocalanus acuspes (Copepoda). Foto: Rob Young

Suitable habitat as predicted by species distribution models (SDMs)...

...in current climate

914

0

...in future climate scenario (SSP585 for 2100)

783

16

Predicted change

Loss

Stable unsuitable

Gain

Stable suitable

From Pagnier et al (2026)
https://doi.org/10.21203/rs.3.rs-8702791/v1

Offshore Wind Parks (EMODnet, 2023)

Marine Protected Areas (WDPA, 2023)

Summed habitat suitability (70 species)

45,005

567

0 250 500 km

Cargo ship releasing ballast water. Photo: International registries

Summing up

What is new with the DTO

- linking the value chain connecting “sensors-data-modelling-decisions”
- accelerating the analysis of ecosystem response to human activities (good or bad) and thereby optimise ecosystem health

Why is digital science and engineering so important

- digital infrastructures help us to organise a highly fragmented research landscape and facilitate complex sensor-to-modelling approaches
- an important component of digital infrastructure is the human element
- We need digital science and engineering capacity to build the “giant biodiversity telescope”

Thank you for your attention…

- *…and special thanks to the guardians of marine life*
- *…the computer vision group*
- *the environmental DNA (eDNA) and modelling group*
- *EDITO and DTO-bioflow team*


Radek Halfar (IT4I)


Victor Anton (Wildlife.ai)


Louis Fiorina (UGOT)


Ghaith Chaabane (IT4I)


Tomáš Martinovič (IT4I)


Tuomas Rossi (CSC)


Emil Burman (UGOT)


Kalindi Fonda (Wildlife.ai)


Justine Pagnier (UGOT)


Sofia Björk (UGOT)

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The conference programme has been published on the conference website and is available
at: https://hpcse.it4i.cz/HPCSE26/program.php#preprogram.

Please note that invited talks are allocated 45 minutes, including Q&A.

Presentation files should be submitted to the hpcse@it4i.cz by Friday, May 15.