BLUE
NATURE-BASED
**SOLUTIONS**
WEEK

05-08 November 2024
UNESCO, Paris

# MaCoBioS

## Marine Coastal Ecosystems Biodiversity and Services in a Changing World

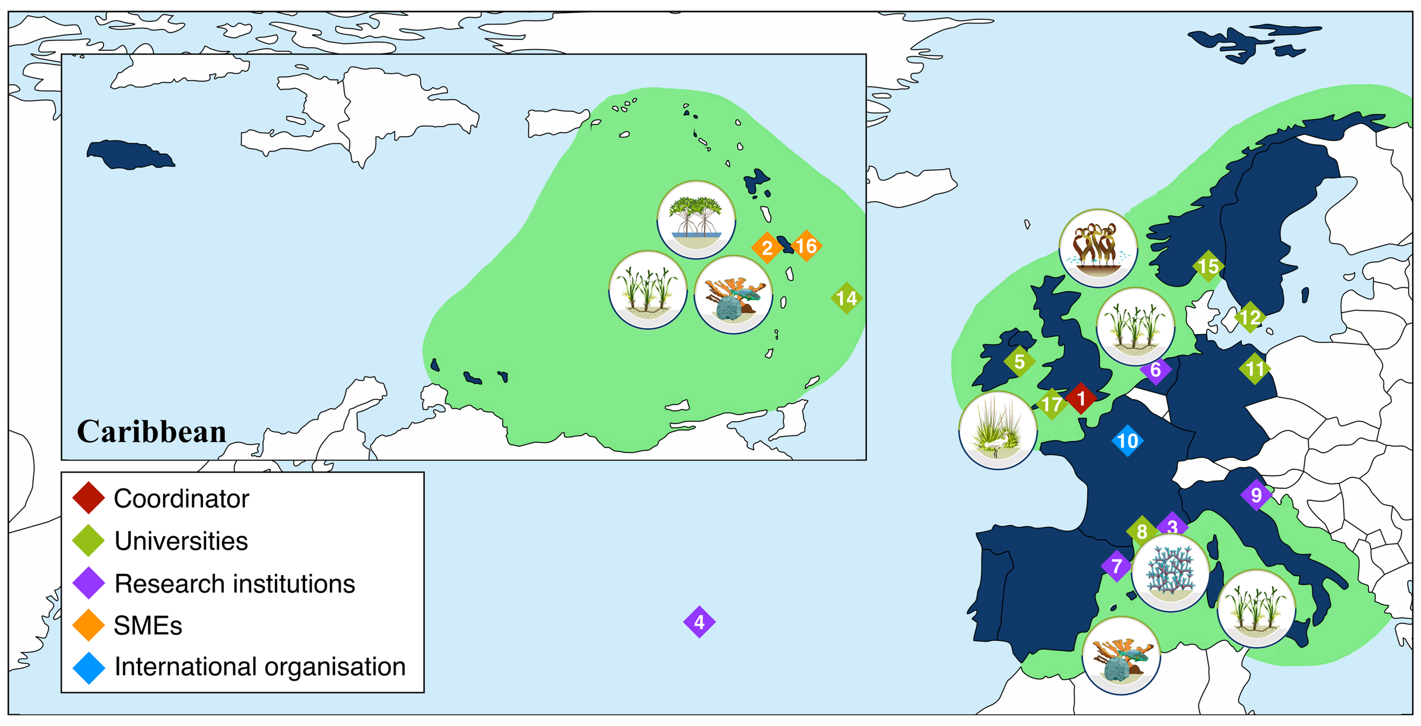
**Ensuring effective and integrated management and conservation strategies for European marine and coastal ecosystems to face climate change.**

MaCoBioS

unesco
Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

# WHERE **WE'RE FROM,** WHERE **WE WORK**




CORAL REEFS

SALT MARSHES

SEAGRASS BEDS

MANGROVE FORESTS

KELP FORESTS

MAËRL BEDS

**16 PARTNER INSTITUTIONS IN EUROPE AND THE CARIBBEAN :**

University of Portsmouth Centre for Blue Governance · Nova Blue Environment · Institut Paul Ricard Océanographique · Fundação Gaspar Frutuoso · Maynooth University National University of Ireland Maynooth · Wageningen University & Research · CSIC · cmcc · unesco Intergovernmental Oceanographic Commission · Freie Universität Berlin · Lund University · LUCSUS Centre for Sustainability Studies · The University of the West Indies · ERMES · HD Creative Institut · University of Exeter

# **MARINE AND COASTAL** ECOSYSTEMS

ARE
### FUNDAMENTAL FOR BIODIVERSITY

Serving as habitats for a vast array of species, offering breeding, feeding, and nursery grounds that support intricate food webs and some of the richest and most diverse communities on Earth.

ARE
### THREATENED GLOBALLY

By increased environmental pressures, either related to climate change or to more direct human pressures. The degradation of these ecosystems alters the services they provide us and ultimately our well-being.

ARE
### VITAL FOR PEOPLE

Providing essential services such as food, carbon sequestration, coastal protection, or biodiversity. They play a critical role in mitigating climate change impacts and sustaining the well-being of coastal communities.

# OUR **GOALS**

Better understand the inter-relations between climate change, biodiversity, functions and services in marine and coastal ecosystems.

Assess the vulnerability of marine and coastal socio-ecological systems under climate change scenarios.

Evaluate the effectiveness of Nature-based Solutions at enhancing the resilience capacity of marine and coastal ecosystems.

Provide evidence-based guidance for policy formulation and innovative research pathways to support policymakers in developing cost-effective strategies.

# WHAT WE ULTIMATELY **HOPE TO ACHIEVE**

We hope to contribute to increase uptake of and investments in blue nature-based solutions that benefit both biodiversity and climate adaptation and mitigation, and ultimately improve human health and well-being, in line with the UN SDGs 3, 13 and 14.

SUSTAINABLE DEVELOPMENT GOALS

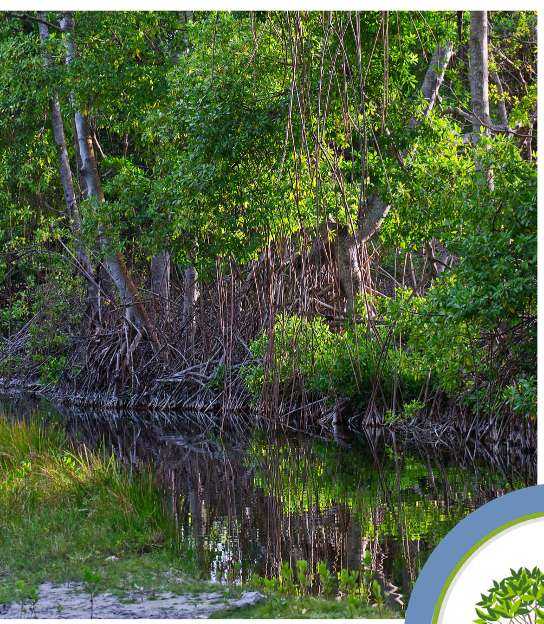
3 GOOD HEALTH AND WELL-BEING

13 CLIMATE ACTION

14 LIFE BELOW WATER

# CARIBBEAN ECOREGION
## MARINE AND COASTAL ECOSYSTEMS

The Caribbean is home to very important marine and coastal ecosystems — mangrove forests, seagrass beds, and coral reefs — that support marine biodiversity, protect coastlines and underpin local economies. Yet, these ecosystems are under threat from global pressures like ocean warming, sea level rise, stronger hurricanes and acidification, as well as local stressors such as overfishing, pollution, and habitat destruction.



### MANGROVE FORESTS

Mangroves act as natural barriers against storms, protecting coastal communities while providing nurseries for marine life. Despite their importance, Caribbean mangroves are under threat from coastal development, pollution, and climate change. Rising sea levels, altered rainfall patterns, and stronger storms jeopardize their health and resilience.

### SEAGRASS BEDS

Beds of seagrass, such as *Thalassia testudinum*, stabilise sediments, store carbon, and provide habitat for species like turtles, fish and small invertebrates. However, they are in decline due to pollution, boating damage, and climate change. Rising sea temperatures and hypersalinity reduce their growth and metabolism, weakening their ability to capture carbon and support marine life.

### CORAL REEFS

Caribbean coral reefs are biodiversity hotspots, vital for marine species, coastal protection and food provision. Unfortunately, 50% of coral cover has been lost due to coral bleaching, overfishing, and pollution. Climate change exacerbates these issues, with rising sea temperatures causing mass coral bleaching.

— Collecting cores from a living ***Siderastrea siderea*** coral.

### FUTURE PATHS

While global efforts are needed to address climate change, local governments can help reduce stressors on coral reefs and associated ecosystems to increase their resilience. Here is a set of management recommendations:

1. Move towards a watershed approach to coastal ecosystems' conservation. Reducing land-based local stressors from the catchment areas will increase their resilience to climate change and, in turn, contribute to mitigating its effects through the regulating services these ecosystems provide.

2. Consider the connectivity between marine and coastal ecosystems. The interconnectivity of coral reefs, seagrass beds and mangrove forests implies that managing a local stressor specifically for coral reefs will indirectly benefit mangrove forests and seagrass beds, and vice versa.

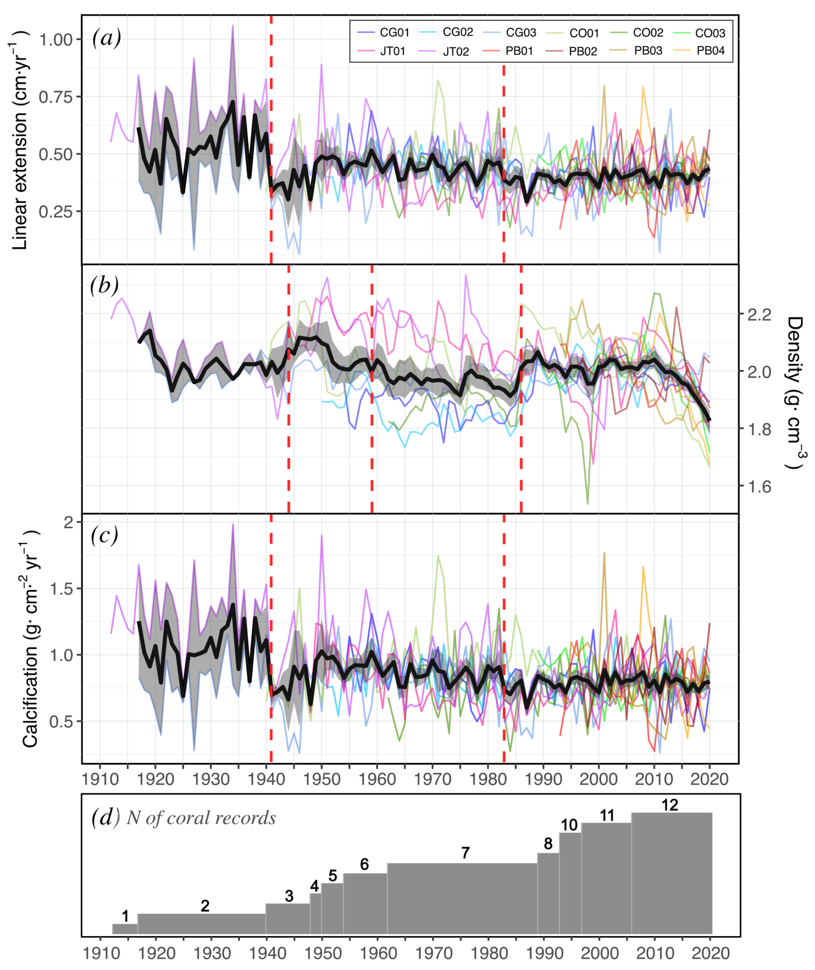
3. Promote community-based ecological restoration actions. Working with nature to restore degraded marine and coastal ecosystems by mimicking natural processes.

4. Support climate adaptation. Integrate nature-based solutions in coastal management, leveraging ecosystems' capacity for storm protection and carbon storage.

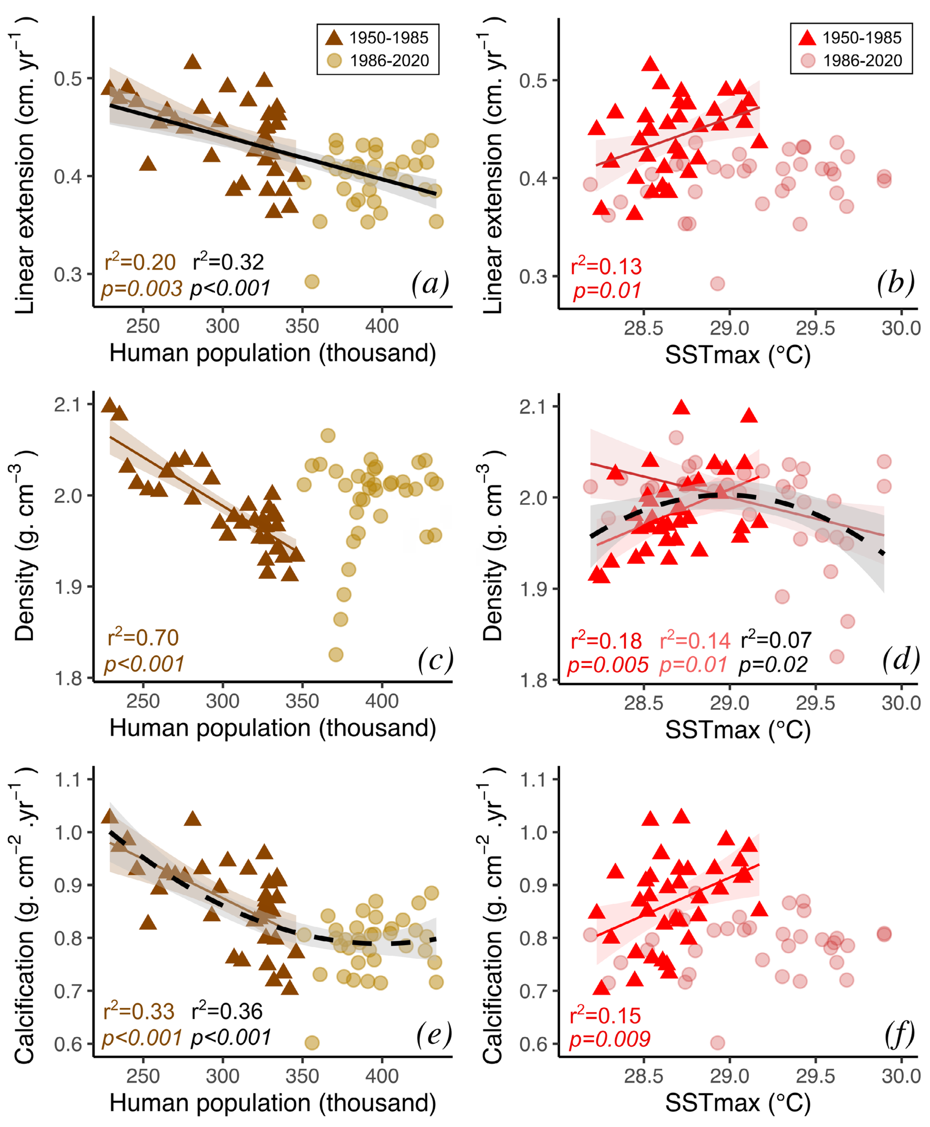
5. Research and monitoring: Enhance long-term monitoring and modelling capacities.

Gathering long-term data on key environmental factors, such as temperature and water quality, is crucial to identify the main sources of stress, but has historically been limited.

Coral skeletons offer valuable insights into past environmental changes, with growth patterns acting like tree rings. Through MaCoBioS, we are studying long-term coral growth rates and geochemistry to offer better guidance for reef management and preservation.




Normalised annual records (1917-2020) of linear extension rate, skeletal density, and calcification rate for coral cores collected in Martinique. Coloured lines represent individual core records, bold black lines represent the master chronology with its associated standard error. Vertical dashed red lines highlight the timings of significant regime shifts in mean values.




Scatter plots based on log-transformed annual time series of growth parameters and human population and monthly mean maxima sea surface temperature (SSTmax). Coloured lines correspond to either time period, and bold black lines correspond to the whole period.

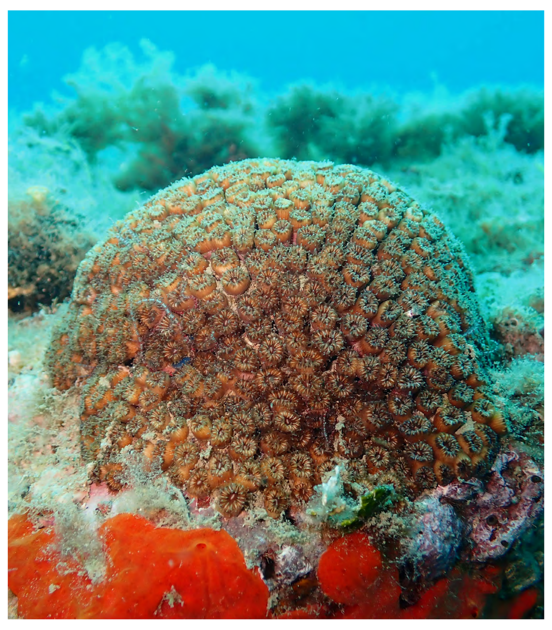
Coral cores can archive annual growth records from decades to centuries.

Photo credits: © Ewan Trégarot, Georg Heiss, Marina Vergotti

# MEDITERRANEAN ECOREGION
## MARINE AND COASTAL ECOSYSTEMS

### POSIDONIA OCEANICA

*Posidonia oceanica*, an endemic seagrass and a foundation habitat for many organisms, provides essential ecosystem services such as food provision, water purification, and coastal protection.
It is classified as vulnerable on the European Red List of Habitats, with a decline of 13-50% since 1960. Stressors like runoff, anchoring, and coastal development cause local impacts, while warming threatens its long-term survival.



### CLADOCORA CAESPITOSA

The endemic coral *Cladocora caespitosa* is the only reef-building coral in the region. It is a long-lived species and its large structures, that provide habitat for many species, are becoming increasingly rare. Alongside habitat destruction, recurrent marine heatwaves are accelerating its decline.
It is classified as endangered on both the IUCN Red List and the European Red List of Habitats.

### RHODOLITH BEDS

Rhodolith beds are aggregations of free-living red calcareous algae found on sandy sediments on continental shelves. They create complex habitats that support biodiversity and provide nursery grounds for commercial fish. They are highly vulnerable to trawling and are listed in Annex I of the Habitats Directive. Their long-term resilience is threatened by climate change, and particularly by ocean acidification.

## Local Stressors:


EUTROPHICATION

COASTAL DEVELOPMENT

FISHING ACTIVITIES

## Global Stressor:

CLIMATE CHANGE

### FUTURE PATHS

Enhancing the resilience of foundation species to climate change starts with managing local impacts (water quality, habitat loss, and fishing).

Expanding habitat conservation through effective Marine Protected Areas is essential.

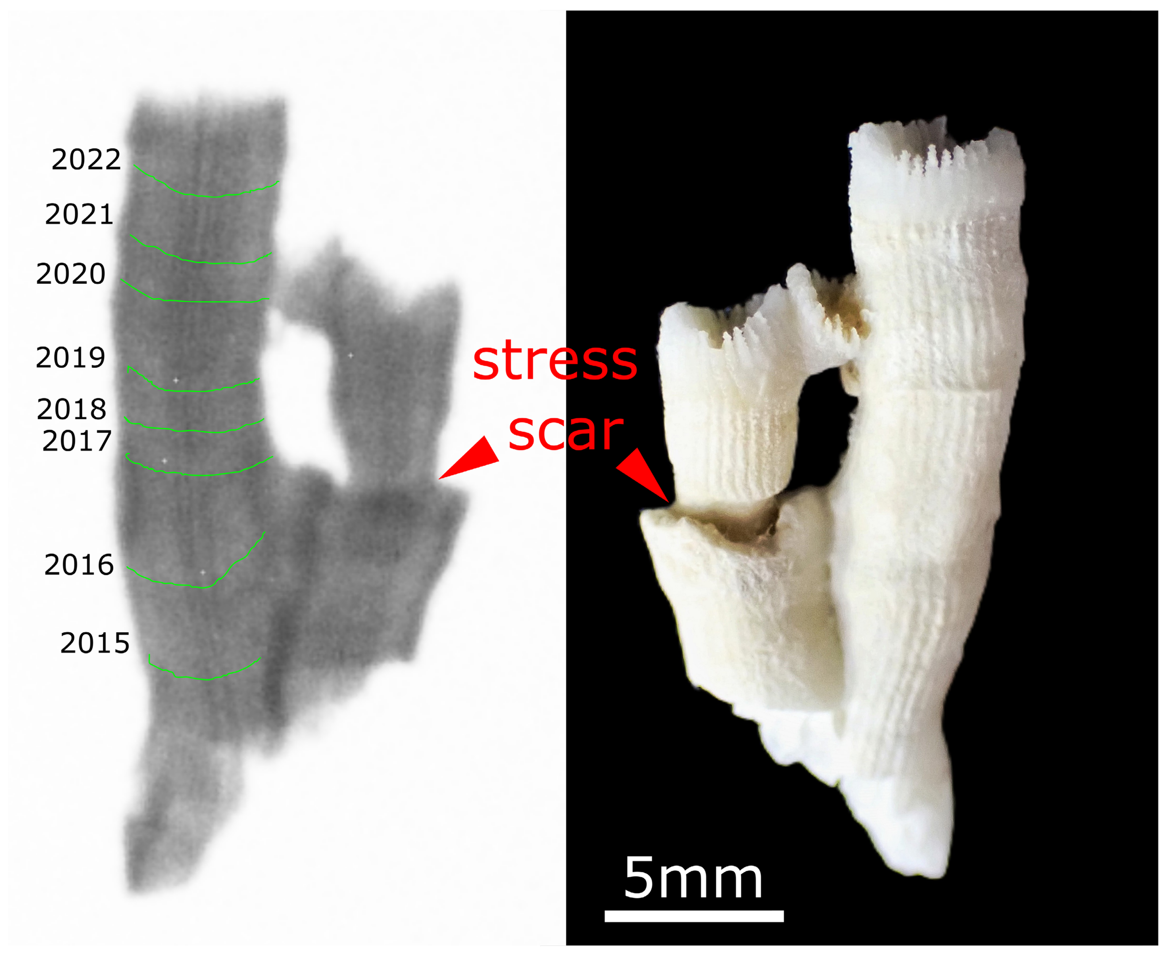
For Posidonia, focus on conservation and restoration efforts.

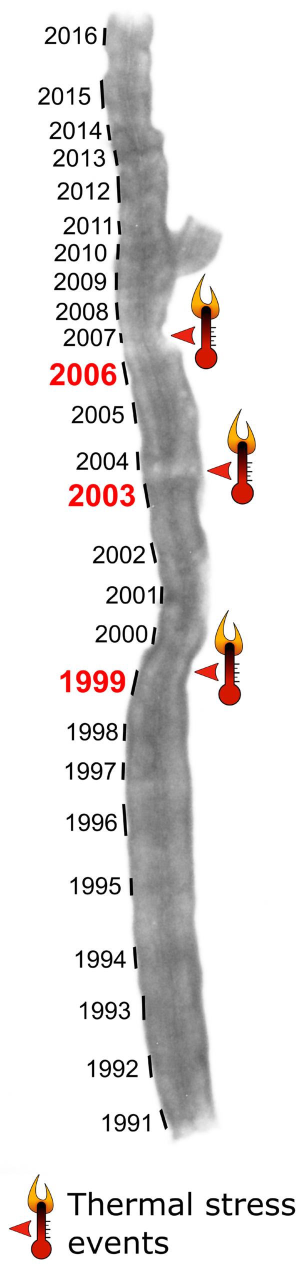
For Cladocora and rhodolith beds, prioritize expanding monitoring programs to track climate responses and identify climate refuges.

## *Cladocora caespitosa*: an environmental archive growing in a climate change hot-spot

warming-mortality affected Cladocora colony

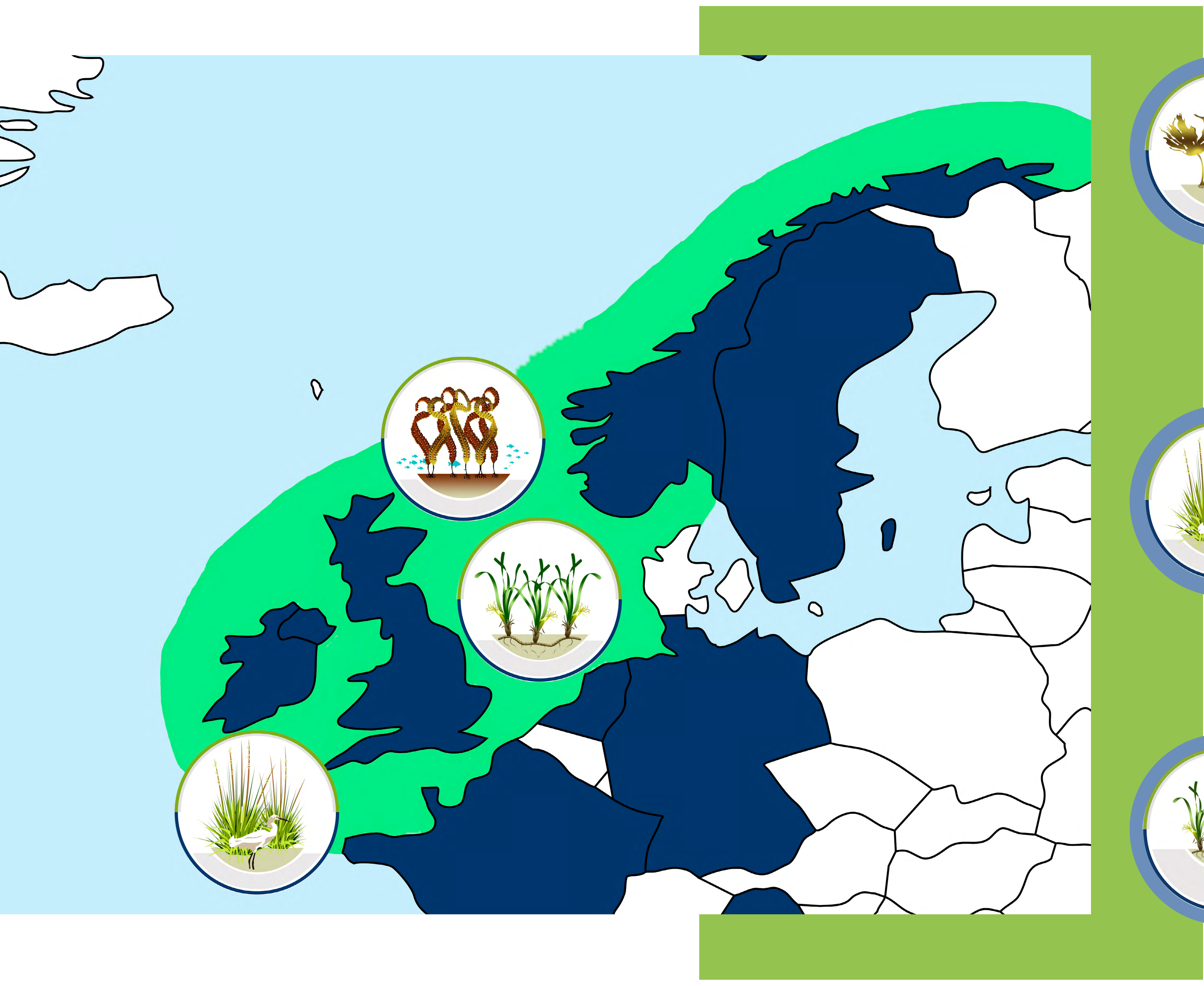
As a scleractinian coral, *C. caespitosa* deposits seasonal growth bands in its skeleton, similary to tree rings, which can be analysed using techniques such as X-rays. With these techniques, we have attempted to reconstruct the life history of this coral and to understand its responses to past environmental changes, including stress events like marine heatwaves.



# **NORTHERN EUROPEAN** ECOREGION

## MARINE AND COASTAL ECOSYSTEMS



### KELP FORESTS

In MaCoBioS "Kelp" refers to large brown algae of the order Laminariales.
Kelp forests are ecosystem engineers, support biodiversity, provide people with food and biochemical products like alginates, regulate nutrient cycling and carbon storage and sequestration, protect coastlines, and hold cultural and recreational value.

### SALT MARSHES

Salt marshes are biodiversity hotspots at the land-sea interface that contribute to carbon sequestration and protection of coastal areas against flooding, erosion and pollution.

### SEAGRASS BEDS

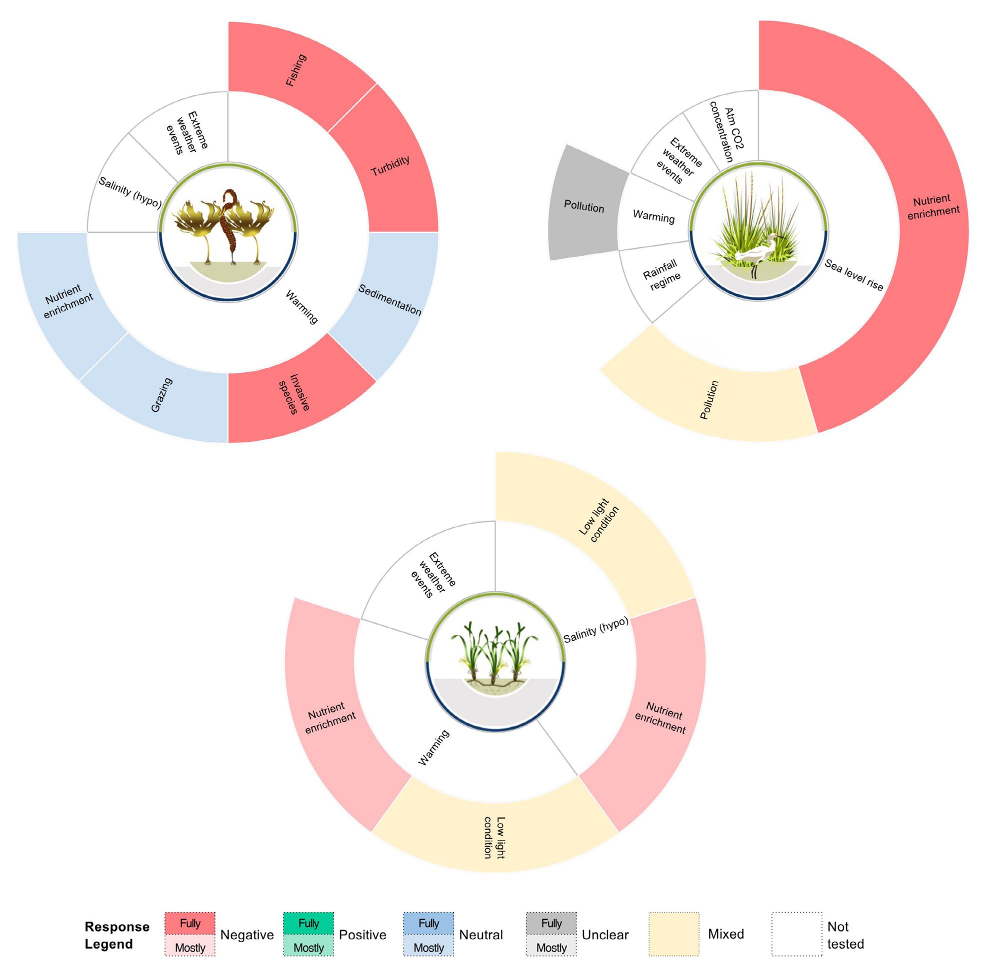
Two seagrass bed-forming species are present here: ***Zostera marina*** and ***Zostera noltii***. They support diverse marine life, aid in coastal erosion control, sustain tourism and recreation, and sequester large amounts of carbon in their leaves, roots, and underlying sediment.

## Climate change pressures
## and local stressors

Kelp forests, salt marshes, and seagrass beds are highly vulnerable to climate change. Local human activities can also severely impact them, affecting «safe operating spaces» and therefore their tolerance to the effects of climate change. While climate change cannot be locally managed, local stressors can be.

| Marine & Coastal Ecosystems North-East Atlantic | RESPONSE VARIABLE CATEGORIES | CLIMATE CHANGE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Warming / heat waves | Extreme weather events | Atmospheric $CO_2$ concentration | Ocean acidification | Sea level rise | Salilinity (hypo) | Cooling | Rainfall regimes (reduced) | Inundation |
| KELP FORESTS | Density/Abundance | 9% | | | | | | | | |
| | Distribution | 23% | | | | | 58% | | | |
| | Growth | 20% | | | | | 8% | | | |
| | Habitat structure | 2% | 100% | | | | | | | |
| | Metabolism | 16% | | | | | | | | |
| | Photosynthesis/Respiration | 17% | | | | | 17% | | | |
| | Reproduction | 13% | | | | | 17% | | | |
| | Other | | | | | | | | | |
| SALT MARSHES | Density/Abundance | 3% | | 7% | | 7% | | | 6% | |
| | Distribution | | | | | | | | | |
| | Growth | 16% | | 21% | | 12% | | | | |
| | Habitat structure | 32% | | 14% | | 52% | | | 69% | |
| | Metabolism | | | | | 5% | | | 19% | |
| | Photosynthesis/Respiration | 41% | | 29% | | 15% | | | 6% | |
| | Reproduction | 8% | | 21% | | 8% | | | | |
| | Other | | 100% | 7% | | 2% | | | | |
| SEAGRASS BEDS *Zostera marina* | Density/Abundance | 18% | | | | | 15% | | | |
| | Distribution | 3% | 100% | | | | 8% | | | |
| | Growth | 15% | | | | | 15% | | | |
| | Habitat structure | 9% | | | | | 15% | | | |
| | Metabolism | 42% | | | | | 38% | | | |
| | Photosynthesis/Respiration | 12% | | | | | 8% | | | |
| | Reproduction | | | | | | | | | |
| | Other | | | | | | | | | |

Summary of studies from the review per climate change drivers and general effects on broad response variable categories. Percentage values represent the proportion of studies per response variable from the total number of studies per climate change driver.




Cumulative overall effects of local stressors combined with climate change drivers for marine and coastal ecosystems in the North-East Atlantic.

Source: Trégarot et al. (2023)

## Drivers of change

Rising sea temperatures are expected to cause kelp forests to shift poleward and shrink at lower latitudes, negatively impacting biodiversity, although warmer waters might help control grazers like sea urchins.

**Increased rainfall could cause flooding, runoff, and freshwater discharge, lowering salinity and adding nutrients to the sea. This would reduce light, limit kelp and seagrass growth, and decrease biodiversity.**

**Sea-level rise will mostly affect salt marshes, though impacts in the North-East Atlantic remain uncertain.**

### FUTURE PATHS

**Improve water quality by reducing nutrient load.**

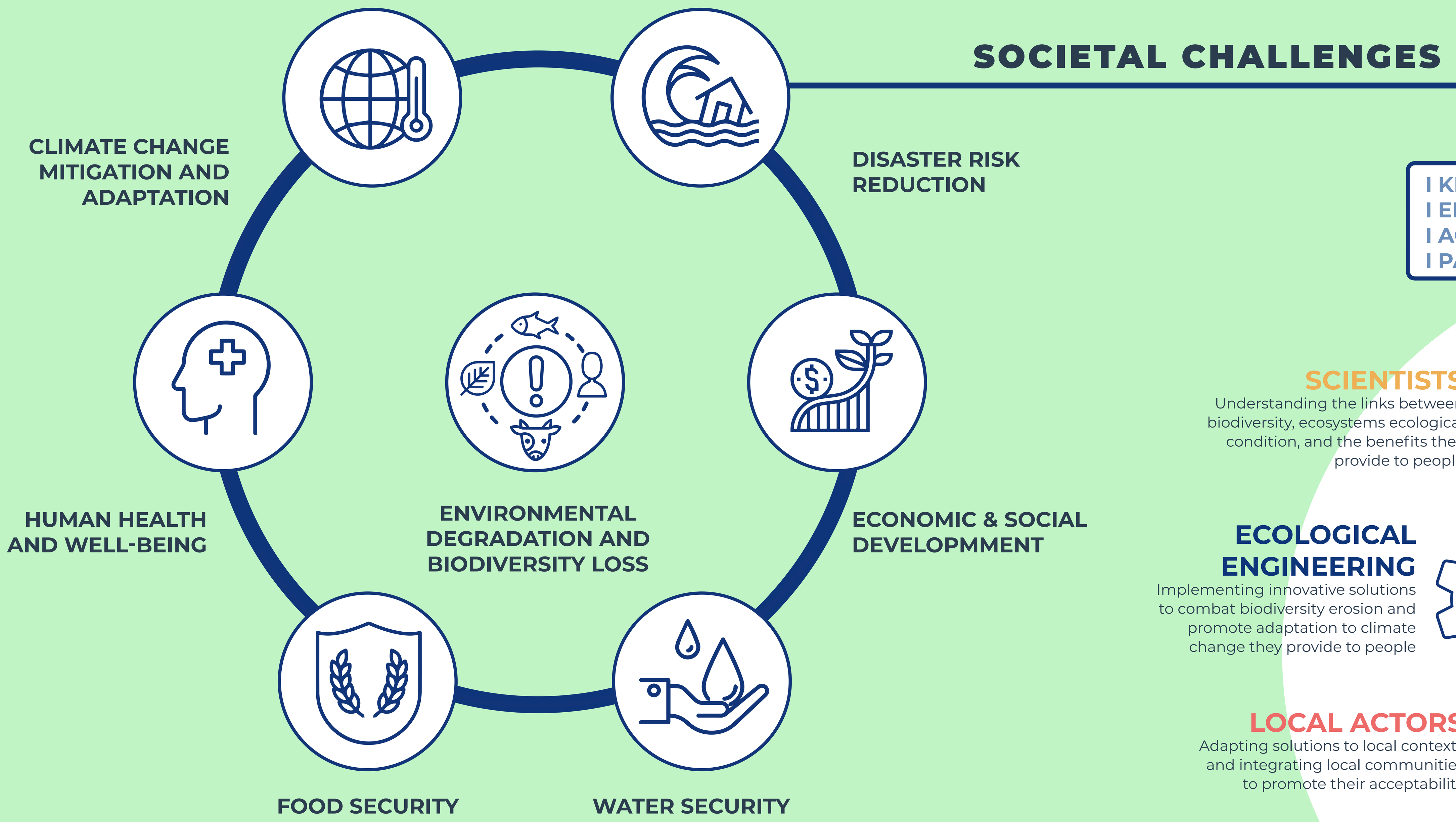
**Allow recovery by reducing exploitation.**

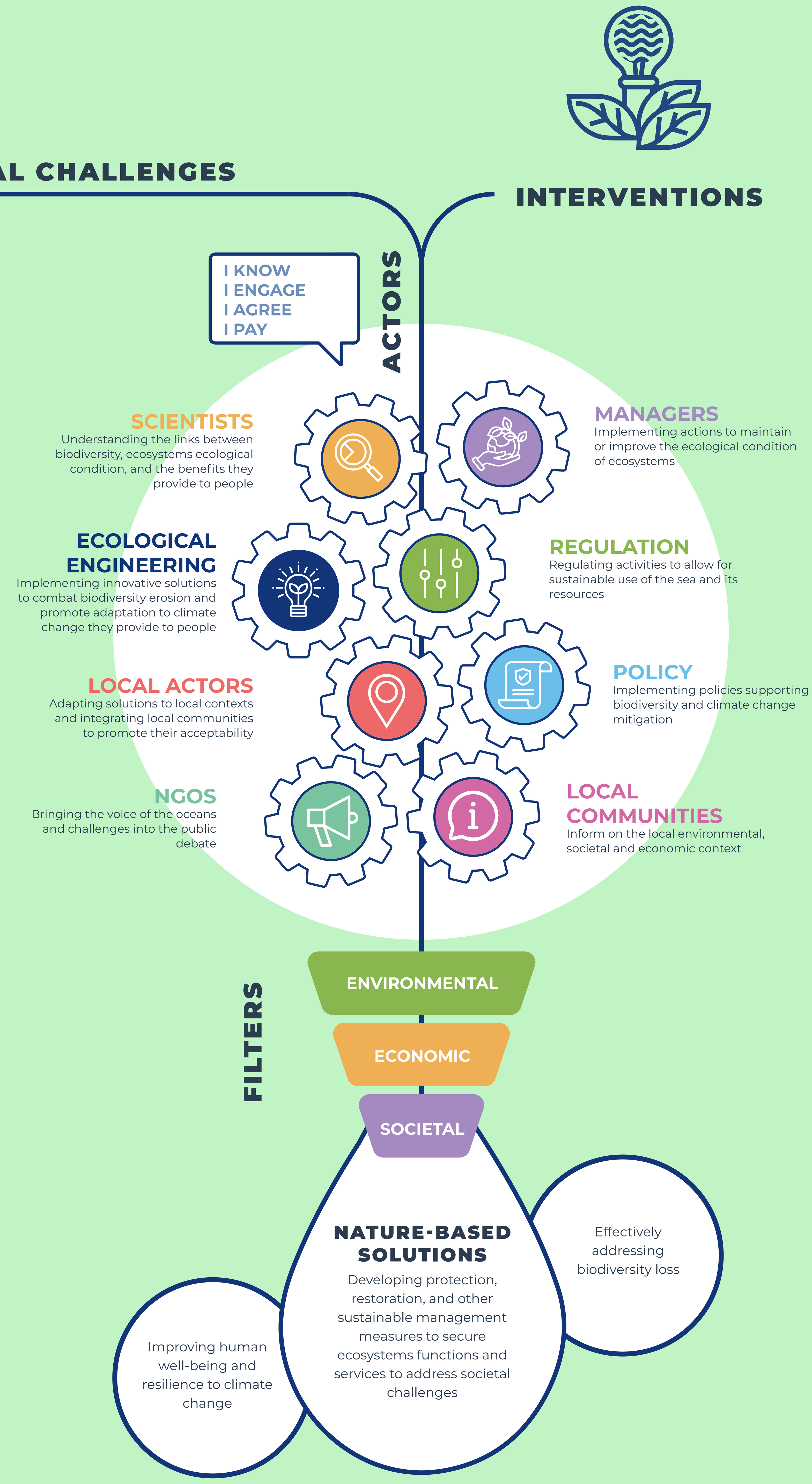
**Promote better management of coastal urbanisation.**

**Address knowledge gaps for assessing safe operating space and thresholds.**

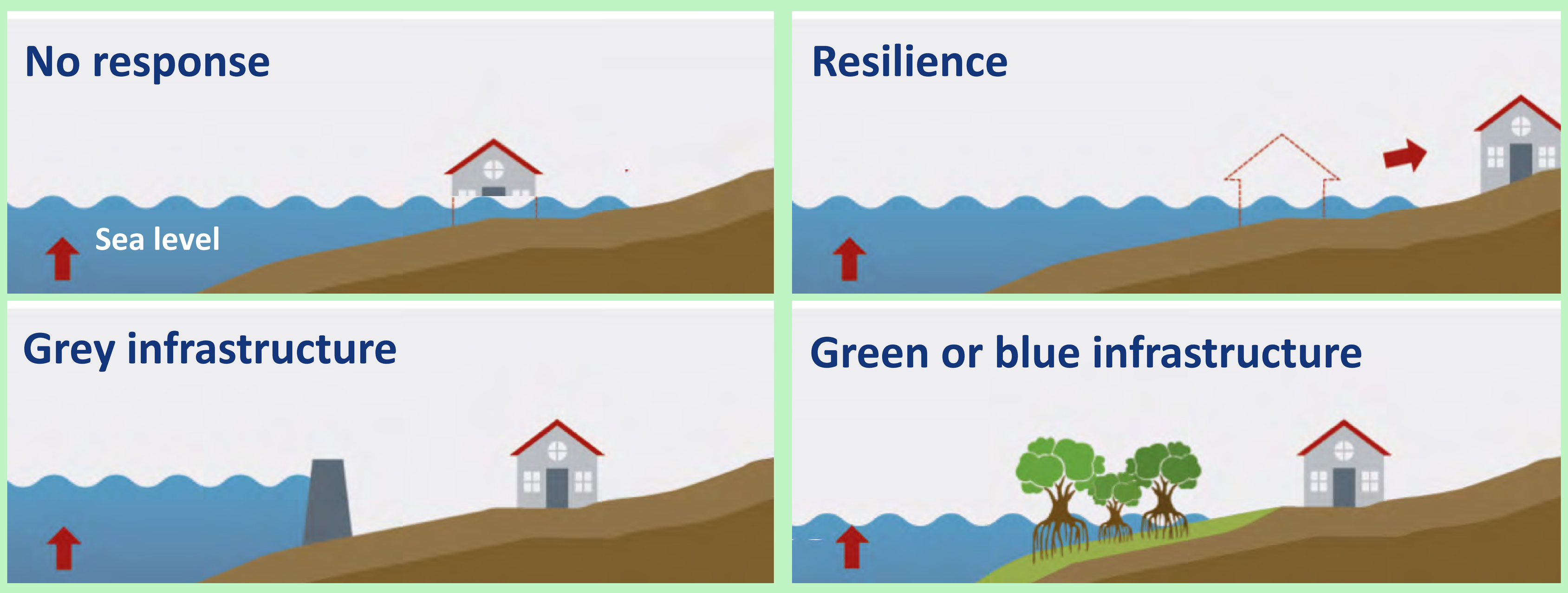
Photo credits: © Ewan Trégarot, Stein Fredriksen

# BLUE NATURE-BASED SOLUTIONS



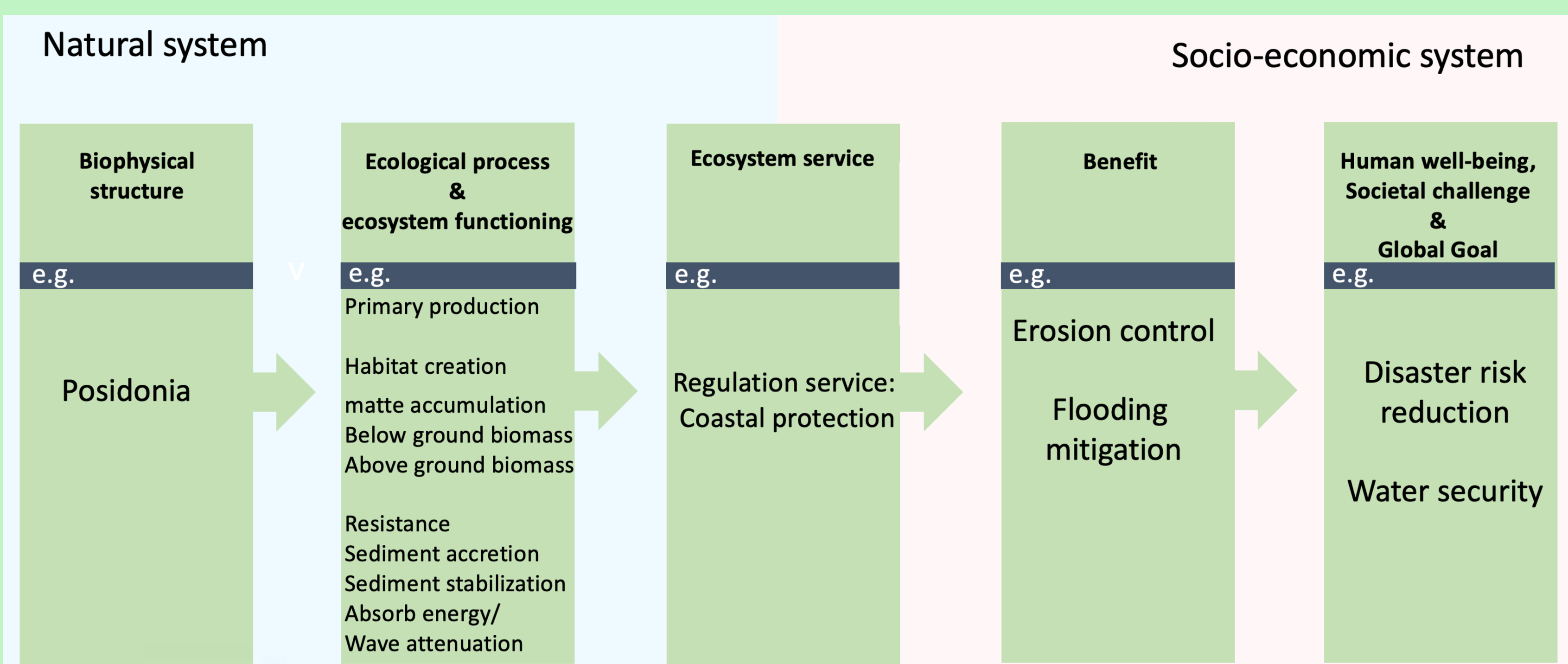

**Nature-based Solutions** (NbS) harness nature and ecosystem services to address societal challenges, such as climate change, while providing benefits to biodiversity. NbS is an umbrella term that encompasses actions to protect, sustainably manage and restore natural or modified ecosystems. Currently, the term has various significations across different sectors. Furthermore, in marine and coastal ecosystems, NbS (or blue NbS) remain relatively underdeveloped and unstructured. We propose framing NbS as a catalyst for expanding nature-based approaches in our societies while bridging the gap between life sciences, blue economy and governance, and strategies for mitigating and adapting to global change.




Adapted form IPCC, 2019

There are several pathways to adapt to or mitigate global changes. Embracing nature as a vital contributor to human societies, helping us address our societal challenges, is critical to building a more resilient and sustainable future.

**The concept of Nature-based Solutions highlights interventions that benefit both nature and people. In the marine environment, it gathers protection (e.g., marine protected areas), restoration (e.g., mangrove replanting) and other management measures (e.g., no-take zones).**




Modified from Liquete et al., 2013.
Assessment of coastal protection as an ecosystem service in Europe.

It underscores the connection between the natural system, which underpins ecological processes and functions, and ecosystem services, which bridge the gap to the socio-economic system and enable us to address societal challenges.

# THE MACOBIOS BLUE NBS TOOLBOX: BREAKING THE GROUND FOR MARINE AND COASTAL NATURE-BASED SOLUTIONS DESIGN AND IMPLEMENTATION

Implementation of Nature-based Solutions in marine and coastal environments (blue NbS) has been slow. Reasons vary but include a lack of supportive tools for practitioners. The MaCoBioS Blue NbS Toolbox is a collection of multidisciplinary tools and products developed with stakeholders to help with blue NbS design and implementation.

## ACCESS THE TOOLBOX:

## THE TOOLS

The toolbox contains five complementary tools, each with guidelines and supporting materials.

**MACOBIOS' CONCEPTUAL MODELS** CONCEPTUAL TOOL TO UNDERSTAND THE RISK THAT CHANGES PRESENT TO ECOSYSTEM SERVICES

WHAT HAPPENS TO THE ECOSYSTEM AND ITS SERVICES IF ...?

Conceptual models to visualise management scenarios based on connections between ecosystem components, human activities and climate change

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**COAST-ADAPT** METHODOLOGICAL FRAMEWORK FOR ASSESSING ADAPTIVE CAPACITY IN COASTAL SOCIAL-ECOLOGICAL SYSTEMS

WILL A COMMUNITY BE ABLE TO ADAPT TO CHANGES?
HOW CAN WE ENHANCE THEIR ADAPTIVE CAPACITY?

Methodological framework guiding index-based adaptive capacity assessment design, implementation and application

---

**MARITIME** MARINE & COASTAL ECOSYSTEM CUMULATIVE IMPACTS ASSESSMENT

WHERE IS THE MANAGEMENT TO REDUCE LOCAL PRESSURES MOST NEEDED?

Machine Learning-Cumulative Impact Assessment model to explore future ecosystem distributions under climate change

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**MAS-NBS** FRAMEWORK TO IDENTIFY AREAS WITH SUITABLE CONDITIONS FOR IMPLEMENTING BLUE NBS

WHERE CAN WE FIND THE MOST FAVOURABLE CONDITIONS FOR INTERVENTION?

Multi-tiered Approach to assess Suitability for NbS combining environmental suitability mapping, cumulative risk assessment and social-economic and governance dimensions

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**PBI-SUPPORT** DECISION-SUPPORT TOOL TO HELP PLAN ACTION(S)

WHAT ARE THE POTENTIAL INTERVENTIONS THAT COULD BE APPLIED?

Potential Blue Interventions Support framework integrating societal challenges, ecosystem services, environmental context and ecosystem-based management approaches

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**STORYMAPS** SHOWCASING MACOBIOS' WORK

INFORMATION ON **BIODIVERSITY DATA COLLECTION METHODS** TO INFORM MONITORING

**POLICY BRIEFS AND GUIDELINES** ON BLUE NBS IMPLEMENTATION, RESEARCH AND INTEGRATION INTO SOCIAL-ECOLOGICAL SYSTEMS

**ALL PROJECT OUTPUTS**

AN INTERACTIVE **WEBGIS**

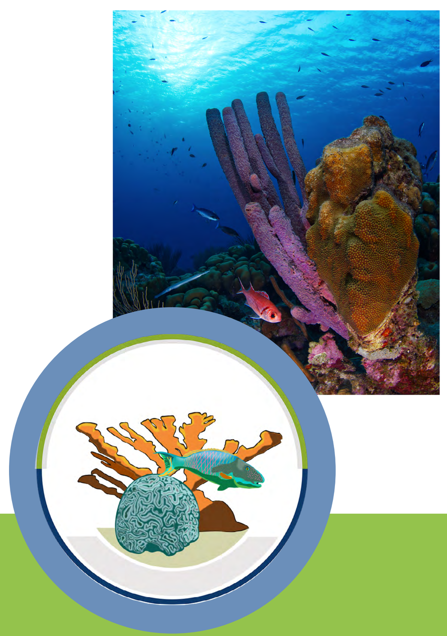
AS SOCIETIES INCREASINGLY RECOGNISE THE VITAL ROLE OF MARINE AND COASTAL ECOSYSTEMS IN ADDRESSING SOCIETAL CHALLENGES, THERE IS GROWING URGENCY TO ACT.

**THE MACOBIOS BLUE NBS TOOLBOX AIMS TO SUPPORT EFFECTIVE BLUE NBS DESIGN AND DEPLOYMENT.**

# MACOBIOS' CONCEPTUAL MODELS: VISUALISING ECOLOGICAL COMPLEXITY IN MARINE AND COASTAL ECOSYSTEMS

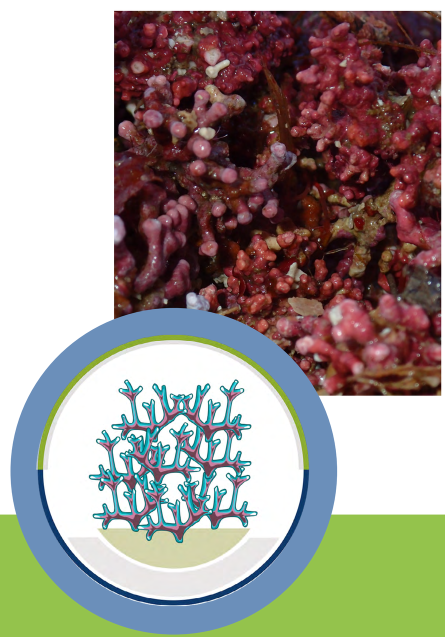
## We developed MaCoBioS' Conceptual Models relying on Fuzzy Cognitive Mapping for :

CORAL REEFS IN THE LESSER ANTILLES



KELP FORESTS IN NORTHERN EUROPE

MAËRL BEDS IN THE WESTERN MEDITER-RANEAN



MANGROVE FORESTS IN THE LESSER ANTILLES

SALT MARSHES IN NORTHERN EUROPE

SEAGRASS BEDS IN THE WESTERN MEDITER-RANEAN

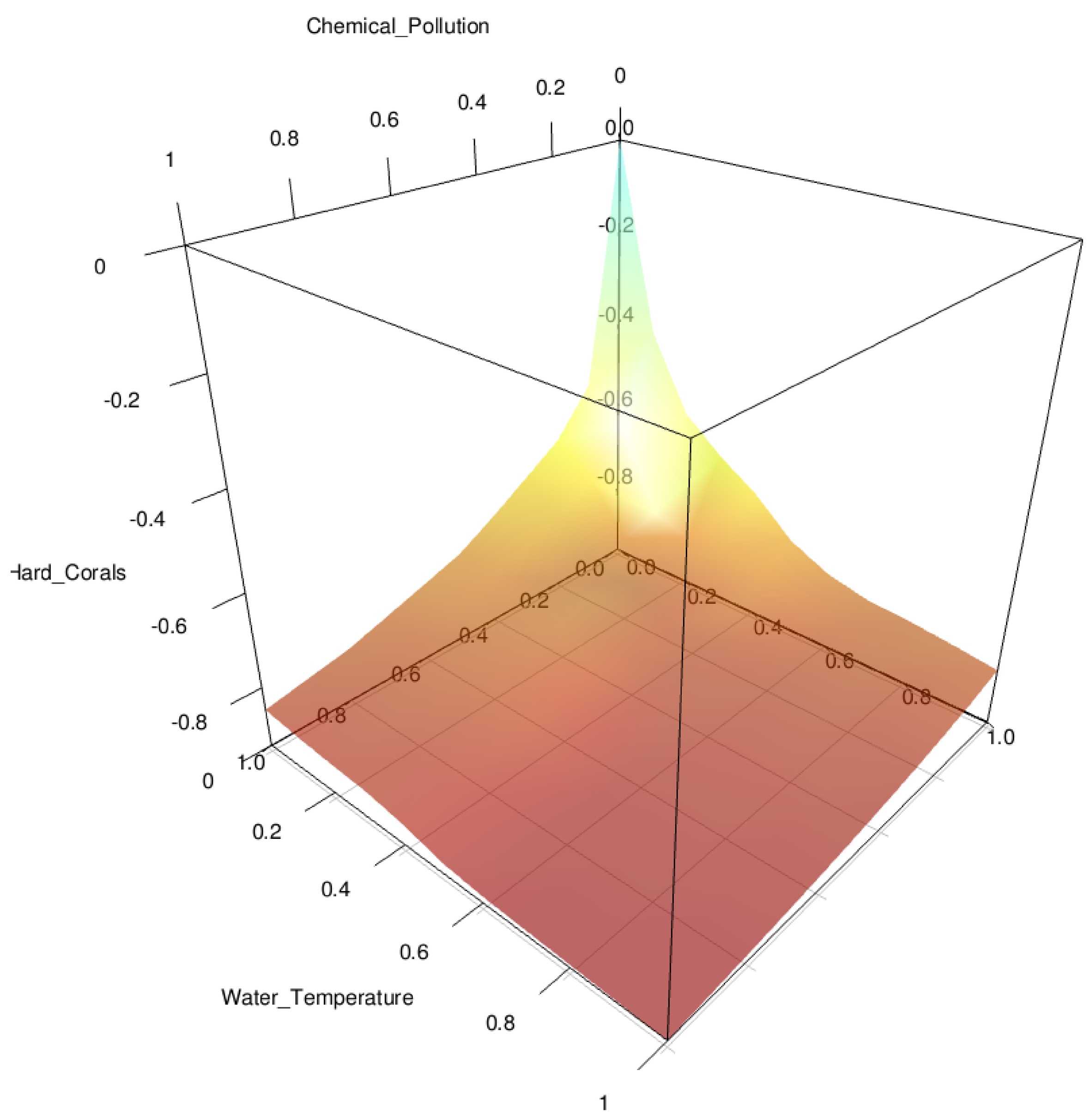
## Fuzzy Cognitive Mapping (FCM)

FCM is a tool used to capture and analyse the complexity of systems where precise data may be scarce and uncertainty is inherent. This approach is particularly beneficial in ecological studies, where multiple variables interact in ways that are not entirely predictable.

Understanding the principles of FCM, including the integrations of fuzzy logic and the iterative refinement process is crucial for effectively modelling marine and coastal ecosystems.

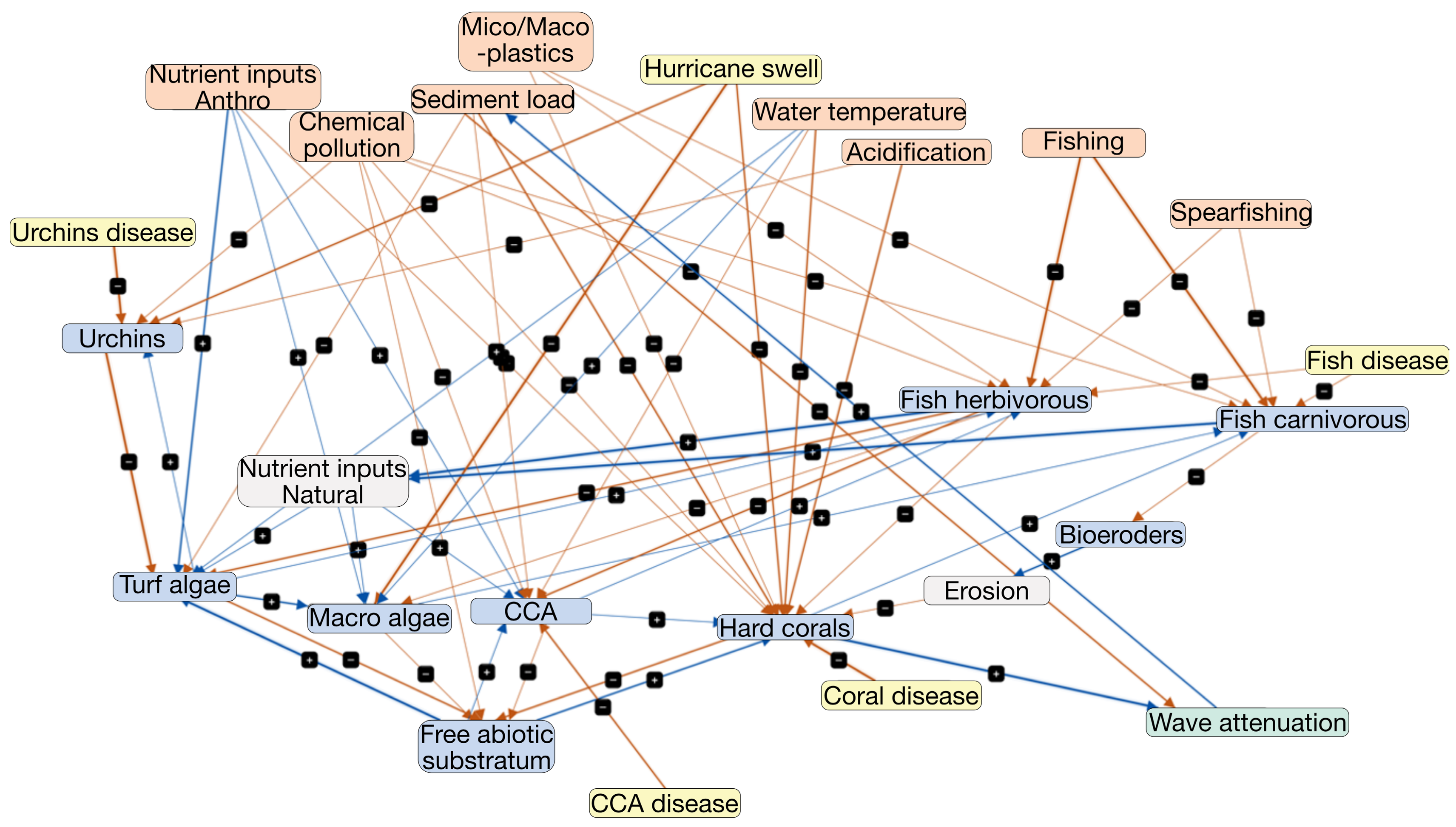
## Scenario simulation

Use the models to simulate the effects of potential changes like climate variables, species interactions, or human interventions (e.g., reducing pollution).




Effect of combined increase in water temperature and chemical pollution on hard corals from the coral reefs conceptual model.

## Coral reef conceptual model




## Conceptual Models' strengths

| | |
|---|---|
| Simplification of Complexity | Helps researchers and Stakeholders to visualise and discuss the system's dynamic |
| Integration of qualitative and quantitative data | Useful in data poor context |
| Identify knowledge gaps | Highlight research needs and priorities |
| Support for scenario analysis | Open the discussion on the cascading effects of environmental changes or management measures |
| Flexibility and Adaptability | Useful in adaptive management strategies |

While FCM offers valuable insights, it has limitations such as subjectivity in weighting, data gaps, simplification of complex systems, static temporal resolution, and the need for future improvements like dynamic models and enhanced data integration. It is recommended to use FCM more as a discussion tool rather than a quantitative predictive model for forecasting ecosystem dynamics.

# **COAST-ADAPT:** COASTAL ADAPTIVE CAPACITY ASSESSMENT GUIDELINES

## What is it and why we need it?

Coast-Adapt* provides clear, step-by-step guidelines for designing, implementing, and applying index-based assessments of coastal communities' adaptive capacity. These assessments help identify which communities are most vulnerable to climate change and what factors support their ability to adapt. This information is essential for determining how blue Nature-based Solutions can effectively support these communities. Therefore, Coast-Adapt is a valuable tool for researchers and practitioners assessing current vulnerabilities and planning future adaptation strategies.

(*) Coast-Adapt was informed by scientific literature as well as existing index-based adaptive capacity assessments of coastal social-ecological systems.

## When should Coast-Adapt be used?

Coast-Adapt is a general set of guidelines, and as such it can be adjusted to be used at all stages of decision-making regarding intervention options, including providing baseline information about the capability of local communities to adapt to changes and facilitating monitoring.

## What is the output?

The output is a collection of qualitative and quantitative information about the capacity level of coastal communities to anticipate and respond to changes, as well as the conditions that underpin such capacity.

## How does it work?

Coast-Adapt is a 9-step framework. For each step, we clarify its purpose and offer advice on how to implement it effectively. We also emphasize important elements that need careful consideration throughout the process to ensure successful adaptation efforts.

## What do we need to use it?

To use Coast-Adapt the following are required:

- A clear conceptualisation of the problem the assessment aims to address, including study context, coastal social-ecological system, risks, as well as economic, institutional, and governance factors.
- Awareness of the roles of different actors in the coastal social-ecological system to be involved in the design and implementation of the adaptive capacity assessment. This includes a clear participatory strategy.
- Coast-Adapt offers comprehensive guidance, but it should be tailored to the specific characteristics of the social-ecological system and local stakeholder priorities.

## The 9-step methodological framework of Coast-Adapt:

| | | | |
|---|---|---|---|
| CONCEPTUALISATION | 1. Diagnosis of the problem and definition of purpose | 2 Definition of adaptive capacity | 3. Selection of a theoretical approach |
| CHARACTERISATION | 4. Determine specific level of society | 5 Determine temporal scale | 6. Select attributes of adaptive capacity |
| POLICY APPLICATION | 7. Consider what stage in the policy process the assesment will contribute to | 8 Incorporate local participation early on and throughout the assessment | 9. Purposely support knowledge sharing-learning |

# **MARITIME:** ASSESSING CUMULATIVE IMPACTS ON MARINE & COASTAL ECOSYSTEMS

## What is the aim of MARITIME?

To support the design of blue Nature-based Solutions by modelling the response of marine and coastal ecosystems to cumulative impacts. Specifically, MARITIME seeks to:

- understand and map the effects of multiple pressures on a selected marine and coastal ecosystem across multiple scenarios;
- investigate the potential interactive behaviours among pressures to capture ecosystem response and effects on ecosystem services capacity;
- identify areas where ecosystems are at risk of disappearance from, or may expand into, as a result of future changes and where local blue Nature-based Solutions could be implemented.

## When should MARITIME be used ?

Ideally, MARITIME should be done early in the strategic prioritisation process, during problem framing and the development of management options. It can also be used to continuously update information as new data and climate change scenarios become available.

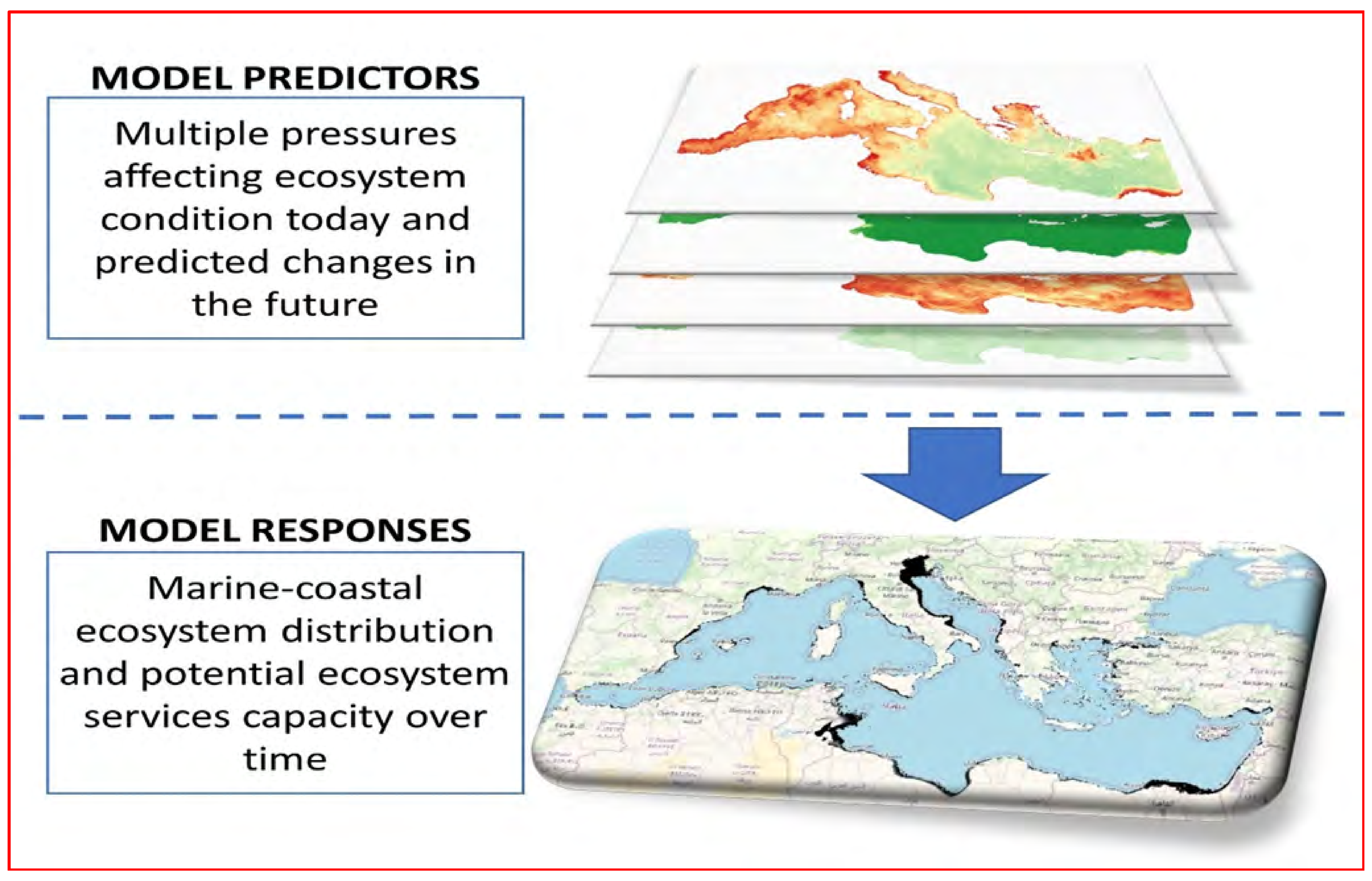
## What is the output of MARITIME ?

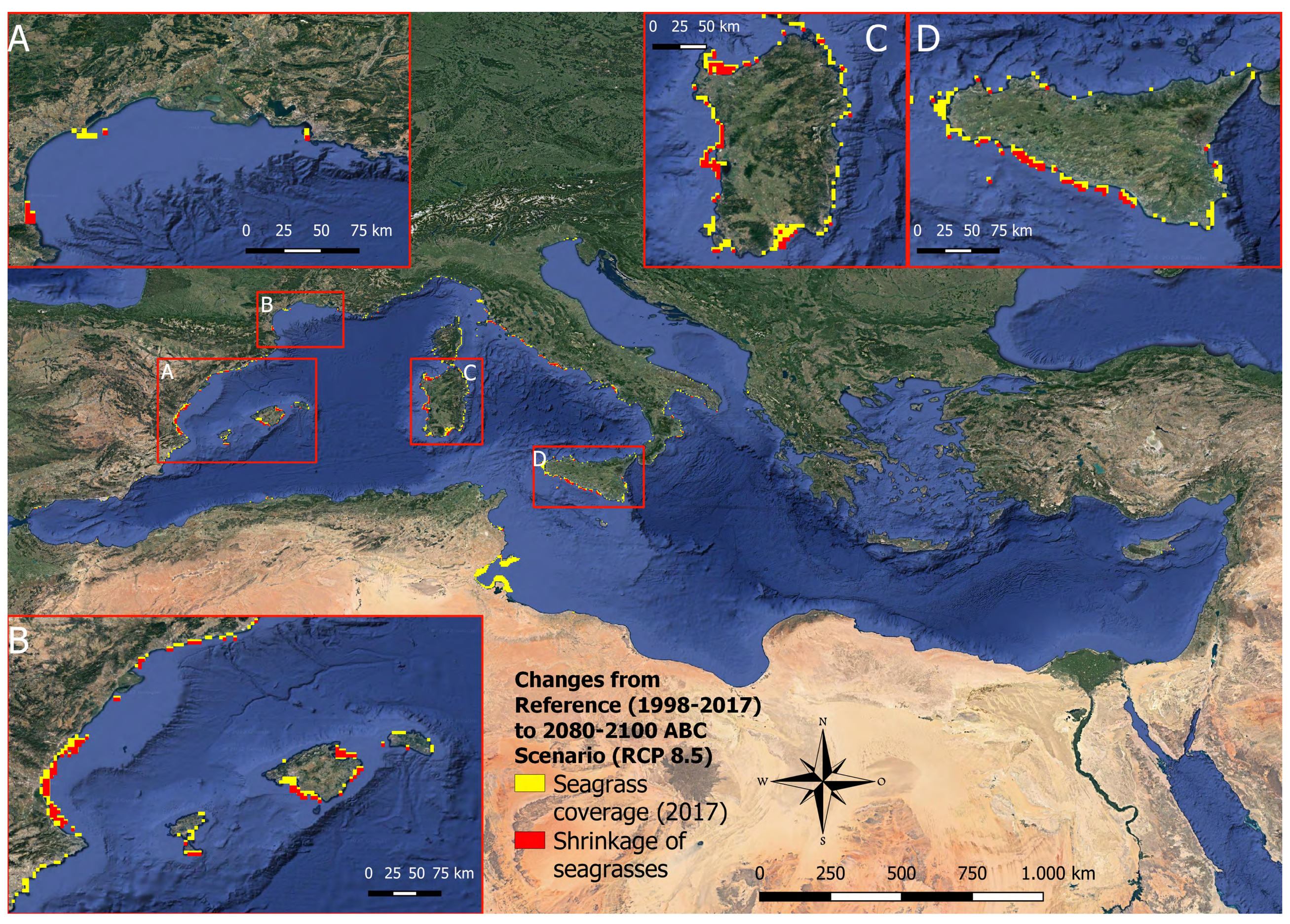
The output is a series of spatial data and visualisations for the examined ecosystem, climate change scenarios, and targeted region. MARITIME can be applied for different ecosystems and climate change scenarios provided spatial data at the desired study scale and appropriate resolution are available.

## How does it work?

MARITIME was developed using a Random Forest-based model to explore predicted future ecosystem changes with two main components: i) model predictors with proxy indicators for key endogenic (e.g., nutrient input, dissolved oxygen, shipping traffic, coastal development, etc.) and exogenic (e.g., sea surface temperature, salinity, currents, etc.) variables that determine ecosystem presence; and ii) model response as the distribution of the specified ecosystem.

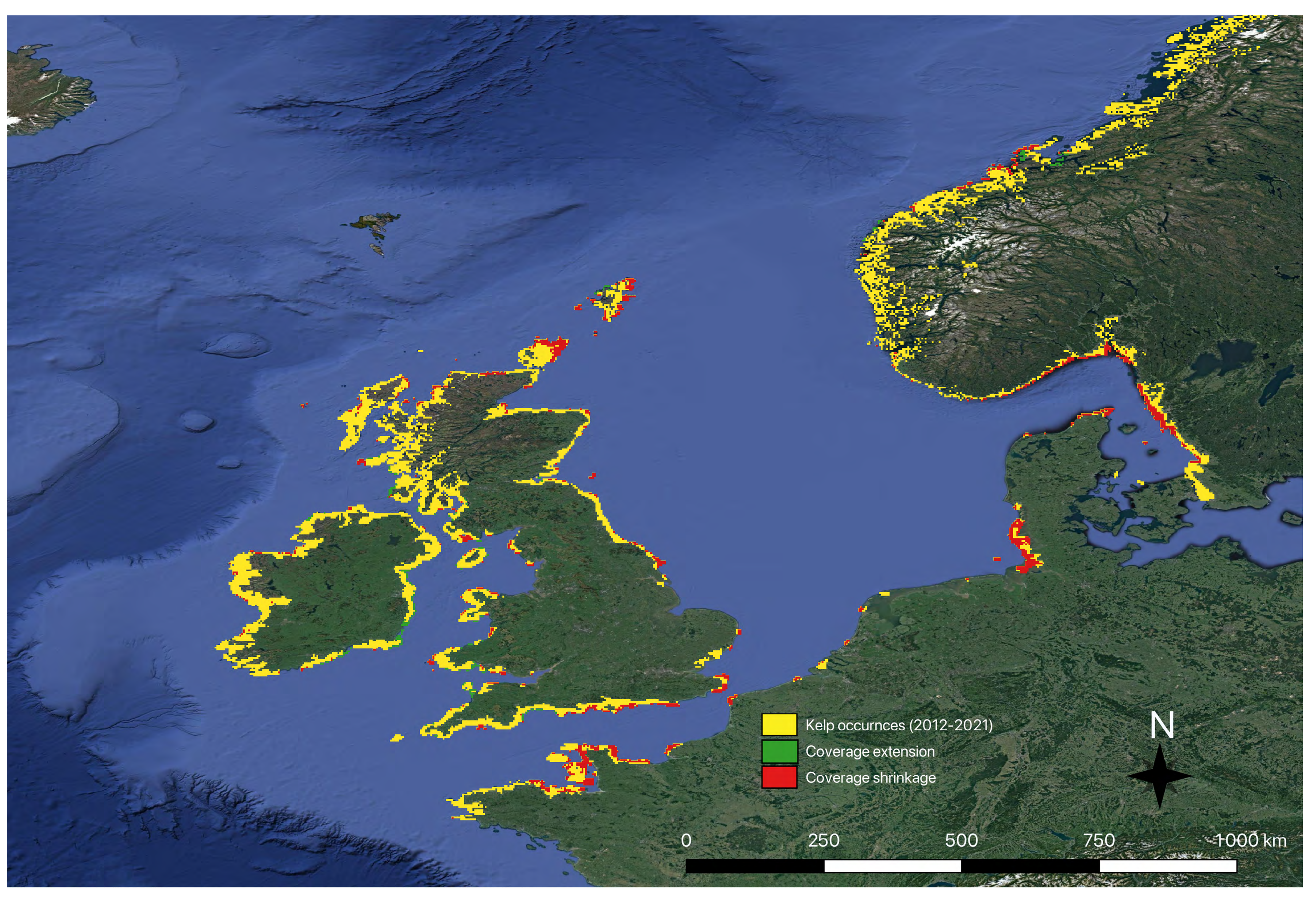
Within MaCoBioS, we have applied MARITIME to two important ecosystems in our ecoregions, namely seagrass beds (i.e., *Posidonia oceanica*) in the Mediterranean and kelp forests in Northern Europe, and looked at predicted changes to these ecosystems by 2050 and 2100 under both RCP8.5 and RCP4.5 climate scenarios.

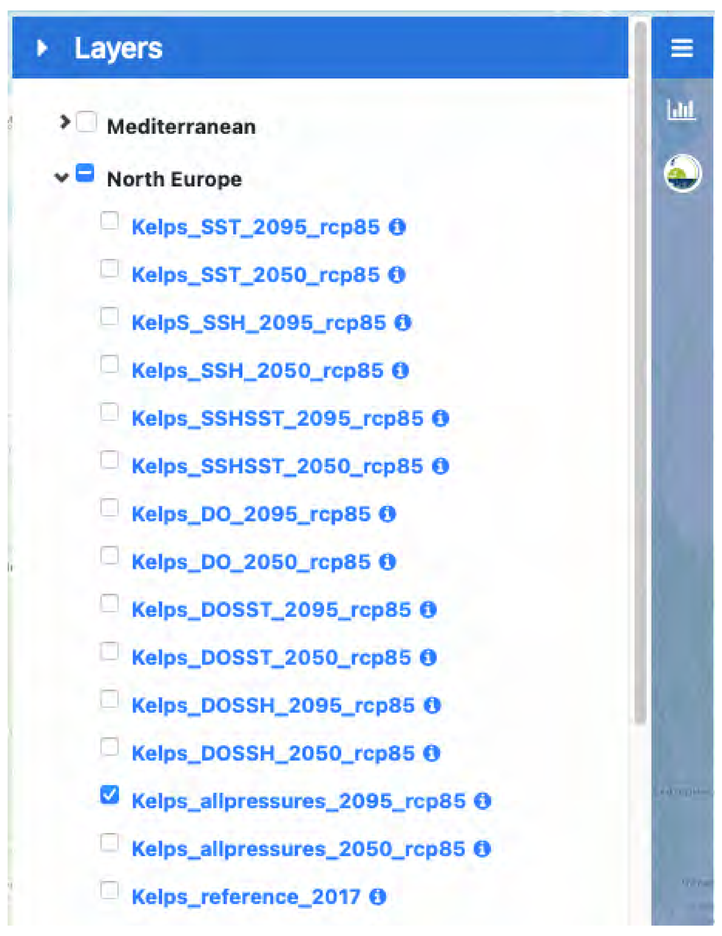




Seagrass beds extent change under the cumulative scenario (2080-2100) RCP 8.5. The simulation considered the combined impact of Sea Surface Temperature (SST), Marine Heat Waves (MHW), Salinity (SAL), and Sea Surface Height (SSH) on seagrass distribution.

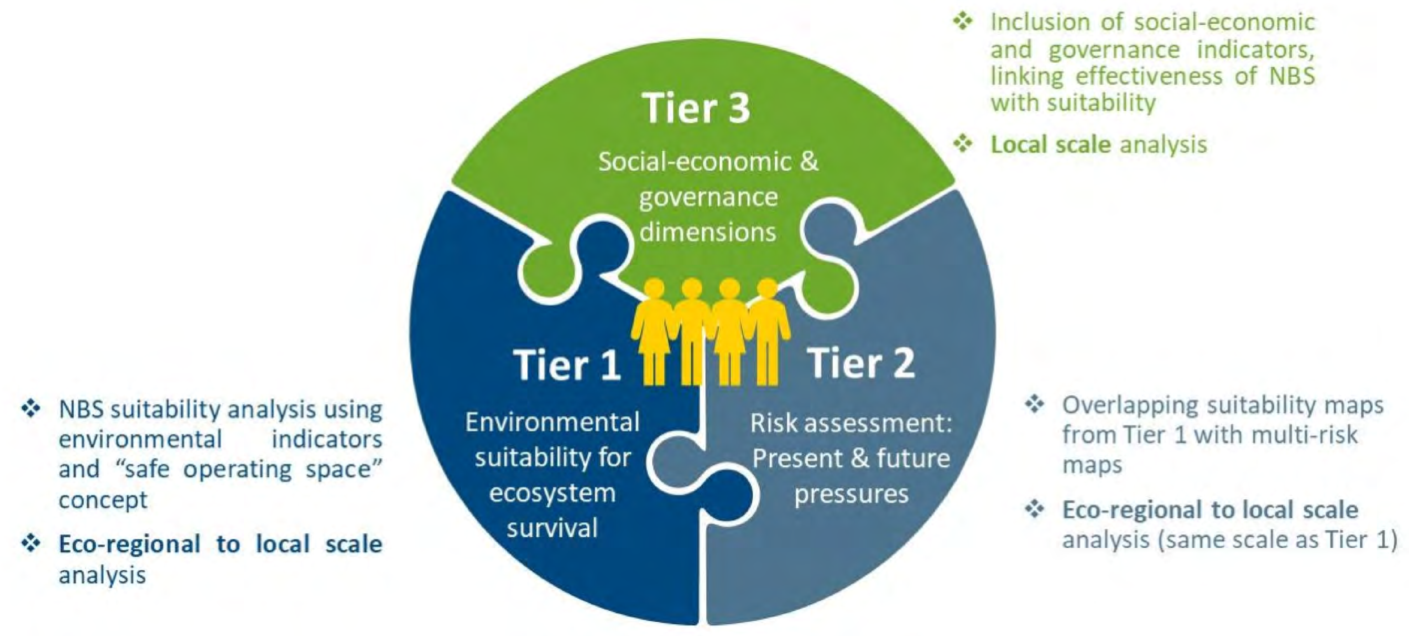



Kelp forests distribution change across the Northern Europe ecoregion in 2095 under climate scenario RCP8.5, considering the combined impact of changes in Dissolved Oxygen (DO) concentration, Sea Surface Height (SSH) and Sea Surface Temperature (SST).

# MAS-NBS: MULTI-CRITERIA APPROACH FOR SUITABILITY OF NBS

**Where can we find the right place and conditions (environmental, socio-economic, governance) to implement management actions?**




## Framework

MAS-NBS integrates environmental suitability mapping (Tier 1) with key outcomes from risk assessment modelling (Tier 2) to identify and predict present and future areas where a specific ecosystem occurs and is likely to persist, considering the pressures it faces and could face under future scenarios, and to prioritise areas for intervention. It then combines this information with context-specific social, economic, and governance features (Tier 3) to inform whether areas have the necessary enabling conditions for real-world implementation and successful interventions.

## TIER 1 - Methodological approach

Species rely on particular environmental conditions for survival and growth. The existence or absence of these conditions facilitates or inhibits the presence of particular species. As blue Nature-based Solutions implementation relies on the ecosystem(s) present in an area, it is important to understand where keystone or foundation species that form the ecosystem of interest currently exist and where they may persist in the future. Environmental suitability assessment, in combination with climate scenarios, can be used to identify such areas as long as key information on the environmental conditions that a foundation species needs is known.

## Key steps

1

**Identify the scale of assessment:** Environmental suitability assessments can be performed at different scales (e.g., local, regional, national), which have implications for data availability and processing. The spatial scale directly depends on the assessment purpose.

2

**Identify key environmental conditions:** It is critical to identify the key environmental conditions, and their indicators, that are required by or affect the foundation species forming a particular ecosystem. Indicators could include aspects such as depth, salinity, or sea surface temperature and these can be identified using existing evidence, expert judgement, and extrapolation methods.

3

**Collect and pre-process data:** The environmental suitability assessment spatially evaluates where suitable environmental conditions exist, presently and in the future, for the presence of a target species. Comparable data for selected key indicators are required for both baseline (present day) and future timeframes under different climate scenarios (e.g., RCPs). Data need to be pre-processed in order to obtain a consistent format to allow comparison and aggregation, e.g., same projection, spatial resolution, etc.

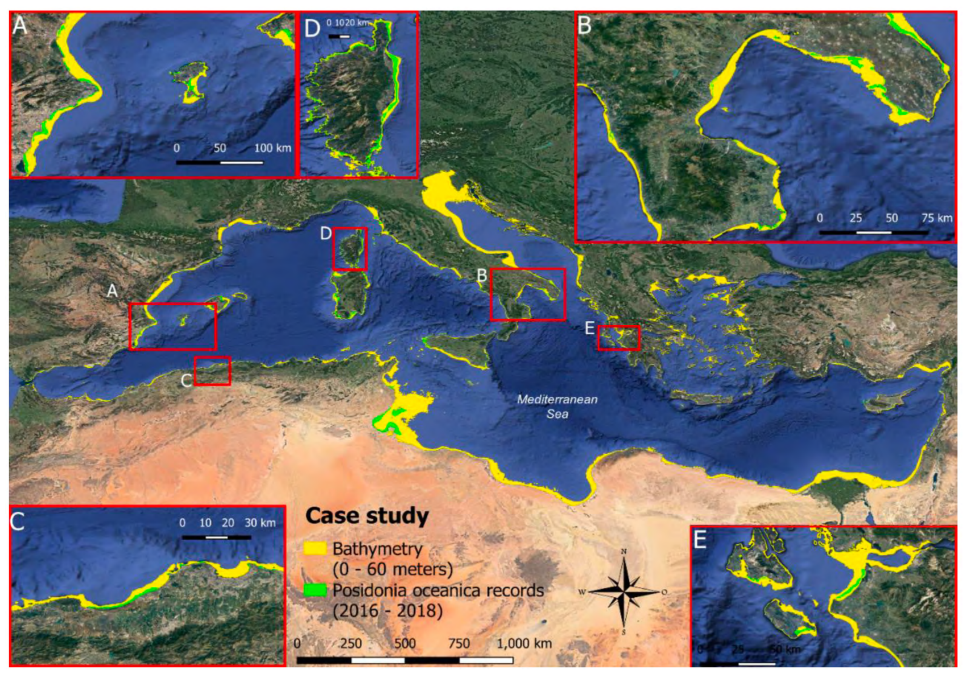
4

**Develop a suitability model:** To assess whether an area has suitable environmental conditions for an ecosystem of interest, various methods can be applied. Among the most common are species distribution models such as Maximum Entropy (MaxEnt) and GIS-based Analytic Hierarchy Process (AHP). Different methods may be applied depending on data availability and problem context.

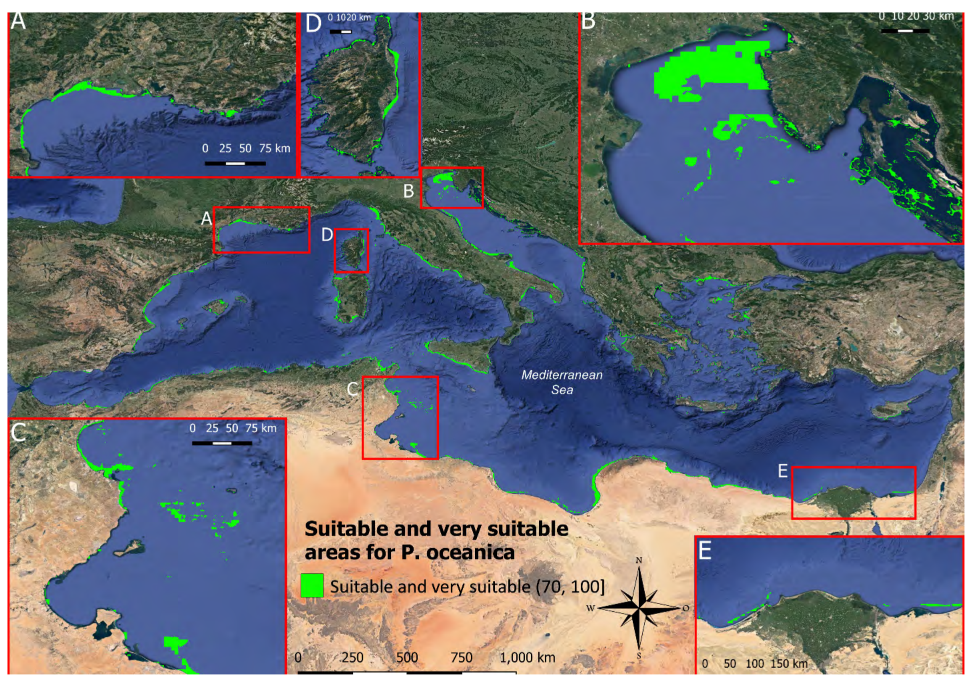
5

**Construct baseline and future suitability maps:** For both MaxEnt and GIS-based AHP modelling approaches, the final suitability maps can be created by extracting the intersecting suitable and very suitable areas as defined by the models under baseline and future scenarios to support decision-makers in identifying the most suitable areas for the ecosystem of interest where interventions can be implemented.

## Application to the Mediterranean eco-region

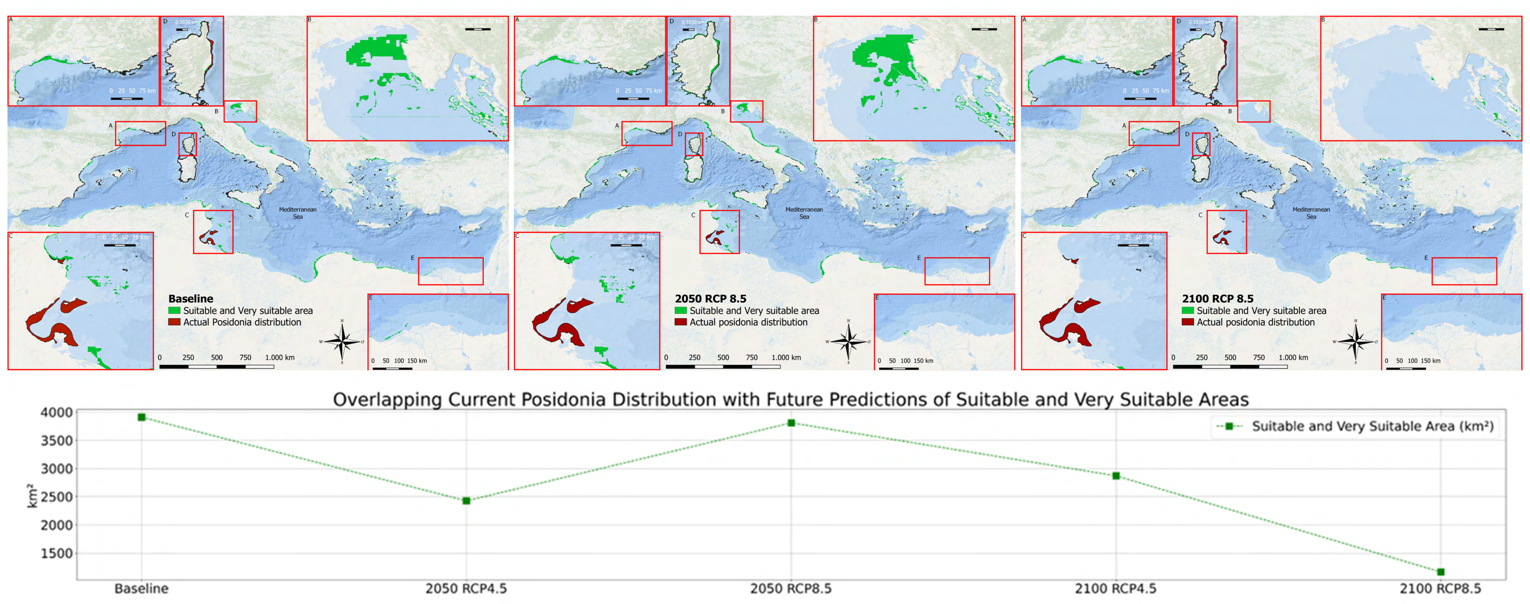



Suitable and very suitable areas intersected for the baseline analysis




Suitable and very suitable areas intersected for future scenarios analysis

The figure showcases a suitability map calculated with the GIS-based AHP approach based on data from 2016-2018 for geomorphology, water quality, and climate indicator groups for *Posidonia oceanica* in the Mediterranean Sea (A: western Mediterranean; B: Northern Adriatic; C: Gulf of Gabès; D: western Corsica; E: Egyptian coasts).

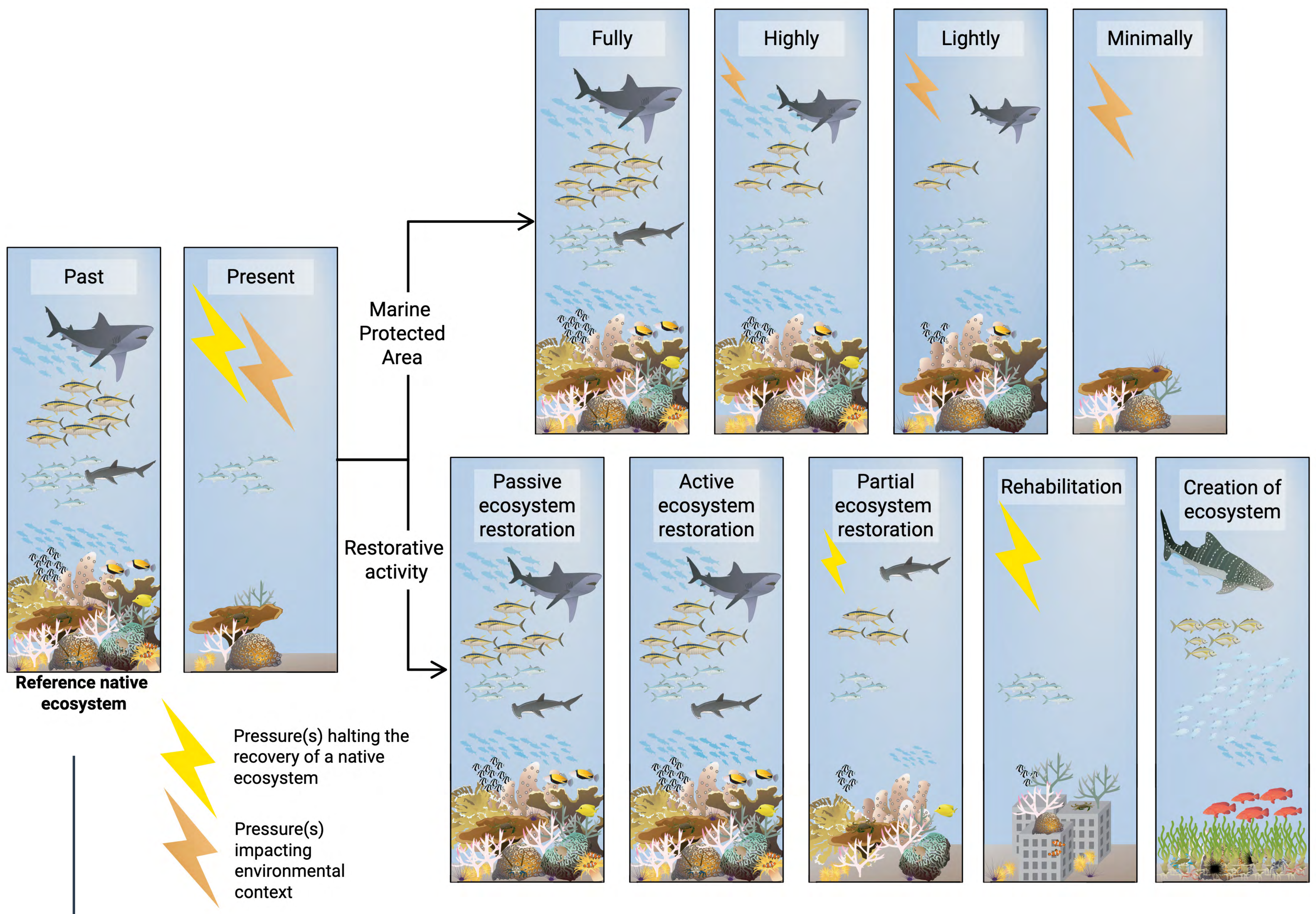



The figure showcases Overlapped maps with the combined suitable and very suitable class areas with the current distribution of P. oceanica (top panel) and line plot (bottom panel) for the area changes comparing the baseline to future scenarios (2050 RCP 4.5, 2050 RCP 8.5, 2100 RCP4.5, and 2100 RCP 85).

# **PBI-SUPPORT:** POTENTIAL BLUE INTERVENTIONS SUPPORT TOOL

**There is growing international interest in Nature-based Solutions (NBS) for addressing global societal challenges, including biodiversity loss and climate change. Implementation of blue NBS has been slow compared with urban and terrestrial NBS despite the importance of marine and coastal ecosystems for people and nature and the numerous threats they face that NBS can address. A major challenge to blue NBS implementation is the lack of an integrated framework to guide decision-makers and practitioners through the initial planning stages.**

## Subset of the blue NbS portfolio




## Step-by-step approch

To help facilitate and improve the decision-making process for practitioners on the potential applicability of blue NBS, MaCoBioS developed PBI-Support (Potential Blue Interventions Support), a tool that uses an evidence-based approach to integrate relationships among societal challenges, ecosystem services, environmental context, and ecosystem-based management approaches (protection, restorative activities, and other management measures) to identify appropriate blue NBS. PBI-Support takes the following step-by-step approach:

**1 CHALLENGE ORIENTATION**

Ascertain the societal challenge(s) to be addressed by the implemented intervention.

**2 ECOYSTEM SERVICES**

Understand the ecosystem services and the underlying biodiversity and ecological functions that contribute to resolving the societal challenge(s).

**3 ENVIRONMENTAL CONTEXT**

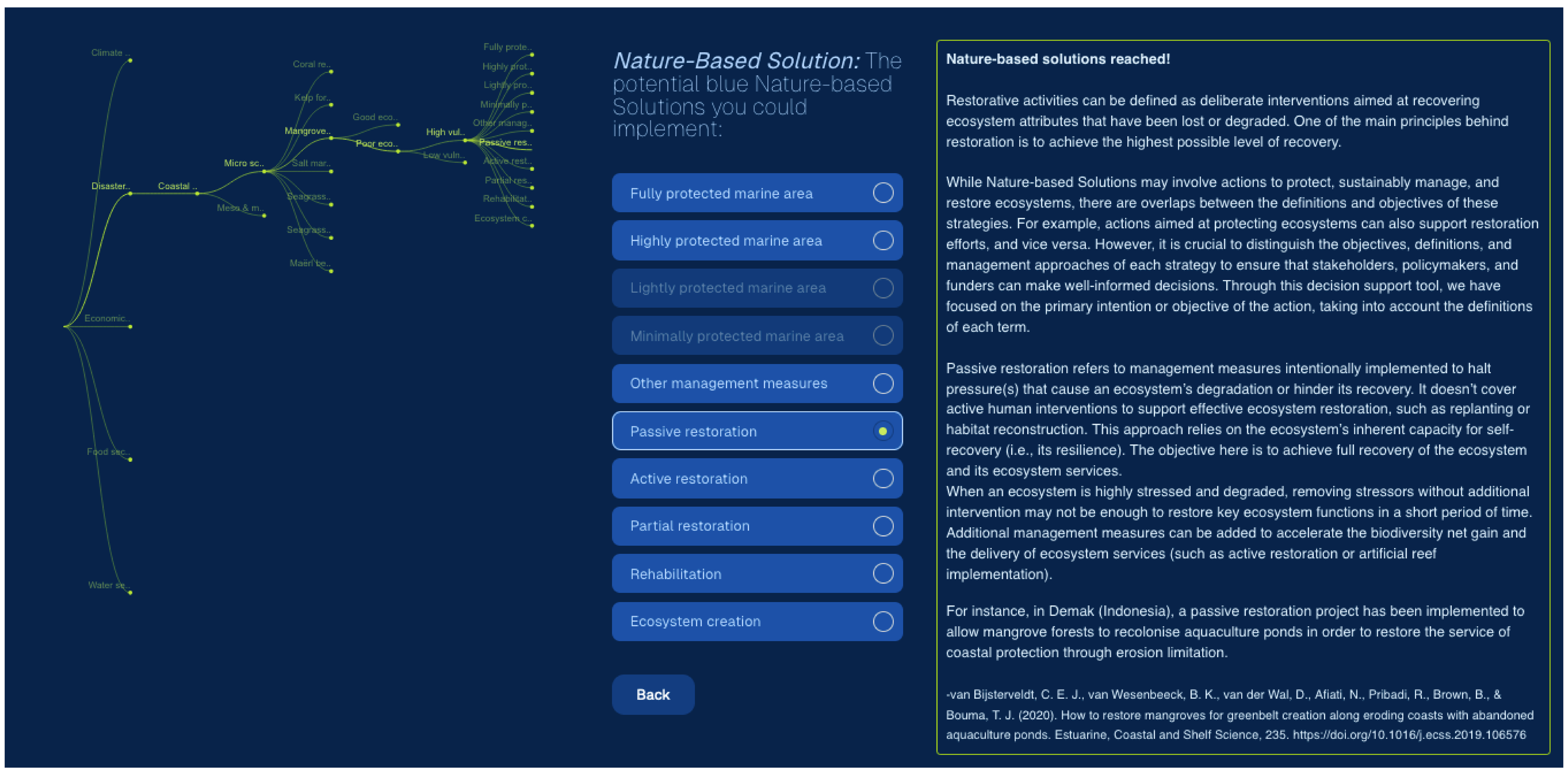
Identify the available and potential ecosystem(s) able to deliver these services within a relevant spatial scale level and assess the environmental context through vulnerability and ecological condition.

**4 INTERVENTION OPTIONS**

Characterise and understand the portfolio of blue NbS to reach the desire environmental context: protection, restorative activities, and other management measures

## Decision tree

To identify each potential intervention in each specific environmental context, we have further developed PBI-Support into an interactive decision tree



# **BIODIVERSITY** DATA COLLECTION METHODS

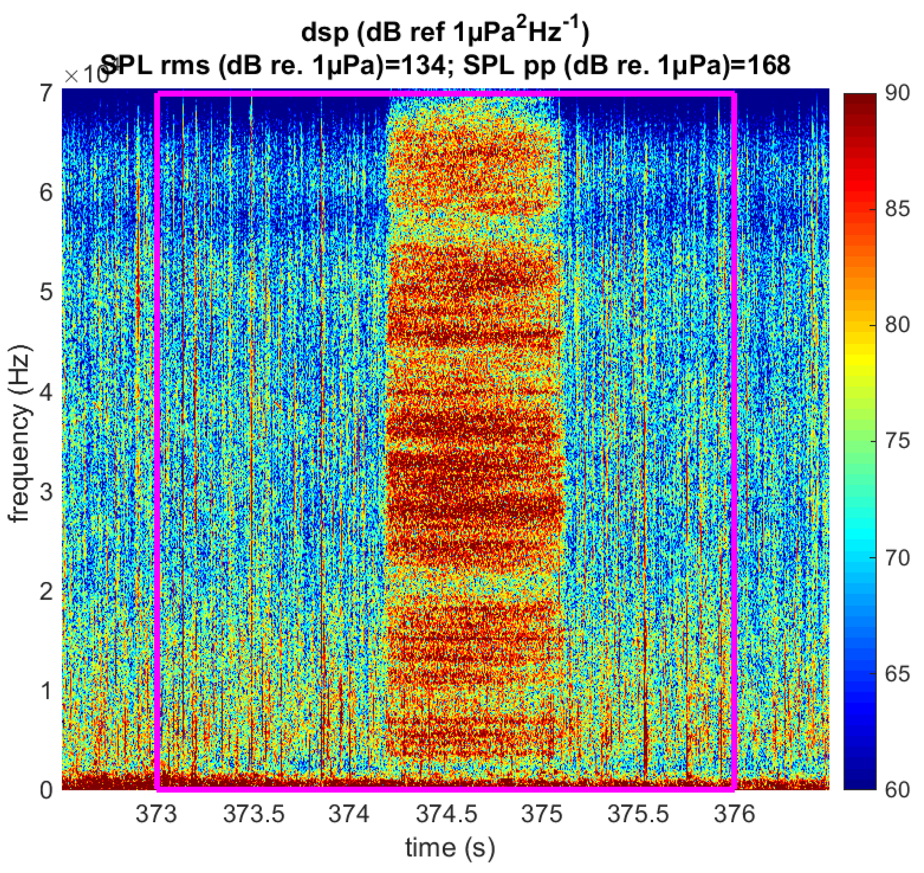
**Each of the following monitoring methods can provide a range of information depending on the study objective, the availability of reference data or the users' methodological knowledge.**

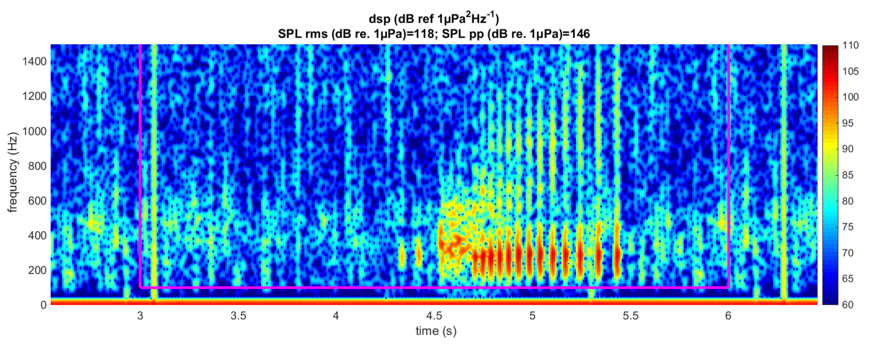
## Visual census

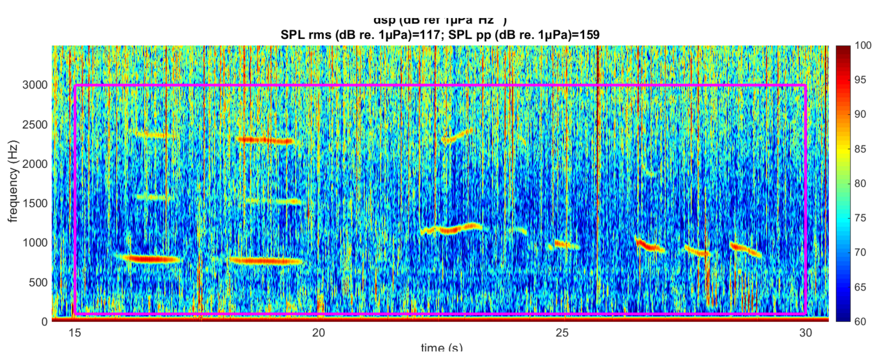
Relies on direct visual observations, photos and videos. A widespread monitoring technique, useful for direct observations of species abundance, distribution and behaviour. As a result, there is a considerable amount of historical data.

## Bioacoustics

Bioacoustics or passive acoustic monitoring (PAM) consists of recording sounds emitted underwater. Results are directly used as indicators of biophony or anthropophony noise. Only organisms that make noise from vocalisations, movement, or feeding can be detected with PAM, leaving a few organisms undetectable.





## eDNA

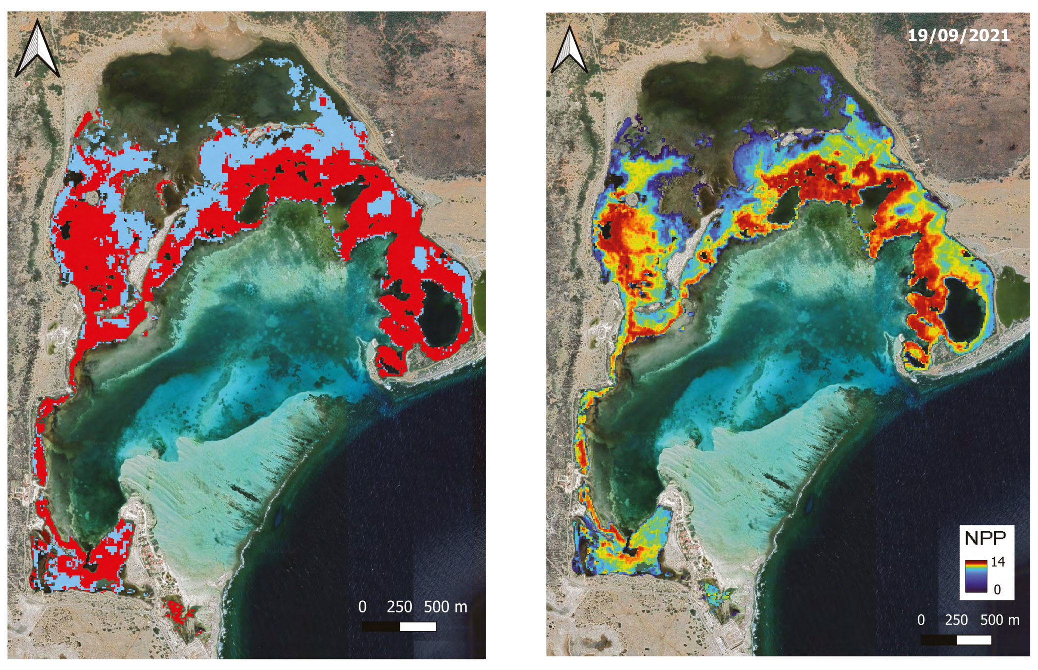
Environmental DNA (eDNA) is a method that consists of collecting traces of DNA material left in the water or the soil by organisms. It is a useful method for the detection of rare, cryptic or wary species. It is also valuable to detect early on the arrival of exotic or alien species on a new site.

## Aerial drone

Aerial drones can carry specific equipment, mainly optical, such as hyperspectral cameras. It is an efficient and easy-to-deploy method for assessing habitat distribution in coastal and shallow marine environments.

## Satellite

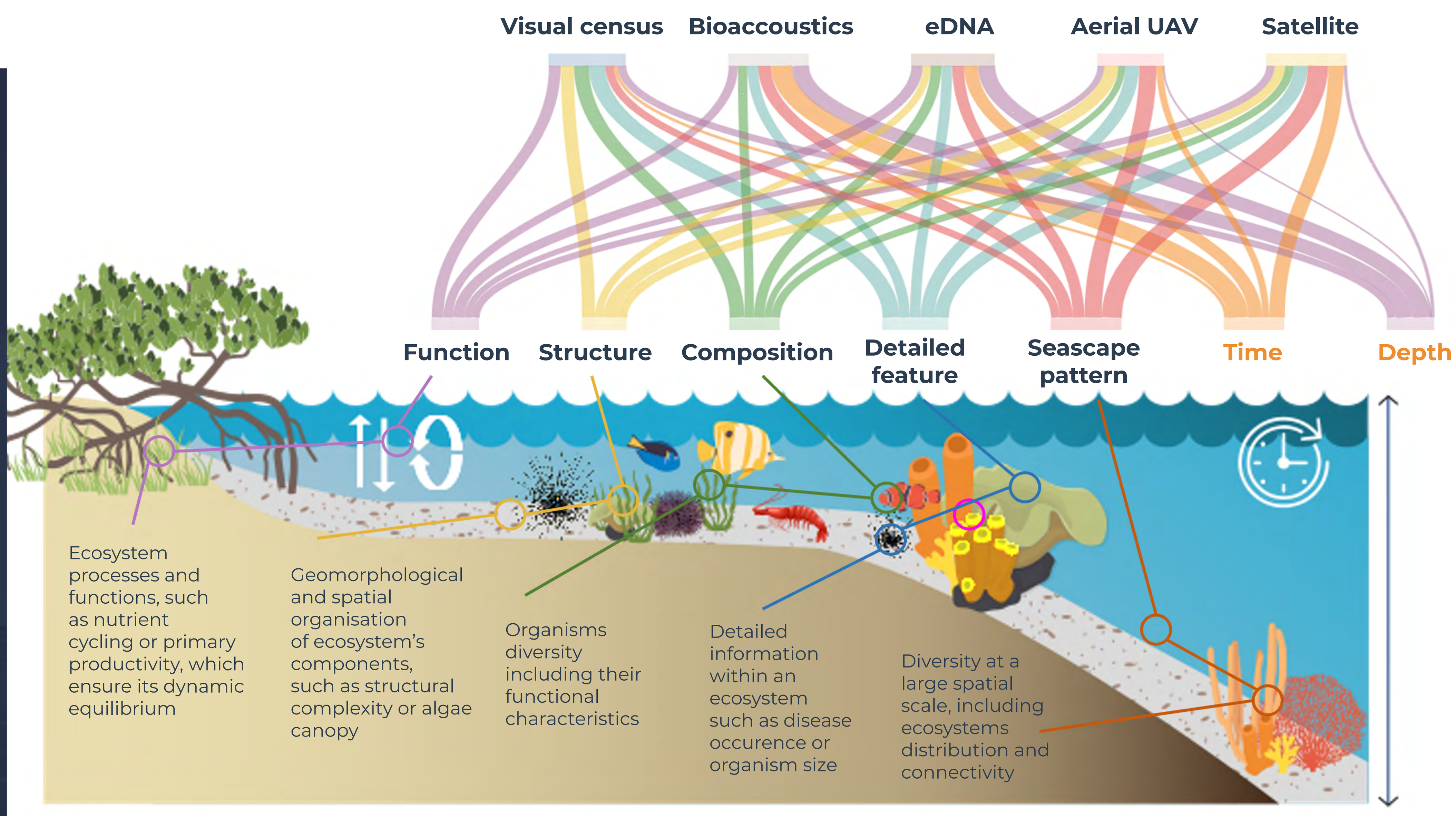
Satellites can provide a large amount of data on the biology, geomorphology, physics and chemistry of an area. It is a powerful tool to monitor coastal and shallow marin habitats over large spatial and temporal scales.




Net Primary Productivity (NPP) values (g Cm -2 d-1) of Lac Bay mangrove forests at the end of the dry season (left); and thematic map of the distribution of the black mangrove Avicennia germinans (in blue) and the red mangrove Rhizophora mangle (in red) in Lac Bay derived from the Sentinel-2 image (right).
Source (with permission): Casal et al. (2024)

**These different approaches allow for assessing different biological compartments and facets of biodiversity, each with their own strengths and limitations. Combining different methods could bring the most out of them, providing more robust indicators of biodiversity or ecosystems' condition.**

**For ethical reasons, scientists and practitioners should choose, whenever possible, non-extractive tools to monitor nature-based solutions, including to assess biodiversity. Combining methods further allows for assessing different facets of biodiversity and gaining a more holistic view.**



# NATURE-BASED SOLUTIONS IN THE FRAME OF FISHERIES: THE VALUE OF MULTI-ACTOR KNOWLEDGE

Climate change's impact on tropical fisheries threatens the livelihoods and food security of people relying on tropical fisheries. Societies feel the impact of climate change through the alteration of marine biodiversity, affecting fishery catches. Adaptation is taking place worldwide, yet evidence of loss and damage keeps increasing.

Nature-based solutions (NBS) are framed as solutions for marine conservation and sustainability. NBS calls for a people-centric approach that recognises, as a first step, the lived experiences of those at the forefront (fisher's) of climate change, and the understanding of the problem from the perspectives of multiple actors in fisheries.

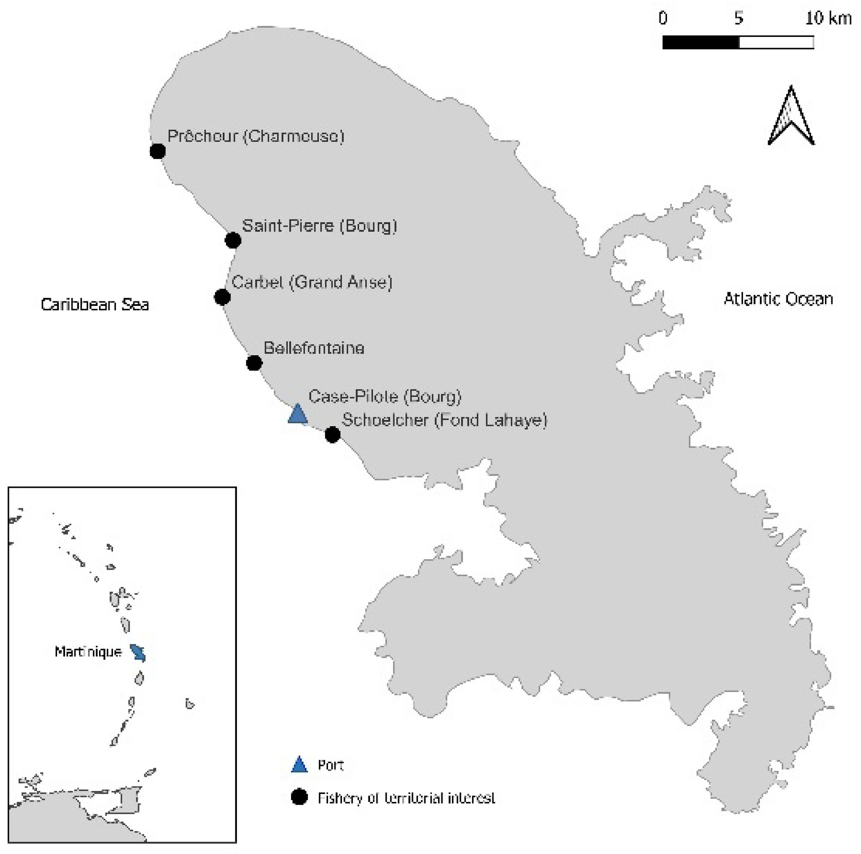
In the context of climate change, this study found that there are tensions (e.g., recognition of lived experiences and knowledge) and trade-offs (e.g., climate, pollution and biodiversity) through fishers and other actors' narratives. NBS appears to overcome those tensions and trade-offs by bringing all stakeholders together for effective and fair climate action and sustainable fisheries management.

## Stakeholders

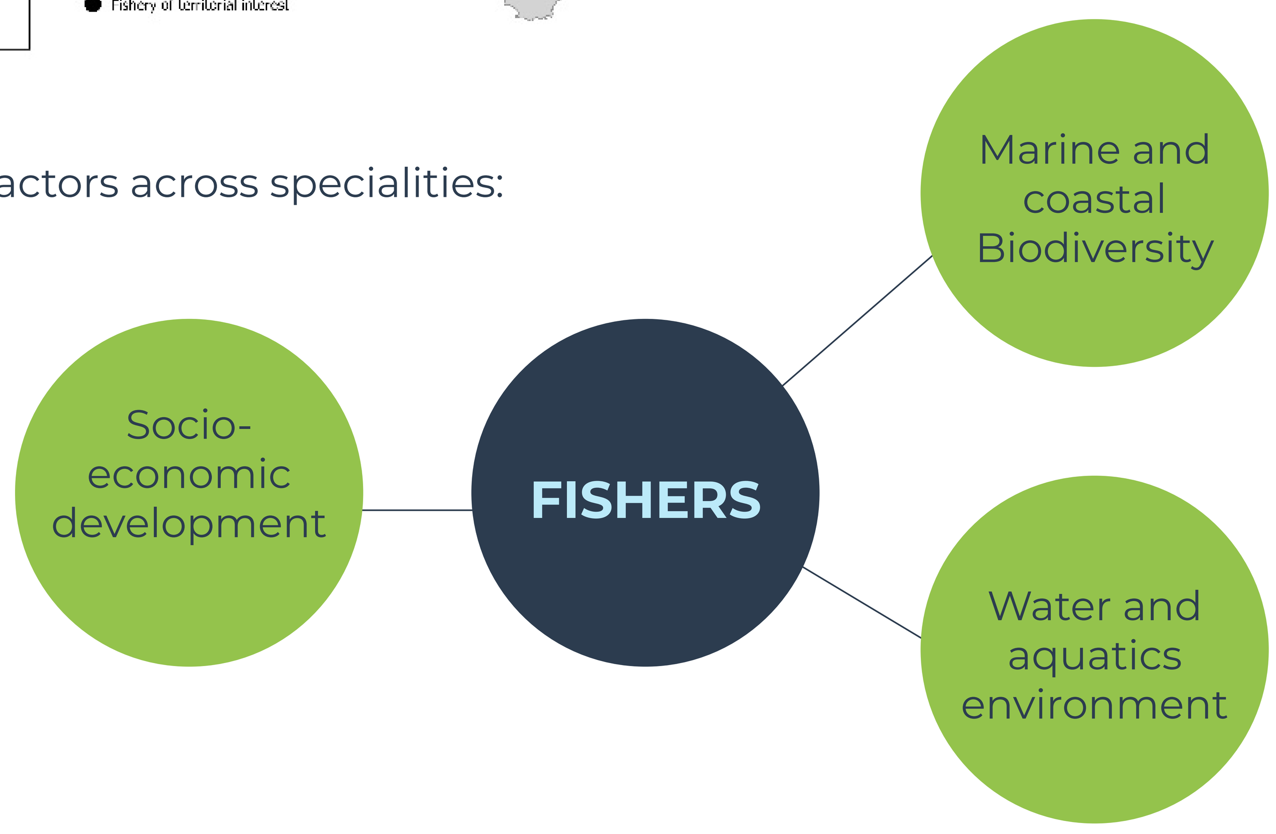
This study primarily draws from fisher's situated knowledge, and secondly from the perspectives of other actors working in different areas in the context of fisheries.

## Case study: Martinique (French West Indies)

Location map of study areas:




Fisheries actors across specialities:




## Results

Challenges and conditions from stakeholders to ensure NBS success in the context of climate change.

### MAIN CHALLENGES

- Biodiversity loss (nature and extent)
- Disentanglement of drivers of loss (climatic and non-climatic), and establishment of simultaneous actions to address those drivers
- Institutional structures
- Who and what structures to support climate actions in fisheries? (synergies, coordination)

### CRITICAL CONSIDERATIONS FOR NBS SUCCESS

- Increase data availability in fisheries (biological, socio-economic, environmental, cultural)
- Recognition of local knowledges, and anterior forms of NBS available before the concept establishment in science and policy

## CONCLUSION

**Multi-actor perspectives from stakeholders are critical to understand the multi-faceted impacts of climate change and biodiversity loss in society.**

**Blue NBS requires inclusive policies, knowledge sharing and capacity building among stakeholders. Practically, it calls for a proactive engagement in synergies, collaborations, and recognition of multiple ways of knowing.**

# BLUE NATURE-BASED SOLUTIONS

## – FOUR INSIGHTS FOR EUROPEAN POLICY

1.

## Innovating with nature and people: insights and recommendations for integrated design of blue Nature-based Solutions

Situate blue NBS in local contexts and recognise spatial and temporal scales for multiple benefits of blue NBS.

Understand spatial dynamics and address the underlying drivers of negative change across a larger spatial area and over time.

Implementing interventions before substantial ecosystem degradation is a more cost-effective option.

Successful restorative activities must account for long-term social and ecological dynamics.

Enhance communication among various stakeholder groups and invest in education and awareness.

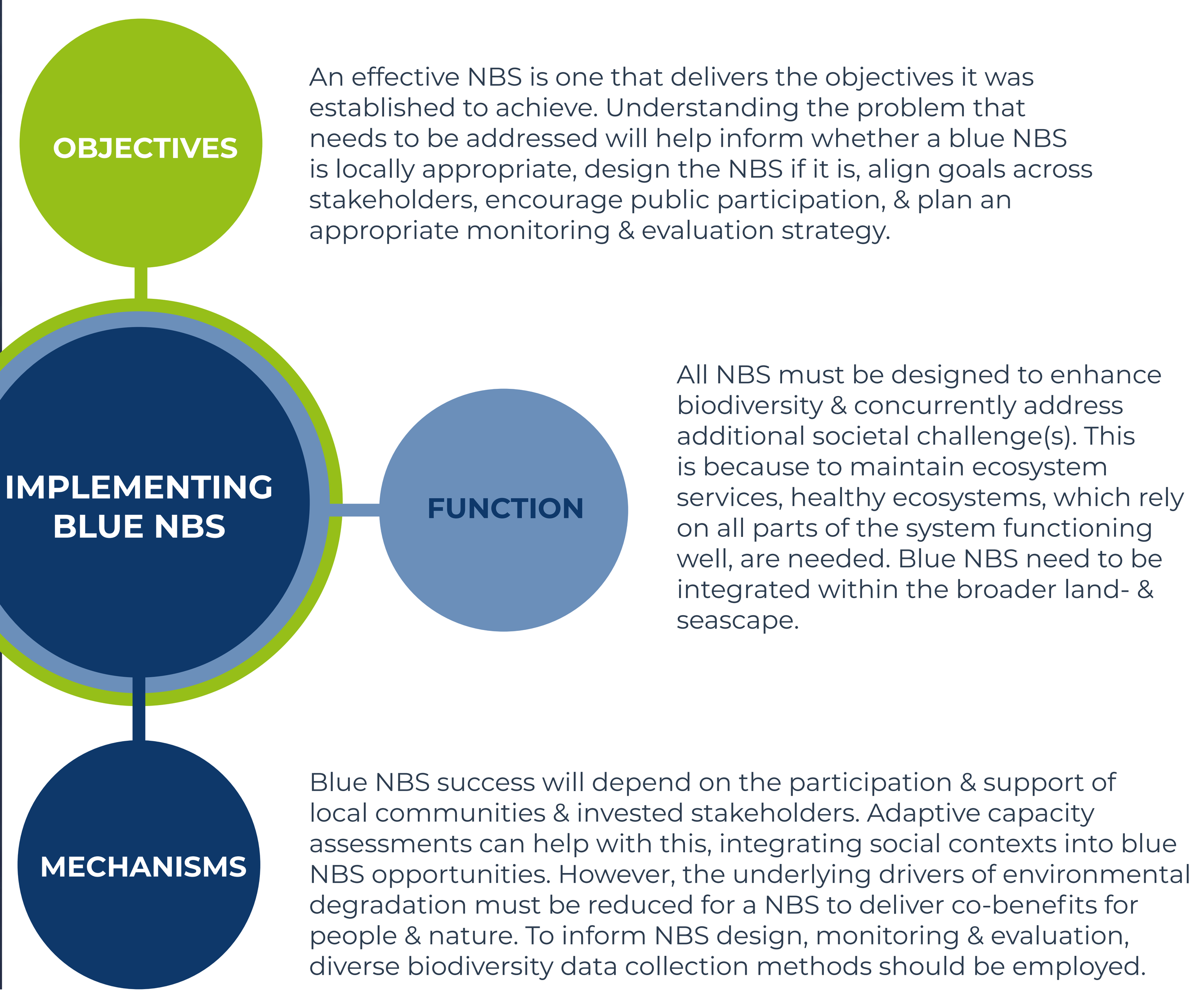
2.

## Implementing blue Nature-based Solutions to tackle climate change and biodiversity loss and improve human health and wellbeing

Encourage blue NBS that embed stakeholders in the project cycle and combine top-down and bottom-up approaches, developing partnerships and responding to local needs.

Ensure blue NBS are implemented with clear, unambiguous, desirable, viable, feasible and complementary objectives that can be measured with suitable indicators.

Require blue NBS to have a long-term continuous monitoring and evaluation strategy that employs diverse data collection methods.
Integrate blue NBS into land- and seascape planning, recognising the impacts of land use on marine and coastal ecosystems and opportunities for synergies in management.




Key aspects that should be considered at all stages of blue NBS implementation.

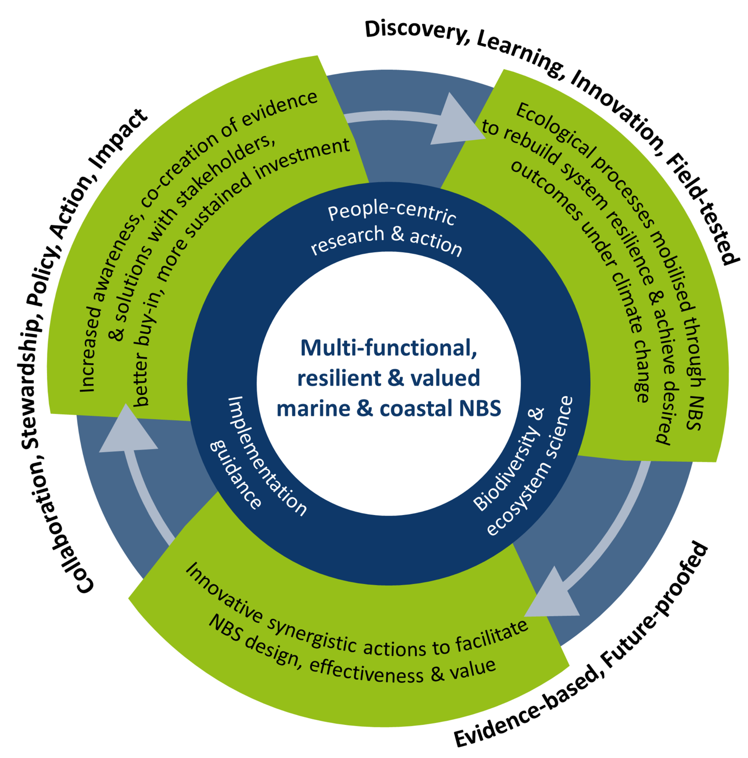
3.

## Research orientations for blue Nature-based Solutions

Promote comprehensive, interdisciplinary research and co-creation to enhance actionable science for blue NBS.

Embed blue NBS in research funding programmes beyond traditional biodiversity topics and support interdisciplinary and intersectoral collaborations.

Encourage research that takes an integrated land- and seascape approach reflecting the interconnected social-ecological systems blue NBS operate within.




Research priorities for advancing understanding and informing the implementation of multi-functional, resilient, and valued marine and coastal NBS. Source (with permission): O'Leary et al. 2023

4.

## Enhancing uptake of blue Nature-based Solutions in European marine and coastal-related policies

There is a need for mainstreaming blue NBS into decision-making processes and in policy frameworks, which then translate into adequate regulations.

NBS should be automatically considered during policy design and formulation linked to marine and coastal environments.

The integration of blue NBS in marine and coastal governance and policies through evaluation and impact assessment allows for a multi-dimensional analysis of their costs and benefits, which is regularly asked by many public and private stakeholders.

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## OUR WEBSITE

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement N° 869710