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Barcelona Convention

SPA/RAC

ASSESSMENT OF NATURE-BASED TECHNICAL SOLUTIONS TO PREVENT OR REDUCE THE IMPACT OF CLIMATE CHANGE ON COASTAL AND MARINE ECOSYSTEMS AND INCREASE THEIR RESILIENCE IN THE MEDITERRANEAN REGION

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ACRONYM LIST

CBD	Convention on Biological Diversity
COP	Conference of the Parties of the Barcelona Convention
CRF	Common Regional Framework
DRM	Disaster Risk Management
EbA	Ecosystem-based Adaptation
EbM	Ecosystem-based Management
Eco-DRR	Ecosystem-based Disaster Risk Reduction
EFH	Essential Fish Habitats
FRA	Fisheries Restricted Area
GEF	Global Environment Facilities
GES	Good Environmental Status
GFCM	General Fisheries Commission for the Mediterranean
ICZM	Integrated Coastal Zone Management
IMAP	Integrated Monitoring and Assessment Programme
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources
MAP	Mediterranean Action Plan
MBPC	Interregional Mediterranean Biodiversity Protection Community
MCPA	Marine and Coastal Protected Area
MedECC	Mediterranean Experts on Climate and environmental Change
MHW	Marine Heat Waves
MME	Mass Mortality Events
MPA	Marine Protected Area
MSP	Maritime Special Planning
MSSD	Marine Strategy for Sustainable Development
NbS	Nature-based Solutions
NbS/CCI/CME	Nature-based Solutions to prevent and reduce climate change impacts on coastal and marine ecosystems
NIS	Non-Indigenous Species

OECD	Organization for Economic Co-operation and Development
Post-2020 SAPBIO	Post-2020 Strategic Action Programme for the conservation of BIOdiversity and sustainable management of natural resources in the Mediterranean region
RCCAF	Regional Climate Change Adaptation Framework for Mediterranean marine and coastal areas
RCP	Representative Concentration Pathway
SCCF	Special Climate Change Fund
SLR	Sea Level Rise
SPA/BD Protocol	Protocol on Specially Protected Areas and Biological Diversity (Barcelona Convention)
SPA/RAC	Specially Protected Areas /Regional Activity Centre
SST	Sea Surface Temperature
SUDS	Sustainable Urban Drainage System
UfM	Union for the Mediterranean
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNEP-MAP	United Nations Environment Programme – Mediterranean Action Plan

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EXECUTIVE SUMMARY

Marine and coastal ecosystems provide direct and indirect ecosystem services to human societies, including food security and livelihood for millions of people, supporting tourism and recreation, contributing to coastal protection, wastewater treatment and climate change mitigation.

Climate change is one of the most critical challenges that the Mediterranean region is currently facing, with Mediterranean marine and coastal ecosystems bearing major climate-driven pressures and threats such as Sea Level Rise (SLR), sea and air warming including increase frequency of heatwaves, increase in intensity and frequency of extreme climatic events (floods, storms, droughts) and coastal erosion. These impacts, exacerbated by other anthropogenic pressures, deteriorate marine and coastal ecosystems and ecosystem services, and threaten human societies and infrastructures.

The risk of irreversible climate change impacts on human and natural systems is high, underscoring the urgent need for effective and efficient strategies to prevent and reduce these impacts.

Nature-based Solutions (NbS) are actions based on natural processes of ecosystems to tackle societal challenges by producing benefits for ecosystems and their biodiversity, and by supporting the delivery of a range of ecosystem services. NbS are based on protection/conservation, restoration and sustainable management actions. Well planned and implemented NbS are adaptable, sustainable, profitable to both ecosystems and society, and capable of preventing and reducing climate change impacts. They are referred to as low or no regret solutions with minimised potential negative outcomes and costs. Therefore, NbS can be adequate solutions to prevent and reduce climate change impacts on coastal and marine ecosystems and societies.

This report focuses on Nature-based Solution to prevent and reduce Climate Change Impacts on Marine and Coastal Ecosystems (NbS/CCI/CME) and enhance ecosystem resilience in the Mediterranean region.

The assessment identifies several barriers to widespread implementation of NbS/CCI/CME in the Mediterranean region. These include the lack of common understanding, language and implementation process which currently hamper institutional and political adoption; insufficient data and ecological knowledge to support informed decisions; challenging stakeholder engagement; and institutional constraints. In addition, NbS initiatives are frequently funded through short- or medium-term projects, limiting the ability to evaluate their effectiveness.

To support broader integration of NbS/CCI/CME across the Mediterranean region, this document presents findings from the assessment, outlines a practical step-by-step framework for NbS assessment, highlights best practices and common challenges, and provides actionable recommendations for NbS integration in climate change adaptation strategies. Results include outcomes from the regional training workshop on Nature-based Solutions to reduce climate change impacts on coastal and marine ecosystems held in Gökova, Türkiye, on December 9th 2025 organised back-to-back to climate change adaptation strategies workshop (Appendix 2. Workshop on Nature-based Solutions to prevent and reduce climate change impacts on coastal and marine ecosystems and enhance their resilience).

CONTEXT, RATIONAL AND OBJECTIVE OF THE ASSESSMENT

Within the framework of the United Nations Environment Programme/Mediterranean Action Plan (UNEP/MAP) and the Specially Protected Areas and Biological Diversity Protocol (SPA/BD Protocol), the Specially Protected Areas Regional Activity Centre (SPA/RAC) and the Contracting Parties of the Barcelona Convention act to protect, preserve and manage sustainably the marine and coastal ecosystems and biological diversity in the Mediterranean.

Currently, the Mediterranean region is undergoing increasing climate change impacts and threats including rising of sea level, increased frequency of extreme weather events, increase of sea temperature, and reduction of fresh water inputs which contribute to ecosystem degradation and loss of ecosystem services.

For the 2024-2025 biennium, in application of the Post-2020 SAPBIO and the UNEP/MAP Mid-Term Strategy (2022-2027), the Contracting Parties to Barcelona Convention requested SPA/RAC during the CoP 23 (Portorož, Slovenia, 5-8 December 2023) to conduct an assessment of nature-based technical solutions to prevent or reduce the impacts of climate change on coastal and marine ecosystems and to enhance their resilience. In addition, a regional training workshop was organised back-to-back with the workshop on climate change adaptation strategies for coastal and marine ecosystems in Gökova, Türkiye (December 9-12, 2025) (see Workshop report UNEP/MAP-SPA/RAC, 2025).

This document is in line with the Marine Strategy for Sustainable Development (MSSD) 2026-2035 and the upcoming Regional Climate Change Adaptation Framework for Mediterranean Marine and Coastal Areas (RCCAF) 2026-2035.

[1] Strategic direction 1.6 "Strengthening national and local capacities on the application of nature-based solutions for climate change adaptation and mitigation"

INTRODUCTION

The Mediterranean Sea is the largest (2 522 000 km^2) and deepest (average 1460 m, maximum 5267 m) enclosed sea in the world. (Piroddi *et al*. 2020). Its coastline is approximatively 46,000 km long of which 54 % is rocky and 46 % is sandy coast (UNEP/MAP, 2012). It is recognized as an area of exceptional biodiversity with around 20% of endemic species (Coll *et al*., 2010). Its marine and coastal ecosystems are highly valued and diverse. They include rocky and sandy shores, coastal plains, lagoons, estuaries, wetlands and transitional areas, seagrass meadows, coralligenous areas, deep sea benthic systems such as seamounts, canyons, cold-water coral reefs and pelagic systems (UNEP/MAP, 2012).

In the Mediterranean Sea, marine and coastal environments and ecosystems are particularly subject to **anthropogenic pressures** such as pollution, over-exploitation, increased coastal artificialisation and climate change impacts (MedECC, 2020a). **Climate change** is one of the most critical challenges that the Mediterranean region is currently facing (Briere Spiteri, 2022; United Nations Environment Programme, 2024), with Mediterranean marine and coastal ecosystems bearing major climatic driven threats (Hassoun *et al*., 2025; MedECC, 2020a). **Climate change impacts** include Sea Level Rise (SLR), sea and air warming including frequent heat waves, increase in intensity and frequency of extreme climatic events (floods, storms, droughts) and coastal erosion. These impacts deteriorate coastal ecosystems and their habitats, as well as ecosystem services and human infrastructures.

Marine and coastal ecosystems provide direct and indirect **ecosystem services** to human societies (Galeotti, 2020; UNEP/MAP, 2012), which include food security and livelihood for millions of people, supporting tourism and recreation, contributing to coastal protection, wastewater treatment and climate change mitigation[2] (Hassoun *et al*., 2025; UNEP/MAP, 2012).

Healthy marine and coastal ecosystems are able to provide numerous essential benefits to coastal populations. However, in the Mediterranean Sea these ecosystems are highly threatened by anthropogenic and climate change impacts, reducing consequently their ability to deliver ecosystem services. Mediterranean population well-being is dependent on marine and coastal ecosystems' health which currently undergos rapid environmental changes. The main drivers of these changes in the Mediterranean region are climate change, land and sea use changes, and non-indigenous species (MedECC, 2020b).

Efficient solutions to prevent or reduce the impacts of climate change on coastal and marine ecosystems are urgently needed; otherwise, the risk of irreversible impacts on human and natural systems is high, as stated by the Intergovernmental Panel on Climate Change (IPCC, 2022).

As opposed to technical engineering solutions or "grey" solutions, Nature-based Solutions (NbS) are built on the idea that natural processes can be used by human societies to provide solutions to environmental, ecological and societal challenges (Lehmann *et al*., 2025). However, NbS need time to be effective.

Nature-based Solutions, as defined at the 5th United Nations Environment Assembly (UNEA)

[2] Ecosystem services can be categorized in provisioning (e.g. food, water, raw materials), regulating (e.g. air and water purification, climate and natural hazard regulation, disease regulation), cultural (e.g. recreation, tourism, aesthetic values) and supporting services (e.g. nutrient cycles, soil formation, habitat) (Malinga *et al*., 2015; Millenium Ecosystem Assessment, 2005).

(March 2022) through the resolution UNEP/EA.5/Res.5, are: "*actions aimed at protecting, conserving, restoring, and sustainably managing natural or modified terrestrial, freshwater, coastal, and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits*". (see here https://www.unep.org/).

This report compiles the findings of the assessment on nature-based solutions[3] to prevent and reduce climate change impacts on coastal and marine ecosystems and the evaluation of their effectiveness in the Mediterranean region. Best practices are identified by documenting case studies from the Mediterranean region. Lessons learned, challenges and opportunities to scale-up NbS are discussed. Finally, a practical implementation framework is proposed and actionable recommendations are formulated for integrating NbS in adaptation strategies and policies to support their implementation. The document also includes inputs from the training workshop on Nature-based Solutions to prevent and reduce climate change impacts on coastal and marine ecosystems held in Gökova, Türkiye December 9th 2025.

[3] Including nature-based technical solutions, where the term« technical solution » is understood as "applied solution" as opposed to theoretical.

1. CLIMATE CHANGE AND ITS MAIN IMPACTS ON MEDITERRANEAN COASTAL AND MARINE ENVIRONMENT

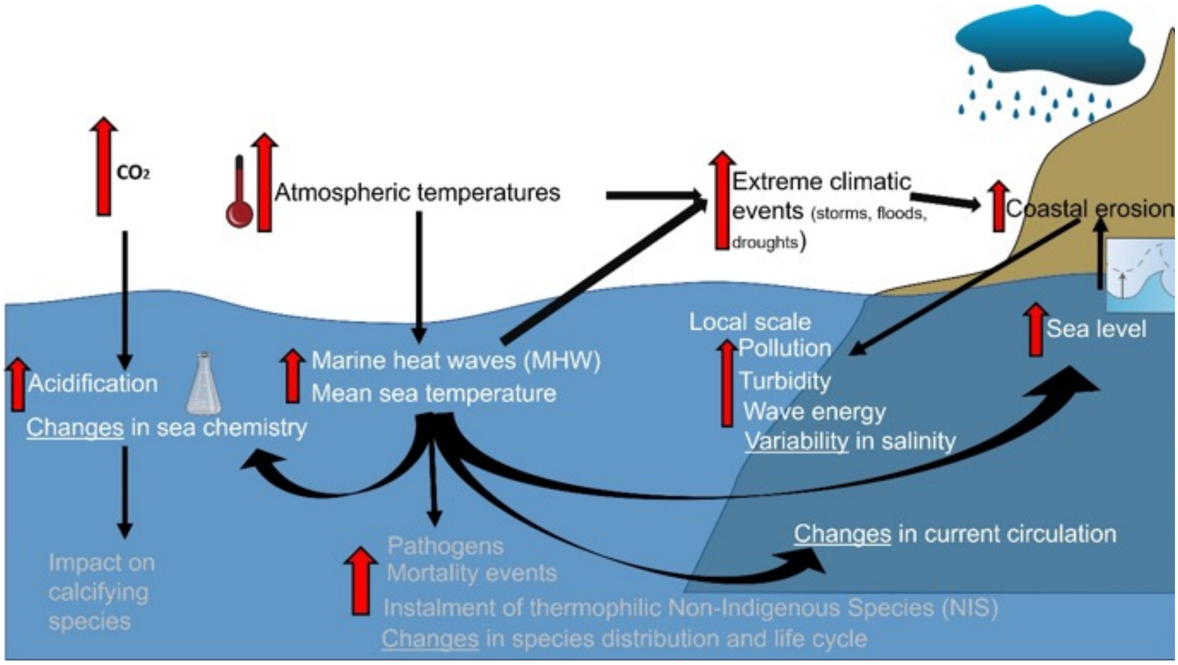


Figure 1.

Schematic illustration of climate change impacts on coastal marine environment.

Global warming is a human-induced phenomenon, mainly due to anthropogenic emissions of greenhouse gases (carbon dioxide, methane, nitrous oxide, CFCs and others). Emissions of carbon dioxide (CO_2) have become significantly more important, greater than what sea, trees, plants and other natural carbon sinks can naturally absorb. This results in an excess of greenhouse gases in the atmosphere which traps the heat and leads in a general increase in temperatures (IPCC, 2023). Global warming has various consequences on climatic processes, resulting in major and rapid changes in global climate. Moreover, these changes can be of greater intensity at the sub-regional scale (Knobler *et al.*, 2025; Lazoglou *et al.*, 2024).

In the Mediterranean basin, climate is changing the environment faster than at the global scale (MedECC, 2020a). Between 1982 and 2019, it has been estimated that Sea Surface Temperature (SST) in the Mediterranean Sea has increased over twice the global SST increase (Hassoun *et al.*, 2025). With high confidence, MedECC (2020a) predicts that future regional average warming will exceed the global mean value by 20% on an annual basis and by 50% in summer.

Climate change can directly affect coastal and marine environments (e.g. increase in sea temperature, acidification of the sea), or indirectly by impacting terrestrial environment (e.g. floods, droughts and storms) which in turn affect coastal and marine environment (Figure 1).

The consequences of climate change on the Mediterranean environment are transboundary (Briere Spiteri, 2022), but are not necessarily of similar intensity throughout the Mediterranean Sea due to different environmental conditions (MedECC, 2020a; MedECC, 2024) (see e.g. Sea Surface Temperatures Figure 2).

The main climate change impacts and threats on coastal and marine ecosystems at regional, sub-regional or local scale, are detailed hereafter.

Sea temperature

Mean annual sea temperature

Global warming has led to rising mean annual sea temperatures. In the Mediterranean Sea the accumulated warming for the Mediterranean Sea Surface Temperature (SST), between 1982 and 2019, has been estimated at 1.3 °C (Pastor *et al.*, 2020). The Mediterranean SST shows a spatially variable warming trend for 40 years, which is higher in the Eastern than the Western Mediterranean Bassin (Pastor *et al.*, 2020) as illustrated also in Figure 2 (map published by Copernicus). Increase in mean sea temperatures is also depth dependent, deep layers warm less than upper layers (Soto-Navarro *et al.*, 2020), therefore coastal ecosystems are more impacted than open marine ec osystems.

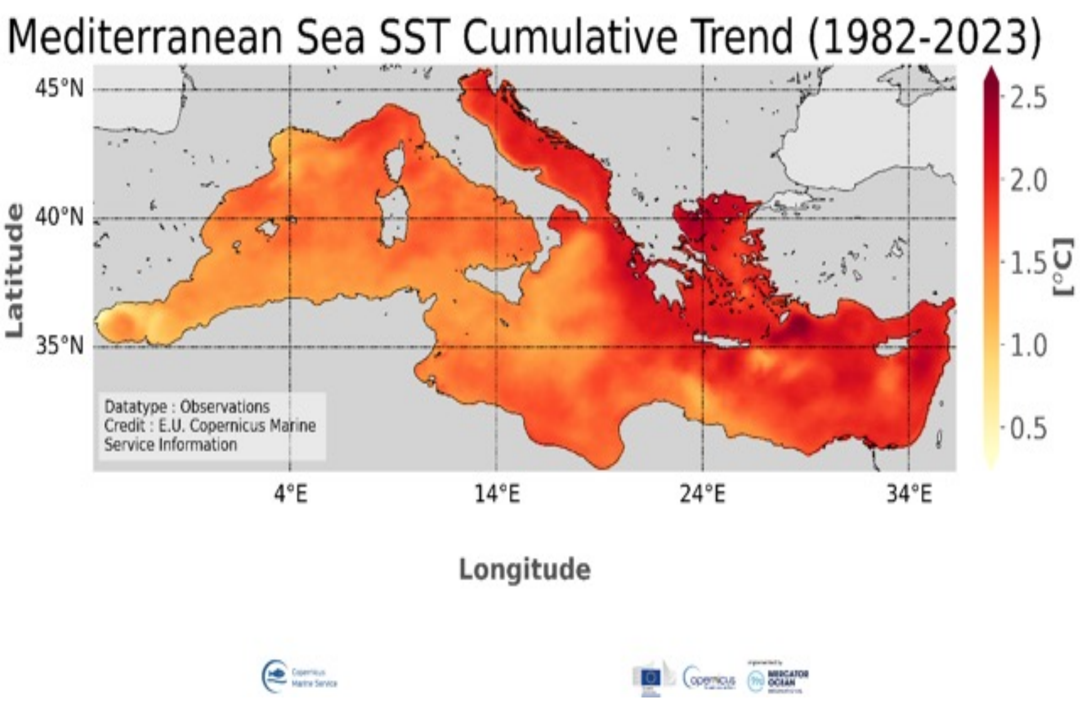


Figure 2.

Mediterranean Sea Surface Temperature (SST) cumulative trend map from Observations Reprocessing. Map E.U. Copernicus Marine. (EU Copernicus Marine Service Product, 2024)

[Source : https://data.marine.copernicus.eu/product/MEDSEA_OMI_TEMPSAL_sst_trend/description.](https://data.marine.copernicus.eu/product/MEDSEA_OMI_TEMPSAL_sst_trend/description)

Global warming has led to rising mean annual sea temperatures. In the Mediterranean Sea the accumulated warming for the Mediterranean Sea Surface Temperature (SST), between 1982 and 2019, has been estimated at 1.3 °C (Pastor *et al.*, 2020). The Mediterranean SST shows a spatially variable warming trend for 40 years, which is higher in the Eastern than the Western Mediterranean Bassin (Pastor *et al.*, 2020) as illustrated also in Figure 2 (map published by Copernicus). Increase in mean sea temperatures is also depth dependent, deep layers warm less than upper layers (Soto-Navarro *et al.*, 2020), therefore coastal ecosystems are more impacted than open marine ec osystems.

In the Mediterranean Sea, although it can be difficult to untangle the impacts of different drivers (e.g. overfishing, interactions with Non-Indigenous Species, sea warming), the increase in mean annual temperature seems to have already led to shifts in ecosystems' species composition and geographic distribution of species (e.g. Righi *et al.*, 2020 concerning the bearded fire worm). In consequence, fisheries are impacted by the increase of mean annual sea temperature affecting food security in the Mediterranean region. The degree of vulnerability of some commercial species and fisheries from different Mediterranean areas has been studied by various authors which predict a northward shifting of certain commercial species (e.g. Farahmand *et al.*, 2023; Panzeri *et al.*, 2024). Combined with Marine Heat Waves (MHW), sea warming has triggered changes in ecosystems by impacting for example structuring species with Mass Mortality Events (MME) in coralligenous ecosystems (Garrabou *et al.*, 2013, 2022).

Further, the increased temperature of the Mediterranean Sea has favoured the instalment of thermophilic Non-Indigenous Species (NIS) which in some cases become invasive, impacting ecosystems and ecosystem services (PAP/RAC, 2024).

Marine Heat Waves

Marine Heat Waves (MHW) are characterized by long periods of exceptionally warm temperatures of the sea. The complex relations of the drivers leading to MHW are still not well understood although certain favorable conditions leading to MHW in the Mediterranean Sea have been identified (Bonino *et al.*, 2025).

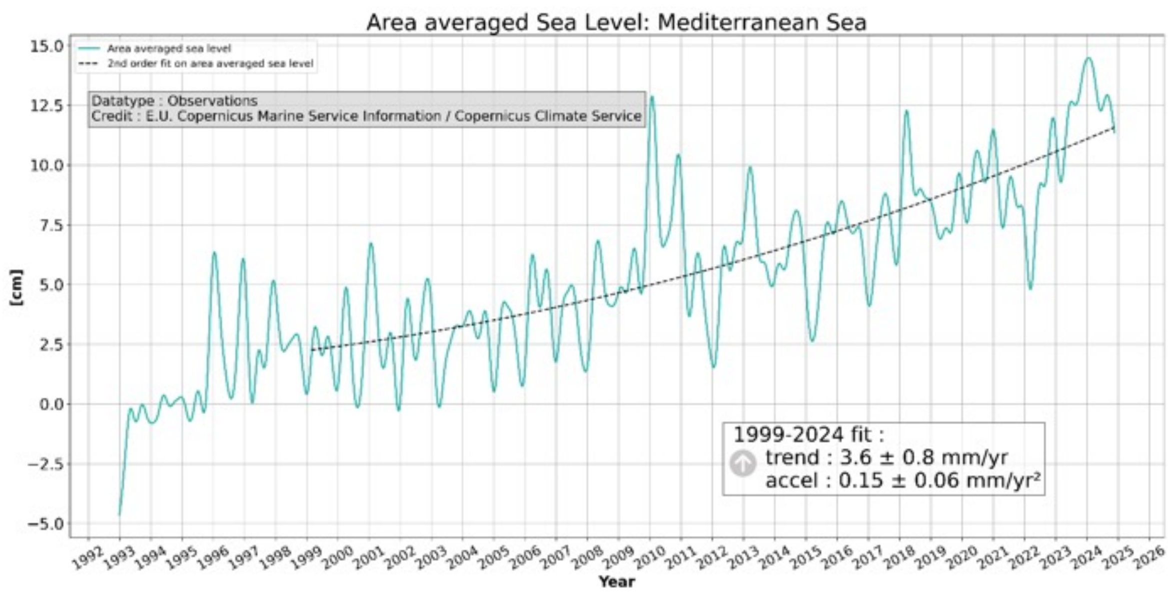
Hobday *et al.* (2016) highlight the importance of having a common definition with clear metrics of MHW and proposes to define a MHW as a warm period event that lasts for three or more days, with temperatures warmer than the 90th percentile based on historical baseline periods. However, in scientific literature, the definition of MHW varies depending in particular on whether the SST data used is detrended (which means that the upward trend of temperature be removed) or not, in order to differentiate the mean increase in temperature from the sudden temperature increase (see Amaya *et al.*, 2023; Darmaraki *et al.*, 2024; Martínez *et al.*, 2023). Nevertheless, several authors agree that the length, frequency and intensity of MHW in the Mediterranean Sea show an increasing trend (Darmaraki *et al.*, 2024).

The literature review published by Darmaraki *et al.* (2024) compiles information on MHW in the Mediterranean Sea and details the impacts on marine and coastal ecosystems. MHW in the Mediterranean can lead to Mass Mortality Events (MME) (e.g. Garrabou *et al.*, 2013; 2022), but because of concomitant impacts of sea temperature increase, the impact of MHW on the life cycle of species and the state of the ecosystems remains difficult to assess.

Annual mean sea warming, together with increasing frequency and intensity of MHW, clearly increase vulnerability of coastal and marine ecosystems by affecting their composition (e.g. biochemistry of coastal lagoons Palmas *et al.*, 2025) and functioning, and this is predicted to continue in the future (e.g; Corinaldesi *et al.*, 2022; Garrabou *et al.*, 2022; Hassoun *et al.*, 2025). Human activities are also directly threatened by warming sea and MHW, such as aquacultures which will have to adapt cultures during summer periods especially (Atalah *et al.*, 2025).

Sea Level Rise

Global warming melts glaciers and ice sheets, and increasing sea temperature expands sea volume which leads to an increasing trend of sea level (see Figure 3) and a consequent retreat of the coastline. The current rate of Sea Level Rise (SLR) in the Mediterranean Sea is estimated to 2.6±0.2 mm/yr on average for the period 1993-2015 by Marcos, Jorda & Le Cozannet, (2016). However, for the period 2013-2022 the global rising rate has been +4.68 mm/yr, twice as much as the rate in 1993-2002 (Cazenave and Moreira, 2022). Under the very high emission scenario (SSP4-8.5), global mean sea level is likely to rise by +0.63 to +1.01 m by 2100 relative to 1995-2014 (MedECC, 2024). In the Mediterranean Sea, Aral and Chang (2017) estimate that by 2100, SLR will attain 60 cm but with spatial variability.



Mediterranean Sea regional mean sea level daily evolution (in cm) over the period 1993/01/01 to 2024/11/19, based on satellite altimeter observations. The data is derived from the average of gridded sea level maps. This ocean monitoring indicator utilizes the DUACS delayed-time reprocessed dataset for climate applications (DT-2024). The sea level trend and acceleration are computed using the data after 1999/02/20 (i.e. after Topex-A period) and is visible on the plot with the dashed line (trend+acceleration).

Figure 3.

Mediterranean Sea Mean Sea Level time series and trend from Observations Reprocessing published by EU Copernicus Marine Service available here

Global warming melts glaciers and ice sheets, and increasing sea temperature expands sea volume which leads to an increasing trend of sea level (see Figure 3) and a consequent retreat of the coastline. The current rate of Sea Level Rise (SLR) in the Mediterranean Sea is estimated to 2.6±0.2 mm/yr on average for the period 1993-2015 by Marcos, Jorda & Le Cozannet, (2016). However, for the period 2013-2022 the global rising rate has been +4.68 mm/yr, twice as much as the rate in 1993-2002 (Cazenave and Moreira, 2022). Under the very high emission scenario (SSP4-8.5), global mean sea level is likely to rise by +0.63 to +1.01 m by 2100 relative to 1995-2014 (MedECC, 2024). In the Mediterranean Sea, Aral and Chang (2017) estimate that by 2100, SLR will attain 60 cm but with spatial variability.

Coastal ecosystems, and species using coastal habitats in their life cycle (e.g. marine turtles which need sandy beaches to nest), are under high threat from SLR.

Further, SLR increases coastal erosion and the frequency and intensity of coastal floods particularly in deltas, lagoons and other coastal wetlands (Hassoun *et al.*, 2025; MedECC, 2020a). Combined with the increase in extreme climatic events, it affects not only coastal ecosystems but also human infrastructures and coastal communities (Hassoun *et al.*, 2025). About 15 large Mediterranean cities are at risk of flooding unless further adaptation is undertaken (Hallegatte *et al.*, 2013; Hanson *et al.*, 2011; UNEP/MAP and Plan Bleu, 2020). Coastal marshes (a type of Mediterranean coastal wetland[4]) are projected to lose 8 to 92% of their current extent by 2100 depending on the area and the climate mitigation scenario (Schuerch *et al.*, 2025).

In parallel, SLR, combined with over-use of ground water and increased droughts, will intensify saltwater intrusions in coastal aquifers and severely deteriorate them (see Ibrahim *et al.*, 2025 and references therein).

Acidification of the sea

Oceans and seas absorb a large proportion of atmospheric CO_2 and are therefore considered as CO_2 sinks. Approximately 30% of the anthropogenic CO_2 is absorbed by the oceans (https://www.noaa.gov/). Studies reveal that anthropogenic CO_2 absorbed by the oceans has increased as a consequence of the atmospheric CO_2 increase (Gruber *et al.*, 2019; https://www.noaa.gov/). Water molecules and CO_2 combine in the sea and changes its chemistry resulting in an increased acidity (pH decreases). Acidification of the Mediterranean Sea is variable in depth, space and shows seasonal variability (García-Ibáñez *et al.*, 2024; Hassoun *et al.*, 2015).

Increase of sea temperature impacts in a more immediate way ecosystems and ecosystem services than the acidification of the Mediterranean Sea. However, it is predicted that acidification and the combination of these two stressors, will lead to significant direct and indirect impacts on ecosystems and societies (e.g. relative to seagrass Ravaglioli *et al.*, 2024; Galdies *et al.*, 2021; Zunino *et al.*, 2019; 2021).

More specifically, it is projected that acidification will impact marine trophic chains by affecting calcification processes in plankton (MedECC, 2020a; Fox *et al.*, 2020), corals (Carbonne *et al.*, 2022; Cerrano *et al.*, 2013), bivalves (Gazeau *et al.*, 2014) and coralline red algae, consequently impacting fisheries (Zunino *et al.*, 2021).

[4] In this document, the term coastal wetland includes delta, coastal lagoons, marshes (salty or not), mud flats and artificial salt pans

Mainly due to a lack of data and to the difficulty of untangling combined effects, uncertainties exist notably on evaluating effects of ocean acidification alone.

Extreme climatic events

Extreme climatic events include storms, torrential rains and floods, droughts and atmospheric heatwaves triggering fires which lead to desertification and erosion (see different warming scenarios and estimated burned area in Turco *et al.*, 2018).

Coastal storms can directly impact shallow marine and coastal ecosystems by wave energy, but the impacts seem to remain local and limited in time. However, Reguero, Losada & Méndez (2019) show that at a global scale, wave energy has increased in correlation with SST increase and conclude that the climate-induced increase of wave energy can have more profound effects in the future.

Yet extreme climatic events (storms, medicanes, flash floods, desertification) together with SLR accelerate coastal land erosion, leading to severe damage or loss of vulnerable ecosystems such as lagoons, wetlands, estuaries and shallow marine coastal ecosystems by sudden and acute changes in physicochemical elements of the environment (decreased salinity, increased turbidity, contaminations). These extreme events also threaten ecosystem services, coastal societies and infrastructures.

Currents and stratification

There is evidence that Mediterranean water masses are becoming warmer and deep masses becoming saltier (MedECC, 2020a, and reference therein; Skliris *et al.*, 2025). However, the changes induced by climate change on thermohaline circulation in the Mediterranean Sea and their consequences on ecosystems remain very uncertain for marine open water ecosystems mainly due to important knowledge gaps (Briere Spiteri, 2022). Nevertheless, Powley, Kron & Van Cappellen (2016) expect that these changes will at least not cause severe oxygen depletion of the deep water.

The warming of the upper layer of the oceans has led to an increased stratification at a global scale (Li *et al.*, 2020). However, there seem to be no significant changes in the vertical stratification of the upper layer in the Mediterranean Sea (Skliris *et al.*, 2025), although a decrease in phytoplankton biomass in response to stratification had been projected by Lazzari *et al.* (2014).

Sea level rise together with sea warming and increase of storm intensity and frequency are likely to generate changes in coastal current patterns but such impacts have not precisely been assessed in the Mediterranean Sea, and impacts on coastal ecosystems remain unpredicted.

Freshwater inputs and salinity

Climate change and increasing demand of freshwater have led to a reduction of river flow into the Mediterranean Sea (Carlson *et al.*, 2024; Macias *et al.*, 2025) and likely to a future reduction of water quality (Dorado-Guerra *et al.*, 2023), directly impacting vulnerable brackish coastal ecosystems such as lagoons. Macias *et al.* (2025), estimate that a 41% river flow reduction (estimated under RCP 8.5 warming scenario) would cause a reduction of 10% in marine primary production and a 6% decrease in biomass of commercial fish and invertebrate species in the Mediterranean Sea.

The decrease of river flows in the Mediterranean Sea will reduce freshwater inputs in coastal ecosystems and combined to warming, sea level rise and other anthropogenic impacts, will highly threaten vulnerable coastal wetland ecosystems such as lagoons, deltas and marshes (Keneally *et al.*, 2025).

Cumulative and cascading impacts

Climate change impacts are often cumulative and their effects difficult to untangle (sea e.g. water warming and acidification; water warming and Marine Heat Waves). These impacts can cumulate spatially and/or over time and severely affect biodiversity, species distribution, ecosystem resilience and be responsible for local extinctions (Briere Spiteri, 2022). Moreover, climate change impacts cumulate with other anthropogenic threats such as pollution, overfishing, coastal artificialisation, especially in coastal areas, further threatening ecosystems, ecosystem services and coastal societies.

Key Points

In the Mediterranean basin, climate is changing the environment faster than at the global scale (MedECC, 2020a). The consequences of climate change on the Mediterranean environment are transboundary (Briere Spiteri, 2022), but are not necessarily of similar intensity throughout the Mediterranean Sea due to different environmental conditions (MedECC, 2020a; MedECC, 2024). Climate change is one of the most critical challenges that the Mediterranean region is currently facing. The main climate change impacts on coastal and marine ecosystems at regional, sub-regional or local scale are:

- ✓ Increase in mean annual sea temperature
- ✓ Increase in frequency and intensity of Marine Heat Waves (MHW)
- ✓ Sea Level Rise (SLR)
- ✓ Increased acidification of the sea

- ✓ Increase in frequency and intensity extreme climatic events such as flash floods, coastal storms, droughts
- ✓ Changes in currents and sea stratification
- ✓ Decrease of freshwater inputs especially impacting coastal wetlands
- ✓ Cumulative climate change impacts and cumulated impacts with other anthropogenic threats

Changing environmental conditions under human-induced climate change modify the ecosystems' functioning. This requires adaptation of human societies to new environmental conditions but also to new condition of the ecosystems.

In the current global and regional situation, rapid climate changes alter profoundly environmental conditions and mechanisms. Consequently, these environmental changes combined to anthropogenic pressures affect ecosystems in their vital functions (e.g. biodiversity loss, changes in essential habitats, essential functions such as reproduction) decreasing their health and directly reducing their ability to adapt and deliver ecosystem services to human societies.

To attempt to slow down these negative impacts on ecosystems and societies, solutions must be found and applied at all levels:

- reduce greenhouse gas emissions (especially CO_2),
- increase and support effectiveness of carbon dioxide sinks,
- create conditions for ecosystems to be able to adapt and/or cope with climate change impacts by reducing other stressors and restoring natural environments or ecosystems.

Since the type, intensity and frequency of environmental changes can be predicted, proactive measures, more efficient than emergency solutions, should be taken.

2. FUTURE RISKS TO MARINE AND COASTAL ECOSYSTEMS AND COASTAL SOCIETIES IN THE PROJECTED CLIMATE CHANGE CONDITIONS

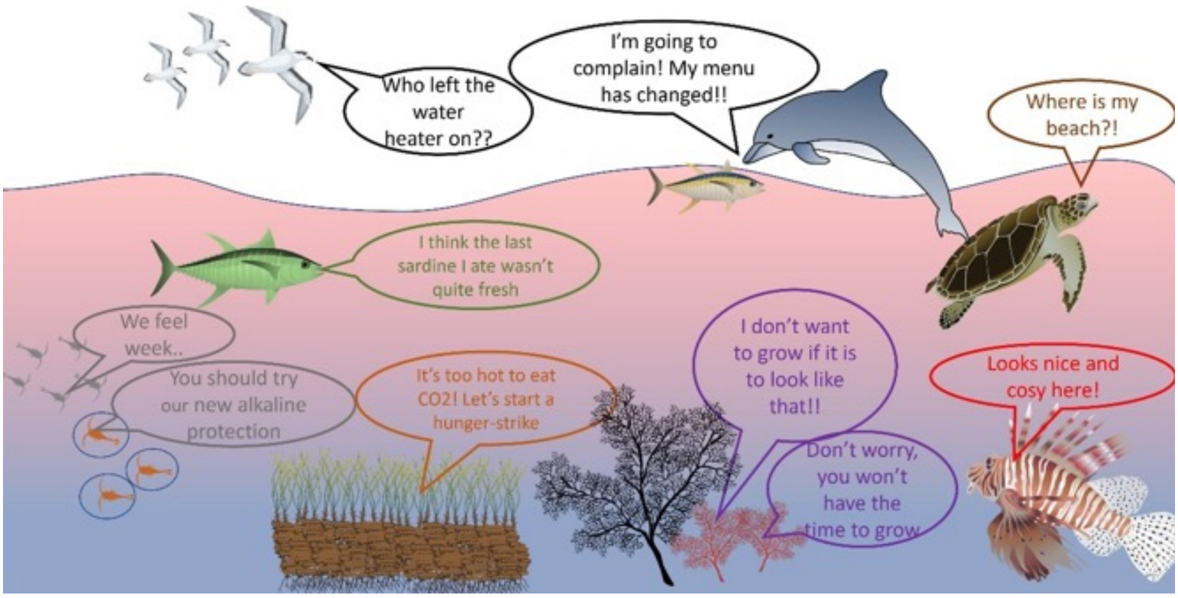


Figure 4.

Humoristic view of main climate change impacts on marine species and ecosystems in the Mediterranean Sea (Maïa Fourt)

To evaluate upcoming climate change impacts on ecosystems, it is necessary to make projections on future climate changes but also to evaluate ecosystems' vulnerabilities.

Mediterranean marine and coastal vulnerability

Vulnerability of ecosystems and species to climate change impacts can be considered as depending upon (i) exposure or risk to environmental climate change impacts, (ii) sensitivity to changes such as functional dependence, including status of the ecosystem, (iii) adaptation capacities such as ability to cope with, adjust and recover.

Exposure to climate change impacts

Climate change impacts are variable depending on natural environments and space. Several climate-driven changes further impact shallow marine and coastal ecosystems more than open sea ecosystems for several reasons (Hassoun *et al.*, 2025):

- Climate-driven changes are more important due to environmental conditions in coastal areas (e.g. increase in mean annual water temperature due to smaller water masses can change physicochemical properties, impact of storms waves on coast compared to open sea)

- Climate-driven changes such as Sea Level Rise which affect primarily the coastal zones
- Climate-driven changes impacting terrestrial areas also affect coastal ecosystems by a cascading effect (e.g. droughts will decrease sweet water inputs in coastal ecosystems)

Further, at the Mediterranean scale, there are spatial differences of climate change impacts. For example, mean annual SST shows a higher warming trend in the eastern Mediterranean than the western (MedECC, 2020a) and sea acidification appears higher in the western Mediterranean Sea (Hassoun *et al.*, 2015).

Additionally, Becker *et al.* (2012) highlight that Mediterranean coastal societies (cities mainly) are particularly exposed to climate change impacts, because along the Mediterranean coast, human settlements have historically developed closer to the sea level than in other regions, due to the quasi-inexistant tidal range, the historically relatively limited storm surges, and the sea use for fishing and commercial purposes.

Sensitivity to changes and ecosystem status

Certain species may have functional dependence on an ecosystem which is highly threatened by upcoming climate change impacts. It's the case of marine turtles which are dependent on availability of beaches for nesting, and beaches are under high risk due to Sea Level Rise and increasing frequency of storms (see Hassoun *et al.*, 2025).

A healthy ecosystem will be less sensitive to threats than one in poor condition. Shallow marine and coastal ecosystems, especially in the very populated Mediterranean coast, undergo already high anthropogenic pressures such as pollution, artificialisation and high frequentation. These cumulate with climate driven changes, and are already further impacting coastal areas than open seas.

At the regional scale, the Mediterranean Sea is globally considered to be in a moderate[5] environmental status based on the MSFD[6] descriptors (Fraschetti *et al.*, 2022). However, spatial variability is reported, with Western Mediterranean Sea considered in Good Environmental Status (GES). Differences are also reported at a higher scale with the environmental state in MPAs being better than in non-protected areas (Fraschetti *et al.*, 2022). This underlines the importance of MPAs to decrease ecosystem sensitivity to climate change impacts.

Adaptation and recovery capacities

A certain number of species have the ability to adapt to climate changes in particular by migrating to more adequate environments for them. This is the case for some temperate-cold fish species in the Mediterranean Sea whose geographic distribution has shifted northward under climate change forcing (Farahmand *et al.*, 2023). Other thermophilic species progressively extend their distribution limits northward (e.g. *Thalassoma pavo* see Arbuatti *et al.*, 2024). Climate change also brings changes in the composition of fish communities at the shelf-break (Valente *et al.*, 2023) as in

[5] Status classes are four bad, poor, moderate and good
[6] EU Marine Strategy Framework Directive

coastal areas where tropicalization is profoundly changing ecosystems in the eastern Mediterranean Sea.

The natural restoration of ecosystems in effectively managed MPAs proves that marine and coastal ecosystems are able to recover in certain conditions from anthropogenic impacts. However, the recovery capacities of marine and coastal ecosystems undergoing cumulated anthropogenic and climate change impacts is poorly known.

For some ecosystems, such as coastal marshes particularly vulnerable to SLR, projections on their recovery capacities are alarming: it is predicted that they will undergo more than 60% of surface loss by 2100 in the Mediterranean area (Schuerch *et al.*, 2025).

Foreseeing and risk evaluation for informed choices - Role of predictive approaches

In the Mediterranean region, climate-driven environmental changes are occurring very rapidly (IPCC, 2023; MedECC, 2020a). The population living in the coastal regions of the Mediterranean grew from about 100 million in 1980 to 150 million in 2005 and could reach 200 million by 2030 (UNEP/MAP, 2017). Further, the Mediterranean region attracts about a third of the world tourism with more than 400 million International Tourist Arrivals in 2019 (Plan Bleu, 2022). **There is little doubt that in the future, Mediterranean marine and coastal ecosystems will have to cope with increasing climate change and anthropogenic pressures.**

Interaction between intensive socio-economic development and growing climate change impacts in coastal zones are a major threat for coastal ecosystems and societies (OECD Environment Directorate, 2021). This situation is exacerbated in the Mediterranean area where the coastal population doubles during the tourist season (UfM, 2016).

The large majority of coastal risk to climate change impacts assessments addresses primarily human urban settlements and infrastructure (e.g. Agharroud *et al.*, 2023 in Morocco; Plan Bleu & UNEP/MAP, 2023 for Montenegro and Morocco sites, Satta *et al.*, 2017 for Mediterranean area; Sciuto *et al.*, 2024 on water flow management in Mediterranean urban areas; Unguendoli *et al.*, 2023 in Italy). These risk assessments are based on different models including climate change projections. For certain ecosystems studies, machine learning has been used as well, based on recorded data to predict environmental changes (e.g. Zennaro *et al.*, 2024 for hypoxia events in lagoons).

However, Hassoun *et al.* (2025) have focused on climate change risks to marine and coastal mediterranean ecosystems, and they project severe risks to biodiversity and function of coastal ecosystems which would be higher than for open marine ecosystems. Plan Bleu (2025) presents possible future trends and disruptions in the Mediterranean at different levels based on today's knowledge and warnings of major shifts that could take place before 2050.

Risk evaluation studies underline the vulnerability of coastal areas in relation to open sea ecosystems; however hardly any studies were found which include risk evaluation of open seas except for Hassoun *et al.* (2025).

Moreover, at the Mediterranean scale, coastal risk could be even higher along southern and eastern coasts since adaptation capacities are limited by lower economic development and by institutional complexity (MedECC, 2024).

Key Points

The Mediterranea Sea ecosystems are:

- ✓ Highly exposed to climate change impacts with coastal ecosystems more exposed than open sea ecosystems
- ✓ Sensitive to climate change impacts because they are globally in a moderate state of conservation
- ✓ Have variable adaptation and recovery capacities

Mediterranean ecosystems are therefore vulnerable to climate change impacts especially in coastal areas where additional anthropogenic pressures reduce resilience capacity of ecosystems. Models show that coastal risks are growing and highlight the vulnerability of mediterranean coastal ecosystems and societies face to future increasing climate change threats combined to increasing anthropogenic pressures.

3. NATURE-BASED SOLUTIONS TO PREVENT AND REDUCE CLIMATE CHANGE IMPACTS ON COASTAL AND MARINE AND ECOSYSTEMS (NBS/CCI/CME[7])

The concept of Nature-based Solutions (NbS) has rapidly developed and is now present in world-wide, European, regional and national policies (Riisager-Simonsen *et al.*, 2022). NbS are alternatives to conventional "grey" solutions to address societal challenges and are considered more flexible, sustainable and profitable for ecosystems (Snoussi & Nibani, 2025). NbS are often referred to as low or no regret solutions, since they minimise potential negative outcomes and costs (Agharroud *et al.*, 2023).

NbS Concept definitions

Several definitions of Nature-based Solutions (NbS) have been published; three are internationally recognised and the most frequently referenced. (Table 1).

Table 1

Table presenting main Nature-based Solutions (NbS) definitions

European Commission (2016)
Nature-based Solutions are "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*." https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en
IUCN (2016)
"*Nature-based Solutions are actions* ***to protect***, ***sustainably manage*** *and* ***restor****e natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide* ***both human well-being and biodiversity benefits***". Cohen-Shacham *et al.*, 2016 and IUCN Resolution WCC-2016-Res-069
UNEA resolution UNEP/EA.5/Res.5 (March 2022)
Nature-based Solutions are "*actions aimed at* ***protecting***, ***conserving***, ***restoring***, *and* ***sustainably managing*** *natural or modified terrestrial, freshwater, coastal, and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively,* ***while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefit****s*". https://www.unep.org/ This definition is also recognized by the RAMSAR Convention on Wetlands (COP14/Resolution XIV.17)

Although there are differences between the definitions, all emphasize the importance of working with nature to tackle societal challenges by producing benefits for biodiversity and by supporting the delivery of a range of ecosystem services (O'Leary *et al.*, 2023; Pérez *et al.*, 2024). The main basis of NbS is protection/conservation, restoration and sustainable management measures (see Figure 5) and actions which can include removal of human constructions. NbS appear as an umbrella concept embedding several categories including issue-specific NbS to mitigate and adapt to climate change.

[7] In this document the initials NbS/CCI/CME are used to refer to Nature-based Solutions to reduce and prevent Climate Change Impacts on Coastal and Marine Ecosystems

Louarn *et al.* (2025) propose 5 key elements that must be included in NbS. According to the authors, "NbS rely on ecosystem functions to **address specific societal challenges** by generating **benefits for biodiversity** and **benefits for human societies**; they are **multifunctional and require the commitment of all stakeholders**".

NbS definition is considered as unclear by several authors (e.g. Louarn *et al.*, 2025; Sowińska-Świerkosz & García, 2022), which hinders the implementation of NbS by policymakers and stakeholders. Grace *et al.* (2021) specify that one of the top priority knowledge needs is a more precise and clear definition of Nature-based Solution.

In literature one can find many different ways of classifying NbS, e.g. depending of the level of human intervention needed (Gómez Martín *et al.*, 2020) or on the type of action to be taken (Riisager-Simonsen *et al.*, 2022), on the ecosystem (IUCN Comité français, 2022), on their focus (Interreg Med Mediterranean Biodiversity Protection Community (MBPC), 2022) etc.

It is essential to keep in mind that NbS actions **protect**, **manage** and/or **restore** ecosystems (see NbS definitions).

NbS in coastal and marine environments

Nature-based Solutions can also be referred to as blue or marine NbS in coastal and marine governance (Frehen *et al.*, 2025). These NbS have been little assessed and implemented in the European and Mediterranean countries (Motta Zanin, 2024; Riisager-Simonsen *et al.*, 2022), although research programs have recognized their benefits. The difficulties remain in the implementation and policy adoption of NbS in marine and coastal areas.

Worldwide, NbS have been much less widely implemented in coastal and marine ecosystems than on land (Frehen *et al.*, 2025; O'Leary *et al.*, 2023). This is due in part to a lack of knowledge and understanding of marine and coastal ecosystems functioning and the ecosystem services they deliver (O'Leary *et al.*, 2023; Pérez *et al.*, 2024), but also because unclear frameworks and classification of NbS hinder their implementation by decision-makers (Gómez Martín *et al.*, 2020).

Examples of NbS in coastal and marine environment in the Mediterranean are rather limited (Interreg Med Mediterranean Biodiversity Protection Community (MBPC), 2022). However, NbS to reduce coastal risks are developing especially in the Mediterranean where floods, storms and sea level rise represent a high risk in the climate change context (see Motta Zanin, 2024).

Therefore, there is an urgent need for knowledge on Mediterranean marine and coastal ecosystem functioning and their ability to deliver ecosystem services under different states of conservation, as well as a need to clarify classification of NbS and assessment methods (Gómez Martín *et al.***, 2020).**

Nature-based technical Solutions to prevent and reduce climate change impacts on coastal and marine and ecosystems (NbS/CCI/CME) in the Mediterranean Sea

In the Mediterranean basin, climate is changing the environment faster than at the global scale (MedECC, 2020a). The Mediterranean coastal and marine ecosystems face, and will have to face in the future, increasing sea temperatures, marine heat waves, storms, Sea Level Rise (SLR), droughts and floods. These climate-derived changing environmental factors impact ecosystems, ecosystem service and coastal societies.

Conventional grey infrastructures to protect human communities are costly to implement and maintain, generally create negative effects on coastal landscape and ecosystems and will not be sufficient in the context of climate change (MedECC, 2024; Plan Bleu & UNEP/MAP, 2019).

New adaptation pathways are developing to enhance the health of natural ecosystems and their capacity to reduce climate change impacts. Healthy ecosystems provide a large range of ecosystem services, have the potential to mitigate climate change and can increase society's resilience (Plan Bleu & UNEP/MAP, 2019). NbS are robust when well-implemented, flexible, cost-efficient, inclusive and long-term oriented (Plan Bleu & UNEP/MAP, 2019). They are therefore of great importance in climate change impacts mitigation, also increasing ecological, social, and economic resilience to climate change impacts (see Figure 5).

Exploring the potentialities of NbS/CCI/CME in the Mediterranean region is rather recent but several promising projects have contributed to pave the way to define adapted NbS. Examples of such projects are:

- the Life Adapto Project (2017-2022) in France to test and evaluate what is defined as the flexible management of coastline in 10 pilot sites
- the research project Life Blue Natura (2015-2021) in Spain which evaluated the potential of decarbonisation of marshes and seagrass meadows
- the Interreg-MED projects POSBEMED (2016-2018), POSBEMED 2 (2019-2022) and POSBEMED+ (2022-2023) in several mediterranean countries on the management of Posidonia-beach-dune system

Outcomes of such projects have led to implementation guidelines for several specific NbS/CCI/CME. The document Interreg Med Mediterranean Biodiversity Protection Community (MBPC), (2022) in its Annex presents a detailed list of NbS projects implemented in Mediterranean coastal zones.

The importance of using NbS in the context of climate change impacts to support Ecosystem-based approaches such as EbM and EbA has been highlighted.

Ecosystem-based Management (EbM), is a holistic and integrated ecosystem approach to manage natural resources and take into account human and environmental needs for a sustainable development.

Ecosystem-based Adaptation (EbA), is a specific orientation of EbM to help communities and ecosystems adapt to climate change impacts. EbA are long-term plans which can be supported by Nature-based Solutions (NbS) in Mediterranean coastal zones by enhancing resilience to climate change impacts addressing ecological and socio-economic challenges (Snoussi & Nibani, 2025). These specific **NbS/CCI/CME** may be combined with other engineering or upgrading existing grey solutions within a EbA plan or spatial planning tools (MSP, ICZM) (see e.g. Foti *et al.*, 2020).

The **main climate change challenges addressed by NbS/CCI/CME** in the Mediterranean region relative to human populations are: coastal erosion due to SLR, wave action and storm impacts, increasing frequency of flash foods which affect coastal communities, decrease in quality of ecosystem services due to degraded ecosystems and environment, climate change mitigation.

To address these challenges, **NbS/CCI/CME** have been developed focusing mainly on the following ecosystems or areas:

- Spatial environmental protection, conservation and management
  - Marine and Coastal Protected Areas with a management plan considering climate change challenges
- Specific ecosystem or habitat conservation, management and/or restoration
  - Seagrass meadows
  - Coastal wetlands (deltas, lagoons, marshes)
  - Dune-beach systems
- Coastal urban areas

There are also effective management measures which may be considered as NbS/CCI/CME even if they are not explicitly labelled as such. In fisheries management for example, the Fisheries Restricted Areas (FRAs) and the Essential Fish Habitats (EFH) increase ecosystems and fish resilience to climate change by reducing fisheries impacts (see Ortega *et al.*, 2023). In the same way, GFCM 2030 Strategy embeds actions which can be considered as NbS/CCI/CME. The objective to reduce pressure on fish population by a more sustainable fishery will potentially favour the resilience of fish stocks to climate change impacts.

Nature-based technical Solutions to reduce climate change impacts on the Mediterranean region, are primarily developed to reduce coastal risks on human communities; They nonetheless increase ecosystem resilience to climatic changes (Figure 5).

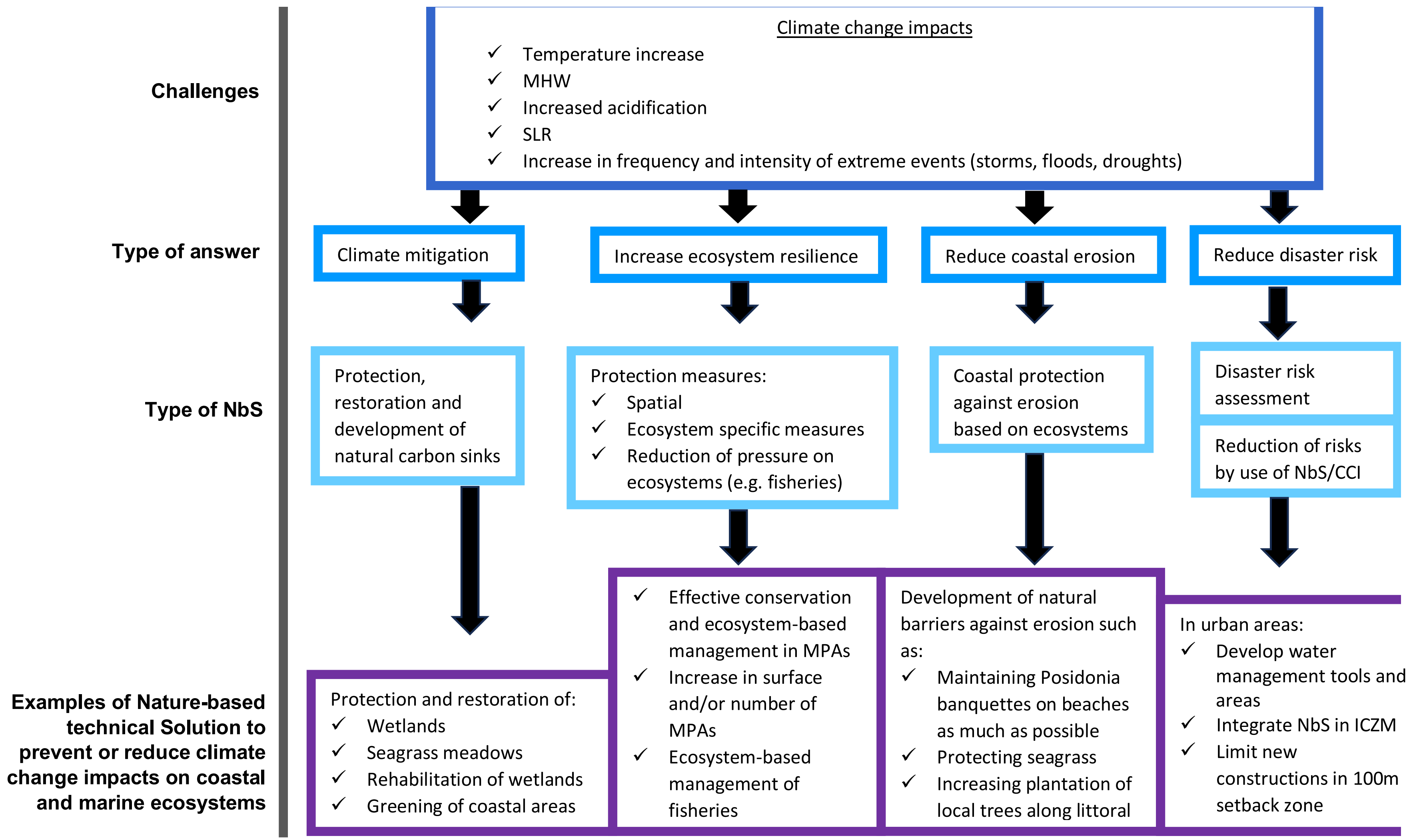


Figure 5.

Examples of solutions to climate change impacts in coastal and marine areas using Nature-based Solutions

There are more than 250 permanently inhabited islands of the Mediterranean Sea whose populations are particularly exposed to climate change as they are more dependent on coastal and marine ecosystem services (Grace *et al.*, 2020).

In the Mediterranean region, it becomes urgent to define sustainable and effective solutions to contribute to climate change mitigation and efficiently reduce climate change impacts on ecosystems and human communities. NbS/CCI/CME are efficient, adaptable and cost-effective solutions which should be prioritised to face climate change impacts.

Assessment of Nature based Solutions

How to choose NbS?

Assessing which Nature-based technical Solutions are most appropriate for a given situation and how to implement them is not an easy task. Different assessment methods have been defined to guide this selection.

IUCN has published the *IUCN Global Standard for Nature-based Solutions*, a guidance document based on 8 Criteria and 28 Indicators for designing NbS and verifying that they produce the outcomes expected (IUCN, 2020b). A second guide gives indications how on how to use them (IUCN, 2020a).

The European Commission refers to the EKLIPS report (Raymond *et al.*, 2017) assessment of NbS effectiveness, but the application of this evaluation method appears unclear and less delimited than the previous IUCN guidelines. However, IUCN requirements can be considered strict and difficult to apply, excluding actions which are otherwise considered as NbS (Riisager-Simonsen *et al.*, 2022).

The European Topic Centre on Climate change impacts, Vulnerability and Adaptation has also published a technical paper proposing a framework for NbS for climate change adaptation and disaster risk reduction (Veerkamp *et al.*, 2021).

Specifically on marine and coastal Nature-based Solutions (NbS) a framework to select appropriate NbS is proposed by Pérez *et al.* (2024). It is structured in four steps which guide stakeholders and decision-makers to possible actions to answer the specific needs (see Figure 6). For further details on the steps, see Pérez *et al.* (2024). However, this process should be done in a collaborative and inclusive way with civil society, policy makers, stakeholders and the private sector concerned.

A conceptual framework to help choose appropriate blue nature-based solutions

(Extracted from Pérez et al. (2024) under CC BY 4.0 license. Article available here)

Step 1 Challenge orientation. Ascertain the societal challenges to be addressed by the implementation intervention.

Step 2 Ecosystem services. Understand the ecosystem services and the underlying biodiversity and ecological functions that contribute to resolving societal challenges.

Step 3 Environmental context. Identify the available and potential ecosystems able to deliver these services within a relevant spatial scale level and assess the environmental context through vulnerability and ecological conditions.

Step 4 Intervention options. Characterise and understand the portfolio of the blue NbS, to reach the desired environmental context: protection, restorative activities and other management measures.

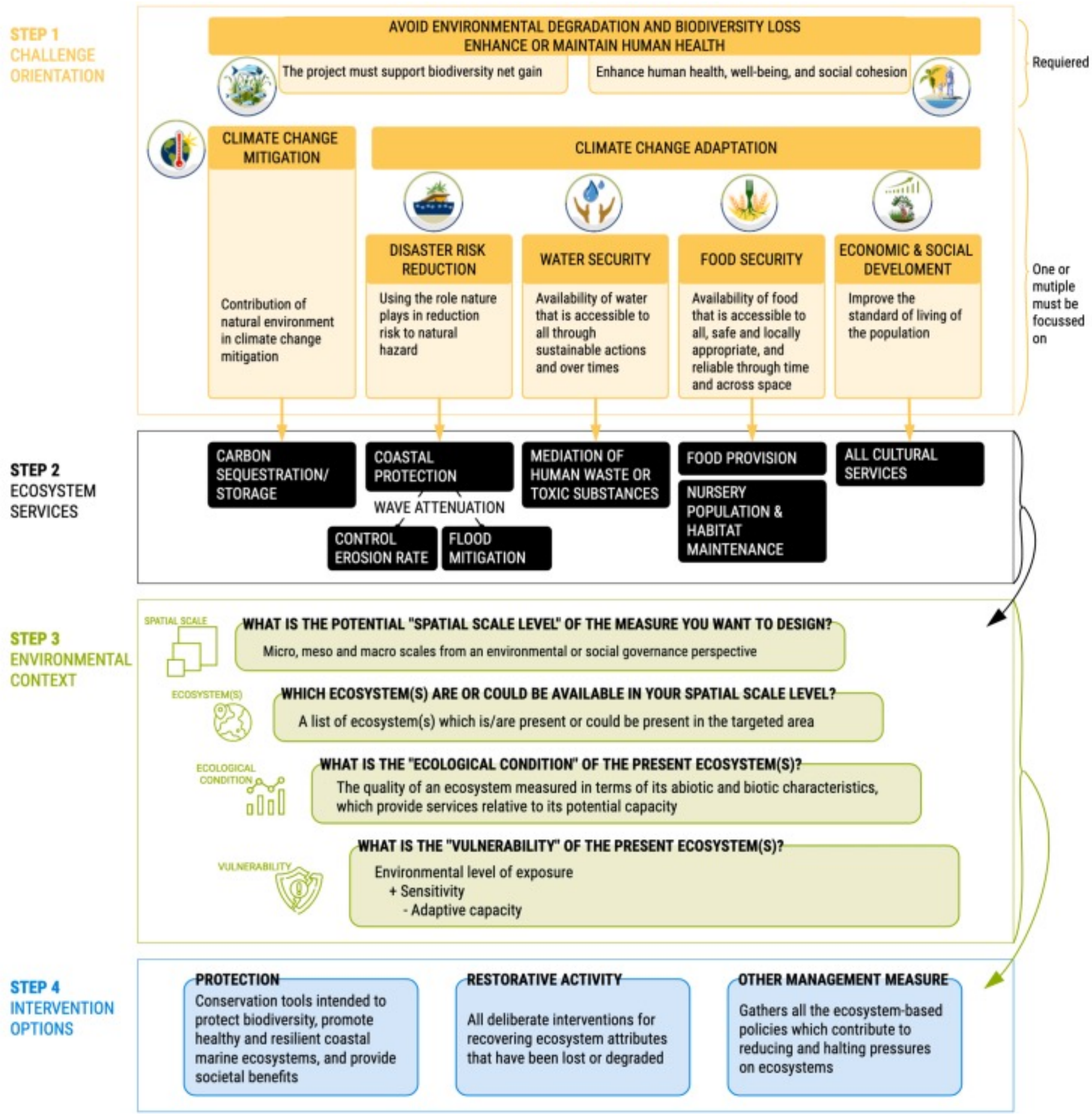


Figure 6.

Conceptual framework to identify suitable marine and coastal NbS, from Pérez *et al.* (2024)

Empowerment of NbS

Empowering NbS with participatory methods, creating a network of actors, communicating through education and increasing awareness are fundamental for successful implementation of NbS in a community. Deciding to use NbS and ecosystem-based approaches requires an integrative approach and can be empowered by certain tools. The European Eklipse Expert Working Group has recently published a useful report for such actions entitled specifically for coastal resilience *Building Resilient Coastal Communities through Nature-based Solutions and Empowerment Tools* (see Sieber *et al.*, 2024).

Evaluating the effectiveness of the NbS

When starting to design NbS implementation, the evaluation and monitoring of the effectiveness (or non-effectiveness) of the NbS should also be planned as it can also be a selection criterion. Indeed, the evaluation and monitoring costs should be taken into account in the implementation plan. Unfortunately, evaluation of the effectiveness of the implemented NbS/CCI/CME in the Mediterranean has rarely been done to date.

Predicting the effectiveness of NbS alone or in association with other NbS can be a useful tool to help choose the most appropriate NbS approach once the challenge is defined. Marino *et al.* (2025) used a model to assess ecosystem service in a coastal flood risk reduction context under present and future climatic conditions using NbS with a building blocks approach.

Eklipse and IUCN (see Raymond *et al.*, 2017 and IUCN, 2020b respectively) each propose a framework to evaluate the NbS projects; however, they do not take into account the impacts of climate change on the NbS itself (Gómez Martín *et al.*, 2020), whereas Gómez Martín *et al.* (2020) include this variable as well in the framework they propose.

A document published by the European Commission (Directorate-General for Research and Innovation (European Commission), 2021) proposes detailed and clear information on the evaluation and monitoring of all type of NbS parameters, including disaster risk reduction NbS. Indicators to evaluate the NbS performance and impact are detailed based on case studies. Useful information such as a table of modelling tools for the assessment of the ecosystems' services provided by NbS (see p. 317, table 7-8) can be found in this document. However, it does not include the assessment of climate change impacts on the NbS itself.

Indicators to evaluate the effectiveness of NbS on ecosystems can be searched for in the Integrated Monitoring and Assessment Programme (IMAP) which is currently being updated and includes several indicators designed to evaluate the state of conservation of some coastal ecosystems. Further, NbS can contribute to attain Good Environmental Status (GES) or good conservation status of ecosystems and therefore comply with Ecosystem Approach and IMAP request.

A Practical Framework for Assessing Nature-based Solutions in the Mediterranean

Resulting from the analysis of different assessment frameworks (EU webpage on Scaling nature-based solutions for climate resilience and nature restoration, 2023; IUCN, 2020a and b; Raymond *et al.*, 2017; Pérez *et al.*, 2024; Veerkamp *et al.*, 2021) and consultation with SPA/RAC, a practical framework in four steps for assessing NbS to reduce climate change impacts on coastal and marine ecosystems is hereafter proposed followed by a table presenting examples of indicators which can be used in NbS/CCI/CME assessment (Table 2).

Assessment Methodology

STEP 1: Screening and scoping

The purpose of **screening** is to decide whether NbS can be an appropriate answer to given societal and/or environmental challenge. For NbS/CCI/CME, it involves identifying the specific impacts and threats of climate change on marine and coastal ecosystems and socio-economic systems of the considered area.

The result may be:

- that climate change threats and impacts are limited, rare and localised not requiring any adaptation strategy including NbS (rare result given today's climate change impacts),
- that climate change threats and impacts are already taken in account sufficiently at a larger scale,
- that a preliminary study is needed to acquire more detailed information to decide,
- that implementation of NbS can be considered to answer challenges which have been defined as priorities.

For the specific climate impacts and threats, the purpose of scoping is to define the possible interactions of impacts, the ecosystems and the socio-economic sectors affected by the impacts. It involves consulting stakeholders, administrations, communities and experts to specifically delineate the objectives and identifying the data needed to establish a base-line state. Connexions and links with spatial planning programmes (MPS, ICZM, other) should be searched for, in view of developing step 2. Gathering existing baseline data is necessary to identify knowledge gaps. Missing data might need to be obtained to complete the picture of the base-line state.

STEP 2: Design and implementation planning

Efficient NbS implementation is not a quick-fix solution to a problem. It is a rather long-term process that needs to be planned. It is recommended to integrate NbS/CCI/CME design and implementation within an ecosystem-based adaptation plan of the area or the MPA.

Designing NbS/CCI/CME can be inspired by NbS implemented in other areas which can be adapted to fit the implementation area and the specific challenges identified. Therefore, creating a catalogue of NbS/CCI/CME which have already been implemented in the region or even in other regions is useful.

A cost-effectiveness and affordability study of pre-selected NbS should be led against alternatives such as other NbS, a combination of NbS, conventional approaches or a combination of NbS and conventional approaches. Such studies contribute to ensure sustainability of the NbS and can also supply precious information to better communicate the stakeholders and other people concerned on the pros and cons of NbS to respond to a climatic challenge.

Once potential NbS have been identified, it is recommended to inform several variables:

- The implementation spatial scale
- The temporal scale of expected results with established targets
- How they link with spatial planning MSP, ICZM and other
- The way ecosystems are expected to benefit from the NbS in terms of conservation, biodiversity and resilience capacities with established targets
- The socio-economic benefits and co-benefits expected from NbS implementation (preferably defined along a roadmap) are identified specifically with established targets
- The governance mechanism to be used for an implementation
- Estimated implementation cost and maintenance cost by year
- Identification of available funds for the project
- The synergies to be established with other sectors and other concerns

The selection process of NbS to be implemented should be inclusive, involving all stakeholders and communities concerned and taking in account current and future coastal planning projections (e.g. MSP, ICZM). To be successful, NbS implementation requires the engagement of stakeholders and local population.

It is recommended to clearly define costs, risks, benefits and co-benefits of NbS/CCI/CME implementation, and to discriminate private sector, governmental and civil society engagement, costs and benefits. Sustainability of NbS depends on detailed planning, integration and commitment of concerned actors and measurable benefits for ecosystems and human societies.

STEP 3: Effectiveness evaluation

To evaluate NbS performance, a monitoring programme should be tailored for the specific NbS and context with assessment of the challenges addressed and the NbS implementation. Indicators should be selected to monitor changes from an initial state in coastal and marine areas concerned with regard to the specific climate change impacts and taking in account established targets. It is recommended that these indicators use as much as possible the IMAP indicators to monitor the state of the ecosystems, but there should also include standardized social and economic indicators and assessment of human well-being and perceptions (see section

Examples of standardized Indicators for NbS evaluation). Finally, evaluating the impacts of climate change on the NbS, is necessary to adapt NbS to climate change impacts mitigation if needed.

STEP 4: Sustainability and replicability

Implementing NbS requires long-term management plan and adaptability potential to be sustainable and to adjust NbS to changes in time. Regular assessment of the challenges and the effectiveness of NbS (on ecosystems and societies), the state of the ecosystems and the socio-economic variables will allow to identify adjustments required in a rapidly changing environment.

Although NbS tend to be site specific, well designed and planned NbS can be replicable, with some adaptation, in other areas, reducing thereby NbS assessment efforts for other areas.

NbS/CCI/CME are highly dependent on socio-environmental context. In consequence, they have higher potential for replication process than for scaling-up. Moreover, replication is often easier to apply than scaling-up which requires systemic changes across different policy and administrative levels.

Major challenges for replication and scaling-up of NbS arise from a lack of detailed and standardized monitoring methods, reporting protocols and guidance at the different stages of the NbS life cycle. A clear and detailed NbS implementation plan will greatly favor replicability and scaling-up.

Examples of standardized Indicators for NbS evaluation

An initial state of the ecosystems concerned, the perception of NbS within the local society, the well-being of local population, of socioeconomic variables in relation, will allow to evaluate the effectiveness of the NbS implementation. Such monitoring will also enable to proceed to adjustments or adaptations if needed, and contribute to increase possibilities of replicating or scaling-up of NbS and contribute to NbS sustainability.

Standardized indicators should be selected in the different fields and able to assess:

- state of conservation of the ecosystems (e.g. reduction/increase of surface occupied by habitats, biodiversity, state of fisheries)
- ecosystem services
- changes in climate impacts (e.g. frequency and intensity of storms, heat waves, sea level rise)
- perception of NbS by the population
- economic variables in sectors concerned (e.g. tourism, fisheries)
- wellbeing of population
- efficiency of NbS compared to targets defined (e.g. carbon mitigation, decrease in ecosystem vulnerability)
- impact of climate change on NbS

Several useful guidelines are available here. Further, one of the documents that develops the most the indicators which can be used for different NbS is the document Evaluating the impact of Nature-based Solutions. A Handbook for Practitioners (Directorate-General for Research and Innovation (European Commission), 2021) available here.

Table 2

Example of indicators which can be useful to assess NbS/CCI/CME

Indicators	Metrics	Unit	Useful references
Environmental carbon mitigation indicators			
Carbon sequestration	Amount of Carbon dioxide sequestrated by seagrass beds or wetlands	tC/ha/y	Martini *et al.*, 2021 Of interest also concerning blue carbon market Comte *et al.*, 2024
Carbon storage	Amount of Carbon dioxide stored by seagrass beds or wetlands	tC/ha	
'Acute' climate-related hazards			
Extreme precipitation total	Frequency and magnitude of unusual precipitation events with respect to the baseline conditions (often using quantiles-based thresholds such as the 95th or 99th percentage of daily rainfall or fixed thresholds).	Millimeters or inches and/or number of days	Crespi *et al.*, 2020 (see table p. 26)
River flood frequency and evolution	Number of river floods by year	No. flooding events by year for the considered area	Llasat, 2021
River flood intensity	Water height using stream gauges and stages	Hight in centimeters	
Droughts	Duration of meteorological droughts which reports the total number of months with anomalously low precipitation conditions based on Standardized Precipitation Index	Number of days	Crespi *et al.*, 202 (see table p. 26)
Economic cost of river floods	Total cost of direct and indirect damages due to floods over a year (property destruction, aquaculture and agricultural loss, business interruption etc.)	Monetary units/y	
Extreme coastal storm frequency	Number of coastal storms. Parameters of what is considered as a storm must be defined: orientation, wind speed and duration (e.g. winds from SE to SW over 70km/h during 6 hours are considered as a storms)	No. storms/y	Martzikos *et al.*, 2021
Economic cost of coastal storms	Total cost of direct and indirect damages due to coastal storms over a year	Monetary units/y	
Sea level	Mean sea level changes using satellite altimetry or tide gauges	mm/y	Pérez Gómez *et al.*, 2022

Habitat and ecosystem health			
Effectively protected MCPAs	Total coverage of effectively managed MCPA in the region or the CP	% of the sea surface % of coastal areas	
Habitat extent	Mapping seagrass meadows using standardized guidelines (UNEP/MAP-RAC/SPA, 2015) (see IMAP indicators of EO1 and EO6)	m^2 or ha	UNEP/MAP-RAC/SPA, 2015
Condition of habitat's typical species	Surface or number of injured individuals or affected conspicuous species (see IMAP indicators EO1/CI2)	Number of individuals or habitat surface	UNEP/MED WG.547/11
Biodiversity	species richness frequenting an ecosystem	Number of species	
Harvested commercially exploited fish and shellfish	IMAP EO3 related indicators		UNEP/MED WG.550/09
Seawater quality	IMAP indicators can be used such as: - EO5/CI13 concentration of key nutrients in water column - EO9/CI17 to 21	Depends on parameter	Monitoring guidelines for these indicators can be found here
Social indicators			
Nature-based recreational areas	Surface of nature-based recreational areas accessible to the population (within a given distance)	Km^2	
Community well-being	Bathing water quality (see seawater quality)	Depends on parameter	
Cultural benefits	Attendance rate to a given new natural coastal area or new environmental structure	Number of local visitors by month	
Perception	Perception of the NbS implemented	Changes in time	
Economic indicators			
Cost-effectiveness	Cost-Benefit Analysis comparing monetary benefits against costs and considering a range of socio-economic benefits such as biodiversity restoration, carbon sequestration etc.	Monetary units	
Jobs created	Jobs created for the implementation of the NbS and associated to its maintenance and attractivity	No.	
Touristic activity enhancement	Number of visitors in the area of implementation	No visitors/year	

Key Points

The concept of Nature-based Solutions (NbS) has rapidly developed and is now present in world-wide, European, regional and national policies (Riisager-Simonsen *et al.*, 2022). Although there are differences in the definitions of NbS, all emphasise the importance of working with nature to tackle societal challenges by producing benefits for biodiversity and supporting the delivery of a range of ecosystem services (O'Leary *et al.*, 2023; Pérez *et al.*, 2024). The main base of NbS is protection/conservation, restoration and sustainable management measures and actions which can include removal of human constructions.

Nature-based Solutions in coastal and marine governance (also blue or marine NbS) have been little assessed and implemented in the European and Mediterranean countries (Motta Zanin, 2024; Riisager-Simonsen *et al.*, 2022) although research programs have recognized their benefits. The difficulties remain in the implementation and policy adoption of NbS in marine and coastal areas.

Although Nature-based technical Solutions to prevent and reduce climate change impacts on coastal and marine and ecosystems (NbS/CCI/CME) have not been frequently implemented in the Mediterranean, some programmes and projects have opened the way. These focus on Coastal and Marine Protected Areas (MCPAs) with an ecosystem-based approach, seagrass meadows, coastal wetlands, dune-beach systems and coastal urban areas.

Several conceptual frameworks to assess and evaluate NbS are available. Some are specific to coastal risk for example, but can be considered difficult to apply. The evaluation of the effectiveness of many of the NbS/CCI/CME implemented through programs in the Mediterranean are not available either because the program has finished and did not include evaluation in the initial plan, or because the implementation is too recent. Careful planning before implementing NbS is essential for its sustainable implementation and efficiency. It is recommended to plan the means to be used for the evaluation of the NbS effectiveness as well as the cost of this evaluation. Inspired by several published frameworks to assess NbS, a simplified practical framework to assess NbS/CCI/CME in the Mediterranean region is proposed followed by a table of examples of indicators which can be used.

4. NBS/CCI/CME IN THE MEDITERRANEAN REGION BY TYPE OF AREA OR ECOSYSTEM

Nature-based Solutions supporting an Ecosystem-based approach in an MPA

NbS/CCI/CME in Marine and Coastal Protected Areas (MCPAs) with an Ecosystem-based Adaptation (EbA) plan
Ecosystems concerned: All coastal and marine ecosystems in Marine and Coastal Protected Areas which have an EbA, or an Ecosystem-based disaster risk reduction, or a climate change adaptation plan or strategy. (See MPA-ADAPT document Mediterranean MPAs providing NbS for climate change; Interreg-Euro-MED program MPA4Change; Frehen *et al.*, 2025)
Threats addressed: Biodiversity loss Habitat and ecosystem vulnerability Anthropogenic impacts Fish stock decline Other site-specific threats
Contribution to specific climate change impacts reduction: Globally: Carbon mitigation. In the area of NbS application: depending on the ecosystems present in the MCPA.
NbS within: Ecosystem conservation Ecosystem restoration Ecosystem-based Management Ecosystem-based Adaptation (EbA) (**Case study A in chapter 5**)
Specific interests: MCPAs represent a delimitated area which should have a management plan and where anthropogenic threats should be reduced. An Ecosystem-based Adaptation plan may be supported by different actions including Nature-based technical Solutions to face climate change impacts and enhance ecosystems resilience.
Ecological benefits: Contribution to climate change mitigation (CO_2 sequestration) Biodiversity conservation Increased habitat resilience to climate change impacts by reduction of other anthropogenic impacts Connectivity of species population
Socio-economic benefits: Development of ecotourism More natural living environment Development of harvested species populations around the area concerned (e.g. fish stocks).
References and resource documents - MPA-ADAPT document Mediterranean MPAs providing NbS for climate change - Interreg-Euro-MED program MPA4Change - Frehen, L., Ferraro, G., & Failler, Pierre, F. (2025). Blue Nature-Based Solutions in marine and coastal EU policies: Challenges, recommendations and policy opportunities throughout the policy cycle. *Marine Policy*, *177*, 106687. https://doi.org/10.1016/j.marpol.2025.106687 - Case study: https://www.unep.org/ecosystem-based-adaptation-albania

Seagrass meadows and beach banquettes

Seagrass meadows and beach banquettes as NbS/CCI/CME

Ecosystems concerned:

Posidonia oceanica meadows
Posidonia oceanica beach banquettes
Cymodocea nodosa meadows
Zostera marina meadows

Threats addressed:

Biodiversity loss

Habitat and ecosystem vulnerability

Anthropogenic impacts

Coastal erosion

Contribution to specific climate change impacts reduction:

Globally: Carbon mitigation by carbon sequestration and storage

In the area of NbS application: increase of oxygen in the water and water quality, decrease of wave action on the coast, beach protection, increase of ecosystem resilience

NbS within:

Ecosystem conservation and protection (**Case study B in chapter 5**)

Ecosystem restoration (**Case study C in chapter 5**)

Ecosystem-based Management (**Case study C in chapter 5)**

Ecosystem-based Adaptation (EbA)

Specific interests:

In the Mediterranean Sea, *P. oceanica* is the most dominant and most studied seagrass. This endemic species forms extended meadows, habitat to many species and largely contributing to trophic and reproduction dynamics of species. This key habitat-forming species is slow growing with rhizomes that accumulate over time creating impressive natural monuments. In Corsica, Monnier *et al.* (2021) revealed that the matte thickness can locally reach 867 cm measured by high-resolution seismic reflection techniques and sampling. These meadow ecosystems provide a wide range of ecosystem services. They are able to: increase water quality and biodiversity, sequestrate carbon (Rigo *et al.*, 2021; Comte *et al.*, 2024), stabilize the sediments (rhizomes and matte of *P. oceanica*), reduce wave energy and action on the coast (Agulles *et al.*, 2024; Pillai *et al.*, 2022) and significantly reduce current amplitude (Pillai *et al.*, 2022) which is dependant also on the seagrass landscape (for *Zostera marina* see Pillai *et al.*, 2022). *Posidonia* meadows are one of the most effective ecosystems in terms of carbon sequestration, so called carbon sinks. Average carbon sequestration of *Posidonia* meadows is considered to be over 1 ton C per hectare, per year (Pergent-Martini *et al.*, 2021; Life Blue Natura project, Blue Carbon in Andalusia see here), which is more than 20 times the average sequestration rate by Mediterranean forests (Pergent-Martini *et al.*, 2021).

The value of the ecosystem services provided by *P. oceanica* meadows in good conservation state has been evaluated between 21,660 € $ha^{-1}yr^{-1}$ by Scanu *et al.* (2022) and 1,720,000 € $ha^{-1}yr^{-1}$ by Vassalo *et al.* (2013) (see costs of restoration and ecosystem value estimates in Appendix 1. Value of *Posidonia oceanica* meadows estimated by different authors). Yet there is a large funding gap in *Posidonia oceanica* conservation between the needs for conservation, and the funding received (Interreg Euro-MED-ARTEMIS, 2025).

Part of the dead leaves of *P. oceanica* naturally wash ashore and depose on the coast forming permanent and/or temporary banquettes which protect beaches from winter erosion and trap sand contributing to beach stabilization (Boudouresque *et al.*, 2017). Along a beach in the Marathon National Park in Greece where banquettes have not been removed since 2018, the banquettes seem to have possibly contributed to an increase of the beach width at some points (Kourliaftis *et al.*, 2022; Vandarakis *et al.*, 2023).

Ecological benefits:

High contribution to climate change mitigation (CO_2 sequestration)

Biodiversity and essential habitat conservation

Increased habitat resilience to climate change impacts by reduction of other anthropogenic impacts

Connectivity of many species' population

Coastline stabilization and defence against erosion from sea and wind

Socio-economic benefits:

Development of harvested species populations around the area concerned (e.g. fish stocks).

Protection of beaches against wave and storm action and coastal erosion.

Contribution to construction and stabilization of dune systems acting as natural barrier against SLR.

Seagrass meadows and beach banquettes as NbS/CCI/CME

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Coastal wetlands

NbS/CCI/CME in coastal wetlands

Ecosystems concerned:

Coastal lagoons

Deltas

Marshes and saltmarshes

Threats addressed:

Biodiversity loss

Habitat and ecosystem vulnerability

Coastal erosion

Floods

Contribution to specific climate change impacts reduction:

Globally: Carbon mitigation by carbon sequestration and storage

In the area of NbS application: increase of water quality, increase of ecosystem wetland resilience, enhanced flood protection, enhanced protection against SLR

NbS within:

Ecosystem conservation and protection

Ecosystem restoration (**Case study D in chapter 5**)

Ecosystem-based Management (**Case study E in chapter 5)**

Ecosystem-based Adaptation (EbA) (**Case study A in chapter 5**)

Specific interests:

Mediterranean wetlands have significantly decreased due to human activities (dams, urbanization, agriculture) and climate change and are at risk of desertification for a certain number (Segura *et al.*, 2018, Zotos *et al.*, 2024). 48% of the Mediterranean wetlands have been lost since 1970 (Satta *et al.*, 2022). Their degradation reduces their capacity to deal with climate change impacts. Healthy wetlands mitigate the adverse impacts of climate change such as floods, storms and SLR. They are a natural buffer zone, a coastal setback protecting inland ecosystems and human societies from SLR, and they absorb water flow during floods (Segura *et al.*, 2018). Further, wetlands are able to store high quantities of carbon and contribute significantly to carbon mitigation. Natural wetlands evolve with climate change and adapt (Segura *et al.*, 2018).

Ecological benefits:

High contribution to climate change mitigation (CO_2 sequestration)

Biodiversity and essential habitat conservation

Increased habitat and ecosystem resilience to climate change impacts by restoring natural functioning

Connectivity of many species' population (e.g. birds)

Reduce pollutants in water

Socio-economic benefits:

Protected and restored wetlands are a natural setback zone which is an efficient buffer zone against SLR and storms for further inland human societies and installations. Natural wetlands lower flood risk and reduce flood peaks but can also contribute to reduce the severity of droughts (Ferreira *et al.*, 2023).

Managed wetlands can be large recreation areas improving human quality of life in adjacent urban areas. Finally, wetlands also contribute to improving water quality and water availability.

NbS/CCI/CME in coastal wetlands

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Dune-beach systems

NbS/CCI/CME in coastal wetlands

Ecosystems concerned:

Beaches

Coastal foredunes and dunes

Threats addressed:

Coastal erosion

Sea floods by storms

Sea Level Rise

Contribution to specific climate change impacts reduction:

In the area of NbS application: enhanced sea flood protection due to storms, enhanced protection against SLR

NbS within:

Ecosystem conservation and protection

Ecosystem restoration

Ecosystem-based Management (**Case E in chapter 5**)

Ecosystem-based Adaptation (EbA) (**Case A in chapter 5**)

Specific interests:

Under current and future climate change conditions, coastal protection against sea floods, SLR, coastal erosion and storms is necessary. Beaches and coastal dunes represent natural barriers and setbacks protecting inland ecosystems (e.g. lagoons) and human populations.

Conserving, restoring and managing such ecosystems can reduce climate change impacts on ecosystem services in coastal areas. However, certain actions such as beach nourishment considered by some as a NbS (e.g. Kindeberg *et al.*, 2023; Motta Zanin, 2024) can jeopardize the natural environment (Saengsupavanich *et al.*, 2023) and even be destructive for other marine ecosystems such as seagrass (Aragonés *et al.*, 2015; Calmet *et al.*, 2025). Such strategies are generally also unsustainable (Parkinson & Ogurcak, 2018). It is the system foredune-beach or lagoon-beach which seems the most appropriate to consider rather than solely the beach (IUCN Comité français, 2022).

Constructing an SLR adaptation plan on a multi-approach NbS can be more effective (e.g. Marino *et al.*, 2025; Unguendoli *et al.*, 2023); however, solutions used must remain compatible. For example, beach nourishment and seagrass bed conservation and restoration in front of the beach may be incompatible.

The beach-dune dynamic is complex and, although several studies have worked on models to determine the best way to limit coastal erosion, few case studies exist (e.g. Costa *et al.*, 2023; Unguendoli *et al.*, 2023).

Anthropogenic direct impacts, such as tramping, hinder plant development (Della Bella *et al.*, 2021) which contribute to retain the sand (Fernández-Montblanc *et al.*, 2020; Sigren *et al.*, 2014). Therefore, managing the access of dunes remains effective to limit vulnerability of dunes.

Further, sand trapping fences appear to increase foredune elevation and thus rehabilitate the dune-beach and increase resilience to erosion. However, many strategies and methods exist which must be adapted to each site in order to be efficient (Eichmanns *et al.*, 2021).

Ecological benefits:

Can contribute to climate change mitigation through dune vegetation and coastal forests (CO_2 sequestration)

Biodiversity and habitat conservation

Increased habitat and ecosystem resilience to climate change impacts

Can contribute to protect fragile ecosystems further inland such as lagoons

Socio-economic benefits:

Protected and restored beaches and dunes are a natural setback zone which is an efficient buffer zone against SLR and storms for further inland urbanised areas.

Managed beaches and dunes can be large recreation areas improving human quality of life there or in adjacent urban areas.

NbS/CCI/CME in coastal wetlands

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Coastal urban areas

NbS/CCI/CME in coastal urban areas

Ecosystems concerned:

Urban beaches
Shallow marine ecosystems
Adjacent coastal ecosystems

Threats addressed:

Flash floods
Sea floods by storms
Sea Level Rise

Contribution to specific climate change impacts reduction:

Globally: Contribution to carbon mitigation by sequestration (vegetation development) but can be variable
In the area of NbS application: increased resilience to flash floods, storms and SLR

NbS within:

Urban and ecosystem management
Sustainable Urban Drainage Systems (SUDSs)

Specific interests:

The use of NbS to manage coastal risks in urbanized areas is not frequent although needs are expressed (Louarn *et al.*, 2025). Because of the lack of space in urbanized areas, hybrid NbS (nature inspired solutions) or grey infrastructures will often be preferred. Integrating NbS/CCI/CME in urban and peri-urban policies and projects is a key point to further implement NbS in coastal urban areas (Louarn *et al.*, 2025).

The main climate change threat for ecosystems in coastal urban areas is represented by storms and sea and/or river flooding. Sea floods will mainly impact anthropogenic structures or artificialized coasts and urban beaches, impacting less the natural ecosystems. Due to impermeabilized grounds, but also to the situation of many mediterranean urbanized areas (Faccini *et al.*, 2021), flash floods can suddenly discharge large quantities of polluted freshwater runoff in coastal marine areas (see photo Figure 7) which can severely impact marine ecosystems (Piazzi *et al.*, 2021). Sustainable Urban Drainage Systems (SUDSs) have immerged as strategies which can be partly based on NbS and mitigate impacts. Nature-based technical Solutions have been identified such as bioretention cells, permeable pavements, infiltration trenches, detention basins, green roofs (Cansian *et al.*, 2025), green corridors strategically implemented along rivers, restoration of riparian forests in peri-urban areas etc. However, there is a gap between science and the practice of NbS to reduce floods (Howarth *et al.*, 2025).

The concept of "sponge cities" is an emerging, innovative concept which has been developed recently and includes NbS (see Iqbal *et al.*, 2025; Tarek, 2025). It is an interesting approach for coastal Mediterranean cities which suffer from flash floods but also droughts in summer periods. The objective is to manage urban rainwater by favoring absorption, collection, eventually filtering and storing rainwater rather than letting rainwater runoff. Rainwater can then be used for urban greening. Sponge city concept has not yet been applied in Mediterranean cities as such, although some coastal cities are developing solutions in this direction (Barcelona, Marseille).

Furthermore, future development in coastal urban areas should also take into consideration SLR and maintain a coastal setback zone (see Article 8 of the ICZM Protocol of the Barcelona Convention which identifies a minimum setback zone of 100 m, UNEP/MAP-PAP/RAC, 2015 and Lincke *et al.*, 2020). Few urban areas in the Mediterranean region have proceeded to integrated management integrating effective NbS/CCI to reduce river floods impacts along their coast. Such planning needs also to take into account the larger areas with watershed management.

Ecological benefits:

Urban biodiversity enhanced
Increased habitat and ecosystem resilience to climate change impacts
Conservation of surrounding wetlands

Socio-economic benefits:

Reduced vulnerability to flash floods, SLR and storms floods

NbS/CCI/CME in coastal urban areas

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Figure 7.

Satellite photo of Paros Island, Greece March 2025 after a powerful storm with intense flooding
Credit: European Union, Copernicus Sentinel-2 imagery (https://www.copernicus.eu/)

5. CASE STUDIES IN THE MEDITERRANEAN REGION

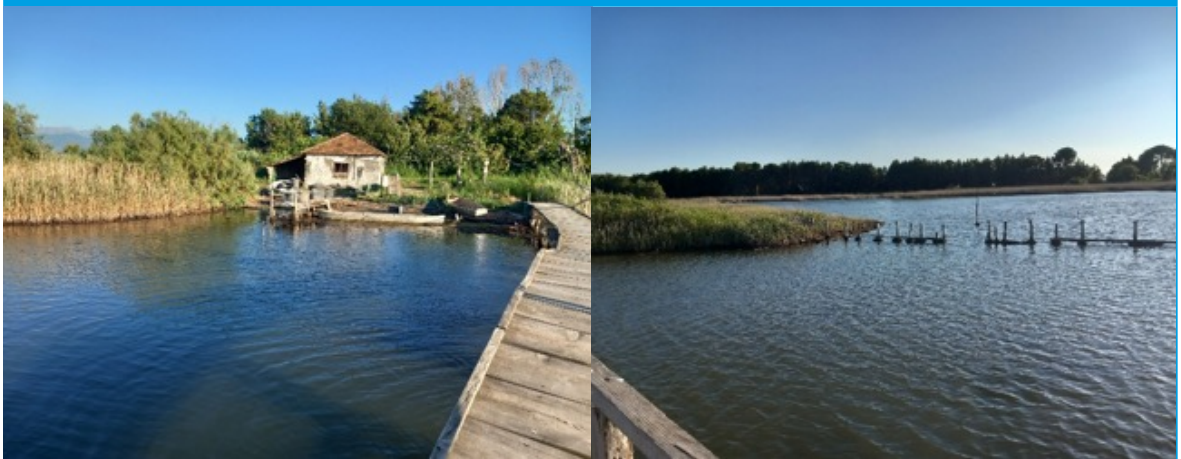
Adaptation to climate change impacts in the Mediterranean region is an urgent need and must include effective solutions at regional, national and local scale. Nature-based Solutions have been put forward as cost-effective solutions for climate change adaptation. However, there are few case studies and fragmented empirical evidence of their effectiveness, in particular concerning coastal and marine ecosystems in the Mediterranean.

NbS should take in consideration current and future environmental conditions and scenarios and be integrated in socio-economic and cultural contexts. Effectively implementing NbS is therefore not an easy task. Moreover, because of the time necessary for restoration for example, the effectiveness of NbS to mitigate climate change impacts is generally not yet known (Bueno-Pardo *et al.*, 2024; Luján Soto *et al.*, 2025). Solutions are urgently needed, but as climate change is a long-term process, effects of measures will often only be measurable in the long term (Plan Bleu, 2025). In literature, effectiveness of NbS is therefore frequently based on models.

The selection of NbS/CCI/CME considered took in consideration the 5 key elements defined by Louarn *et al.* (2025). NbS/CCI/CME must rely on ecosystem functions to "***address specific societal challenges by generating benefits for biodiversity and benefits for human societies; they are multifunctional and require the commitment of all stakeholders***".

Ecosystem-based Adaptation (EbA) for a coastal lagoon

Case study A
Lagoon Ecosystem-based Adaptation using NbS/CCI/CME



Photos : Kune-Vaine-Tale Lagoon ©Maïa Four

Location	Northern coast of **Albania** in the **Kune-Vain-Tale Nature Reserve**
Initial cost estimated	13.4 million USD (see here)
Information on the area and project or program	The Kune-Vain-Tale is a costal lagoon separated with the Adriatic Sea by coastal dunes. The area is a National Nature Reserve and is habitat to many bird species. The program *Building the resilience of Kune-Vain Lagoon through Ecosystem-based Adaptation (EbA)* was supported by Special Climate Change Fund and co-financed by GEF Grant. The executing entity was the Albanian Ministry of Tourism and Environment. (see https://www.unep.org/ecosystem-based-adaptation-albania and https://iucn.org/sites/default/files/2023-12/nbs-compendium-western-balkans_finalo.pdf)
Ecosystems concerned	Wetland (lagoon), riparian forest and vegetation, coastal dunes
Operational scale	7 to 10 hectares and 2,000 meters of dune
Time frame	2016-2020
NbS implemented within an Ecosystem-based approach	The program *Building the resilience of Kune-Vain Lagoon through Ecosystem-based Adaptation (EbA) (2016-2020)*, included the implementation of several NbS/CCI/CME (2016-2020): - Management of a lagoon connection with the sea - Reforestation of 7ha of degraded riparian forest with indigenous climate-resilient tree species (from seedlings) Rehabilitation of 2 km of coastal dunes by planting indigenous climate-resilient plant species (including seedlings) against erosion
Threats addressed	Biodiversity loss, coastal erosion, ecosystem vulnerability, anthropogenic impacts by unsustainable use of the lagoon, coastal flood of human communities

Case study A Lagoon Ecosystem-based Adaptation using NbS/CCI/CME	
Contribution to specific climate change impacts reduction	Globally: Carbon mitigation In the area of NbS application: contribution to flood protection, protection against coastal erosion and increase of ecosystem resilience
NbS within	Ecosystem-based Adaptation (EbA)
Specific interests:	Nature ecosystems and human communities in the area are vulnerable to SLR and coastal erosion. Conservation actions had already been implemented.
Ecological benefits	Contribution to climate change mitigation (CO_2 sequestration) Biodiversity conservation Increased habitat resilience to climate change impacts by reduction of other anthropogenic impacts Increased lagoon ecosystem resilience to SLR and coastal erosion threatened by disappearance Connectivity of species population (birds)
Socio-economic benefits	Development of ecotourism around the MPA More natural living environment Possible development of harvested species populations around the area concerned (e.g. fish stocks) Community awareness on these ecosystems through communication Policy and stakeholders' capacity building
Quantifiable results	
Monitoring	No monitoring seems to have been planned.
Evaluation after time	No evaluation has been found to assess the efficiency of the EbA and the NbS.

Effectively protecting Posidonia oceanica at national level

Case study B **Effectively protecting *Posidonia oceanica* at national level**	

Photo: *Posidonia oceanica*, Lesvos, Greece © Maïa Fourt

Location	The case study here concerns France, but Spain protects also *P. oceanica*
Initial estimated cost	No estimated costs for the state but income from non-respect of the laws.
Information on the area and project or program	Resulting from successive regulations, in France it is illegal to destroy, take or use the entire or part of plant, either alive or dead. However special authorizations are regularly given to municipalities to remove banquettes from beaches. Recent regional and local regulations limit the anchoring and even stopping possibilities of vessels over 20 or 24 meters (depending on the area). Authorized or unauthorized areas for anchoring are delimited on the marine charts and available on the Donia app where the *P. oceanica* is precisely mapped as well. Furthermore, a toolkit to establish eco-mooring areas for recreational vessels under 24 meters has been published to support the protection of *P. oceanica* from anchoring damages (see Fontcuberta & Piante, 2025). The document details all steps and technical aspects and details costs and benefits of such installations.
Ecosystems concerned	*Posidonia oceanica* meadows *P. oceanica* beach banquettes
Operational scale	French mediterranean coast
Time frame	Since 2016 - ongoing
NbS implemented within an Ecosystem-based approach	- Protection of *P. oceanica* meadows, mainly from mechanical destruction (anchoring), which increases resilience of the habitat to anthropogenic and climate change impacts. - Conservation of *P. oceanica* banquettes on the coastline to protect beaches from erosion.

<u>Case study B</u> Effectively protecting *Posidonia oceanica* at national level	
Threats addressed	Biodiversity loss, mechanical destruction of *P. oceanica* meadows, habitat destruction, coastal and beach erosion, ecosystem vulnerability
Contribution to specific climate change impacts reduction	<u>Globally</u>: Carbon mitigation <u>Regionally</u>: Contribution to connectivity of species ecologically linked to seagrass meadows <u>In the area of NbS application</u>: contribution to protection against coastal erosion and increase of seagrass ecosystem resilience to climate change.
NbS within	Legislation and regional decisions
Specific interests:	Applied and efficient protection of the habitat from an important anthropogenic pressure destroying the habitat. Many co-benefits including increased resilience to climate change but also improved water quality and coastal protection from erosion.
Ecological benefits	Biodiversity conservation Increased habitat resilience to climate change impacts by reduction of other anthropogenic impacts Connectivity of species population especially fish
Socio-economic benefits	Contribution to climate change mitigation (CO_2 sequestration) Better water quality Possible development of harvested species populations (e.g. fish stocks) Community awareness on these ecosystems through communication Increased knowledge and capacity building of stakeholders
Monitoring	No monitoring seems to have been planned.
Evaluation after time	No evaluation has been found to assess the efficiency of the EbA and the NbS.

A plan to enhance P. oceanica near a city

Case study C A plan to safeguard *Posidonia oceanica* and its ecosystem services	

Photos : *Posidonia oceanica* banquette (left), in situ (right), Lesbos, Greece © Maïa Fourt

Location	Marseille Baie and around the Frioul islands, France (see map in document here). The actions are mainly within a new MPA "Iles du Frioul" but not solely.
Initial estimated cost	The total project is estimated at 1,175,050 €.
Information on the area and project or program	Marseille agglomeration population is over 1.5 million inhabitants and Marseille receives 3.9 million tourists every year. It is a port city open on the Mediterranean with large urban beaches. The Posidonia plan aims at increasing resilience and reducing anthropogenic pressures on *P. oceanica* meadows and better managing banquettes to favour coastal protection taking into account beach users. The Posidonia plan focuses on protecting, conserving and restoring an important marine ecosystem of 600 hectares of *Posidonia oceanica* meadows which have suffered numerous anthropogenic impacts. The plan is articulated around three axes: (i) **Monitoring and studying** state of the habitat and the connectivity role in the Baie of Marseille, (ii) **active management** (management of pleasure and diving boats anchoring, restoration actions of the meadows, development of an alert procedure in case of acute pollutions, integrated and sustainable management of banquettes and beaches, and ecological cleaning of beaches, increased control of the prohibition of anchoring on meadows and information for leisure boats on *P. oceanica* meadows), (iii) **awareness and communication** (photographic expositions, environmental education for the young public, a connected walk along the seaside).
Ecosystems concerned	*Posidonia oceanica* meadows *P. oceanica* beach banquettes
Operational scale	Local, municipality scale. The *P. oceanica* meadows cover over 600 hectares although actions do not concern the entire meadows.
Time frame	2024-2028
NbS implemented within an Ecosystem-based approach	The following NbS are or will be implemented within the ecosystem-based approach of the Posidonia plan: - Protection of *P. oceanica* meadows from mechanical destruction from anchors by increasing mooring buoys in frequented places and further controlling respect of the legislation (anchoring on meadows is forbidden) - Restoring the meadows by seed planting (REPOSEED project) and transplanting around artificial reefs (implemented a long time ago) where anchoring, diving and fishing are prohibited - Integrated and sustainable management of *P. oceanica* banquettes on beaches by testing the "mille-feuille" technique which consists of covering the banquettes with sand (see Martin *et al.*, 2018).

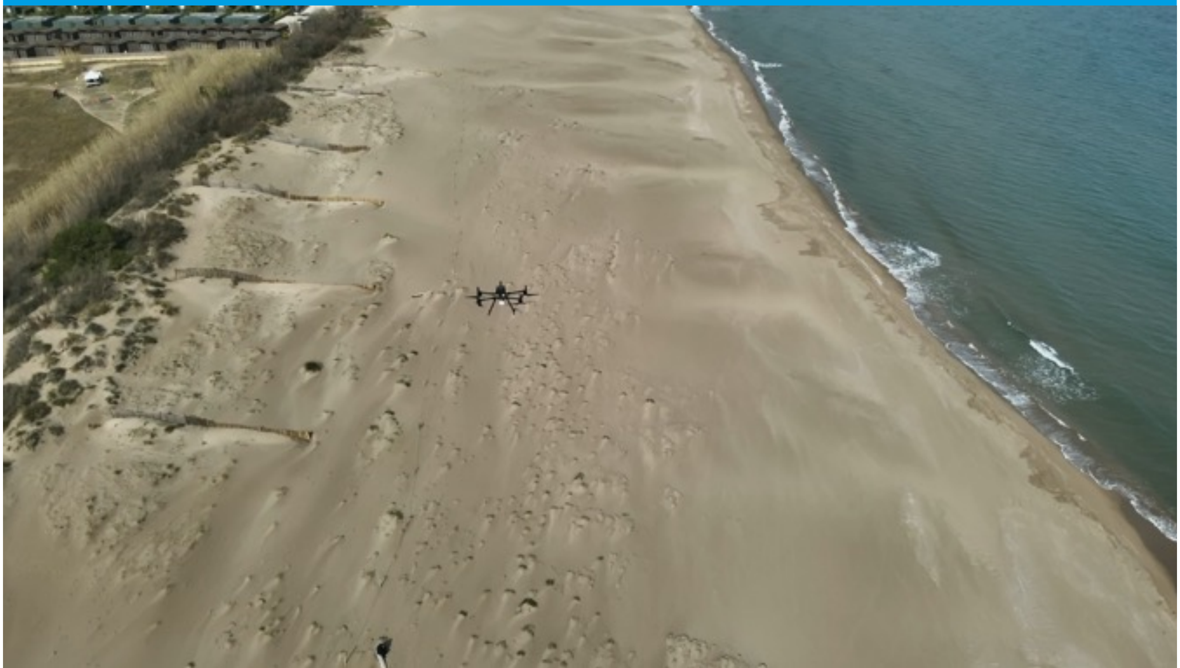
Case study C **A plan to safeguard *Posidonia oceanica* and its ecosystem services**	
Threats addressed	Biodiversity loss, mechanical destruction of *P. oceanica* meadows, habitat destruction, coastal and beach erosion, ecosystem vulnerability
Contribution to specific climate change impacts reduction	Globally: Carbon mitigation Regionally: Contribution to connectivity of species ecologically linked to seagrass meadows In the area of NbS application: contribution to protection against coastal erosion and increase of seagrass ecosystem resilience to climate change impacts.
NbS within	Municipal strategy and action plan with an ecosystem-based approach.
Specific interests:	Applied and efficient protection of the habitat. Many co-benefits including increased resilience to climate change but also improved water quality and coastal protection from erosion. Testing of the sustainability of the "mille-feuilles" NbS to manage banquettes on four frequented beaches. Awareness and communication actions in an urban area. The area benefits for a site where restoration of meadows could be effective because the area is protected from several pressures. The monitoring and evaluation of the state of conservation is planned and builds on a previous monitoring program.
Ecological benefits	Biodiversity conservation Increased habitat resilience to climate change impacts by reduction of other anthropogenic impacts Connectivity of species population especially fish
Socio-economic benefits	Contribution to climate change mitigation (CO_2 sequestration) Better water quality Possible development of harvested species populations (e.g. fish stocks) Community awareness on these ecosystems through communication Increased knowledge and capacity building of stakeholders Facility of mooring on buoys instead of anchoring in certain areas
Quantifiable results	Expected quantifiable results: ✓ State of conservation of the meadows which are monitored ✓ Surface occupied by live *P. oceanica* ✓ Evaluation of the sustainability of "mille-feuille" NbS to manage banquettes
Monitoring	*P. oceanica* meadows have been monitored for many years previously and new monitoring will benefit from installations and methods already in place. Monitoring of planted and transplanted *P. oceanica* is ongoing.
Evaluation after time	The efficiency of the "mille-feuille" management technique of the banquette will be evaluated at the end of the project. The changes in people's perception of banquette on beaches are not planned to be evaluated.

Adaptative management and restoration of saltworks

Case study D **Adaptative management and restoration of former saltworks in a Delta**	
 Photo: Capture from the video of presentation of the website tourduvalat.org see here	
Location	Southeast part of the Camargue Delta, France. See here.
Initial estimated cost	Between 7 and 13 million euros (see here)
Information on the area and project or program	The former saltworks cover an area of over 6,500 ha. The site was purchased by the Conservatoire du Littoral in 2011 with the objective to restore the wetland to a more natural functioning. Several organisations came together to create an adaptive management plan with the objective to restore ecosystem functionality by reconnecting the lagoons within the site and with the surrounding aquatic ecosystems and the sea (Segura *et al.*, 2018).
Ecosystems concerned	Coastal lagoons Mediterranean salt steppes Coastal dunes Wooded dunes
Operational scale	Local, municipality scale. The area extends on two municipalities
Time frame	2012-ongoing
NbS implemented within an Ecosystem-based approach	The restoration project focuses on Ecosystem-based Adaptation (EbA) and Ecosystem-based Disaster Risk Reduction by restoring the functionality of the site and ecosystems. This enhances the resilience of ecosystems to climate change impacts. Further, adaptative management to Sea Level Rise is also applied.

Case study D Adaptative management and restoration of former saltworks in a Delta	
Threats addressed	Sea Level Rise Biodiversity erosion
Contribution to specific climate change impacts reduction	Globally: Carbon mitigation In the area of NbS application: contribution to protection against SLR and increase of wetland ecosystems to resist climate change impacts. Management objectives: - Restore a more natural hydrological functioning that reconnects the surrounding hydrological systems - Restore the natural ecosystems characteristic of coastal lagoons and sandy coastlines, including dunes, salt steppes and saltmarshes - Implement adaptive management to sea-level rise, including controlled coastal retreat in areas affected by erosion
NbS within	Regional Natural Park of the Camargue, the Tour du Valat research Institut, the National Society for Nature Protection and the Conservatoire du Littoral through an ecosystem-based approach.
Specific interests:	The approach will inform on how such restored ecosystems can face climate change impacts and in particular SLR. Changes in the coastline have already occurred with coastal retreat in some places and coastal progression in others (Segura *et al.*, 2018).
Ecological benefits	Habitats and ecosystems recover to a natural functioning (300 hectares of salt marsh habitat were restored) Fish migration corridors between sea and lagoon restored Increased biodiversity Connectivity lagoon – sea reestablished Biodiversity conservation Increased habitat resilience to climate change impacts by restoring natural functioning Connectivity of species population Nursery for fish
Socio-economic benefits	Buffering zone against sea floods and SLR Contribution to climate change mitigation by carbon sequestration Aesthetic and recreational areas Better water quality Community awareness on these ecosystems through communication
Quantifiable results	Biological and ecological temporal surveys on different species
Monitoring	Biological monitoring is taking place on e.g. fish species, macrophytes, salt-marsh vegetation, benthic invertebrates.
Evaluation after time	The evaluation of the effectiveness of the NbS is based on the EKLIPSE guideline for NbS (Raymond *et al.*, 2017) The ecological evaluation of the former saltworks NbS indicate improved functioning of the restored costal lagoons and salt marsh ecosystems (Segura *et al.*, 2018). See also evaluation of the global standard criteria here.

Foredune rehabilitation

Case study E **Foredune rehabilitation**	
	
	Photo from climate-impetus.eu
Location	Sant Pere Pescador, Costa Brava, Catalonia Spain
Initial estimated cost	Not provided
Information on the area and project or program	The beach of Sant Pere Pescador in a rural area has narrowed by 50 meters over the past 50 years due to erosion. In response, the Government of Catalonia and Costa Brava's Natural Park with local support began the Climate IMPETUS project of dune restoration. The climate IMPETUS project was launched in 2021 and is an EU-funded project coordinating on climate change with objective to turn climate commitments into tangible, urgent actions. This dune restoration program is part of Climate IMPETUS Project.
Ecosystems concerned	Coastal dune-beach ecosystem
Operational scale	Local, municipality scale. Two sites that cover 2 km of beach.
Time frame	2019-2024
NbS implemented within an Ecosystem-based approach	Ceasing mechanical cleaning of the beaches with tractors Protection of the foredunes by installing rope fences to delimit walk ways Installation of 21 sand trapping fences 10-15 meters long each, 85 cm high with 60% porosity (see https://climate-impetus.eu/wp-content/uploads/2024/12/POSTER_Garcia-Lozanoetal.pdf). The rehabilitation project focuses on Ecosystem-based Disaster Risk Reduction by restoring part of the functionality of the dune-beach ecosystem. This enhances the resilience of the ecosystems to coastal erosion and storm impacts by restoring a natural dynamic barrier.

Case study E **Foredune rehabilitation**	
Threats addressed	Sea Level Rise Coastal erosion Storm impacts
Contribution to specific climate change impacts reduction	In the area of NbS application: contribution to protection against SLR and coastal erosion of beaches by storms. Management objectives: - Restore a more natural functioning of the foredune-beach ecosystem - Protect the development of vegetation on the foredune
NbS within	EU IMPETUS project
Specific interests:	It is a technical approach with applied tools and monitoring which has shown in this case its effectiveness. The method and concept are being applied in an urban area in Calafel, where the beach has a critical economic value (tourism). Part of the artificial promenade that was covering the foredune has been removed and sand fences have been placed.
Ecological benefits	Dune-beach recover to a more natural functioning Dune vegetation is protected and grows Biodiversity conservation Increased habitat resilience to climate change impacts by restoring natural functioning
Socio-economic benefits	Buffering zone is enhanced against sea floods, storms and SLR Community awareness on these ecosystems through communication
Quantifiable results	Mean height gain and volume increase in the foredune between 2019 and 2024.
Monitoring	Monitoring by drones and high resolution (10 cm) digital elevation models pre and post management measures in 2019 and 2024.
Evaluation after time	The results of the rehabilitation using NbS has been done after 5 years see here.

6. BEST PRACTICES

Climate change is a reality and the Mediterranean region is particularly vulnerable. Therefore, adaptation to new environmental and ecological conditions is necessary for ecosystems and societies. Nature-based Solutions gain momentum as promising tools. However, between theory and application there is a large gap.

Nature-based Solutions (NbS) change the way environmental challenges are addressed. These solutions should deliver benefits to people AND to ecosystems. The NbS which prevent or reduce climate change impacts on coastal and marine ecosystems (NbS/CCI/CME) are a subset of NbS. Their implementation in the Mediterranean region is still rather recent and the results in terms of reduction of climate change impacts not yet always measurable. NbS are effective, but are not quick-fix solutions to answer urgent needs. For an efficient implementation NbS need knowledge, planning, forecasting and an inclusive approach.

To be effective, Nature-based Solutions need to be properly implemented and need time to be correctly evaluated; however, they are cost-effective, sustainable and beneficial for natural ecosystems and no or little regret solutions. NbS/CCI/CME are a necessary investment for the future.

Implement in a holistic and collaborative approach (e.g. case study A)

Best practices to efficiently implement Nature-based technical Solution to reduce or prevent climate change impacts on coastal and marine ecosystems (NbS/CCI/CME) include:

1. Developing NbS/CCI/CME in an integrated way within an ecosystem-based approach such as ecosystem-based Adaptation (EbA), disaster risk management (DRM), Ecosystem-based Disaster Risk Reduction (Eco-DRR), Regional Coastal Schemes, climate change adaptation strategies. The elaboration of such strategies has locally been supported for example in Montenegro and Morocco by the Climagine participatory approach and workshops which favors exchanges and co-construction between stakeholders and develop capacity building. These integrated approaches are supported by NbS/CCI/CME implementation.
2. Developing implementation plan of NbS/CCI/CME within a defined framework. Several guidelines exist among which:
    - general guidelines such as IUCN (2020b), Directorate-General for Research and Innovation (European Commission) (2021) or Eklipse *et al.* (2024)
    - more specific to climate adaptation such as Secretariat of the Convention on Biological Diversity (2019) or Terton & Jang (2024)
    - more specific to coastal and marine ecosystems such as Pérez *et al.* (2024)
    - more specific to urban areas such as IUCN (2021a, b) or Raymond *et al.* (2017)
    - more specific to hydrological extreme events Gómez Martín *et al.* (2020)

The main points highlighted by the guidelines for developing an implementation plan of NbS/CCI/CME include:

- **Identifying societal challenges** to address and have knowledge on their projected future evolution
- **Identifying ecosystems benefiting from NbS** to reduce climate change impacts
- **Defining time and space frame**
- **Acquiring knowledge** on functioning of the ecosystems and their vulnerability to current and future climate change scenarios. Scientific approach should be multidisciplinary and transdisciplinary as much as possible
- **Identifying impacts and risks of future climate change** scenarios on NbS themselves
- **Building a plan in an integrated and collaborative way** including civil society, state and policy, and private sectors concerned. Stakeholder engagement is very important and represents almost one fourth of the lessons learnt from implementing NbS (see Moraes *et al.*, 2022). Take in consideration gender and social inclusion (IUCN, 2020b; World Bank, 2023).
- **Planning the evaluation of the NbS effectiveness** including monitoring of ecosystems and variables
- **Connecting with** relevant national and regional **policies** and strategies
- Keeping in mind that:
    - NbS/CCI/CME should be **site specific**, multifunctional and adaptable
    - NbS/CCI/CME should be planned to be effective on **medium and long term**
- **co-benefits and disservices** which a NBS can produce must be assessed (Gómez Martín *et al.*, 2020)
- **Using empowerment tools** and instruments to favor successful implementation and acceptance of NbS
- **Communicating** on the project

Learning from the past and anticipating future challenges (e.g. case study D, E)

Climatic changes have already heavily impacted mediterranean coastal and marine ecosystems and will continue to do so. Depending on the future anthropogenic emissions, different climate scenarios have been envisaged with different climate change impacts, but all projecting an increase in mean sea temperatures and SLR.

A wait-and-see attitude or making small short-term programs is not a sustainable solution in the long-term (Plan Bleu, 2025). The priority is to adopt a pro-active position, to foresee future climate threats and adapt climate policies and approaches to effectively prevent major risks and avoid their socio-economic and environmental impacts (Galeotti, 2020). To develop appropriate solutions for preventing and reducing climate change impacts on ecosystems and human societies, knowledge on climate change impacts on ecosystems at regional and sub-regional scale are necessary. Alteration of the climate system, which can be specific to a region or even a sub-region, as well as the effects on environmental variables and mechanisms and the profound changes they lead to in the ecosystems, need to be known with precision down to local scale. Given the timescale for some Nature-based Solutions to be effective, it is also useful to anticipate future risks by use of models.

Modelling and assessing coastal risks (e.g. Agharroud *et al.*, 2023; Satta *et al.*, 2017) is necessary to anticipate the degree of climate change impacts on societies and ecosystems and foresee future vulnerabilities. This is also important for selecting or adapting NbS. For example, climate and environmental conditions may change the spatial distribution of suitable environmental conditions for a species, which could have an impact on the NbS to select in a given area (see Ozkiper *et al.*, 2024).

Protect and conserve now, rather than restore tomorrow (e.g. case study B, C)

Conservation of ecosystems is a cost-effective way of maintaining biodiversity. This is especially true for long-living and slow-growing structuring ecosystems such as coralligenous ecosystems or Posidonia meadows. Protecting such ecosystems from anthropogenic impacts will increase their resilience to climate change impacts. Moreover, the capacity of natural capital stored within *P. oceanica* meadows grows with time which results in older meadows having a more important value of natural capital stored than younger meadows (Rigo *et al.*, 2021) highlighting the importance of protection and conservation measures.

Active restoration of Posidonia meadows, which consists in transplanting shoots or planting seedlings, is time-consuming and can cover only small surfaces. If such type of restoration is to be considered, it is recommended to proceed in an area where the species existed before, and where the anthropogenic impacts responsible for the decline of the species has been removed. It is estimated that median survival of restored seagrass after few years is 38%, one of the lowest compared to other habitats (Bayraktarov *et al.*, 2016). Publications reveal that restoration by planting or transplanting can be more successful if it is done on dead matte but generally gives variable results. Therefore, protecting dead matte is also important.

Wetlands supply essential ecosystem services in the context of climate change, such as flood reduction, water availability and water quality. However, they are under severe pressure from anthropogenic activities, reducing their number and their ability to provide essential ecosystem services. The value of sustainable management of European wetlands is estimated to be from ten to fifty times higher than the average wetland restoration costs (Strzęciwilk & Grygoruk, 2025). The average value of ecosystem services provided by wetlands is estimated to 4,011 euros /habitant/year (Strzęciwilk & Grygoruk, 2025), which economically justifies the conservation and protection of wetlands.

In France, the Conservatoire du Littoral is a public organization with no equivalent in Europe. Its mission is to acquire coastal land threatened by urbanisation, or degraded, to create restored, naturally balanced sites accessible to the public, taking into account climate change concerns. Currently it has acquired over 750 sites accounting for more than 13% of coastal linear protected areas. These areas are conserved and act as buffer zones and protect inland urbanized areas and ecosystems.

7. CHALLENGES AND RISKS ASSOCIATED WITH NBS/CCI/CME IN THE MEDITERRANEAN

In the current climate change situation and considering the future projections and the state of marine and coastal ecosystems, the use of Nature-based Solutions for the prevention and reduction of climate change impacts on coastal and marine ecosystems (NbS/CCI/CME) should be highly encouraged in the Mediterranean region. However, challenges and risks associated to the implementation of Nbs are issues which must not be ignored.

The following points highlighting **challenges and risks associated with NbS/CCI/CME** emanate from several publications including Castelo *et al.* (2023); Hou-Jones *et al.* (2021), Lehmann *et al.* (2025):

Common understanding

- **Need of a common understanding and language of NbS** (e.g. to what degree can beach nourishment, artificial reefs or actions and innovations inspired by nature be considered as NbS?)
- **Need of a common understanding of different Ecosystem-based approaches** relative to climate change (Ecosystem-based Adaptation, coastal risk assessment and adaptation, ecosystem-based disaster risk reduction)

Planning, approach and knowledge for informed choices

- **Careful planning** is needed for a successful NbS implementation.
- **There is a general lack of scientific knowledge** in the functioning and interrelations of marine and coastal ecosystems in the Mediterranean necessary for informed choices of NbS. Tis point was also highlighted by the participants to the workshop on NbS for coastal and marine ecosystems held in Gökova, Türkiye on December 9th 2025.
- **Maladaptation or unintended consequence pose real risks** when implementing NbS without sufficient scientific knowledge on the ecosystems, the environment and the specific site and case.

Communication and co-construction of NbS for success

- Setting-up sustainable and adapted NbS can be a long process which needs to **be co-constructed** with stakeholders and civil society and local private sector for a better acceptance and contribution to NbS success. Incorporating people from different sectors with different needs may not be an easy job.

From planning to implementation

- **NbS/CCI can be effective only through time**; they cannot be immediate solutions even though human societies generally have a short-term view. NbS are an investment for ecosystems and human societies with a medium and long-term view which is not always easy to accept.
- Ecosystem-based approaches are necessary for NbS/CCI/CME implementation and are often unknown to policy-makers, stakeholders and civil society. There is a strong need to **mainstream these ecosystem-based approaches** for NbS to be accepted and efficiently implemented.
- There are successful pilot sites where NbS/CCI/CME have been tested, but further sustainable **implementation is stalling due to limited funding, short projects, institutional difficulties and fragmented mandates** (Wendling *et al.*, 2025). These barriers need to be identified for each site at the early planning stage to be overcome.

Shadows of success

- By focusing on NbS, there is a **risk of diverting attention from the immediate need to decarbonise economies** and human ways of living
- NbS have gained momentum rapidly with the development of many "new" NbS, but there is a **danger of overlooking the key protection and restoration concepts**
- **Be aware of "bluewashing" practices** with poorly constructed NbS actions for marketing reasons, to promote an environmentally friendly image so as to counter other unsustainable practices of the entity. These practices are relatively frequent and must be identified.

Scaling-up NbS

- To be efficient, NbS/CCI/MCE must be site and case-specific taking into account environment, ecosystems, national policy, socio-economic and cultural context (e.g. Ernoul & Hetherington). Currently in the Mediterranean they are generally local stakeholder-driven projects. To address regional and global climate challenges, **scaling-up NbS is necessary** but adjustments are often needed, requiring for example knowledge of original context and success factors (European Environmental Agency, 2023). Three scaling approaches are often considered (Salafsky *et al.*, 2021 in European Environmental Agency, 2023):
  - o by replicating the NbS in a similar context with few adjustments (scaling out),
  - o by expanding the scope of the NbS beyond local area which requires addressing regulatory barriers and sustainable adaptation (scaling up),
  - o by addressing socio-economic and political drivers of ecosystem degradation which requires a fundamental shift in perceptions, institutions and policies but is efficient for the construction of long-term sustainability of NbS (scaling deep).

Uncertainties

- **There are uncertainties concerning future climate changes** and their effects on ecosystems, despite the projections proposed by models.
- **The degree and speed of coastal and marine ecosystems' natural adaptation to climate change are poorly known**.
- **Impacts of climate change on NBS/CCI/CME** are delicate to assess.

Ecosystems with few known NbS/CCI/CME available

- Hardly any Nature-based technical Solutions concern **offshore marine ecosystems** in the Mediterranean. Yet, there are effective management measures which may be considered as NbS/CCI/CME, even if they are not explicitly labelled as such. In **ecosystem-based fisheries** management, for example, the Fisheries Restricted Areas (FRAs) and the Essential Fish Habitats (EFH) increase ecosystem and fish resilience to climate change by reducing fisheries impacts (see Ortega *et al.*, 2023). In the same way, GFCM 2030 Strategy embeds actions which can be considered as NbS/CCI/CME. The objective to reduce pressure on fish population by a more sustainable fishery will potentially favour the resilience of fish stocks to climate change impacts. However, they are rarely recognised as NbS/CCI/CME. **There is a need for development for NbS/CCI in the fishery sector**.
- Coastal urban areas undergo extreme events which can highly impact surrounding marine and coastal ecosystems. **NbS/CCI/CME are minimally developed for coastal urban areas**. They could be further researched relative to coastal urban areas.
- **Aquaculture** could also benefit from NbS/CCI/CME by exploring more ecologically sustainable practices which could benefit surrounding ecosystems such as integrated multi-trophic aquaculture.

8. SUGGESTED POLICY AND INSTITUTIONAL FRAMEWORKS TO SUPPORT THE IMPLEMENTATION OF NBS/CCI/CME

Implementation of Nature-based Solutions answer to policies' requests. At regional and global scale, several strategies and frameworks support the implementation of Nature-based Solutions to reduce Climate Change Impacts on Coastal and Marine Ecosystems (NbS/CCI/CME) (see Figure 8). The main regional frameworks to support the implementation of NbS/CCI/CME are further detailed.

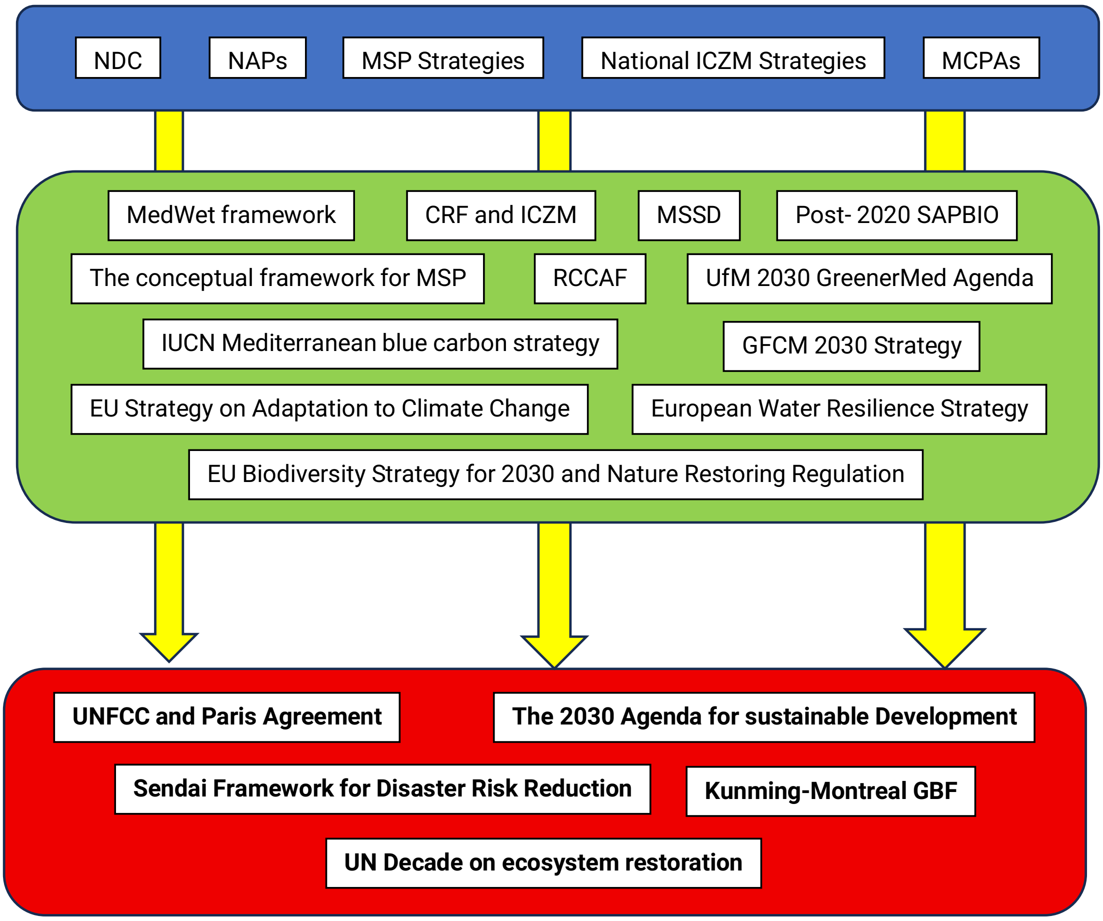


Figure 8.

National, regional and global policies to which NbS implementation answers.

Bleu: national and sub-national scale, green: regional scale and red: global scale.

Mediterranean frameworks and strategies

Regional Climate Change Adaptation Framework for the Mediterranean marine and coastal areas (RCCAF). The objective of the strategy is to define a regional strategic approach to increase resilience of the Mediterranean marine and coastal natural and socioeconomic systems to the impacts of climate change (UNEP/MAP, 2017b). Its geographical scope is that of the Barcelona Convention (the Mediterranean Sea and the coastal zones of the 21 countries that border it). The Framework recognizes that climatic changes will have impacts that do not respect the boundaries of a coastal zone as it is usually defined, and that coastal adaptation actions may be required further inland, in particular in inland watersheds (UNEP/MAP, 2017b). The 2016-2025 framework was endorsed by the Contracting Parties of the Barcelona Convention at COP 19 in 2016. The 2026-2035 framework is currently under review and should be endorsed at COP 24 in December 2025.

Whereas Nature-based Solutions were not referred to in the 2016-2025 RCCAF, the 2026-2035 RCCAF puts Nature-based Solutions at the forefront by:

- enabling environment for the formulation of and implementation of efficient solutions for the complex and cross-cutting problems created by climate change (Strategic Objective 1)
- supporting with ICZM the identification and preservation of areas of special interest (such as heritage sites, nature reserves, biodiversity and ecosystems, coastal mega-cities, river deltas etc.) as well as Marine Protected Areas (MPAs) and undertaking their risk assessments against various climate change scenarios, development of methodologies and guidelines for subnational levels for the integration of climate adaptation dimensions into their development and management plans (Strategic Direction 1.5)
- strengthening national and local capacities on the application of Nature-based Solutions for climate change adaptation, including via pilots in the Southern Mediterranean, North and Ionian/Adriatic sub-regions, and based on the best practiced developed in the framework of the 2020-2024 Special Climate Change Fund (SCCF) established the Project for “Enhancing regional climate change adaptation in the Mediterranean Marine and Coastal Areas (Strategic Direction 2.1)
- considering Nature-based Solutions approaches, the ICZM Protocol and Post 2020 SAP/BIO adaptation practices as priority policy and actions tools for encouraging adaptation efforts (Strategic Direction 2.2)

The Mediterranean Strategy for Sustainable Development (MSSD). It seeks to address the needs of current and future generations, utilizing natural resources and ecosystems in ways that preserve and sustain them and ensure equitable access to them in the present and the future. It sets the framework for securing viable and lasting development and decent livelihoods for all, which are particularly important considerations in the current challenging Mediterranean socio-economic context (UNEP/MAP, 2016). It translates the 2030 Agenda for Sustainable Development and the Sustainable Development Goals at regional, sub-regional, national and local levels in the Mediterranean region. The 2016-2025 MSSD was adopted during COP 19 in 2016.

The 2016-2025 MSSD does not refer to Nature-based Solutions. The time frame of the 2026-2035 MSSD is aligned the upcoming 2026-2035 RCCAF. These strategies were updated in parallel especially concerning climate change with emphasis on adaptation. The new MSSD should be endorsed at COP 24 in December 2025.

Nature-based Solutions are at the heart of 2026-2035 MSSD Strategic Direction 1.6 "Strengthen national and local capacities on the application of nature-based solution for climate change adaptation and mitigation". Further, water management which is a concern of MSSD could integrate NbS in coastal urban areas to reduce rainfall runoffs.

The Common Regional Framework for Integrated Coastal Zone Management (CRF) adopted at COP 21 in 2019, is designated as the strategic instrument meant to facilitate the implementation of the ICZM Protocol from 2020 up to 2027.

The CRF aims to provide recommendations and measures to strengthen regional cooperation for processes, indicators, methods and practices to achieve objectives and principals of the ICZM Protocol. One of the objectives is *to address natural hazards and the effect of natural disasters, in particular coastal erosion and climate change risk by, amongst other, promoting ecosystem approach and nature-based solutions to maintain or restore the natural capacity of the coast to adapt to changes*.

The Conceptual Framework for Marine (or Maritime) Spatial Planning (MSP) in the Mediterranean (document available here) has two objectives: (i) to introduce MSP in the framework of the Barcelona Convention, and in particular link it to ICZM, considering MSP as the main tool/process for the implementation of ICZM in the marine part of the coastal zone and specifically for planning and managing maritime human activities according to EcAp goals, (ii) to provide a common context to CPs for the implementation of MSP in the Mediterranean Region. Although it is not directly linked to the use of NbS, implementing NbS requests interactions with national, regional and/or local Marine Spatial Planning. A practical guide to support MSP implementation is available here (see UNEP/MAP & PAP/RAC, 2023).

Post-2020 Strategic Action Programme for the conservation of BIOdiversity and sustainable management of natural resources in the Mediterranean region (Post-2020 SAPBIO). It was adopted at COP 22 in 2021 by the Contracting Parties of the Barcelona Convention. *The Strategy is focused on narrowing the gap between most and less developed countries and promotes mainstreaming biodiversity into all environmental and sectorial policies relevant for the protection and sustainable use of marine living resources. It incorporates the main emerging issues, such as challenges from climate change, the ecosystem approach, ecosystem services,* ***Nature-based Solutions****, and the need for ecosystem restoration, regarding not only marine but also coastal habitats, such as estuaries, wetlands and dunes (UNEP/MAP-SPA/RAC, 2021)*. It calls on CPs to reduce threats to biodiversity by targeting ecosystem restoration, climate change mitigation, adaptation and use of **Nature-based Solutions (NbS)** and calls on them to *enable the necessary transformative change, putting in place tools and* ***Nature-based Solutions*** *for implementation and mainstreaming* with expected results by 2027 and 2030. In particular task T 1.8 demands that By 2030, *all countries have adopted and started implementing* ***short- and medium-term measures for climate change mitigation and adaptation****, particularly to warming, acidification and contributing to disaster risk reduction, through reducing emissions, nature-based solutions, ecosystem-based approaches, and restoration as appropriate, ensuring resilience and minimizing any negative impacts on biodiversity, thereby also contributing to halt global warming and acidification*. Further task T2.6 calls for sustainable and responsible aquaculture encouraging the use of nature-based solutions.

UfM 2030GreenerMed Agenda aims to define the post-2020 UfM Environment Agenda which addresses key environmental issues in the Mediterranean that require cooperation across borders and sectors. It was developed collaboratively with countries and stakeholders, linking local experience with decision-making processes at national, regional and international levels. Thematic axis 1 supports the transition to a green, circular and socially inclusive economy based on sustainable consumption and production practices and nature-based solutions, and thematic axis 3 supports protection, preservation, management and restoration of natural resources in the Mediterranean region within an integrated ecosystem approach, including terrestrial, marine and coastal dimensions (KA3.9. Promotes nature-based solutions) (see UfM, 2022).

IUCN Mediterranean blue carbon strategy aims to establish a comprehensive framework for the protection, restoration, and sustainable management of blue carbon ecosystems, such as *Posidonia oceanica* meadows and other seagrasses (see Hidalgo *et al.*, 2025). The strategy outlines a roadmap from 2025 to 2030 to safeguard the Mediterranean's natural heritage by integrating scientific, economic, and community efforts.

GFCM 2030 Strategy for sustainable fisheries and aquaculture in the Mediterranean and the Black Sea (GFCM 2030 Strategy) (FAO, 2021). It aims *to preserve the heritage of fisheries and aquaculture as pillars for the livelihoods of Mediterranean and Black Sea coastal communities, ensuring their transformation into a productive and sustainable food system that contributes to thriving economies and healthy ecosystems* through 5 targets. Expected targets are formulated including the use of NbS, such as in target 1, outcome 1.3: *Efficient area-based conservation measures, technical and nature-based solutions strengthened to conserve biodiversity and enhance the productivity of marine living resources*; target 3, outcome 3.2 supporting *blue transformation of the aquaculture industry, following an ecosystem approach and through science- and nature-based solutions, effective spatial planning tools, digitalization and innovation*. Although in this strategy NbS are not specifically oriented to reduce climate change impacts on fish, reducing the fishing pressure will contribute to enhanced resilience to climate change impacts.

Wetlands for sustainable Mediterranean region (MedWet). This is a regional intergovernmental network operating within the framework of the Ramsar Convention. It is dedicated to promoting and supporting multi-stakeholder policies and actions on the ground for the conservation, restoration and sustainable use of Mediterranean wetlands. Their actions develop within the framework defined in the document Wetlands for sustainable development in the Mediterranean Region. A Framework for Action 2016-2030 (MedWet Secretariat, 2016) and include Nature-based Solutions with the will to "*improve the understanding and promote the use of wetlands as nature-based solutions to mitigate extreme events*" (Action 11.bis.6).

European frameworks, strategies and policies

EU Strategy on Adaptation to Climate Change. It was adopted by the European Commission in 2021 and projects climate resilience of EU states by 2050. The Strategy supports further development and implementation of adaptation strategies and plans with three priorities including Nature-based Solutions for adaptation. Greater efforts are requested including more investments in NbS to generate benefits for climate adaptation and mitigation, disaster risk reduction, biodiversity and health. To support this the European Climate Adaptation Knowledge Platform Climate-ADAPT has been operationalized.

Nature Restoration Regulation (Regulation (EU) 2024/1991 amending Regulation (EU) 2022/869) within the framework of the EU Biodiversity Strategy for 2030 entered into force in august 2024. *It calls for legally binding restoration targets, particularly for the habitats in Annex I of the EU Habitats Directive, as well as for ecosystems with the highest potential to capture and store carbon and reduce the impacts of extreme climate events*. Restoration measures should be put in place in at least 30% of the total area of all habitat types listed in Annex I that are not in good condition, as quantified in the national restoration plan referred to in Article 15 by 2030, increasing to 60% by 2040 and 90% by 2050. The Regulation *also requires Member States to integrate adaptation in all policy areas and promote ecosystem-based adaptation and nature-based solutions. Nature-based solutions are solutions that are inspired and supported by nature, that are cost-effective, and that simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. Nature-based solutions need to therefore benefit biodiversity and support the delivery of a range of ecosystem services*.

The regulation provides the opportunity to enhance resilience against climate change impacts with NbS.

European Climate Resilience and Risk Management – Integrated Framework to prevent and prepare for growing impacts of climate change is in preparation and is expected to be adopted during the second half of 2026.

European Water Resilience Strategy (COM/2025/280 final). It promotes the "sponge cities" in urban areas based on NbS to absorb and release water in a controlled way and to establish an integrated management of fresh and marine waters, recognizing the importance of coastal areas in the water cycle and the need for protection from pollution of the sea, as well as the strong impact of pollution in rivers, water shortages and sediment flows disruption on the health of marine ecosystems and the viability of the social and economic activities that depend on them, such as fisheries, aquaculture or tourism. It promotes *the source-to-sea approach, the use of nature-based solutions, investment in sustainable water and sanitation for all, and innovation-driven policy reforms*.

9. ACTIONABLE RECOMMENDATIONS FOR INTEGRATING NATURE-BASED SOLUTIONS INTO CLIMATE CHANGE ADAPTATION STRATEGIES

Nature-based Solutions to prevent and reduce Climate Change Impacts on Marine and Coastal Ecosystems (NbS/CCI/MCE)

Regional Scale

European scale

- EU Strategy on Adaptation to Climate Change
- Nature Restoration Regulation
- European Climate Resilience and Risk Management – Integrated Framework
- European Water Resilience Strategy

Mediterranean scale

- Regional Climate Change Adaptation Framework for the Mediterranean marine and coastal areas (RCCAF)
- The Mediterranean Strategy for Sustainable Development (MSSD)
- The Common Regional Framework for Integrated Coastal Zone Management
- Post-2020 SAPBIO
- GFCM 2030 Strategy for sustainable fisheries and aquaculture in the Mediterranean and the Black Sea
- Wetlands for sustainable Mediterranean region Framework

National scale

- Adaptation plans
  - In National Adaptation Plans
  - Ecosystem-based Disaster Risk Reduction plans
  - Nationally Determined Contributions
- Spatial planning tools
  - ICZM
  - MSP
  - Coastal Management plan
- Marine and Coastal Protected Areas (MCPAs)
- National Water Resilience strategies
- Fisheries management

Local scale

- Adaptation plans
  - Subnational and local climate coastal adaptation strategies including in watershed
- Spatial planning tools applied locally
  - ICZM
  - MSP
  - Coastal Management plan
- Marine and Coastal Protected Areas (MCPAs)
- National Water Resilience strategies
- Subnational fishery management
- Local community network

NbS in marine and coastal areas can be an essential part of sustainable economies and contribute to implementing long-term social and natural resilience for future climatic context (O'Leary *et al.*, 2023).

For NbS implementation in Mediterranean marine and coastal areas to succeed, there is a need for training in Ecosystem-based approaches and climate change adaptation strategies including NbS (Plan Bleu & UNEP/MAP, 2025). An in depth understanding of ecological dynamics, ecosystem functioning and how they can be managed in a climate change context is necessary to efficiently implement NbS/CCI/CME. Research, experience sharing, participatory workshops, training and increased resources are essential for Mediterranean countries to implement sustainable Nature-based Solutions to prevent and reduce Climate Change Impacts on Coastal and Marine Ecosystems.

Up until recent years, regional climate change adaptation strategies (Mediterranean or European) barely took into account Nature-based Solutions (NbS). Recent updates however have included NbS in these new strategies.

The **Climagine participatory methodology** and foresight analysis process developed by Plan Bleu and PAP/RAC, builds on stakeholder engagement and focuses on the development of coastal adaptation plans and solutions supported by MedProgramme Special Climate Change Fund (SCCF) project. These climate change adaptation plans include as well Nature-based Solution. Workshops to develop capacity building and implement the approach have been organised for example to support the coastal management plan of the Bay of Kotor (see here and Plan Bleu-PAP/RAC, 2024), or the regional coastal scheme in the Tangier-Tetouan-Al Hoceima (TTA) region in Morocco. Such tools support the development of coastal adaptation plans in the Mediterranean. The Climagine methodology was presented during the NbS and Climate Adaptation Strategies for Coastal and Marine Ecosystems workshop, 9th-12th December 2025, in Gökova Bay, Türkiye (Appendix 2 for NbS workshop, and workshop report UNEP/MAP-SPA/RAC, 2025).

Nature-based Solution to reduce and prevent climate change impacts on coastal and marine ecosystems (NbS/CCI/CME) in the Mediterranean region are still at the stage of demonstration projects, lacking effective integration in national and local climate change adaptation strategies. They are progressively recognised as multifunctional, cost-effective and sustainable approaches able to answer simultaneously several challenges such as climate change impacts, biodiversity and ecosystem health erosion, and socio-economic concerns. However, their practical implementation and efficiency remain a challenge due to lack of long-term financing, inclusive governance, stakeholder engagement and policy complexity. **In the Mediterranean region, NbS implementation needs to be developed. It is therefore recommended to act for integrating NbS at all levels (regional, national and local)**.

Spatial planning and community-based management with shared decision-making and combining economic, cooperative and knowledge-based approaches are powerful instruments to mainstream and develop implementation plans for NbS (Wendling *et al.*, 2025).

In national adaptation plans

It is recommended to incorporate NbS/CCI/CME into climate change national adaptation plans (e.g. National Adaptation Plans, Nationally Determined Contributions/Paris Agreement) and Disaster Risk Reduction plans (see Plan Bleu & UNEP/MAP, 2019).

Further, all local and national marine and coastal ecosystem and biodiversity conservation plans should consider NbS/CCI/CME. More specifically, the effective protection and assessment of key marine ecosystems such as Posidonia meadows (based on IMAP indicators) at local or national scale, should be examined.

Adequate institutional structures and economic instruments to facilitate the implementation of NbS/CCI/CME would contribute to reducing obstacles for action (see Interreg Euro-MED-ARTEMIS, 2025 and Plan Bleu & UNEP/MAP, 2019). Adapted policies to NbS approach are needed at national and sub-national level.

In spatial planning

It is recommended to further take into consideration NbS/CCI/CME in national spatial planning policies such as Integrated Coastal Zone Management (ICZM), Maritime/Marine Spatial Planning (MSP), Coastal management Planning. In the framework of GEF MedProgramme (see Climagine project) for example, after a coastal risk assessment, a Coastal Plan development was launched in Kotor Bay (Montenegro) and in the Moroccan region of Tanger-Tetouan-Al Hoceima including Ecosystem-based Adaptation approach and NbS (Snoussi & Nibani, 2025).

> Snoussi & Nibani (2025) p.17 clearly detail how NbS can inform ICZM: "*NbS offer valuable insights and strategies that can considerably improve Integrated Coastal Zone Management (ICZM) by proposing sustainable and resilient approaches to coastal challenges. In addition to the ecosystem services of protection from natural disasters, support for biodiversity and fisheries, and carbon sequestration, NbS encourage adaptive and flexible approaches that integrate ecosystem restoration and conservation into coastal planning. By using ecosystem approaches, ICZM can be better prepared for climate-induced changes, by adjusting policies and practices in line with changes to environmental conditions. NbS can promote adaptive monitoring frameworks that adjust management strategies to ecosystem responses in real time, making ICZM more resilient. In addition, and as mentioned above, NbS often rely on community involvement and local knowledge, particularly in the restoration and management of natural coastal components. This fits in well with the inclusive approach of ICZM, which enhances local management and incorporates diverse interests. By capitalising on NbS, Mediterranean coastal zones can strengthen their resilience to climate risks, improve water management, enhance food security and preserve biodiversity.*"

Moreover, the regional **ICZM Protocol** (Art. 8) which entered into force in 2011 and was enforced by the **Common Regional Framework for Integrated Coastal Zone Management** (CRF) adopted in 2019, requests a minimum width of 100 meters setback to preserve the coastal natural habitats, landscapes, natural resources and ecosystems, in compliance with international and regional legal instruments and sustainable use of coastal zone.

Such a setback clearly represents a NbS/CCI/CME since it protects coastal populations from climate change impacts such as storms and SLR and benefits coastal ecosystems by preserving natural coast. Both ICZM and NbS promote sustainable development and resilience in coastal zones (PAP/RAC, 2024).

Currently not all CPs have signed the ICZM Protocol and translated it into national policies. **It is highly recommended to do so and in certain vulnerable areas even consider increasing the setback zone.** Guidelines **for the preparation of national ICZM have been published (see UNEP/MAP-PAP/RAC, 2015).**

In Marine and Coastal Protected Areas

Marine and Coastal Protected Areas (MCPA) can be considered as NbS/CCI/CME when Ecosystem-based Adaptation (EbA) to climate change is implemented through protecting, restoring and managing. The CPs have endorsed Post-2020 SAPBIO which includes NbS/CCI/CME implementation, **it is therefore recommended to implement Post-2020 SAPBIO tasks related to climate change (especially task T1.8) and act in MCPAs by defining Ecosystem-based Adaptation plans based on NbS/CCI/CME adapted to the priorities of each MCPA**. Also use all means available to mainstream NbS approach and search for capacity building workshops or programmes to implement NbS/CCI/CME in MCPAs.

In wetlands framework

For coastal wetlands, it is recommended to develop NbS/CCI in collaboration with MedWet which promotes the use of wetlands as NbS to mitigate extreme climatic events (MedWet Secretariat, 2016). Such a collaboration could be especially productive in terms of projects, capacity building and awareness development.

In coastal urban areas through water resilience strategies

Climate change adaptation plans for coastal cities. In the majority of the climate change adaptation plans of Mediterranean European cities, there are proposals for NbS (Pietrapertosa *et al.*, 2023). However, these concern essentially urban nature restoration and greening interventions. Pietrapertosa *et al.* (2023) highlight that as most mediterranean cities are old cities densely constructed, space needed for NbS will represent a challenge for their efficient implementation. **It is recommended to further explore the use of NbS/CCI/CME in coastal urban areas in particular with respect to flash flood mitigation which can highly impact coastal and marine ecosystems**. The concept of "**sponge cities**" could probably be further adapted to coastal Mediterranean cities. **Links with national and local water management plans could be developed** to reduce rainwater losses and reuse water. In water management plans, NbS are frequently used tools for ecological and societal resilience. Some are particularly interesting (see CARDIMED project).

In fisheries ecosystem-based management

Concerning the reduction of climate change impacts on marine ecosystems and especially fish stocks, reducing overfishing would help reduce their vulnerability to climate change. Therefore, **it is recommended to identify overexploited stocks and reduce fishing pressure on them at national scale** in line with the GFCM 2030 Strategy for sustainable fisheries and aquaculture in the Mediterranean and the Black Sea. Moreover, efficient area-based conservation measures such as GFCM Fisheries Restricted Areas (FRAs) for the conservation of stocks, habitats and deep-sea ecosystems can act as NbS/CCI/CME since they enhance the resilience of habitats and stocks. It is therefore recommended to identify essential areas for vulnerable fish stocks and take appropriate measures or consider submitting a proposal for GFCM FRA.

10. DATABASES AND REFERENCE DOCUMENTS FOR NBS/CCI/CME IN THE MEDITERRANEAN

It is important to build on an evidence base for NbS/CCI/CME in the Mediterranean area. As NbS are site specific and dependent on socio-economic and cultural context for their success, the most informative are case studies from the Mediterranean region. However, case studies from around the world can also be of interest.

Conservation and development practitioners, policymakers, stakeholders, researchers and NGOs need to better appreciate what nature and societies can benefit from NbS (UNEP/MAP and Plan Bleu, 2020). How to implement NbS, in which conditions, what results should be expected and how to measure them are some legitimate questions stakeholders can have.

Thus, it is important to compile information on possible NbS in relation to the challenges being faced (Climate change impacts), the ecosystems concerned (coastal and marine) and the area (the Mediterranean region).

Nature-based Solutions are being developed world-wide and some databases attempt to regroup wide ranges of NbS to share experience such as the Nature-based Solutions Initiative which has a Case Study platform and Network Nature, a European platform which gives access to many case studies (see following Table 2). However, these world-wide databases generally have only a few or no case studies relative to climate change impacts on coastal and marine ecosystems in the Mediterranean.

The following table is a non-exhaustive list of documents, scientific articles, websites and digital platforms which compile examples of NbS/CCI/CME practical applications or guidance documents for their application.

Table 3

Resources presenting several NbS/CCI/MCE case studies or guiding documents for their application

Document/website	Links	Subject or Interest for NbS/CCI/CME	Comments
Documents compiling NbS with examples of NbS/CCI/CME			
Adapto and Adapto+ projects on coastal wetland and coast adaptation to climate change.	https://www.lifeadapto.eu/ https://lifeadaptoplus.eu/	Site of Adapto and Adapto+ Life projects which use NbS for the flexible management of coastal zones across altogether 22 shoreline sites in France.	There are 6 sites in the Mediterranean. Both the ecological and economic benefits of NBS are highlighted.
CARIMED	https://www.cardimed-project.eu/about-us/	Site of CARIMED project funded under the Horizon Europe program under the Adaptation to Climate Change Mission. The project uses technology to make it easier for people to collect and share information about NbS and climate resilience.	There are 9 demo-site primarily on water management but interesting for urban areas.
European Climate Adaptation Knowledge Platform Climate-ADAPT	https://climate-adapt.eea.europa.eu/en	This platform gives access to guidance documents and tools and gives the possibility to explore case studies in Europe. Different climate change adaptation approaches are compiled in a case study database accessible through the Case study explorer.	Only two concern the Mediterranean and Nature-based Solutions
Interreg Med Mediterranean Biodiversity Protection Community (MBPC). (2022).	https://planbleu.org/wp-content/uploads/2022/11/Technical-factsheet_Plan-Bleu-NbS.pdf	Nature-Based Solutions (NbS) in Mediterranean Coastal Zones. There is a detailed table of 24 "NbS projects implemented in the Mediterranean coastal zone". Many concern MPAs, few do not concern NbS/CCI/CME	The document is concise but detailed on the programs and includes projects with a large spectrum of NbS/CCI/CME including sustainable fisheries practices
Littorex platfom-	https://littorex.brgm.fr/fr (currently not accessible)	Platform created to share experiences with NbS in coastal, marine and estuary ecosystems in France.	The website was not available.
Nature-based Solutions Initiative	https://casestudies.naturebasedsolutionsinitiative.org/	The NbS Case Study platform gives access to examples of best practice Nature-based Solutions from around the globe. This database contains 150 rural and coastal NbS world-wide. Five concern the Mediterranean Sea, and none are NbS/CCI/CME.	No NbS/CCI/CME for the Mediterranean found
NBS Italy Hub	https://www.nbsitalyhub.it/en/#	The main purpose of the National hubs is to support the collaboration among stakeholders, enhancing new skills development and productive know-how circulation.	Proposes many Italian case studies. The platform is user-friendly. Summarized information is uneven between NbS. Several NbS/CCI/CME are informed.
NetworkNature	https://networknature.eu/networknature/about-nn	The platform gives access to a certain number of case studies mainly in Europe but also world-wide. It contains over 560 case studies, 98 concern coastal and marine ecosystems and climate resilience. However, the selection criteria do not give the possibility to select NbS/CCI/CME in the Mediterranean. Platform to explore and learn about NbS.	The selection process of NbS Case studies to consult is not user friendly.

Document/website	Links	Subject or Interest for NbS/CCI/CME	Comments
Oppla	https://oppla.eu/	Oppla is a global knowledge platform bringing together the latest research on natural capital, ecosystem services and nature-based solutions.	Over 400 case studies but the access to the case studies is not very user-friendly.
RES-COAST project	https://rest-coast.eu/about	*The Large scale RESToration of COASTal ecosystems through rivers to sea connectivity* project aims at improving coastal restoration practices and techniques through new hands-on restoration tools to address some key challenges to coastal ecosystems including Pilot sites where conservation and management actions are combined to NbS for a holistic approach.	This project has several sites in the Mediterranean. It is part also of the Mediterranean Biodiversity Consortium.
Tour du Valat	https://tourduvalat.org/en/actions/	French research Institute for the conservation of Mediterranean wetlands offering detailed examples of their numerous actions in Camargue (France) very often supported by NbS.	Several past and current projects on wetland protection and adaptation to climate change can be discovered, several of which are NbS/CCI.
Wetland based Solutions	https://www.wetlandbased-solutions.org	Site dedicated to the restoration of wetlands.	Proposes resources on wetland NbS which are briefly presented and factsheets on sites where NbS for wetlands are implemented. Several concern climate change impacts.
Canals Ventín, P., & Lázaro Marín, L. (2019).	https://iucn.org/sites/default/files/2022-07/towards_nature-based_solutions_in_the_mediterranean.pdf	IUCN document on Nature-based Solutions in the Mediterranean. 14 NbS are detailed, 5 can be considered as NbS/CCI/CME	The case studies are detailed and impacts of the NbS are assessed.
Interreg Med Mediterranean Biodiversity Protection Community (MBPC). (2022).	https://planbleu.org/wp-content/uploads/2022/11/catalogue_Mediterranean-ecosystem-Restoration.pdf	Mediterranean ecosystem restoration sites. Not explicitly on NbS but several case studies from wetland and coastal ecosystems use NbS.	Although Case studies do not exclusively use NbS, the case studies from wetland ecosystems and coastal and marine ecosystems are detailed and of interest for NbS/CCI/CME
IUCN Comité français. (2022).	https://uicn.fr/wp-content/uploads/2022/07/sfn-littoraux-web.pdf	Nature-based Solutions for coastal risks in France (Les Solutions fondées sur la Nature pour les risques littoraux en France)	Nine case studies are detailed with difficulties encountered and results. Document in French.
Moraes, R., Reguero, B. G., Mazarrasa, I., & Ricker, M. (2022).	https://doi.org/10.3389/fenvs.2022.829526	Nature-Based Solutions in Coastal and Estuarine Areas of Europe.	In supplementary material the NbS studied are listed with general information.
Motta Zanin, G., Muwafu, S. P., & Máñez Costa, M. (2024).	https://doi.org/10.1016/j.jenvman.2024.120667	The article is a literature review of Nature-based Solutions for coastal risk management in the Mediterranean basin.	Figure 6 are several tables of NbS for coastal risk with detailed information and references. Many are not effective NbS but models. However, the tables remain very informative.

Document/website	Links	Subject or Interest for NbS/CCI/CME	Comments
Plan Bleu/RAC, & UNEP/MAP. (2024).	https ://planbleu.org/wp-content/uploads/2024/07/Plan-Bleu-NbS-in-Mediterranean-cities-report_Final.pdf	Nature-based solutions for Mediterranean cities. 14 nbS are presented for urban areas, 5 at least concern NbS/CCI/CME	Detailed description of the case studies and recommendation are formulated.
Snoussi, M., & Nibani, H. (2025).	https://planbleu.org/wp-content/uploads/2025/03/MedP_SCCF_Report_NbS-and-EbA-in-the-Mediterranean.pdf	The document describes how NbS can effectively support Ecosystem based Adaptation (EbA) based on two examples.	Two case studies in relation with climate risks in Montenegro and Morocco are detailed and several examples of NbS/CCI/CME are referred to in restoration. Lessons learned and recommendations are given.
Riisager-Simonsen *et al.* (2022)	https://doi.org/10.1016/j.marpol.2022.105198	The paper raises a set of research priorities and policy advice aimed at ensuring the successful advice and deployment of marine NBS in support of multiple societal goals.	The authors refer to several NbS/CCI/CME but with little information
Assessment and guidance documents			
IUCN online Self-assessment tool	https://nbs-sat.iucn.org/	IUCN Global Standard for Nature-based Solutions self-assessment online tool	Not tested
Life ADAPTA BLUES (2019-2024) project and platform.	https://lifeadaptablues.eu/ipages/flipbook/2 https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE18-CCA-ES-001160/adaptation-to-climate-change-through-management-and-restoration-of-european-estuarine-ecosystems	It is an EU project on adaptation to climate change through management and restoration of European estuarine ecosystems.	Although it is meant for the Atlantic European coast, the project has developed protocols to assess ecosystem services, risk assessment for estuarine areas and includes Nature based solutions (flipbook).
Directorate-General for Research and Innovation (European Commission). (2021).	https://data.europa.eu/doi/10.2777/244577	*Evaluating the impact of nature-based solutions : A handbook for practitioners.*	
Gómez *et al.* (2020).	https://doi.org/10.1016/j.ecolecon.2019.106460	An operationalized classification of Nature Based Solutions for water-related hazards: From theory to practice.	Presents a table in Appendices with the type of risk, the area, the additional co-benefits and ecosystem disservices as well as climate change impacts on NbS to take in account when deciding to apply an NbS. However, the list of NbS is not limited to NbS/CCI/CME.
IUCN. (2021).	https://life-bluenatura.eu/wp-content/uploads/2021/05/manual-bluecarbon_eng_lr.pdf	Manual for the creation of Blue Carbon projects in Europe and the Mediterranean	The manual gives guidance on assessing carbon stocks and a chapter is dedicated to seagrass meadow restoration and coastal wetland restoration.

Document/website	Links	Subject or Interest for NbS/CCI/CME	Comments
IUCN. (2020b).	https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf	IUCN Global Standrd for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. Description of a framework with 8 criterion and 28 indicators to assess whether a NbS is adapted or to verify its efficiency.	The document is clearly presented but criterion and indicators appear difficult to apply. The process is considered complicated.
IUCN. (2020a).	https://portals.iucn.org/library/node/49071	Guidance for using the IUCN Global Standard for Nature-based Solutions.	Guidance document to apply Global standards presented in previous document.
PAP/RAC. (2024).	https://iczmplatform.org//storage/documents/elw3O-biJ8gPdHA1b6tL5b6IN-q8FNS6ZSt0tDrKGb.pdf	Nature-Based Solutions for Adaptation to Climate Change in Different Coastal Typologies of the Mediterranean	General information not technical or applied
Pérez *et al.*, 2024	https://doi.org/10.1016/j.jenvman.2023.119936	Conceptual 4 step framework to facilitate the selection of suitable blue NbS	The framework proposed is an interesting tool to help select appropriate NbS to apply in a given area.
Plan Bleu, & UNEP/MAP. (2019).	https://planbleu.org/sites/default/files/publications/policy_brief_nbs_en_final_light_0.pdf	Enhancing the Mediterranean's climate resilience through Nature-based Solutions. Several examples of NbS/CCI/CME are given.	Clear document to start with on NbS in the Mediterranean

11. CONCLUSION

Since the beginning of the industrial era, human activities have released increasing quantities of greenhouse gases, particularly carbon dioxide (CO2), disrupting the balance between CO2 emissions and environment carbon storage. This situation has driven to global climate change, which impacts vary in magnitude across regions.

The Mediterranean region has been undergoing climate change impacts over recent decades, exceeding global average trends and significantly affecting both human societies and ecosystems. Climate models project that these changes will intensify, with continued increases in air and sea temperature, ocean acidification, Sea Level Rise (SLR), frequency and intensity of Marine Heat Waves (MHW) and extreme events such as storms, floods and droughts. Additional projected changes include alteration in Mediterranean Sea circulation and stratification, as well as reduced freshwater inputs to the Mediterranean Sea.

Nature-based Solutions (NbS) are defined as "*actions aimed at* ***protecting, conserving, restoring, and sustainably managing*** *natural or modified terrestrial, freshwater, coastal, and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively,* ***while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits***" (UNEA/Res.5, 2022). NbS contribute to climate change mitigation by enhancing CO2 sequestration and reducing climate-related risks to societies and ecosystems. NbS effectiveness is maximised when integrated into ecosystem-based approaches such as Ecosystem-based Adaptation (EbA), Disaster Risk Management (DRM), Disaster Risk Reduction (Eco-DRR) and other climate change adaptation strategies.

NbS to reduce and prevent climate change impacts on marine and coastal ecosystems (NbS/CCI/CME) are a subset of NbS of particular interest for the Mediterranean countries especially affected by climate change. Coastal ecosystems are more vulnerable than open-sea systems due to their exposure to multiple and often intensified climate stressors, compounded by additional anthropogenic pressures such as pollution and urbanization. Moreover, the recovery capacity of coastal ecosystems is limited, given the widespread human pressures all around the Mediterranean Sea and the limited effectively managed Marine and Coastal Protected Areas (MCPAs). NbS/CCI/CME can therefor play a key role in fostering sustainable coastal economies and strengthen social and ecological resilience for future climate impacts (O'Leary *et al.*, 2023).

Successful NbS implementation in Mediterranean marine and coastal areas, requires in depth understanding of ecological dynamics, ecosystem functioning and how they can be managed in climate change context, as well as being familiar with ecosystem-based approaches and climate change adaptation strategies (Plan Bleu & UNEP/MAP, 2025). Research, experience sharing, capacity building, and increased financial and institutional resources are essential for Mediterranean countries to deploy sustainable Nature-based Solutions to prevent and reduce Climate Change Impacts on Coastal and Marine Ecosystems.

To date, the implementation of NbS/CCI/CME in the Mediterranean region remains at a development stage. Further progress requires improved coordination, stronger integration into ecosystem-based frameworks, mainstreaming within national policies and governance structures, and more robust baseline assessments and effectiveness evaluations. While NbS/CCI/CME implementation advances, the protection of key ecosystems should be prioritized, as restoration of essential ecosystems able to mitigate climate change impacts is costly, time-consuming and uncertain.

APPENDIX 1. VALUE OF *POSIDONIA OCEANICA* MEADOWS ESTIMATED BY DIFFERENT AUTHORS AND COST OF RESTORATION

	Unit	Method used	Mean value
Active restoration cost of *P. oceanica* seagrass meadow[1]	Euros/hectare	516 -942	729
Passive restoration (conservation) coast of *P. oceanica* meadow [8]	Euros/hectare/year	38.1-57.8	47.95
Value of ecosystem services of *P. oceanica*			
In Italy (Scanu *et al.*, 2022)[2]	Euros/hectare/year	Region specific market values basic benefit transfer	21,660
In France	Euros/hectare/year	Estimated by using total surface of *Posidonia* mapped in France 79 852 ha[3] and total value estimate by Medtrix (46 billion euros)[4]	576,000
In Tunisia (El Zrelli *et al.*, 2023)	Euros/hectare for the year 2014		915
Ligurian Sea, Italy (Vassalo *et al.*, 2013)[5]	Euros/hectare/year	Environmental Energy to Money Ratio	1,720,000
Here according to recent decision by French Court[6]	Euros[7]		86,000

[1] Interreg Euro-MED-ARTEMIS. (2025). *Investment Opportunities in Seagrass Restoration.*

[2] Scanu, S., Piazzolla, D., Bonamano, S., Penna, M., Piermattei, V., Madonia, A., Manfredi Frattarelli, F., Mellini, S., Dolce, T., Valentini, R., Coppini, G., Fersini, G., & Marcelli, M. (2022). Economic Evaluation of *Posidonia oceanica* Ecosystem Services along the Italian Coast. *Sustainability*, 14(1), 489. https://doi.org/10.3390/su14010489

[3] Document from the Prefecture Maritime Mediterranée available here

[4] *MEDTRIX - Monitoring logbook Special edition : Posidonia, the endemic forest of the Mediterranean*. (2024). Edition L'Œil d'Andromède / Agence de l'Eau Rhône Méditerranée Corse. https://medtrix.fr/wp-content/uploads/2024/12/cahier21-anglais.pdf

[5] Vassallo, P., Paoli, C., Rovere, A., Montefalcone, M., Morri, C., & Bianchi, C. N. (2013). The value of the seagrass *Posidonia oceanica* : A natural capital assessment. *Marine Pollution Bulletin*, 75(1), 157167. https://doi.org/10.1016/j.marpolbul.2013.07.044

[6] see decision and WWF. (2025, juin 6). *New WWF study highlights urgent need to protect Mediterranean Seagrass meadows from anchoring* d. https://www.wwf.mg/?18355891/New-WWF-study-highlights-urgent-need-to-protect-Mediterranean-Seagrass-meadows-from-anchoring-damage

[7] Destruction of *P. oceanica* by anchoring three times in *Posidonia* meadow

APPENDIX 2. WORKSHOP ON NATURE-BASED SOLUTIONS TO PREVENT AND REDUCE CLIMATE CHANGE IMPACTS ON COASTAL AND MARINE ECOSYSTEMS AND ENHANCE THEIR RESILIENCE

Location

The workshop, organised on the 9th of December 2025, was held in Gökova Bay (Türkiye) which hosts an exemplary Marine Protected Area that is home to nearly 73% of all fish species known to exist in Turkish waters. The workshop on Climate Change Adaptation Strategies for Coastal and Marine Ecosystems took place back-to-back to the Nature-based Solution workshop on the 10th and 11th of December.

Objectives

The workshop had four objectives:

1. To **share the preliminary findings and insights from the assessment on the Nature-based technical Solution to reduce and prevent climate change impacts on coastal and marine ecosystems in the Mediterranean region** resulting from the preparation of the report on the subject.
2. To **validate, complete, and refine** the information collected and recommandations through direct exchange with country representatives, stakeholders and practitioners, researchers and policy makers.
3. **To build participant capacities** on implementing Nature-based technical Solution to reduce and prevent climate change impacts on coastal and marine ecosystems.
4. **To promote networking**, peer learning, and the exchange of experiences among participants.

The insights from participants and the outcomes of the workshop are included in this report.

Participants

Around 19 stakeholders attended the workshop, including representatives from **Albania, Bosnia & Herzegovina, Egypt, Lebanon, Libya, Montenegro, Morocco, Tunisia and Türkiye**. The participants comprised public authorities' representatives, sustainability officers and coordinators, environmental consultants, protected areas and national parks directors, marine biologists and biodiversity experts, academic researchers, university professors, and conservation organisations. Additionally, experts from PAP/RAC and Plan Bleu also attended the workshop and contributed their technical expertise, regional insights and valuable inputs to the discussions and outcomes.

Workshop content

The workshop was organized over one day, and included knowledge-sharing presentations and participatory sessions.

- Session 1

Following the opening session, session 1 focused on an **introduction to Nature-based Solutions (NbS)**, the different definitions and implementation frameworks as well as the advantages of implementing NbS for ecosystems and human societies.

Specifically, the introduction to NbS focused on:

- NbS implementation challenges
- Advantages in implementing NbS
- Requirements for an efficient NbS implementation
- Different frameworks available to guide NbS implementation and evaluation
- IUCN Global Standard for NbS which was specifically detailed

Following the general introduction on NbS, the talk and exchanges focused more specifically on **Nature-based Solutions to prevent and reduce Climate Change Impacts on Coastal and Marine Ecosystems and human communities (NbS/CCI/CME)**. The mechanisms of actions of these NbS, case studies based on technical NbS, as well as policy aspects and implementation framework were detailed for the Mediterranean region.

- Session 2

Plan Bleu presented the **MedProgramme SCCF Project "Enhancing Regional Climate Change Adaptation in the Mediterranean Marine Coastal Areas"** applied in Montenegro and Morocco which developed capacity building for wetland and dune restoration including the implementation of NbS.

PAP/RAC presented Nature-based Solutions for adaptation to climate change in different coastal typologies of the Mediterranean and ICZM Protocol integrating NbS.

- Session 3

Professor Bayram Öztürk, from Istanbul University presented examples of NbS for coastal and marine ecosystems implemented in Türkiye. These counted *Posidonia oceanica* transplantations which turned out to be unsuccessful, efficient ecofriendly mooring systems to protect Posidonia from anchors, mapping Posidonia to better protect it, stock enhancement of certain species, restoration of deltas and dealing with Invasive Alien Species (IAS) such as the lionfish.

Mr. Zafer Kizilkaya, president of Akdeniz Koruma Derneği (Mediterranean Conservation Society - MCS) (AKD), presented the successes of the Gökova Bay community-managed marine protected area. He detailed how they work with local fishers trained to be marine rangers and stakeholders to protect and restore the gulf's ecosystem with success. Nature-based Solutions include increasing fishing pressure on comestible Invasive Alien Species (IAS) by collaborating with high level restaurants to reduce IAS impacts on ecosystems, protect the bay from trawling, monitoring and strict protection of a shark reproduction area.

- Session 4

The session consisted of collaborative work in 4 round tables.

The participants were invited to divide in 4 tables. Each table focused during 30 to 40 minutes on one of the following **aspects**:

1. **Environment (Mediterranean context)**. Objective: Identify the environmental and socio-economic elements which can influence the NbS/CCI/CME implementation.
2. **Means and Methods** (Science, finances, capacity, community, standards and protocols). Objective: Identify the needs and best methods to implement the NbS/CCI/CME.
3. **Workforce** (governance, coordination etc.). Objective: Clarify who does what and define coordination.
4. **Measures** (Indicators, monitoring and evaluation). Objective: Define how to monitor and evaluate the effects of the NbS/CCI/CME (ecosystem but also ecosystems services and social evaluation).

For each aspect, **challenges solutions** and **concrete actions** were requested to be informed.

This process was followed for two NbS/CCI/CME:

(i) Enhancing resilience of seagrass in particular *Posidonia* meadows

(ii) Supporting and defining littoral set-back zone

Hereafter the two tables represent the outcomes for each subject (Posidonia and set-back zone) and for each table (1 to 4). Points in blue were suggested after hand.

Workshop outcomes from the round tables

These results were presented to all by a representative of each table for the two subjects.

(i) Subject 1: Nature-based Solutions enhancing resilience of seagrass/ Posidonia meadows

It benefits **ecosystems** by enhancing good condition or supporting natura rehabilitation to increase the resilience of the ecosystems to climate change.

Also, it benefits **human societies** by contributing to carbon mitigation, coastal protection and fishery resources (food security). Further dead leaves (banquettes) help against erosion of beaches.

Table 1

Results of the 4 round tables on the NbS/CCI/CME on enhancing resilience of seagrass/Posidonia meadows

1. Environment (Mediterranean context) Objective: Identify the environmental and socio-economic elements which can influence the NbS/CCI/CME implementation		
Challenges	**Solutions**	**Concrete actions**
Tourism (Anchoring) Tourism impact and perception of Posidonia banquets	Mapping Posidonia meadows Introduce fees for tourist/ beach owners for removing sea grasses	Eco-friendly mooring for recreational boats (e.g. see wwf mooring toolbox)
Illegal Unreported Uncontrolled Fishing	Ban trawling fishing Protect by reefs?[8]	National regulation applied Introduce ecofriendly fishing gears Restorative aquaculture
Climate change increasing invasive species		
Plastic pollution: lack of waste management	Enhance the action plan on Posidonia at mediterranean level	Increase cooperation with NGOs, academy and citizen science Effective treatment of waste
Low public awareness on seagrass importance	Increase the engagement of local communities	Public awareness and education
	Increase research	Create more MCPAs and increase no take zones Effective management MCPAs
2. Means and Methods (Science, finances, capacity, community, standards and protocols) Objective: Identify the needs and best methods to implement the NbS/CCI/CME		
Challenges	**Solutions**	**Concret actions**
Lack of scientific data: NO data No clear cartography	Integrate scientific researchers in national monitoring program	Centralize data Increase citizen science Data availability Use Standardized protocols such IMAP, Mapping through different methods
Weak collaboration between Med countries	Enhance the med Posidonia network Field training, national Regional Sharing information, bank of data	National/ regional workshops Create national/ regional data bank Capacity building (training) on financial mechanisms (in cooperation with mediterranean countries) (Exp: BIOFIN Adjust the mechanisms based in national/ regional context
Unsustainable financial resources	Rasing national regional funds Diversify the financial mechanisms (donors, NGO, private sector…)	Financial instruments at regional scale?

[8] Points in blue were suggested after hand

3. **Workforce** (governance, coordination etc.) Objective: Clarify who does what and define coordination		
Challenges	**Solution**	**Concrete actions**
Governance: laws governing pollution Control of tourism activities	MPA establishment	Establish MPAs with implementation mechanism Pollution prevention on land and sea Maybe local NGOs can contribute?
Control of marine aquaculture farms Excessive fishing	Fishing laws	Implementation blue economy Maybe see about more natural practises in aquaculture which are used in some areas?
Lack of coordination between stakeholder	Marine spatial planning	Monitoring plan Local, national regional
Marine spatial planning	Blue economy concept	Endorsement of fishing law
Poorly drafted MPAs	Build coordination entity mechanism Develop data base of location of Posidonia	Awareness campaign Capacity building
New littoral constructions	Environmental Impact Assessment (EIA)	Integrate protection of Posidonia in EIA including minimum distance of new constructions from Posidonia meadows

4. **Measures** (Indicators, monitoring and evaluation) Objective: Define how to monitor and evaluate the effects of the NbS/CCI/CME (ecosystem but also ecosystems services and social evaluation)		
Challenges	**Solutions**	**Concrete actions**
Lack of data Lack of knowledge	Capacity building through training, workshops, etc.	Creating international action plans/ workshops
Difficulties of monitoring of *Posidonia oceanica*	Sea grass mapping, using AI interpretations	Unifying the standardized protocol
Lack of sustainable funding	Attracting private sector	Blue carbone bank/finance ?
Difficult and not sufficient equipment to measure blue carbon (ecosystem services)	Regional prioritized spots for blue carbon	Using standardized protocols Creating techniques with Research & Development
Lack of definition of the thresholds of Good Environmental Status	See perhaps appropriate indicators of IMAP?	Define threshold at national level?

(i) Subject 2: Nature-based Solutions supporting and defining littoral set-back zone

It benefits **ecosystems** by increasing littoral biodiversity and enhances littoral habitats by protection from construction. Such habitats can be essential for reproduction and life of certain species. Ecosystems which are in better conditions are more resilient to climate change and can be more efficient to protect the littoral from erosion.

Benefits for **human societies** include protecting human infrastructures from climate change impacts such as Sea Level Rise (SLR) and storms. It also increases human wellbeing by conserving natural littoral areas accessible to all.

Table 2

Results of the 4 round tables on the NbS/CCI/CME on supporting and defining littoral set-back zone

1. Environment (Mediterranean context) Objective: Identify the environmental and socio-economic elements which can influence the NbS/CCI/CME implementation		
Challenges	**Solutions**	**Concrete actions**
Corruption		Laws that mandate green spaces along coast Master plan with green infrastructure corridors and NbS
High urbanisation	Remove coastal infrastructure Introduce green spaces along the coast, create promenades and reforest	Create a fund to support incentives and diversification Support local economy development to decrease the pressure
Bad spatial planning	Mainstream information on set-back zone advantages?	Integrate NbS approach and ecosystem-based approach in MSP?
Touristic pressure	Diversify touristic offer in hinterland (inland) and diversify coastal tourism (eco-tourism)	Publicity on the touristic attractions inland?
Sea Level Rise and storms	Create real set-back zone	Legal and financial instruments
Increasing population concentrating and economic activities	Create economic incentives for hinterland	Socio-economic studies
2. Means and Methods (Science, finances, capacity, community, standards and protocols) Objective: Identify the needs and best methods to implement the NbS/CCI/CME		
Challenges	**Solutions**	**Concret actions**
Lack of knowledge What is buffer zone or set-back zone?	Mainstream and inform?	Information campaigns in areas under high coastal pressure from Climate change impacts?
Laws and regulations	Environmental regulations and laws (in cooperation with the ministries)	Lobbying Adopt laws and legislations nationally
Engagement of local stakeholders	Engage local stakeholders	Organize awareness campaigns and training
Understand their ecosystems and their benefits	Increase the knowledge through public awareness, capacity building	Develop locally based educational tools for schools?
Carrying capacity of tourism	Define national set-back zone, carrying capacity regulations	Establish national and regional fundraising Implement threshold limits

<table>
<tr><td colspan="3">3. Workforce (governance, coordination etc.)
Objective: Clarify who does what and define coordination</td></tr>
<tr><th>Challenges</th><th>Solution</th><th>Concrete actions</th></tr>
<tr><td>Governance local and national
No participatory approach for local knowledge</td><td>Government institutional coordination mechanism
Governance complying domestic laws to ICZM law (national, Regional)</td><td>Implement existing laws</td></tr>
<tr><td>Lack of coordination
Too many actors at local, national, regional scale</td><td>Coordination
• Identify lead actors
• Include private sector in coordination
Capacity building at all levels</td><td>Create coordination committee
Awareness campaign
Capacity building
Curricle change</td></tr>
<tr><td>Governance, no monitoring</td><td>Law enforcement</td><td>Awareness of police</td></tr>
<tr><td>Accountability</td><td></td><td></td></tr>
<tr><td>Governance implementation of law</td><td></td><td>Implement existing laws</td></tr>
<tr><td>No clear jurisdiction</td><td></td><td></td></tr>
<tr><td colspan="3">4. Measures (Indicators, monitoring and evaluation)
Objective: Define how to monitor and evaluate the effects of the NbS/CCI/CME (ecosystem but also ecosystems services and social evaluation)</td></tr>
<tr><th>Challenges</th><th>Solutions</th><th>Concrete actions</th></tr>
<tr><td>Tourism pressure</td><td>Creating responsible tourist programs
Creating regulatory/policy monitoring program</td><td>Mapping, remote sensing, regular surveys</td></tr>
<tr><td>Weakness of local community engagement</td><td>Integration of local community in decision activities
Use the knowledge of the local community
Influence the law/authority/decisions maters</td><td>Advocacy, legislation
Creating communication campaigns</td></tr>
<tr><td>Increased population and housing</td><td>Informing the future resident about the future choices</td><td>Modeling the sea-rise level and effect
Bruun effect</td></tr>
<tr><td>Not enough spatial width to apply 100 meters setback zone (required by ICZM Protocol) in all countries</td><td>Adapt width to situation especially on islands?</td><td>Consider slope and future SLR models at local scale to consider reducing setback zone?</td></tr>
</table>

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SPA/RAC WORKING AREAS

SPA/ RAC, the UNEP/ MAP ***Specially Protected Areas Regional Activity Centre****,*
was created in 1985 to assist the Contracting Parties to the Barcelona Convention
(21 Mediterranean contries and the European Union) in implementing the Protocol
concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol).

POST-2020
SAPBIO

Strategic Action Programme for the **Conservation**
of **Biodiversity** and **Sustainable Management**
of **Natural Resources** in the **Mediterranean Region**

Marine turtles

Cetaceans

Mediterranean Monk Seal

Cartilaginous fishes
(Chondrichtyans)

Marine and coastal bird species
Listed in Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean

SPAMI

Specially Protected Areas of
Mediterranean Importance

Specially Protected Areas

Monitoring

Coralligenous and other calcareous bio-concretions

Marine vegetation

Dark Habitats

Habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena

Species introduction and invasive species

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