Karpathos & Saria MPAs: Seagrasses and meadows, soft/rocky bottom

Storyline 27

NBS 2
EFFECTIVE CONSERVATION

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Future MARES

Introduction to FutureMARES

The EU Horizon project FutureMARES (2020-2024) was designed to develop science-based advice on viable actions and strategies to safeguard biodiversity and ecosystem functions to maximise natural capital and its delivery of services from marine and transitional ecosystems in a future climate. The program investigates effective habitat restoration, conservation strategies and sustainable harvesting at locations across a broad range of European and other marine and transitional systems. The restoration of habitat-forming species (plants or animals) and habitat conservation (e.g. marine protected areas, MPAs) represent two nature-based solutions (NBS) defined by the EU as "resource efficient actions inspired or supported by nature to simultaneously provide environmental, social and economic benefits that help to build resilience to change". A third action that will interact with these two NBS and have positive effects on marine biodiversity is nature-inclusive harvesting (NIH) such as the sustainable farming of plants and animals at the base of marine food webs and ecosystem-based management practices for traditional (artisanal) and commercial fisheries.

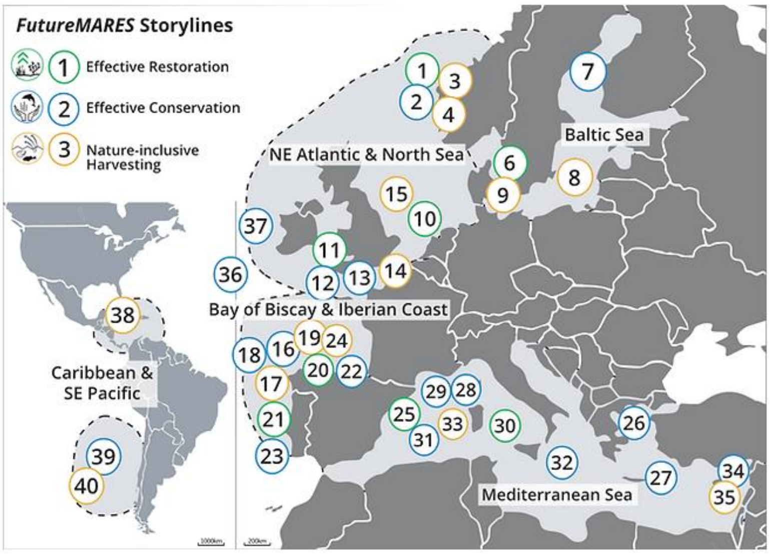


Figure 1: *Overview of FutureMARES Storylines*

FutureMARES was designed to:

- advance the state-of-the-art forecasting capability for species of high conservation value,
- explore new and less carbon intensive aquaculture production methods,
- perform modelling analyses geared towards informing the development of climate-smart marine spatial planning approaches, and
- provide an assessment of ecosystem services based on scenarios of climate change and the implementation of NBS and NIH.

This document provides a summary of activities conducted in FutureMARES in a specific area on specific NBS and/or NIH. The activities are multi-disciplinary and include marine ecology (analyses of historical time series and experiments performed in the field and laboratory), climate change projection modelling (future physical, biogeochemical and ecological changes), economic analyses and social-ecological risk assessments. Many of these components and analyses were co-developed with local and regional stakeholders through regular engagement activities. The work presented in this Storyline document represent activities conducted by a large number of FutureMARES project partners. Broader comparisons and syntheses (across regions and/or topics) are provided in the FutureMARES deliverable reports submitted to the European Commission (www.futuremares.eu).

Regional Storyline Context

The Northern Karpathos and Saria MPA is located in the Dodecanese islands (Greece), Eastern Mediterranean Sea, and covers an area of about 154 km^2. Saria is a small island separated from Karpathos by a narrow sea strait less than 100 m wide. The MPA is included in the list of Natura 2000 sites (GR4210003) and hosts a rich biodiversity and many endemic species (flora and fauna, including birds). Populations of several charismatic marine species such as the Mediterranean monk seal (*Monachus monachus*), the dolphin *Tursiops truncates* and the marine turtles *Caretta caretta* and *Chelonia mydas* are present in the MPA. Tristomo Bay is an enclosed highly productive fishing area in the MPA with extensive *Posidonia oceanica* and *Cymodocea nodosa* meadows surrounded by hard substrate. The bay hosts thriving populations of the bivalves *Arca noae* and *Pinna nobilis*. The area has a significant archaeological value due to the 7th-10th century AC settlements that are present, while the Ephorate of Underwater Antiquities performs field research as there are remains which are yet to be studied. The Management Agency of Dodecanese Protected Areas (formerly Management Agency of Karpathos-Saria) was established in 2002, and its primary objective is the management, protection and conservation of the species and habitats of the MPA.

P. oceanica is spread around the coasts of Karpathos and Saria. The meadows are healthy, existing for about a decade, hosting rich populations of invertebrates. Although the number of non-native species, such as *Caulerpa taxifolia* and *Halophila stipulacea,* are increasing in the area, *P. oceanica* has been proven so far, a good competitor maintaining the ecosystem balance. These habitats provide a range of services, such as: a) provisioning services (i.e. dead leaves can be used in industry and agriculture); b) regulation and maintaining services (i.e. seawater is purified by filtration, the leaves reduce water turbidity, offer shelter and nursing habitat, protect the seabed from erosion and support nutrient cycling and oxygenation; and c) cultural services (preservation of the underwater cultural heritage, diving tourism, marine environmental education).

The information in this document should help inform key stakeholders such as the Ministry of the Environment and Energy; the Management Agency of the Dodecanese Protected Areas

(MADPA) under the Natural Environment & Climate Change Agency (NECCA/ Ο.ΦΥ.ΠΕ.Κ.Α); the National Centre for the Environment and Sustainable Development (ΕΚΠΑΑ); the Management Unit of the South-eastern Aegean Protected Area; as well as the South Aegean Region and Karpathian Mayor.

Figure 2: *Map of the northern Karpathos and Saria MPA (Greece).*
Credit: EMODnet Seabed Habitats Map Viewer (map GR789365)

Figure 3: *Posidonia oceanica and Cymodocea nodosa meadows in northern Karpathos and Saria MPA (Greece). Credit: Georgios Chatzigeorgiou - HCMR, IMBBC*

Figure 4*: The critically endangered bivalve Pinna nobilis in northern Karpathos and Saria MPA HCMR, IMBCC*

Projected impacts of climate change

FutureMARES has made projections of physical and biogeochemical impacts of climate change in the region including three IPCC scenarios (SSP 126, SSP 245 and SSP 585 (for background see Deliverable Report 2.2). Climate change may impact the seagrass meadows of the *Posidonia oceanica* and the associated benthic assemblages at the MPA of northern Karpathos and Saria in different ways. Firstly, the region is close to the Suez Canal, which is the main point of entrance for invasive alien species (IAS) in the Mediterranean [1]. Thus, the islands of Karpathos and Saria are characterized by the high prevalence of marine IAS, which form dense populations. Examples of such IAS are the seaweed *Halophila stipulacea*, the lionfish (*Pterois miles*) and the invasive long-spined sea urchin (*Diadema setosum*). *H. stipulacea* does not seem to compete with *P. oceanica* since the two species are ecologically very different; however, the temperature increase poses a potential threat at the naturally occurring meadows of *P. oceanica* which, in turn, could be substituted by *H. stipulacea*, one of the “100 Worst Invasive Alien Species in the Mediterranean” [2]. Despite the capability of *P. oceanica* plants to acclimate to temperature changes, it has been predicted that even under a relatively mild greenhouse-gas emissions scenario, this species might face functional extinction by the middle of this century [3].

Figure 5: *Thriving populations of the invasive lionfish (Pterois miles) in northern Karpathos and Saria MPA. Credit: Georgios Chatzigeorgiou - HCMR, IMBBC*

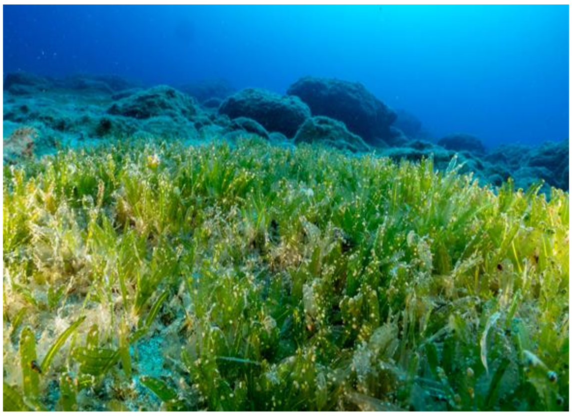
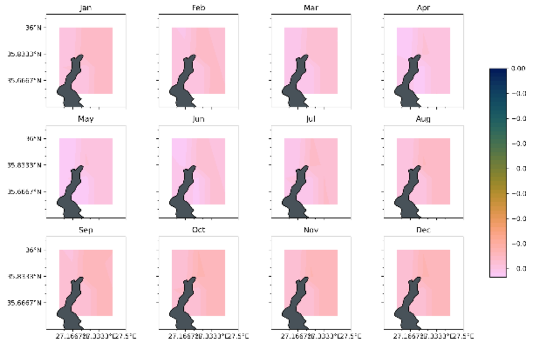


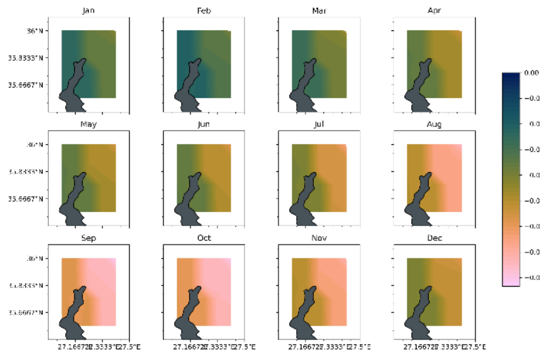
Figure 6: *Meadows of the invasive Halophila stipulacea in northern Karpathos and Saria MPA. Credit: Georgios Chatzigeorgiou – HCMR, IMBCC.*

In addition, changes in the sea currents imposed by climate change may impact the gene flow and connectivity of the *P. oceanica* meadows with other meadows in the Eastern Mediterranean, since population connectivity is strongly influenced by environmental factors such as oceanic currents, depth profiles, changing water flows and gyres [4].

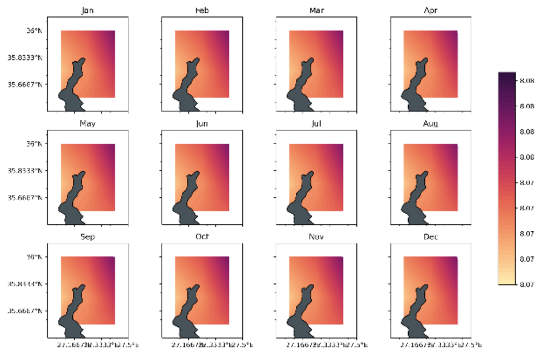
Furthermore, Tristomo gulf is a naturally occurring semi-enclosed gulf in the region, protected by sea waves that may act as a climate refugium in terms of warming for several species; it is considered as the most important marine site in Karpathos [5]. There is also very limited anthropogenic activity in Tristomo gulf, therefore it can act as a hotspot for preservation and conservation of several marine species, from schools of fish to the critically endangered noble pen shell (*Pinna nobilis*) and the Noah's Ark shell (*Arca noae*).



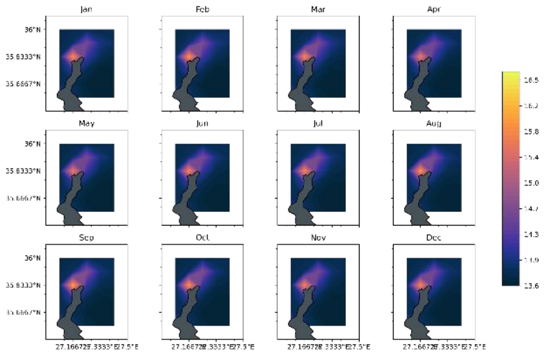
pH changes in the near future at seafloor under scenario SSP5-8.5



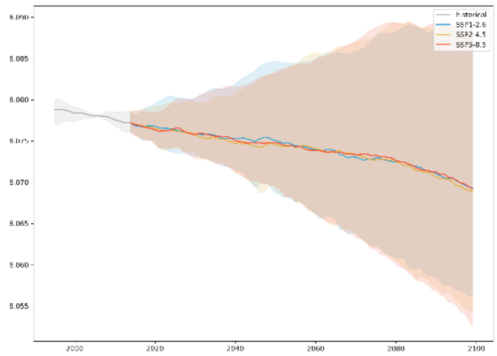
Potential Temperature (in degrees °C) changes in the near future at seafloor under scenario SSP5-8.5



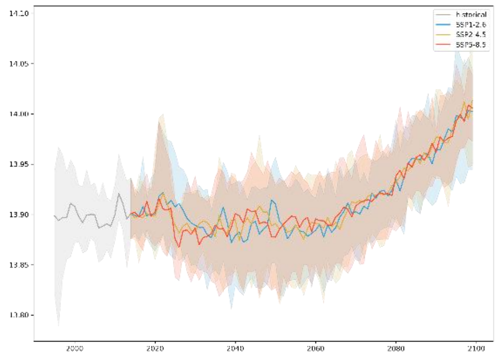
pH at seafloor under present day conditions



Potential Temperature (in degrees °C) at seafloor under present day conditions



pH [1] at seafloor



Potential Temperature (degrees °C) at seafloor

Figure 7: *Climate projections for the northern Karpathos and Saria MPA. The figures were produced using trend preserving statistical downscaling (Lange, 2019) of a multi-model ensemble Earth System Model historical simulations and future projections from the CMIP6 archive trained on reanalysis datasets from the Copernicus Marine Environment Monitoring Service.*

Geographical Maps were extracted from the full dataset by averaging over the following periods, consistent with the periods considered in the IPCC AR6 WG1 report:

- present day: 1995-2014
- near future: 2021-2040
- mid future: 2041-2060
- far future: 2080-2099

Time-series plots were produced averaging over the area of interest for each storyline and show the ensemble mean in the full lines and the range of model responses in the shaded areas as represented by the 2.5 and 97.5 percentiles of the ensemble. Credit: Momme Butenschön, Euro-Mediterranean Center on Climate Change.

Scenarios describing future society and economy

FutureMARES developed three policy-relevant scenarios for NBS and NIH based on commonly used IPCC frameworks (for more details see hyperlink). These scenarios were regionalised based on stakeholder perspectives to guide activities such as model simulations and risk assessments.

(GS) Global Sustainability (SSP126) - Low challenges to mitigation and adaptation

The world shifts gradually but pervasively to a more sustainable path, emphasising inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, investments in educational and health accelerate lower birth and death rates, and the emphasis on economic growth shifts to an emphasis on human well-being.

(NE) National Enterprise (SSP385) - High challenges to mitigation and adaptation

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to focus on domestic or regional issues. Policies shift over time to be oriented more on national and regional security. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development.

(WM) World Markets (SSP585) - High challenges to mitigation, low challenges to adaptation. The world increasingly believes in competitive markets, innovation and participatory societies to produce rapid technological progress and train and educate people for sustainable development. The push for economic and social development is coupled with exploiting abundant fossil fuel resources and adopting resource and energy intensive lifestyles around the world.

Figure 8: The three, broad scenarios that were regionalised to guide activitiesin FutureMARES.
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***Figure 8**: The three broad scenarios that were regionalised to guide activities in FutureMARES.*

At the present time, the current national policy is officially to protect the MPA - but in reality, there is still work to be done. Greece has gradually developed a strong institutional framework for environmental protection and nature conservation, adopting several international conventions (since 1974) and all relevant EU Directives (since 1983) while enriching it with numerous national protection provisions (since 1950). The current legislative framework covers a wide range of environmental issues, spanning from the conservation of genetic resources to climate change, with an emphasis on the establishment and legal protection of the country's protected areas. The Karpathos and Saria MPA is included in the list of Natura 2000 sites (GR4210003) and hosts a rich biodiversity and many endemic species (flora and fauna, including birds).

9.21% of the Karpathos & Saria MPA network is protected only through national laws, 58.22% of the MPA network consists solely of Natura 2000 sites and 32.57% consists of and overlaps between the two. Regulations exist for fish stock management, regarding legal restrictions on fishing methods, years of fishing, types of vessels, sizes of fish etc. Greece is establishing the appropriate national plans for marine strategies to follow the strict schedule of MSFD implementation plan, reaching the "good environmental status" years. The general tendency for the NBS lies somewhere between scenarios II (High challenges to mitigation and adaptation) and III (High challenges to mitigation, low challenges to adaptation). Another important drawback is the recent centralization of environmental management and conservation through the establishment of a central management agency in the capital (Athens) and the elimination of responsibilities of management bodies of individual protected areas.

In September 2021, Greece was one of the 8 Mediterranean governments to sign the action plan "The Mediterranean: a model sea by 2030" at the opening of the IUCN Congress. As part of this initiative, Greece is committed to increase the spatial coverage of marine protected areas to 30% (from 22% today), establish strong protection measures (including ban to fishing) to 10% of the national waters, and reduction of marine litter by 50%, among other measures aiming to the preservation of marine and coastal biodiversity.

In the future, the GS scenario brings positive change regarding the enforcement of protection activities. There is better application of existing policies. Additional protected areas are established. The existing protected area in Karpathos & Saria is managed more efficiently, e.g. under gradual usezones (red zones = no activities allowed). There is a better budget concentrated in Natura 2000 network protected areas. Sensibilisation and environmental/biodiversity education has a strong place in schools. More regulations exist regarding overexploitation of marine resources. This is the most favourable and supportive scenario compared to the current agenda and would aid its implementation with minimal societal conflict and delay.

In the NE scenario, there is much more neglect of MPA regulations. A lack of globalization in the application of protection measures and regulations will eliminate the MPA conservation efficiency. There is a lower budget for environmental education. Fewer regulations of overexploitation of marine resources exist. In the WM scenario, there is more efficient marine protection than the NE one, since technological development will be boosted and some environmental problems will be efficiently addressed. The budget for environmental education is lower and fewer regulations of overexploitation of marine resources exist. In both the NW and WM scenarios there are some positive opportunities (rather short-term), but there are significant risks of things become worse.

FutureMARES research needs

Research needs to continue to understand the magnitude and interaction between various threats facing the Dodecanese (eastern Greece) to better plan how management goals and actions for the Marine Protected Area. Critical threats are those from climate change and marine invasive species (this area is an entry point for the latter). Specific environmental pressures include temperature increase, acidification, local heavy rainfalls, sea level rise and turbidity increase.

A better understanding of the role of the area in connectivity of protected species is also needed. Several key habitats and protected species, such as *Posidonia oceanic* meadows and *Pinna nobilis* populations, which are important for genetic connectivity between areas and for the provision of ecosystem services, are present in this Eastern Mediterranean area.

At the same time, needs and conflicts between different users in the area (i.e. fishing, tourism, conservation) need to be understood and taken into consideration before implementing any management plan. The NBS2 approach (Effective Conservation) could benefit the parallel implementation of conservation and economic activities (i.e. fishing and eco-tourism) that need to be combined in a sustainable way. The Risk Assessment can be used for planning concrete adaptation measures at local level focusing on the restoration and conservation of the Storyline area.

FutureMARES research (T = Task – see program structure at futuremares.eu)

- **T1.1** Biodiversity data for macrobenthos, macroalgae and macrophytes for Storyline #27, as well as environmental data, are available for 2018; However, this task required a time series analysis, therefore data (1980 – 2010) from a similar area located in Ionian Sea were used (D1.3).
- **T1.2** Biological traits data for macrobenthos, macroalgae and macrophytes species, as well as environmental data for Storyline #27 have been used for RLQ and HMSC analysis in order to investigate the trait – environment relationships (D1.4).
- **T1.3** Data from Storyline #27 have contributed to the estimation of ecological, social, and economic indicators of biodiversity by ecosystem services in relation to policy targets and climate change (D1.5).
- **T1.4** Stakeholders were engaged to regionalise narratives for Storyline #27 (Karpathos area) and the Scenario regionalisation Survey was completed (D1.2).
- **T2.1, 2.2 and 2.3**: Data for the environmental background of Storyline #27 were provided in order to contribute to the physical and biogeochemical projections of the effects of climate change including uncertainty and the potential locations of climate hot spots or refugia.
- **T3.1** In situ experiments were implemented in four different benthic habitats with or without vegetation and with or without the presence of invasive macrophytes, in order to compare community metabolic rates and benthic diversity (D3.1).
- **T3.3** Genetic cluster analysis using genetic connectivity data on *Posidonia oceanica* micro-satellites (13 loci) from 5 different meadows in Storyline #27 has been performed (D3.3).
- **T4.1** Climate change impacts on *Posidonia oceanica* seagrasses using modeling approaches were investigated under different emissions scenarios (D4.1).
- **T5.1**: A Climate Risk Assessment (CRA) was implemented at the level of species (two urchins, two seagrasses and one bivalve) against six hazards (4 climatic and 2 human) to address the effect of NBS2 Conservation in Storyline #27 (D5.1).
- **T5.2**: Regarding provision of services Storyline #27 addressed the effect of NBS2 Conservation on one provisioning (animal material which can be used for the

maintenance and establishment of populations), one regulation (filtration and/or accumulation of waste or toxic substances through living processes) and one cultural (opportunities for education and training) Ecosystem Services (D5.2).

- **T6.1:** Six species (*Posidonia oceanica, Cymodocea nodosa, Halophila stipulacea, Pinna nobilis, Arbacia lixula* and *Paracentrotus lividus*) with specified habitat preferences were selected for Storyline #27. Although modeling datasets (ERSEM & CMIP6), references for habitat preferences (e.g. Aquamaps) and Climate change mitigation/adaptation measures (literature) were indicated, finally Storyline #27 was not included in T6.1 due to the lack of modeling data in T4.4 for Greece.
- **T6.2:** Results from existing economic analysis for Storyline #27 were reported.
- **T7.1:** Direct engagement with MPA managers for exploitation of FutureMARES knowledge and products.
- **T8.1:** Identification of involved stakeholders has been provided and their engagement is being performed throughout the project.

Figure 9*: Scientific diving in action in the northern Karpathos and Saria MPA.*
Credit: Georgios Chatzigeorgiou - Hellenic Centre for Marine Research (HCMR), IMBBC

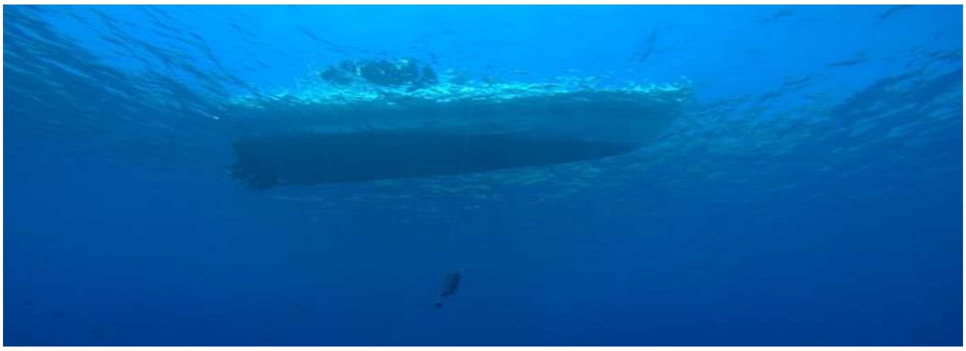

Figure 10: A *Niskin bottle is used to collect seawater samples for measuring nutrients.*
Credit: Georgios Chatzigeorgiou - Hellenic Centre for Marine Research (HCMR), IMBBC

2.1 Ecological Knowledge

The long-term monitoring of marine biodiversity in relation to climate change and variability was based on a time series dataset from an area similar to the Storyline #27, located in the Ionian Sea. The CTI analysis did not show a clear or significant trend; from 1980 until 1995 the CTI increased, while between 1995 and 2010 the opposite trend was observed (Fig. 11 b,c). Temperature changes in the area were within the species' temperature preference and, even if some species were replaced by others, the latter were also species with similar temperature preference. Most data points were distributed in borealization (increasing abundance of cold-affinity species), followed by tropicalization (increasing abundance of warm-affinity species). This is expected since the CTI decreased over time (Fig 11a).

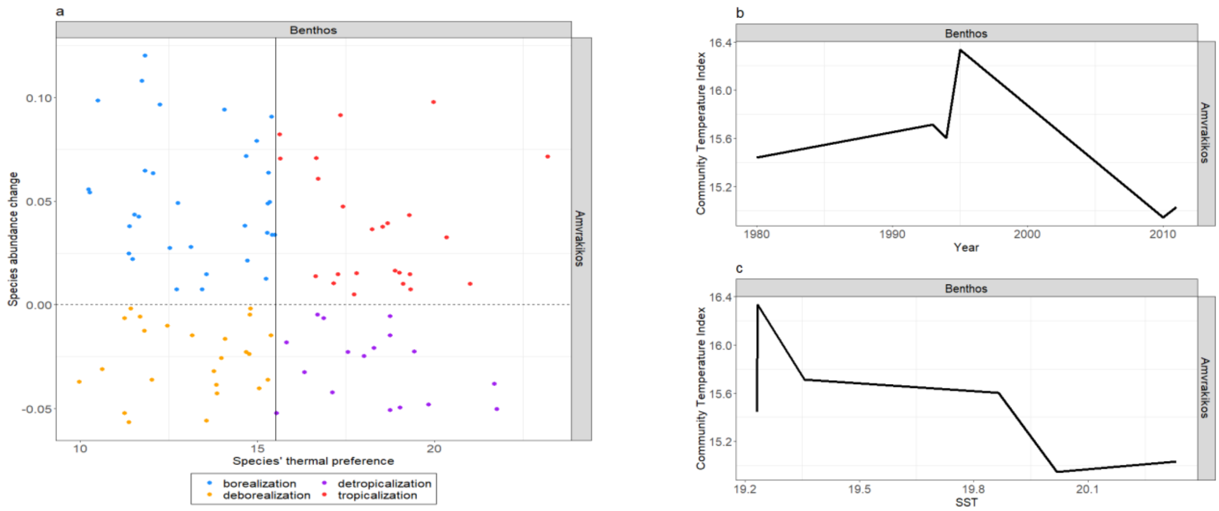

***Figure11. a**) Species abundance change in relation to the species thermal preference, b and c) Community Temperature Index (CTI) in relation to time (year) and surface sea temperature (Ionian Sea, Greece).*

The investigation of trait-environment relationship for macrobenthic communities of SL#27 showed broadly consistent results across the two methods (RLQ and HMSC), indicating that patterns and findings seem robust to model choice (Fig. 12). The primary traits explaining the spatial occurrence and/or abundance patterns of species are mainly associated with ecosystem engineering and mobility, indicating that these are the primary "response" traits of macrobenthic communities, and more specifically of molluscs and polychaetes. Finally, the key environmental variables explaining the distribution of species are primarily associated with nutrients (POC, phosphate, chlorophyll-a and nitrite) and water temperature.

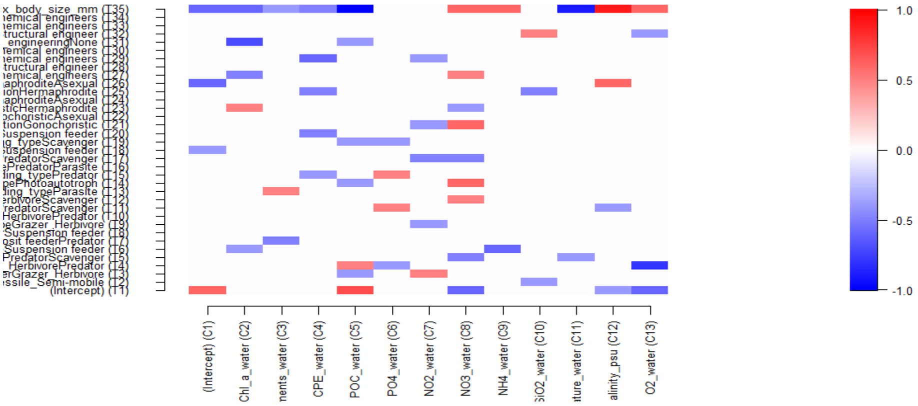

Figure12. *Pair-wise relationship between traits and environmental variables, illustrated by the mean posterior estimates of the gamma parameters (p>0.7). Red and blue colours indicate positive and negative parameter values, respectively.*

Field in-situ incubation experiments (Fig. 13) were performed in four different benthic habitats: invasive macrophyte *Halophila stipulacea*, native macrophyte *Cymodocea nodosa,* vegetated (turf) hard substrate and non-vegetated (barren) hard substrate. Nutrients, carbon, oxygen, temperature and light intensity were measured, while diversity and biomass of benthic invertebrates and macrophytes were estimated.

Figure13. *Field incubation experiments in soft (right) and hard (right) substrate during the light phase.*

Macrophyte habitats were less rich in nutrients (PO_4 and NO_3) when compared to hard substrates with restricted or no vegetation, due to the increased absorption of nutrients by direct plant uptake or symbiotic bacteria. Community net primary production and gross primary production were higher in both macrophyte communities in comparison to hard substrate communities, while the non-native *Halophila stipulacea* had higher community respiration (based either on O_2 or DIC fluxes) than all habitats (Fig. 14). In addition, *H. stipulacea* hosted the highest abundances and biomass of macrofauna in most taxonomic categories. *H. stipulacea* soft substrates had a significantly higher organic carbon content, indicating that the introduction of this invasive in native ecosystems may actually contribute in the increase of carbon sequestration in the Eastern Mediterranean. Finally, O_2 reduction and increase rates were higher for *H. stipulacea* in comparison to the native species meadows. The invasive *H. stipulacea* populations are able to shift their thermal niche and adapt rapidly towards the lower thermal regimes in the Eastern Mediterranean.

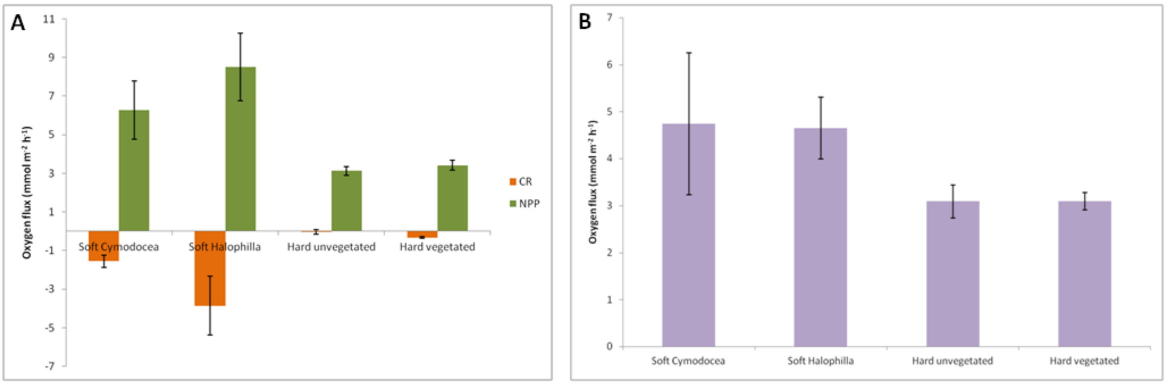

Figure14. *Community metabolic rates in the four habitats A) community net primary production (NPPO2) and community respiration (CRO2) and B) gross primary production (GPPO2) based on oxygen fluxes estimated during in situ incubations. Error bars correspond to standard deviation (SD).*

Genetic connectivity was studied through microsatellite analysis of *Posidonia oceanica* (5 meadows, 13 microsatellite loci). The highest number of haplotypes was found in Saria and Astakida, the most isolated and pure areas of the SL#27 MPA. The average population heterozygosity (Ho) was lower than the expected one (He) which could be explained by increased inbreeding, also supported by the positive values of the inbreeding coefficient F_{IS}. The clonal diversity index R had values closer to 1 indicating that samples do not originate from one single clone. The STRUCTURE HARVESTER analysis indicated resemblance for the meadows of Astakida and Saria, while the meadows of Diafani and Steno belonged to a different group (Fig. 15). The meadows of Tristomo, which are growing in an enclosed bay, were found to be different from the rest, although they were closer to the Saria-Astakida group. Gene flow between the sites was remarkably low with strong indications for inbreeding. Connectivity patterns between the *P. oceanica* populations around Karpathos-Saria MPA, should be considered before planning conservation activities. The MPA hosts two different populations of seagrasses that should be protected. Moreover, the limited gene flow of the two populations should be regarded in restoration activities, as each population is necessary to be treated independently.

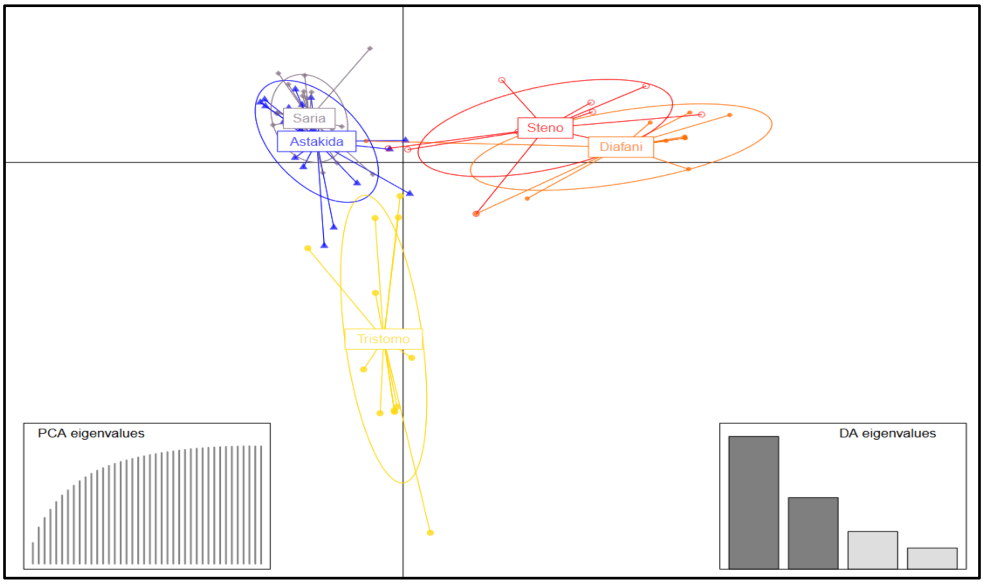

Figure15. *PCA plot for genetic cluster analysis of the Posidonia meadows of Storyline #27. Variance plot at bottom left: 60% of variance is explained by 7 PCs retained, 80% of variance is explained by 13 PCs retained; Eigenvalues at bottom right.*

2.2 Projections of future biological effects

The investigation of climate change impacts on *Posidonia oceanica* seagrasses through modeling approaches indicates a widespread decline in *P. oceanica* biomass this century, with the projected decline increasingly dramatic in higher emissions scenarios (Fig. 16). A decline in Mediterranean wide biomass of over 70% is projected across the ensemble for SSP 585. Projected changes within Mediterranean countries Exclusive Economic Zones across the full seagrass model ensemble are shown in Fig 17. The changes within the ensemble are notably larger if you do not exclude the “hot” models, and there is a clear relationship between impacts on *P. oceanica* and the overall equilibrium climate sensitivity of the global model used in the projections.

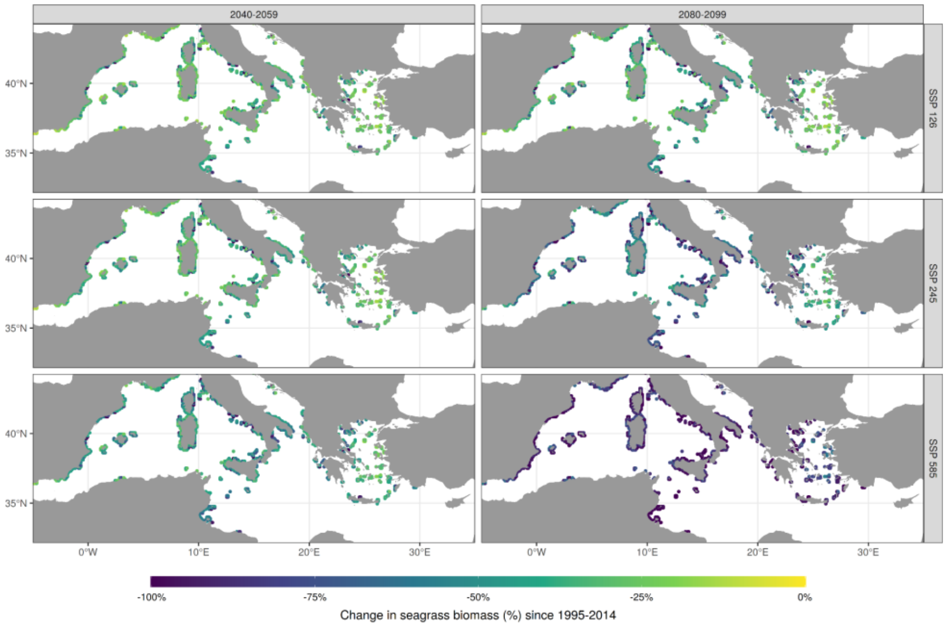

Figure 16: *Median modelled projected changes in surface Posidonia oceanica biomass between early 2000's (1995-2014) and mid-2100 Century (2040-59, left panels) and end-2100 Century (2080-99, right panels) under three different GHG-emission scenarios (top,mid, and lower panels). Projections are based on a large climate model ensemble and a mechanistic seagrass population model. FutureMARES storylines of interest 25, 26,* ***27****, 28.*

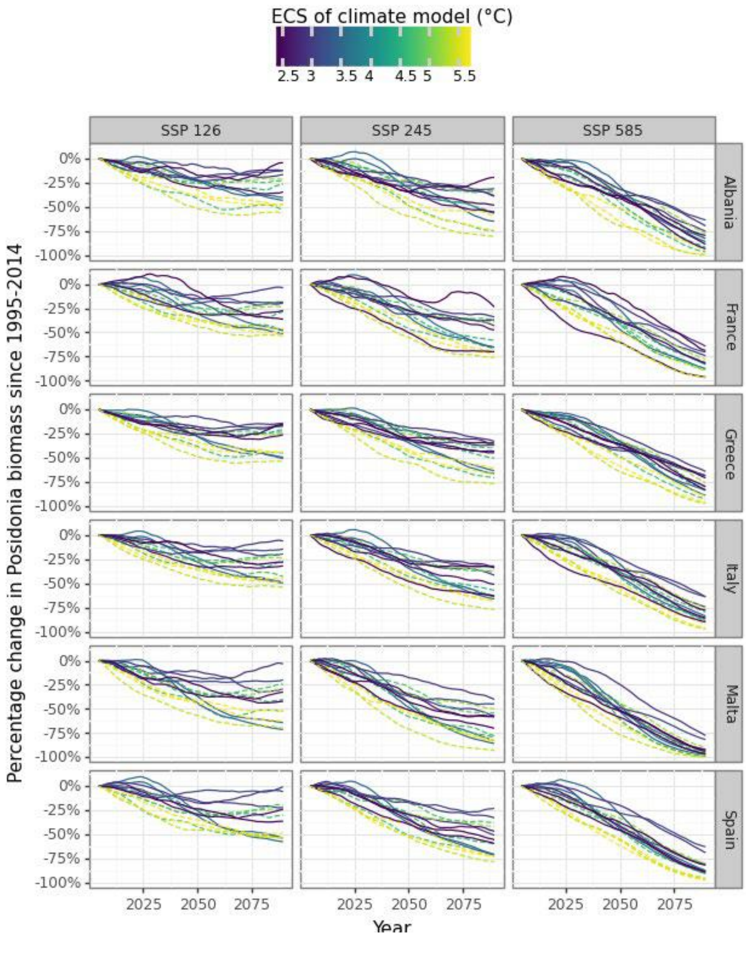

Figure 17. *Projected changes in EEZ-wide Posidonia biomass using a seagrass population model and a large ensemble of climate models. Each line represents the outcome when driven by a specific global climate model. Line colour represents the equilibrium climate sensitivity (ECS). Global models with ECS outside the IPCC's assessed credible range (1.5-4.5) have dashed lines. Each column represents a different climate change scenario. FutureMARES storylines of interest 25, 26,* ***27****, 28.*

3.1 Social-ecological vulnerability

A Climate Risk Assessment (Task 5.1) at the level of species (two urchins, two seagrasses and one bivalve) (Task 5.1), as well as at the level of ecosystem services (Task 5.2), against six hazards (4 climatic and 2 human) was performed for Storyline #27 addressing the effect of NBS2 Conservation. The taxa evaluated in SL#27 (Fig. 18) show similar climate risk across scenarios and time slices. In Global Sustainability, *Posidonia oceanica* and *Halophila stipulacea* are at moderate risk in both time slices, while *Pinna nobilis* and *Paracentrotus lividus* are at high risk. Only *Arbacia lixula* changes categorical risk value from moderate in 2040 to high in 2080. Under National Enterprise and World Market scenarios, all the taxa show high risk in both time slices. Only *Halophila stipulacea* is at moderate risk in both scenarios and time slices.

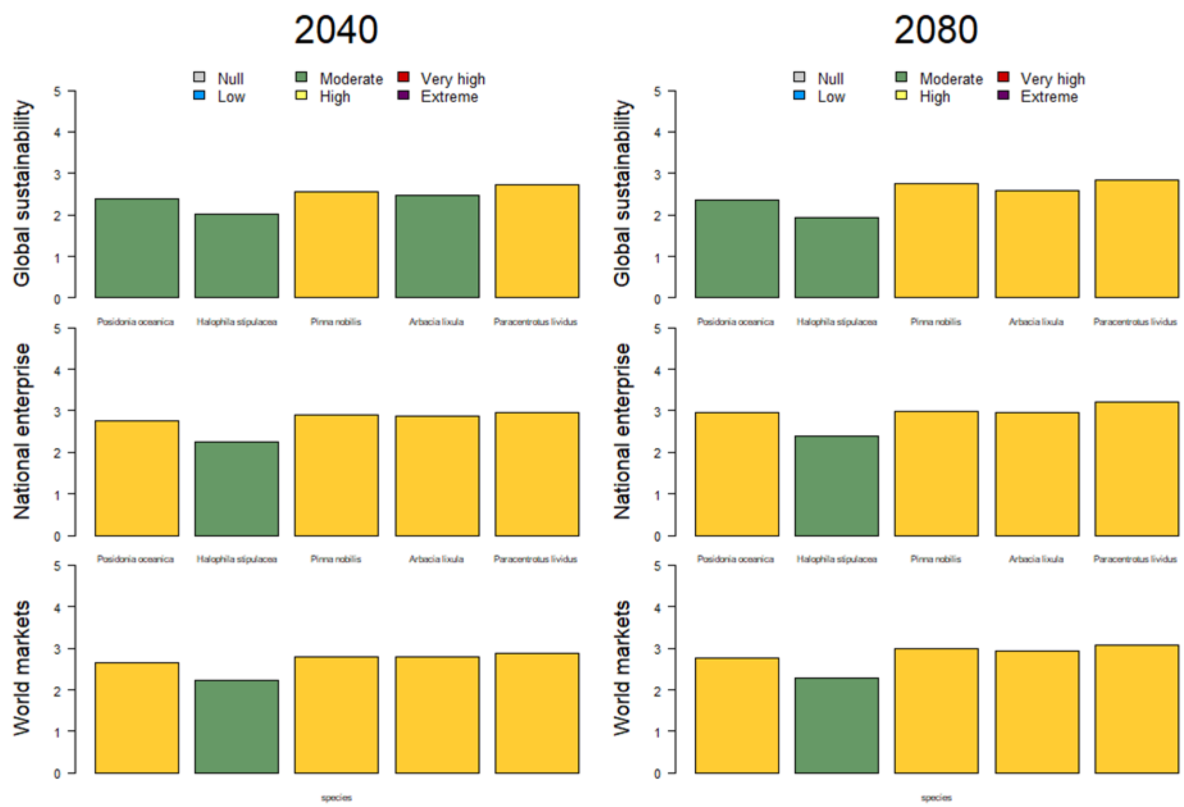

***Figure 18**. Overall climate risk (NBS ON) assessed for* the five taxa of *SL27 under the 3 scenarios and 2 time slices*

NBS2 conservation of seabed organisms in the Karpathos & Saria MPAs has mixed effects with four taxa (out of 5) showing consistently positive (decrease) effect on the overall risk across scenario and time-slices, while one taxa shows a consistent negative effect (increase). *P. nobilis* shows the most pronounced response to the NBS and *P. lividus* shows the highest level of risk. Change of risks across scenarios is mostly due to the NBS effects on Hazard and Adaptive Capacity and across taxa, it is due on change of Exposure and

Sensitivity. The negative effect of NBS on some taxa is either due to negative effects on both Exposure and Sensitivity (*P. oceanica)* or on Sensitivity only (*A. lixula*, *P.lividus*).

Regarding provision of services (Task 5.2), SL#27 addressed the effect of NBS2 Conservation on one provisioning (animal material which can be used for the maintenance and establishment of populations), one regulation (filtration and/or accumulation of waste or toxic substances through living processes) and one cultural (opportunities for education and training) Ecosystem Services (Fig. 19).

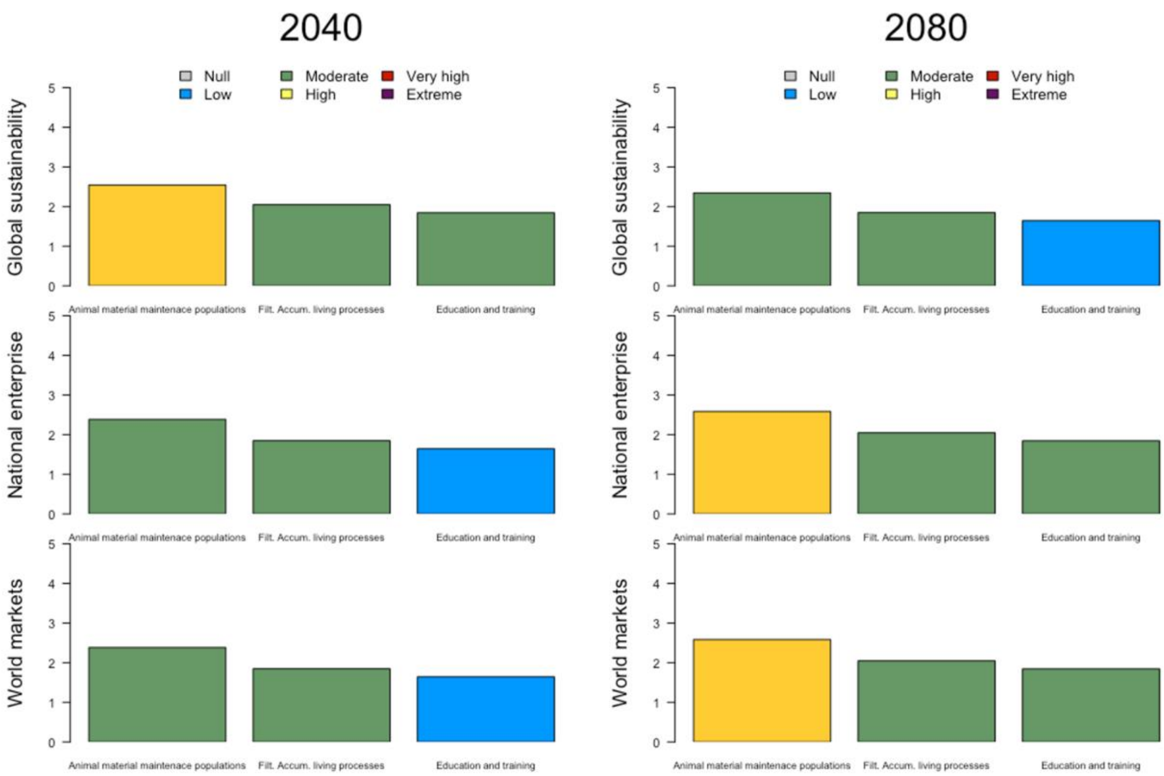

Figure 19 *Overall climate risk (NBS ON) assessed for the three ES of SL 27 under the 3 scenarios and 2 time slices.*

The presence of the NBS had the capacity to lower the overall risk for the provision of animal material (high to moderate) and for education and training (moderate to low) between 2040 and 2080 in the Global Sustainability scenario. In National Enterprise and World Market scenarios, the overall risk for the two above mentioned Ecosystem Services increases with time. The filtration/accumulation of waste/toxic substances remained unchanged across time regardless of the presence of the NBS. GS 2080 was the scenario which showed the lowest overall risk for the Ecosystem Services with the presence of the NBS. Risk levels across scenarios ranged from Low to High, with the lowest risk found for Education and training. The lower risk values for the different Ecosystem Services appeared to be linked to a greater extent to the conditions of the different scenarios across time, rather than to the effect of NBS2 conservation of seabed organisms in the Karpathos & Saria MPAs.

4.1 Testing NBS Implementation Scenarios

The approach used for capturing and revealing the economic benefits from the diverse Ecosystem Services (ES) was the Total Economic Value (TEV) which is based on individuals' preferences. Those are extracted via 1) stated preference methods based on the construction of hypothetical markets and conducted through direct questionnaires where the participants are asked to directly place a value to the ES described, or 2) revealed preference methods based on market prices or observed choices (e.g. touristic destinations) as proxies of people's preferences over ecosystem services. In SL#27 the main habitat of interest was *Posidonia oceanica*, which was evaluated as of High ecological status, while the soft- and hard-substrates have ECS that ranges between 8,3 and 9,7 and qualifies them as Good or Moderate ecological status. All the WTP (willingness to pay) values reported here refer to *Posidonia oceanica* habitats.

The relative WTP values for fish abundance and the high increase (40%) scenario were equal to 0.27€/person/year for the minimum estimate and 17.32€/person/year for the maximum estimate. Regarding water clarity the values were equal to a WTP of 0.55€/person/year for the minimum estimate and 45.23€/person/year for the maximum estimate. Regarding the aesthetic benefits, the relative WTP values for a high increase (90%), were equal to 1.22€/person/year for the minimum estimate and 78.58€/person/year for the maximum estimate. Regarding the carbon sequestration the WTP values for a high increase (25%) were equal to 0.05€/person/year for the minimum estimate and 3.11€/person/year for the maximum estimate. For the preservation of underwater cultural heritage, the WTP values for a medium increase were equal were 1.00 €/person/year for the minimum estimate and 64.38€/person/year for the maximum estimate.

The results and achievements of the project were continuously disseminated throughout its duration through events, scientific conferences, press releases and newspaper articles. Several workshops or in person meetings were organized with scientific experts and local MPA managers during the activities of T5.1 (CRA) and T1.4 for the Scenario Regionalisation Survey. Furthermore, representatives of SL#27 participated in an educational event organized in the Natural History Museum of Crete (February 2023) by WWF Greece and the Open Technologies Alliance for enhancing public knowledge and offering support for public interference in environmental issues. The event involved scientists, citizens, governmental officers, lawyers, NGOs and local businesses. The FutureMARES NBSs were presented giving focus to NBS2 and SL#27.

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