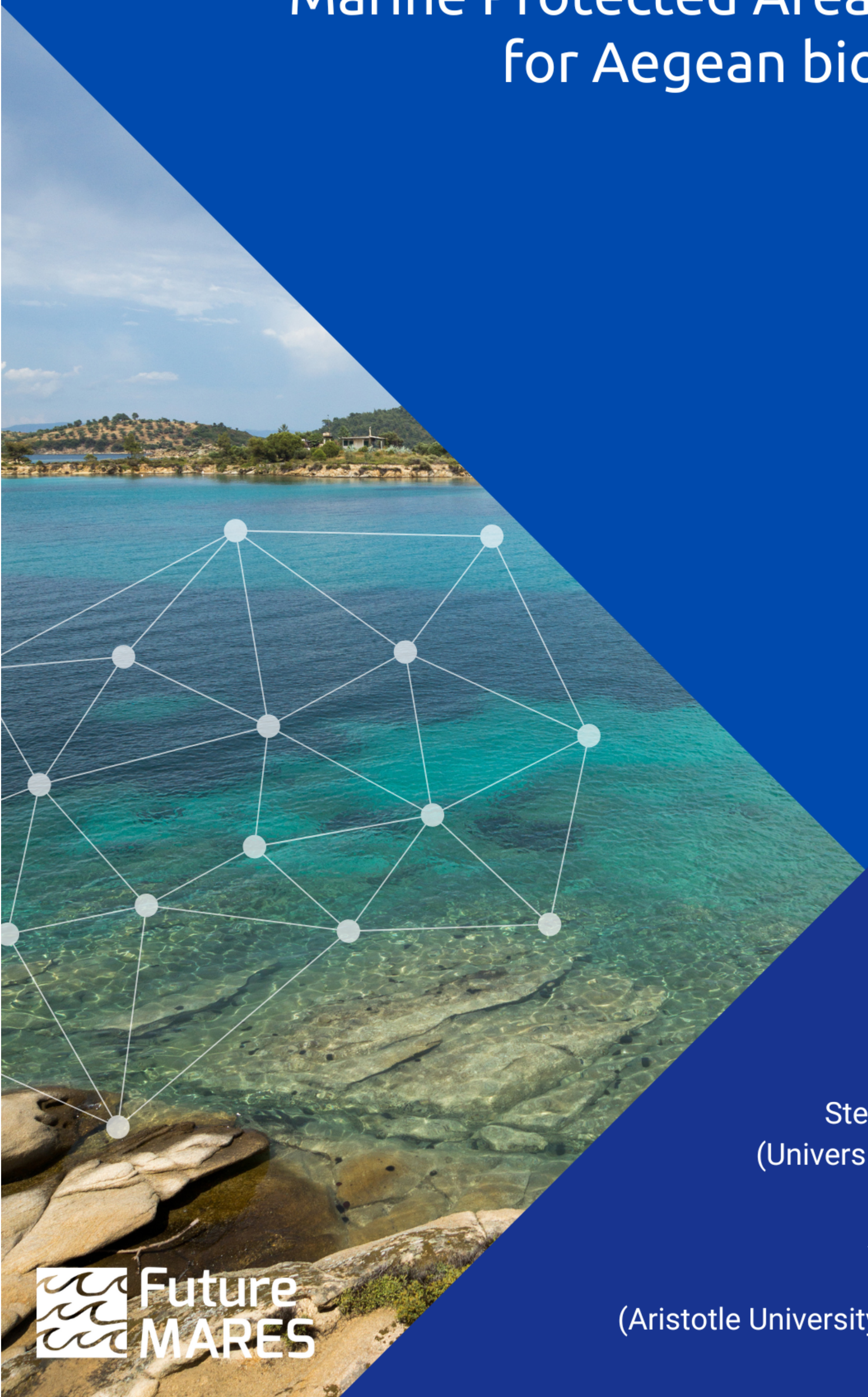
Marine Protected Area network for Aegean biodiversity

Storyline 26

NBS 2
EFFECTIVE CONSERVATION



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Future MARES

Introduction

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. FutureMARES will 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 multi-disciplinary summary of activities conducted in FutureMARES in a specific area on specific NBS and/or NIH. The activities include work across various disciplines including 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, social-ecological risk assessments. Many of these components and analyses, including NBS / NIH scenarios tested, were co-developed with local and regional stakeholders through regular engagement activities. The work presented in these Storylines 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 (www.futuremares.eu) submitted to the European Commission.

NBS regional context

The Aegean Sea is a distinct ecoregion situated in the crossroads of three continents. It has an insular character with more than 1,400 islands and islets, and an intricate geomorphology, with a mixture of shallow shelves and deep basins with troughs reaching 2500 m in depth (Sakellariou et al. 2005). A variety of habitats, including seagrass beds, reefs, soft bottoms, estuaries, coastal lagoons, coralligenous formations, deep-sea oxic sediments, submarine volcanoes with seafloor hydrothermal vents, and >600 submerged or semi-submerged marine caves, supports a very rich biodiversity (e.g., Gerovasileiou et al. 2015, Sini et al. 2017, Polymenakou et al. 2020, Papaconstantinou and Conides 2021, Panayotidis and Tsiamis 2021). The Aegean Sea hosts the largest population of the endangered Mediterranean monk seal (*Monachus monachus*), the only resident population of the harbour porpoise (*Phocoena phocoeana*) in the Mediterranean Sea, unique cave biodiversity, and important populations of many endangered and protected species (Gerovasileiou et al. 2015, Sini et al. 2017).

The marine environment of the Aegean Sea offers a variety of ecosystem services, with coastal tourism, and food provision (fishing and aquaculture) being among the most important in terms of socio-economic benefits. However, the Aegean Sea is heavily impacted by human activities and global stressors, mainly due to historical and current overfishing (Tsikliras et al. 2013, Sini et al. 2019), pollution (Papathanassiou and Zenetos 2005, Katsanevakis et al. 2007), eutrophication (Triantafyllou et al. 2001), climate change, and invasive species (Katsanevakis et al. 2020), which compromise the sustainable flow of ecosystem services.

The eastern Mediterranean is a global hotspot of biological invasions. Most of the invasive species are thermophilic Red Sea species, introduced through the Suez Canal, whose further spread northwards in the Aegean Sea is assisted by the fast warming of the basin (Katsanevakis et al. 2020). These species can have detrimental impacts on native biodiversity (Katsanevakis et al. 2014) and compromise conservation efforts (Mačić et al. 2018). In particular, rocky reefs in southern Aegean have been degraded in recent decades, largely due to the invasive herbivore alien rabbit fish *Siganus luridus* and *Siganus rivulatus*, from a habitat dominated by lush and diverse brown algal forests to another dominated by bare rock (Panayotidis and Tsiamis 2021). Recently, in an assessment of the status of coastal benthic ecosystems in the Mediterranean Sea, the rocky habitats of the Aegean Sea were assessed as having the poorest condition in the Mediterranean (Bevilacqua et al. 2020).

Conservation efforts in the Aegean Sea fall short to reach conservation targets, mainly because no systematic approaches to conservation planning have been followed, enforcement of regulations is poor, most of the 'protected' areas are actually paper-parks, and there are continuous conflicts with the fishing industry and other sectors (Sini et al. 2017, Fraschetti et al. 2018, Mazaris et al. 2018).

Figure 1: (Left) Sponge aggregation in an Aegean Sea rocky reef. Photo: T. Dailianis (MARISCA); (Right) The Aegean Sea includes important nesting sites for the vulnerable marine turtle Caretta caretta. Credit: Stelios Katsanevakis

Projected impacts of climate change

The Aegean Sea, located at the eastern part of the Mediterranean Basin has already experienced great climatic changes, which are projected to intensify in the next decades (Giorgi and Lionello 2008). An increase in the frequency, duration and magnitude of marine heatwaves, the intensification of severe wave and storm surge events and an increase in sea temperature (Makris et al. 2016), would have major impacts on the structure and function of ecosystems hosted in this sensitive region.

The Aegean Sea is among the European regions with a very high probability of compound flooding from precipitation and storm surges under climate change (Bevacqua et al. 2019). Projected mean sea level rise, coupled with episodic storm events, will aggravate beach erosion, with devastating impacts on the ability of beaches to support recreation/tourism (tourism being the 'heavy industry' of Greece). Under a mean sea level rise of 0.5 m – Representative Concentration Pathway (RCP) 4.5 of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate change (IPCC) – a storm-induced sea level rise of 0.6 m is projected to result in the complete erosion of 31 to 88% of all beaches in the Aegean archipelago (Monioudi et al. 2017).

The Aegean Sea is highly impacted by biological invasions with 209 alien species reported through 2019, of which 149 are considered as established (Katsanevakis et al. 2020). The Aegean Sea is highly impacted by thermophilic Lessepsian species, initially arriving in the Levantine and spreading anticlockwise along the eastern Mediterranean coastline. Hence, the current status in the Levantine Sea is a harbinger of the situation in the Aegean Sea in a few decades as sea warming continues. Currently, the marked temperature gradient of the Aegean Sea, is reflected in the degree of impact by invasive Lessepsian species, with the southern regions heavily impacted and the northern Aegean much less impacted.

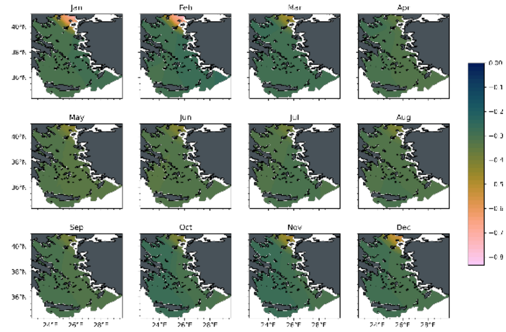
Model projections suggest that by the mid-21st century, high levels of species replacement including the immigration of many coastal fish are likely to pose an additional change in the community structure of the Aegean (Albouy et al. 2012). More dramatic changes in species richness are expected by the end of the 21st century from the warming exceeding the thermal niche of many such species (Albouy et al. 2013 & 2014).

These changes in ocean climate would impact the functionality and structure of ecosystems, further triggering redistribution of biodiversity. However, the magnitude, dimensionality and, thus, the anticipated impacts of such changes are not expected to be uniform across all marine areas of the Aegean. Several marine sites distributed across the Aegean could also serve as climatic refugia offering a shelter for a number of species while others are likely to exhibit a very limited climatic stability (Kyprioti et al. 2021).

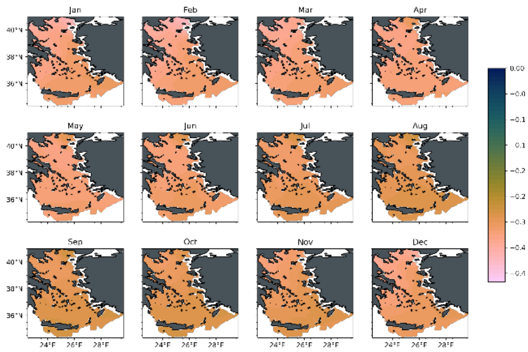
To improve our ability to protect the biodiversity and natural capital of the region, conservation planning needs to account for climate change. Moreover, ecologically informed strategies have to consider the spatial properties of the system and species, such as dispersal potential, population connectivity, and local adaptation.

Figure 2: (Left) Algal forests of the Aegean have been largely degraded to rocky barrens due to the combined effect of invasive herbivores, overfishing and sea temperature growth. Photo: S. Katsanevakis; (Right) Increased coastal erosion and storm frequency and intensity threaten coastal infrastructure and beaches, as depicted here in Eressos beach, Lesvos, North Aegean. Credit: O. Andreadis.

Chlorophyll (in mg m-3) changes in the far future at 5m depth under scenario SSP5-8.5

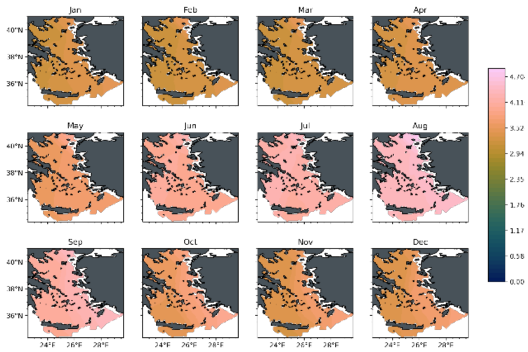


Oxygen (in ml/l) changes in the far future at 5m depth under scenario SSP5-8.5

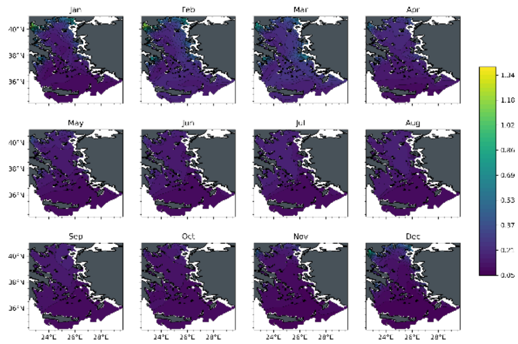


pH changes in the far future at 5m depth under scenario SSP5-8.5

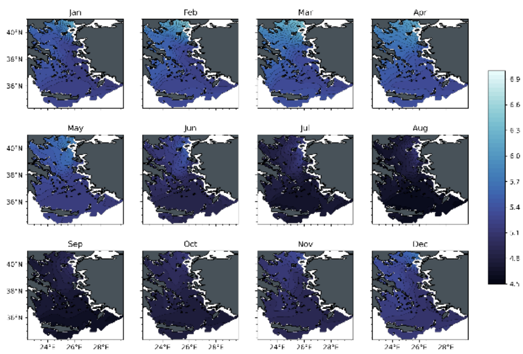
Salinity (in PSU) changes in the far future at 5m depth under scenario SSP5-8.5



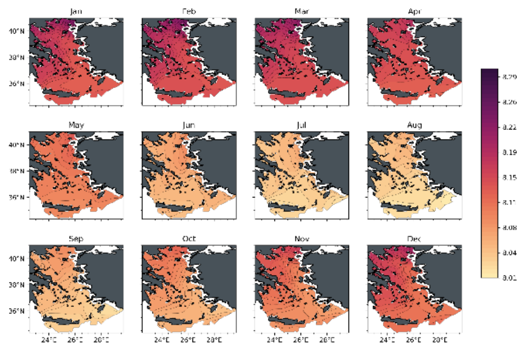
Potential Temperature (in degrees C) changes in the far future at 5m depth under scenario SSP5-8.5



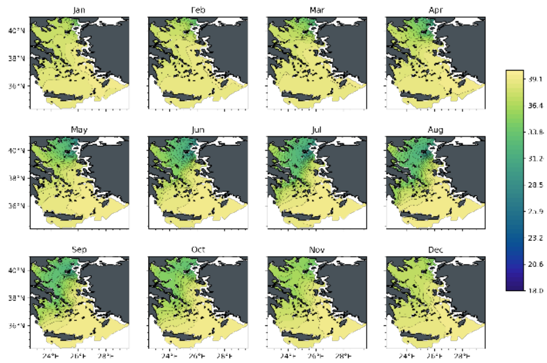
Chlorophyll (in mg m-3) at 5m depth under present day conditions



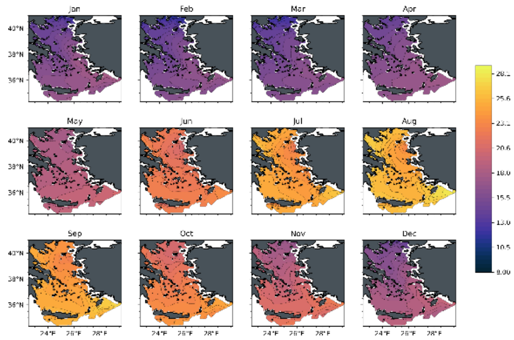
Oxygen (in ml/l) at 5m depth under present day conditions



pH at 5m depth under present day conditions



Salinity (in PSU) at 5m depth under present day conditions



Potential Temperature (in degrees C) at 5m depth under present day conditions

Figure 3: Climate projections for the region and surrounds. 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

Credit: Momme Butenschön, Euro-Mediterranean Center on Climate Change.

Scenarios describing future society and economy

FutureMARES will develop policy-relevant scenarios based on commonly used IPCC frameworks including SSPs and RCPs. These broad scenarios are regionalised based on stakeholder perspectives to guide activities such as model simulations in specific Storylines. Each of these scenarios has implications for the three NBS examined in this program (effective restoration, effective conservation, sustainable seafood harvesting):

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. Societies increasingly commit to achieving development goals and this reduces inequality across and within countries. Consumption is oriented toward lower material growth, resource and energy intensity.

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. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialised countries and high in developing ones. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.

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. Global markets become more integrated and strong investments in health, education, and institutions are made to enhance human and social capital. 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. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

Figure 3: Representation of three, broad scenarios to be regionalised to guide activities such as model simulations in FutureMARES project. Credit: FutureMARES

FutureMARES research needs

The existing network of MPAs in the Aegean Sea was designed with no consideration of climate change impacts, hence conservation efforts in the region might turn out to be futile in the near future. An extended network of MPAs needs to be designed in the region to reach the ambitious targets of the new EU Biodiversity Strategy. For planning this network, areas need to be identified and prioritised for protection that have the greatest conservation potential, benefits and future resilience. To achieve this, main research questions and objectives are:

(1) to better understand the level of exposure of key habitats and species to climate change threats (such as Posidonia oceanica beds and canopy algal forests on rocky reefs);

(2) determine how best to identify climate change refugia in the region, where climate change impacts are minimal, by assessing the level of sensitivity of the ecological features targeted for conservation;

(3) determine how to account for biological invasions in conservation planning; (4) better understand the consequences of multiple local and global pressures, and how to include potential cumulative impacts in conservation planning.

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

- **T1.1** Assess current status and temporal trends of reefs, macroalgal forests and associated fish communities;
- **T1.2** identification of fish traits related to their response to climate change;
- **T1.4** Regionalise scenarios for use in the Aegean Storyline;
- **T2.3** Identification of climate hotspots and refugia in the Aegean Sea
- **T3.1** Comparison of ecosystem functions between intact and degraded communities on rocky reefs (algal forests vs barrens);
- **T4.1** Modelling the future distribution of Posidonia oceanica and canopy algal forests in the Aegean Sea;
- **T4.2** Modelling the future distribution of the loggerhead sea turtle in the Aegean Sea;
- **T4.4** Perform simulations of the Aegean Sea food-webs under different CC and MPA network scenarios;
- **T5.1** Climate risk assessment for Posidonia oceanica, macroalgal forests and fish communities in the Aegean Sea;
- **T5.2** Assess Ecosystem Services Provision and potential changes in their flow under climate change scenarios;
- **T5.3** Assess socio-ecological climate risks in the Aegean Sea
- **T6.1** Create maps of climate readiness in the existing and proposed networks of MPAs in the Aegean Sea, to enhance communication with stakeholders and policy makers;
- **T6.2** Assessment of the potential socio-economic benefits of the proposed network of MPAs in the Aegean Sea;
- **T7.1** Co-development the Aegean research with relevant policy makers;
- **T8.1** Dissemination of the results to national and regional stakeholders, and the international scientific community; capacity building; interactions with previous and ongoing projects (e.g. MARISCA, PROTOMEDEA, ALAS) and engage relevant stakeholders to gain their perspectives on the benefits (and costs and trade-offs) of implementing the proposed network of MPAs in the Aegean Sea.

Figure 5: Surveys and field experiments contribute to improving our knowledge base and understand how climate change, biological invasions and other stressors impact biodiversity. Credit: S. Katsanevakis

Storyline Contact

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