Basin-wide sea turtle conservation in the Mediterranean Sea

Storyline 32

NBS 2
EFFECTIVE CONSERVATION

Authors:

Antonios Mazaris
Aggeliki Doxa
Anastasia Chatzimentor
Stelios Katsanevakis
(Aristotle University Thessaloniki)

Sevrine Sailley
(Plymouth Marine Laboratory)

Future MARES

European Commission

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 accelerated pace of contemporary climate change and the increased degradation of their habitats raise serious concerns on their persistence (Fuentes, et al. 2011; Cuevas et al. 2019). Sea turtles are highly mobile organisms, with their life cycle taking place in a variety of habitats. Adult individuals take long migration trips from foraging areas to nesting grounds, where females lay their nests in the sandy shores (Hays& Scott 2013, Schofield et al. 2010). This charismatic species has even distinct foraging areas for different life history stages. Thus, connections among ecosystems along different realms are critical for their persistence (Mazor et al. 2016). In addition, as ectothermic animals, their entire life cycle is closely related to climatic conditions (Poloczanska et al. 2009). All these features require conservation planning across broad spatial scales, with the potential measures implying the commitment of many nations.

Sea turtles, iconic representatives of marine biodiversity, are also considered as:

a) an umbrella species, whose protection could ensure the conservation of several species, even under changing climatic conditions (Fish & Drews 2009)

b) ecological indicators while they could reflect alterations at various environmental parameters and respond to climatic differences both in the air and sea (Aguirre & Lutz 2004)

c) keystone species as top-level consumers feeding on large quantities of marine invertebrates (Coleman & Williams 2002)

d) flagship species with hundreds of organisations and volunteers being involved in conservation actions.

The Mediterranean hosts a distinct population of loggerhead sea turtles (*Caretta caretta*), with specific demographic and genetic features, which is subjected to multiple human-related pressures (Wallace et al. 2011, Wallace et al. 2010). In addition, the Mediterranean loggerheads are considered to be adapted to the discrete climatic characteristics of the basin (Almpanidou et al. 2017), exhibiting some level of resilience to climate change (Fuentes et al. 2013). The loggerhead sea turtles are priority species in the European Union (EU) and listed in Annexes II and IV of the Habitat Directive 92/43/EEC, also being protected by several international agreements (e.g. Bern Convention, Bonn Convention, CITES etc.). Mediterranean loggerheads are considered as Least Concern by the IUCN, even though the global population is classified as Vulnerable. However, we shouldn't be complacent as their conservation status is attributable to long-term systematic efforts (Mazaris et al. 2017), highlighting the need for strengthening their protection.

Protection at multiple levels is essential and conservation measures should consider the different life stages of loggerheads and their vulnerability due to altered conditions at the various habitats that use to fulfil their needs (Casale et al. 2018). Given the nature of the species, several challenges arise in the application of systematic conservation planning under climate change but also in the establishment of proposed measures for migratory species.

Figure 1: Adult and hatching loggerheads turtles in Zakynthos nesting rookery, Western Greece. Credit: Charis Dimitriadis, Antonios Mazaris

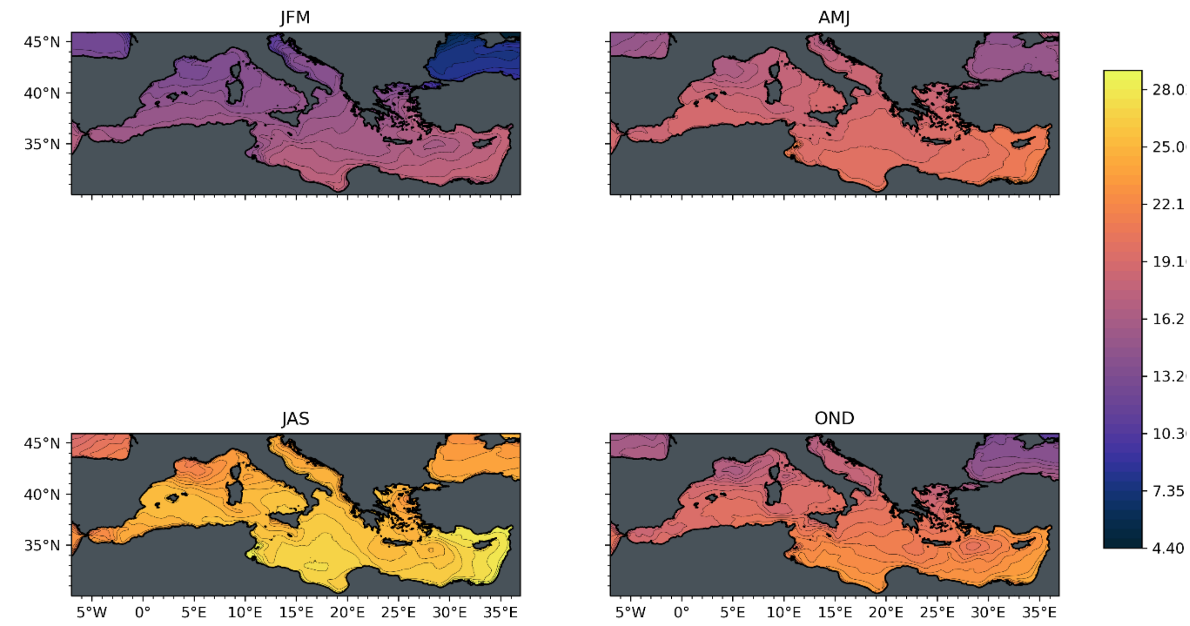
Projected impacts of climate change

The Mediterranean region represents a climate change hotspot, with future projections revealing temperatures increases at a higher rate compared to the global average (Lionello & Scarascia 2018). Towards the end of the 21st century, the intensity and the severity of marine heatwaves are going to be increased by 4 and 42 times, respectively, with at least one long-lasting event being predicted every year, up to three months longer (Darmaraki et al. 2019). Therefore, it becomes apparent that climate change impacts pose serious and multi-faceted challenges to the conservation of marine biodiversity.

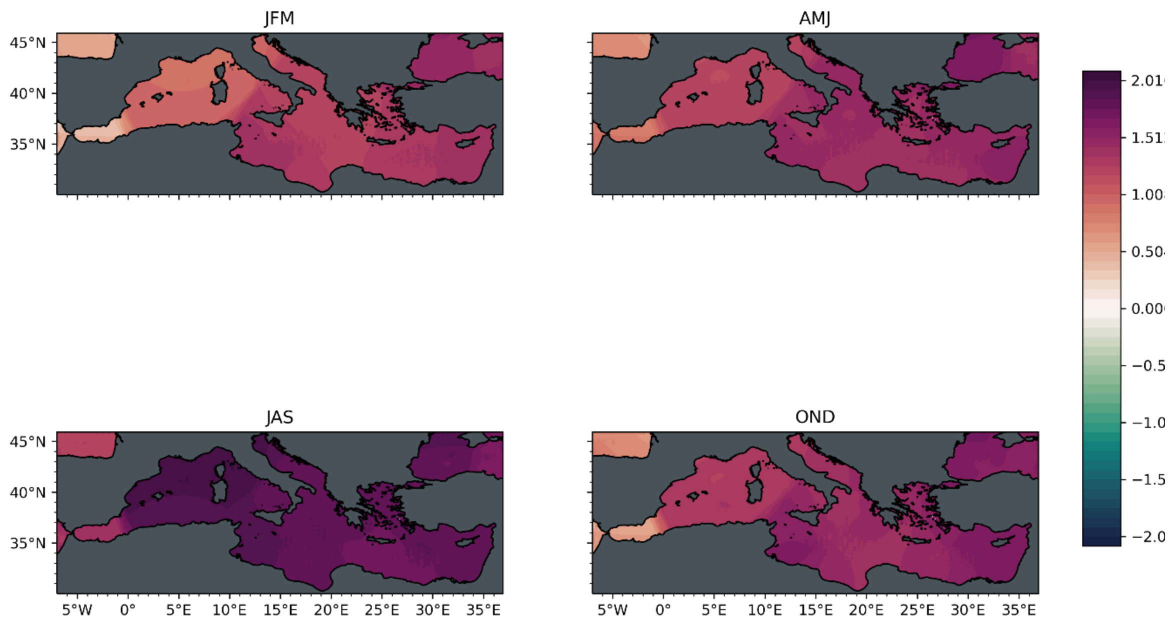
Climate change is a key component that alters biological and behavioural features but also the conditions of the sites inhabited by sea turtles, with all these aspects affecting species viability (Poloczanska et al. 2009). The altered climatic conditions have a profound impact on breeding ecology of sea turtles, increasing the risk of female-skewed sex ratios of offspring, reduced hatching success and abnormal embryonic development due to raising beach temperatures (Fuentes & Porter 2013, Laloë et al. 2017). Potential differentiations on the suitability of nesting sites have been also proposed (Witt et al. 2010), with an increase in thermally suitable nesting sites at higher latitudes [e.g. in the Western Mediterranean (Maffucci et al. 2016)]; or a risk for nesting grounds closer to the equator to approach upper thermal limits (Pike 2014). Given that range shifts of sea turtles nesting habitat have been already observed at local scales (Reece et al. 2013), there is a need to explore potential future suitability of nesting sites at a regional level.

Considering that sea turtles spend most of their life within the marine realm, it is crucial to have a comprehensive view on their potential vulnerability in the marine environment, under climate change. Variability of ocean temperature could influence reproductive output [e.g. determining inter-nesting intervals (Hamann et al. 2013)], but also foraging activities [e.g. altering primary productivity, prey distribution (Poloczanska et al. 2009)]. In the Mediterranean Sea, where sea turtles experience lower water temperature compared to the tropics, increased temperatures could affect behavioural mechanisms and activities at different life-cycle stages. For example, rising temperature could reduce the length of winter dormancy (Hochscheid et al. 2007), extend the foraging period (Witt et al. 2010), and improve nesting conditions, but reduce post-hatchling survival (Maffucci et al. 2016). In addition, the increased temperatures could lead to higher metabolic rates of sea turtles (Marn et al. 2017), impeding them to use energy reserves slowly and survive the long periods of fasting related to long distance migration (Hays et al. 2014). Raising water temperatures could also lead to intense stress because of the increase of pathogens and toxic phytoplankton (Milton & Lutz 2003).

It becomes apparent that for sea turtles with multi-realm, complex life cycles a better comprehension of the consequences of climate change at the different life stages represents a key challenge to guide management decisions and mitigation investments. The comparison of different scenarios on the future distribution of the Mediterranean loggerheads is also vital so as to identify and prioritise important areas for conservation, alleviating the uncertainty which is inherent to model projections.



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



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

Figure 2: Climate projections for the Mediterranean Sea 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

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 will develop policy-relevant scenarios with stakeholders across the world. These scenarios are based on commonly used IPCC frameworks including SSPs and RCPs.

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

Given the role of marine megafauna in ecosystem functioning, we need to quantify the species vulnerability to climate change. There is also an existing gap of information on critical sea turtle areas and on how future conservation planning should include climate change impacts. Our main research questions and objectives are to: 1) Identify tipping points for climate change on species behaviour and phenology, as for foraging activities, reproduction and migration, 2) Improve current knowledge on distribution and habitat use and their possible alterations by climate change, 3) Investigate possible links between habitat suitability and prey distributions, by developing and applying innovating process-based modelling, 4) Develop metrics on climatic stability, identify climatic refugia and assess the vulnerability of critical habitats, 5) Incorporate climate change in conservation planning and develop a 3D based Systematic Conservation Planning framework, 6) Identify areas of potential conflict between the conservation needs and human activities and detect hotspots of risk.

The outputs of the storyline will provide information on how and where the expected impacts will be more severe. They will also provide management guidelines for conservation managers, but also stakeholders representing other human activities (e.g. fisheries, tourism) that are connected to marine biodiversity of the Mediterranean region.

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

- Task 1.1 – Assess all available monitoring data on species distribution, occurrences and habitats for sea turtles
- Task 1.4 – Regionalise scenarios for use in storyline
- Task 2.3 – Identify hotspots of persistent climate change and regions that can serve as climatic refugia in the Mediterranean Sea
- Task 4.1 – Modelling the future distribution of potential habitats for sea turtles in the Mediterranean Sea
- Task 4.2 – Modelling of present and future distributions of sea turtles in the Mediterranean Sea
- Task 4.4 – Use of the outcomes of food-web models as input in process-based modelling
- Task 5.1 – Climate risk assessment for Caretta caretta in the Mediterranean Sea
- Task 6.1 – Provide maps of climate readiness in current and future important sea turtle areas in the Mediterranean Sea
- Task 6.2 – Assessment of the potential socio-economic benefits of the proposed important sea turtle areas
- WP7 – Co-development of the storyline with relevant policy makers
- Task 8.1 – Dissemination of the results to national and regional stakeholders, and the international scientific community
- Task 8.2 – Engage relevant stakeholders on the benefits (and costs and trade-offs) of establishing the proposed important sea turtle areas in the Mediterranean Sea

Figure 4: Monitoring sea turtles on the sea. Credit: Mazaris research Group

Figure 5: Protection cages of sea turtle nest in Zakynthos Island, Western Greece. © National Marine Park Zakynthos

Storyline Contact

Antonios Mazaris (AUTH) - amazaris@bio.auth.gr

References

Aguirre AA, Lutz PL (2004) Marine turtles as sentinels of ecosystem health: is fibropapillomatosis an indicator? EcoHealth, 1:275-83.

Almpanidou V, Schofield G, Mazaris AD (2017) Unravelling the climatic niche overlap of global sea turtle nesting sites: Impact of geographical variation and phylogeny. Journal of Biogeography, 44:2839-48.

Casale P, et al. (2018) Mediterranean sea turtles: current knowledge and priorities for conservation and research. Endangered species research, 36:229-67.

Coleman FC, Williams SL (2002) Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends in Ecology & Evolution, 17:40-4.

Cuevas E, Liceaga-Correa M, Uribe-Martínez A (2019) Ecological vulnerability of two sea turtle species in the Gulf of Mexico: an integrated spatial approach. Endangered Species Research, 40:337-56.

Darmaraki S, et al. (2019) Future evolution of marine heatwaves in the Mediterranean Sea. Climate Dynamics, 53:1371-92.

Fish M, Drews C (2009) Adaptation to climate change: options for marine turtles. WWF report, San José20p.

Fuentes M, Limpus C, Hamann M (2011) Vulnerability of sea turtle nesting grounds to climate change. Global Change Biology, 17:140-53.

Fuentes M, Porter W (2013) Using a microclimate model to evaluate impacts of climate change on sea turtles. Ecological Modelling, 251:150-7.

Fuentes M, et al. (2013) Resilience of marine turtle regional management units to climate change. Global Change Biology, 19:1399-406.

Hamann M, et al. (2013) Climate change and marine turtles. In: Wyneken J, Lohmann KJ, Musick JA (ed) The Biology of Sea Turtles III. CRC Press, Boca Raton, FL, p. 353-378.

Hays GC, Scott R (2013) Global patterns for upper ceilings on migration distance in sea turtles and comparisons with fish, birds and mammals. Functional Ecology, 27:748-56.

Hays GC, et al. (2014) Route optimisation and solving Zermelo's navigation problem during long distance migration in cross flows. Ecology letters, 17:137-43.

Hochscheid S, et al. (2007) Overwintering behaviour in sea turtles: dormancy is optional. Marine Ecology Progress Series, 340:287-98.

Laloë JO, et al. (2017) Climate change and temperature-linked hatchling mortality at a globally important sea turtle nesting site. Global Change Biology. 2017;23:4922-31.

Lionello P, Scarascia L (2018) The relation between climate change in the Mediterranean region and global warming. Regional Environmental Change, 18:1481-93.

Maffucci F, et al. (2016) Seasonal heterogeneity of ocean warming: a mortality sink for ectotherm colonizers. Scientific reports, 6:1-9.

Marn N, et al. (2017) Inferring physiological energetics of loggerhead turtle (Caretta caretta) from existing data using a general metabolic theory. Marine Environmental Research, 126:14-25.

Mazaris AD, et al. (2017) Global sea turtle conservation successes. Science advances, 3:e1600730.

Mazor T, et al. (2016) The value of migration information for conservation prioritization of sea turtles in the Mediterranean. Global Ecology and Biogeography, 25:540-52.

Milton SL, Lutz PL (2003) Physiological and genetic responses to environmental stress. In: Lutz PL, Musick JA, Wyneken JW (ed) The Biology of Sea Turtles II. CRC Press, Boca Raton, FL, p 163-197.

Pike DA (2014) Forecasting the viability of sea turtle eggs in a warming world. Global Change Biology, 20:7-15.

Poloczanska ES, Limpus CJ, Hays GC (2009) Vulnerability of marine turtles to climate change. Advances in Marine Biology, 56:151-211.

Reece JS, et al. (2013) Sea level rise, land use, and climate change influence the distribution of loggerhead turtle nests at the largest USA rookery (Melbourne Beach, Florida). Marine Ecology Progress Series, 493:259-74.

Schofield G, et al (2010) Fidelity to foraging sites, consistency of migration routes and habitat modulation of home range by sea turtles. Diversity and Distributions, 16:840-53.

Wallace BP, et al. (2011) Global conservation priorities for marine turtles. PloS one, 6:e24510.

Wallace BP, et al.(2010) Regional management units for marine turtles: a novel framework for prioritizing conservation and research across multiple scales. Plos one, 5:e15465.

Witt MJ, et al. (2010) Predicting the impacts of climate change on a globally distributed species: the case of the loggerhead turtle. Journal of Experimental Biology, 213:901-11.