Future MARES

Policy Brief 2

2024

MARINE BIODIVERSITY: CLIMATE SENSITIVITY AND RESILIENCE

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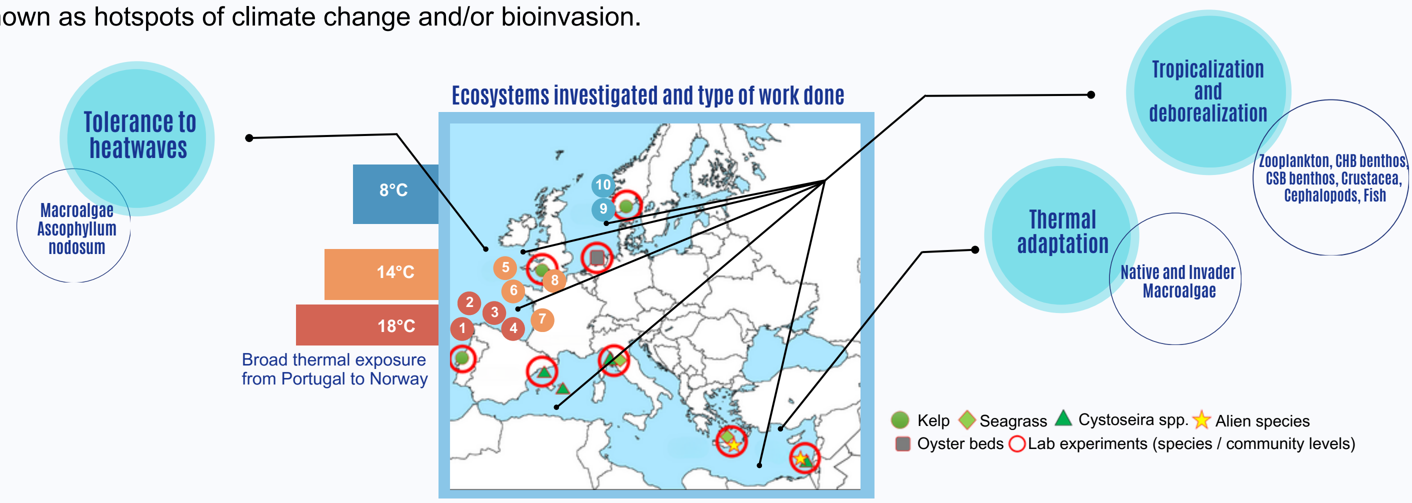
HIGHLIGHTS

Climate change poses a huge challenge to implementing effective Nature-based Solutions (NBS) - marine conservation and restoration - and Nature-inclusive Harvesting (NIH) for sustainable seafood harvesting. Local and regional shifts in the composition of marine species have occurred and can be particularly rapid in climate change hotspots* where sensitive species decline while warmer-water species thrive. The question is: what biodiversity do we preserve or restore in a future climate? This is more complex in areas also recognized as hotspots of bioinvasion where invaders from warmer waters will do better than native species in a future climate.

Marine communities altered by climate change and/or bio-invasion may not always represent degraded, or poorly-functioning systems. These altered systems may function similarly and provide similar services as the original, pristine communities, but homogenise regional diversity. Therefore, marine ecosystem health descriptors such as those used by the EU Marine Strategy Framework Directive (MSFD), may be improved by not only considering the richness of native species but also - or alternatively - the complementarity, functions and services offered by marine communities, especially in regions known as hotspots of climate change and/or bioinvasion.

Sensitivity to climate-driven stressors may differ within a species as local populations adapt to specific thermal conditions. In these cases, climate sensitivity is best defined by measurements made on local populations along latitudinal or thermal gradients. A correct sensitivity identification allows more reliable future climate-driven change estimations in species distribution. Moreover, differences in sensitivity can also be harnessed to increase the success of future restoration efforts by, for example, selectively using more climate-resilient populations of habitat-forming species.

This policy brief presents **FutureMARES** results from field and laboratory studies that increase our understanding of historical changes in marine biodiversity and our ability to predict future ecological impacts. **FutureMARES** aims to give solid science-based knowledge for better management of restoration and conservation targets (Rilov et al. 2019) and to improve EU directives on this matter, such as the MSFD as well as the Marine Spatial Planning (MSP) including Marine Protected Areas (MPAs) (Rilov et al. 2020).



*For a wider analysis of hotspots and refugia in future climate, see our Policy Brief 1

KEY STATEMENTS

- **FutureMARES** has documented historical shifts in diverse marine taxa and habitats that can be attributed to climate change. These alarming trends have potential economic and social consequences and highlight the importance of NBS for climate adaptation and mitigation (Chust et al., 2024).

- **FutureMARES** confirmed that tropical non-native reef macrophytes perform better at warm temperatures than native species in the Mediterranean Sea, suggesting that invaders will function much better than natives under future ocean warming.

- Experiments demonstrated local thermal adaptation and population differences in climate sensitivity. This information can improve estimations of future habitat suitability and thus boost climate resilient habitat restoration efforts.

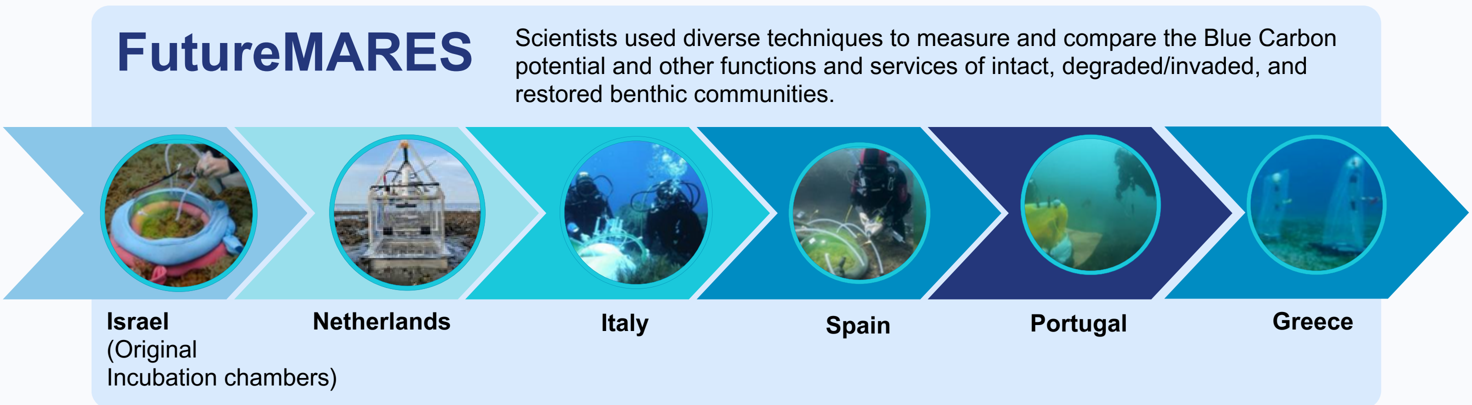
- Shallow reefs that are either alien-dominated, altered but rich, or formed by restored macrophyte communities can function similarly or superiorly to the original communities. This gives hope that even highly altered communities can be healthy ecosystems and continue providing some essential functions and services when native/original species are lost.

CONTEXT & BACKGROUND

Climate change is a major driver of biodiversity change worldwide and particularly within European regional seas (Worm & Lotze 2021). This is especially challenging for the implementation of marine NBS such as habitat restoration or conservation (O-Leary et al. 2023), because the intended targets, like key habitat-forming species or local biodiversity characteristics, are rapidly changing due to externally-driven global forces (Rilov et al. 2020) alongside local drivers (Gissi et al. 2020). These climate-drivers include the increased frequency and intensity of marine heatwaves that have caused local, catastrophic losses in marine biodiversity (Garrabou et al. 2022).

FutureMARES have filled fundamental gaps in ecological knowledge by:

1) Compiling and analyzing the most comprehensive, long-term marine ecological time series across European regional seas to understand the types and rates of biodiversity change.
2) Measuring the sensitivity to main stressors projected to continue change in a future climate such as temperature (ocean warming) and pH (acidification) of key species in different regions.
3) Conducting laboratory experiments to examine how multiple factors interact to impact on the performance of key habitat-forming species (shellfish forming reefs and kelp creating the foundation for biodiverse forests).
4) Comparing ecosystem functions and services stemming from intact/endemic and degraded/altered marine benthic communities.



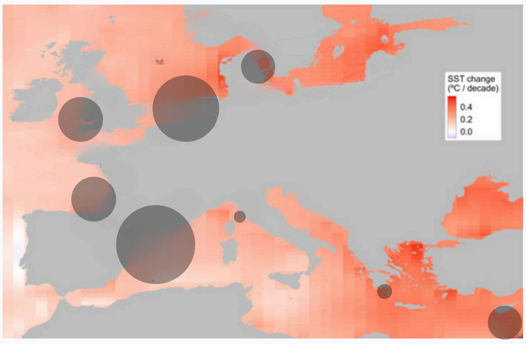
KEY RESULTS

1) Tropicalization and deborealization of European seas.

FutureMARES has documented historical changes in marine species (zooplankton, benthos, pelagic and demersal invertebrates, fishes) and habitats that can be attributed to climate change. Over the past 40 years, the NE Atlantic Ocean has experienced a tropicalization of its communities, with an increase in the abundance of warmer-water species. The Mediterranean and Baltic Seas, where warming has been more rapid, have seen a marked decline in cold-water organisms.

Temperature trends from 1980 to 2020

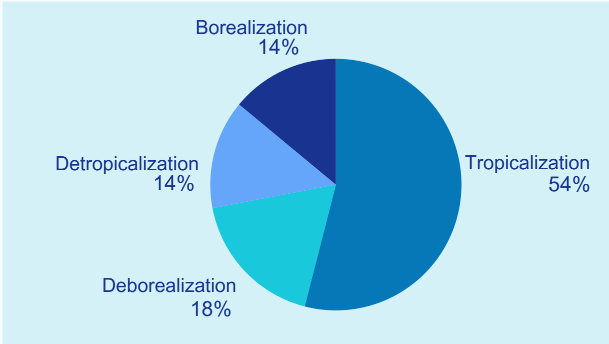
Sampling site locations are shown in black circles.



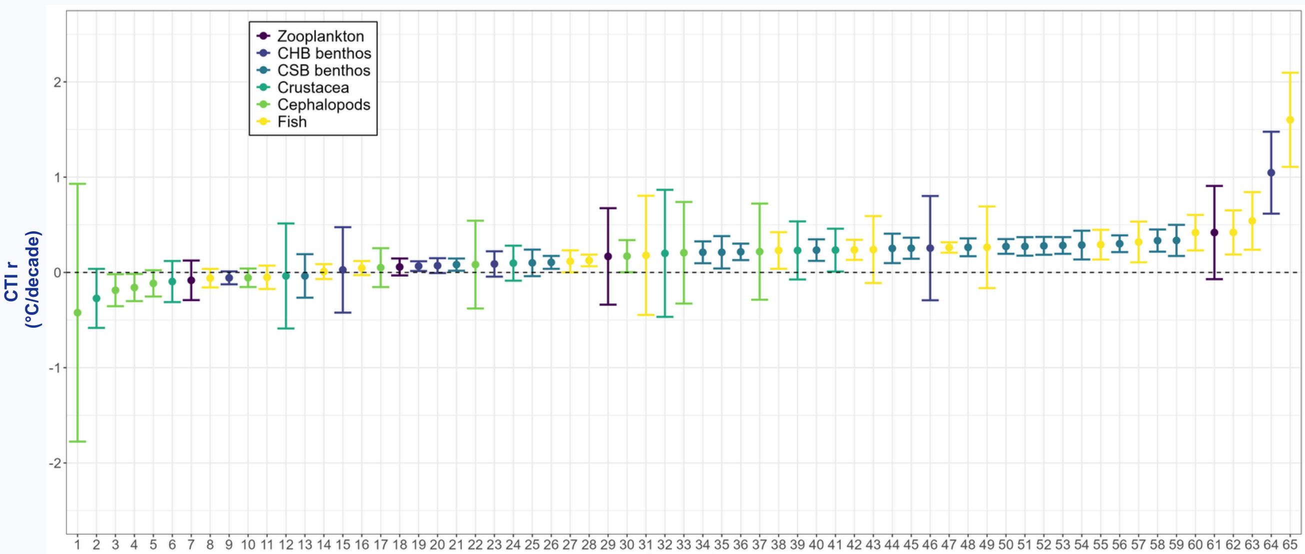
SST: Mean Sea Surface.
GODAS (Global Ocean Data Assimilation System)

Environmental time series from 65 monitoring programmes, including historical data for 1.817 marine species

Based on the CTI analysis, warming impacted more than 70% of European marine biodiversity time series via either tropicalization or deborealization.



Rate of change in Community Temperature Index (CTI) trends over time



Community Temperature Index (CTI) is a standardised indicator that provides quantitative information on community composition and its affinity for warm or cold waters.

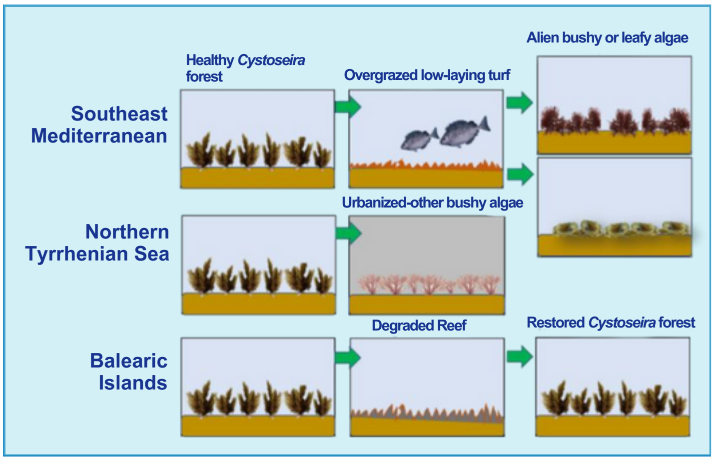
2) Community shift could lead to alternative ecosystem state while keeping services.

On the highly invaded southeast Mediterranean coast, tropical non-native reef macrophytes have much higher thermal tolerance than two native, forest-forming species. This indicates much higher vulnerability of the natives to warming and better resilience of the invaders. Tropical aliens could also maintain the habitat and some metabolic functioning (carbon uptake) of the reef, as they could thrive through the hot and fast-warming summer, while the natives would be lost due to increased thermal stress.

On the Tuscany coast of Italy, urban, highly altered coastal macrophyte communities were functioning in most seasons quite similarly to pristine communities in marine protected areas on islands.

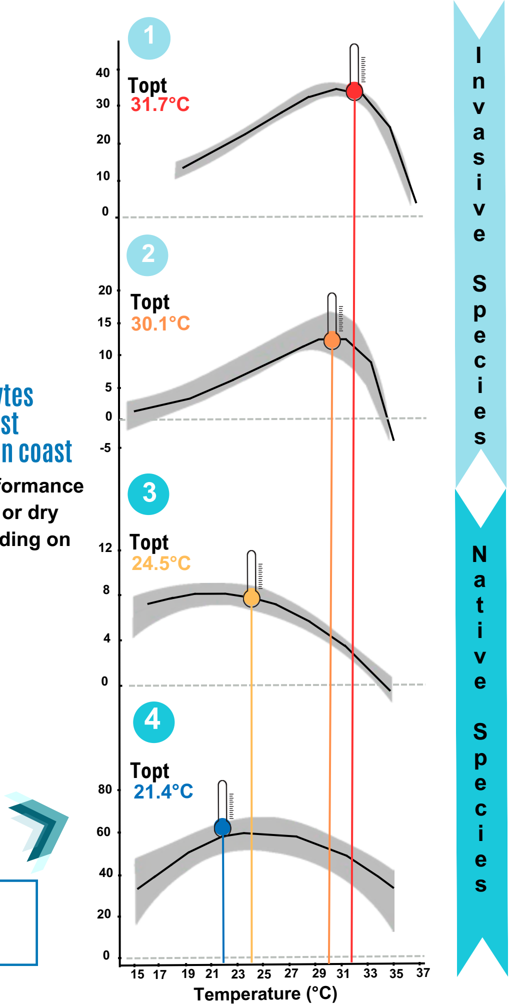
On reefs of the Balearic Islands where macroalgae forests have been destroyed in many areas, **FutureMARES** found that 10 years after a forest restoration began, the area was almost as diverse and productive as a healthy forest. It is also much more functional than a nearby, still-degraded reef.

Shifts in community state of macroalgal communities in shallow water reefs in Mediterranean Sea in the different study regions.



Macrophytes southeast Mediterranean coast

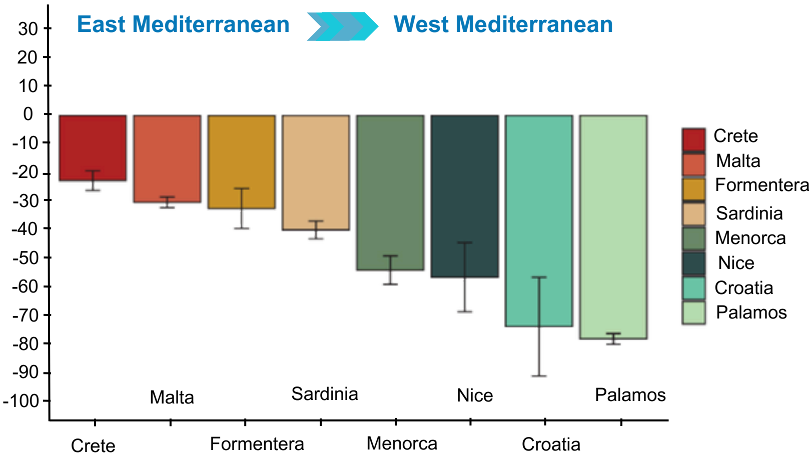
Metabolic performance (per gram wet or dry weight, depending on the species)



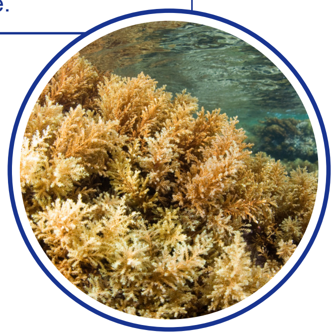
3) Clear evidence of local thermal adaptation and population differences in climate sensitivity.

On the Atlantic southern coast (Portugal) populations of intertidal kelp are more adapted to high temperatures and atmospheric heatwaves than northern (Norway) ones.

Similarly, in the Mediterranean, eastern populations of shallow subtidal forest-forming macroalgae have a higher temperature tolerance than western populations.

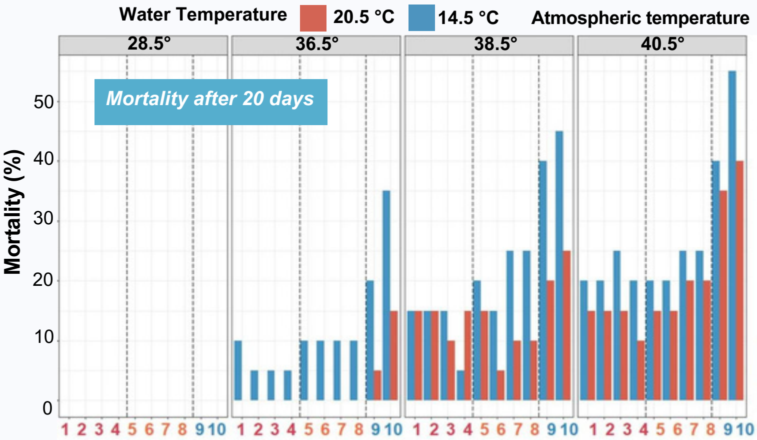


Biomass loss of different populations of *Cystoseira crinita* across the Mediterranean Sea under a warming experiment at 29°C after 80 days of exposure.



Macroalgae Ascophyllum nodosum

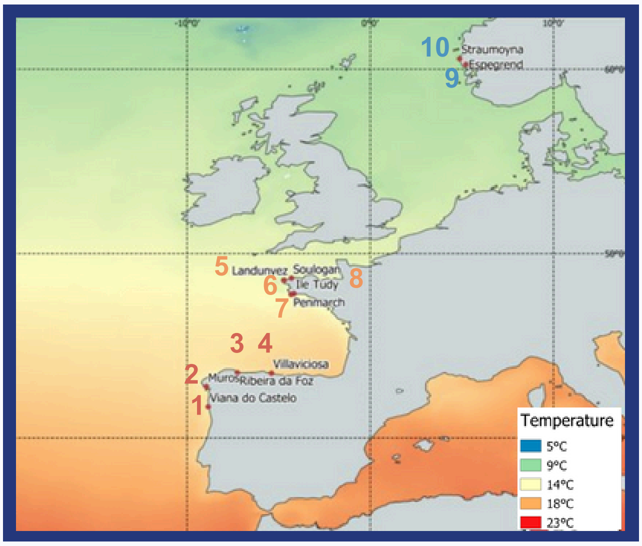
An atmospheric (aerial) heatwave lab experiment was designed to simulate present and extreme future atmospheric conditions



Seawater temperature has synergistic role in shaping the ecophysio-logical response of this seaweed

Collection sites of different population of Ascophyllum nodosum

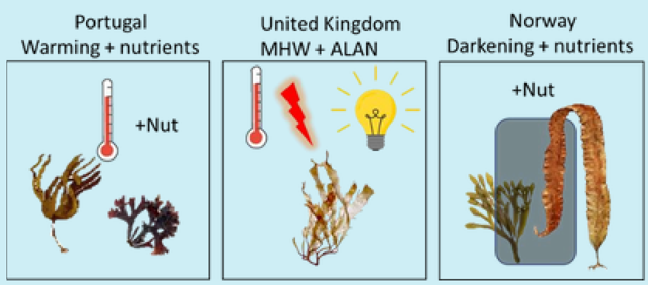
Identification of heat-resistant ecotypes is a crucial factor for successful restoration efforts



1-Viana do Castelo, 2- Ria de Muros, 3 - Ria da Foz, 4- Ria de Villaviciosa, 5- Landunvez, 6- Île- Tudy, 7-Penmarch, 8- Soulogan, 9- Espegrend and 10- Straumoyna

4) Complex impacts on marine species arise from climate change and other interacting stressors.

Laboratory and outdoor experiments conducted in Portugal, Norway and the UK showed the potential for both additive and antagonistic effects of different combinations of drivers to macroalgae forest functioning and community structure. In Portugal, experiments have shown complicated interactions between warming and nutrient levels (both influenced by changes in upwelling regime expected due to climate change) on two species of kelp and turf. Similarly, in Norway, both additive and contradicting impacts of darkening and nutrient additions were observed at species and community levels. In the UK, complex interactions were found between the impacts of artificial light at night (ALAN) and the exposure to a marine heatwave, with some evidence that ALAN can counteract the negative impact of heatwaves on growth and metabolic functioning of the kelp.



Multiple stressor experiments tested on Kelp in diverse locations and under different combinations of scenarios

Policy Recommendations

- Promote targeted research to understand the functioning of novel communities- incorporating climate bionvasion indicators - under current and future climate conditions, and within the context of other local or global stressors. This will help decision-makers and managers prioritize planning and financing NBS such as MPAs and habitat restoration to safeguard future marine biodiversity.
- Add descriptors of Good Environmental Status that consider changes in community characteristics, such as the CTI. This is a relevant indicator to track fast shifts observed in marine communities across European regional seas and could improve the EU Marine Strategy Framework Directive.
- Emphasize that conservation effort be directed to preserve ecosystem functions and services, even if they are provided by different (e.g., non-native) species, rather than only focusing on preserving native species.
- Create EU or national research opportunities to better understand climate sensitivity in more species and locations. Moreover, continue supporting efforts for long-term ecological time series to broaden the understanding of ongoing changes and to assess tipping points from climate and other (local) stressors.

References

Chust G, Villarino E, McLean M, Mieszkowska N, Benedetti-Cecchi L, Bulleri F, Ravaglioli C, Borja A, Muxika I, Fernandes-Salvador JA, Ibaibarriaga L, Villate F, Iriarte A, Uriarte I, Zervoudaki S, Carstensen J, Somerfield PJ, Queirós AM, Auber A, Hidalgo M, Coll M, Garrabou J, Gómez-Gras D, Ramírez F, Margarit N, Lepage M, Dambrine C, Lobry J, Peck MA, de la Barra P, van Leeuwen A, Rilov G, Yeruham E, Lindegren M (2024) *Cross-basin and cross-taxa patterns in biodiversity turnover in warming seas*. Nature Communications 15: 2126 DOI: https://doi.org/10.1038/s41467-024-46526-y

Garrabou J, D. Gómez-Gras D, Medrano A, Cerrano C, Ponti M, Schlegel R, Bensoussan N, Turicchia E, Sini M, Gerovasileiou V, Teixido N, Mirasole A, Tamburello L, Cebrian E, Rilov G et al. (2022) *Marine heatwaves drive recurrent mass mortalities in the Mediterranean Sea.* Global Change Biology 18: 5708-5725. DOI: https://doi.org/10.1111/gcb.16301

Gissi E, Manea E, Mazaris AD, Fraschetti S, Almpanidou V, Bevilacqua S, Coll M, Guarnieri G, Lloret-Lloret E, Pascual M, Petza D, Rilov G, Shonwald M, Stelzenmüller V, Katsanevakis S (2020) *A review of the combined effects of climate change and other local human stressors on the marine environment.* Science of the Total Environment:142564
DOI: https://doi.org/10.1016/j.scitotenv.2020.142564

O'Leary BC, Fonseca C, Cornete CC, Degia AK, Failler P, Furlan E, Garrabou J, Gil A, Hawkins JP, Krause-Jensen D, Le Roux X, Peck MA, Pérez G, Queiros AM, Różyński G, Sanchez-Arcilla A, Simide R, Sousa Pinto I, Trégarot E, Roberts CM (2023) Embracing Nature-based Solutions for resilient marine and coastal ecosystems. Nature Based Solutions 3: 100044.
DOI: https://doi.org/10.1016/j.nbsj.2022.100044

Rilov, G, Fraschetti S, Gissi E, Pipitone C, Badalamenti F, Tamburello L, Menini E, Goriup P, Mazaris DA, Garrabou J, Benedetti-Cecchi L, Danovaro R, Loiseau C, Claudet J, Katsanevakis S (2020) *A fast-moving target: achieving marine conservation goals under shifting climate and policies.* Ecological Applications 30:e02009. DOI: https://doi.org/10.1002/eap.2009

Rilov G, Mazaris AD, Stelzenmüller V, Helmuth B, Wahl M, Guy-Haim T, Mieszkowska N, Ledoux JB, Katsanevakis S (2019) *Adaptive marine conservation planning in the face of climate change: What can we learn from physiological, ecological and genetic studies?* Global Ecology and Conservation 17:e00566. DOI: https://doi.org/10.1016/j.gecco.2019.e00566

Worm B, Lotze HK (2021) *Chapter 21 - Marine biodiversity and climate change*. In, Letcher TM (Ed) Climate Change (Third Edition). Elsevier. Pages 445-464.

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Cite this Policy Brief as:

Rilov G, Chust G & Peck MA (2024): Marine Biodiversity: Climate sensitivity and resilience. FutureMARES Policy Brief 2. Available at: https://www.futuremares.eu/policy-papers

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869300. This publication reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.