The Mediterranean Sea: a hotspot of environmental change

Insights from MedECC and Plan Bleu

The Mediterranean Sea is far more than a stretch of water between continents. It is a living space shaped by ecosystems, civilizations, trade routes, and cultural exchanges that have evolved over millennia. Despite covering less than 1% of the global ocean surface, it hosts approximately 18% of all known marine species, making it one of the richest reservoirs of marine biodiversity on Earth. At the same time, it supports densely populated coastlines and remains one of the planet's leading tourism destinations.

Yet this unique semi-enclosed sea has become one of the world's major hotspots of environmental change. Climate warming, pollution, overexploitation of marine resources, habitat degradation, and the spread of non-indigenous species are no longer isolated pressures. They interact, reinforce one another, and accelerate transformations already underway. The Mediterranean is warming faster than the global ocean average, becoming more acidic, accumulating plastics and contaminants, and progressively losing ecosystems that have long defined its ecological identity.

These transformations extend well beyond the marine environment itself. Fisheries, tourism, coastal protection, food security, and cultural heritage are all increasingly affected. Understanding the scale of these interconnected changes has therefore become essential for both policymakers and citizens across the region.

This is precisely the role of the Mediterranean Experts on Climate and environmental Change (MedECC), an independent scientific network that has assessed thousands of scientific publications to provide an integrated understanding of environmental and climate risks in the Mediterranean. Its assessments examine both terrestrial and marine systems, while also considering the interactions between climate change and other environmental pressures. This article focuses specifically on the Mediterranean marine environment: the drivers of change, the impacts already observed, the projections for the future, and the solutions that could strengthen resilience across the basin.



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WHAT IS MEDECC?

Established in 2015, the Mediterranean Experts on Climate and environmental Change (MedECC) is an open and independent international scientific expert network. Its Scientific Secretariat is hosted by Plan Bleu in Marseille, France. Since its creation, MedECC has brought together a broad voluntary network of scientists working across disciplines and national boundaries to produce assessment reports aimed at supporting evidence-based policymaking. Through this science-policy interface, MedECC has become a key regional actor in supporting more resilient, inclusive, and sustainable pathways for the Mediterranean region.

One of its major milestones was the publication of the First Mediterranean Assessment Report (MAR1) in 2020, which provided the first integrated scientific overview of environmental and climate risks across the Mediterranean Basin. In recognition of its contribution to peace and democratic cooperation through science, MedECC received the North-South Prize of the Council of Europe in 2022.

In 2024, MedECC released two Special Reports:

1. Interlinking climate change with the Water - Energy - Food - Ecosystems (WEFE) nexus in the Mediterranean Basin
2. Climate and environmental coastal risks in the Mediterranean

In 2026, MedECC Expert Analysis Environmental change, conflict and human migration in the Mediterranean Basin has been published.

Together, these reports deepen understanding of the multiple interconnected risks shaping the future of the region.

A sea undergoing rapid transformation

Warming waters, marine heatwaves and acidification

Climate variability has always characterized the Mediterranean region. However, the pace and intensity of recent changes are unprecedented. The projected warming under different climate scenarios is primarily driven by future trajectories of greenhouse gas (GHG) emissions, which determine the magnitude of radiative forcing and subsequent changes in the climate system. The ocean plays a critical role in regulating climate by absorbing a substantial fraction of the excess heat and anthropogenic carbon dioxide (CO_2) released into the atmosphere. The ocean has absorbed more than 90% of the excess heat accumulated in the climate system since the 1970s and approximately a quarter of all anthropogenic CO_2 emissions, leading to widespread ocean warming and acidification. These changes are particularly relevant for the Mediterranean Sea, where increasing temperatures are occurring alongside declining oxygen levels and changes in carbonate chemistry. Continued GHG emissions will intensify these interconnected pressures, affecting marine ecosystems through increased thermal stress, ocean acidification, and deoxygenation. Therefore, the different warming projections associated with different scenarios reflect contrasting future emission pathways and their consequences for the physical and biogeochemical state of the Mediterranean Sea.

Sea surface temperatures have already risen by 0.86°C since pre-industrial times. Satellite observations indicate a sustained warming trend of +0.29 to +0.44°C per decade since the 1980s, with faster warming in the eastern Mediterranean than in the western basin. At the same time, marine heatwaves have become increasingly frequent and persistent. Over the last 20 years, their frequency has increased by 40% and their duration by 15%. Events once considered exceptional are progressively becoming part of a new climatic reality.

Marine heatwaves trigger large-scale mortality events among benthic organisms, particularly corals, sponges, bivalves, ascidians, and bryozoans. Deep-water corals are especially vulnerable because they already live near their thermal tolerance thresholds. At the same time, warming waters reduce oxygen availability, with each additional degree of temperature increase expanding hypoxic zones by approximately 10%.

Future projections point toward continued warming throughout the century. Relative to 1976–2005, Mediterranean Sea surface temperatures are expected to rise by 0.6–1.3°C by mid-century (2021–2050), reaching 2.7–3.8°C by 2071–2100 under a very high greenhouse gas concentration pathway (RCP8.5). Under an intermediate scenario (RCP4.5), warming is projected at 1.1–2.1°C by the end of the century (Figure 1).

This warming is expected to be particularly pronounced during summer months and will likely intensify both the duration and severity of marine heatwaves. By mid-century, extreme events comparable to the devastating 2003 marine heatwave may become the norm, especially under high-emission scenarios.

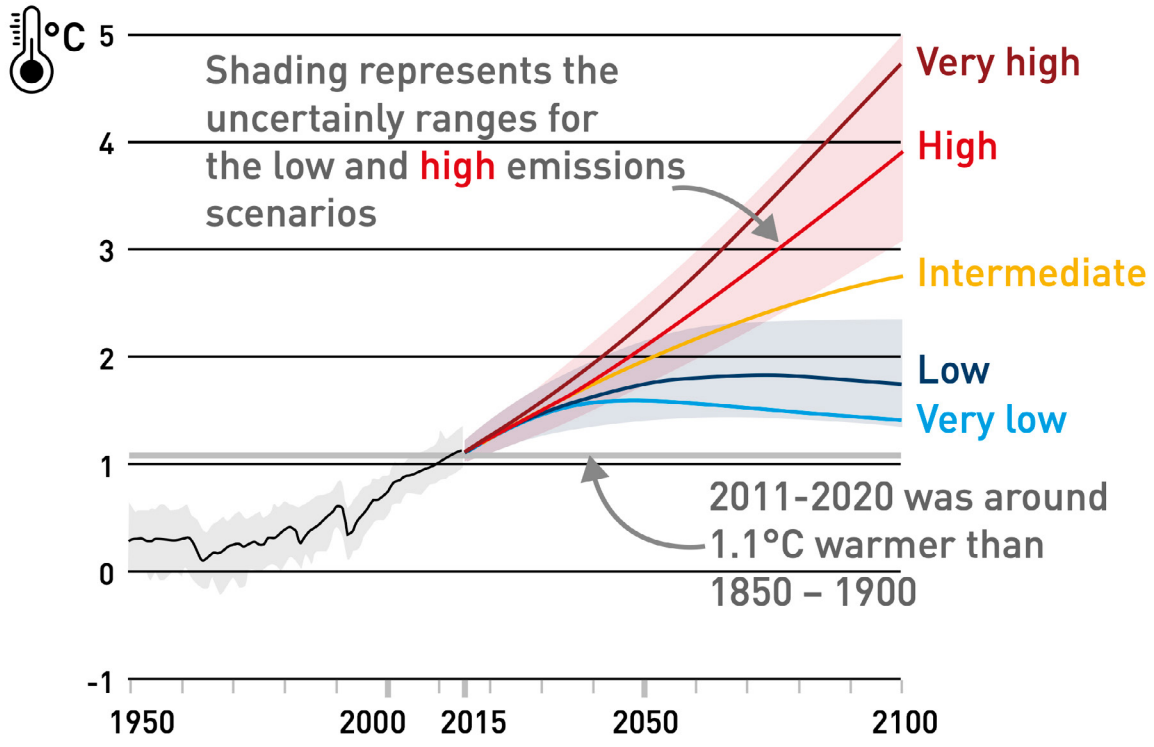


Fig.1 *Projected global surface temperature change relative to the 1850–1900 baseline. Shaded areas represent uncertainty ranges (MedECC 2024a; modified from IPCC 2023).*

Alongside warming, the Mediterranean Sea is also becoming more acidic. Since the pre-industrial era, surface waters have acidified by 0.055–0.156 pH units. Due to its alkalinity and rapid deep-water ventilation, the Mediterranean absorbs anthropogenic CO_2 more efficiently than the global ocean, making it especially vulnerable to acidification processes. Under very high greenhouse gas emission scenarios, surface water pH is projected to decline by 0.25–0.46 units by 2100 compared to pre-industrial conditions. Although less visible than warming, acidification profoundly alters marine chemistry and directly affects organisms that rely on calcium carbonate structures, like corals, shellfish, and several planktonic species, including some key primary producers.

Rising sea levels

Sea-level rise constitutes another major dimension of change across the Mediterranean Basin. During the 20th century, Mediterranean sea levels increased at approximately 1.4 mm year^{-1}, accelerating to 2.8 ± 0.1 mm year^{-1} between 1993 and 2018. In many coastal areas, these impacts are amplified by local factors such as land subsidence and the extraction of groundwater, oil, and gas. By mid-century, sea levels are projected to rise by 0.15–0.33 m relative to 1995–2014 levels. By 2100, projections indicate: 0.32–0.62 m under very low emissions and 0.63–1.01 m under very high emissions (Figure 2). The consequences are expected to be significant: beach erosion, wetland degradation, shoreline retreat, and increased coastal flooding. Extreme sea-level events that currently occur once every century may occur every few decades by the end of the century, increasing in frequency by 10–30% by mid-century and by 22–65% by 2100. With close to 20 million people living at less than 5 m above sea level within the 100 km Mediterranean coastal belt, the exposure of the Mediterranean shoreline to the coastal risk of flooding and erosion is a major challenge, in particular in Egypt (Nile Delta) and Italy (Venice lagoon) (Figure 3).

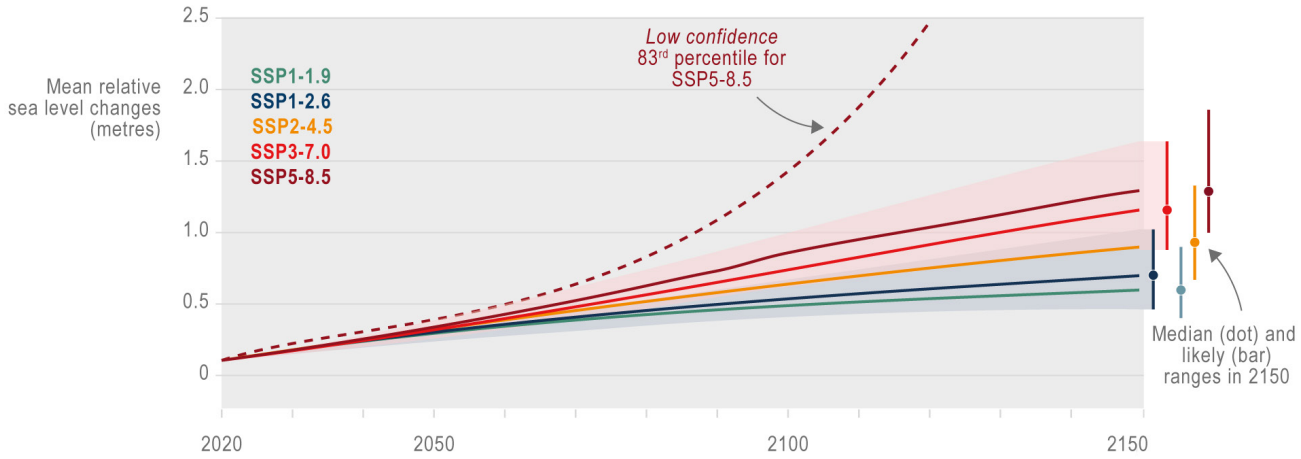


Fig.2 *Mediterranean Sea level rise projections (Ali et al. 2022).*

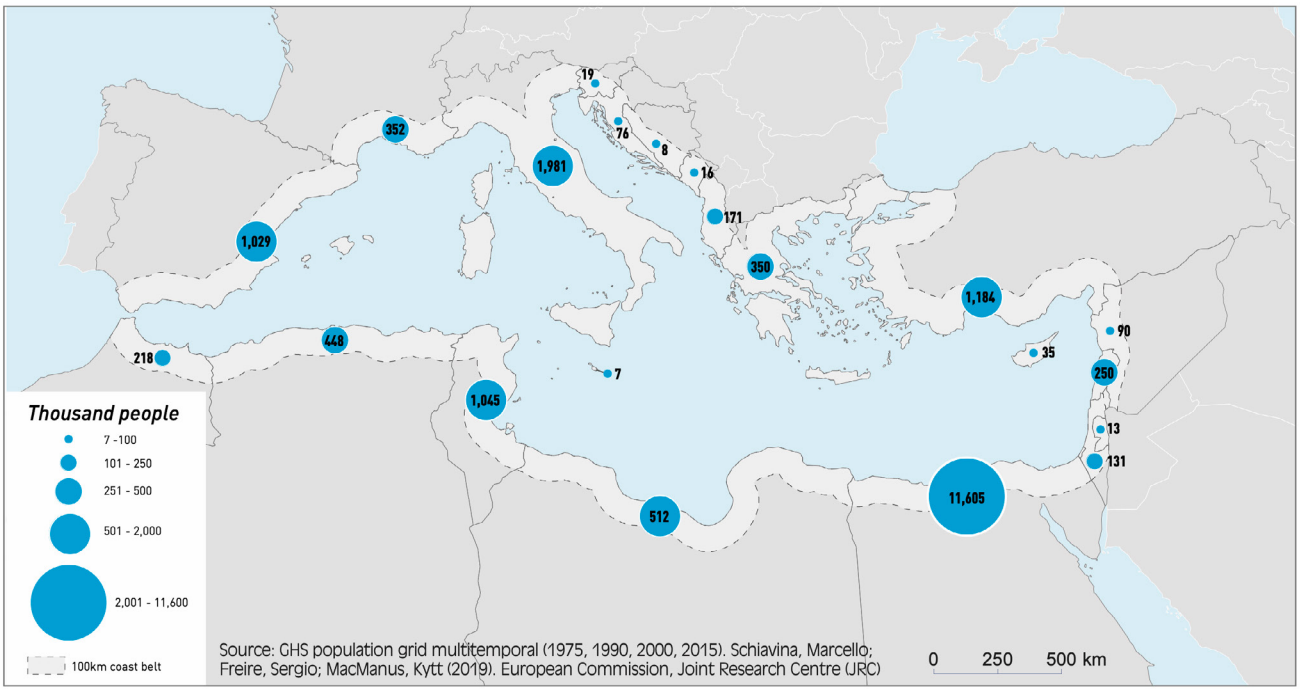


Fig.3 *Population living at less than 5 m above sea level within the 100 km Mediterranean coastal belt, per country (Schiavina et al. 2019).*

Socio-economic changes

Beyond climate change, the rapid transformation of the Mediterranean Sea is also driven by profound socio-economic changes occurring throughout the region. The Mediterranean Basin is one of the most densely populated coastal regions in the world, with approximately 540 million people living in Mediterranean countries in 2020, of whom around one-third are concentrated in coastal areas, increasing pressure on marine and coastal ecosystems. Rapid urbanization, expanding tourism, intensified maritime transport, and growing industrial and agricultural activities are placing additional stress on marine environments. The Mediterranean is the world's leading tourism destination, attracting about one-third of global tourism, with more than half of European Union tourist accommodation establishments located in coastal areas, leading to strong seasonal increases in water demand, waste generation, and coastal development.

Pollution pressures intensifying

Coastal expansion and population growth have increased the discharge of untreated or insufficiently treated wastewater, while intensive agriculture contributes substantially to nutrient enrichment, pesticide inputs, and chemical pollution through riverine runoff. These pressures are particularly pronounced in southern and eastern Mediterranean countries, where nutrient pollution has risen alongside agricultural intensification and urban-industrial development. Industrial activities and maritime traffic further contribute to contaminant inputs, including hydrocarbons, heavy metals, persistent organic pollutants, and emerging contaminants. The Mediterranean is often described as one of the world's most polluted seas. Its semi-enclosed nature, combined with intense coastal development, dense maritime traffic, and concentrated human activities, promotes the accumulation and persistence of contaminants throughout the basin.

Plastic pollution represents one of the most visible and widespread threats. Plastics account for approximately 82% of observed litter, 95–100% of floating debris, and more than 50% of seabed litter. Around two-thirds of land-based plastic waste accumulates along coastlines, where it gradually fragments into microplastics that increasingly enter marine food webs (Figure 4). If current production trends continue, with an annual growth rate of approximately 4%, plastic leakage into the Mediterranean could double by 2040.

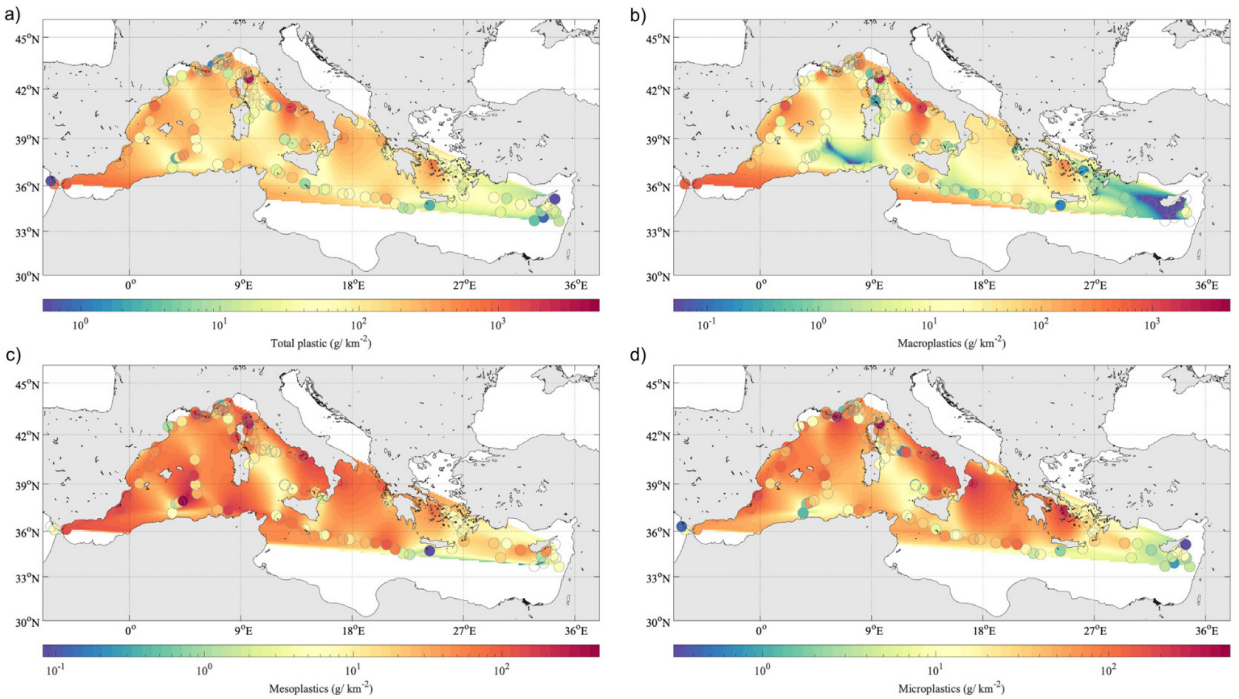


Fig.4 *The mass concentrations of floating plastic debris (g km^{-1}) in the Mediterranean Sea: a) total mass concentration, b) macroplastics (>20 mm), c) mesoplastics (between 5 and 20 mm), and d) microplastics (<5 mm) (MedECC 2024a; modified from Pedrotti et al. 2022).*

Heavy metals, including mercury, lead, and cadmium, remain widespread across the basin. Mercury contamination is of particular concern, as concentrations measured in top predatory fish frequently exceed European Union safety thresholds. Methylmercury levels in the western Mediterranean are also approximately twice those reported in the eastern basin. Persistent organic pollutants (POPs), such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), continue to accumulate near river mouths, industrial areas, harbors, and densely urbanized coastlines. Oil pollution further intensifies these pressures, with approximately 90% of tanker spills occurring near shorelines, where ecosystems are particularly vulnerable.

Excessive nutrient inputs from land-based sources are driving eutrophication processes in coastal waters. These nutrient imbalances contribute to hypoxia, anoxia, harmful algal blooms, and mucilage events, with significant consequences for marine ecosystems, fisheries, and tourism. The balance between nitrogen and phosphorus inputs is a key factor in regulating these processes, as altered nutrient ratios can modify plankton communities and favor the proliferation of harmful algal species. While nutrient inputs have declined in northern Mediterranean countries due to improved wastewater treatment and agricultural management, they continue to increase in southern and eastern regions of the basin.

Emerging contaminants, including pharmaceutical residues, personal care products, and other chemical compounds, are increasingly detected in aquatic environments, particularly in areas with insufficient wastewater treatment infrastructure. Although their long-term ecological impacts remain incompletely understood, available evidence indicates potential effects such as endocrine disruption, impaired reproduction, and chronic toxicity in aquatic organisms.

Biodiversity under pressure

The Mediterranean's exceptional biodiversity is increasingly threatened by the cumulative effects of climate change and human activities (Figure 5, Figure 6). Currently, 32% of Mediterranean marine habitats are threatened, including 21% considered vulnerable and 11% classified as endangered. Seagrass meadows, coralligenous reefs, and benthic ecosystems are among the most affected habitats.

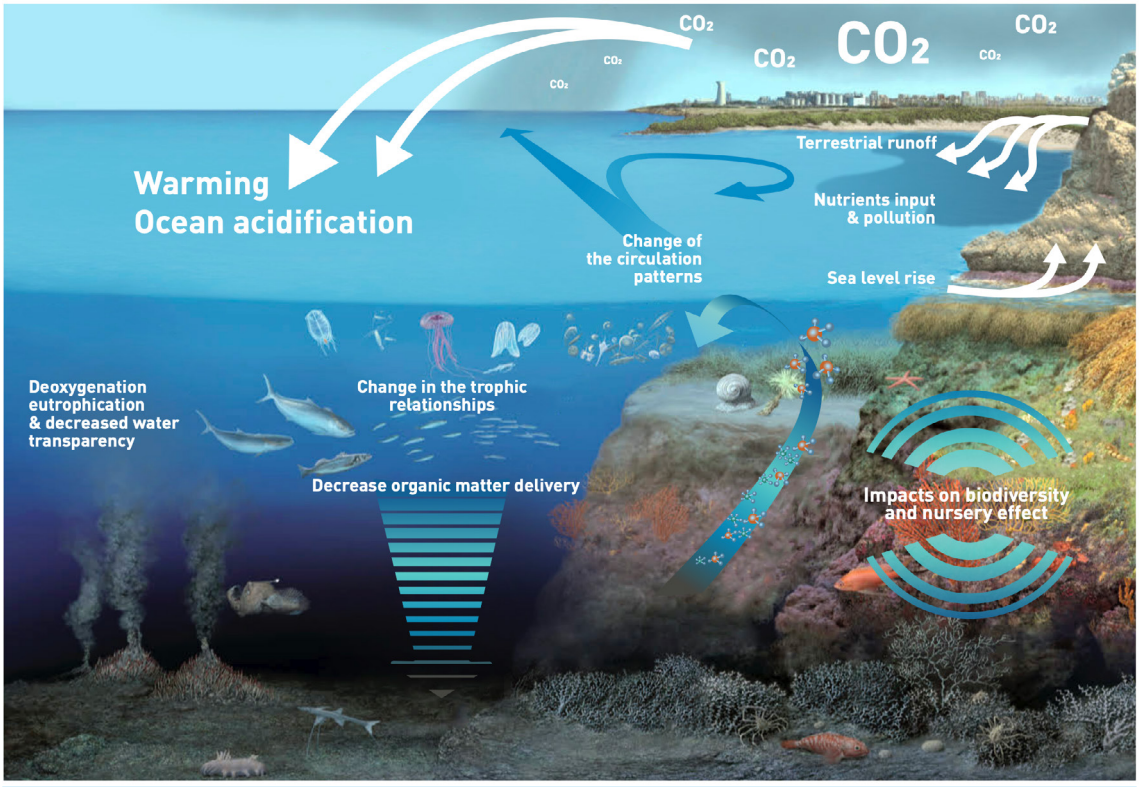


Fig.5 *Different drivers potentially affecting marine pelagos and benthos in the Mediterranean Sea (MedECC 2020; modified from Rossi et al. 2019, artwork by A. Gennari).*

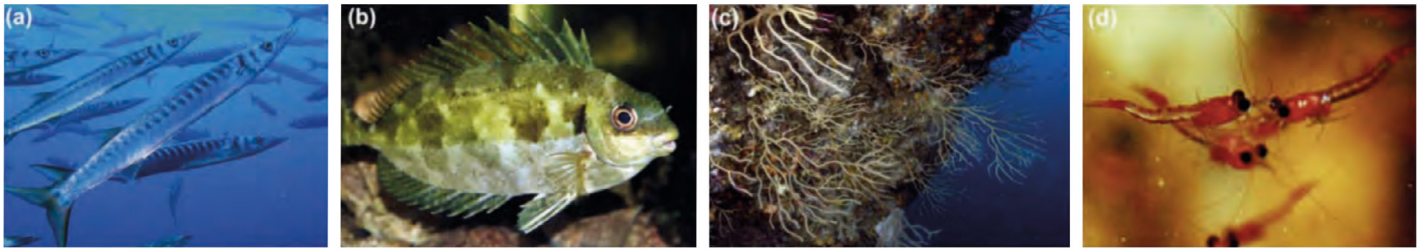


Fig.6 *Representative examples of marine species responding to climate change in the Mediterranean (a) The natural distribution range of the Sphyraena viridensis barracuda has increased greatly over the last 30 years; (b) the Lessepsian herbivorous rabbitfish Siganus rivulatus is affecting Eastern Mediterranean ecosystems, and its introduced range area is increasing. In 2008, it was found in the Gulf of Lions (Carry-le-Rouet, France); (c) a seascape of dead Paramuricea clavata sea fans after the 2003 thermal anomaly in the NWM; (d) the Hemimysis spp. crustacean mysids are a classic example of a species shift related to climate change. Photographs (reproduced with permission) by T. Pérez (a), J.G. Harmelin (b) and R. Graille (c, d) (UNEP/MAP and Plan Bleu 2020, initial source: Lejeusne et al. 2010).*

Since 1950, the Mediterranean has lost 41% of marine species located at the top of the food chain due to climate change and overfishing. By 2010, more than 60% of fish stocks were already collapsed or overexploited, with the eastern Mediterranean particularly affected. Total landings of the entire Mediterranean Basin exceeded 1.16 million t in 1994 and declined to around 842,000 t in 2017, i.e., a decrease of 28% (Figure 7). The European hake *(Merluccius merluccius)* is currently harvested at rates 5.8 times above sustainable limits. Climate warming is also reshaping species distribution patterns. Warm-water species are progressively expanding northward, while cold-water species decline. By 2050, fish species richness is projected to increase in the eastern Mediterranean but decline in the western basin. Some small pelagic and thermophilic species may temporarily benefit from these changes. However, larger commercially valuable species are expected to face increasing stress. Projections suggest that more than 20% of exploited fish and invertebrate species could face local extinction by 2050. This could have significant economic impacts, as fisheries and aquaculture generate an economic output of nearly USD 12 billion, including both first-sale value and the broader economic impact across the value chain. The sector is estimated to provide direct and indirect employment for at least one million people, including at least 250,000 people directly employed aboard capture fishing vessels.

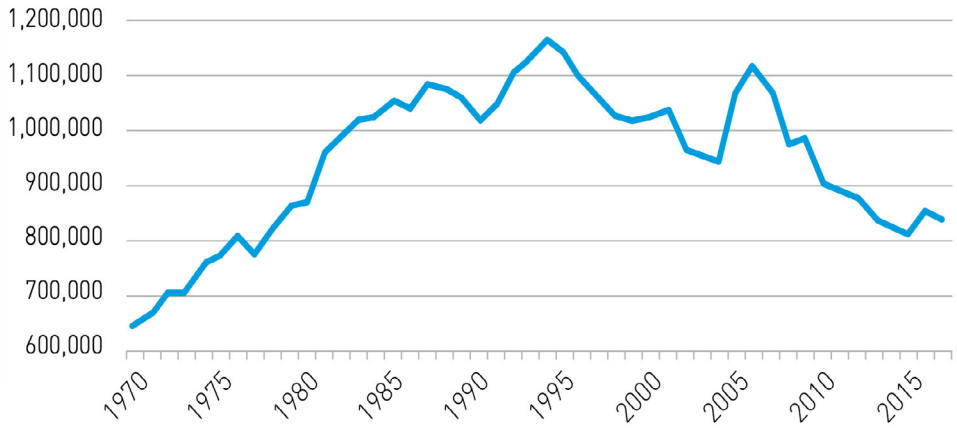


Fig.7 *Total fish landings (tonnes) in the Mediterranean Sea from 1970 to 2017 (MedECC 2020).*

Aquaculture has expanded rapidly across the Mediterranean, particularly in Egypt and Türkiye, followed by Greece, Italy, Spain, France, and Tunisia. More than 100 species are currently cultivated. While aquaculture contributes significantly to food production and local economies, its expansion also raises environmental concerns, including nutrient pollution, pathogen transmission, genetic contamination, and the accidental release of non-indigenous species.

The Mediterranean contains between 1.35–5 million hectares of seagrass meadows, representing 5–17% of the global total, largely dominated by Posidonia oceanica. Yet these emblematic ecosystems are declining at rates of 1.2–5% per year, with nearly half of monitored sites losing more than 20% of their net density within a decade.

Coastal wetlands and estuaries have already lost around 50% of their extent during the 20th century due to agriculture, urbanization, and infrastructure development. Rising sea levels further accelerate erosion and habitat degradation.

The Mediterranean has become one of the world's principal hotspots for biological invasions. More than 1000 non-indigenous species have already been recorded (Figure 8). Over the last three decades, 58% were invertebrates, 23% primary producers, and 18% vertebrates. Most introductions occur directly from the Red Sea, but also through ballast water, shipping activities, and aquaculture. Rising temperatures increasingly favor thermally tolerant species, while native species retreat, driving a process often described as the "tropicalization" of the Mediterranean. One of the clearest examples of this transformation is the destruction of algal forests caused by herbivorous rabbitfish species (*Siganus luridus* and *S. rivulatus*). Their intense grazing activity creates extensive barren zones dominated by bare rock and encrusting algae, replacing formerly biodiverse habitats.

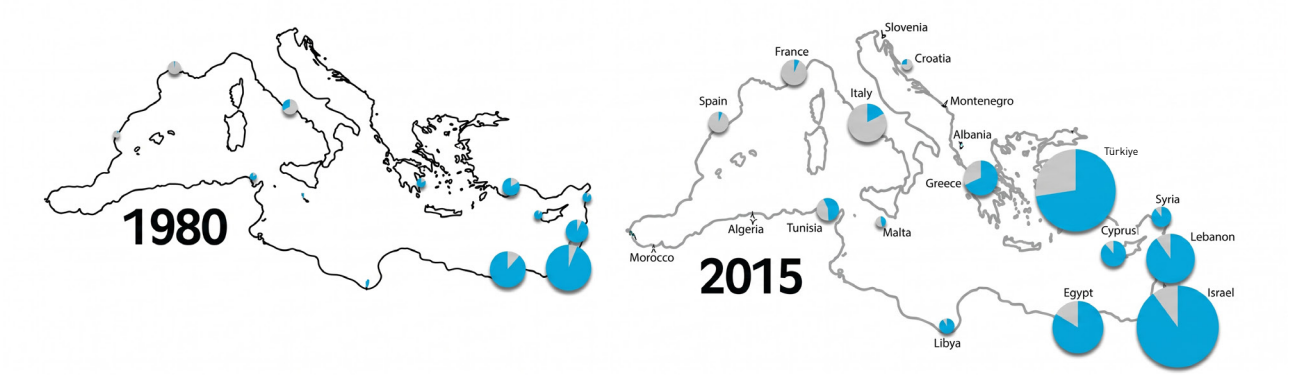


Fig.8 *Non-indigenous species (NIS) in the Mediterranean Sea: size of pie charts proportional to number of NIS in a country; proportion of Lessepsian species in blue (UNEP/MAP and Plan Bleu 2020, initial source: Galil, Marchini & Occhipinti-Ambrogi, 2018).*

Climate change and human pressures are also profoundly affecting planktonic ecosystems. Changes in temperature, nutrient loads, and coastal conditions influence the timing, intensity, and composition of harmful algal blooms (HABs), while also contributing to increasingly frequent jellyfish outbreaks. Approximately 40% of bloom-forming microalgae produce toxins capable of causing human intoxication. In the Mediterranean, the most significant toxic events are linked to dinoflagellates of the genera Alexandrium and Dinophysis, responsible respectively for paralytic shellfish poisoning (PSP) and diarrheic shellfish poisoning (DSP). These phenomena pose ecological, sanitary, and economic risks, particularly in semi-enclosed bays, lagoons, estuaries, and river deltas located near densely populated coastlines. In both the Mediterranean and Black Seas, 23 jellyfish species are capable of forming blooms, including nine species considered particularly problematic because of their ecological and socio-economic impacts.

Human societies on the frontline

The degradation of marine ecosystems directly threatens the services upon which Mediterranean societies depend. Fisheries and aquaculture — both essential components of regional food security — are increasingly exposed to warming, salinization, acidification, and declining marine productivity. Tourism, another pillar of the Mediterranean economy, also faces growing vulnerability. The traditional tourism model built around stable summers and accessible beaches is becoming increasingly fragile. Rising sea levels are narrowing beaches, while more frequent extreme heat events may gradually shift tourism flows toward cooler seasons. These examples illustrate only part of the broader range of ecosystem services currently under threat across the Mediterranean Basin (Table 1).

PROVISIONING SERVICES
Food: Provision of biomass (fishery and aquaculture) from the marine environment for human consumption
REGULATING AND MAINTENANCE SERVICES
Water purification: Biochemical and physicochemical processes involved in the removal of waste and pollutants from the aquatic environment
Air quality: Regulation of air pollutant concentrations in the lower atmosphere
Coastal protection: Natural protection of the coastal zone against inundation and erosion from waves, storms or sea level rise
Climate regulation: Carbon sequestration
Weather regulation: Influence on local weather conditions (e.g. influence of coastal vegetation on air moisture and temperature)
Ocean nourishment: Natural cycling processes leading to the availability of nutrients and organic matter
Lifecycle maintenance: Maintenance of key habitats that act as nurseries, spawning areas or migratory routes.
CULTURAL SERVICES
Symbolic and aesthetic values: Senses and emotions heightened by seascapes, habitats or species
Recreation and tourism: Opportunities for relaxation and entertainment (e.g. bathing, sunbathing, snorkelling, scuba diving, sailing, recreational fishing, whale
Cognitive effects: Inspiration for arts and applications, material for research and education, information and awareness

Table 1. *List, type, and description of marine ecosystem services (MedECC et al. 2024).*

Building resilience in the Mediterranean

Despite the scale of the challenges, solutions exist. The MedECC reports emphasize that resilience can still be strengthened through coordinated, science-based, and inclusive action across multiple sectors.

Expanding Marine Protected Areas and restoring degraded ecosystems such as seagrass meadows, wetlands, dunes, and nursery habitats can simultaneously support biodiversity, stabilize coastlines, and enhance carbon storage. Reducing non-climatic pressures — including coastal artificialization and destructive coastal infrastructure — is equally essential.

Transitioning toward ecosystem-based fisheries management, reducing overfishing, and protecting spawning and nursery grounds are central priorities for maintaining marine resources over the long term. Aquaculture systems must also become more sustainable through improved site selection, reduced nutrient releases, and integrated approaches adapted to environmental conditions.

Preventing pollution at its source remains more effective than relying solely on end-of-pipe solutions. Measures promoting circular economies, reducing single-use plastics, improving recycling systems, and strengthening wastewater treatment are all essential for limiting marine contamination.

Broader greenhouse gas mitigation efforts, cleaner maritime transport, and reduced dependence on fossil fuels along coastlines are also critical to limiting long-term warming and acidification.
Finally, effective adaptation depends on governance systems capable of integrating climate and environmental risks across all sectors, from tourism and fisheries to energy and transport.
The MedECC assessments also underline the importance of participatory approaches, stronger science-policy-society interfaces, climate education, and more inclusive decision-making processes involving women, youth, and vulnerable communities.

Conclusion

The Mediterranean Sea offers a striking illustration of the global environmental crisis unfolding at planetary scale. Within this relatively small and highly interconnected basin, climate change, pollution, biodiversity loss, and human pressures combine to push ecosystems toward critical thresholds. The transformations already visible today foreshadow challenges that many other marine regions may soon encounter. Yet the Mediterranean is not only a space of vulnerability. It is also a region with a long history of scientific cooperation, cultural interconnectedness, and collective action.

Scientific evidence clearly demonstrates that coordinated and ambitious policies can still reduce environmental degradation, reinforce resilience, and preserve the ecosystem services upon which millions of people depend. The decisions taken today — locally, regionally, and globally — will determine whether the Mediterranean remains a living sea that continues to sustain biodiversity, livelihoods, and cultures, or becomes a symbol of irreversible environmental decline. Acting now is therefore not only an environmental necessity, but also a social, economic, and moral responsibility.

SUPPORTING INSTITUTIONS

Since 2018, Plan Bleu has hosted the MedECC Scientific Secretariat as part of a partnership with the Union for the Mediterranean (UfM) and has contributed to its operation through various funding sources. The UfM supports MedECC via technical assistance contracts with the GRECSUD Association, with funding provided by the Swedish International Development Cooperation Agency (SIDA). The Mediterranean Action Plan of the United Nations Environment Programme (UNEP/MAP) also provides support to MedECC. Since September 2025, MedECC has benefited from funding from the Directorate-General for the Middle East, North Africa, and the Gulf (DG MENA). Other partners that currently support, or have supported, MedECC in the past include the Rhône Méditerranée Corse Water Agency, the French Agency for Ecological Transition (ADEME), the Advisory Council for Sustainable Development of Catalonia (CADS), the Mediterranean Trust Fund (MTF), the Princely Government of Monaco, the French Ministry of Ecological Transition (MTE), the French Ministry of Europe and Foreign Affairs (MEAE), and the Italian Ministry of the Environment and Energy Security (MASE).

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