



# Fisheries Sustainability under Environmental Variability in the Mediterranean Sea

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## DESCRIPTION

Climate change has emerged as a dominant driver of environmental variability in marine ecosystems, with pronounced effects in semi-enclosed seas such as the central Mediterranean. This region is characterized by high biodiversity, complex oceanographic features, and long-standing fishing traditions that rely heavily on demersal species. Demersal fisheries target organisms living close to or on the seabed, including key commercial stocks such as hake, red mullet, deep-water shrimp, and cephalopods. Changes in temperature, circulation patterns, oxygen availability, and primary production have altered the ecological conditions that sustain these stocks, influencing productivity, spatial distribution, and population structure. Understanding how climate-driven processes interact with fishing pressure is essential for adaptive management in this environmentally sensitive and socioeconomically significant area.

The central Mediterranean Sea is warming faster than many other marine regions, driven by atmospheric heat transfer and altered water mass exchange. Rising sea temperatures influence biological processes across trophic levels. For demersal species, temperature affects growth rates, metabolic demand, reproduction, and early life survival. Many species exhibit thermal preferences that determine habitat suitability, and even small changes in bottom temperature can shift distribution patterns. In the central Mediterranean, several demersal stocks have shown poleward or depth-related redistribution, with species occupying deeper waters to remain within favorable thermal ranges. These shifts have consequences for fishery accessibility, survey consistency, and long-term stock assessment reliability.

Climate change also affects benthic habitats that serve as essential grounds for feeding, spawning, and juvenile development. Ocean warming, acidification, and changes in sediment composition influence benthic invertebrate communities, altering prey availability for demersal fish. Seagrass meadows and biogenic reefs, which provide structural complexity

and nursery functions, are under stress from temperature anomalies and extreme weather events. Habitat degradation reduces carrying capacity and resilience of demersal stocks, particularly for species with limited mobility or specialized habitat requirements. The cumulative effect of habitat change and fishing disturbance amplifies ecosystem vulnerability.

Fishing pressure interacts with climate-driven stressors in complex ways. Overexploitation reduces population age structure and genetic diversity, limiting adaptive capacity to environmental change. In the central Mediterranean, many demersal stocks have historically been subject to high exploitation rates, leading to truncated size distributions and reduced spawning potential. Younger populations may respond differently to environmental variability, often exhibiting less stable recruitment patterns. Climate variability can therefore intensify the effects of fishing, while depleted stocks may struggle to recover under changing conditions.

Management of demersal fisheries in the central Mediterranean has traditionally relied on effort control, technical measures, and spatial restrictions. While these tools remain important, climate change challenges their effectiveness if environmental drivers are not considered. Static management boundaries may no longer align with shifting species distributions, and fixed seasonal closures may fail to protect spawning events that change in timing due to temperature variation. Adaptive management approaches that incorporate environmental indicators offer a pathway toward more responsive governance.

Ecosystem-based fisheries management has gained attention as a framework that accounts for species interactions, habitat conditions, and environmental variability. In the central Mediterranean, this approach is particularly relevant due to the region's multispecies fisheries and diverse fleet structure. Climate-informed management can use indicators such as bottom temperature trends, productivity indices, and recruitment forecasts to guide decision-making. Integrating such information into harvest control rules may improve the capacity

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to respond to environmentally driven changes in stock productivity.

Scientific monitoring plays a vital role in understanding climate effects on demersal stocks. Long-term survey programs in the central Mediterranean provide valuable data on abundance, size structure, and spatial distribution. Maintaining consistency in survey design while adapting to shifting species ranges is a growing challenge. Enhanced monitoring of environmental variables alongside biological data supports more robust interpretation of observed trends. Collaborative research efforts among Mediterranean countries are essential for addressing shared resources and transboundary stock dynamics.

Socioeconomic considerations are also central to fisheries management under climate change. Coastal communities in the central Mediterranean depend on demersal fisheries for livelihoods, cultural identity, and food security. Changes in stock availability and composition affect income stability and operational costs, particularly for small-scale fishers with limited capacity to adapt. Management strategies that account for social resilience, fleet diversity, and equitable access to resources are necessary to ensure long-term sustainability.

In conclusion, climate change is reshaping the ecological and productive foundations of demersal fisheries in the central Mediterranean. Rising temperatures, altered productivity patterns, habitat change, and increased variability in recruitment interact with fishing pressure to influence stock dynamics. These changes challenge traditional management approaches and call for adaptive strategies that integrate environmental drivers, ecosystem processes, and socioeconomic realities. Strengthening scientific monitoring, incorporating climate information into assessment and decision-making, and fostering regional cooperation are key steps toward sustaining demersal fisheries in a rapidly changing Mediterranean environment. By embracing flexible and forward-looking management frameworks, stakeholders can better navigate uncertainty and support the long-term viability of both marine ecosystems and the communities that depend on them.

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