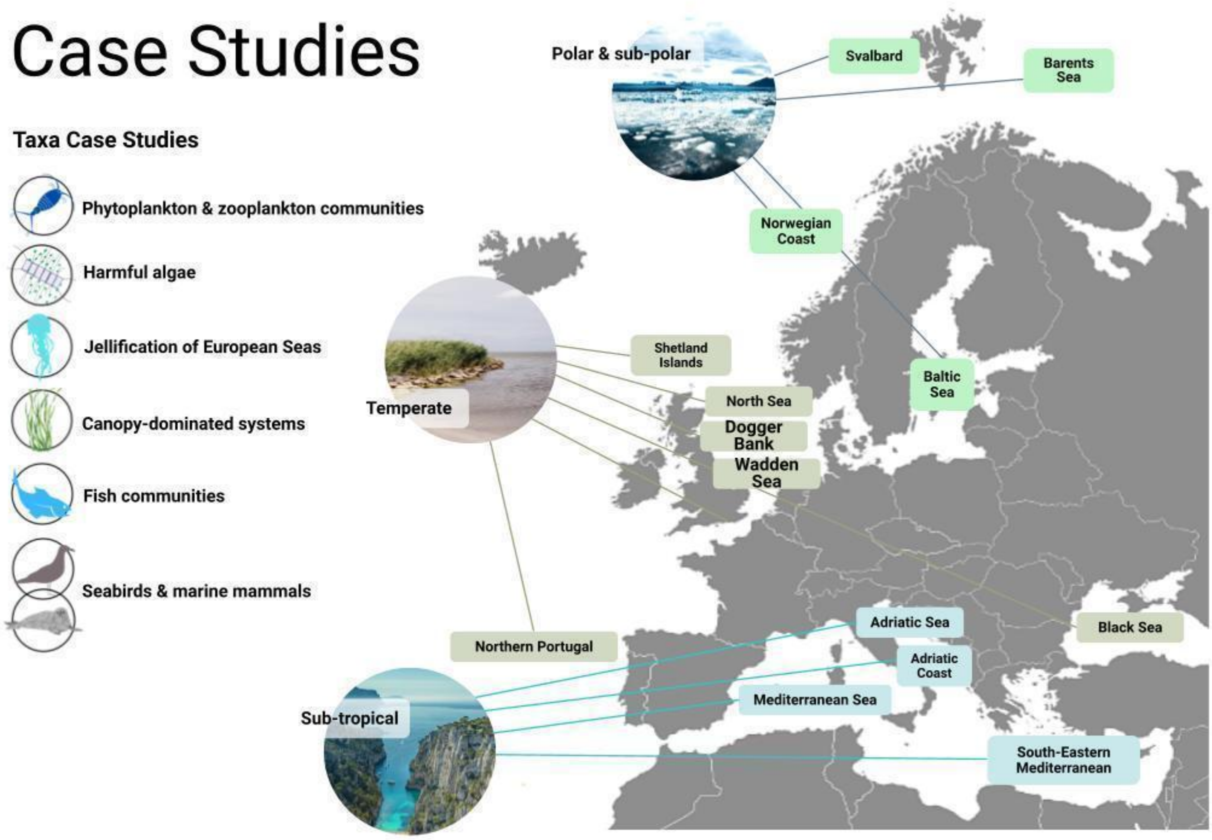
Case Study 16
Taxa

Drivers of Fish Communities



ACTNOW

ACTNOW is an EU-funded research project aimed at understanding the cumulative impacts on European marine biodiversity, ecosystem functions, and services for human wellbeing. The project equips regulators and decision-makers with essential knowledge and tools to combat biodiversity loss in coastal and marine habitats threatened by climate change and other regional drivers.

Conducted across various Case Study Regions in Europe, ACTNOW focuses on delivering scientific support for adaptation and mitigation measures, sustainable blue economy expansion, and contributions to the UNFCCC.

The project is structured into six Workpackages: WP1 (Data, Indicators and Scenarios), WP2 (Marine Organisms under Multiple Drivers), WP3 (Community, Food-Web and Ecosystem), WP4 (Cumulative Risks & Biodiversity Assessments), WP5 (Synthesis, Impacts & Solutions Options), and WP6 (Communication and Dialogue).

Objectives include developing 'what if' scenarios, understanding combined impacts on ecosystems, employing advanced biologging and molecular methods, and enhancing awareness of the links between marine biodiversity and human health.

ACTNOW has 17 CSs, 11 are regional CSs while 6 are pan-European (group / taxon) CSs. All are designed to deliver a cause-and-effect understanding, build predictive capacity in models, and to develop indicators and tools for decision-makers charged with the stewardship of European marine biodiversity under threats from multiple drivers (stressors in call). In each case, drivers examined represent the local/regional priorities from regulators who co-create what-if scenarios of interacting drivers including envisioned management actions.

• Case Study 16: Drivers of Fish Communities

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Description

Work on fish communities harnesses long-term time series on the abundance, species composition and condition of fish species across European basins along with remote sensing and other in situ measurements to disentangle the drivers of regional to local change including projections accounting for connectivity with adjacent marine areas.

The CS aims to explore the impacts of oceanic warming on marine ecosystems across European seas, using long-term data on phytoplankton, fish, and fisheries indicators. By harnessing satellite-derived datasets, in situ measurements, and ecosystem models, the CS assesses the abundance, species composition, and condition of fish communities. This CS seeks to uncover the drivers of change from regional to local scales, accounting for environmental variability and connectivity with adjacent marine areas. The research focuses on understanding how warming, including extreme events like marine heatwaves, influences biodiversity and fisheries, supporting future projections to inform sustainable management across Europe's marine regions.

Services

This CS will deliver relevant policy indicators and propose management interventions for sustaining fisheries and biodiversity in European seas. Engaging key stakeholders, it aims to co-develop research scenarios, test plankton, fish, and fisheries indicators, and identify sustainable pathways in response to the rapidly warming environment. The goal is to inform decision-making and provide actionable tools for conservation, fisheries management, and biodiversity protection across European seas.

The ecosystem services provided by marine fish communities are extensive and include:

- **Regulating services**: Fish communities help control invasive species, regulate disease, and support different habitats, which increase resilience to stressors such as eutrophication.
- **Provisioning services**: Fisheries provide food for humans, raw materials for industry, fish for livestock feed, and species for aquaculture breeding.
- **Cultural services**: Marine ecosystems hold cultural and historical significance, offering inspiration for research, arts, and education. They also promote outdoor recreation (e.g., diving, snorkelling, angling), ecotourism, and carry spiritual or symbolic value.
- **Supporting services**: Fish communities contribute to carbon sequestration, nutrient cycling, and biomass production, essential for maintaining healthy marine ecosystems.

Through workshops and collaborative efforts, the study ensures its research is practical and tailored to the needs of end-users, supporting effective management of marine resources in the context of global environmental change.

Interacting Drivers of Biodiversity Change

Ocean warming and marine heatwaves (MHWs) are critical drivers of biodiversity change in the Mediterranean Sea and other European waters. Rising temperatures, projected to increase by up to 4°C by the end of the 21st century, have already led to significant ecological disturbances. Marine ecosystems are exposed to a multitude of natural drivers and anthropogenic stressors that directly or indirectly impact biodiversity and fish communities. The key pressures include:

- **Climate Change**: Climate change leads to changes in ocean conditions with various implications for fish at all life stages (Rijnsdorp et al., 2009). Increasing seawater temperatures may cause physiological changes (e.g., higher growth rates) or lead to behavioural responses (e.g., moving to deeper, colder waters). MHWs are increasing in frequency and duration, causing mass mortality and reproductive failure in some fish populations (Smith et al., 2023). However, effects of MHWs do not appear to have had much impact on demersal fish community biomass across temperate and polar ecosystems yet (Fredston et al., 2023).
- **Overfishing**: Fishing is a key driver of biodiversity change (IPBES, 2019), with 20.6% of fish stocks in the Northeast Atlantic and 62.5% in the Mediterranean & Black Sea currently overexploited (FAO, 2024). Sharks and rays are particularly sensitive to fishing due to their low reproductive output and late

maturity, often ending up as unintended bycatch (Jennings & Kaiser, 1998; Carpentieri et al., 2021). The extinction risk of sharks has been continuously increasing since the 1980s, linked to rising fishing mortality and poor fisheries management, while this decline has been reversed for tunas and billfishes in the 2010s due to effective management measures (Juan-Jordá et al., 2022).

- **Invasive Species**: Invasive species, whether introduced deliberately or inadvertently, can negatively impact local biodiversity. For instance, the collapse of anchovy populations in the Black Sea has been attributed to the arrival of the comb jelly **Mnemiopsis leidyi**, which became a significant predator of anchovy eggs and larvae and a competitor for zooplankton (Kideys, 2002).
- **Habitat Disturbance**: The disturbance or destruction of essential habitats for fish—such as through bottom trawling or the construction of harbors—can reduce local populations or even lead to their disappearance (Rochette et al., 2010). However, human constructions may also locally promote or restore biodiversity by creating new habitats, especially when nature-based solutions are applied (Riisager-Simonsen et al., 2022).
- **Pollution and Eutrophication**: Pollutants from land sources or human activities at sea (e.g., oil spills) may harm local fish populations and pose risks to predators, including humans (IPBES, 2019). Eutrophication, often induced by agricultural runoff, can lead to severe hypoxia in some areas (e.g., the Baltic Sea), hampering fish condition or even causing mortality, including of fish eggs and larvae (Breitburg, 2002).

The abovementioned drivers of biodiversity change often do not act in isolation, but instead impact fish populations and communities simultaneously. Notably, the presence of one pressure may exacerbate the effect of another (IPBES, 2019). Scientists should thus consider the range of multiple stressors and integrate this notion into their advice to policymakers and managers when taking action on the conservation of biodiversity and the ecosystem services that fish provide.

Regional Context

The Mediterranean is a recognized climate change hotspot, with over 480 million people relying on its marine resources. The region's rising temperatures and frequent marine heatwaves (MHWs) threaten marine biodiversity, fisheries, and socio-economic systems. Understanding the long-term ecological impacts of warming on phytoplankton, fish populations, and fisheries is critical for developing strategies that address the complex environmental challenges faced by Mediterranean countries.

Similarly, other European seas, such as the North Sea and the Baltic Sea, are experiencing significant ecological changes due to warming temperatures and anthropogenic pressures. In these regions, shifts in fish distribution, changes in community structure, and declines in fish stocks have been observed, necessitating integrated management strategies that address the cumulative impacts of climate change, overfishing, and pollution.

Research Needs

There is a pressing need for integrated, long-term data on the ecological impacts of warming, particularly in linking phytoplankton indicators to higher trophic levels, such as fish (fisheries) and zooplankton. Holistic approaches that combine satellite derived ecological indicators, in situ measurements, and ecosystem models are currently scarce but essential for understanding the future trajectory of marine ecosystems in European seas. Additionally, there is a critical need to examine how fish and fisheries respond to marine heatwaves (MHWs), particularly during the exceptionally warm years of 2023 and 2024, which have significantly impacted all European seas.

To address these gaps, this case study aims to provide insights into the potential impacts of climate change on biodiversity and ecosystem services across the European seas. Furthermore, it will support collaborative efforts to develop joint-species distribution models (HMSC) for the Northeast Atlantic fish, North Sea jellyfish, North Sea and Baltic Sea fish, and Baltic Sea benthic invertebrates, while also calculating biodiversity indicators based on model outputs (DTU Aqua). Additionally, analyzing spatial and temporal changes in the feeding strategy composition of fish communities at both local (e.g., bays) and larger scales (Northeast Atlantic) will be vital. The production of common fish indicators across ecosystem models and case study regions, in collaboration with multiple partners, will enhance our understanding of ecological dynamics and support effective management strategies.

Research Planned in ACTNOW

● T2.1[CS1]: conduct monitoring and fisheries cruises for Polar cod (*Boreogadus saida*) and other gadoids around Svalbard, document the ongoing Atlantifaction of the Polar ecosystems and catch live fish for further multi-driver experiments (T2.3).

● T2.3 [CS1]: conduct multi-driver experiments with Polar cod (*Boreogadus saida*) in the laboratory and in the field to simulate climate change scenarios coupled with oxygen and food availability, also including seasonal thermal variability. In field cages in Svalbard, we will monitor seasonal metabolic rates over the course of a full year via heart rate biologgers in Polar cod.

● T3.1**:**

- Develop joint-species distribution models (HMSC) for (1) Northeast Atlantic fish, (2) North Sea jellyfish, (3) North Sea & Baltic Sea fish, and (4) Baltic Sea benthic invertebrates, and calculate biodiversity indicators based on model output (DTU Aqua) (Figure 1)
- Apply a MHW algorithm to the Mediterranean Sea to assess long-term linkages (1998-2023) between phytoplankton dynamics and warming using satellite-derived ecological indicators, such as phytoplankton size structure and associated metrics of phenology (bloom timing, [Racault et al., 2012]). The outputs from T1.2 [CS13] - regarding the dataset of regionally-tuned satellite-derived estimates of phytoplankton size structure for the Mediterranean Sea - will also be utilised to investigate potential associations with fisheries indicators.
- Use a 25yr zooplankton and chlorophyll time series to assess linkages between plankton and fisheries (Figures 2, 3) (Kalloniati et al., 2023) (NKUA, HCMR).
- Write and submit a paper on the subject of: Modelling the distribution of the mesopelagic fish *Maurolicus muelleri* in the Greek seas, utilizing in situ ecosounder data and satellite-derived observations.

● T3.2:

- Analyse spatial and temporal changes in the feeding strategy composition of fish communities at local (e.g., bays) and larger scales (Northeast Atlantic).
- Write and submit a peer-reviewed literature review on the impacts of marine heatwaves on Mediterranean biodiversity. Participate in a submission to a peer-reviewed journal on the subject "Ecopath Modelling Unravels the Food Web of the Gulf of Corinth, a deep Mediterranean Important Marine Mammal Area". In these works, including other datasets, satellite-derived information has been incorporated (NKUA).

● **T3.3:** produce common fish indicators across ecosystem models and case study regions

● T5.1: Satellite-derived phytoplankton ecological indicators will be incorporated into modelling-based projections to investigate biodiversity and community structure in the Mediterranean Sea (NKUA, CMCC).

● T6.2 Contributing to the development of the serious game "*Playing for change: Using experiential learning for bridging science and policy making to drive holistic understanding* "

Pictures, graphs and maps

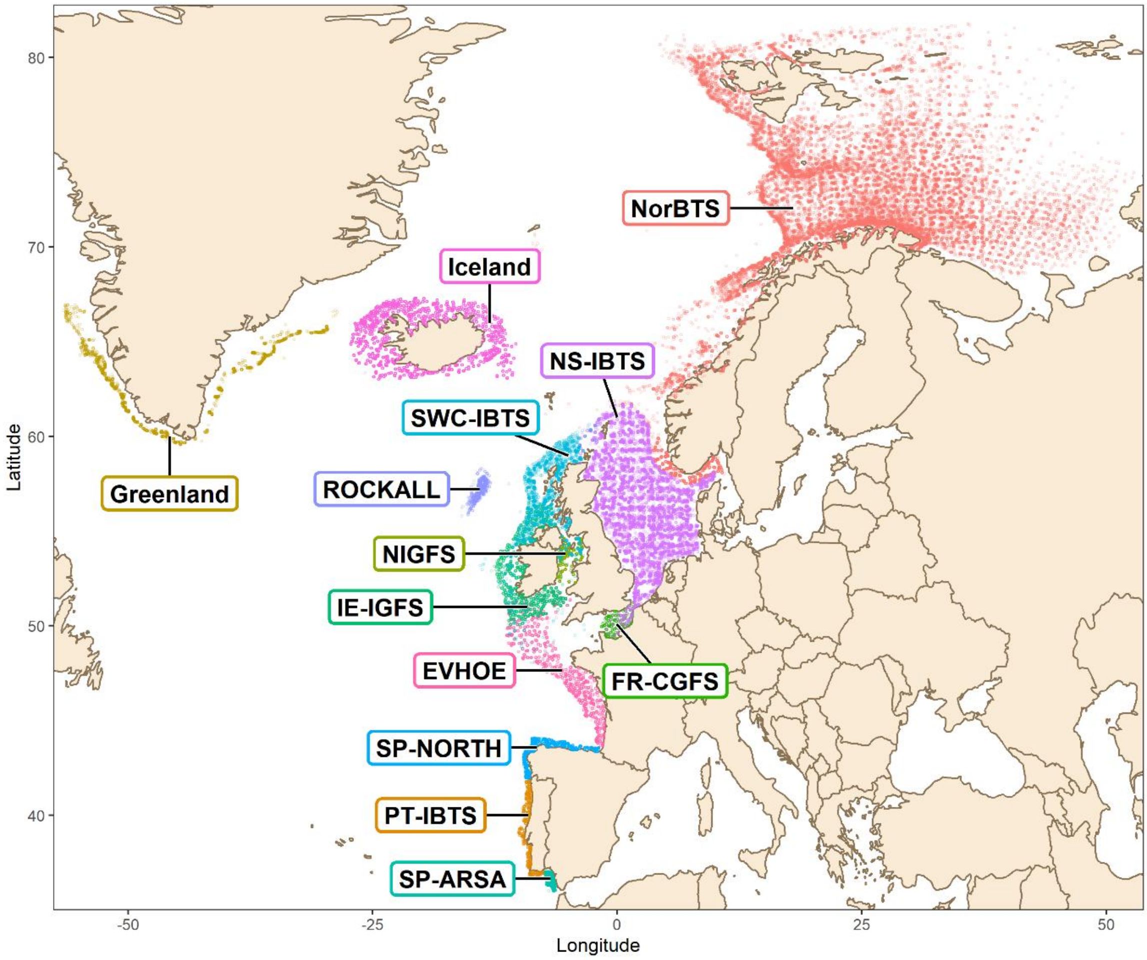

Figure 1. Position of all unique hauls from the different scientific bottom trawl surveys performed in the study area between 1989 and 2021 used to construct the join-species distribution model on Northeast Atlantic fish communities under Task 3.1. Source: PhD thesis Marcel Montanyès Solé.

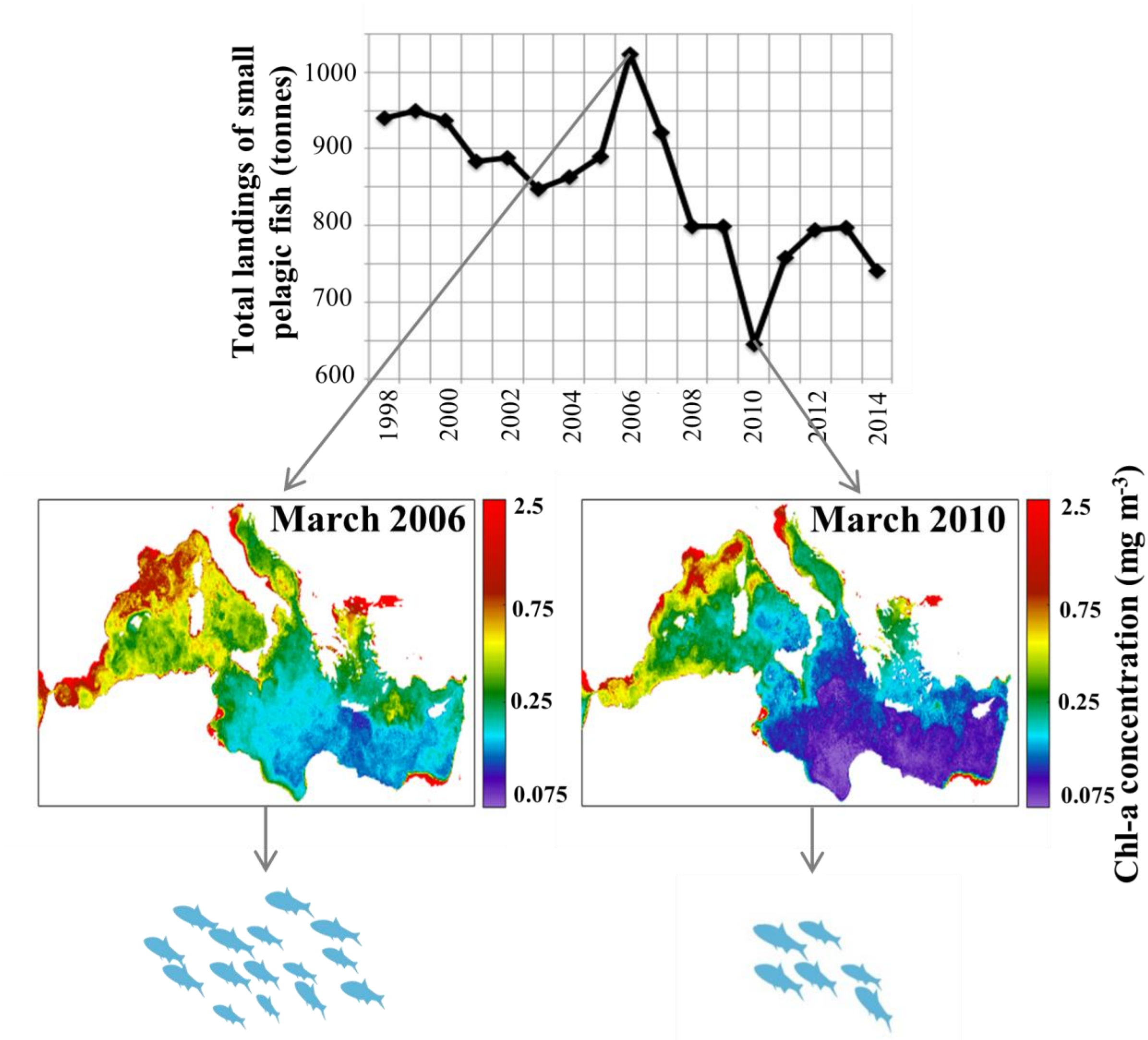

Figure 2: Plots highlighting the potential association between Mediterranean fisheries (FAO) and Chlorophyll-a concentration (an index of phytoplankton biomass) during an anomalously cool year in 2006, and a warm El Niño year in 2010. Total landings of small pelagic species [< 30cm] over the whole Mediterranean are shown in the top panel. Corresponding maps of Chl-a concentration, averaged over March (the typical winter peak growth period), are presented below.

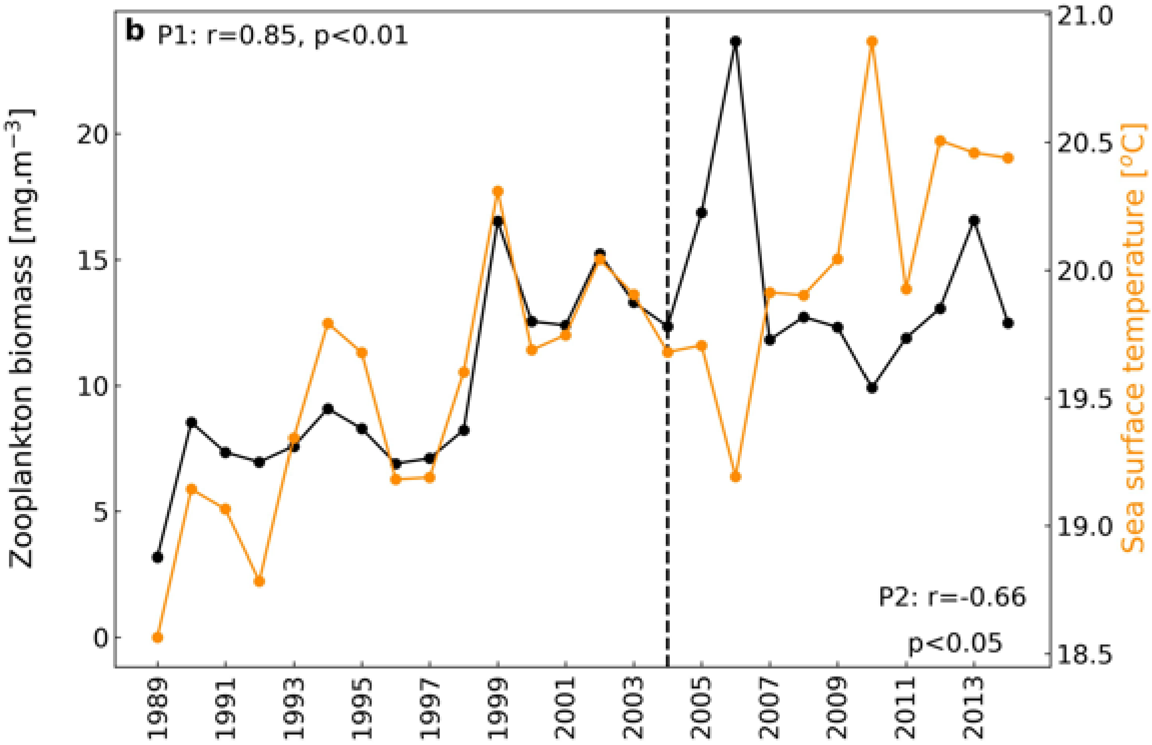

Figure 3: Interannual variability of zooplankton biomass versus SST for the period 1989–2014, in a nearshore region of the Saronikos Gulf (Eastern Med), based on annual mean values. The correlation between zooplankton biomass and SST was significantly positive for the period 1989-2004 (P1) and significantly negative for the period 2005-2015 (P2) (Kalloniati et al., 2023).

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