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Editorial: Impacts of environmental variability related to climate change on biological resources in the Mediterranean

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Editorial on the Research Topic

Impacts of environmental variability related to climate change on biological resources in the Mediterranean

Introduction

Current estimates of the increasing trend in Sea Surface Temperature (SST) from satellite-based remote sensing represent the main evidence of Mediterranean climate change (Pisano et al., 2020; Juza and Tintoré, 2021; Copernicus Marine Service Information, 2022a). The sea warming is known to affect primary production at global and regional scales by increasing stratification of the sea, reducing the input of nutrients into surface waters from mixing (Behrenfeld et al., 2006; Copernicus Marine Service Information, 2022b). The observed reduction in primary production is able to indirectly impact the biological processes governing the dynamics of fish stocks and the sustainability of fisheries, as already found in previous studies even in the Mediterranean Sea (Brander, 2007; Blanchard et al., 2012; Tzanatos et al., 2014; Corrales et al., 2018; Schickele et al., 2021). However, the observed warming trends have uneven spatial patterns, and more insights on their impacts on the primary production and on fishery resources are needed, especially in the neritic zone where most of the processes supporting fish populations take place. This Research Topic (RT) aimed to relate the available information about Mediterranean warming to a set of indicators of spatial distribution and productivity of marine populations, as well as the impacts of climate change on hydrological and biogeochemical features. Eleven manuscripts have been finally published in this RT dealing with the following main sub-topics.

Variability in hydrological and biogeochemical features

Three studies focused on oceanography in an area adjacent to the Strait of Gibraltar. A first study by Vargas-Yañez et al. (2022) searched for long-term trends of the mixed layer depth (MLD) as a potential proxy of changes in a warming scenario. Increased SST would imply greater stratification, hampering the supply of nutrients to the euphotic layer from below. The shallowing of MLD would partially compensate for this shortage, hence the interest in following changes of MLD. No noticeable changes during the observations were detected by the authors, who ascribed this fact to the effect of the accompanying salinity increase that compensates for the warming effect on water density. As a result, stratification was almost not modified, and MLD hardly changed. Authors advised some caution in their results, given that the length of the series analyzed could be insufficient to ensure the lack of trend, which could be masked by decadal variability. The second study investigated the link between large-scale variability modes of the SST and the surface chlorophyll-a (Chl-a) concentration in spring along the Alboran Sea (AS) (Western Mediterranean) (López-Parages et al.). Results indicated that El Niño Southern Oscillation (ENSO) could be used to estimate the coastal Chl-a concentration in spring in northern Alboran 4 months in advance, while the tropical North Atlantic SST allowed predicting, up to 7 months in advance, the offshore Chl-a. The third paper is an updated review of the AS oceanography based on fieldwork and numerical studies with a description of process dynamics and their role in shaping primary productivity and regional fisheries resources (Sánchez-Garrido and Nadal). Main gaps in understanding the physical drivers for transitions between the most recurrent one-gyre and two-gyre modes of circulation of the AS were identified. Research strategies based on end-to-end regional biophysical modelling were suggested to gain new insights into past and present physical control of fisheries resources and assess climate change impacts on the AS ecosystem. A fourth paper updated the knowledge on hydrological and biogeochemical patterns in the Strait of Sicily (SoS) (Central Mediterranean) in the last decade (Placenti et al.). Temperature and salinity in the intermediate waters showed a sharp annual increase at about 50% higher rates observed within the previous decade. Similar trends were also present in deep waters, although with smaller temperature and salinity variations. The time series in the intermediate waters also highlighted the presence of quasi-cyclic fluctuations that can be associated with the alternation of the circulation modes (cyclonic and anti-cyclonic) of the Northern Ionian Gyre (NIG). Moreover, an opposite trend emerged by comparing the nutrients and salinity time series in intermediate waters, while similar patterns have been evidenced between nutrients and chlorophyll-a concentration. A fifth study investigated relationships between thermohaline and biochemical patterns in the upper and intermediate water masses in the Levant Sea (Eastern Mediterranean) (Ozer et al.). Interannual fluctuations of salinity and temperature of the Levantine Intermediate Waters (LIW) were greater in the years 2008–2010, 2014–2015 and 2018–2019, coinciding with periods of anti-cyclonic circulation of the NIG. The enhanced warming in 2018–2019 has caused a decrease in density of the LIW core, bringing these nutrient-rich waters well inside the lower photic layer and supporting the observed maximum of chlorophyll recorded during 2018–2019. No significant change in the MLD but significantly higher average levels for integrated primary production, chlorophyll and bacterial abundances were observed during the anti-cyclonic period. The increase in LIW residence time and buoyancy may impact the primary producers' biomass at the photic zone and slightly counter the enhanced oligotrophication due to enhanced stratification resulting from climate change.

Hydrological pattern and species distribution

Two studies investigated the impact of hydrographical patterns on the spatial distribution of larvae of three tuna species (Atlantic bluefin tuna, bullet tuna and albacore) (Russo et al.), and on the biodiversity of ichthyoplankton assemblages (Patti et al.) in the SoS an area characterized by relatively stable mesoscale oceanographic processes, such as fronts and upwelling (Patti et al., 2010; Patti et al., 2020). The first one showed that the highest concentration of tuna larvae occurred in the easternmost part of the study area, south of Capo Passero, an area with a stable haline front and warmer, nutrient-poor water. The second study reported a decreasing trend in total larval abundance and biodiversity of ichthyoplankton assemblages, more pronounced in the shelf area and in the slope area, respectively. A third study addressed the settlement and recruitment patterns of juvenile fish in different habitats of the Adriatic Sea in relation to interannual environmental variability (Matić-Skoko et al.). Nurseries within transitional waters in the north resulted more prone to interannual water temperature changes. The associated community composition differed from that recorded in the southern Adriatic, where groups were mostly determined by water salinity and were less sensitive to interannual temperature fluctuations.

Effects of climate change and fisheries on species ecology

Two papers used Ecopath with Ecosim (EwE) and addressed the synergistic effects of climate change and fisheries exploitation in the Central and Eastern Mediterranean, contributing to the advancement of Ecosystem-Based Fishery Management approach (Heymans et al., 2016). The first study (Agnetta

et al.) presented an EwE dynamic model for the food web in the SoS, made up of 72 functional groups and including 13 fleet segments and a temporal simulation window until 2050, to evaluate the bio-economic interactive effects of the reduction of bottom trawling effort in different scenarios of fishery and climate change. A net increase in biomass of many functional groups with an immediate decline of trawlers' catches and economic incomes resulted, followed by a long-term increase mainly due to biomass rebuilding of commercial species, which lasts 5-10 years after fishing reduction. In the mid-term, the effects of trawling effort reduction are higher than those of climate change and seem to make exploitation of marine resources more sustainable over time, as well as fishery processes more efficient as a consequence of improving ecosystem health. The second study (Tsagarakis et al.) produced an EwE model for the North Aegean Sea (Eastern Mediterranean), highlighting the synergistic effect of environmental and anthropogenic processes during the three-decade hindcast period. Trends in biomasses, catches, and ecosystem indicators declined from 1993 to 2010, followed by a strong recovery thereafter. Sea warming scenarios for 2021-2050 indicated contrasting responses to increased temperature among the main commercial groups, while simulations of changes in productivity had relatively straightforward effects. Two scenarios of 10% and 25% reduction in fishing effort revealed quick increases in the biomass of most commercial species, though coupled with lower catches, except for a few groups. Adding reduction of productivity to temperature increase, the model forecasted lower biomass increases for the warm water species and even higher decreases for the cold water ones. These biomass losses were compensated by a 10% reduction in fishing effort, but this was not overall enough to counterbalance losses in catches. The last study (Scannella et al.) investigated the potential factors affecting the population dynamics of the regal cucumber (*Parastichopus regalis*), a species that is not commercialized in the SoS, to explore the impacts of fishing pressure and environmental factors on its abundance on trawlable bottoms. Long time series on species density indices (2008-2021) was modelled as a function of environmental parameters (i.e. salinity, dissolved oxygen, ammonium, pH and chlorophyll-a) and fishing effort. Results showed a big change in the species distribution over time with rarefaction of spatial distribution and a slight deepening starting from 2017 and 2011, respectively. No significant effects of fishing effort have been found. Conversely, a positive relationship with pH concentration in surface waters during the larval dispersal phase and nutrient concentration at the sea bottom has been identified, suggesting that this species is sensitive to climate change and food availability.

Conclusions

The RT evidenced contrasting regional responses to the warming of the Mediterranean Sea for the ensemble of indicators of spatial distribution and productivity of biological resources that were investigated in the contributing papers. Although the observed trends appear to be related to different sub-regional oceanographic features, similarities also emerged between the Central and Eastern Mediterranean in the ecosystem response to the alternation of the circulation modes (cyclonic and anti-cyclonic) in the Northern Ionian Gyre. In addition, it is worth noting how oceanographic processes involving the intermediate waters may impact primary production and compensate for the expected reduction in nutrient availability due to the enhanced stratification and reduced land input induced by climate change. However, this conclusion cannot be extended to all Mediterranean regions. Furhermore, the RT confirmed the complexity of interaction between climate and fisheries on biological resources dynamics. Although reduction of fishing effort was found as a main factor affecting the productivity of fisheries resources in the mid-term, the current warming phase could decrease the long term yield of fisheries in some areas of the basin. Future studies focusing on the biological response of the Mediterranean Sea to global warming have to consider these local differences to estimate trends in the biomass budget at the basin level.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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