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Editorial: Impact of extreme climate events on marine ecosystems: Adaptation and challenges

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Editorial on the Research Topic
Impact of extreme climate events on marine ecosystems: Adaptation and challenges

Marine ecosystems provide diverse and essential services to humankind, but multiple stressors (e.g., overfishing, climate change, and pollution) are reshaping ecosystem structures with potentially negative impacts on ecosystem functions (Doney et al., 2012; Costanza et al., 2014; Bland et al., 2018). Especially, extreme climate events (ECEs) are found to have profound and diverse impacts on marine populations and ecosystems (Wernberg et al., 2013; Zhang, 2020). In recent decades, the frequency and intensity of ECEs, e.g., tropical cyclones, and heatwaves, tend to increase in marine ecosystems (Kendrick et al.). In contrast to gradual climate change, ECEs feature drastic and rapid changes in environmental conditions. These sudden changes can affect both the structure and function of marine ecosystems in a way that resembles pulse disturbance (Smale et al., 2019; Zhang et al., 2022). Consequently, novel responses to ECEs may be observed in the variations in the physiological functioning, behavior, and demographic traits of marine organisms, shifts in the size structure, spatial range, and seasonal abundance of populations, and changes in the community structure and ecosystem function. To cope with challenges associated with ECEs, it is important to understand the mechanisms *via* which they affect marine ecosystems. Therefore, the purpose of this special issue is to understand the effects of ECEs on marine ecosystems at different levels and seek management solutions. The main results of papers submitted to this special issue are:

Biological responses to marine heatwaves

Marine heatwaves are discrete and large-scale warm water events, and have been considered as a major threat to marine ecosystems and their functioning (Oliver et al., 2018). The annual duration of marine heatwaves has increased by 54% globally over the past century, and eight of the 10 most extreme marine heatwaves on record have occurred since 2010 (Smith et al., 2021). In the context of global warming, understanding the biological responses of marine heatwaves is especially important for marine management. In three articles of this special issue, impacts of marine heatwaves on planktonic foraminiferal assemblages, fish assemblages and diversity in nekton community have been studied. Lane et al. analyzed the community composition and abundance of planktonic foraminifera in the northern California Current based on survey data during 2010–2019. They found evidence that two marine heatwaves (2014–2016, and 2019) had significant impacts on foraminiferal species composition; foraminiferal assemblage variability correlated with changes in temperature and salinity in the upper 100 meters. These results demonstrate that the foraminiferal assemblage response to transient warming events makes them a promising tool for quantifying the frequency and intensity of marine heatwaves. Robinson et al. examined the response of resident nearshore fish assemblage in eelgrass habitats on the southwestern coast of Vancouver Island to 2014–2016 marine heatwaves based on fish survey data during 2004–2021. Their results showed marine heatwaves had caused changes in fish species abundances and composition but these changes were short-lived. This study suggests caution in generalizing about the effects of heatwaves on nearshore marine fish. Liu et al. investigated the influences of marine heatwaves on alpha and beta diversity in nekton community in the East China Sea based on trawl survey data during 2014–2017. They found marine heatwaves fundamentally changed the nekton community structure, which was mainly caused by dominant species alternation, along with biomass declines of forage fish and crustaceans with short life cycles. Besides, there were differences in the response rates with various thermal preferences and diverse species compositions to the extreme climate change. Overall, marine heatwaves are forceful agents of disturbance with wide-ranging impacts on marine ecosystems. In addition to the ecological responses described above, they also have significant socioeconomic impacts (Smith et al., 2021). Therefore, it is in urgent need to explore effective approaches to predicting the occurrence and impacts of marine heatwaves, along with adaptation and management approaches (Smith et al., 2023).

Population response to climate-induced environmental changes

Retrospective analysis using long-term data series is important for understanding both long-term and short-term impacts of climate change on marine organisms. Combined with environment data and climatic indices, e.g., Pacific Decadal Oscillation index (PDO), Monsoon Index (MOI), North Pacific Index (NPI), and Siberian High Index (SHI), variations in survey abundance or fish catch could help us to understand climate-induced relationships between fish abundance and physical drivers. Wang et al. estimated the average temperature suitability index (TSI) for chub mackerel in main spawning areas during its spawning period. Results showed that the TSI for the Tsushima Warm Current stock displayed abrupt changes in the late 1990s, while the TSI for the Pacific stock had a regime shift in the late 1970s. Besides, there is a non-stationary relationship between chub mackerel abundance and TSI, which is driven by climate variabilities such as the Siberian High and the Aleutian Low. This study offers an improved understanding of the climate-induced non-stationary relationships between fish abundance and physical drivers.

Forecasting by species distribution models

Modelling species' distributions is an important aspect of ecological research. As global warming intensifies, the use of species distribution models (SDMs) to explore the distribution shifts in marine species has experienced rapid growth (Melo-Merino et al., 2020). SDMs provide an excellent tool for predicting the impact of future climate change on habitats of marine organisms. Xiong et al. built a maximum entropy model to simulate the seasonal habitat changes of largehead hairtail *Trichiurus japonicus* in the Beibu Gulf. They also applied three different Representative Concentration Pathways (SSPs 126, 370, 585) to evaluate geographic distribution changes under the different climate change scenarios. The overall results indicate that seasonal differences in suitable habitat should be considered to ensure effective planning of future management strategies for *T. japonicus*.

Revisiting the footprints of climate change in Arctic marine food webs

Brandt et al. assessed the climate-driven impacts on Arctic marine ecosystems by reviewing 98 footprints described and analyzed during 2011–2021. They found primary production has been observed to further increase in Arctic seas, and Arctic seas are likely to experience increasing species richness in the future. Meanwhile, they also expressed concern that the Arctic-endemic species will go extinct as warming and/or acidification will exceed their physiological adaptation capacity. Overall, the future Arctic Ocean will very likely experience increasing numbers and intensities of climate-change footprints.

Author contributions

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

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