Intense and prolonged subsurface marine heatwaves pose risk to biodiversity

An insight into the global patterns of marine heatwaves from the surface to depths of 2,000 m reveals that subsurface events are more intense and long-lasting than surface ones. Biodiversity exposure to the effects of marine heatwaves is higher at depths of 50–250 m, suggesting that subsurface biodiversity could be at considerable risk.

This is a summary of:
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The question

Marine heatwaves (MHWs) — extreme events of high seawater temperatures — are becoming increasingly common across the global ocean[1]. Their impacts are unprecedented, both for marine ecosystems and the humans who depend on them[2]. As a result, there is growing academic and societal interest in understanding MHW patterns and drivers and the potential effects of MHWs on biodiversity.

Global MHW insights have been based on surface-temperature observations because these data are readily available; MHWs across the water column have been overlooked. Notably, only a handful of studies, all localized, have investigated subsurface MHWs, which have been found to be more intense than surface events, at times occurring without a surface signal. But it is unclear whether these observations provide a general rule for the global ocean. A global overview of subsurface MHW characteristics could tackle this question and provide a better understanding of the potential effects of MHWs on marine biodiversity.

The discovery

The greatest challenge in estimating the prevalence of global subsurface MHWs is the availability of the necessary daily temperature data, which should be global in scale, across a range of depths, and span at least a 30-year period[3]. Such data are typically scattered and available only for very few regions, collected by oceanographic instruments such as buoys and gliders. To overcome this, we used reanalysis temperature data, derived from models that are calibrated using observations. We estimated MHW metrics[3] — such as intensity, duration and number of events — at 11 depths spanning from the surface to 2,000 m and covering the period from 1993 to 2019. Then, we overlaid the MHW cumulative intensity, a proxy of thermal stress, with 25,078 species range maps to estimate regional biodiversity exposure to MHWs. We also estimated MHW exposure in regions where most species are living at their upper thermal tolerance limits, and are thus potentially more sensitive to MHW effects.

We found that, globally, subsurface MHWs are up to two times longer and 19% more intense than surface events and can occur without a surface signal. Different patterns of subsurface MHWs emerged depending on oceanographic conditions, with high intensities in regions of boundary currents and tropical gyres (Fig. 1). We further found that potential biodiversity impacts are greater in the upper 250 m of the ocean, where MHW cumulative intensity was the highest. Up to 22% of the ocean was characterized as highly exposed to MHW effects, with high cumulative intensity overlapping high biodiversity levels. Although MHWs at depths greater than 250 m were estimated to be half as intense as those at the surface, they were particularly long-lasting.

The implications

Previous studies at the global scale addressed MHWs at the ocean surface. Here, we provide insight into global patterns of subsurface MHWs. These events occur globally and across depths, with even higher intensity and duration than at the surface. Notably, subsurface biodiversity can be exposed to the detrimental effects of MHWs. This can be particularly relevant for range-edge populations living at the upper limits of their thermal tolerance, as they are likely to struggle more to cope with extreme temperatures[4]. As a response to recurrent MHW exposure, species might shift their distribution to deeper, cooler waters, with consequent effects on ecological interactions and ecosystem processes[5]. Such MHW impacts on subsurface biodiversity might be going unnoticed as there is limited monitoring beyond coastal, shallow regions.

Our estimates of MHWs are based on modelled temperature data not observations, as there is still a major lack of systematic global ocean monitoring, and therefore carry uncertainties, particularly in deeper parts of the ocean and polar latitudes. Furthermore, potential MHW impacts on biodiversity need to be supported by long-term monitoring of biodiversity responses. Particularly for the deep ocean, where organisms are more sensitive to environmental change, it is still not known whether or how MHWs that are recurrent and long-lasting might affect biodiversity patterns.

Future work could consider the potential synergistic effects of additional local stressors, such as oxygen declines, on biodiversity patterns. Whatever the future directions, systematic global monitoring of the ocean's physical properties (such as temperature, density, oxygen and salinity) and its biological responses (for example, time-series before, during and after MHWs) is undeniably necessary to broaden our understanding of how extreme events and environmental changes will affect biodiversity from the surface to abyssal depths.

Eliza Fragkopoulou & Jorge Assis
Centre of Marine Sciences, Faro, Portugal.

EXPERT OPINION

"The authors of this manuscript perform a global, full-depth analysis of MHWs using an ocean reanalysis product and explore impacts on biodiversity using species richness as an indicator. Because of the drastic ecological and economic impacts of ocean temperature extremes, it is important to improve our understanding of the drivers of MHWs beyond the surface layer and to form direct connections to the marine ecosystem." **Svenja Ryan, Woods Hole Oceanographic Institution, Woods Hole, MA, USA.**

FIGURE

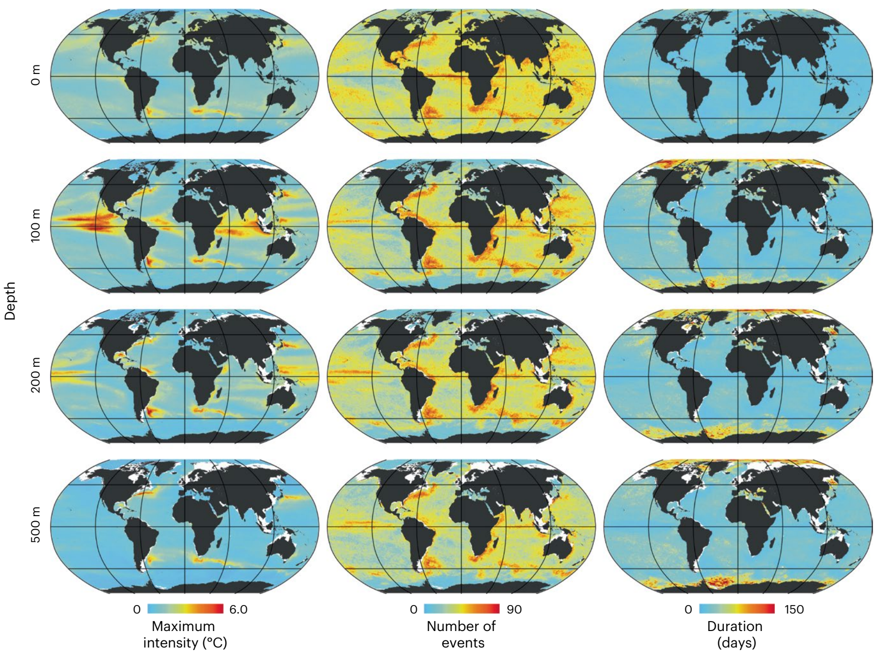

Fig. 1 | Spatial distribution of MHW metrics at varying depth for the period 1993–2019. The maps show how the maximum intensity of MHWs, the number of events and their average duration are all higher below the surface. Map areas in white have no corresponding data because the ocean floor does not reach these depths. © 2023, Fragkopoulou, E. et al.

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BEHIND THE PAPER

As part of my PhD project, I was investigating the effects of thermal stress on marine biodiversity, particularly exploring the possibility of depth shifts or refugia for marine species. Researching the literature, I saw MHWs were often reported as a potential cause of mortality, but I couldn't find any estimates of MHW intensity changes with depth; existing studies relied on surface data. So, our team came up with the idea of producing our own subsurface estimates using the reanalysis data from the European Union's Copernicus Marine Service. The task was more complex than anticipated, and we had to overcome many technical challenges, starting with how to handle the massive temperature dataset. Despite the challenges, the preliminary results — showing higher subsurface intensity and duration — were unexpected and exciting. To interpret them, we joined a multidisciplinary team with diverse backgrounds. This study transformed the initial plan of my PhD project and paved the way for exciting future research for our team. **E.F.**

FROM THE EDITOR

"MHWs have become increasingly frequent and intense, so understanding their patterns and impacts is particularly important. This study stands out because of its focus on global MHW occurrence not just at the ocean surface but also down to depths of 2,000 m, as well as its inclusion of impacts on biodiversity." **Editorial Team, *Nature Climate Change*.**