Climate change effects hit marine ecosystems in multiple waves, according to marine ecologists

November 15 2023

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A new approach to examining the effects of climate change on marine ecosystems may provide a more accurate understanding of climate

change responses—and predictions for future consequences—according to a new paper co-authored by a Brown University biologist.

The paper, published in the *Annual Review of Ecology, Evolution, and Systematics*, highlights the interplay between the trend of climate warming and the fluctuations in local temperature. These two properties cause atypically warm events such as marine heat waves to occur with increasing frequency and magnitude.

However, the interaction between the steadily warming climate and the spikes in local temperatures tends to be underappreciated, according to study co-author Jon Witman, a professor of biology at Brown University.

"Climate change studies often focus on the trend of global warming," Witman said. "But organisms in the ocean are also experiencing temperature fluctuations, and that's less studied and therefore less understood. What we're trying to do is to add more reality into ocean climate change studies by considering both the smooth, upward trend of climate warming as well as the variability on top of that trend."

The paper proposes a new approach for understanding and modeling the effects of marine climate change, with suggestions for future research.

Witman offered coral as an example that illustrates the need for a new approach. While an organism like coral is already trying to adapt to the trend of rising temperatures, he noted, it then endures a heat wave, which causes a large and sudden spike in temperature.

Temperature spikes tend to lead to coral bleaching, which is when metabolically stressed corals expel the beneficial microscopic algae living within them and turn white. If the temperature stays high and algae are unable to return to their host coral, the bleached coral will die.

Witman pointed to heat waves in the Mediterranean that have led to an increase in coral bleaching and death of corals and sea fans.

Extreme events such as heat waves may alter or damage marine ecosystems in ways that leave them more vulnerable to both progressive climate change as well as the next temperature fluctuation, Witman added. A more realistic model may help scientists better identify areas where coral is more likely to die off in an extreme event leaving coral-dependent organisms at risk over time, he said.

In other cases, temperature variability can lead to an opposite response in the affected organism: an ability to acclimatize or adapt to temperature extremes, depending on their frequency and intensity.

These responses to variable events like heat waves compound and are compounded by the effects caused by rapidly and steadily increasing ocean temperatures, Witman said.

Witman collaborated with Andrew Pershing of the nonprofit Climate Central, who studied biology as an undergraduate at Brown; and John Bruno, a professor of biology in the University of North Carolina at Chapel Hill, who earned a Ph.D. in ecology and evolutionary biology from Brown.

In their paper, Bruno, Pershing and Witman considered how organisms and communities adapt or adjust to both smooth trends and variable changes, and then reviewed processes that influence the rate at which marine communities adjust to changes in their physical environment—as well as those processes that might hamper adaption or acclimatization. The researchers stressed that all of these factors illustrate why it's key to consider both types of change when studying marine climates.

"If we just study how organisms respond to the smooth trend, we miss all

the variability, which is driving ecological change," Witman said. "It's not just a matter of worsening physiological stress over time; there are also variable events that have their own ripple effects."

In the paper, the researchers created a global model that shows the variability in temperature relative to trend, highlighting regions where extreme temperatures are likely to have particularly deleterious effects. In the areas of the Gulf of Maine, the Caribbean Sea and the Mediterranean Sea, they write, there are high probabilities of exceptional warming events and "ecological surprises." Research shows that key foundation species in these regions, such kelp and corals, have already experienced substantial climate-related changes.

"These areas, especially, warrant investigation to improve our understanding of what's going to happen in the future—as well as our conception of what we're calling 'the new ocean,'" Witman said.

More information: Jon D. Witman et al, Smooth and Spiky: The Importance of Variability in Marine Climate Change Ecology, *Annual Review of Ecology, Evolution, and Systematics* (2023). DOI: 10.1146/annurev-ecolsys-022323-082123

Provided by Brown University