Climate change could lead to a dramatic temperature-linked decrease in essential omega-3 fatty acids

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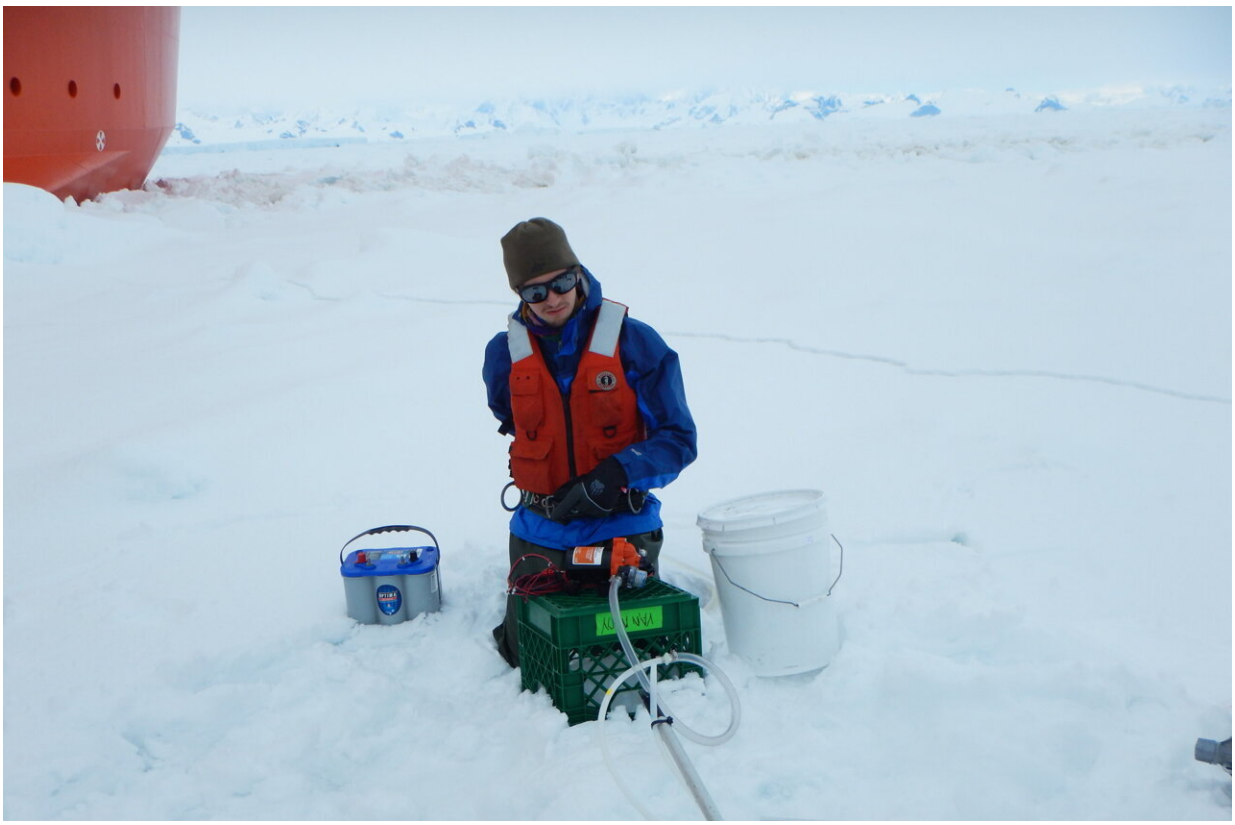

MIT-WHOI Joint Program student Henry Holm pumping seawater for lipid samples from beneath sea ice on the Western Antarctic Peninsula, 2018. This is for a WHOI-led study that conducted a global survey of lipids in the ocean in order to analyze omega-3 fatty acids. Credit: Benjamin Van Mooy / © Woods Hole Oceanographic Institution

The effects of global climate change already are resulting in the loss of sea ice, accelerated sea level rise, and longer and more intense heat waves, among other threats.

Now, the first-ever survey of planktonic lipids in the global ocean predicts a temperature-linked decrease in the production of essential omega-3 fatty acids, an important subset of lipid molecules.

A significant implication of the survey is that as global warming proceeds, there will be fewer and fewer omega-3 fatty acids produced by plankton at the base of the food web, which will mean less omega-3 fatty acids available for fish and for people. Omega-3 fatty acid is an essential fat that the human body cannot produce on its own, and is widely regarded as a "good" fat that link seafood consumption to heart health.

The survey analyzed 930 lipid samples across the global ocean using a uniform high-resolution accurate mass spectrometry analytical workflow, "revealing heretofore unknown characteristics of ocean planktonic lipidomes," which is the entirety of hundreds to thousands of lipid species in a sample, according to a new paper led by authors from the Woods Hole Oceanographic Institution (WHOI).

"Focusing on ten molecularly diverse glycerolipid classes we identified 1,151 distinct lipid species, finding that fatty acid unsaturation (i.e., number of carbon to carbon double bonds) is fundamentally constrained by temperature. We predict significant declines in the essential fatty acid eicosapentaenoic acid [EPA] over the next century, which are likely to have serious deleterious effects on economically critical fisheries," states the paper, "Global ocean lipidomes show a universal relationship between temperature and lipid unsaturation," published in *Science*.

EPA is one of the most nutritious omega-3 fatty acids, has been linked to numerous health benefits, and is widely available as a dietary

supplement. "The lipids in the ocean affect your life," says journal article co-author Benjamin Van Mooy, senior scientist in WHOI's Marine Chemistry and Geochemistry Department. "We found that the composition of lipids in the ocean is going to change as the ocean warms. That is a cause for concern. We need those lipids that are in the ocean because they influence the quality of the food that the ocean produces for humanity."

"All organisms in the ocean have to contend with water temperatures. With this study, we have revealed one of the important biochemical ways cells are doing that," says journal article lead author Henry C. Holm, a doctoral student in the Massachusetts Institute of Technology (MIT)—WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering. "These findings about EPA were made possible by using a method that gives us a very complete picture of the gylcerolipids in each sample. We saw that temperature was linked with the saturation of cell membranes everywhere we looked in the ocean."

Lipids are a class of biomolecules produced and used by organisms from all domains of life for energy storage, membrane structure, and signaling. They make up about 10–20 percent of the plankton in the surface ocean where lipid production and inventories are greatest. Oceanographers have used lipids as biomarkers of chemical and biological processes for decades, and there has been robust research into their biogeochemistry. Only recently, however, has the combination of high-resolution mass spectrometry and downstream analytical tools allowed for the comprehensive untargeted assessments of ocean lipids on scales similar to surveys of other molecules such as nucleic acids and proteins.

In this new survey, researchers examined a global-scale mass spectral dataset of planktonic lipidomes from 146 locations collected during seven oceanographic research cruises from 2013–2018. The researchers

note that that although planktonic community lipidomes are affected by numerous environmental factors such as nutrient availability, the paper reports on "the relationship between lipids and arguably the most fundamental control on their composition: temperature."

Researchers examined the saturation state for the 10 major classes of lipids with glycerol (i.e. glycerolipids) and found that among those classes, "temperature was highly influential in structuring the relative abundance of fatty acid species." In addition, researchers found a clear transition from lipid species with more unsaturated fatty acids at colder temperatures to fully saturated species at the warmest temperatures.

"These trends are also evident in all the other glycerolipid classes as well as the total aggregated lipidomes of all glycerolipid classes," the paper states. "Indeed, it is striking that the relationship between temperature and unsaturation emerges from our dataset despite spanning such diverse and disparate planktonic communities, from the nutrient-depleted subtropical gyres to the highly-productive Antarctic coastal shelf."

The researchers also found that the percent abundance for eicosapentaenoic acid (EPA) species showed a strong relationship to temperature. To determine how the upper and lower limits for the composition of EPA might shift under future warming conditions, researchers generated maps using end-of-century sea surface temperature conditions for different climate scenarios. Under climate scenario SSP5-85, which the paper notes is considered a worst-case scenario with continued high greenhouse gas emissions, some ocean regions —particularly at higher latitudes—see a drastic decrease of up to -25% of the EPA relative to the amount they have now, according to the paper.

Van Mooy said the research "is another example of how human activities are perturbing the oceans in ways that we never expected, and of the

uncertainty of how the ocean is going to respond to warming."

More information: Henry C. Holm et al, Global ocean lipidomes show a universal relationship between temperature and lipid unsaturation, *Science* (2022). DOI: 10.1126/science.abn7455

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