Research team publishes groundbreaking methane synthesis discovery

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An upcoming publication by a collaborative team across several Montana State University departments highlights new findings from over a decade of research in Yellowstone Lake examining the ways organisms process and produce atmospheric methane. Credit: MSU photo by Kelly Gorham

An interdisciplinary team of scientists from Montana State University's College of Agriculture and College of Letters and Science recently published research casting new light on a previously unknown element of the carbon cycle, thanks to data collected from Yellowstone National Park over more than a decade.

Tim McDermott, a professor in MSU's Department of Land Resources and Environmental Sciences, began studying the microbiology of Yellowstone Lake in 2007. While collecting data to analyze the lake's chemistry and the interaction of various microbes in the lake with the park's underlying thermal features, McDermott noticed something seemed off.

"We came across some lake water gas chemistries that didn't make a lick of sense," said McDermott. "We were seeing a lot of methane in places we didn't expect and wondering, 'what's going on here?'"

That discrepancy illustrated what has been termed the "methane paradox." For years, scientists have understood that when microorganisms produce methane, they do it anaerobically, meaning they don't use oxygen. But in the surface waters of the lake where the team was seeing methane, none of those organisms were found.

Methane is a naturally occurring gas made up of carbon and hydrogen atoms. It is the byproduct of a number of biological processes, though human activities like mining coal and refining natural gas also produce methane. It is a greenhouse gas known to be much more potent when trapping heat in the atmosphere than carbon dioxide, which is why many researchers are interested in identifying where in the biosphere it is created and where it goes.

So began a years-long collaborative effort with John Dore, also of the Department of Land Resources and Environmental Sciences; Brian

Bothner and Roland Hatzenpichler of the Department of Chemistry and Biochemistry; and Qian Wang, an assistant research professor in the Department of Microbiology and Cell Biology. The study is the subject of a new paper published this week in the journal *Proceedings of the National Academy of Science* titled "Aerobic Bacterial Methane Synthesis."

Wang led the work at Yellowstone Lake for five summers of data collection and analysis.

"At the beginning, we didn't realize what was going on," she said. "But when we did the DNA extraction from the lake water, it turns out we couldn't find the anaerobic organisms that are usually responsible for the presence of methane. Instead, we discovered aerobic bacteria were involved, isolating a bacterium called Acidovorax, which then allowed us to begin understanding this process."

The Bothner lab group used analytical equipment to identify the presence of methylamine and glycine betaine in the lake water, biochemicals the team hypothesized to be key in the process of methane production. To test the theory, Wang narrowed down which gene the Acidovorax bacteria needed to convert methylamine or glycine betaine into methane.

"We can break this down to a basic discovery about methylamine conversion to methane under aerobic conditions," said McDermott. "Scientifically, this wasn't supposed to be happening based on all the knowledge we had. So, we went through a process of elimination to identify how and why this was happening and is another example of fundamental discoveries made from Yellowstone research."

Through a series of microbial experiments and extensive analysis of the wider biological community present in the lake samples, Wang identified a known gene that encodes aspartate aminotransferase, or AAT, that seemed to be catalyzing the methane synthesis.

The next step was to see if the AAT enzyme itself was capable of catalyzing the conversion of methylamine into methane. To do that, Wang isolated the gene, transferred it to E. coli, which is commonly used by microbiologists and biochemists because of its capability to express foreign genes; McDermott likened it to inserting in a cassette tape into a player.

A common E. coli cell, explained Wang, cannot convert methylamine into methane. But when provided with the AAT gene, it could.

"It's rare these days to come upon something that can't be explained by our current understanding of biochemistry," said Bothner. "That has made this an interesting and challenging project to work on."

The magnitude of the discovery cannot be overstated, said Bothner. The fact that aerobic methane synthesis can happen at all is a seismic shift in the field of biogeochemistry. Since methane is a much more potent greenhouse gas than carbon dioxide, scientists are interested in identifying where in the biosphere it is created and where it goes. This project, he said, creates a springboard for extensive further research in Yellowstone National Park and beyond.

"This is a fundamentally different process from anaerobic methane synthesis," said McDermott. "In an ecological sense, it's logical to think that this is occurring throughout the biosphere, not just in Yellowstone Lake. It's conceivable to think that it's even occurring across the world's oceans and throughout the world."

More information: Qian Wang et al, Aerobic bacterial methane synthesis, *Proceedings of the National Academy of Sciences* (2021). DOI:

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