Study shows water hundreds of feet below the surface of Lake Michigan is warming

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Climate change is reaching all the way down to the depths of one of Earth's largest lakes.

Water hundreds of feet below the surface of Lake Michigan is warming, especially in winter, according to a report published last week by the National Oceanic and Atmospheric Administration. The warming could change the seasonal patterns of the lake—and alter a way of life for ecosystems and industry alike.

It's been known that Lake Michigan surface temperatures are increasing and ice cover is lessening as human activity spurs climate change.

"These changes may seem very small, a couple tenths of a degree per decade, but this has been going on for several decades now, perhaps longer than is reflected in our monitoring," said Craig Stow, a NOAA Great Lakes Environmental Research Laboratory scientist and author of the study.

The lakes have been changing, ever since they were formed, Stow said. "But when they change fast it means humans have to adapt to the changes that occur. And if we don't monitor for them we run the risk of being caught by surprise."

The first-of-its-kind look at deep water warming fills in another gap in climate change research, revealing what's happening below Lake Michigan's surface.

The overall warming, ice loss and shrinking winters could lead to long-term shifts, altering the lake's food web and sending fisheries toward uncharted territory.

Some of the surfaces of the world's largest lakes are warming faster than ocean and air temperatures.

"We've known for a while now based on surface temperatures—not just in Lake Michigan but smaller lakes and large lakes worldwide—that the

surface temperatures seem to be increasing," Stow said.

Lake Michigan surface temperatures are estimated to be warming at a rate of as much as a third to a fourth of a degree Celsius per decade.

But the story of what's going on as far as 460 feet below the surface is sparse. Deep water understandings had previously relied on translating surface data or limited observations. So starting in 1990, researchers turned to a string of thermometers floating vertically in southern Lake Michigan to gather measurements. NOAA Great Lakes Environmental Research Laboratory scientists looked at 30 years of measurements, some hourly, to track seasonal patterns far below the surface.

The study, published in *Nature Communications*, notes that Lake Michigan is "likely the world's only large lake with this type of long-term observations of water temperatures at depth."

In deeper water, warming is estimated to be as much as .06 degrees Celsius per decade.

"This is a big lake," Stow said. "That's a lot of water. That's a lot of change."

Warming so far below the surface wasn't necessarily a surprise, Stow said, but it's hard to know what's happening without data.

"It could have been that we'd only see an effect down in the first 30 or 40 meters," Stow said. "But we saw it down really far."

Lakes can serve as "climate change sentinels," the study says, and deep water measurements can be particularly important because they provide a "climate memory."

"What we can see from this data is a reflection of larger scale and longer-term processes," Stow said. "They're not obscured by the noise that might occur from a couple very warm or a couple very cold years."

The water's warming winters reflect rising surface temperatures and prolonged summers. Some of the most pronounced jumps in winter temperatures are occurring near the Great Lakes. Records dating back to 1973 show maximum ice coverage across the Great Lakes is declining 5% per decade; Lake Michigan's ice coverage decline is about 3.6%.

Lake Michigan is dimictic, meaning there's a top-to-bottom mix of the water column twice a year. With warmer surface temperatures, the fall mixing cycle is starting later, leading to a shortened cooling period for deep waters and a longer summer period without mixing.

"The organisms that live there, the plankton and the fish, are used to the lake the way it was," Stow said. "They evolved over thousands of years to take advantage of those systems that mixed twice a year."

If the lake changes to warm monomictic, mixing once a year, Stow said it would signal fundamental change.

"And the other thing you have to remember is this is not the only thing going on," Stow said, noting changes spurred by invasive zebra and quagga mussels. "All of that's happening at the same time."

The report lays out some examples of what's happened in other large lakes. Thermal change can mix up the food web and lead to the proliferation of invasive species. Longer periods when the lake is not mixing can exacerbate low-oxygen conditions. In Lake Erie, for example, low oxygen has contributed to fish die-offs.

Researchers hope to add more sensors to gain a better overall picture of

how the lakes are responding.

"In all, the consequences of changes in subsurface water temperatures will result in a profound shift in lake ecology," the report says. "Without high-frequency long-term monitoring of subsurface waters, we will be blind to the impacts of climate change on most of Earth's fresh surface water."