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This Great Lakes fish may have evolved to see like its ocean ancestors did

New research could inform fisheries restoration efforts in the Great Lakes

BUFFALO, N.Y. — In the dark waters of Lake Superior, a fish species adapted to regain a genetic trait that may have helped its ancient ancestors see in the ocean, a study finds.

The research focuses on kiyis, which inhabit Lake Superior at depths of about 80 to over 200 meters deep. These fish, known to scientists as "*Coregonus kiyi*," belong to a group of closely related salmonids known as ciscoes.

In contrast to three other Lake Superior ciscoes that dwell and feed in shallower regions of water, the kiyis are far more likely to carry a version of the rhodopsin gene that probably improves vision in dim "blue-shifted" waters, the study concludes. Every one of 21 kiyis the team examined from this deep-water population carried only this variant of the gene.

The adaptation appears to mark a return to an ancient state: Some 175 million years ago, the kiyis' ocean-dwelling forebears likely harbored the same genetic variant, according to a reconstruction of the species' evolutionary history.

Then, as ancestral fish populations moved from blue-shifted marine waters into shallower, "red-shifted" streams and lakes, a form of rhodopsin that's beneficial in those habitats became more common, scientists say. Finally, the kiyis, reaching the deep waters of Lake Superior, adapted again to the "blue-shifted" color of the waters they now inhabit.

The study was published online Nov. 28 in the journal Genome Biology and Evolution. The project, funded by the Great Lakes Fishery Commission, was a collaboration among researchers at the University at Buffalo and the U.S. Geological Survey's Great Lakes Science Center.

"Evolution is often thought of as a one-way process, at least over deep time, but in this example, over 175 million years, we have this reversal back to a much earlier ancestral state," says Trevor Krabbenhoft, PhD, assistant professor of biological sciences in the UB College of Arts and Sciences and a faculty member in the UB RENEW Institute. Krabbenhoft led the research with first author Katherine Eaton.

"Fishery biologists are trying to restore native fish populations in the Great Lakes, so it's important to understand the adaptations that species have," says Eaton, a PhD student at Auburn University who completed the study at UB as an undergraduate in biological sciences. “Knowledge of a species’ adaptations can help us restore them in environments that are better suited to their biology.”

Restoring fish in the Great Lakes

It’s unclear whether the kiyis’ ancestors completely lost the blue-shifted gene variant before re-evolving it, or if the variant simply became less frequent in this fish lineage before re-emerging to become more prolific again.

Either way, today, “There is a really clear distinction between the deep-water and shallow-water species,” Eaton says.

Whereas all of the kiyis studied had the blue-shifted form of rhodopsin, the shallower water ciscoes sampled — *Coregonus artedi*, *Coregonus hoyi* and *Coregonus zenithicus* — primarily had the version of the gene that may be helpful in red-shifted waters.

Eaton notes that the same blue-shifted variant of rhodopsin is present in a number of other fish that live in the sea or deep lake water. This repeated “parallel” evolution can indicate that an adaptation has an important function: in this case, probably helping fish see in different environments, she says.

These insights are important because light in the Great Lakes is changing, Krabbenhoft says. For example, invasive zebra and quagga mussels, which filter organic matter from lakes, are increasing the clarity of the water in places.

The knowledge is also valuable as scientists look to restore native fish populations. In addition to the rhodopsin research, Krabbenhoft is a co-author of a study examining the genetics, morphology and ecology of ciscoes more broadly. That work, also funded by the Great Lakes Fishery Commission, was led by Moisés Bernal, PhD, now an assistant professor of biological sciences at Auburn University. The study results were posted on Dec. 16 to the preprint server bioRxiv, and have not yet been published in a peer-reviewed journal.

“Collectively, these projects have implications for restoring the native biodiversity in the Great Lakes toward a healthy ecosystem,” Krabbenhoft says. “Ciscoes were once much more abundant and diverse across the five Great Lakes, but some species went extinct due to overfishing, sea lamprey invasion and pollution. Our data are informing restoration strategies as these fish are being re-established in places where they were lost or highly reduced in number, such as in Lake Ontario.”

“Ciscoes were once the dominant native prey species in the Great Lakes, supporting top predators such as lake trout and walleye. They remain an important component of the tribal, commercial and recreational fisheries, which are valued at more than $7 billion annually,” says Bill Taylor, PhD, Commissioner for the Great Lakes Fishery Commission and a University Distinguished Professor in Global Fisheries Systems at Michigan State University. “Research to better understand their biology and morphology is critical to designing successful restoration efforts in the future.”

Authors of the rhodopsin paper are Krabbenhoft; Eaton; Bernal, who completed the work as a UB postdoctoral researcher in biological sciences; Nathan Backenstose, a UB PhD student in biological sciences; and Daniel Yule, a research fisheries biologist at the Lake Superior Biological Station, part of the U.S. Geological Survey Great Lakes Science Center. Eaton's research was supported by the Philip G. Miles Undergraduate Research Fellowships in the UB Department of Biological Sciences, and the UB Honors College.