Fish eggs are suffocating in Lake Michigan reefs. What will it take to save these nurseries?

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Across the Great Lakes, collections of underwater rocks have been incubators for native fish eggs.

In Lake Michigan, this reef habitat can vary from a field of cobblestones the size of baseballs to a hulking assemblage of boulders. Every fall, species like lake trout return to these spawning grounds to deposit eggs into crevices between the rocks, which protect the unhatched fry. For months, even after they've hatched, juveniles hide in these cracks to avoid being eaten by predators.

Over the past 30 years, scientists and fishery managers have tried to replicate that success, building numerous artificial reefs to boost fish populations. But experts question whether these reefs are a viable solution because of threats posed by invasive species and climate change.

Without a suitable nursery habitat, the fish population will keep shrinking, said Alex Gatch, a former fisheries technician with Cornell University and the U.S. Geological Survey who is researching approaches to restore spawning reefs for a master's degree at Purdue University.

"It's just one piece to the puzzle, but it's an important one," he said.

Many Great Lakes reefs, man-made and natural, have been smothered by invasive zebra and quagga mussels that have colonized the lake bottom, leaving eggs exposed and more vulnerable to predators. In other areas near the mouths of rivers and tributaries, scientists say, these reefs are being buried by sand and silt, the result of increased precipitation, soil erosion and runoff from climate change.

Man-made reefs have proven capable of beckoning large numbers of fish, but it is unclear how much these structures are helping the overall wild fish population.

Native fish in the Great Lakes have already faced a number of obstacles to survive: overfishing, pollution, less food availability, competition with

invasive species. Researchers are now wondering how lake trout and other species—including walleye, lake whitefish, smallmouth bass—will respond to this habitat degradation.

Some lawmakers believe there have been significant enough strides in curtailing agricultural runoff that it may be time to rebuild reefs again. The U.S. Environmental Protection Agency last year awarded $980,000 to the state of Michigan to reconstruct two reefs in Saginaw Bay, where downstream sand plumes have been a problem.

"It's a sandbar rather than a rocky reef," Gatch said about one of the Saginaw Bay sites.

Purdue researchers are attempting a different approach.

With funding from the geological survey, Gatch hopes to restore natural and constructed reefs that have been buried by sedimentation and caked with invasive mussels. Gatch built two sled-like devices, one equipped with propeller fans and another with water jets, that can be towed behind a boat to clean reefs.

The contraptions were used to clean sand from two reefs in Saginaw Bay and mussels from one in Thunder Bay last year. Gatch said he plans to bring the operation to three sites in southern Lake Michigan this summer including an artificial reef known as Carlsons Reef about a mile offshore of Chicago's Museum of Science and Industry. The reef, made up of 4,500 tons of large granite rock spread over an area the size of two football fields, was built in 1999 to boost the population of smallmouth bass and provide a reliable fishing hole for anglers.

"The goal will be to create something portable and affordable to try to clean off these reefs and create quality habitat for fish spawning," Gatch said. "Ultimately, we want to have a more sustainable population of sport

fish, both for the ecosystem and for the general public to catch."

As early as the 1800s, rock piles were built along the lakefront to protect important infrastructure from wave damage. These rocky fortifications incidentally became reefs for large schools of fish. Starting in the 1980s, fishery managers began constructing rock piles in shallow water to improve sport fishing.

By the 1990s, the heyday of reef construction in the Great Lakes, fishery managers saw reefs as a potential avenue for increasing spawning.

According to a 2015 study published in the Journal of Great Lakes Research, Lake Michigan has the most man-made reefs with eight. Plankton-rich Lake Erie, which has the most abundant fish population, has six. Lakes Huron and Ontario each have three and Lake Superior, which has remained relatively free of quagga mussels, has two.

Fishermen are generally in favor of creating habitat that could provide them with more dependable places to fish in these lakes, according to Jeff Goad, past president of the Elliott Donnelley Chapter of Trout Unlimited. Many anglers use sonar to scan the lake bottom for changes in elevation in hopes of finding reefs where fish congregate.

In the ocean, artificial reefs have been made from vehicle tires, retired train cars and sunken ships. As part of a conservancy group, however, Goad and others want policymakers to be mindful of what these reefs are made of. While sunken ships have been reef habitat in the Great Lakes, these are primarily intended for recreational divers.

"I think it's always great to add habitat when nature isn't able to do it itself," said Goad, who often fishes at Belmont Harbor. "The conflict comes in where we're putting artificial things in the lake, like sinking boats. In so many coastal places, in saltwater, they'll take a boat out, cut

holes in it, blow it up and sink it—and, boom, now it's a reef. The challenge is, here, this is drinking water for millions of people. We don't want to put anything in there that will pollute our freshwater."

Goad also wants to see the Great Lakes' $7 billion fishing industry protected.

"There's a notion that there's a lot of water, it's a big place, there's an unlimited supply of fish and we'll always have a lot of everything," Goad said. "But, as an angler, we understand there is no promise of unlimited resources of fish and clean, clear water that will be sustainable for these species."

Matt Herbert, an aquatic ecologist with the Nature Conservancy in Michigan, said that if state and federal governments are going to pour money into building reefs, there needs to be a clear strategy.

Since 2015, the Nature Conservancy, Central Michigan University and the state of Michigan have been restoring reef habitat in Grand Traverse Bay, an area where powerful waves have kept rock formations clear of mussels and sand.

Under the project, 450 tons of limestone has been added to one reef and barriers have been built to control egg predators like the rusty crayfish. While egg survival could still suffer from strong storms, the preliminary results have been "encouraging," Herbert said.

"Our message is reef creation is not necessarily a bad idea," Herbert said. "It just requires due diligence and good science behind it. Historically, we've just haphazardly constructed reefs, and those days are over."

Purdue is part of a team of institutions studying reefs in Michigan's

Saginaw Bay, which once was touted as one of the most robust walleye fisheries in the Great Lakes but is now recovering after drastic changes in the region's logging and agriculture industries more than a century ago.

Because of deforestation near the Saginaw River, soil that otherwise would have been anchored by tree roots was washed into the river with rainfall. Some of this freshly cleared land was converted into farmland, and a sizable amount of soil and nutrients from fertilizer was also swept into the waterway each year.

As carbon emissions have increased and temperatures have risen, runoff has gotten worse. The warmer atmosphere is capable of holding more moisture, according to scientists. In the Great Lakes region, heavier downpours are increasingly eroding the soils, strengthening the flow of streams and possibly spilling more sand and silt over the reefs in areas like Saginaw Bay.

After heavy storms, aerial images show large sediment plumes emanating from rivers and tributaries feeding into the Great Lakes. The underwater avalanche of sediment spells trouble for fish eggs.

In laboratory experiments, Gatch, the Purdue researcher, found that whitefish eggs had less of a chance at survival when blanketed by sand and, even more so, silt. These eggs rely on lake currents to pass through the gaps between rocks to provide them oxygen.

"After a certain amount of sedimentation, there's not enough oxygen flow and the eggs just basically suffocate," Gatch said.

While Michigan rivers contribute to the sandy shores of eastern Lake Michigan, Illinois waters are characterized by a rocky lake bottom.

At Julian's Reef, a natural deep-water reef nearly 14 miles offshore from Fort Sheridan, scientists in 1990 took video of the pristine cobblestones and bedrock where lake trout had been known to congregate and spawn. Twenty years later, scientists returned to survey the area and found it had been completely overtaken by fingernail-sized quagga and zebra mussels.

"We knew (mussels) would be out there, but we were all shocked to see this complete blanket effect," said Rebecca Redman, a scientist who has studied reef habitat with the Illinois Natural History Survey. "Our immediate concern was, well, where are those spaces? Those mussels have encrusted the rocks and filled in all those spaces that we think lake trout need for their eggs to thrive."

Since the 1980s, Julian's Reef is the only place in Lake Michigan where the U.S. Fish and Wildlife Service stocks lake trout in Illinois waters. Researchers say much of the 100,000-plus fingerling lake trout survive to adulthood today, but conservationists worry that the increase in fouled reef habitat will impede natural spawning.

The superabundant quagga mussels are also believed to be asphyxiating fish eggs. They already take up much of the oxygen near the lake bottom, and they excrete feces that breeds nuisance algae known as Cladophora that contributes to lower levels of oxygen.

Even if eggs get enough oxygen to survive, because mussels are blocking the spaces between reef rocks, the eggs can be easy pickings for predators. Now, in addition to tiny, invasive bottom-feeders like round gobies and rusty crayfish that were already able to prey on eggs safeguarded by rocks, larger fish like channel catfish are gobbling them up as well.

Gatch said his reef-cleaning devices are untested against invasive mussels, which use sticky, thread-like appendages to stick to hard

surfaces. But the in the coming summer Lake Michigan will be their proving ground.

Meanwhile, fish are still returning to mussel-blanketed reefs to spawn. At Julian's Reef, researchers have observed lake trout eggs and fry—some of which were where they least expected them to be, according to Jeffrey Stein, a senior research scientist with the Illinois Natural History Survey.

There are still many questions, including whether the formations can protect eggs from potential predators such as whitefish, which researchers have observed rooting around in the beds of dead shells. But the discovery is an encouraging development.

"I don't know if you want to call it resilience, because their rehabilitation has been slow," Redman, the state scientist, said about lake trout. "But it's a realization that they might be finding a way to successfully reproduce."