CAUSE AND EFFECT

Sediment plume creates perfect incubator for *Microcystis* bloom

by Stacy Brannan, Ohio Sea Grant Communications

Pea soup. Green Kool-Aid™. Spinach soufflé. No matter which food item comes to mind when you see harmful algal blooms (HABs) in Lake Erie's Western Basin or washed up along its shorelines, their existence is certainly unwelcomed. Blooms of blue-green algae called *Microcystis*—a common species of cyanobacteria that can produce toxins harmful to animals and people—have shut down beaches, negatively affected sport fishing and boating, and created a headache for water treatment companies. Some scientists believe that the blooms also contribute to the Dead Zone, floating out to the Central Basin where they sink and decompose, consuming the limited oxygen near the lake bottom. The blooms had disappeared in the 1980s, when Lake Erie seemed to be on the road to recovery, but the last 10 years have seen their resurgence.

In his work at the Lake Erie Center at the University of Toledo, Ohio Sea Grant researcher Dr. Tom Bridgeman was on the scene to witness one of the first large *Microcystis* blooms that formed in Maumee Bay in 2003. In the next few years, he began to see a pattern.

"We noticed from satellite photos that the blooms overlapped almost exactly with this big, muddy river plume coming from the Maumee River," he recalls. "We started to think there might be a connection between the plume and the bloom."

Turbid or muddy water acts as the perfect incubator for *Microcystis* blooms. The picture on the left shows the plume of sediment coming from the Maumee River on August 26, 2008—a breezy day when the water column was mixing. On the right, in a picture taken on September 3, 2008, you can see that the bloom had grown over the plume.

So in the summers of 2007 and 2008, Bridgeman's graduate student Justin Chaffin set out to see if there was indeed a connection between the two. It turns out that sediment plumes are the perfect incubator for the HABs, and limiting the mud that gets swept downriver and into Lake Erie's Western Basin could go a long way toward reducing their occurrence.

In Full Bloom

Chaffin's data collection endeavors didn't start out successfully. The summer of 2007 was unusually dry, which meant fewer, smaller blooms. "I only found *Microcystis* the first and last days I went out to sample," he says. The next year, however, was a different story. *Microcystis* levels were moderate all summer, and then, in August, a strong storm swept through the Western Lake Erie region, stirring up a lot of sediment that poured from the Maumee River and into the

In 2008, Ohio Sea Grant researcher Dr. Tom Bridgeman and his graduate student Justin Chaffin collected samples at six different sites a total of six times from July through September. Chaffin determined that the *Microcystis* had plenty of nitrogen but were still phosphorus deprived, indicating that phosphorus levels determine how much the blue-green algae will grow.

Maumee Bay. As Bridgeman and Chaffin had predicted, by September a massive bloom spread over the muddy plume, starting from the river and extending nearly 75 miles to Avon Point.

"Justin found that the summer of 2008 had the largest, most extensive *Microcystis* bloom since we started keeping track in 2002," Bridgeman explains. "It was 20 times larger than what we'd seen in 2002 and six times larger than 2007."

Bridgeman and Chaffin boarded their 25-foot research vessel to collect samples six times, starting in late July 2008 before the large bloom and continuing through September, from six different sites: two near shore at the mouth of the Maumee River, two at mid-range, and two off shore, toward the center of Lake Erie's Western Basin. The mid-range points, it turned out, had the perfect characteristics of a *Microcystis* incubator.

"Near shore is too shallow, so light is able to penetrate down to the lake floor, giving all species of algae more than enough light to thrive. *Microcystis* doesn't have an advantage there," Chaffin says. "Further out, the sediment and nutrients from the river plume are too dispersed. Those points in the middle have the right combination of turbidity, or muddiness, and depth."

All things being equal, beneficial phytoplankton like green algae and diatoms will outgrow *Microcystis*, but the harmful cyanobacterium has one ability the others don't: it can regulate its buoyancy. In a typical 24-hour period, a *Microcystis* alga gathers carbon in its cells via photosynthesis. The process causes it to grow heavier, and it eventually sinks toward the bottom of the lake. As it respires, or uses up its carbon stores, bubble-like structures called gas vacuoles are formed internally, causing it to rise to the surface again. Given enough time, *Microcystis* can adjust to conditions that might keep it from gathering light at the surface of the water. Very choppy water that would cause strong mixing of the water column, for instance, is too strong for it to overcome.

When waters are calm, 90% of all *Microcystis* cyanobacteria can be found at the surface. This can further shade other varieties of algae that don't have the buoyancy benefit.

But there is a downside to *Microcystis*' floating ability. In testing the samples, Chaffin found that bright, direct sunlight in calm water can actually damage the blue-green algae, regardless of the amount of mud in the water, as illustrated in Figure A. "On calm, sunny days, *Microcystis* floating on the surface became damaged quickly, showing loss of up to 50% of photosynthetic capacity in samples collected between 10 a.m. and 2 p.m.," he explains. "Even after 2 to 5 hours of recovery time in the dark, traveling to the lab for testing, much of this damage was still unrepaired." So the longer *Microcystis* is stuck in the sun's direct rays, the more likely it is to be damaged significantly.

However, when the water is filled with sediment and breezes help to mix the water column, muddiness acts as a protective shield, as illustrated in Figure B. "On sunny days when the water was turbid and winds were blowing above 7 miles per hour, *Microcystis* was mixed more evenly throughout the water column, and no significant damage to its photosynthetic machinery was observed," Chaffin relays. In having the opportunity to float just below the surface of the muddy water, the *Microcystis* can gather all the light it needs without sustaining ill effects.

Its responses even adapt to maximize its light-collecting efforts. "Any photosynthesizer will become more efficient at photosynthesis when it's kept in low light conditions, whether it's a small tree growing in a shaded forest or *Microcystis* growing in murky water," Chaffin says. To prove that the cyanobacteria had made such an adjustment, Chaffin extracted the photosynthetic pigments from his *Microcystis* samples and tested them to determine how much chlorophyll and phycocyanin were present per gram of blue-green algae, knowing that both pigments are responsible for harvesting light energy. He found that *Microcystis* will produce double the amount of chlorophyll and six times the amount of phycocyanin, a pigment unique to cyanobacteria, when it's in muddy water compared to when it's in clear water.

But the turbidity of the Maumee River plume is not the only thing contributing to the massive *Microcystis* blooms. The river also washes high levels of nutrients into Lake Erie from agricultural runoff in the region. Chaffin tested his samples for the nutrients most commonly blamed for increased HAB growth: phosphorus and nitrogen.

"It's typically thought that *Microcystis* does well when nitrogen is very low and phosphorus is high," he explains. "Sure enough, when I tested the samples, the cyanobacteria had plenty of nitrogen but were still phosphorus deprived. So, the hypothesis still holds true: *Microcystis* is phosphorus limited in Lake Erie. The amount of phosphorus in the water is going to determine how much the cyanobacteria can grow."

This result underscores the importance of determining the source of the phosphorus that has plagued Lake Erie for decades. Following the passage of the Great Lakes Water Quality Agreement and the Clean Water Act, phosphorus loading was limited in the 1970s, resulting in a cleaner, clearer lake. But even though the amount of phosphorus being dumped into the lake has remained below the amount recommended by management agencies, the level of soluble reactive phosphorus in the lake water has increased since the mid-1990s. Researchers believe this may be attributable to a shift in the kind of phosphorus being flushed into the lake via runoff. Phosphonates—a kind of phosphorus commonly found in chemical weed killers—might be more biologically available to harmful varieties of blue-green algae, such as *Microcystis*, than to beneficial algae. Scientists at Ohio Sea Grant and other agencies are currently working to solve this puzzle.

Clearing the Water

As for clearing up the turbid plume that originates at the Maumee River, any management practice that would limit erosion would improve the situation. "Impermeable surfaces, such as roads, parking lots, and even hard-packed land, do not allow water to infiltrate the ground," Chaffin relates. "Instead, the water is forced into storm drains and streams, taking soil

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particles along with it. The key is to create barriers that slow down the water's flow, allowing it to be absorbed. This applies to any watershed, not only Lake Erie."

Plants are very good at capturing water in their root systems, so placing them in an area where water tends to flow is recommended. For instance, farmers can install buffer strips of vegetation around plowed fields and along rivers, and regional land managers can design drainage ditches with a number of turns to give rain water a chance to be absorbed. Wetlands also slow the flow of water and are natural contaminant filters, so restoring or creating them will reduce both sediment and nutrient loading.

People who are interested in doing their own part to limit soil runoff can catch rain from their home's gutters in a rain barrel, the water from which can be reused for garden irrigation. Rain gardens—a planted strip along the edges of driveways, walkways, and any other impervious surface—will absorb storm water as well. Native plants, such as wild flowers, are particularly well suited to this task.

Storms will always stir up a certain amount of sediment that already exists in the Maumee River and Lake Erie, simply because they mix the water column. However, implementing some of these land use practices could make a real difference.

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For more information about this research, which was jointly funded by Ohio Sea Grant and the Lake Erie Protection Fund, contact Dr. Tom Bridgeman at *thomas.bridgeman@utoledo.edu*. TL

Microcystis' Response to Light

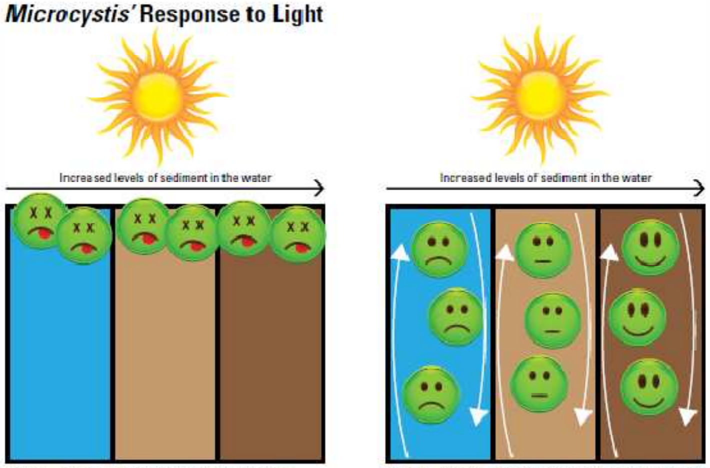

Figure A – *Microcystis* is damaged on calm, sunny days when they float on the surface of the water

Figure B – Sediment protects *Microcystis* when the lake is mixing

Bright, direct sunlight in calm water can actually damage *Microcystis*, even if the water is muddy, because of its tendency to float on the water's surface (Figure A). However, when the water is filled with sediment and breezes mix the water column, muddiness acts as a protective shield, helping the *Microcystis* to thrive (Figure B).