The Zebra Mussel Connection: Nuisance Algal Blooms, Lake Erie Anoxia, and other Water Quality Problems in the Great Lakes

Microcystis Blooms Return

Nuisance blooms of the potentially toxic blue-green alga *Microcystis* have returned to Lake Huron's Saginaw Bay and Lake Erie. Saginaw Bay has experienced blooms three out of five summers monitored during 1991-1996. Lake Erie experienced a bloom resembling a thick slick of grass-green paint that extended over the entire surface of the western basin during September 1995 (Figure 1), and other large blooms occurred in 1998 and 2000. Blooms of *Microcystis* and other blue-greens have not occurred since the 1970's and early 1980's when phosphorus controls began to reduce phosphorus inputs to the Great Lakes. Excessive phosphorus is the usual culprit for nuisance blooms, but now other causes must be considered.

These recent blooms occurred a few years after the invasion of zebra mussels and their cousins the quagga mussels in the Great Lakes. The prodigious filtering by these mussels makes the water clear by removing particles. Even in years when blooms have occurred, zebra mussel filtering caused the water to be very clear during spring and early summer before the blooms took off. A similar pattern of *Microcystis* or other blue-green blooms is now being seen in some small lakes that have been invaded by mussels.

Blooms are of concern because *Microcystis* is poor food for the aquatic food chain and because it contains a potent toxin called microcystin that is harmful to the aquatic food chain, including fishes, and to waterfowl or other animals that might drink untreated water. The Lake Erie and Saginaw Bay strains of *Microcystis* are toxic; however, there has to be a high concentration of *Microcystis*, such as that found in a thick surface scum, to be dangerous to wildlife or pets drinking the water. Such conditions can occur when *Microcystis* floats up to the surface under calm conditions and is concentrated by winds or currents in areas near shore.

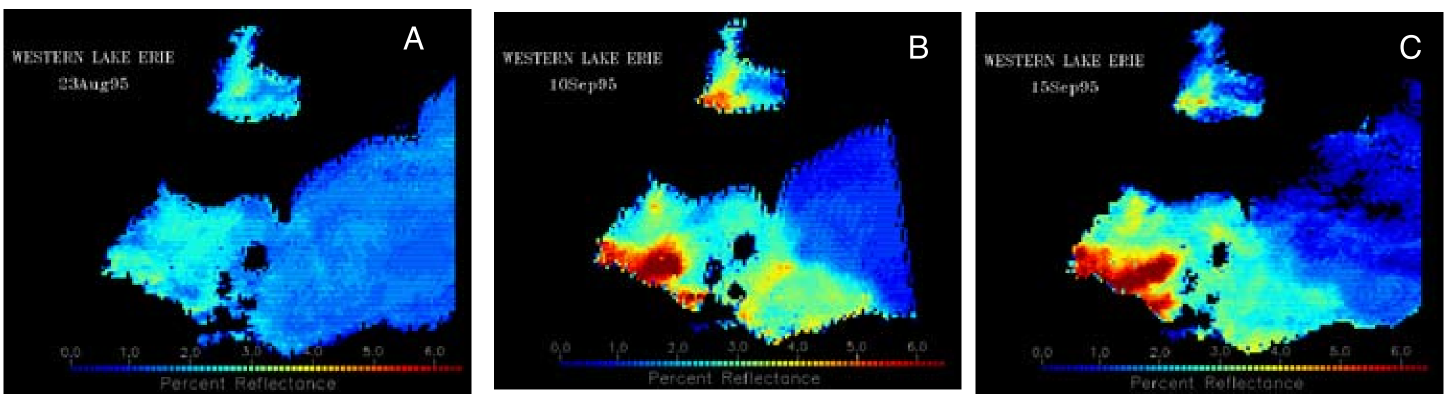

Figure 1. NOAA CoastWatch satellite images of western Lake Erie showing development of the *Microcystis* bloom as measured by percent reflectance, which is a measure of concentration of particles—in this case *Microcystis*—in the water. Little reflectance was seen on (A) 23 Aug 95, before the bloom got underway. Concentration of *Microcystis* started to increase in the southwestern part of the western basin (B) (10 Sep 95) and continued until much of the whole basin was covered (C) (15 Sep 95). The water body near the figure captions is Lake St. Clair.

The Zebra Mussel Connection

The extensive monitoring and experimental program of NOAA's Great Lakes Environmental Research Laboratory (GLERL) on Saginaw Bay as well as a program supported by the Lake Erie Protection Fund (LEPF) provided hypotheses and some answers to explain the zebra mussel-*Microcystis* connection. GLERL was one of many agency and academic participants in the LEPF program.

Experiments at GLERL with water from Saginaw Bay and Lake Erie have shown that zebra mussels selectively filter and reject phytoplankton so as to promote and maintain *Microcystis* blooms as follows. Using special video equipment, GLERL showed that mussels filter the water whether or not *Microcystis* is present, but they spit *Microcystis* back into the water, while at the same time they eat other algae (Figure 2). Thus, the competitors of *Microcystis* are removed. This probably explains why *Microcystis* has been Saginaw Bay's dominant alga in many summers. At the same time this selective feeding process is occurring, the mussels are excreting nutrients (phosphate and ammonia) derived from the phytoplankton they eat as part of digestion and metabolic processes. These nutrients, in turn, serve to fertilize further growth of *Microcystis*.

The zebra mussel (*Dreissena polymorpha*).

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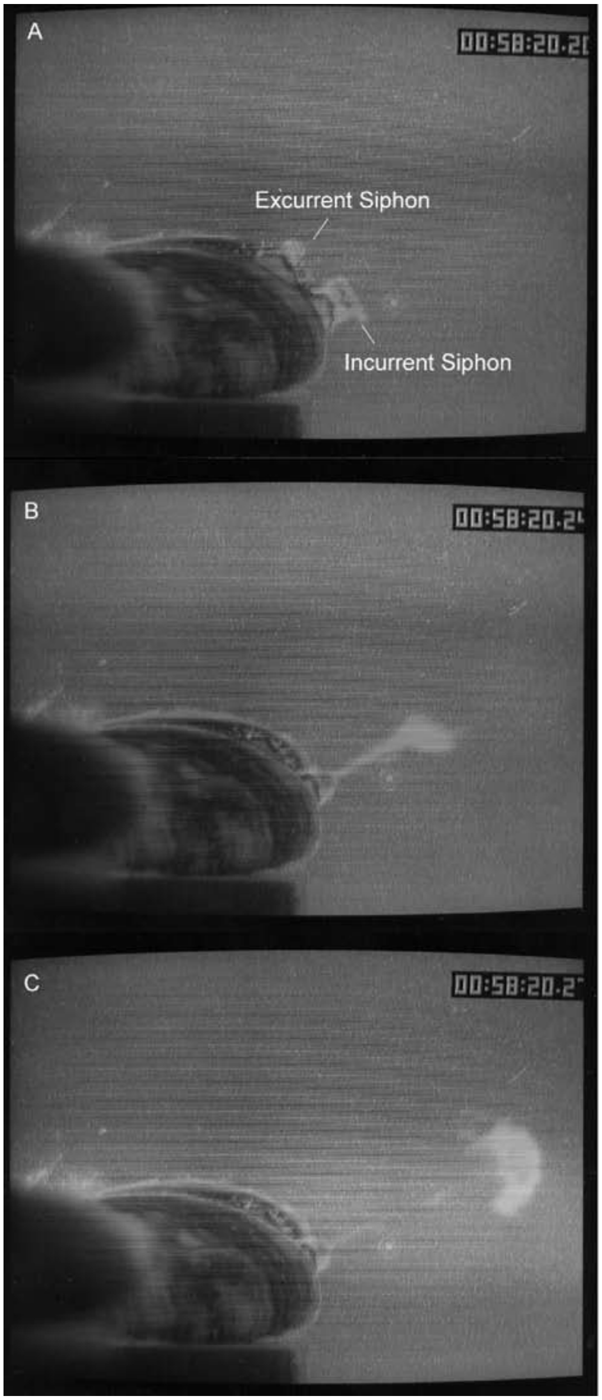

Figure 2. Zebra mussel expelling *Microcystis* as pseudofeces. (A) Mussel filtering with siphons in normal position. (B) Excurrent siphon retracted and incurrent siphon starting to expel the *Microcystis* as pseudofeces. (C) Pseudofeces ejected.

What Needs To Be Done?

Work suggests that zebra and quagga mussels are responsible for recent water quality problems in the Great Lakes, and it is important to prevent the mussels from spreading to inland lakes, where impacts are also beginning to be seen. Impacts of the mussels depend on how much hard substrate is available for the mussels to attach to and grow on, depth of the lake, degree of eutrophy (nutrient enrichment), and other factors. Unfortunately, there are many factors that we just do not understand. Mitigation of impacts may involve, for example, more stringent controls on nutrients so the potential for blooms of Microcystis and other nuisance plant species is diminished. More research is required to develop management strategies to adapt to these invaders, which are now a permanent part of the Great Lakes ecosystem.

Drinking Water and Aquatic Weed Problems

Microcystis can create taste and odor problems in drinking water supplies. *Microcystis* is not eaten by grazers, and as Microcystis uses up all the nutrients it dies and sinks to the bottom where it is decomposed by bacteria, including actinomycetes. Actinomycetes produce the musty taste and odor compounds geosmine and MIB (methyl-isoboreol) that give a foul taste to drinking water. Some municipal water supplies in the Great Lakes have reported taste and odor problems. Besides *Microcystis*, other algae and aquatic plants, including filamentous algae, can also be linked to taste and odor problems. Because zebra mussels clear the water of particles, more light reaches the bottom allowing these algae to better grow. As these algae decompose, they too can be food for actinomycetes to create geosmine and MIB. In addition, some filamentous blue-green algae are themselves odor producers.

Increased light penetration to the bottom also stimulates the growth of macrophytes (rooted aquatic weeds). Aquatic plants, both filamentous algae and macrophytes are much more common in bays and shallow areas of the Great Lakes. Lake St. Clair is an obvious example, where during storms the weeds have washed up on shore and fouled the beaches.

Lake Erie Nutrient and Anoxia Problems

Recently, managers have become alarmed by increased phosphorus concentrations in Lake Erie as well as by anoxia (low oxygen concentration) in the hypolimnion (cold deep waters of a lake that are separated from the warm surface layers) of the central basin. Anoxia is of concern in that it will kill fish and other animals near the bottom of the lake.

Work at GLERL has shown that zebra and quagga mussels are important regulators of nutrient availability. In the relatively phosphorus-rich waters of Lake Erie, mussels increase phosphorus availability by immediately excreting phosphorus contained in the phytoplankton they ingest. In other systems, where phosphorus is found in very low concentrations, the phytoplankton ingested contain little phosphorus, and the mussels retain the phosphorus in their tissues, because they need a certain minimum concentration of this essential element.

The anoxia problem can be related to weather, mussels, or a combination of both factors. In a warm year, the surface waters will warm quickly, shutting off connection with the deeper, cooler layers, where naturally occurring decomposition of organic matter that depletes oxygen will occur over a longer period of time. The zebra and quagga mussels may be playing a role in the anoxia problem if the excess, unutilized plant material such as *Microcystis*, filamentous algae, and other aquatic plants they stimulate get washed into the deep waters of the central basin to provide more organic material to decompose.