Madison's Lake Beaches
Results of a Three-Year Pilot Study

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Using floating booms to prevent blue-green algal scums and debris from fouling Madison's lake beaches

Introduction

Excessive growths or "blooms" of blue-green algae (cyanobacteria) commonly occur during the summer months (Figure 1) in the nutrient-rich Yahara lakes (Mendota, Monona, Waubesa, and Kegonsa) near Madison, Wisconsin. Such blooms are a serious health concern to humans and wildlife because certain species of blue-green algae can produce hepatotoxins, neurotoxins, and/or skin toxins leading to symptoms such as: liver and kidney lesions; and gastrointestinal, muscular, and respiratory symptoms including seizures and respiratory arrest. Although algal blooms often form throughout the lakes' upper well-mixed waters, some species of blue-green algae have gas vacuoles that cause the algae to rise towards the water surface when winds are relatively calm. Water currents from moderate winds then push the buoyant algae to downwind shorelines where the algae can pile up as thick mats or scums along with other floating debris such as cut aquatic plants ("weeds"), detached globs of filamentous algae, dead fish, and trash.

Besides scums and other floating debris piling up on the downwind shorelines of the Yahara lakes, the noxious material can also accumulate along other shorelines in protected backwater areas due to eddy formation from "long-shore" water currents moving laterally to the shoreline. Public beaches on the Yahara lakes are particularly susceptible to eddy formation and trapping material because many of the local beaches are constructed as tapered sand bottom cutouts into rip-rapped shorelines (Figure 2).

The floating debris can break up and move elsewhere when wind conditions change; otherwise the trapped debris remains until it decomposes producing a smelly noxious mess. While park staff periodically remove the cut weeds and other large debris to make beaches more aesthetic, blue-green algal scums, due to their watery nature, cannot be removed except by specialized pumping equipment that has not yet been widely applied for removing algae from lakes. Thus, when scums accumulate at beaches, the exposure risk of associated toxins is raised triggering public health officials to post advisories and close beaches until the scums dissipate and algal densities are no longer elevated.

While the ultimate solution to blue-green algal blooms in the Yahara lakes is reducing the level of nutrients that fuel the growth of algae – efforts that are the

Figure 1. Blue-green algal scum on the Yahara lakes (Lake Kegonsa, June 6, 2012) (photo: Dane County Land and Water Resources Dept.).

Figure 2. Algae pile-up in the protected shoreline cutout at B.B. Clarke Beach, Oct. 5, 2010 (photo: G. Steinhorst, City of Madison Engineering Dept.).

centerpiece of past and ongoing watershed management programs – this pilot study evaluated whether more limited measures such as relatively inexpensive floating booms could prevent scums and other floating debris from fouling public swimming beaches. Our article summarizes the results of a three-year experiment conducted during 2010-2012.

Materials and Methods

Three-sided “deflector” floating boom systems were deployed from June through August at B.B. Clarke Beach (Monona) in 2010-2012, Bernie’s Beach (Monona Bay) in 2010-2011 and then Olin Beach (Monona) in 2012, and Warner Beach (Mendota) in 2012. In addition, a single “interceptor” boom for trapping floating debris was tested at the UW Center for Limnology shoreline (Mendota) in summer 2010.

Environetics, Inc. (Lockport, Illinois), a company specializing in water baffles and liners for various environmental engineering applications, fabricated the booms with design specifications provided by project leaders. The boom systems were constructed to fit the rectangular swimming area dimensions and shoreline configurations for each beach.

Boom system design. Each deflector boom system consisted of three individual boom walls connected to form three sides of a trapezoid surrounding a beach’s swimming area (designated by floating ropes) with the much wider “base” of the trapezoid being the park shoreline extending beyond each side of the sand beach (Figure 3). Thus, the shorter endwall boom of the trapezoid was deployed parallel to shore just beyond the roped swimming area. The two longer sidewall booms were designed to ideally attach at the park shoreline with an approximate 120-degree angle on the outside corner of the trapezoid. This design allowed the obtuse-angled sidewall boom when subjected to long-shore currents to “deflect” floating material away from the beaches and out into the lake. During other times, floating material could be temporarily trapped outside the boom near shore.

Dimensions for the different boom systems deployed in 2010-2012 were:

B.B. Clarke Beach:
sidewall = 160 ft, endwall = 100 ft

Bernie’s Beach/Olin Beach:
sidewall = 140 ft, endwall = 100 ft

Warner Beach:
sidewall = 140 ft, endwall = 110 ft

Center for Limnology:
single boom = 100 ft

Each boom wall was constructed of 8 oz. polypropylene geotextile fabric. The boom wall’s floatation collar consisted of a series of 10-foot long Styrofoam tubes

Figure 3. Three-sided, trapezoid-shaped deflector boom system deployed at B.B. Clarke Beach during June-August 2010-2012 (photo: R. Lathrop, WDNR).

(6-inch diameter) covered by a double layer of fabric for extra durability (Figure 4). A hanging fabric curtain weighted with a ballast chain extended one foot below the floatation collar to ensure good interception of floating debris in the lake while allowing water to circulate freely underneath the boom. This design prevented water from stagnating within the swimming area. During windy periods with strong waves and water currents, the curtain was designed to "billow" sideways thereby reducing pressure on the boom wall. A stainless steel tension cable in the curtain directly underneath the floatation collar allowed each boom wall to be tightly stretched in a straight line between two anchoring points on the shoreline and/or in the water.

The total cost of the Warner Beach deflector boom system purchased in 2012 was a little more than $9,000, which included the cost of the boom, shipping, two floatation barrels and hazard buoys, and miscellaneous hardware. Concrete anchors were available or fabricated by county personnel. Based on experience with the booms deployed for three summers during 2010-2012, the booms are durable and should be usable for five years or more if they are air dried and stored in racks under cover at the end of each summer season.

Figure 4. Boom wall being unloaded from a barge, June 2012 (photo: R. Lathrop, WDNR).

Boom installation. Deploying each boom system required a county barge and boat plus crew (Figure 4). After unfurling a boom wall from the barge, the shore end of each sidewall boom was attached by chain to a large tree, rip-rapped boulder, or iron tie-down rod on shore. In the lake, each sidewall boom was connected to the endwall boom by bolting the curtain edges together to form a tight seal at each corner. Then the two boom tension cable ends on the outside of each boom corner were attached to a large floatation barrel. Ropes attached to each corner barrel allowed the barge and boat to stretch the three-sided boom system to its full size. Heavy concrete anchors were then placed in deeper water some distance away from the corners in the general direction of a perpendicular bisector of each corner angle to equalize the tension on the two boom walls. Finally, the anchors were chained to each floatation barrel with full tension put on the boom system to make all three boom walls straight while the floatation barrels prevented the boom corners from being pulled underwater. For safety, navigation hazard buoys were attached to each anchor chain.

Because the shoreline attachment point was usually well above the waterline, the boom wall tended to lift out of the lake near shore. That problem was rectified by placing a heavy block at the water's edge and chaining the boom's tension cable downward to the block at a point right next to the edge of the first floatation tube (Figure 5). A 5-ft piece of geotextile curtain fabricated on each sidewall boom's shore end helped ensure a tight seal at the shoreline to prevent floating debris from leaking into the swimming area.

Another problem was anchoring the deflector boom corners. For the more exposed beaches with relatively sandy lake bottoms, single block anchors weighing ~300 pounds shifted when high waves and strong water currents pushed on the boom walls causing the tension cables to slacken and the boom walls to bow. In 2011, new modified anchor blocks were installed that had an attached heavy steel plate extending below one edge of each block. With the anchor block positioned with the steel plate facing the boom corner, the plate acted like a shovel digging into the sand bottom with little anchor movement.

Water quality testing. Besides frequent observations made on each boom system's ability to keep algal scums and other floating debris from becoming trapped and accumulating at the various swimming beaches, water samples were collected regularly within each boom's enclosed swimming area and the area just outside of each boom sidewall. Algal densities and microcystin toxins were analyzed at the Public Health Madison–Dane Laboratory in 2010-2012 using rapid screening tests using a tiered approach. Following the microscopy for the abundance of taxa capable of producing the microcystin toxin, antibody-based microcystin strip testing was conducted on all samples. Microcystin ELISA (enzyme-linked immunosorbent assay) was conducted on a percentage of the samples, and when strip testing showed detections of microcystin.

The microcystin toxin test was used as a surrogate for the presence of other toxins produced by blue-green algae (e.g., anatoxin, saxitoxin, cylindrospermopsin) because the microcystin strip and ELISA tests were relatively rapid and inexpensive to perform. Precise testing for all toxins can only be conducted at laboratories

Figure 5. Concrete block and chain used to prevent boom wall from being lifted out of lake at shoreline (photo: R. Lathrop, WDNR).

having sophisticated analytical equipment. Because these analytical tests are very expensive and the turnaround time for results is long, the tests are not suitable for real-time health alerts. However, this testing was not needed during our study because samples were not collected with dense blue-green algae taxa capable of producing other toxins besides microcystin.

Results

B.B. Clarke Beach. The three-sided deflector boom system worked well at B.B. Clarke Beach (Figures 3, 6) during all three summers of boom deployment in 2010-2012 because this beach is often exposed to long-shore water currents (Figure 7). Beach users and lifeguards during informal interviews felt the beach was much cleaner with high public acceptance of the boom system. However, in 2010 the popular diving platform was not installed in deeper water beyond the boom endwall due to concerns that lifeguards could not easily traverse the boom wall if an emergency occurred. Experience showed that the boom wall was not a barrier (even acting as a safety float) such that the diving platform was installed in subsequent summers.

While blue-green algal blooms were particularly dense throughout the summers of 2008 and 2009 in both Mendota and Monona, algal bloom scums rarely occurred during the period when the deflector boom systems were deployed in 2010-2012. In 2010, a blue-green algal bloom occurred at B.B. Clarke Beach in late May prior to the deployment of the boom system and another algal bloom was present at the beach in early October after the boom system was removed (Figure 2). Microcystin toxin concentrations found in the fall bloom were greater than the highest measureable concentration (>125 µg/L) for a sample taken of the scum itself, and 8 µg/L for a sample taken below the scum layer. (For reference, 20 µg/L is the threshold limit established by the World Health Organization for microcystin health advisories in recreational waters.)

The only other significant algal bloom observed in 2010 was on July 7 when microcystin concentrations were recorded outside the deflector boom at 21-29 µg/L. No microcystin toxins were detected above the analytical reporting limit (4 µg/L) inside the boom system at that time. Algal densities remained low through the 2011-2012 swimming seasons. Only a trace level of microcystin was detected in four samples during 2012. Throughout the study period when algal densities were low, colony counts of non-scum-forming algae species inside and outside the boom system were relatively

Figure 6. Photo showing the deflector boom system preventing algal scums and other floating debris from entering the enclosed swimming area at B.B. Clarke Beach, June 2012 (photo: C. Betz).

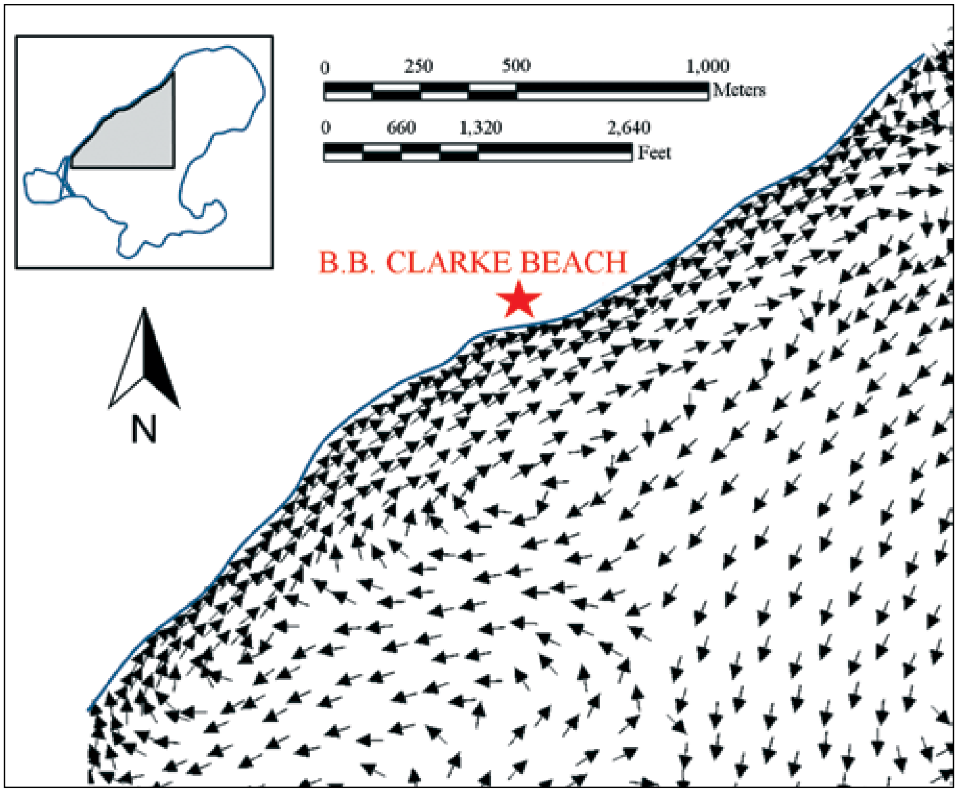


Figure 7. Diagram of the B.B. Clarke shoreline area in Lake Monona showing directional vectors of long-shore surface water currents occurring with prevailing southwesterly winds. (Source: J. Reimer, City of Madison Engineering Dept.)

similar – evidence that water was circulating under the boom walls.

In addition to the water sampling results, a photo taken by a lake user in June 2012 showcased how the western sidewall boom prevented algal scums and other floating debris from entering the swimming area (Figure 6). The floating material was trapped in the southwest corner of the boom at shore. No health advisory was posted at the beach during this period and the trapped debris later left the area. In another example of how floating debris interacted with the boom wall, photos taken every five minutes for a period of 90 minutes during mid-July 2010 showed a mass of floating aquatic plants moving along the sidewall boom to its end where the plant mass was released into deeper water.

Bernie's Beach. The deflector boom system deployed at Bernie's Beach (Figure 8) during the summers of 2010-2011 maintained the swimming area free of algal scums and other floating debris. Because of the more sheltered and restricted location of the beach area in the corner of Monona Bay, the two sidewall booms were attached to shore with outside wall angles only slightly greater than 90 degrees. Floating material was often observed trapped outside the corner of the west sidewall boom (Figure 9).

Algal densities at this beach were low in 2010 and 2011. Microcystin was detected only once on June 30, 2011 outside the boom system at a toxin concentration (16 µg/L) below the WHO threshold of 20 µg/L; the toxin was not detected above the reporting limit (4 µg/L) inside the boom system. No beach closures due to elevated algal densities occurred during the two years of boom deployment at Bernie's Beach (2010-2011).

Olin Beach. The deflector boom system tested at Olin Beach on Monona's southern shoreline in 2012 did not work particularly well even though the boom system itself was a good fit for the beach (Figure 10). The main problem was the swimming area inside the boom system was very shallow with a significant amount of aquatic plants and filamentous algae growing from the lake bottom. This area was cleaned out with a weed

Figure 8. Deflector boom system deployed at Bernie's Beach, June-August 2010-2011 (photo: R. Lathrop, WDNR).

Figure 9. Algae scum and other floating debris trapped outside the sidewall boom at Bernie's Beach, July 2010 (photo: G. Steinhorst, City of Madison Engineering Dept.).

Figure 10. Deflector boom system deployed at Olin Beach in 2012 showing aquatic plants and filamentous algae growing inside and outside the boom system (photo: R. Lathrop, WDNR).

harvester prior to installing the boom, but the filamentous algae quickly grew back into thick masses that created unappealing swimming conditions. This southwest beach shoreline often was on the upwind end of the lake where water currents could not remove the floating material trapped outside of the boom walls.

Warner Beach. The deflector boom system tested at Warner Beach in 2012 presented some challenges that were different from the other beaches tested. First, during prevailing southwesterly winds, Warner Beach on Mendota's northeast end had a very long fetch (longest distance waves travel unobstructed) and hence was subjected to high waves and strong water currents. While blue-green algal scums were not a problem in Lake Mendota in summer 2012, decaying filamentous algae fragments originating from shallow areas all over the lake apparently had passed underneath the boom walls and became trapped as a thick brown mass of rotting sludge suspended near the beach shoreline (Figure 11).

If park personnel had the capability to suction out this suspended material, then the deflector boom system at Warner Beach could be beneficial. Otherwise, further testing is needed to determine if the deflector boom can help prevent blue-green algal scums from entering the Warner Beach area. Although this beach exhibited dense algal blooms in 2008 and 2009, water quality testing in 2012 showed only low algal densities and only trace levels of microcystin measured outside the boom during four sampling events and no toxins detected inside the boom.

Single boom test (UW-Madison shoreline). The single boom tested at the UW Center for Limnology shoreline in 2010 was deployed with a 60-degree angle on the west side of the boom to trap material coming from that direction. However, floating material occasionally became trapped for short periods on the obtuse-angled side of the boom wall (Figure 12) due to prevailing winds that summer. While large scums did not occur in 2010, this test demonstrated that a single boom could intercept and temporarily trap floating material.

Summary and Recommendation

The three-sided deflector boom systems tested at lakes Monona and Mendota during the summers of 2010-2012 demonstrated that such boom systems could prevent swimming beaches in certain shoreline locations from becoming fouled with blue-green algal scums and other floating debris. Conclusions from our three-year pilot study indicated that deflector booms can work well on shorelines frequently subjected to long-shore currents that move parallel to the shoreline during prevailing winds. At upwind shorelines, booms may not work due to reduced water circulation. At downwind shorelines results from our one-year trial were inconclusive. While in theory floating material should be kept away from downwind beaches inside the boom system, suspended debris could become trapped inside the boom causing the swimming area to be fouled unless this material is removed.

Even though blue-green algal scums and associated toxins were not a major problem on the two lakes during the three study years, water quality monitoring confirmed that if blue-green algal densities were low, then the algae did not produce enough toxins to cause a health threat for water recreation users. On a few dates during the three-year study, microcystin toxins were detected above reporting limits outside the deflector boom systems, but toxins were *never* detected above reporting limits inside the boom systems.

While blue-green algal densities were relatively low during the three study summers, many suspended algae taxa had similar concentrations between the lake water outside the boom system and water inside the boom's swimming area. This finding substantiated that water was freely circulating under the boom walls and that water inside the swimming area was not stagnant.

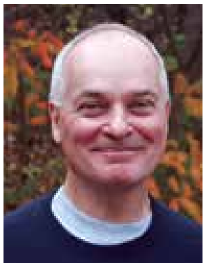
However, it is important to emphasize if non-scum-forming algae were dense and the algae were producing toxins, then deflector boom systems would not reduce the toxin exposure risk for people at beaches. Similarly, deflector booms would not reduce the exposure risk to pathogenic bacteria at beaches. Monitoring for elevated algae and bacterial levels should continue at beaches with boom systems, similar to monitoring done at other beaches.

Finally, our experiment did illustrate that relatively low-cost floating booms placed strategically around lake shorelines could be used in conjunction with other lake clean-up efforts to improve water quality and overall lake aesthetics. Some forms of floating debris (e.g., cut weeds, dead fish and trash) trapped by booms could be removed by more traditional mechanical measures (e.g., weed harvester conveyor systems) or hand tools. However, blue-green algal scums, due to their watery nature and safety concerns especially if the toxins were to become aerosolized, would require removal by specialized suction pump equipment. Such equipment is widely used in other applications (e.g., cleaning out storm sewer traps), so we encourage efforts to develop and test equipment for removing blue-green algal

Figure 11. Suspended debris in the water and on shore inside the deflector boom system at Warner Beach in late July 2012 (photo: R. Lathrop, WDNR).

Figure 12. Floating material trapped on the single boom deployed at UW Center for Limnology in 2010 (photo: R. Lathrop, WDNR).

scums. We believe removing such scums (including associated nutrients and toxins) and other floating debris as a routine in-lake management practice to enhance user enjoyment of eutrophic lakes would complement longer-ranging watershed pollution reduction efforts.



Dr. Richard C. Lathrop was a research limnologist for 33 years with the Wis. Dept. Natural Resources until retiring in 2010. He continues to work and volunteer on various lake research/management projects including the North-Temperate Lakes Long-Term Ecological Research Project conducted by the Center for Limnology at UW–Madison.

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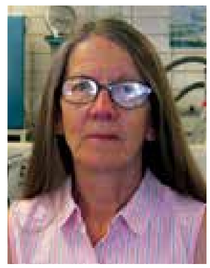

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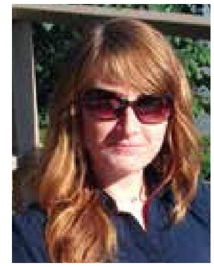

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