Floating booms to prevent blue-green algal scums and other floating debris from fouling Madison area swimming beaches: a pilot test

Richard C. Lathrop, Wis. Dept. Natural Resources
John R. Reimer, Madison Engineering Dept.
Kirsti K. Sorsa, Public Health Madison−Dane County
Genesis M. Steinhorst, Madison Engineering Dept.
Chin H. Wu, Univ. Wisconsin−Madison, Dept. Civil Environ. Engineering

Introduction

Excessive growths or "blooms" of blue-green algae (a.k.a. cyanobacteria) commonly occur during the summer months in the nutrient-rich Yahara lakes (Fig. 1). Such blooms are a serious health concern to humans and wildlife because certain species of blue-green algae can produce neurotoxins, skin toxins, and/or heptatotoxins 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 lake's 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 to obtain more light for photosynthesis. 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.

Fig. 1. Blue-green algal scum on the Yahara lakes. (Lake Kegonsa, June 2012; Photo credit: Dane County Land and Water Resources Dept.)

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 (Fig. 2).

The floating debris can break up and move elsewhere when wind conditions change; otherwise the trapped debris remains until it decomposes making a smelly noxious mess. While life guards and other 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 rarely (if ever) used to remove scums from any lake. 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.

Fig. 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.)

While the ultimate solution to blue-green algal blooms in the Yahara lakes is reducing the level of nutrients that fuel algae growth – efforts that are the centerpiece of past and ongoing watershed management programs – this pilot-scale project tested whether more limited measures could prevent scums and other floating debris from fouling public swimming beaches. To that end, experimental boom systems designed to prevent this fouling were deployed on lakes Mendota and Monona during the summers of 2010-2012. This report evaluates that 3-year experiment.

Materials and Methods

Three-sided 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. Environetics, Inc. (Lockport, Illinois), a company specializing in water baffles and liners used in various 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. For the Warner Beach boom deployed in 2012, minor modifications were made to the original boom design (discussed later). In addition, a single boom for trapping floating debris was tested at the UW Center for Limnology shoreline (Mendota) in summer 2010. (Results of that experiment are discussed at the end of this report.)

<u>Boom system design</u>. Each 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 (Fig. 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

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

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 would be temporarily trapped outside the boom near shore.

It should be noted that the deflector boom system was not designed to prevent non-scum-forming planktonic algae, bacteria or other suspended matter from entering the swimming area. Such algae would be expected to have similar concentrations between the lake water outside the boom system and water inside the boom. As such, if non-scum-forming algae were dense and the algae were producing toxins, then the deflector boom system would not reduce the toxin exposure risk for people at a beach with a deflector boom system deployed.

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 flotation collar consisted of a series of 10-foot long styrofoam tubes (6-inch diameter) covered by a double layer of fabric for extra durability (Fig. 4). A hanging fabric curtain weighted with a ballast chain extended one foot below the flotation 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 would "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.

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

The cost of the Warner Beach deflector boom system purchased in 2012 was $7,750 (plus $875 for shipping). The booms purchased in 2010 were comparable to 2012 costs although slightly discounted due to the booms being experimental prototypes for this application. Other items purchased for each boom system were floatation barrels, hazard buoys, and miscellaneous hardware. Concrete anchors were available or fabricated by county personnel. Thus, the total cost of materials for the 3-sided deflector boom system deployed in 2012 was about $9,000.

One minor design problem had to be rectified for the booms first tested in 2010. While the fabric gaps between each tube section allowed the long boom wall to be folded during transport and storage, the fabric gaps tended to sag when the geotextile fabric became waterlogged. To maintain the entire length of boom wall above the waterline, short sections of foam swimming “noodles” were inserted between the two fabric layers to stiffen the gaps on the boom walls fabricated in 2010. Minor design modifications were made that corrected this sagging problem for the new boom system tested at Warner Beach in 2012.

Boom installation. Deploying each boom system required a barge and a boat plus crew from Dane County (Fig. 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-rap boulder, or installed iron tie-down rod on shore. In the lake, the two sidewall booms were connected to the endwall boom by bolting the respective fabric curtain edges together to form a tight seal at each corner. Then the two boom tension cables 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 3-sided boom system to its full size. Heavy concrete block 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 attached by a long chain to each floatation barrel with full tension put on the boom system to ensure all three boom walls were straight while the floatation barrel prevented the boom corner 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 (Fig. 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.

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

However, the biggest problem that had to be overcome for successful deployment of the 3-sided boom system was anchoring the two boom corners. At Bernie’s Beach with mucky sediments and a more sheltered location, one heavy cement block anchor at each boom corner was sufficient. For the other more exposed beaches with relatively sandy lake bottoms, single block anchors weighing ca. 300 pounds tended to shift when high waves and strong water currents pushed on the boom walls. Thus, the tension on each boom wall was loosened causing the boom wall to bow. Extra anchors were added in 2010 to overcome this problem. In 2011-2012, 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. Once the anchor dug in, little boom corner movement occurred even at Warner Beach, a shoreline with one of the longest fetches on the Yahara lakes.

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 regularly collected 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. Other tests associated with algae blooms (e.g., suspended solids, chlorophyll-a, phycocyanin pigments, and nutrients) were sampled on the two boom systems deployed in 2010 and analyzed at the UW-Madison Microbiology Dept. (Prof. Trina McMahon's lab).

Because water samples were routinely assessed only as approximate algal densities at a colony level for colony-forming genera, precision for algal cell densities was low. Therefore, it was not feasible to use the World Health Organization's health alert threshold of 100,000 cells/mL. Consequently, a tiered approach was used to assess toxin exposure risk. Following the microscopy for the abundance of potentially toxic 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. Over the course of the three-year study, significant cell densities were rare and differences inside and outside the booms were deemed minor and not significantly different between samples. On the basis of experience for 2010 and 2011 monitoring, testing frequency was reduced from three times per week to once a week in 2012 unless conditions indicated further need for testing.

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 having sophisticated analytical equipment such as at the Wisconsin State Laboratory of Hygiene (WSLH). Because these analytical tests are very expensive and the turnaround time for results is long, the tests are not used for real-time health alerts. Arrangements were made ahead of time to have a few samples analyzed at WSLH during the summers of 2010-2011, but this testing was not needed because samples were not collected with dense blue-green algae taxa capable of producing other toxins besides microcystin.

Results

B.B. Clarke Beach. The 3-sided deflector boom system worked well at B.B. Clarke Beach (Figs. 3, 6) during all three summers of boom deployment in 2010-2012 because this beach is often exposed to long-shore water currents (Fig. 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 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 blooms rarely occurred during the period when the floatation boom systems were deployed (early to late June through late August in 2010-2012). A blue-green algal bloom was detected at B.B. Clarke Beach on May 25, 2010 prior to the deployment of the deflector boom system. Another algal bloom was present at B.B. Clarke Beach on October 5-6, 2010 after the boom system was removed (Fig. 2). Microcystin toxin concentrations found in this algal 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.)

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

The only other significant algal bloom observed in 2010 was on July 7 when microcystin concentrations were recorded in two samples outside the deflector boom at 21 µg/L and 29 µg/L. No microcystins toxins were detected above the analytical reporting limit 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 similar – evidence that water was circulating under the boom walls.

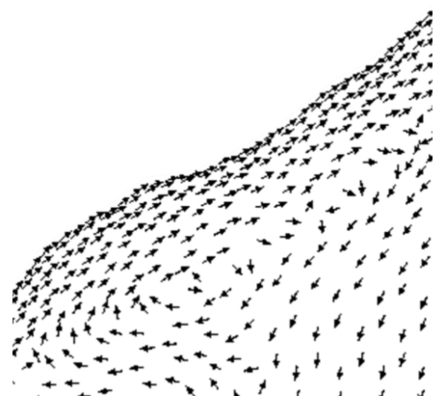

Fig. 7. Diagram of the B.B. Clarke shoreline area in Lake Monona showing directional vectors of long-shore surface water currents that occur when winds are from the southwest. (Source: J. Reimer, City of

In addition to these results, a graphic photo taken in June 2012 showcased how the western sidewall boom prevented algal scums and other floating debris from entering the swimming area (Fig. 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. Time-elapsed photos taken every 5 minutes for a period of 90 minutes during mid-July 2010 also showed how floating debris interacted with the same boom subjected to long-shore currents. In the sequence of photos, a mass of floating aquatic plants was filmed moving along the deflector sidewall boom to its end where the plant mass was released into deeper water.

<u>Bernie's Beach</u>. The deflector boom system deployed at Bernie's Beach (Fig. 8) during the summers of 2010-2011 maintained the swimming area relatively 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 (Fig. 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). The deflector boom system was moved to Olin Beach in 2012, as an in-situ swimming exclosure was tested at Bernie's Beach that summer.

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

Fig. 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.)

Fig. 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)

<u>Olin Beach.</u> 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 (Fig. 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. Some effort was made to clear out this area with a weed harvester prior to installing the boom, but the filamentous algae quickly grew back into think masses that created unappealing swimming conditions at the beach. 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.

Throughout much of the summer, Olin Beach appeared to get very little use as filamentous algae piled up on the edge of the beach's sand shoreline. During one period in July, the two sidewall booms were unhooked and tied to the endwall boom so that canoes and kayaks could be launched from the beach area. Only one water monitoring event took place at this site, yielding low algal densities and no detection of microcystin. The deflector boom was removed in mid-August prior to a recreational event.

<u>Warner Beach</u>. A new deflector boom system was tested at Warner Beach in 2012 (Fig. 11) as the location presented some challenges that were different from the other beaches tested during the previous two years. First, during prevailing southwesterly winds, Warner Beach on Mendota's northeast end had a very long fetch (the longest distance that waves travel unobstructed) and hence subjected to high waves and strong water currents. Modeling of water currents in Warner Bay indicated large opposing gyres of water currents (i.e., one circulating clockwise and one circulating counterclockwise) occur in the bay near the beach shoreline (Fig. 12). Thus, floating debris potentially could be intercepted by either or both sidewalls of the boom system prior to the surface water currents leaving the bay. These water circulation patterns helped explain why floating material sometimes accumulates in large amounts at Warner Beach (Fig. 13).

Fig. 11. Deflector boom system deployed at Warner Beach in 2012. (Photo: R. Lathrop, WDNR)

Fig. 12. Diagram of surface water currents in Warner Bay (Lake Mendota) where vectors show that opposing gyres of currents occur during southwesterly winds. (Source: J. Reimer, City of Madison Engineering Dept.)

The deflector boom system with the modified "shovel" anchors deployed at Warner Beach in 2012 did not appreciably shift due to strong wave action and water currents, although one corner anchor chain had to be readjusted after the anchors had "settled in." The boom system did appear to absorb some of the wave energy, calming the water in the shallow swimming area.

While blue-green algal scums were not a problem in Lake Mendota in summer 2012, decaying filamentous algae material originating from shallow areas all over the lake was particularly dense along the Warner Bay shoreline. This unaesthetic detrital material had entered the boom system and become trapped as a thick dark brown mass of suspended rotting sludge in a zone extending a few feet from the beach shoreline (Fig. 13). The park shoreline farther to the east also had this same sludge for a number of weeks, but the boom system likely would prevent the suspended material from leaving the beach when exposed to high winds.

Fig. 13. Suspended debris in the water and on shore inside the deflector boom system at Warner Beach in late July 2012. (Photo: R. Lathrop, WDNR)

If park personnel had the capability to suck 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 floating blue-green algal scums from entering the Warner Beach area. Although this beach exhibited dense algae blooms in 2008 and 2009, water quality testing over eight sampling events in 2012 showed only low algae densities and only trace levels of microcystin measured outside the boom during four sampling events. Toxins were not detected inside the boom systems during these four events.

Single boom test (UW-Madison shoreline). The single boom tested at the UW Center for Limnology shoreline in 2010 (Fig. 14) 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; material was rarely trapped on the boom side facing University Bay. While large scums did not occur in Lake Mendota during 2010, this test demonstrated that a single boom could intercept and temporarily trap floating material especially along shorelines subjected to long-shore currents.

Fig. 14. Floating material trapped on the single boom deployed at UW Center for Limnology in 2010. (Photo: R. Lathrop,

Summary and Recommendations

The 3-sided deflector boom systems tested at lakes Monona and Mendota during the summers of 2010-2012 were able to prevent swimming beaches in certain shoreline locations from becoming fouled with blue-green algal scums and other floating debris. While 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 during the study period.

Even though blue-green algal densities were relatively low and algal scums were rare throughout the three study summers, many suspended algae taxa were found (as expected) to have similar concentrations between the lake water outside the boom system and water inside the boom's swimming area. This finding substantiates that water was circulating under the boom walls and that water inside the swimming area was not stagnant.

However, it should be noted that the deflector boom system is not designed to prevent non-scum-forming blue-green algae, bacteria or other suspended matter from entering the swimming area. If such blue-green algae were dense and the algae were producing toxins, then the deflector boom system would not reduce the toxin exposure risk for people at a beach with a boom system deployed. Monitoring for elevated algae and bacterial levels should continue at beaches with boom systems similar to monitoring at other beaches.

Specific conclusions and recommendations based on this study are given below:

1. The deflector boom systems worked particularly well at B.B. Clarke Beach (Monona), a shoreline exposed to long-shore currents. Water testing and digital photo images documented that the boom system kept that beach's swimming area from being fouled with algal scums and other floating debris; a few instances were observed with the floating material on the outside of the boom wall being "deflected" into the deeper area of the lake and away from the swimming area. Thus, it is recommended that the boom system continue to be deployed at B.B. Clarke Beach as public acceptance is high.

2. The deflector boom system kept algal scums and other floating debris out of the swimming area at Bernie's Beach (Monona) while floating debris was trapped outside the boom wall near shore. It is recommended if the in-situ swimming exclosure were not to be used at Bernie's Beach in future years, then the deflector boom used in 2010-2011 be re-deployed.

3. The boom system did not work well at Olin Beach (Monona) on the upwind end of the lake where the swimming area is very shallow. Aquatic plant and filamentous algae growth was particularly dense and objectionable inside the boom system during 2012. This beach was also frequently used for recreational events requiring the launching of kayaks and canoes where the boom system was an obstruction. Thus, it is not recommended that a boom system be deployed at this beach in future years.

4. The boom system at Warner Beach (Mendota) was an inconclusive test as no blue-green algal scums were observed at that beach in 2012. However, a large amount of suspended detrital material (mostly decomposing filamentous algae) was trapped inside the boom system near (and on) the beach shoreline thus making it more difficult for the material to be flushed out during very windy days with strong water currents. Nearby shorelines also had large amounts of this suspended debris for extended periods, which coupled with information on the bay's water circulation patterns, indicated why Warner Bay is susceptible to debris piling up. Observations of this non-toxic debris indicated that it could potentially be removed by relatively inexpensive pumps capable of handling not only water but solids up to a certain diameter. Thus, further testing of the deflector boom system at Warner Beach is recommended in conjunction with testing of a pump system to remove the debris trapped near the beach shoreline inside the boom system. This pump system may be helpful in cleaning up other beaches, too.

5. Given the positive response of the boom system at B.B. Clarke Beach where long-shore currents are prevalent, it is recommended that other local beaches be evaluated as possible candidates for deflector boom deployment tests.

6. The single floatation boom tested at the UW Center for Limnology (Mendota) in 2010 indicated that booms could trap floating material and temporarily prevent its movement to other locations. If equipment could be designed and tested to remove such trapped material, then a network of booms strategically placed around a lake's shoreline could help provide cleaner public beaches and other shorelines.