Otter Lake '05—A Successful Response

A Case Study of a Successful Response to a Potentially Toxic *Cylindrospermopsis raciborskii* Bloom

Terri Holland, Ann St. Amand, & Greg Good

Introduction

Since the 2001 discovery of a *Cylindrospermopsis raciborskii* bloom in Ball Lake, Indiana, Midwestern states have been looking more diligently for this invasive, toxigenic species (Figure 1). *C. raciborskii*'s small size, highly variable taxonomy, and atypical bloom habit (it does not form scums) make it a challenging algal species to monitor (St. Amand 2002). While concerned about these findings in surrounding states, the Illinois Environmental Protection Agency (IL EPA) didn't necessarily feel an urgent need to grapple with how to monitor and respond to *C. Raciborskii* blooms because *C. raciborskii* had never been clearly identified in Illinois waters—at least not by IL EPA. That said, Illinois has had an extensive monitoring program in place for several decades, patterned after the National Water Quality Monitoring Council's *Framework for Water Quality Monitoring* (Figure 2).

Algal community monitoring has been a part of the Illinois Ambient and Clean Lakes Monitoring Programs since the mid-1980s and includes algal identifications, often down to the species-level, cell counts, and biovolume estimates. These data exist for approximately 104 lakes and reservoirs in Illinois. Fortunately, all analyses to date have been conducted by a single experienced phycologist, Dr. Larry O'Flaherty (Western Illinois University), which has helped tremendously with data consistency. Despite no known documented *C. raciborskii* blooms in Illinois, there were numerous recorded bloom events

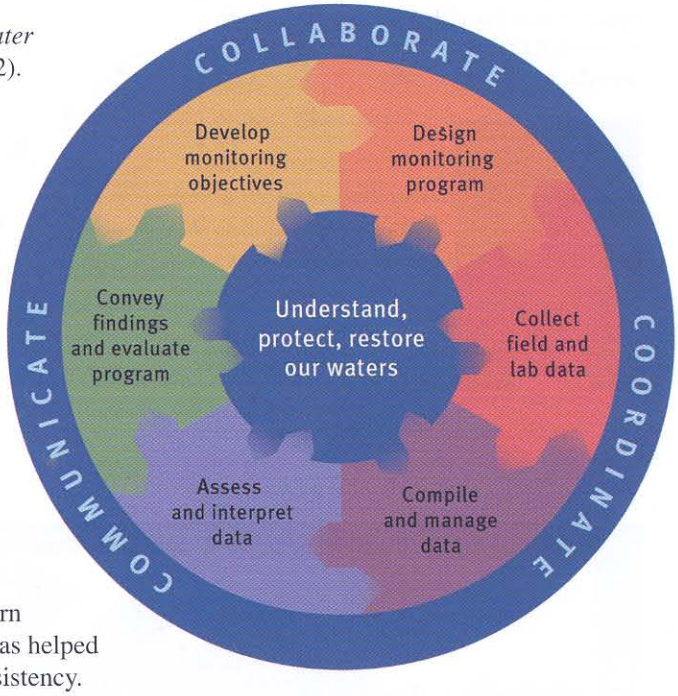

Figure 2: Framework for Water Quality Monitoring. National Water Quality Monitoring Council.

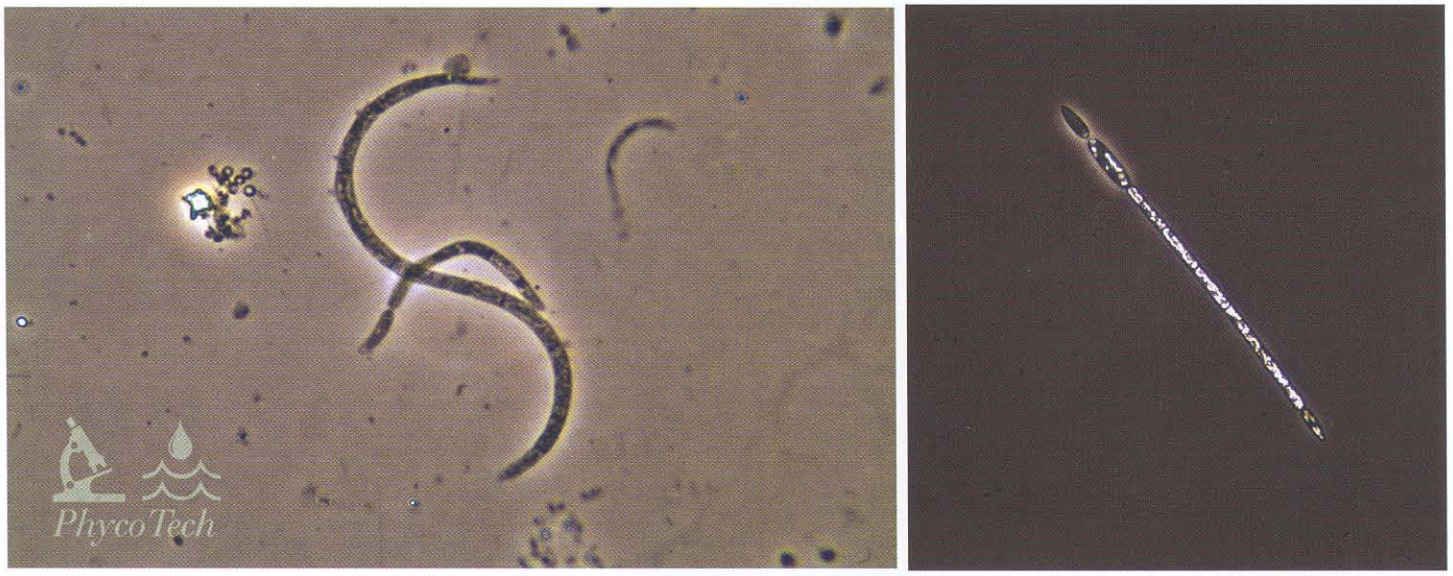

Figure 1. Cylindrospermopsis raciborskii, *curled morph and straight morph (left and right, respectively, both panels: 1000x, phase)*

over the years of a species with similar temperature and habitat requirements, *Raphidiopsis curvata*.

Otter Lake Bloom Event

Otter Lake, a 765-acre drinking water supply reservoir located in south-central Illinois, is very familiar to IL EPA staff. Otter Lake and IL EPA have been working together for ten years on projects conducted through the Illinois Clean Lakes (ICLP) and Nonpoint Source (NPS) Pollution Control Programs. Otter Lake officials contacted IL EPA staff in July 2005 when they began to experience taste and odor problems as a result of an algal bloom. The hot, dry conditions throughout Illinois during the summer were creating numerous algae-related problems. To identify the cause of the taste and odor problem, a water sample was collected July 22, 2005 and sent to Dr. Larry O'Flaherty, who, although recently retired, looked at the sample and reported it to contain high counts of *R. curvata*. We heard that *C. raciborskii* could easily be misidentified as *R. curvata* due to overlapping descriptions and *C. raciborskii*'s relatively new appearance in North America (Ann St. Amand, personal communication). Furthermore, there was additional evidence to suggest that *R. curvata* is genetically identical to *C. raciborskii* (Gugger et al. 2005) and both species produce cylindrospermopsin, a highly potent liver toxin, as well. For these reasons, a second Otter Lake sample was collected July 28, 2005 and sent to Dr. St. Amand, who confirmed the presence of *C. raciborskii* in Otter Lake at a cell count exceeding 305,000 cells/mL. Coincidentally, the taste and odor problem had nothing to do with the *C. raciborskii* bloom!

The confirmation of a *C. raciborskii* bloom in Otter Lake was crucial because three days later Otter Lake was hosting a cardboard boat regatta as part of a Sesquicentennial celebration. The safety of regatta participants, as well as other recreational lake users, was at stake. In 2001 when *C. raciborskii* cell counts exceeded 300,000 cells/mL in Ball Lake, Indiana, officials issued a recreational use advisory for the lake. The Ball Lake advisory was removed after it was confirmed that a several-inch rain had reduced toxin levels to just above detection. In light of a potential human health risk at Otter Lake, IL EPA managers needed to know how to advise Otter Lake officials regarding the regatta and whether or not to issue a health alert for the lake, which is where the "3 C's" of the Framework for Water Quality Monitoring really come into play: collaborate, coordinate, and communicate.

Risk Assessment and the Decision Process

Although the decisions made during the two-three weeks of the bloom event were not made according to any grand plan, they did, in hindsight, loosely follow standard risk assessment for human health risk. Risk assessment has been commonly used for other human health threats over the years such as risk of chemical exposure in an industrial setting, but it's a relatively new approach within water quality. The method for risk assessment that we are starting to implement worldwide is based on guidelines published by the World Health Organization (WHO) which outlines risk from source to supply, including assessment and monitoring, and not just at

Using a risk assessment matrix, initial assessment is based on not only risk of a poor outcome (in this case human exposure to high concentrations of toxins), but also probability of that outcome. So for Otter Lake, we knew that *C. raciborskii* was blooming in concentrations well exceeding 300,000 cells/mL. WHO recommends shutting down recreational water supplies to contact if the concentration of toxin producing blue-green algae exceeds 100,000 cells/mL due to the high probability of the presence of toxins. The cardboard boat regatta could put people in direct contact with the water for an extended period of time. So already, professionals in IL EPA and at Otter Lake were leaning toward a conservative action plan.

In a formal risk assessment, the next tier of assessment would be to determine whether the *C. raciborskii* population in Otter Lake was, in fact, producing cylindrospermopsin. That was unknown, and would take several more days of field and laboratory work to determine. Historically in southern systems in the U.S., at least in the late 1990s and early 2000s, *Cylindrospermopsis* produced toxin consistently and at high concentrations. This trend started to reverse around 2002-2003, where *C. raciborskii* populations were reported as not producing toxins in high concentrations. Recent data from 2004 and 2005 indicate that, at least in Florida, where specific lakes that maintain dense populations, *C. raciborskii* has started to produce cylindrospermopsin on a more frequent basis, but still at relatively low levels (0.1-1.6 μg/L) compared to 1999-2000 values. Continued monitoring on more lakes is necessary to see if this trend continues (Williams et al. 2006, Williams et al. 2001).

In the case of Otter Lake, our risk of a poor outcome given exposure was high. In other words, if *C. raciborskii* was producing toxin, the risk of exposure was very high because of the nature of the regatta. Our uncertainty about whether toxin was actually being produced was moderate. Other surrounding Midwestern states had been closing down lakes with confirmed toxic algal blooms for weeks, but most were a result of microcystin (a different toxin produced by different algal species), and none for cylindrospermopsin. These factors added up to a moderately high human health risk. Again, implementing the "3 C's" approach, in close association with all of the stakeholders, Otter Lake officials followed an IL EPA recommendation (not requirement) and canceled the cardboard boat regatta on Saturday, July 30, 2005. On the following Tuesday, August 2, Otter Lake officials issued a press release, which was followed by a potential recreational heath advisory posting at the lake.

Study Plan

On Monday August 1, 2005, IL EPA hosted a meeting with local and state health departments, lake managers, the Indiana Department of Public Health, leading phycologists, and representatives from the IL EPA's Division of Public Water Supply to outline a course of action for addressing the harmful algal bloom (HAB) conditions in Illinois. While no decisions were reached for when and how to issue a health alert for Illinois waters, IL EPA decided to immediately implement a study in Illinois for toxigenic algae.

The first objective of this study was to determine if the *C. raciborskii* population at Otter Lake was producing toxins, cylindrospermopsin in particular, and if it were, to ascertain the public health risks associated with recreational and public water supply uses. The second objective was to determine the distribution of *C. raciborskii* in the state. Within one week of confirming the *C. raciborskii* bloom at Otter Lake, IL EPA was able to secure almost $10,000 to conduct the study and initiate a contract with Green Water Laboratories in Florida to conduct the analyses.

The first study objective specifically addressed concerns at Otter Lake, but this objective was quickly expanded to include a southern Illinois reservoir. Marion City Reservoir also serves as a recreational and drinking water supply reservoir. The reservoir was experiencing algae-related problems, similar to those at Otter Lake. However, Marion officials treated the reservoir with copper sulfate to kill the algae. An unfortunate sequence of events that followed the treatment resulted in a massive fish kill due to low dissolved oxygen concentrations. Since the fish kill occurred at about the same time as the Otter Lake bloom, IL EPA staff began to wonder about the possibility of toxins in the water as a result of the copper sulfate treatment. If *C. raciborskii* had been present and producing toxins at the time of treatment, any toxin released from the dead *C. raciborskii* may still be in the water. Since there was no way of knowing which algal species were actually present at the time of treatment, Marion City Reservoir raw and finished water samples were analyzed for cylindrospermopsin, anatoxin-a, and microcystin. Because the algal species of concern at Otter Lake was known, raw and finished water samples from Otter Lake were analyzed for cylindrospermopsin and anatoxin-a only.

The second study objective included a plan to sample as many reservoirs as possible in Illinois during a one-week period beginning August 8, 2005. Personnel and budget constraints limited the scope of the study, but regardless, samples were still collected at 15 central and southern Illinois multi-purpose (drinking water and swimming) reservoirs; three southern Illinois farm ponds because of livestock watering concerns, and four sites along the Fox River, a slow-moving, low-gradient stream located in northeastern Illinois. For the most part, both raw and finished water samples were collected if a site was a source of drinking water. For other sites, an integrated raw water sample was collected. Green Water Laboratories performed identification and cell counts for blue-green algae first. Other analyses were determined based on the species identified and the cell counts obtained. If no toxigenic species were identified, no further analyses were performed. If the species identified was a known toxin producer, samples were analyzed for the toxin most likely to occur (e.g., microcystin when *Microcystis*, or other species capable of producing microcystin, was identified). The cost of toxin analyses was an issue, and consequently, toxin analyses were limited to nine of the 22 sites included in the study.

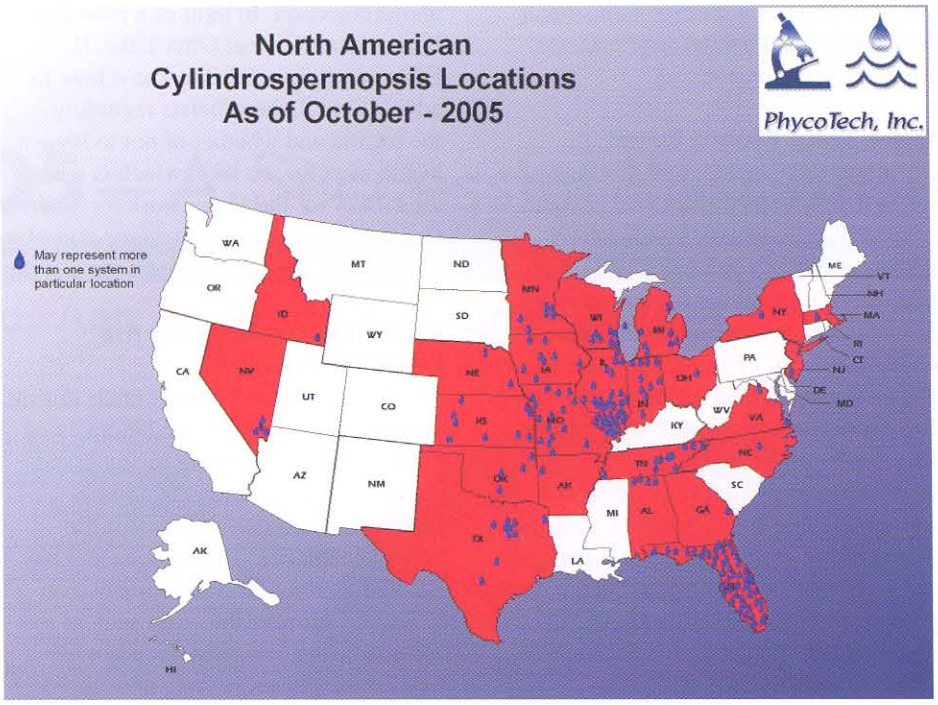

Figure 3. North American Occurrence of Cylindrospermopsis raciborskii *(combination of data from PhycoTech and other contributing studies).*

Results

No toxins were detected in any of the raw or finished Otter Lake water samples tested. In fact, cylindrospermopsin was not detected in any sample analyzed, even with *C. raciborskii* densities exceeding 300,000 cells/mL. Low levels (0.09 and 0.01 μg/L) of microcystin were detected in the Marion City Reservoir raw water sample, but again, no toxins were detected in finished water. In addition to the Marion City Reservoir raw water sample, microcystin was detected in all four Fox River samples at concentrations varying between 3 and 8 μg/L. The only other sample with detectable toxin levels was the Cedar Lake (southern Illinois) integrated water sample. Very low levels of anatoxin-a (0.05-0.01 μg/L) were detected.

C. raciborskii was found in 45 percent of all sites sampled, but at densities exceeding 100,000 cells/mL in only two, Otter Lake and Sam Dale Reservoir (Figure 4). When considering the presence of any toxigenic algal species, we find that they occur in 87 percent of the reservoirs sampled, 67 percent of the farm ponds, and 100 percent of the Fox River sites sampled (Figure 5). Of the 19 sites with toxigenic species, densities exceeded 100,000 cells/mL at eight of the sites sampled, or 36 percent of the sites. The highest density of toxigenic species was found in a Fox River site. At this site, the density of toxigenic species was greater than 1.3 million cells/mL. *Microcystis* and *Planktothrix agardhii* accounted for more than 90 percent of the total cell numbers.

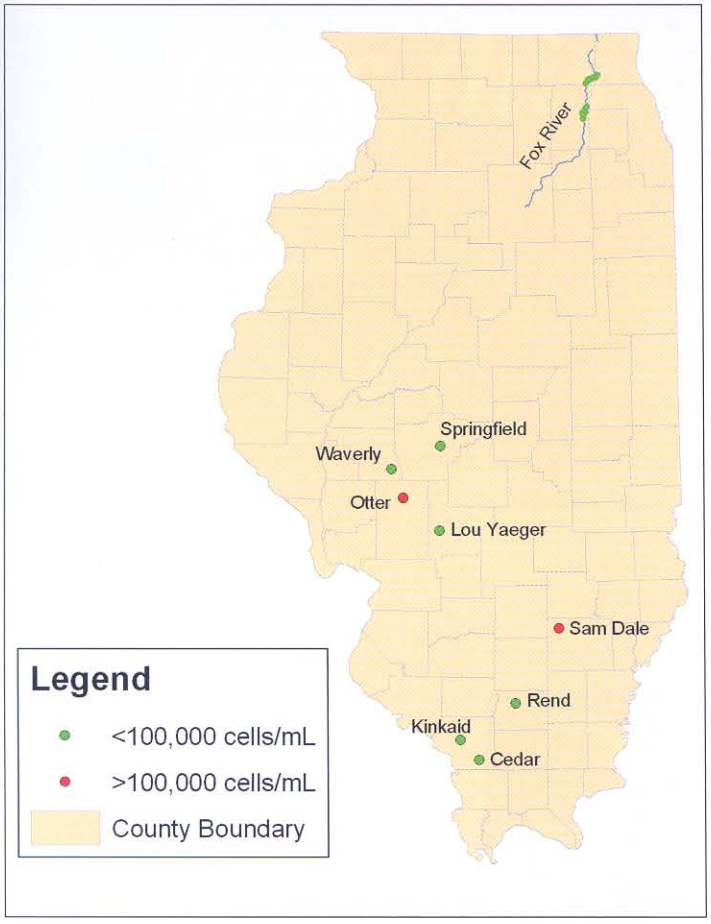

Figure 4. 2005 IL EPA sampling sites with Cylindrospermopsis raciborskii *detected.*

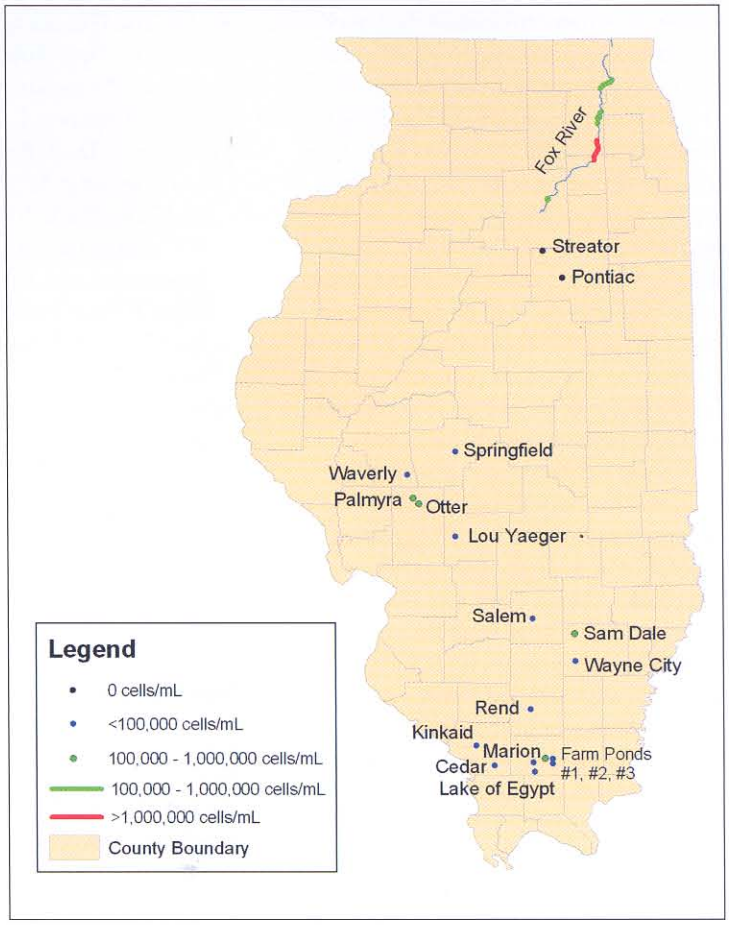

Figure 5. 2005 IL EPA sampling sites with all toxigenic algae identified.

Discussion

On a general level, we can say that we were able to answer the first, primary question. The *C. raciborskii* population in Otter Lake was not producing toxins at the time of sampling, nor does it seem likely that any population of *C. raciborskii* identified in Illinois during the summer of 2005 was producing toxins at the time of sampling, at least not cylindrospermopsin.

The concentration of anatoxin-a in Cedar Lake was reported at a level between the analytical methodology established detection and quantification limits, so the actual concentration of anatoxin-a in this raw water sample is unknown. The presence of large numbers of dead *C. raciborskii* cells observed in this sample may indicate that toxins were released from the cells during a recent bloom die-off, but results should be interpreted with caution. Overall, these findings are not particularly surprising in light of similar findings in Indiana and other states during the summer of 2005 (William Jones, personal communication).

It also came as no real surprise that C. *raciborskii* was found in 45 percent of the sites sampled, especially considering that reservoirs where *R. curvata* had previously been identified were targeted for this effort. A somewhat unexpected result from this study was the prevalence (86 percent of the sites sampled) and abundance of toxigenic algal species found. For 36 percent of the sampled sites, cell counts exceeded 100,000 cells/ml, a density level that represents a WHO guideline for a moderate health alert in recreational waters. At this density, toxin concentrations of 20 μg/L are likely if the bloom is dominated by *Microcystis* (WHO 2004). Fortunately, we did not detect toxin concentrations near that level in our study.

No toxins were detected in finished water during this study, but only two finished water samples were analyzed for toxins (Otter Lake and Marion City Reservoir). Of the two sites, toxins were detected in raw water, albeit at low concentrations, at Marion City Reservoir only and these levels were reduced to below detection due to water treatment. It seems likely that current water treatment processes effectively remove cyanobacterial cells and cyanotoxins, especially at the levels detected, but the actual effectiveness is mostly untested in Illinois. Water treatment plant operators and lake managers are cautioned that management practices leading to cell lysis (e.g., copper sulfate application at Marion City Reservoir) may increase the risk of cyanotoxins in source water.

With high densities of potentially toxic cyanobacterial species found in more than a third of the Illinois sites sampled, the HAB issue is one that IL EPA cannot afford to overlook. While documented cases of harmful human health effects due to algal toxins are few in the U.S., it is likely that at least some cases go unreported due to the general inability to recognize adverse health effects and make a correlation between those effects and a recreational exposure to algal toxins. With an ever-increasing recreational demand for our surface

waters, it is more important than ever to continue monitoring efforts that can adequately assess human health risks due to recreational exposure to algal toxins. In this 2005 study, the observed frequency and abundance of some microcystin-producing algal species suggest that microcystins may be more of a threat in Illinois surface waters than some of the other cyanotoxins. Although no formal plan is in place at this time, IL EPA will continue to work with partners to define protocols for detecting toxic conditions in multi-purpose reservoirs and rivers.

In the final analysis, it was the relationships built through established partnerships that made the biggest difference in the response to the Otter Lake bloom. For Otter Lake, it was the relationships built through years of involvement with ICLP and NPS programs that led Dennis Ross, General Manager of the Otter Lake Water Commission, to seek guidance in dealing with an algal driven taste and odor problem. For IL EPA, it was the partnerships that existed between Illinois state agencies and those developed among other states' agencies and professionals that allowed them to gather information quickly, make appropriate recommendations to Otter Lake officials, and develop a monitoring plan, all within a very short time period. Ultimately, it was a matter of trust that prompted Ross to cancel the regatta and post a recreational health advisory for Otter Lake, knowing that by doing so he could negatively impact reservoir use in the future. In 2005, communication, collaboration, and coordination ("3 C's", Figure 2) were the guiding principles in Illinois. The importance of developing and fostering partnerships at the local, state, and federal level cannot be overemphasized.

References

Gugger,M., R. Molica, B. LeBerre, P. Dufour, C. Bernard, and J.F. Humbert. 2005. Genetic Diversity of Cylindrospermopsis Strains (Cyanobacteria) Isolated from Four Continents. *Applied and Environmental Microbiology*, 71(2):1097-1100.

St. Amand, A. 2002. Cylindrospermopsis: An invasive toxic alga. *LakeLine*, 22(1):36-38.

WHO. 2004. Guidelines for Drinking-water Quality. Third Edition, Volume 1, Recommendations. Geneva: World Health Organisation. 515 pp.

Williams, C.D., J. Burns, A. Chapman, L. Flewelling, M. Pawlowicz, and W. Carmichael. 2001. Assessment of Cyanotoxins in Florida's Lakes, Reservoirs, and Rivers. Florida Harmful Algal Bloom Task Force, St. Johns River Water Management District. Annual Report.

Williams, C.D., J. Burns, A. Chapman, M. Pawlowicz, and W. Carmichael. 2006. Assessment of Cyanotoxins in Florida's Surface and Drinking Water Resources (2000). Florida Harmful Algal Bloom Task Force, St. Johns River Water Management District. Annual Report.

Ann St. Amand has been involved in managing lakes across the United States since 1990, as President of PhycoTech, Inc., and is a Certified Lake Professional. St. Amand has processed well over 20,000 algal samples in her career and has co-chaired a workshop on Algal Identification at the annual NALMS symposium since 1991. She is currently serving as Secretary for NALMS.

Gregg Good is the manager of Illinois EPA's Bureau of Water, Surface Water Section. He has been employed with the Agency for 21 years, and oversees the development and implementation of inland lake, river/stream, and Lake Michigan Clean Water Act Section 305(b)-related monitoring and assessment activities.

Teri Holland is employed as a lakes biologist with the Illinois EPA's Bureau of Water, Lakes Unit. She manages the Illinois Clean Lakes Program.