A Minnesota Story: Urban Shallow Lake Management

William Bartodziej, Peter W. Sorensen, Przemyslaw G. Bajer, Keith Pilgrim, and Simba Blood

Carp, alum, water quality, and aquatic plants

Introduction

The Ramsey-Washington Metro Watershed District (RWMWD) manages surface waters in a 65-square-mile watershed located on the eastern side of the Twin Cities Metropolitan Area in Minnesota. As part of its directive, the RWMWD leads efforts to improve the water quality of lakes that are considered "impaired" by the Minnesota Pollution Control Agency (MPCA). Management efforts on one of these waters, Kohlman Lake, have substantially improved water quality while also creating the need to address citizen expectations regarding aquatic plant abundance in the lake.

When dealing with impaired lakes having excessive total phosphorus (P), the standard process involves Total Maximum Daily Load (TMDL) studies that look for management practices to reduce P inputs from both watershed and in-lake sources. In shallow Minnesota lakes, the two most common practices for reducing in-lake P inputs is alum treatment and the reduction of bottom feeding fish, such as the common carp (*Cyprinus carpio*). In the United States, carp is an invasive species that can significantly degrade lake systems. It feeds on the lake bottom, which uproots aquatic plants and increases water turbidity. This physical disturbance of the lake bottom can facilitate the release of P into the water. Carp also function as a "biological pump" by foraging on benthos and excreting metabolites into the water column.

In 2008, Kohlman Lake was placed on the MPCA's 303(d) Impaired Waters List due to excessive P levels (growing season ten-year average of 98 µg/l). Here we provide a detailed account of the alum treatment and carp management approaches used to address internal P loading in Kohlman Lake. We report results and relate these to MPCA standards that were set for the lake. We discuss how the change in lake water quality corresponded to an increase in aquatic plant cover, and the management challenges that now exist.

Characterizing Kohlman Lake

Kohlman is the northernmost lake of the Phalen Chain of Lakes in the eastern portion of the Twin Cities (Figure 1). Water flows from Kohlman Lake (residence time 30 days) to the south and eventually drains into the Mississippi River. Kohlman Lake is polymictic, small, and shallow (88 acres, maximum depth of 12 feet, and a mean depth of 4 feet), with the littoral area covering the entire lake surface. Approximately 50 percent of the shoreline is in private ownership, with 37 single-family homes sharing the water's edge. A majority of these residents are members of the Kohlman Lake Association.

Kohlman is a popular lake for recreational boating, wildlife viewing and fishing. The lake supports several species of native fish, including bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), and stocked tiger muskie (*Esox masquinongy* x *lucius*). Prior to management, even with a robust carp population and high P levels, Kohlman Lake was not in a perpetual algae-dominated state. Algal blooms did take place during the summer months, but the lake was still able to support a submersed aquatic plant community that was dominated by the native coontail (*Ceratophyllum demersum*) and flatstem pondweed (*Potamogeton zosteriformis*), the invasive non-native Eurasian watermilfoil (*Myriophyllum spicatum*), and curly-leaf pondweed (*Potamogeton crispus*). In addition, a fringe of white water lily (*Nymphaea odorata*) encircled the lake. Plant control efforts focused on dock areas and boat channels (Figure 2).

The management plan

The RWMWD completed a comprehensive TMDL investigation for Kohlman Lake where both in-lake and watershed loading were estimated. The total P contribution from the watershed was estimated at 943 lbs. during an average precipitation year. From sediment core analyses, the maximum potential loading rate of P under anaerobic conditions was estimated to be 9.7 $mg/m^2/day$. The loading rate of P from senescing curly-leaf pondweed in the lake was estimated at 1.54 $mg/m^2/day$ (James et al. 2001). These estimates were used to calculate a combined average seasonal internal P load of 290 lbs. The P release from carp feeding activity was not figured into these calculations.

For shallow lakes like Kohlman, the state standard for P is 60 µg/L. In order to reach this goal, we focused on reducing both watershed and internal loading. Mass balance modeling suggested that growing season reductions of 209 pounds (22 percent) of P from watershed loading and 255 pounds (88 percent) from internal loading would need to be achieved. The TMDL outlined numerous large-scale watershed BMP projects to be implemented in a stepwise manner over the next 20 years (Aichinger and Wentz 2012). Below, we provide detail regarding the in-lake alum treatment and carp

Figure 1. Map of the Phalen Chain of Lakes.

management that we used to address the internal P loading.

Alum treatment

In order to clear the lake bottom for the alum treatment, two large-scale (nearly whole lake) herbicide applications were conducted to reduce the abundance of two invasive species, curly-leaf pondweed and Eurasian watermilfoil. In 2008, 95 percent of the lake area was treated with liquid endothall at a dose of 1.0 ppm to reduce curly-leaf pondweed. In addition, this same lake area was treated with liquid triclopyr at a dose of 0.5 ppm to reduce Eurasian watermilfoil. In spring 2009, Eurasian watermilfoil was not observed, but curly-leaf pondweed was present. Hence, a repeat treatment of endothall (1.0 ppm covering 95 percent of the lake area) was conducted to treat the remaining curly-leaf pondweed. Spot treatments (total area equaling less than 10 acres) targeting these two species have taken place since the last whole lake treatment.

Figure 2. A 2006 aerial photo of Kohlman Lake showing a fringe of white water lily around the shore and maintained boat lanes to open water.

Approximately 33,000 gallons of liquid aluminum (Al) sulfate [$Al_2(SO_4)_3 \cdot 14(H_2O)$] with 4.4 percent Al by weight, and 11,000 gallons of liquid sodium aluminate [$NaAl(OH)_4$ in the hydrated form] with 10.4 percent Al by weight composed one alum treatment. Two treatments were conducted, one in fall 2009, and one in spring 2010, when lake temperatures were above 50^o F. Using a barge, alum was applied to the entire lake surface area except for a 50-foot buffer zone along the lake shoreline. A 3:1 ratio (3 gallons of aluminum sulfate for every 1 gallon of sodium aluminate) was used to ensure that the pH of the lake water was maintained between 6 and 9. A GPS mapping and dosing system ensured that the treatment was evenly distributed throughout the lake. In order to ensure acceptable lake pH, minor dosing rate changes were made based on continual in-lake pH monitoring.

Carp research and management

In 2009, the RWMWD began a study with the University of Minnesota to investigate common carp ecology and population dynamics in the Phalen Chain of Lakes. Carp biomass was estimated at 160 lb. ac^{-1} for Kohlman Lake. Biomass over 100 lb. ac^{-1} often has negative impacts to water quality through lake-bottom disturbance and nutrient release (Bajer et al. 2016). In addition, Huser et al. (2016) found that carp mixed sediments to a depth of 6 inches, and this increased physical mixing could reduce the effectiveness of alum treatments. We also learned that bluegill sunfish, through carp egg and larvae predation, were inhibiting carp recruitment in the Phalen Chain (Silbernagel and Sorensen 2013). Mark-recapture studies revealed that young-of-year carp were migrating to the main lakes from nursery areas comprised of smaller connected shallow lakes and wetlands that experience fish winterkill (Bajer et al. 2012; Koch 2014).

Long-term management called for the reduction of adult carp in the main lakes to under 100 lb. ac^{-1}, while simultaneously eliminating carp in nursery areas and sustaining game fish communities as a natural carp bio-control. Beginning in 2010, we used winter netting under the ice to remove adult carp (Figure 3). Over

Figure 3. Commercial fisherman used seine nets under the ice to harvest common carp in the Phalen Chain of Lakes.

the last couple of years, we set baited box-nets in the summer to trap adult carp (Figure 4). Through these efforts, we reduced the adult carp population from 8,000 to 2,000 adults in the Phalen Chain, with a biomass currently estimated at 40 lb. ac^{-1} in Kohlman Lake. We are now well under our 100 lb. ac^{-1} management goal. Through winter drawdowns, we were also able to eliminate adult and young-of-year carp in connected spawning/nursery areas.

Figure 4. Common carp are harvested in the summer by using a baited box net.

Kohlman Lake's response

Kohlman Lake's water quality has significantly improved since the commencement of the TMDL plan (Figure 5 a,b,c). Seasonal averages for P, chlorophyll-*a*, and Secchi depth were below the MPCA standards set for shallow lakes. In 2020, RWMWD lakes will again be assessed for impairment under MPCA guidelines. If Kohlman Lake's water quality remains consistent over the next few years, there is the possibility of "de-listing" this lake as an impaired water of the state for P.

The aquatic plant community responded to the herbicide treatments, carp biomass reduction, and the increase in water clarity. Eurasian watermilfoil and curly-leaf pondweed occurrence have remained at low levels (Figure 6), while coontail continued to express some of the highest frequency of occurrence levels. One native species, Canada elodea (*Elodea canadensis*), has become abundant after the TMDL implementation, with occurrence levels ranging from 30 to near 70 percent (Figure 7). Beginning in 2013, field observations indicated that mats of surfaced vegetation, consisting mainly of coontail and Canada elodea, were increasing, and these mats were typically colonized with large expanses of filamentous algae (Figure 8). In response to the increase in plant abundance, the RWMWD decided to support mechanical harvesting for two years on an experimental basis (Figure 9). Boating channels were cut and an open water area was maintained for recreation (Figure 10).

Water quality standards and citizen expectations

At the beginning of Kohlman Lake's TMDL management effort, there was widespread support for improving water quality and reducing invasive plant and animal species. The shallow lake water quality standards seemed to mesh quite well with citizen goals for Kohlman Lake. One of our educational messages at the beginning of the project was that aquatic plant cover would likely increase with improved water quality. This probable response was based on numerous published shallow lake studies that describe a "clear water state" where aquatic plants take advantage of increased water transparencies and become abundant. The key issue today with Kohlman Lake's condition has to do with exactly how the plant community responded to the increase in water quality. A modest increase of coontail and Canada elodea may have been tolerated by informed citizens. However, the presence of large expanses of surfaced plant mats with filamentous algae growing on top seemed to be the tipping point. Many residents around the lake were troubled by the look and described this type of algae as "bobbing expanses of green steel wool." Floating mats of coontail migrated around the lake and caused a nuisance for boaters, skiers, and severely clogged beach and dock areas. This plant response is not acceptable to a majority of the lake-users and frustration has become evident.

Aquatic plant management

The Kohlman Lake Association, while generally recognizing the improved water quality, is now seeking an agency to take the lead and develop a long-term solution to control aquatic plants and filamentous algae. However, in Minnesota, there is not an agency that heads aquatic plant management in state waters. The Department of Natural Resources only permits aquatic plant control activities. Furthermore, the TMDL process does not address aquatic plant management, and the MPCA and watershed organizations are not legally obligated to take on plant management activities. Aquatic plant management is typically directed on a local level by lake associations, cities, and counties. As it stands now, if the shoreland owners wish to control plants in the central portion of Kohlman, this activity would need to be directed by the Lake Association. Frankly, members are quite aggravated about this bureaucratic situation.

Balancing lake use with water quality improvement

Although the RWMWD does not have a legal obligation to take on aquatic plant management, we believe that it is worthwhile to investigate solutions that will help satisfy both water quality and recreation-based goals. This effort is not motivated by hard rules, but rather goodwill towards the lake users. RWMWD's objective is to find a reasonable balance with water quality regulation, watershed management, ecological function, and human use of the lake resource.

One potential solution is the possibility of supporting aquatic plant harvesting through a RWMWD cost-share grant program, where the Kohlman

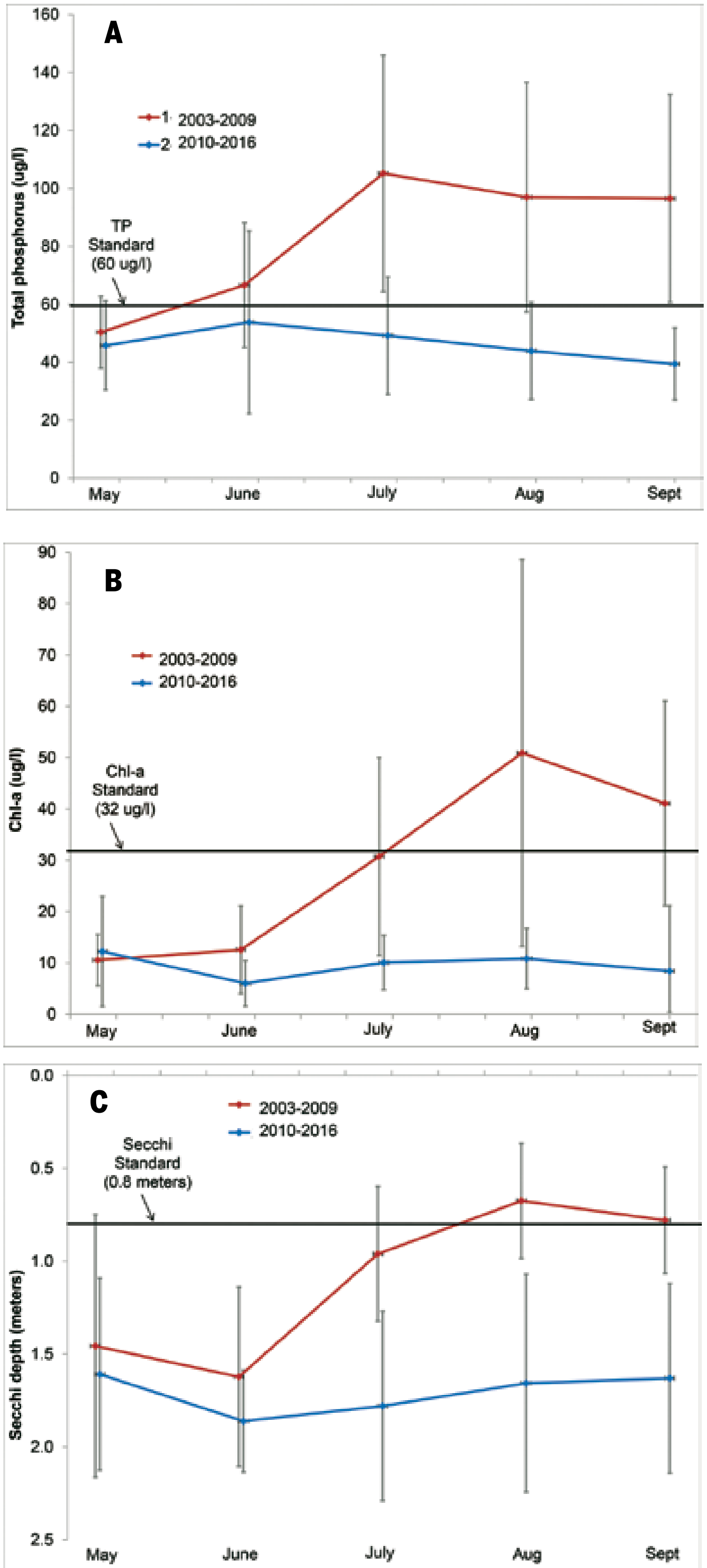

Figure 5. (A): Total phosphorus in Kohlman Lake reported for two periods, before (2003-09) and after (2010-16) alum treatment and carp control; (B): Chlorophyll-a in Kohlman Lake reported for two periods, before (2003-09) and after (2010-16) alum treatment and carp control; (C): Secchi depth in Kohlman Lake reported for two periods, before (2003-09) and after (2010-16) alum treatment and carp control.

Lake Association may be able to seek financial assistance. In a nearby shallow lake, Bartodziej et al. (2017) found that substantial quantities of total P were removed by plant harvesting at a reasonable cost. Strategic aquatic plant harvesting will certainly help with improving recreation and aesthetics, and will also remove phosphorus. Nutrient removal can be viewed as an ancillary benefit to harvesting. In Kohlman, this can be regarded as another tool to go along with several other P management activities.

By supporting thoughtful and effective aquatic plant management, our watershed district may help lake users to better accept the changes in the aquatic plant community brought about by improved water quality. Along with this management option, we believe that it is also important to continue to educate the residents of our watershed. Specifically, we must share straightforward water quality and ecological information on shallow lakes, and effectively communicate how shallow lakes are inherently different from our deep lakes. Over time, this will aid in formulating reasonable expectations for our shallow lakes.

Citations

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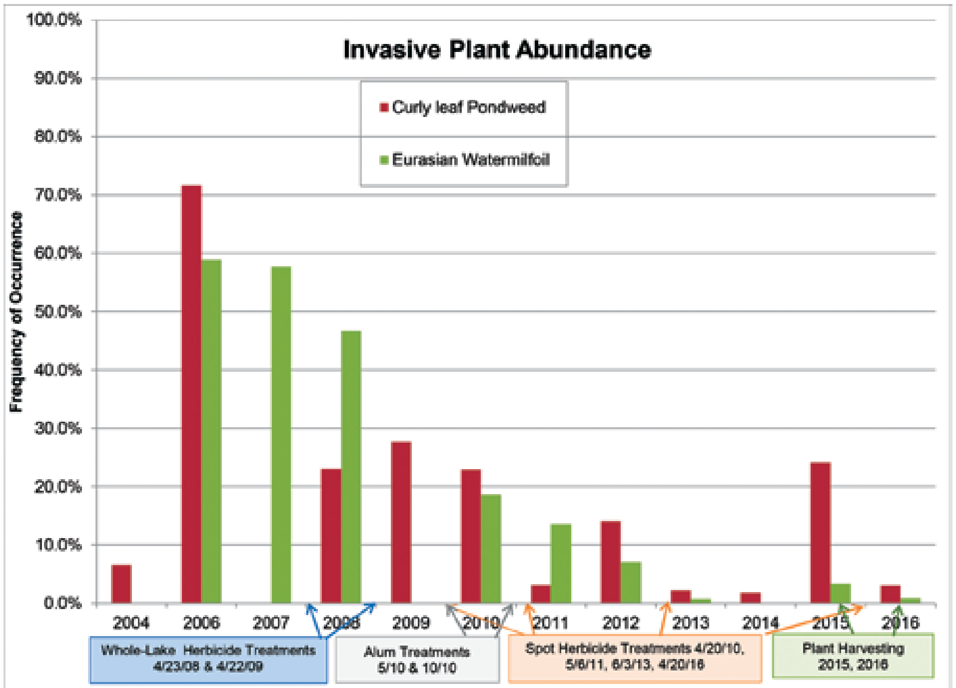

Figure 6. Curly-leaf pondweed and Eurasian watermilfoil percent frequency of occurrence.

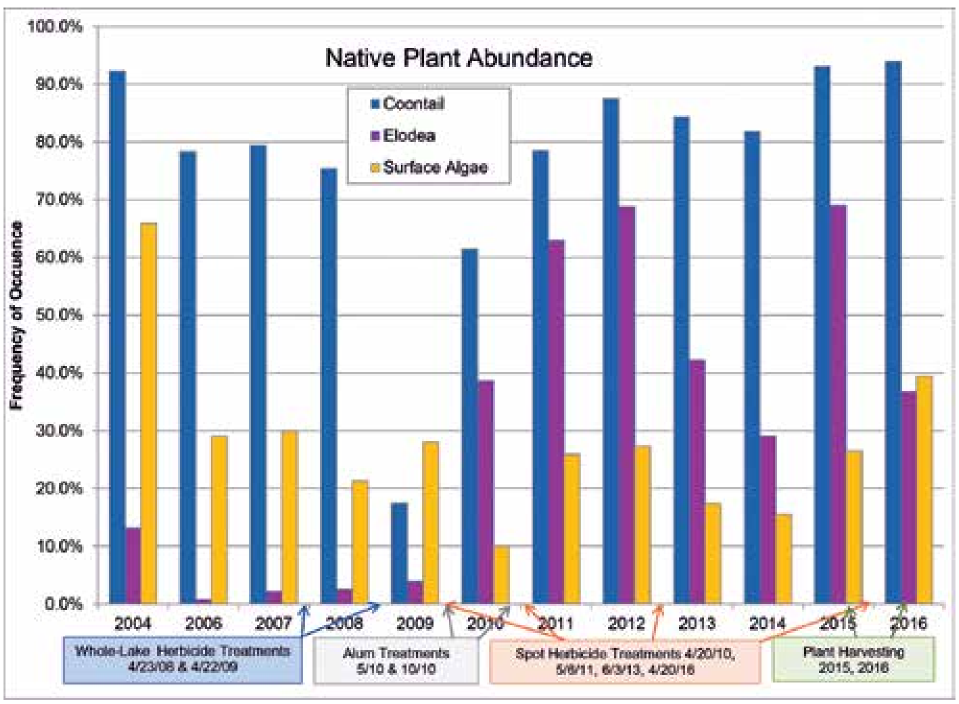

Figure 7. Coontail, Canada elodea, and surfaced filamentous algae percent frequency of occurrence.

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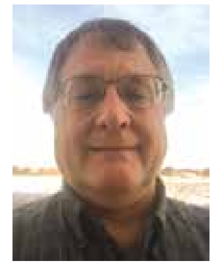
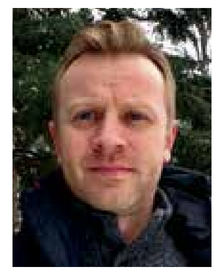
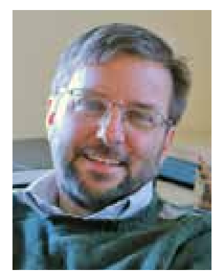
Bill Bartodziej is a natural resources specialist with the Ramsey-Washington Metro Watershed District. He has the opportunity to meld ecological restoration with water resources management in an urban setting. He supports applied research involving common carp, aquatic plants, and lakeshore restoration.



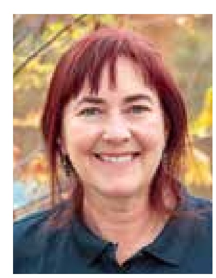
Dr. **Peter Sorensen** is a professor in fisheries, wildlife and conservation biology at the University of Minnesota with an interest in fish biology and behavior. Carp have been focus of his for the past decade, especially how and why they are invasive, and often function as ecosystem engineers in the Midwest.



Dr. **Przemek Bajer** is a research assistant professor at the University of Minnesota. He studies various aspects of the life history of common carp to understand their success as an invasive species and to develop sustainable management strategies for carp.



Dr. **Keith Pilgrim**, a water resources scientist at Barr Engineering Company, has been captivated by the complexity and mysteries of lakes ever since his graduate days at the University of Minnesota. His work often involves developing custom models to interpret and understand monitoring data and to estimate the outcome of management decisions.



Simba Blood is the natural resources technician at the Ramsey-Washington Metro Watershed District. She leads field crews in ecological restoration, aquatic plant monitoring and carp management projects. She also enjoys teaching ecology and water management to citizen volunteers and school groups.

Figure 8. A typical mat of surfaced filamentous algae growing on top of coontail and Canada elodea.

Figure 9. An aquatic plant harvester was used to cut one foot under the water and collect a mix of filamentous algae and submersed vegetation.

Figure 10. The aquatic plant harvester cut lanes to docks and also cleared an open water area in the center of the lake. Strips in the surfaced vegetation were evidence of the harvester's activity.

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