Strategic Aquatic Plant Harvesting as a Multi-faceted In-Lake Management Tool

Bill Bartodziej, Keith Pilgrim, and Simba Blood

Introduction

The earliest record of aquatic plant harvesting in the Phalen Chain of Lakes Watershed, located in the Twin Cities (Minnesota), dates back to 1923. At that time, the county engineer stated that: "Weed growth has an evil effect on Ramsey County lakes in several ways" (Coates 1924). Hence, a paddle-wheel boat was customized with a mechanical cutting blade to chop vegetation under the water (Figure 1). This vegetation would then float to the surface, where it was laboriously harvested by hand, and then piled on the shore to dry. The main objectives of this operation were to create open water for navigation and improve the look of the lake. The practitioners were innovative county workers who were not privy to even the most basic concepts of limnology. The plants were just an unsightly physical barrier that had to be removed.

Fast-forward almost 100 years, and we have dramatically increased our knowledge of aquatic plant ecology in lake systems, as well as our efficiency in harvesting, with bigger, faster, and more powerful machines. Now, government agencies find it necessary to permit aquatic plant management activities with the primary goal of preserving beneficial aquatic plant stands. Over the years, it has become more common to see aquatic plant management as a component in comprehensive lake management plans, especially ones that address shallow systems. In addition, harvesting has recently been considered as a nutrient reduction tool in watershed and Total Maximum Daily Load (TMDL) studies.

What is strategic aquatic plant harvesting?

Intensive in-lake and watershed management caused Kohlman (34 ha), the northernmost lake in the Phalen Chain of Lakes, to go from a relatively turbid to a clear water state (Figure 2). Aquatic plants responded by growing to the water surface, and the general lake condition seemed to mimic the 1920s historical accounts that prompted harvesting. This change in lake state and a comprehensive water quality monitoring dataset gave us an excellent opportunity to develop and assess a strategic aquatic plant harvesting approach (Figure 3). We set out to be methodical and have the best available data to drive the aquatic plant harvesting process on Kohlman Lake. We balanced realistic management goals centering on navigation, recreation, aesthetics, water quality, and ecological function. We viewed the aquatic plant community as a critical component in the lake system and control was judicious. Available data and best professional judgement were used to set limits on the aquatic plant harvest. Data were collected during the operation to assess the degree of control and the effects of harvesting on water quality. Below, we summarize our experience with this approach and detail how Kohlman Lake responded to the harvesting operation. We also discuss how this tool may be used in lake and watershed management.

Figure 1. A 1924 Ramsey County harvester working in surfaced vegetation on Keller Lake.

The backstory: Kohlman Lake turning to a clear water state

Surrounded by urban-residential land use, Kohlman Lake is relatively shallow with a maximum depth of four meters. The littoral area covers a majority of the lake surface, but Kohlman is still popular for boating and fishing. In the 1980s and '90s, total phosphorus (TP) levels were high, with a growing season average of near 100 ug/L. Nevertheless, Kohlman supported a rooted aquatic plant community with moderate algal blooms; however, notable blue-green algal blooms were rare. The submersed plant and algal communities did not severely impede recreational use, and shoreland owners

Figure 2. The Phalen Chain of Lakes.

were generally happy with the overall condition of the lake.

In 2008, the Minnesota Pollution Control Agency placed Kohlman on the 303(d) Impaired Waters List due to growing season TP levels being consistently over the state standard of 60 ug/L. This triggered the Ramsey-Washington Metro Watershed District (RWMWD) to conduct a TMDL study. It was estimated that the watershed contributed 426 kg of TP and Kohlman experienced an internal TP load of 132 kg during a normal precipitation year. Mass balance modeling suggested that growing season reductions of 95 kg (22 percent) of TP from the watershed and 116 kg (88 percent) from internal loading would be needed to meet the state standard. Alum treatment, common carp management, and watershed best management practices were used to substantially reduce TP loading. Since project implementation, transparency and TP values in Kohlman have satisfied the state standards (Figure 4). This combination of practices now seems to be a fairly standard approach for TP management in Twin Cities area shallow lakes.

The aquatic plant quandary in a shallow lake

With an improvement in water quality we observed a dramatic increase in the abundance of aquatic plants. During the first growing season after intensive in-lake and watershed management, a majority of the littoral zone had plants growing to the water surface. Point-intercept surveys indicated that the dominant species were coontail (*Ceratophyllum demersum*), Canada elodea (*Elodea canadensis*), and expansive stands of surfaced filamentous algae (Figure 5). Spot herbicide treatments were used to control the invasive curly-leaf pondweed (*Potamogeton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*). For more background data on the project, see Bartodziej et al. 2017a.

This expected aquatic plant response was clearly spelled out in our educational messages at the beginning of the project. We used straightforward phrases like, “clear water grows plants” and “a lot of plants in a shallow lake is normal.” But in reality, preemptive education did not work. Once a popular recreational lake is dominated by large expanses of topped-out vegetation, shoreland owners and lake users often become frustrated and disgruntled. Although our watershed district does not have any sort of legal obligation to conduct aquatic plant management, we set out to investigate a solution that would satisfy water quality, ecological, and recreational based goals. Hence, a strategic aquatic plant harvesting approach was developed by the Ramsey-Washington Metro Watershed District (RWMWD) to address this shallow lake system’s response to improved water quality.

Strategic Aquatic Plant Harvesting

1. Use a judicious and conservative approach to set goals and limits on harvesting
2. When possible, secure data to support the overall harvesting operation
3. Collect data and closely monitor the harvesting activity and make necessary adjustments
4. Use the final dataset to assess if specific goals were achieved and to improve on future harvesting efforts
5. Incorporate harvesting into lake and watershed management plans when feasible

Figure 3. The main components of strategic aquatic plant harvesting.

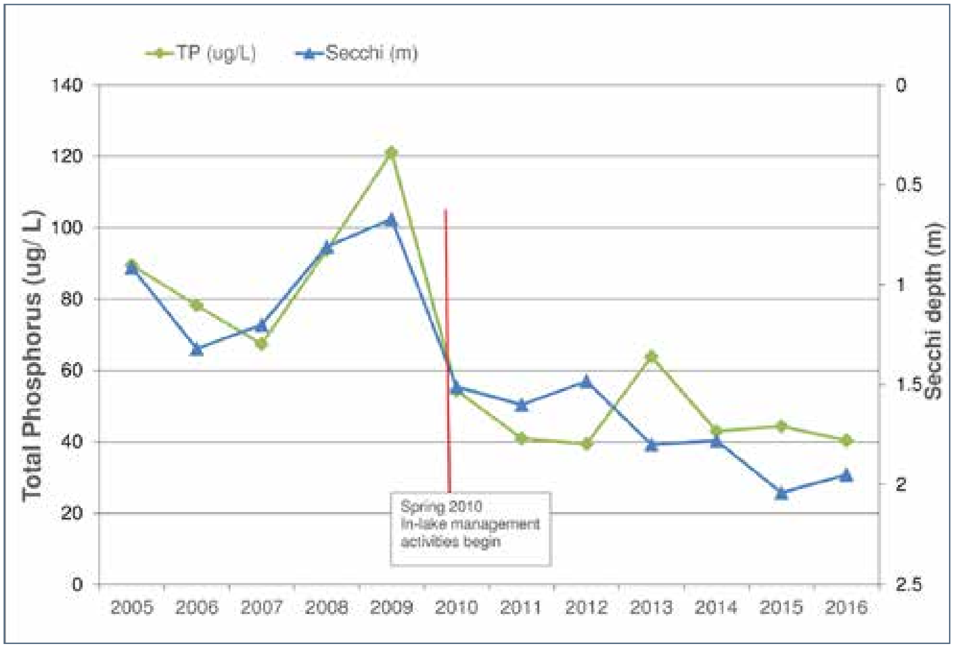


Figure 4. Lake Kohlman TP and Secchi depth before and after watershed and in-lake management activities.

Figure 5. Surfaced coontail and Canada elodea with mats of filamentous algae.

Our general approach

Our aim was to conduct strategic harvesting as a trial and then assess performance. In taking on this sort of management, we realized that aquatic plants lie at the center of shallow lake ecosystems, as they provide several ecosystem services such as habitat, food, cover and shading, temperature moderation, and nutrient uptake and sequestration (Carpenter and Lodge 1986). With this in mind, our overall approach to aquatic plant control was conservative. In June-August 2015, the RWMWD employed a private contractor to conduct aquatic plant harvesting. A paddlewheel driven harvester with a two-meter cutting swath was used in Kohlman Lake.

In developing a harvesting plan, the first question that naturally came to the forefront was: “To what degree can we manage aquatic plants without affecting water quality?” While this question was being asked for Kohlman Lake, it was soon clear that the lake management literature did not provide solid guidelines or limits on harvest. Thus, we used our best professional judgement to determine a target control area and frequency of harvest. We mapped out a 20 ha area in the center of the lake that we wanted to keep perpetually free of surfaced aquatic plants and algae during the growing season. This is approximately 55 percent of the total surface area of the lake. In harvesting this area, it provided a large open-water space for power boat recreation. On average, the harvester worked two to three days per week to keep this area open. We instructed the harvester to set the cutting blade to a one-meter maximum depth. This decreased the efficiency of the harvesting operation and was costlier, but safeguarded against overharvest. It was our goal to create a balance, being conservative in plant control and preserving water quality, but still providing an ample area for recreational opportunities.

Data collection and water quality model construction

We used sonar, point-intercept surveys, and plant biomass sampling to closely monitor the aquatic plant community. GPS mapping was used to track the harvesting. Harvested plant material was hauled off site to a local public works yard for composting. The total wet weight of each harvesting effort was calculated using the total number of trailer loads and the average plant material payload weight. Random plant samples were taken off the trailer and sent to a laboratory for TP and wet to dry weight analyses.

We formulated a list of data necessary to quantitatively assess the effects of harvesting. This list included: (1) phosphorus in submerged plant tissue and in attached filamentous algae, (2) total biomass of plants and algae during the growing season, (3) water quality in Kohlman Lake and in the tributaries, (e.g., phosphorus, solids, chlorophyll *a*), (4) mass of plants harvested over time, and (5) mass of phosphorus harvested in plants. To glue these data together and understand the effect of harvesting, a custom zero-dimensional, completely mixed mass balance water quality model was built that included inflows (flow and chemistry), lake temperature, climate (e.g., solar radiation), settling, phytoplankton growth and mortality, and aquatic plant growth and mortality. This model was used to quantify the Kohlman Lake phosphorus mass balance including uptake by aquatic plants and removal by harvesting, aquatic plant growth rate and deduced effects of harvesting, and the overall effects of harvesting on phytoplankton growth and abundance.

Effects of harvesting: Plant community and water quality

The depth of cut and the extent of harvesting can be surmised from the sonar images in Figure 6. Open water areas provided boaters with water skiing opportunities, and observations suggested that recreation was not substantially impeded by aquatic plants. One of our goals of the harvesting was to avoid severely setting back the native plant community through overharvest. Our measurements of aquatic plant biomass and modeling simulation suggest that aquatic plant growth was not affected by the harvesting (Figure 7). It's reasonable to consider that this result was due to the conservative approach of only cutting to a depth of 1 m.

The role of aquatic plants in moderating phosphorus availability and phytoplankton blooms is qualitatively understood, but rarely quantified by most lake managers. It is largely recognized that any management activity that measurably affects aquatic plants also has the potential to affect phosphorus, triggering phytoplankton blooms, and affecting lake clarity. Water quality monitoring data suggest that the extent of harvesting did not impact water quality as total phosphorus remained within recently observed historic ranges during harvesting (Figure 8). There was a slight decrease in Secchi disk depth at the start of harvesting, however this corresponded with a large storm event delivering high flows, phosphorus, and suspended solids. Mass balance modeling confirms that increases in suspended solids, phosphorus and reduced Secchi disk depth in July was a function of external solids and phosphorus loading. Furthermore, harvesting in August corresponded to a decline in phosphorus and an increase in Secchi disk depth which were a response to lowered external solids and phosphorus loads.

Plant mass and phosphorus removal through harvesting

While substantial harvesting took place to preserve recreation, the mass of plants taken out of the lake was approximately 14 percent of the peak mass that would be present without harvesting. Modeling was necessary to generate an estimate of plant mass without harvesting, and to account for the macrophyte dynamics, which included both growth and mortality. As a result, phosphorus uptake by plants (138 kg) was more than may be estimated by standalone plant biomass and phosphorus measurements. Aquatic plants were capturing a significant fraction of the phosphorus delivered by tributaries to Kohlman Lake (Table 1). Harvesting removed 24 percent of the TP captured by aquatic plants, and this accounted for four percent of the TP load derived from external sources.

Because harvesting removes a considerable amount of TP, the idea of incorporating this activity in TMDL studies as well as using submersed plants in water treatment systems has been discussed (Reisinger et al. 2008, Evans and Wilke 2010, Souza et al. 2013,). In addition, the cost of TP removal by aquatic plant harvesting is quite economical when compared to phosphorus management practices that take place in upland watershed areas, e.g., rain gardens (Bartodziej et al. 2017b). The cost of TP removal was $545 per kg in Kohlman, and this is comparable to estimates generated from another RWMWD harvesting study.

Can harvesting be a multi-faceted lake management tool?

Overall, we are pleased with the results of the strategic harvesting approach used on Kohlman Lake. This shallow system was able to withstand a 14 percent (peak mass) harvest of aquatic plants while preserving water quality and

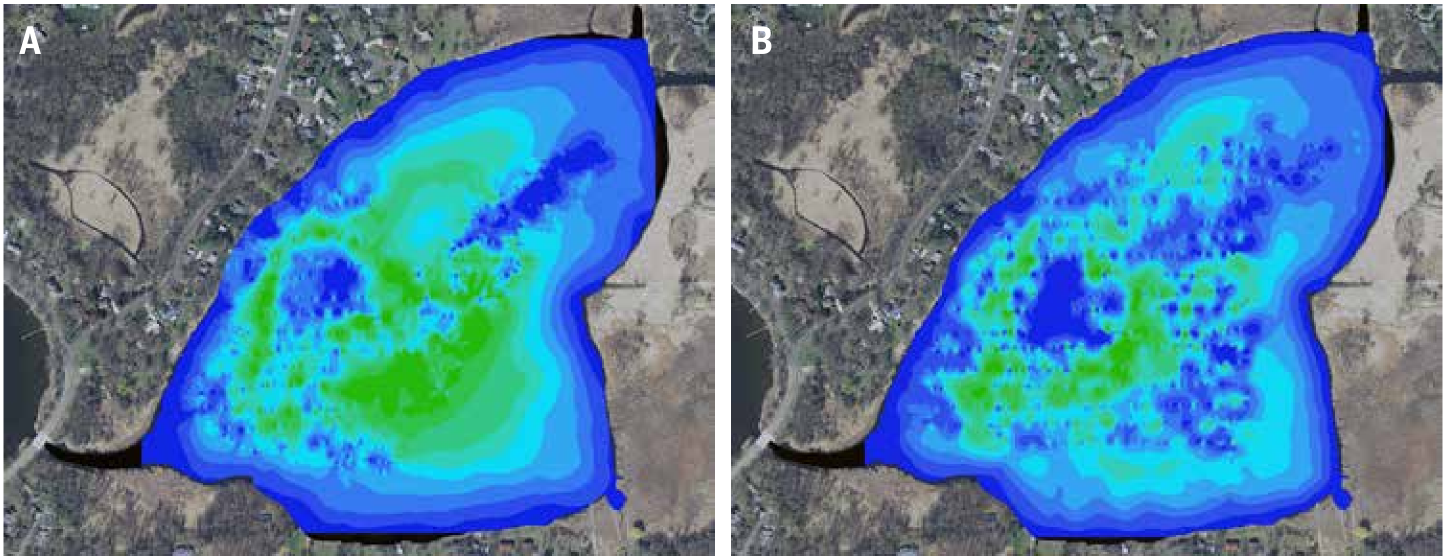


Figure 6. Results of sonar surveys showing plant height prior to the start of harvesting on June 23rd (A) and after the completion of harvesting on August 27th (B). The blue colors represent gradations of plant height between 0 and 1.5 meters while the green colors are plant heights between 1.5 to 2.7 meters.

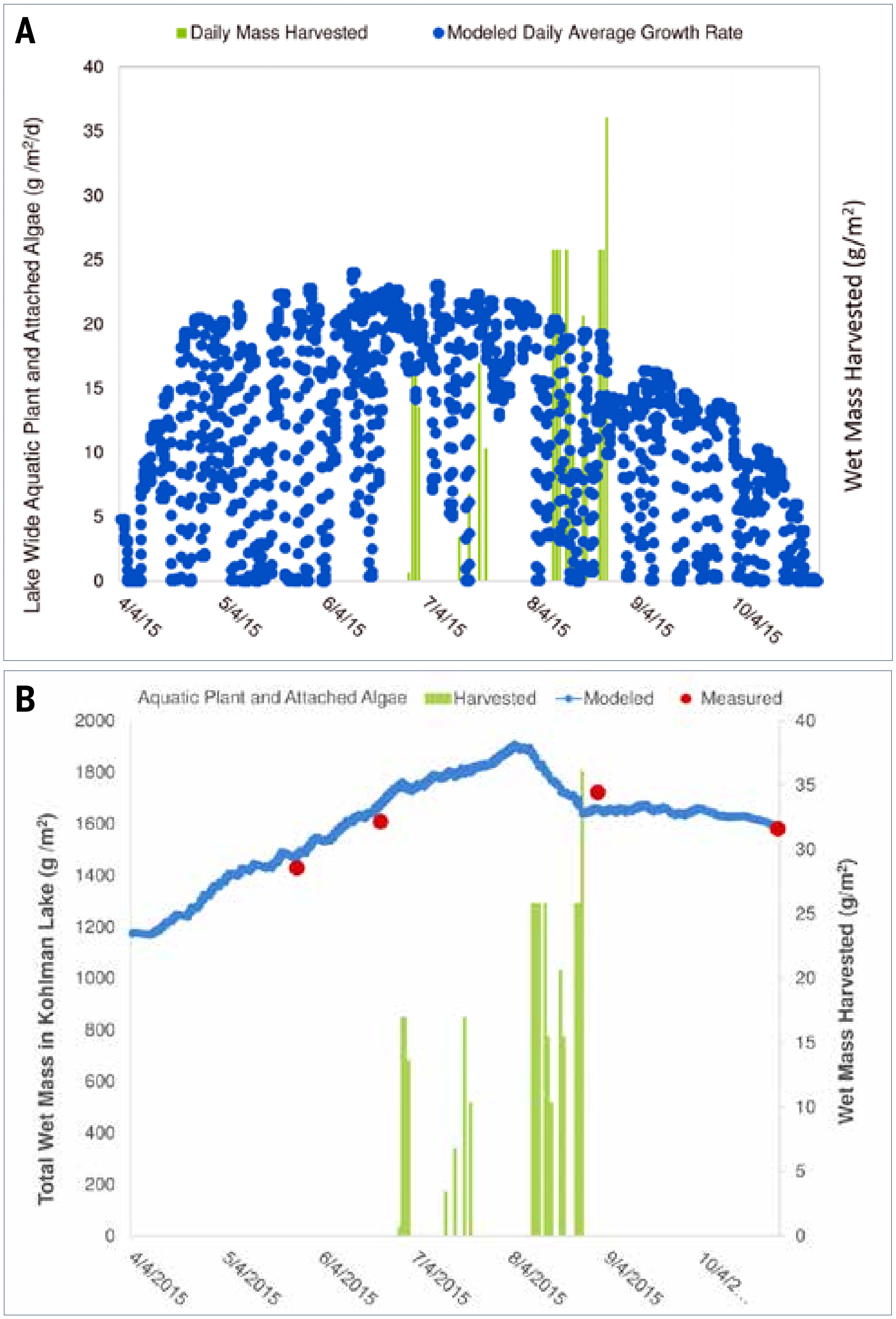


Figure 7. Modeled aquatic plant growth rate and aquatic plant mass harvested during the growing season (A), and a comparison of measured and modeled aquatic plant biomass (B).

improving recreation. Best professional judgement is always a component of lake and natural resources management, and this certainly came into play when setting a harvesting plan for Kohlman Lake. At the onset, we didn't have the luxury of citing a body of literature to support our plant management approach. However, having a robust historical dataset on Kohlman and collecting data while harvesting gave us the ability to make critical assessments during the control operation. As more strategic harvesting studies become available, robust datasets will help managers determine precise harvesting objectives and relate these to water quality and other natural resources goals.

Data from this study suggest that harvesting certainly presents cost-effective opportunities for TP removal, and has the potential to factor into dynamic and creative watershed management approaches. For instance, the RWMWD Board of Managers recently passed a resolution supporting a cost-share grant program for aquatic plant harvesting. Although the RWMWD as an organization does not manage aquatic plants, the Board may financially support and partner on harvesting efforts that fit into comprehensive TP reduction plans. This approach may gain some momentum as resource management organizations are increasingly challenged with excessive plant growth following intensive lake and watershed management, especially in shallow systems with urban watersheds.

This study points to strategic harvesting being an effective multi-faceted tool for lake and watershed managers. Although we currently do not have many data-rich, shallow lake harvesting studies to reference, we are making progress in better understanding shallow lake ecology and aquatic plant management. Consider 100 years ago, when the managers of the Phalen Chain of Lakes viewed all aquatic plants as "evil" that must be destroyed. We have certainly come a long way, and we look forward to the creative ways that strategic harvesting can contribute to water resources management in the future.

Citations

Bartodziej, W., P.W. Sorensen, P.G. Bajer, K. Pilgrim and S. Blood. 2017a. A Minnesota Story: Urban Shallow Lake Management. *NALMS Lakeline, 37: 23-29.*

Bartodziej, W., S.L. Blood and K. Pilgrim. 2017b. Aquatic plant harvesting: an economical phosphorus removal tool in an urban shallow lake. *J Aquat Plant Manage*, 55: 26-34.

Carpenter, S.R. and D.M. Lodge. 1986. Effects of submersed macrophytes on ecosystem processes. *Aquat Bot,* 26: 341-370.

Coates, P.N. 1924. Special report on lake improvement: Ramsey County, Minnesota, Board of County Commissioners, 110p.

Evans JM, Wilke AC. 2010. Life cycle assessment of nutrient remediation and bioenergy production potential from the harvest of hydrilla (*Hydrilla verticillata*). *J Environ Manage,*

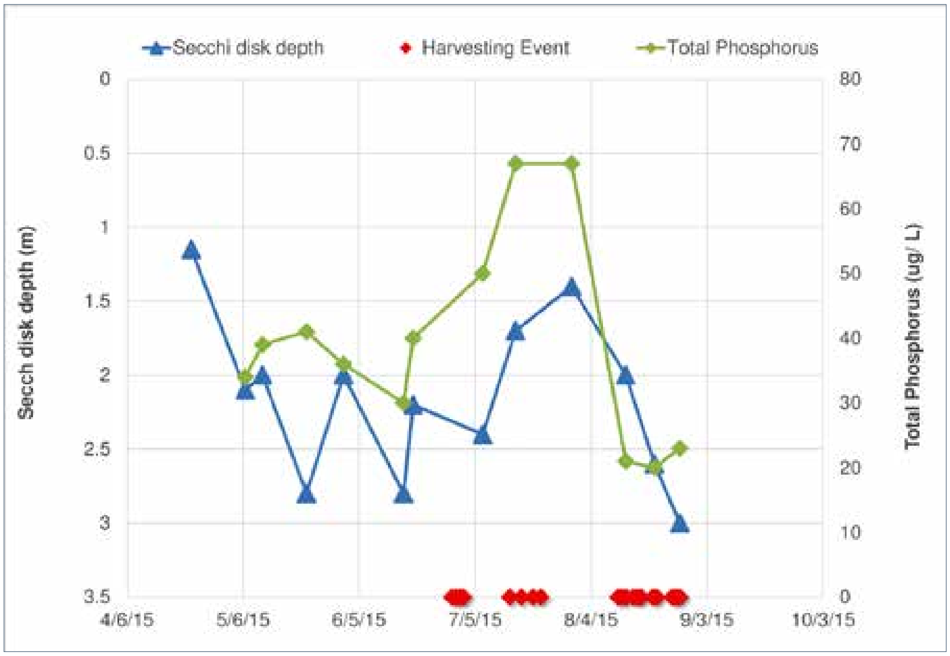


Figure 8. Secchi disk depth and total phosphorus in relation to harvesting events.

Table 1. Model estimates, total phosphorus (TP), and aquatic plant harvesting data generated from Kohlman Lake, April 15 to October 31, 2015.

Total Phosphorus and Aquatic Plant Data	**Value**
Estimates based on Model Output	
TP Total taken up by Plants (macrophytes plus attached filamentous algae)	138 kg
External TP Load from Primary Tributary	802 kg
Peak Wet Mass of Plants and Filamentous Algae - with no harvesting	2,014 g/m^2
Lakewide Peak Wet Mass of Plants and Algae - with no harvesting	680,732 kg
Harvesting Mass and TP in Plant Tissue	
Total Wet Mass of Plants Harvested	95,254 kg
Total Dry Mass of Plants Harvested	9,144 kg
Total Mass of Plants Harvested - by unit area (wet)	282 g/m^2
Peak Mass of Plants and Filamentous Algae (wet)	1,722 g/m^2
Average TP in Plants (dry)	3.6 g/kg
TP in Plants Harvested	33 kg
Percentages and Cost	
Total Mass of Plants Harvested versus Peak Mass in the Lake	14 percent
TP in Plants Harvested versus TP Total taken up by Plants	24 percent
TP in Plants Harvested versus TP Load	4 percent
Total Cost of Harvesting	$18,000
Cost of TP Removal via Harvesting	$545/kg

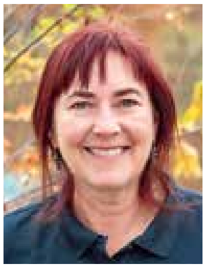
91(12):2626–2631.

Reisinger D.L., Brabham M., Schmidt M.F., Victor P.R., and Schwartz L. 2008. Methodology, evaluation, and feasibility study of total phosphorus removal management measures in Lake George & nearby lakes. *Fla Water Res. J,* 60(9):42–50.

Souza F.A., Dziedzic M., Cubas S.A., and Maranho L.T. 2013. Restoration of polluted waters by phytoremediation using *Myriophyllum aquaticum* (Vell.) Verdc., Haloragacae. *J. Environ. Manage,* 120:5–9.

Bill Bartodziej is a natural resources specialist with the Ramsey-Washington Metro Watershed District. For over 20 years, he has had the privilege of practicing ecological restoration in an urban watershed with progressive leadership. He supports applied research involving aquatic plant communities, common carp, and shore restoration.

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 a natural resources technician at the Ramsey-Washington Metro Watershed District. She works with 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.