SAUK RIVER
STEARNS COUNTY
MINNESOTA

FLOWERING RUSH
NEW INFESTATION AND INNOVATIVE CONTROL PROJECT
2022-2023

Sauk River Flowering Rush New Infestation and Innovative Control Project

Prepared For Stearns County COLA

2022-2023

System: Sauk River
County: Stearns
Surveyors: Ethan Hosey, Chris Berry, Linnea Thomas, and Ryan Melek (Limnopro Aquatic Science, Inc.)
Survey Dates: June 26-29, 2022 and September 22-26, 2023
Herbicide Applicator: Minnkota Aerial (imazapyr via drone)
Herbicide Application Date: October 14, 2022
Partners: Stearns County COLA, Stearns County Environmental Services, Clarke, Black Lagoon, Sauk River Chain of Lakes, Limnopro Aquatic Science, and MN DNR
Report Date: November 8, 2023
Report Authors: Dan McEwen and Ethan Hosey (Limnopro Aquatic Science, Inc.)

LIMNOpro
Lake, River, and Pond Management
www.limnopro.com

1848 3rd Street North
PO Box 721
St. Cloud, MN 56302
Phone: (320) 342-2210

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Dan McEwen and Ethan Hosey
Limnopro Aquatic Science, Inc., 1848 3rd St. N., St. Cloud, MN 56303

EXECUTIVE SUMMARY

This project was designed to aid in the discovery of new flowering rush in the Sauk River between the outlet of Sauk Lake and an area approximately five miles south of Melrose Reservoir and to determine the effectiveness of chemical herbicide treated of infested areas. Flowering rush was found to be well distributed through the sampled reach during June 2022 with densities as high as 52 plants per mile with plants found in all but 2 of 23 mile long segments surveyed. Given low water conditions in late 2022, it was not possible to get boats into the areas that were targeted for subsurface diquat application as called for in the original plan. In the place of this, areas were selected for a drone foliar treatment using imazapyr. This treatment was completed in October 2022. Treated and control areas were revisited in September 2023, and while less flowering rush was present in the treated areas compared with the June 2022 pretreatment survey, the reduction was not significantly different than in control areas. Overall there was less flowering rush detected in the system in 2023 compared to 2022. We were left to conclude that there was not enough evidence to suggest that drone treatments using imazapyr is a viable method for control of flowing rush in the river system. Even if good control would have been achieved, likely the high cost of the application would have been prohibitive to scaling up the treatment through the entire 20 mile reach. We suspect flowering rush will move downstream. Continued monitoring is recommended to attempt to intercept flowering rush prior to it getting into the Sauk River Chain of Lakes. Additional efforts at subsurface controls using diquat is recommended as it has been used successfully in lake systems. Whether or not subsurface applications of chemical can work in flowing water systems remains to be understood, and high variability of water levels annually may make flowering rush a moving target that provides difficulty for control.

INTRODUCTION

The Stearns County COLA was awarded a MN DNR New Infestation and Innovative Control Grant in 2022 for management of flowering rush in a reach of the Sauk River extending south from Sauk Centre from where the river outflows Sauk Lake to an area south of Melrose where the river crosses Riverview Road south of I-95. This report details the outcome of the project (Fig. 1).

Fig. 1. Example of flowering rush in flowering stage.

A survey conducted by the Sauk River SWCD and MN DNR during 2016 indicated the presence of flowering rush in areas surveyed north of Sauk Lake to

Juergens Lake. During the years of 2021-2023, Limnopro performed point intercept surveys in Sauk Lake and identified flowering rush in nearshore areas of the lake but its distribution south of the lake was not known although anecdotal observations indicated flowering rush was present south of Sauk Lake (Fig. 2).

This project provided an opportunity to add distributional data for flowering rush south of Sauk Lake through a reach of the river that had yet to be surveyed.

While flowering rush has been successfully managed in Minnesota lake systems, there has been little work done within rivers as flowing water systems provide difficulties for standard chemical treatments. The plan for this project was to treat and control flowering rush identified south of Sauk Lake in the river using subsurface applications of diquat as has been successfully accomplished in lake systems.

Unfortunately, conditions during the project were such moving a treatment boat for a subsurface application of diquat into the river was not possible. River water levels were too low to allow for navigation, partly due to a dam project and drawdown at Melrose, MN during 2022.

Subsequently, there was a pivot from using subsurface applications of diquat to using a drone to determine whether foliar application of imazapyr would be a useful way to control flowering rush in hard to reach areas of the river where flowering rush was present.

This project would allow for a better understanding of the distribution of flowering rush in the Sauk River south of Sauk Lake and provide some indication of potential mitigation strategies for the future.

The project was undertaken as a cooperative effort by partners from Stearns County COLA, Stearns County Environmental Services, Sauk River Chain of Lakes, Clarke, Black Lagoon, Minnkota Aerial, Limnopro Aquatic Science, and the MN DNR.

METHODS

There were four parts to the project. First, a full reach survey was conducted in order to identify the distribution of flowering rush (June 2022). Second, an herbicide treatment of selected regions containing flowering rush was conducted (October 2022). Third, a full reach survey was conducted post treatment to add information about distribution of the invasive plant in the river and document any background changes (September 2023). Fourth, a post-treatment survey was conducted in order to determine the effectiveness of the herbicide treatment and assess for nontarget impacts (September 2023). Further details are provided for each of the four parts below:

PART 1: Pretreatment survey (Limnopro, June 2022). The pretreatment survey

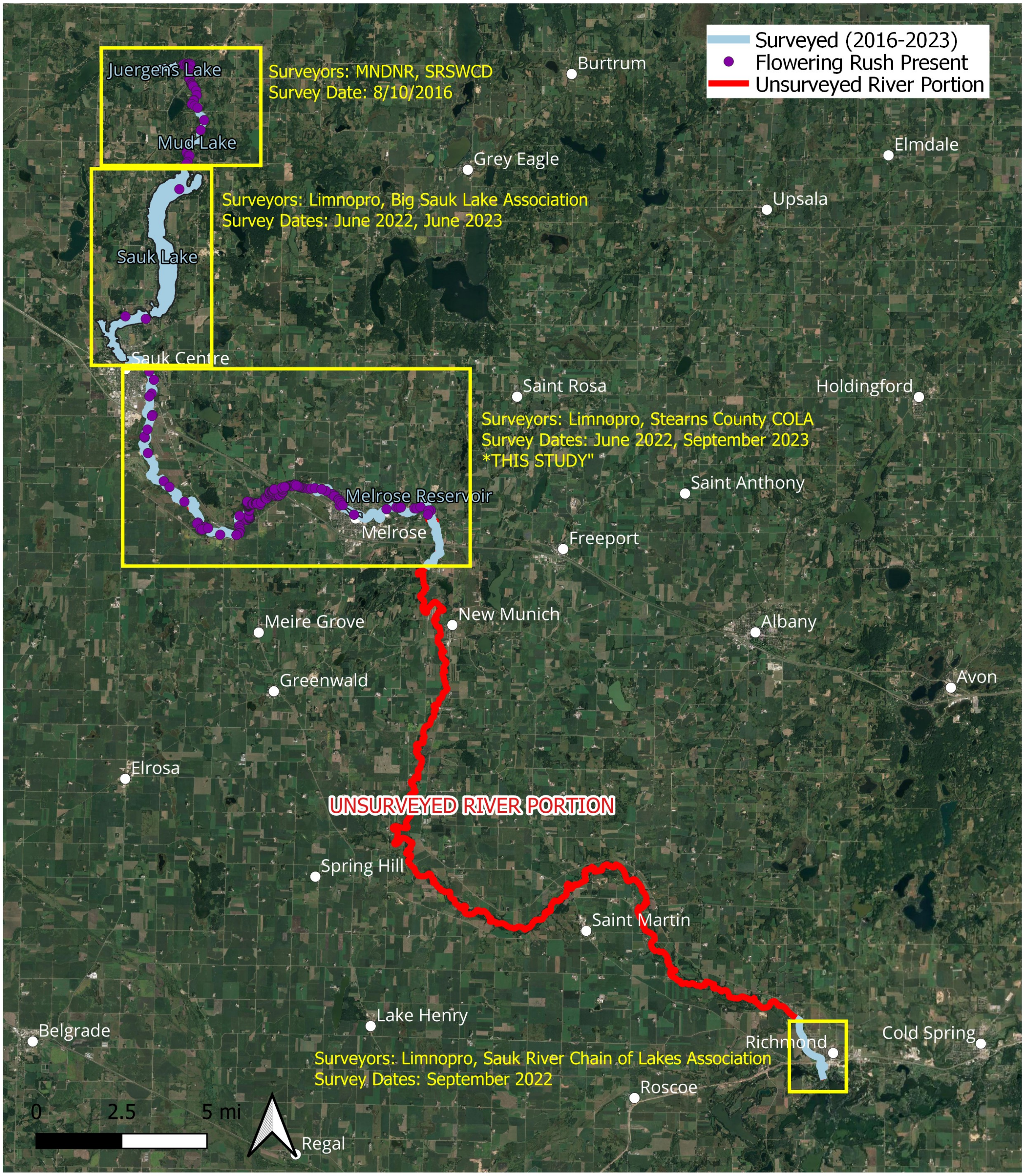

Fig. 2. Composite map showing flowering rush distribution along a reach of the Sauk River combined from four different projects occurring between 2016-2023. The third yellow box from the top frames the area that is the subject of this report.

was done as two separate steps The first step was the search, identification and mapping of flowering rush plants along the traveled target reach. As surveyors paddled downstream in a canoe, they visually detected the occurrence of flowering rush and marked plants with a waypoint. These points were then mapped with a GIS.

For the second step, points identified during the first step were randomly selected from those mapped. A return trip was made where surveyors would quantify flowering rush present as well as other cooccurring plants. This would allow a post-treatment assessment of nontarget impacts. The sampling procedure during this second step was modified from a USFWS 2022 flowering rush river survey done in the upper Mississippi (personal communication : Chris Jurek, MN DNR). In short, after navigating to each randomly selected point, the canoe was anchored at each point. Six sampling quadrats of a 2 x 2 m area were assessed surrounding the canoe. For each quadrat an estimate of percent cover was taken for each species present, which were then categorized into one of the following plant groups: submerged aquatic vegetation, emergent, non-rooted floating, flowering rush, and native rooted floating plants.

PART 2: Chemical herbicide treatment (Minnkota Aerial/Black Lagoon/Clarke, October 2022). The original project plan called for a subsurface application using diquat in a similar manner to successful efforts controlling the invasive plant in some Minnesota lakes (eg., Madsen et al. 2016); however, water levels were too low to maneuver a treatment boat into areas where treatment needed to occur. An alternative was proposed and accepted by the partners to subcontract a drone applicator to apply foliage spray of imazapyr. In the end, the drone treatment ended up costing much more than the budgeted diquat treatment. As such, the number of points that could be treated was greatly reduced Two areas were selected for treatment, including one north of the Melrose dam and one south of it. Treatments were successfully completed in October 2022.

PART 3: Posttreatment survey (Limnopro, September 2023). A posttreatment survey was conducted for determining the change of flowering rush in the entire system. Methods generally followed the first step of the pretreatment survey described in Part 1. As with the pretreatment survey, surveyors started with a meandering canoe search to identify all flowering rush along the river stretch surveyed in 2022. Points identified with flowering rush in 2023 were added to those found in 2022 and mapped using GIS.

PART 4: Treatment effectiveness assessment (Limnopro, September 2023). All points mapped during 2022 that fell within the drone treated areas were revisited. There were a total of 53 points that were identified from 2022 within the drone treatment zones. To these, 53 additional points where flowering rush was detected in 2022 but not treated,

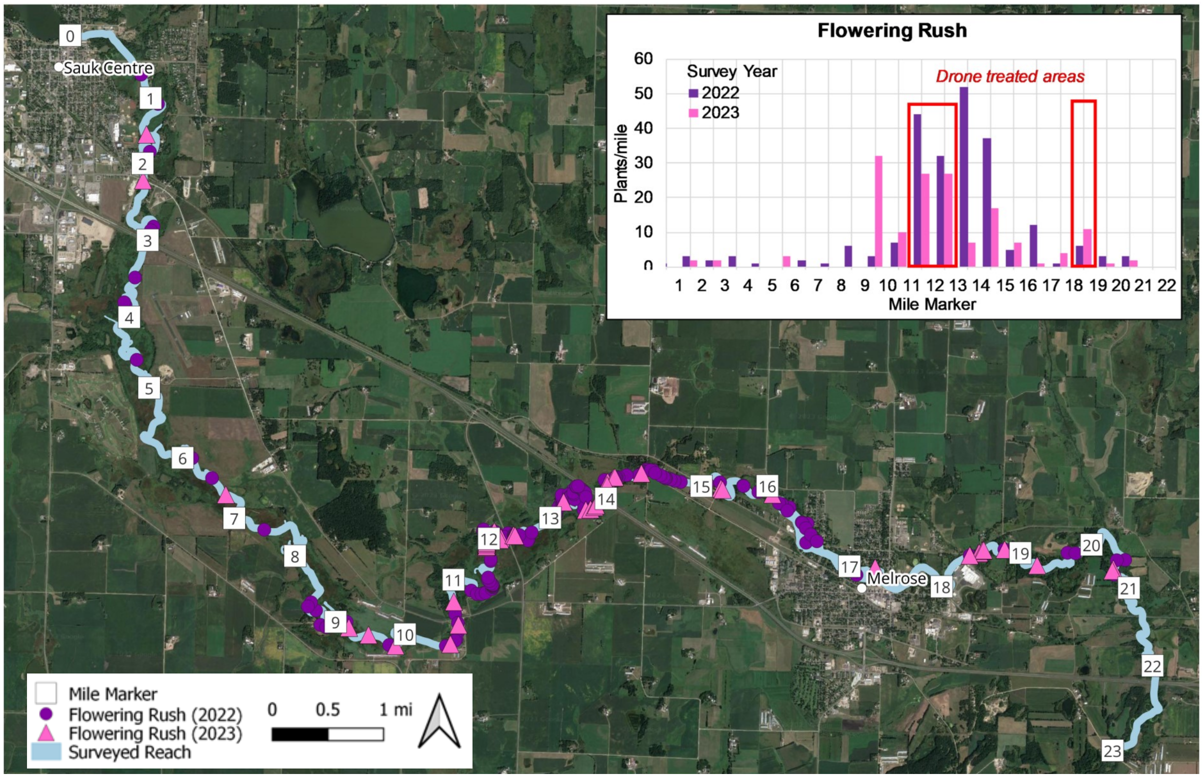

Fig. 3. Waypoints marked where plants were located during a survey along the Sauk River for flowering rush in 2022 and 2023. Mile markers are set beginning at the outlet of Sauk Lake and mark 1 mile lengths of the river. Shown inset is density of points between each mile marker with a box around the general locations where the drone treatment would occur in late 2022.

were randomly selected to act as a control. This set of 106 points were targeted for doing whole community assessments using the quadrat method described above in Part 2.

Mapping and Statistical Analysis. We divided the stretch into mile-long segments, which allowed for some spatial appreciation of where there was more or less of the plant along the reach. Within each segment, we determined the number of waypoints marked in both 2022 and 2023 and reported the points (plants) per mile segment as density. Additionally, we attempted to determine probability of linear stretches of the river to have flowering rush by creating 100 ft buffers around each point, dissolving those, and then clipping the stream polyline to assess the likely linear coverage of flowering rush over the Sauk River.

To determine the effectiveness of the drone treatment, we used a before-after control-impact (BACI) statistical assessment (Steward-Oaten and Bence 2001). The temporal factor was whether the data were collected in 2022 (before the treatment) or in 2023 (after the treatment). The treatment factor was associated with whether the point considered was within the drone treated plots (n=53) or outside of the treatment areas

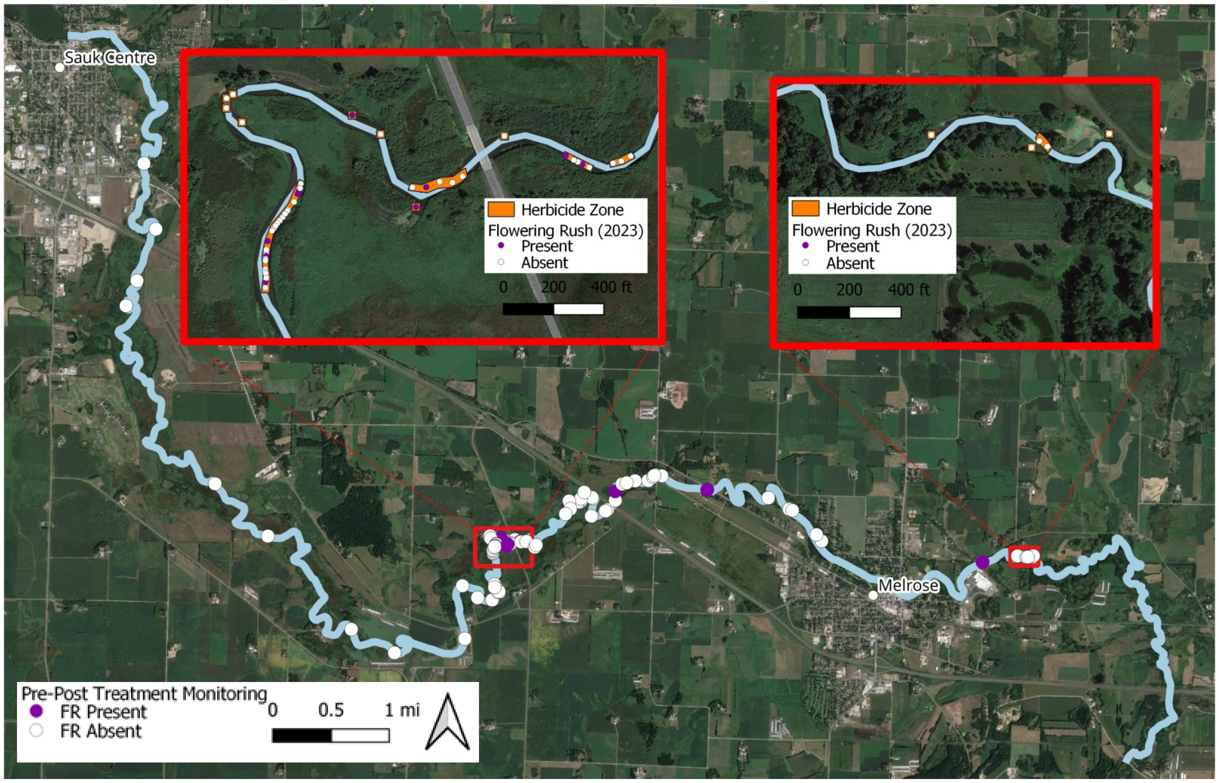

Fig. 4. Location of pre-post points that were surveyed to determine drone treatment effectives. At each point presence/absence and proportion of coverage for all specs present were assessed. A total of 53 points were within the treatment zones (orange) and 50 points were surveyed outside of the treatment zones. During 2022 all points had flowering rush present. As shown, points colored purple show where flowering rush still exists in 2023 after treatment.

(n=50 as three samples were dropped because they were on land). Because for each of these 103 points we had complete community data, as a response, we used both presence/absence for a given species as well as percent of quadrat covered. In the former case, we used a logistic regression model to test whether there was a significant interaction between time and treatment. In the latter case, we used a log-transformed coverage estimate with an ANOVA to test for a significant interaction.

We acknowledge that this is not a robust experiment design (i.e., lack of true replication and randomization), which was not possible due to the post-hoc reduction in points and limitation in areas treated. As such, the results reported should be considered exploratory.

RESULTS

In total, 23 miles of river were surveyed for flowering rush. In 2022, only 3 of 23 mile segments surveyed had no flowering rush, while in 2023, 8 of 23 mile segments had no flowering rush. Where plants existed, densities ranged from 1 plant per mile to a high of 52 plants per mile with averages of 11.2 and 10.2 plants per mile for 2022 and 2023 re-

Table 1. Treatment impact statistical summary for groups of plants. Tests shown are for interaction in BACI term using (a) logistic regression on presence/absence data, and (b) an ANOVA on log transformed percent coverage to account for non-normality. No adjustments were made for multiple tests. A species by species accounting is provided at the end of the report as an appendix.

a. Presence of plant group at quadrats

	Control			Treatment			Treatment	p-value
Habit	**2022**	**2023**	**Change**	**2022**	**2023**	**Change**	**Impact**	
Flowering rush	100%	6%	-94%	100%	19%	-81%	13%	0.318
Emergent	100%	42%	-58%	100%	51%	-49%	9%	1.000
Nonrooted floating	76%	58%	-18%	67%	57%	-10%	8%	0.667
Rooted floating	57%	14%	-43%	78%	6%	-72%	-29%	0.092
Submersed	95%	32%	-63%	78%	9%	-68%	-5%	0.868

b. Coverage of plant group at quadrats

	Control			Treatment			Treatment	p-value
Habit	**2022**	**2023**	**Change**	**2022**	**2023**	**Change**	**Impact**	
Flowering rush	14%	1%	-13%	12%	2%	-10%	3%	0.220
Emergent	12%	8%	-4%	13%	10%	-3%	1%	0.632
Nonrooted floating	8%	10%	2%	7%	6%	-1%	-3%	0.987
Rooted floating	6%	2%	-5%	9%	1%	-8%	-4%	0.052
Submersed	14%	6%	-8%	10%	1%	-9%	-1%	0.713

spectively (Fig. 3). The coverage translated to 4.85 linear miles out of 23 miles (2022: 4.1 miles and 2023: 1.4 miles) being estimated to have flowering rush or approximately 21% of the areas surveyed. Plants were not equally distributed over the target reach but were concentrated in an area beginning one mile upstream from the Melrose dam to another five miles north.

For the drone treatment, while flowering rush was reduced in 2023 compared to 2022, neither by presence/absence (p=0.318) or quadrat coverage (p=0.220) was there a reduction over and above reductions seen in the control plots (Table 1). In fact, more flowering rush was reduced at control points than at treatment points.

When comparing nontarget impacts between treatment and control plots, the only statistically significant signal we saw was in a reduction of water smartweed by 6% in treated quadrats relative to untreated quadrats.

DISCUSSION

The drone treatment done with imazapyr did not show a statistically significant effect on controlling flowering rush compared to nontreated areas. Unfortunately, we found a relatively high amount of flowering rush in the reach surveyed and as such spot treatments likely will not be enough to contain the plants, particularly

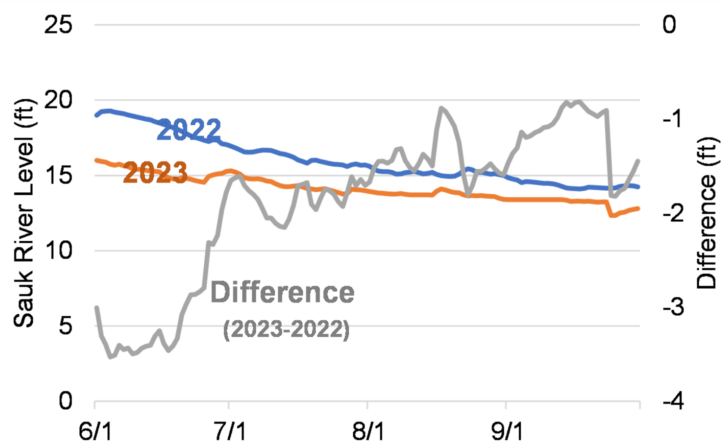

Fig. 5. Gauged water levels on Sauk River near St. Martin, MN at CR 12 for 2022 and 2023

in the areas it is most dense. Given the high cost of doing these drone treatments, it is difficult to justify additional efforts using similar treatments.

The original plan was to treat infested areas with subsurface application of diquat; however, low water levels in 2022 prevented access for the applicator to apply chemical. This remains a viable alternative worth exploring.

Flowering rush, and most other plant species encountered in 2022 were overall reduced in 2023. There could be several reasons for this, but certainly one reason is that water levels were much lower in 2023 than in 2022 (Fig. 5). In fact, in a number of cases, points revisited in 2023 from 2022 were completely dry and on land. Certainly the timing may have also impacted findings, although many sources indicate that flowering rush is still metabolically active and should be observable well into October.

Genetic tests of subsample of these plants indicated they were triploid. There are two basic varieties known to exist, one being diploid, which is fertile producing viable seeds and the other triploid, which is considered infertile and reproduces vegetatively by spread of underground structures or portions of the plant that break off. The triploid type is thought to be able to withstand greater environmental conditions and subsequently may be better at spreading to new areas.

In summary, this project established a new distribution for flowering rush on the Sauk River in areas it was not known to exist before. Unanticipated environmental conditions including low water and a dam project that involved a drawdown made completing the project as originally designed difficult.

We are left without being able to make conclusions about methods for control of flowering rush in flowing water systems .

Given the rather large differences in distributions between the two years and the rather extreme differences in water levels year to year, it may be that the flowering rush is a moving target as it responds to changing water levels from year to year.

Of concerns is the invasive plant continuing movement down the Sauk River into the Sauk River Chain of Lakes, which is already struggling with infestations of hybrid watermilfoil, curlyleaf pondweed, and zebra mussels.

Flowering rush is known to occur in Sauk Lake and north of it, but the origin of flowering rush is not known as to our knowledge no survey has been conducted either in Juergens Lake or north of it. It was found south near the outlet of Juergens Lake in 2016.

The Sauk River Chain of Lakes commissioned a separate study in 2023 to determine whether it was nearby, and we found no evidence of that being the case. Without additional evidence otherwise, we suspect we identified the southern-most distribution of flowering rush as of the date of this report. Additional surveys south of that area may show otherwise. Completing the nonsurveyed of the reach is recommended.

Annual monitoring upstream from Horseshoe lake and spot treatments of the plant may help to slow the spread into the chain of lakes.

LITERATURE CITED

Madsen, J.D., Sartain, B., Turnage, G. and M. Marko. 2016. Management of flowering rush in the Detroit Lakes, Minnesota. J Aquat Plant Manage, 54:61-67.

Stewart-Oaten, A, and J.R Bence. 2001. Temporal and spatial variation in environmental impact assessment. Ecological monographs, 71:305-339.

Table 1. Treatment impact statistical summary for species of plants. Tests shown are for interaction in BACI term using logistic regression on presence/absence data, No adjustments were made for multiple tests.

			Control			Treatment			Treatment	Logistic Regression
Habit	**Common Name**	**Scientific Name**	**2022**	**2023**	**Change**	**2022**	**2023**	**Change**	**Impact**	**BACI p-value**
Emergent (I)	Flowering Rush	*Butomus umbellatus*	90%	6%	-84%	89%	19%	-70%	14%	0.318
Emergent	Sedge	*Carex* spp.	67%	12%	-55%	56%	17%	-39%	16%	0.378
Emergent (I)	Purple loosestrife	*Lythrum salicaria*	0%	2%	2%	0%	0%	0%	-2%	0.999
Emergent (I)	Reed canary grass	*Phalaris arundinacea*	81%	16%	-65%	89%	11%	-78%	-13%	0.437
Emergent	Arrowhead	*Sagittaria* spp.	48%	4%	-44%	22%	0%	-22%	21%	0.995
Emergent	Bulrush	*Schoenoplectus acutus*	48%	14%	-34%	22%	26%	4%	38%	0.063
Emergent	Burread	*Sparganium* spp.	14%	0%	-14%	11%	0%	-11%	3%	0.999
Emergent	Cattail	*Typha* spp.	10%	2%	-8%	22%	6%	-17%	-9%	0.960
Emergent	Water speedwell	*Veronica anagallis*	19%	4%	-15%	22%	2%	-20%	-5%	0.540
Nonrooted floating	Filamentous Algae	Various	5%	26%	21%	0%	9%	9%	-12%	0.991
Nonrooted floating	Duckweed	*Lemna* spp./*Spirodela polyrhiza*	76%	52%	-24%	67%	55%	-12%	12%	0.546
Rooted floating	Water smartweed	*Polygonum amphibium*	19%	2%	-17%	56%	0%	-56%	-39%	0.994
Rooted floating	Floating pondweed	*Potamogeton natans*	48%	2%	-46%	44%	0%	-44%	1%	0.995
Rooted floating	Long-leaved pondweed	*Potamogeton nodosus*	10%	10%	0%	22%	6%	-17%	-17%	0.225
Submerged	Coontail	*Ceratophyllum demersum*	62%	14%	-48%	56%	8%	-48%	0%	0.682
Submerged	Canadian waterweed	*Elodea canadensis*	5%	12%	7%	0%	8%	8%	0%	0.991
Submerged	Water stargrass	*Heteranthera dubia*	19%	18%	-1%	0%	0%	0%	1%	0.999
Submerged (I)	Curlyleaf pondweed	*Potamogeton crispus*	33%	2%	-31%	33%	2%	-31%	0%	0.971
Submerged	Fries' pondweed	*Potamogeton friesii*	5%	0%	-5%	0%	0%	0%	5%	0.999
Submerged	Sago	*Stuckenia pectinata*	71%	4%	-67%	78%	0%	-78%	-10%	0.994
Submerged	Wild celery	*Vallisneria americana*	10%	0%	-10%	0%	0%	0%	10%	0.999

Table 1. Treatment impact statistical summary for species of plants. Tests shown are for interaction in BACI term using an ANOVA on log transformed coverage data, No adjustments were made for multiple tests.

			Control			Treatment			Treatment	ANOVA
Habit	**Common Name**	**Scientific Name**	**2022**	**2023**	**Change**	**2022**	**2023**	**Change**	**Impact**	**BACI p-value**
Emergent (I)	Flowering Rush	*Butomus umbellatus*	14%	1%	-13%	12%	2%	-10%	3%	0.220
Emergent	Sedge	*Carex* spp.	7%	2%	-5%	6%	2%	-3%	1%	0.415
Emergent (I)	Purple loosestrife	*Lythrum salicaria*	0%	0%	0%	0%	0%	0%	0%	0.607
Emergent (I)	Reed canary grass	*Phalaris arundinacea*	10%	3%	-7%	12%	4%	-8%	-1%	0.503
Emergent	Arrowhead	*Sagittaria* spp.	5%	0%	-4%	2%	0%	-2%	2%	0.066
Emergent	Bulrush	*Schoenoplectus acutus*	5%	3%	-1%	2%	4%	2%	3%	0.086
Emergent	Burread	*Sparganium* spp.	1%	0%	-1%	1%	0%	-1%	0%	0.887
Emergent	Cattail	*Typha* spp.	1%	0%	-1%	2%	1%	-2%	-1%	0.390
Emergent	Water speedwell	*Veronica anagallis*	2%	0%	-2%	2%	0%	-2%	-1%	0.627
Nonrooted floating	Water smartweed	*Persicaria amphibia*	2%	0%	-2%	8%	0%	-8%	-6%	< 0.001
Nonrooted floating	Floating pondweed	*Potamogeton natans*	5%	0%	-5%	4%	0%	-4%	1%	0.833
Rooted floating	Long-leaved pondweed	*Potamogeton nodosus*	1%	1%	0%	2%	1%	-2%	-2%	0.183
Rooted floating	Filamentous Algae	Various	8%	9%	1%	7%	5%	-1%	-2%	0.892
Rooted floating	Duckweed	*Lemna* spp./*Spirodela polyrhiza*	0%	4%	4%	0%	1%	1%	-3%	0.404
Submerged	Coontail	*Ceratophyllum demersum*	6%	2%	-4%	6%	1%	-5%	0%	0.943
Submerged	Canadian waterweed	*Elodea canadensis*	0%	2%	2%	0%	1%	1%	-1%	0.935
Submerged	Water stargrass	*Heteranthera dubia*	2%	2%	0%	0%	0%	0%	0%	0.998
Submerged (I)	Curlyleaf pondweed	*Potamogeton crispus*	3%	0%	-3%	3%	0%	-3%	0%	0.956
Submerged	Fries' pondweed	*Potamogeton friesii*	0%	0%	0%	0%	0%	0%	0%	0.215
Submerged	Sago	*Stuckenia pectinata*	15%	1%	-13%	12%	0%	-12%	1%	0.544
Submerged	Wild celery	*Vallisneria americana*	1%	0%	-1%	0%	0%	0%	1%	0.073