J. Aquat. Plant Manage. 60: 79–84

Small-plot evaluations of aquatic pesticides for control of starry stonewort (*Nitellopsis obtusa*) in Lake Koronis, Minnesota

PATRICK CARVER, RYAN M. WERSAL, AND BRADLEY T. SARTAIN*

ABSTRACT

Nitellopsis obtusa (Desv.) J. Groves (starry stonewort) is a green macroalga native to Eurasia in the family Characeae. It has become an invasive species in much of the Midwestern United States. Starry stonewort is difficult to control due to its rapid and dense growth, and its ability to produce underground structures called bulbils. These bulbils act as a method of asexual reproduction that can serve to recolonize previously managed locations. There has been a lack of research on the efficacy of chemical treatments and combinations of chemical treatments on starry stonewort. Therefore, treatments of copper, diquat, and copper + diquat combinations were evaluated in small plots in Lake Koronis, MN, during the summers of 2020 and 2021. In 2020, applications of copper reduced aboveground biomass at 8 wk after treatment by > 90%. Copper treatments in 2020 had no effect on bulbil densities. Diquat was not effective at reducing starry stonewort biomass or bulbil density at 4 and 8 wk after treatment. Bulbil densities in diquat plots ranged from 33.3 ± 33.3 to 4,266.7 ± 3,963.3 bulbils m^{-2} depending upon sample time and site. The estimated diquat half-life in Lake Koronis was < 2 h among all treated plots, which was a factor in the lack of diquat efficacy. In 2021, copper treatments resulted in a 78 and 27% reduction in aboveground biomass at 4 and 8 wk after treatment, respectively. Copper treatments also reduced bulbil density by 4 wk after treatment. Plots treated with the copper + diquat had aboveground biomass reductions of 76 and 65% at 4 and 8 wk after treatment, respectively. Bulbil densities did not show a reduction in the combination plots. Regrowth was evident in all plots regardless of treatment by 8 wk. Additional strategies are needed to target bulbil production, induce bulbil mortality, or gain longer-term control of aboveground biomass.

Key words: algae, aquatic plant management, bulbil, concentration exposure time, copper, diquat, thalli.

*First and second authors: Graduate Research Assistant, Associate Professor, Department of Biological Sciences, Minnesota State University, Mankato, S-242 Trafton Science Center South, Mankato, MN 56001. Third author: U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS 39180. Corresponding author's E-mail: ryan.wersal@mnsu.edu. Received for publication March 4, 2022 and in revised form October 12, 2022.

INTRODUCTION

Nitellopsis obtusa (Desv.) J. Groves (starry stonewort) is a green macroalga native to Eurasia in the family Characeae (Groves 1919). Starry stonewort forms star-shaped bulbils, from which the common name is derived, as a means of asexual reproduction and for spatial and temporal dispersion. White bulbils form beneath the sediment along the nodes of the rhizoid, and green bulbils form along the main axes and branchlet nodes (Bharathan 1987). While starry stonewort is able to reproduce both vegetatively and sexually it appears to undergo vegetative reproduction more frequently in both its native and invasive ranges (Larkin et al. 2018). Reductions in macrophyte species richness has been observed at various depths and locations in the invaded range of starry stonewort (Brainard and Schulz 2017, Harrow-Lyle and Kirkwood 2022).

Its current invaded range includes the St. Lawrence River, the St. Clair–Detroit river system, Lake Ontario, Lake Erie, Lake Huron, Michigan's Lower Peninsula, New York, Vermont, Pennsylvania, northern Indiana, Wisconsin, and as of 2015, Minnesota (Mills et al. 1993, Sleith et al. 2015, Midwood et al. 2016, MISIN 2017). The first known occurrence of starry stonewort in Minnesota was in Lake Koronis in 2015 and has spread to 18 other lakes and the Mississippi River (Minnesota DNR 2022). The likely causes of overland dispersal in the United States are boats and boating equipment transporting the bulbils and vegetative fragments of starry stonewort (Larkin et al. 2018). Lakes lacking boat launches were surveyed within heavily starry stonewort infested areas and did not detect presence of the species (Sleith et al. 2015).

Starry stonewort, like other macrophytes, poses multiple challenges for management (Madsen 1993, Hussner et al. 2017, Glisson et al. 2018). The importance of understanding the efficacy of control methods is imperative for the management of invasive species in a cost-effective manner while still achieving management goals. Currently sufficient research is lacking on the effective management strategies for starry stonewort. Mechanical harvesting has seen limited success as starry stonewort regrew rapidly after harvesting events (Pullman and Crawford 2010, Glisson et al. 2018).

Commonly used pesticides for control of starry stonewort and other algae include copper-based algaecides (Lembi 2014, Glisson et al. 2018, Wersal 2022). Copper algaecides can differ in efficacy and in the species targeted based on the formulation; for instance, chelated copper formulations have increased efficacy on planktonic and filamentous algae when compared to copper salt formulations (Bishop and Rogers 2012, Calomeni et al. 2014, Iwinski et al. 2016, Pokrzywinski et al. 2021).

The efficacy of herbicide applications is limited by concentration and exposure times (CET) leading to decreased efficacy of those products. To overcome CET issues herbicide combinations have been utilized to reduce the exposure time needed for effective control (Madsen et al. 2010). Improved efficacy for copper and noncopper combinations on submersed macrophytes have also been documented (Sutton et al. 1970, 1971; Pennington et al. 2001; Pokrzywinski et al. 2021). However, underground bulbils can survive treatment from contact herbicides and grow into new aboveground structures.

Diquat has been effective on multiple taxa of green algae, such as *Selenastrum capricornicum* (Printz), with sensitivity being species-specific (Phlips et al. 1992, Peterson et al. 1997). Numerous filamentous green algae, including *Cladophora glomerata* (L.) Kuetzing, have also shown sensitivities to diquat at low concentrations under 1 mg L^{-1} (Robson et al. 1976). More recently diquat has shown efficacy in small-scale trials on starry stonewort (Wersal 2022) where diquat and herbicides containing diquat led to $> 95\%$ biomass reductions 4 wk after treatments.

Other studies reported activity of copper, noncopper, and pesticide combinations on starry stonewort (Pokrzywinski et al. 2021, Wersal 2022). A lab-based study as well as a field study on Lake Koronis of copper algaecides found similar effective control of starry stonewort (Glisson et al. 2018, 2022a). All of these studies have shown promising results for the chemical control of starry stonewort using copper and other herbicides in combination with copper, and as such scaling up to and corroborating field trials is appropriate. Therefore, the objectives of this field demonstration are to 1) verify copper efficacy in small plots at the lake scale and 2) evaluate efficacy of diquat applied alone or in combination with copper under field conditions to control starry stonewort. To our knowledge this is the first field evaluation of diquat for use on starry stonewort.

MATERIALS AND METHODS

Site description

The field demonstration took place on Lake Koronis, near Paynesville, MN (45°21′36″N; 94°41′55″W), during the growing seasons (June to September) of 2020 and 2021. Lake Koronis is a 1,201-ha lake with a maximum depth of 40 m and a littoral zone that encompasses 476 ha. Lake Koronis has had starry stonewort for the longest known period of time (since 2015) in Minnesota and has a well-established population in regard to biomass and bulbils. Within the 476-ha littoral zone macrophytes such as *Vallisneria americana* (Vict.) Michx., *Ceratophyllum demersum* L., *Lemna* spp., *Potamogeton* spp., and *Nymphaea odorata* Aiton can be found. Currently, starry stonewort is present in 324 ha, or 68% of the littoral zone. In 2020 approximately 51 ha were undergoing management for starry stonewort via copper triethanolamine complex (25 ha), diquat (15 ha), and copper triethanolamine complex + mechanical pulling (11 ha). In the 2021 roughly 55 ha were treated for starry stonewort via copper triethanolamine complex (40 ha), diquat + copper triethanolamine complex (6 ha), and copper triethanolamine complex + mechanical pulling (9 ha). Six plots were established in 2020 and 2021 as part of the operational management program for starry stonewort in order to evaluate chemical treatments (Table 1).

Table 1. Herbicide and treatment rates for starry stonewort control in small plots in Lake Koronis.

Year	Plot	Hectares	Average Depth (m)	Copper Rate (mg L^{-1})	Diquat Rate (mg L^{-1})
2020	2B	3.1	2.0	—	0.37
2020	3B	2.3	2.2	—	0.37
2020	A4	1.3	1.4	1.0	—
2020	13	1.3	1.2	1.0	—
2021	13	1.3	1.2	1.0	—
2021	6B	1.7	2.6	1.0	—
2021	2B	3.1	2.0	1.0	0.37
2021	3B	2.3	2.2	1.0	0.37

2020 Field demonstration

Prior to herbicide applications, 15 biomass samples were randomly harvested from two copper plots, two diquat plots, and two reference plots using a polyvinyl chloride coring device (Madsen et al. 2007). Pretreatment sampling occurred on 8 July 2020. Harvested samples were placed into individually labeled Zip-loc bags and stored on ice for transport to the Aquatic Weed Science Lab at Minnesota State University, Mankato, for postprocessing. In the lab, samples were rinsed and sorted to aboveground biomass and bulbils. Bulbils were counted at the time of biomass sorting to estimate density (bulbils m^{-2}) Each tissue type was put into labeled paper bags and dried in a forced air oven at 48 C for at least 48 h to obtain dry-weight (g m^{-2}) for aboveground biomass. Following the pretreatment assessment, copper (copper ethanolamine complex) or diquat was applied by a licensed applicator to the plots during the week of 13 July. Water samples were collected at the time of application, 1 h after treatment (HAT), 3 HAT, 6 HAT, 24 HAT, and 48 HAT from both diquat plots. Water samples were shipped to Pace Analytical (Minneapolis, MN) for diquat residue determination. Residues were used to estimate exposure time of starry stonewort to diquat. All diquat residue samples from Lake Koronis were combined to model the overall diquat exposure. Copper residues were not collected as part of this study. At 4 and 8 wk after treatment (WAT) (12 August and 12 September 2020, respectively), 15 biomass samples were collected from each plot in a similar fashion as pretreatment samples to assess posttreatment efficacy. Samples were collected and processed in a similar manner to the pretreatment samples.

2021 Field demonstration

In summer of 2021 two plots were chosen for copper treatment, two plots for copper + diquat treatments, and two plots for nontreated references. Sampling and processing methods in 2021 were similar to those in 2020.

Pretreatment sampling for the 2021 season occurred 1 July, 4 WAT occurred 10 August, and 8 WAT occurred 5 September. After the pretreatment assessment, copper (copper ethanolamine complex) and copper + diquat were applied by a licensed applicator to the plots during the week of 12 July. Water samples were not taken for residue determination during the 2021 season as general water exchange patterns were established in the treatment plots during the 2020 season.

Statistical analysis

Biomass data did not meet the assumption of normality according to a Shapiro-Wilk test. Therefore, data were subjected to a Kruskal-Wallis test within plant tissue type, sampling times, and year. If a significant treatment effect was detected means were separated using a Dunn's All-Pairwise Comparison test. All analyses were conducted at the $\alpha \leq 0.05$ significance level. Additionally, an exponential decay regression model was used to model diquat dissipation over time in order to estimate an overall diquat half-life for the herbicide treatments conducted in 2020.

RESULTS AND DISCUSSION

2020 Field demonstration

At the start of the 2020 season, plots had similar levels of aboveground biomass and similar bulbil densities. Aboveground biomass was more effectively controlled by treatments of copper algaecide, where a 96% reduction was seen by 8 WAT (Figure 1). Bulbil production in the copper plots had increased from 105.6 m^{-2} during the pretreatment sampling to 524.1 m^{-2} by the 8 WAT sampling period (Figure 2). Bulbil production was prolific at the end of this season and preventing or limiting this excessive production of bulbils is imperative for the control of this species.

Applications of diquat showed no reductions in aboveground biomass during the 2020 season (Figure 1). By 4 WAT aboveground biomass in the diquat-treated plots increased by 198% when compared to the reference plots (Figure 1). Throughout the study there were no significant changes in bulbil density in the diquat-treated plots (Figure 2). Diquat residue analysis indicated that water exchange and diquat dilution was rapid within treated plots (Figure 3). Under the assumption that the target concentration of 0.37 mg L^{-1} was achieved, 52% of the diquat was lost by 1 HAT and 98% was lost by 6 HAT. The estimated half-life of diquat was < 2 h among all treated plots on Lake Koronis.

The efficacy of diquat is greatly affected by the CET relationships, or the length of time a lethal dose of the herbicide is maintained near target plants. In lab trials the 0.37 mg L^{-1} concentration of diquat with a 12-h exposure time reduced starry stonewort biomass (Wersal 2022). During the field demonstration water exchange and diquat dilution limited this exposure time to 2 h, thereby impacting the efficacy of diquat. The efficacy of future pesticide applications will be dependent on the rapid dilution and off-target movement of that herbicide. Additional water exchange studies are needed to characterize bulk water flow in more areas of the lake. This information will be crucial in developing more effective treatment recommendations, and better timing of application. Additional research is needed on other copper formulations, herbicides, and pesticide combinations.

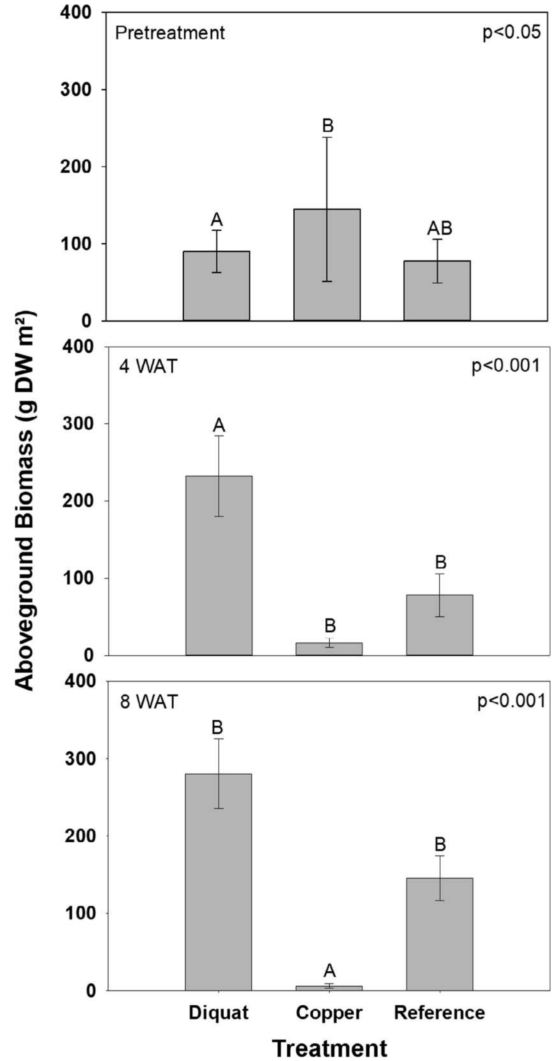

Figure 1. Mean (± 1 SE) aboveground biomass of starry stonewort at pretreatment, 4 wk after treatment (4 WAT), and 8 wk after treatment (8 WAT) with select herbicides, summer 2020. Bars with the same letter are not different according to a Dunn's All-Pairwise Comparison test at an $\alpha \leq 0.05$. All analyses were conducted within sampling time.

2021 Field demonstration

Aboveground biomass was similar in all plots during the pretreatment sampling event ($P = 0.41$). By 4 WAT the copper plots showed a 78% reduction in aboveground biomass when compared to the reference plots (Figure 4). Regrowth was observed by 8 WAT; however, biomass was still lower than nontreated reference plots. Copper applications resulted in an 82% reduction in bulbil densities by 4 WAT, potentially due to heavy damage to aboveground structures and preventing the allocation of resources to bulbil production (Figure 5). By 8 WAT bulbil production

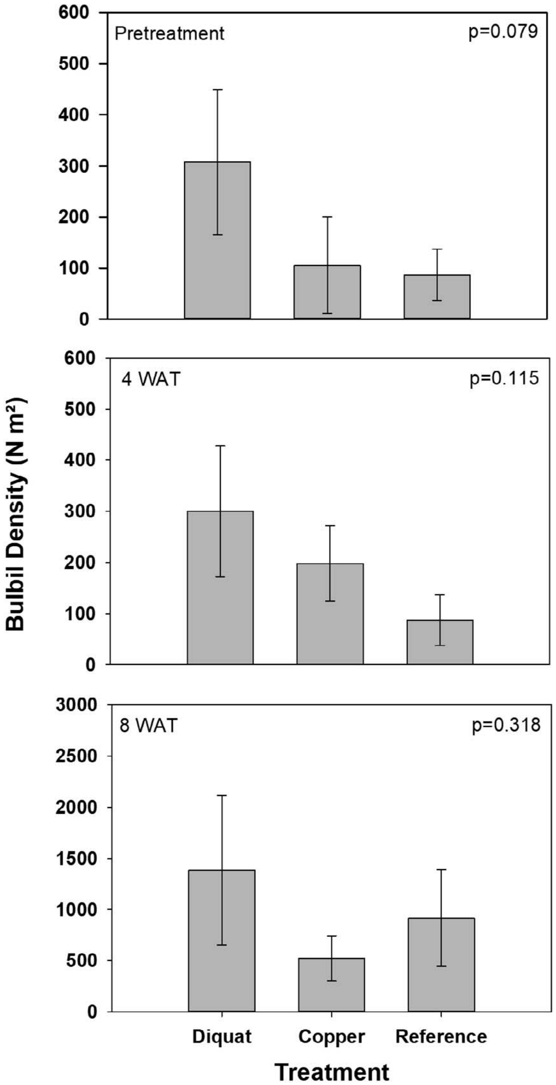

Figure 2. Mean (± 1 SE) bulbil density of starry stonewort at pretreatment, 4 wk after treatment (4 WAT), and 8 wk after treatment (8 WAT) with select herbicides, summer 2020. Bars with the same letter are not different according to a Dunn's All-Pairwise Comparison test at n $\alpha \leq 0.05$. All analyses were conducted within sampling time.

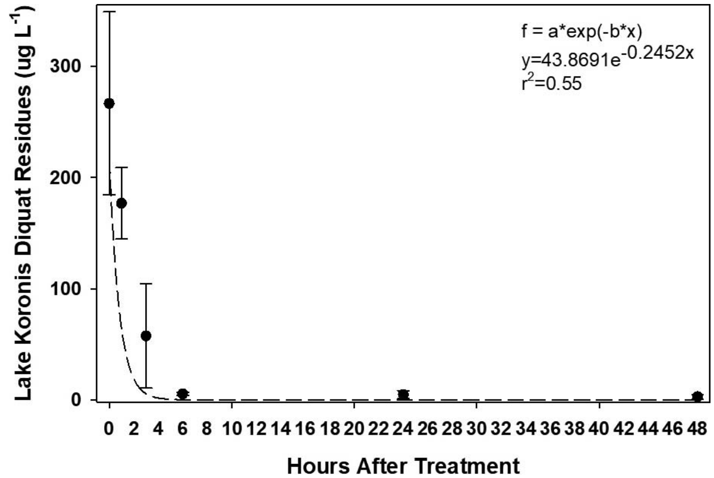

Figure 3. Exponential decay model of mean (± 1 SE) diquat residues from four plots in Lake Koronis following applications made on 15 July 2020 for starry stonewort control.

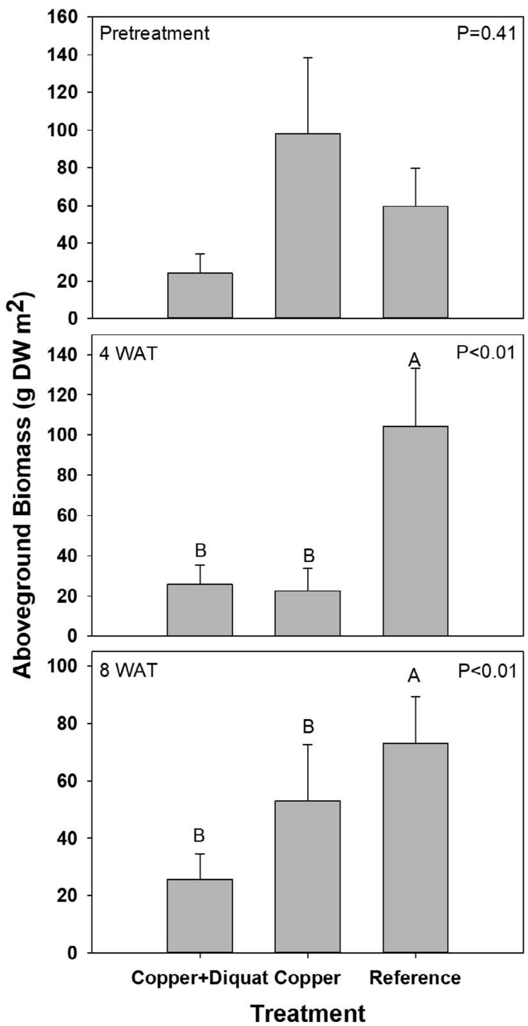

Figure 4. Mean (± 1 SE) aboveground biomass of starry stonewort at pretreatment, 4 wk after treatment (4 WAT), and 8 wk after treatment (8 WAT) with select herbicides, summer 2021. Bars with the same letter are not different according to a Dunn's All-Pairwise Comparison test at n $\alpha \leq 0.05$. All analyses were conducted within sampling time.

had recovered when compared to untreated reference plants. Combinations of copper + diquat resulted in a 75% reduction of aboveground biomass by 4 WAT (Figure 4). Unlike in the copper plots, there was no indication of regrowth in the combination plots at 8 WAT. The combination plots, at 1,985.2 m^{-2}, had greater bulbil densities than either the copper or reference plots (Figure 5). By 4 WAT the bulbil density had more than doubled (5,035.2 bulbils m^{-2}) in these plots and stayed near that level by 8 WAT. This wide discrepancy is due to the high spatial variability seen in bulbil production.

While management of algae has been successful for decades using copper compounds the bulbils of starry stonewort have been shown to be problematic (Glisson et al. 2018). This is due to the inability of copper algaecides to reduce the viability of starry stonewort bulbils either by inhibiting sprouting or the direct destruction of bulbils (Glisson et al. 2018). A variety of

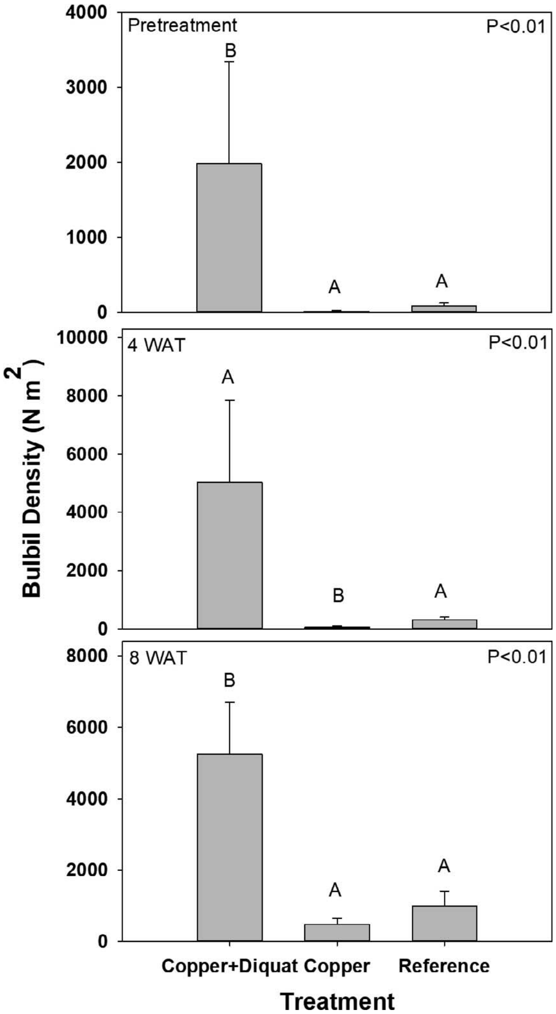

Figure 5. Mean (± 1 SE) bulbil density of starry stonewort at pretreatment, 4 wk after treatment (4 WAT), and 8 wk after treatment (8 WAT) with select herbicides, summer 2021. Bars with the same letter are not different according to a Dunn's All-Pairwise Comparison test at n $\alpha \leq 0.05$. All analyses were conducted within sampling time.

copper formulations were found to have negatively affected the viability of bulbils but had not confirmed viability via sprouting experiments (Pokrzywinski et al. 2021). The ability of starry stonewort to recover from management via bulbils is cause for serious consideration when developing management plans. As we currently know there are no workable strategies to prevent bulbil formation in established populations of starry stonewort.

Observations in this study corroborated the findings of another study on Lake Koronis in that a single algaecide application was not enough to prevent regrowth or regeneration via bulbils of starry stonewort (Glisson et al. 2018). An integrated approach to management may be the best option until application timing can be optimized (Glisson et al. 2018). An understanding of water exchange is needed, as well as a thorough analysis of starry stonewort's seasonal phenology (Glisson et al. 2022b) over multiple years to optimize the timing of treatment and subsequently the efficacy of treatment.

The overall impacts of management must be weighed against the decision to do nothing. When evaluating management, the assumption is erroneously made that doing nothing is environmentally neutral. In dealing with nonnative aquatic species, the environmental consequences of doing nothing may be high, possibly even greater than the effects of management (Madsen 1997). Unmanaged, these species can have severe negative effects on water quality; native plant distribution, abundance, and diversity; and the abundance and diversity of aquatic insects and fish (Madsen 1997). If left unmanaged, the dense growth of starry stonewort will likely extirpate native aquatic plants from those areas (Larkin et al. 2018). It has already been observed that starry stonewort reduces the species richness of macrophytes in several lakes within its invaded range (Brainard and Schulz 2017, Harrow-Lyle and Kirkwood 2022). It has been speculated that infestations of starry stonewort may limit fish spawning habitat, as well as limit the long-term viability of benthic organisms (Brainard and Schulz 2017). These impacts are cause for concern for managers and stakeholders alike.

Lake Koronis has a 476-ha littoral zone of which 324 ha have starry stonewort. No more than 55 ha were managed for starry stonewort in the 2021 season, leaving 269 ha of starry stonewort unmanaged. In the current study one application of copper or copper + diquat was enough for nuisance management when compared to nontreated reference areas; the alternative of no management will lead to an increased population in future years. Management projects should focus on maintaining current levels of starry stonewort by treating at least once a year only if multiple treatments are not feasible. However, multiple treatments should be used to reduce starry stonewort levels until more effective control methods are found or until a more accurate timing for treatment can be utilized. Research should focus on the efficacy of various copper formulations as well as combinations with other pesticides, while also investigating the hydrological properties of the water bodies that are to be treated.

ACKNOWLEDGEMENTS

Funding for this project was provided by the U.S. Army Engineer Research and Development Center (federal award number W912HZ-21-2-0025) awarded under the Cooperative Ecosystem Studies Units Great Lakes Northern Forest unit. Additional funding was provided by the Minnesota Department of Natural Resources under project R29G20201700352, and in part by a grant to the Minnesota Department of Natural Resources (DNR) from the Great Lakes Restoration Initiative under award F17AP00352. We would like to thank Alyssa Haram, Allison Squires, Alyssa Anderson, Amber Fistler, Sara Ademi, Frank Rogers, Ashley Kasper, Kari Solfest, and Vincent McKnight for their tireless efforts in data collection in both the lab and field. We would also like to thank Christine Jurek, Keegan Lund, and Kylie Cattoor with the Minnesota DNR for their assistance in field sampling. Additional logistical support was provided by Koronis Lake Association, Kevin Farnum, and Blue Water Science.

LITERATURE CITED

Bharathan S. 1987. Bulbils of some charophytes. Proc. Plant Sci. 97:257–263.

Bishop WM, Rogers JH, Jr. 2012. Responses of *Lyngbya wollei* to exposures of copper-based algaecides: The critical burden concept. Arch. Environ. Contam. Toxicol. 62:403–410.

Brainard AS, Schulz KL. 2017. Impacts of the cryptic macroalgal invader, Nitellopsis obtusa, on macrophyte communities. Freshw. Sci. 36:55–62.

Calomeni A, Rogers JH, Jr., Kinley CM. 2014. Response of *Planktothrix agardhii* and *Pseudokirchneriella subcapitata* to copper sulfate ($CuSO_4 \cdot 5H_2O$) and a chelated copper compound (Cutrine®-Ultra). Water Air Soil Pollut. 225:1–15.

Glisson WJ, Contreras-Rangel R, Bishop W, Larkin D. 2022a. Laboratory evaluation of copper-based algaecides for control of the invasive macroalga starry stonewort (Nitellopsis obtusa). Manag. Biol. Invasions 13:303–325.

Glisson WJ, Muthukrishnan R, Wagner CK, Larkin DJ. 2022b. Invasive Nitellopsis obtusa (starry stonewort) has distinct late-season phenology compared to native and other invasive macrophytes in Minnesota, USA. Aquat. Bot. 176:103452.

Glisson WJ, Wagner CK, McComas SR, Farnum K, Verhoeven MR, Muthukrishnan MR, Larkin DJ. 2018. Response of the invasive alga starry stonewort (*Nitellopsis obtusa*) to control efforts in a Minnesota lake. Lake Reserv. Manag. 34:283–295.

Groves J. 1919. Notes on Lychnothamnus Braun. J. Bot. 57:125–129.

Harrow-Lyle TJ, Kirkwood AE. 2022. The non-native charophyte Nitellopsis obtusa (starry stonewort) influences shifts in macrophyte diversity and community structure in lakes across a geologically heterogeneous landscape. Aquat. Ecol. 56:829–840.

Hussner A, Stiers I, Verhofstad MJJM, Bakker ES, Grutters BMC, Haury J, van Valkenburg JLCH, Brundu G, Newman J, Clayton JS, Anderson LWJ, Hofstra D. 2017. Management and control methods of invasive alien freshwater aquatic plants: A review. Aquat. Bot. 136:112–137.

Iwinski KJ, Calomeni AJ, Geer TD, Rogers JH, Jr. 2016. Cellular and aqueous microcystin-LR following laboratory exposures of *Microcystis aeruginosa* to copper algaecides. Chemosphere 147:74–81.

Larkin DJ, Monfils AK, Boissezon A, Sleith RS, Skawinski PM, Welling CH, Cahill BC, Karol KG. 2018. Biology, ecology, and management of starry stonewort (Nitellopsis obtusa; Characeae): A Red-listed Eurasian green alga invasive in North America. Aquat. Bot. 148:15–24.

Lembi CA. 2014. The biology and management of algae, pp. 97– 104. In: L. A. Gettys, W. T. Haller, and D. G. Petty (*eds*.). Biology and control of aquatic plants. A best management practices handbook. 3rd ed. Aquatic Ecosystem Restoration Foundation: Marietta, GA.

Madsen JD. 1993. Biomass techniques for monitoring and assessing control of aquatic vegetation. Lake Reserv. Manag. 7:141–154.

Madsen JD. 1997. Methods for management of nonindigenous aquatic plants, pp. 145–171. In: J. O. Luken and J. W. Thieret (*eds*.). Assessment and management of plant invasions. Springer, New York.

Madsen JD, Wersal RM, Getsinger KD, Skogerboe JG. 2010. Combinations of endothall with 2,4-D and triclopyr for Eurasian watermilfoil control. APCRP Technical Notes Collection (ERDC/TN APCRP-CC-14). U.S. Army Engineer Research and Development Center, Vicksburg, MS. 10 pp.

Madsen JD, Wersal RM, Woolf TE. 2007. A new core sampler for estimating biomass of submersed aquatic macrophytes. J. Aquat. Plant Manag. 45:31–34.

Midwood JD, Darwin A, Ho ZY, Rokitnicki-Wojcik D, Grabas G. 2016. Environmental factors associated with the distribution of non-native starry stonewort (*Nitellopsis obtusa*) in a Lake Ontario coastal wetland. J. Gt. Lakes Res. 42:348–355.

Mills EL, Leach JH, Carlton JT, Secour C. 1993. Exotic species in the Great Lakes—A history of biotic crises and anthropogenic introductions. J. Gt. Lakes Res. 19:1–54.

[Minnesota DNR] Minnesota Department of Natural Resources.. 2022. Infested Waters List.https://www.dnr.state.mn.us/invasives/ais/infested.html. Accessed September 9, 2022.

[MISIN] Midwest Invasive Species Information Network. 2017. Reported Sightings Database. Michigan State University Extension. http://www.misin.msu.edu. Accessed March 25, 2020.

Pennington TG, Skogerboe JG, Getsinger KD. 2001. Herbicide/copper combinations for improved control of *Hydrilla verticillata*. J. Aquat. Plant Manag. 39:56–58.

Peterson HG, Boutin C, Freemark KE, Martin PA. 1997. Toxicity of hexazinone and diquat to green algae, diatoms, cyanobacteria, and duckweed. Aquat. Toxicol. 39(2):111–134.

Phlips EJ, Hansen P, Velardi T. 1992. Effect of the herbicide diquat on the growth of microalgae and cyanobacteria. Bull, Environ. Contam. Toxicol. 49:750–756.

Pokrzywinski K, Bishop W, Grasso C, Volk K, Getsinger K. 2021. Chemical management strategies for starry stonewort: A mesocosm study. ERDC/EL TR -21-10. U.S. Army Engineer Research and Development Center, Vicksburg, MS. 29 pp.

Pullman DG, Crawford G. 2010. A decade of starry stonewort in Michigan. LakeLine. 30:36–42.

Robson TO, Fowler MC, Barret PRF. 1976. Effect of some herbicides on freshwater algae. Pestic. Sci. 7:391–402.

Sleith RS, Havens AJ, Stewart RA, Karol KG. 2015. Distribution of *Nitellopsis obtusa* (Characeae) in New York, USA. Brittonia 67:166–172.

Sutton DL, Blackburn RD, Barlowe WC. 1971. Response of aquatic plants to combinations of endothall and copper. Weed Sci. 19(6):643–646.

Sutton DL, Weldon LW, Blackburn RD. 1970. Effect of diquat on uptake of copper in aquatic plants. Weed Sci. 18:703–707.

Wersal RM. 2022. Small scale evaluations of select pesticides for development of management recommendations for starry stonewort (*Nitellopsis obtusa*). J. Aquat. Plant Manag. 60:10–15.