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Aligning Research and Management Priorities for *Nitellopsis obtusa* (Starry Stonewort)

A Workshop Summary

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Jonathan Midwood

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A Workshop Summary

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Abstract

In 2018, the US Army Corps of Engineers and Washington and Waukesha Counties in Wisconsin hosted a workshop on the invasive macroalga starry stonewort (*Nitellopsis obtusa*). Leading water resource managers (agencies and commercial applicators), researchers, regulators, and other interested parties discussed issues surrounding starry stonewort invasions in the Great Lakes Region (GLR). Technical sessions presented information on current research, invasion monitoring, early detection, rapid-response efforts, and operational management activities. Research summaries included invasion in Lake Ontario, prediction of invasion risk in Minnesota and Wisconsin using water chemistry data, and bulbil efficacy and distribution modeling in New England. In addition, the workshop offered summaries of attempted chemical and mechanical control tactics. Following presentations on previous studies, workshop participants identified research and management priorities. Critical research gaps identified from this workshop include (a) better understanding of the biology, invasion ecology, and management of starry stonewort; a greater understanding of distribution and movement, especially in the Great Lakes basin; enhanced population monitoring, applied research, and management strategies; and increased technical cooperation across government, academia, industry, and nonprofit organizations. Conclusions from this meeting will help prioritize future efforts focused on the adaptive management of starry stonewort in the United States and Canada.

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Contents

Abstract	ii
Contents	iii
Figures	v
Preface	vi
1 Purpose and Scope	1
2 Background	3
2.1 Identification	3
2.2 Biology	4
2.3 Spatial distribution	4
3 Prior and Current Research	6
3.1 Invasion of starry stonewort in Lake Ontario (Jonathan Midwood, Fisheries and Oceans Canada).....	6
3.2 Using water chemistry to predict lake-level starry stonewort invasion risk (Dan Larkin, University of Minnesota–St. Paul).....	7
3.3 Starry stonewort bulbil distribution modeling in New England (Ken Karol and Robin Sleith, New York Botanical Garden).....	8
3.4 Conclusions.....	9
4 Management Options for Starry Stonewort	10
4.1 Chemical control.....	10
4.2 Mechanical control	11
4.3 Conclusions.....	11
5 Identifying Research and Management Priorities	13
5.1 Determine how starry stonewort infestations occur.....	13
5.2 Phenology and life cycle.....	14
5.3 How invasive is starry stonewort likely to be outside of the Great Lakes Region (GLR)?	14
5.4 New management strategies	14
5.5 Is early detection/rapid response (EDRR) a practical technical objective? ..	15
5.6 Education and outreach.....	15
6 Conclusions	17
7 Points of Contact	19
Bibliography	20
Acronyms and Abbreviations	23
Appendix A: Workshop Agenda	24

Appendix B: Workshop Participants.....27

Figures

Figure 1: Starry stonewort bulbil..... 3

Preface

The information reported herein was presented in a workshop organized by the US Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL) in partnership with the Land and Conservation Division of Washington and Waukesha Counties, Wisconsin, with additional workshop support provided by the Aquatic Ecosystem Restoration Foundation. The workshop was funded by the Great Lakes Restoration Initiative through the US Army Corps of Engineers Buffalo District managed by Mr. Michael Greer, in partnership with the Aquatic Plant Control Research Program (APCRP). Dr. Warren Lorentz was the APCRP technical director, Dr. Jennifer Seiter-Moser was the associate technical director, and Dr. Christine VanZomeren was the APCRP manager.

The work was performed by the Environmental Processes Branch of the Environmental Processes and Engineering Division, US Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication of this report, Dr. Michael Rowland was Branch Chief, and Dr. Mark Noel was Division Chief. The Deputy Director of ERDC-EL was Dr. Jack E. Davis, and the Director was Dr. Edmond J. Russo Jr.

The authors gratefully acknowledge the substantial contributions to the workshop by over 50 participants and technical experts. Reviews of this report were provided by Dr. Christopher Mudge and Dr. Bradley Sartain.

COL Teresa Schlosser was Commander of ERDC, and Dr. David W. Pittman was ERDC Director.

1 Purpose and Scope

Starry stonewort (*Nitellopsis obtusa* [Desv. in Loisel.] J. Groves) is a macroalga of the Characeae family categorized as invasive in North America, including the United States (Kipp et al. 2020; State of Michigan 2016). Despite claims that this plant-like organism is highly invasive, little published information regarding factors that promote or inhibit growth and expansion of this species exists. In general, the published information about starry stonewort that does exist consists of anecdotal reports from the field such as viable phenology records and management strategies. As the species spreads across the northern states and Canada, scientists, resources managers, industry, and other stakeholders must establish a data-driven approach to environmental impacts of the species and develop environmentally compatible starry stonewort management strategies.

To that end, the US Army Engineer Research and Development Center (ERDC) partnered with the Land and Water Conservation Division of Washington and Waukesha Counties, Wisconsin, to host the workshop “An Action Plan for Starry Stonewort: Aligning Research and Management Priorities” in Oconomowoc, Wisconsin, from 7 to 8 September 2017. This venue provided a forum for leading water resource managers (agencies and commercial applicators), scientists, regulators, and other interested parties to present and discuss issues surrounding starry stonewort invasions in waterbodies of the Great Lakes Region (GLR). The workshop consisted of approximately 35 representatives across 11 states and Canada. The workshop’s technical sessions focused on current research studies, survey monitoring of lake invasions, early detection and rapid-response (EDRR) efforts, and outcomes of large-scale operational management activities. Following technical sessions, attendees participated in break-out sessions designed to capture the viewpoint of researchers, resource managers, commercial applicators (industry), and private citizen stakeholders. The workshop agenda and a list of participants are available in appendices A and B.

The objectives of the workshop included the following:

1. Review the current understanding of the biology, invasion ecology, and management of starry stonewort.

2. Discuss current distribution and movement of starry stonewort and why it poses a significant threat to the Great Lakes.
3. Identify and prioritize research, monitoring, and management needs for starry stonewort that will address crucial information gaps and encourage innovative approaches to addressing this problematic species.
4. Provide technical guidance on starry stonewort issues for stakeholders from federal, state, and local governments; academia; field practitioners; industry, and nonprofit organizations.
5. Unite personnel from government, academia, and industry to develop a nexus for addressing starry stonewort with a focus on minimizing the duplication of efforts and stimulating new collaborations.

This report provides a summary of the findings from the workshop, highlighting starry stonewort research and management priorities and detailing discussions to help educate resource managers, stakeholders, and legislators in the GLR.

2 Background

2.1 Identification

Starry stonewort is a dioecious green macroalga of the Characeae family native to Europe and western Asia. While considered threatened in its native environment, it now occurs at high densities throughout northern-tier lakes of the United States. Starry stonewort is similar in appearance to other macroalgae, such as muskgrasses and native stoneworts. It is related to the genera *Chara*, *Nitella*, *Tolypella*, and *Lychnothamnus*, among others. Similar to vascular submersed plants, these macroalgae tend to improve water clarity/quality through competition for nutrients and sediment stabilization. There are several distinguishing features that clearly identify starry stonewort. First, the plant is much larger compared to other stoneworts and muskgrasses. Most stem and branch cells are around 1 mm¹ in diameter, and stems can reach over 80 cm in length (Hargeby 1990, Sher-Kaul et al. 1995). The smooth body structure of starry stonewort lacks cortication and is composed of node and internodal regions. Nodes of whorls consisting of four to six branchlets are connected by smooth, elongated, single-celled, multinucleoid internodal regions. Each branchlet emerging from the whorl has a bract cell near the terminal end, giving the branchlet an uneven forked appearance.

Figure 1. Starry stonewort bulbil. The star-shaped bulbils produced on the clear rhizoids (root-like structures) of *N. obtusa*, known for giving starry stonewort its name (photo from Wisconsin DNR 2017).



1. For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–52, <https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf>.

In North America, current research asserts that only male specimen have been observed (Minnesota DNR 2015; Wisconsin DNR 2017); however, it remains unclear if there is a lack of females or a lack of fertile females. The reproductive organs in starry stonewort are oogonia (female) and antheridia (male). The most distinguishing feature of starry stonewort is the starchy star-shaped bulbils (figure 1) connected by clear, filamentous rhizoids or root-like structures (Minnesota DNR 2015; Wisconsin DNR 2017). Researchers have not yet observed bulbils on the photosynthetic part of the macroalgae; however, while nodes do grow adventitious rhizoids, researchers do not consider them bulbils. The starry stonewort bulbils produce a clone of the parent, since the bulbils do not reproduce sexually. Few macroalgae produce bulbils, and no native bulbils are distinctly star-shaped as with starry stonewort.

2.2 Biology

Starry stonewort can persist to an ultimate stage of invasion known as *packing*, where the population fills all available habitats and moves into areas that are not considered optimal for growth (Pullman and Crawford 2010). In Michigan, for example, starry stonewort has become particularly prolific, and whether this rate of spread is related to aquatic plant management practices, the invasive nature of starry stonewort, or a combination of both remains unclear (Aquatic Weed Control 2015; Brainard and Schulz 2017). Despite claims of this macroalga's highly invasive character, limited published information regarding factors that promote or inhibit growth and expansion of this species, including light and nutrient requirements, temperature range, and pH, exists. See Larkin et al. 2018 for a comprehensive review of the biology, ecology, and management of starry stonewort.

2.3 Spatial distribution

The first record of starry stonewort in North America was in the St. Lawrence River near Montreal, Québec, Canada in 1974 (Karol and Sleith 2017). Its first record in the United States is from 1978 also in the St. Lawrence River in the state of New York (Sleith et al. 2015). By 2005, starry stonewort had spread within the state of New York, and by 2014 had also reached Indiana, Michigan, Wisconsin, and Pennsylvania (Sleith et al. 2015). By 2017, starry stonewort had been discovered in additional locations surrounding the Great Lakes and Canada including Minnesota, Vermont, and Ontario (Sleith et al. 2018). In the absence of sexual

reproduction, starry stonewort spreads rapidly from lake to lake through the transport of bulbils and fragments. Bulbils may be transported on boats, trailers, anchors, and in ballast water. In comparison, the role of water fowl in distributing starry stonewort appears to be minimal, as the starchy bulbils are easily and quickly digested (Wisconsin DNR/Golden Sands 2016).

3 Prior and Current Research

Starry stonewort has recently become an invasive problem of note in North America, yet applied research activities have been limited. Much of the effort has focused on describing the growth of the algae in various waterbodies (Geis et al. 1981; Bharathan 1983; Sleith et al. 2015; Escobar et al. 2016; Escobar et al. 2018; Kipp, McCarthy, and Fusaro 2018). In addition, some studies have linked field occurrence to environmental conditions (for example water quality, hydrology, sediment type, light) where problematic populations exist (Hilt et al. 2010; Kisnieriene et al. 2014; Midwood et al. 2016; Alix, Scribailo, and Weliczko 2017; Boissezon, Joye, and Garcia 2017; Genco and Russell 2014).

Research efforts presented at the workshop included a summary of the invasion of starry stonewort in Lake Ontario, the use of water chemistry to predict lake-level starry stonewort invasion risk in Minnesota and Wisconsin, and studies on starry stonewort bulbils and distribution modeling in New England.

3.1 Invasion of starry stonewort in Lake Ontario (Jonathan Midwood, Fisheries and Oceans Canada)

A Canadian effort is investigating regional drivers of starry stonewort invasion and subsequent impacts on invertebrate communities. In 2013, starry stonewort was identified in Presqu'île Bay, Lake Ontario by the Ontario Ministry of the Environment and Climate Change (Midwood et al. 2016). In 2014, the Canadian Wildlife Service conducted a detailed field survey of starry stonewort in Presqu'île Bay (Midwood et al. 2016). The study sought to determine the spatial distribution of starry stonewort in shallow (<2 m) waters of the bay and to identify environmental and anthropogenic factors that might predict of starry stonewort presence. Findings showed the presence of starry stonewort at 43 out of 209 surveyed sites (21%). Researchers used a boosted regression tree analysis to identify the best metrics for predicting starry stonewort occurrence. Primary driving metrics included dock density (25.9%) and conductivity (23.0%), followed by distance to a marina (16.1%) and mean fetch (13.1%) (Midwood et al. 2016). The study could not determine if water chemistry influenced starry stonewort, as anthropogenic activities prevented reliable

data gathering. Dispersal by watercraft was likely an important mechanism for distribution not directly associated with water chemistry, but water chemistry proximate to boat launches was generally different compared to more natural areas. The survey did suggest starry stonewort is likely to occur in areas where fetch is less than 600 m (for water depths <2 m) (Midwood et al. 2016). Based on a more expansive survey of wetlands along the north shore of Lake Ontario, it appeared that sites with good water quality (high water clarity, low turbidity) were more likely to support starry stonewort (Midwood et al. 2016). However, determining optimal conditions for starry stonewort at a regional scale was difficult because of spatial differences in anthropogenic disturbance. Lastly, time-lapse imagery documented a seasonal peak in starry stonewort biomass and highlighted the potential for mapping dense pockets using remote sensing. Collectively, these studies provided valuable baseline information on starry stonewort ecology, guiding further in-depth laboratory studies of this species and helping to manage it in the wild and track its distribution.

3.2 Using water chemistry to predict lake-level starry stonewort invasion risk (Dan Larkin, University of Minnesota–St. Paul)

The University of Minnesota (UMN) is using models to predict the ecological niche of starry stonewort and where those conditions may occur in the United States (for example, lake chemistry parameters in European lakes also found in the northern states and Canada). Escobar et al. (2016) created an ecological niche model based on occurrences of starry stonewort in both native and invaded environments using climate-based prediction of suitable habitats. Using this model, researchers identified uninvaded areas with the highest potential suitability for starry stonewort infestations, including the Mid-Atlantic, Great Plains, and Intermountain West regions. The model also demonstrated that although starry stonewort has already invaded Minnesota, there may be limited suitability. Researchers are currently testing the model empirically where starry stonewort has been observed in two lakes in Minnesota, outside of the designated suitable area. From here, Larkin's group at UMN–St. Paul, in collaboration with Ken Karol's group at the New York Botanical Garden, enhanced the model by adding water chemistry information such as pH,

conductivity (Ca² and Mg), N and P levels, chlorophyll a (chl a) concentrations, and Secchi depth. Using data from New York, Larkin's research showed that invaded lakes had a higher pH, conductance, N, and productivity (chl a). Utilizing information from previously infested sites in New York, researchers then incorporated into the ecological niche model the presence, absence, and water-quality information. The best modeling approach tested was random forests, applied to 985 lakes already with complete environmental data. Spatial interpolation was used for missing lakes. In this model, Secchi depth, chl a and conductivity were the most influential factors. Despite the low initial sample size, the model performed reasonably well at predicting lakes' susceptibility to starry stonewort in both Minnesota and Wisconsin. Larkin's group is continuing work on using spatial interpolation of this model to incorporate more lakes and compile water chemistry risk maps (Romero-Alvarez et al. 2017).

3.3 Starry stonewort bulbil distribution modeling in New England (Ken Karol and Robin Sleith, New York Botanical Garden)

Ken Karol's group at the New York Botanical Garden is working on bulbil and macroalgae viability, germination, and distribution. In their 2017 study, starry stonewort presence and absence and water chemistry parameters were collected at 740 sampling sites across New York and New England (Sleith, Wehr, and Karol 2018). Researchers characterized the ambient chemical conditions favoring four native submersed macro-algae (*Chara braunii*, *Nitella flexilis*, *Nitella microcarpa*, and *Chara contraria*) and starry stonewort based on conductivity, pH, and nutrient concentrations. They found that starry stonewort preferred high conductivity and basic environments having a wide range of nutrient concentrations. All others, with the exception of *C. contraria*, demonstrated a preference for an environment with both lower conductivity and lower acidity present. The chemical properties observed in lakes containing starry stonewort directly correlated with those for *C. contraria*. Karol's group then used boosted regression trees to ecologically model the response of these macroalgae to projected future changes in water chemistry (Elith and Leathwick 2016; Sleith, Wehr, and Karol 2018). Results suggested that while the ecological impacts of *N. obtusa* are not clearly understood in its growth range, starry stonewort will more

2. For a full list of the spelled-out forms of the chemical elements used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 265, <https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf>.

likely benefit from projected changes in water chemistry (increased conductivity and Ca/Mg cations) than native macroalgae.

3.4 Conclusions

Midwood et al. (2016), Larkin et al. (2018), and Karol and Sleith (2017) unanimously reported that starry stonewort prefers lakes with high conductivity (225–300 uS/cm)(threshold). Additionally, Larkin and Karol's groups both reported a direct association of starry stonewort with high pH (8.0–9.2). Other factors that may influence starry stonewort growth and productivity are nutrient concentration (soluble phosphate, approximately 12 µg/L; nitrate, 178–231 µg/L), primary production (chl a), mean fetch, and Secchi depth. However, the various studies did not conclusively report these factors. Several studies have begun to investigate the water quality associated with starry stonewort invasive potential, but the key conditions are proving more complex in field situations owing to confounding factors such as anthropogenic influences and the occurrence of other invasive species. Therefore, it is crucial to expedite investigations on starry stonewort physiology and management in a controlled environment (for example, growth chambers and greenhouses) as well as continue investigations of occurrence, density, and distribution in the GLR.

4 Management Options for Starry Stonewort

Current control methods for starry stonewort have had minimal impacts on established populations, and many treatment strategies' effectiveness is anecdotal (Larkin et al. 2018; Hackett, Cahill, and Monfils 2017; Wisconsin DNR 2017). A review of some management techniques, including chemical and mechanical harvesting, follows. Additionally, no known viable biological control options for starry stonewort currently exist.

4.1 Chemical control

Chemical controls include copper-, diquat- and endothall-based algaecides, with some level of effect reported on starry stonewort at smaller scales in a single growing season (Aquatic Weed Control 2015; Glisson et al. 2018; Larkin et al. 2018). For example, aggressive chemical applications in June, July, and August in two Indiana lakes temporarily controlled starry stonewort for a season, but no method achieves long-term control, and starry stonewort populations are expanding (Aquatic Weed Control 2015). Applications of chelated coppers in a Minnesota lake provided mixed results, with starry stonewort biomass greatly reduced during the initial early-season application only to prove more resistant to a second treatment later in the growing season (Glisson et al. 2018). Current techniques require multiple applications and are nonselective against nontarget and native vegetations. Using chemicals in higher concentrations by distributing the chemicals inside curtains might assist with determining the viability and effectiveness of specific agents. Researchers have not yet determined whether contact herbicides (for example, flumioxazin or endothall), either alone or in combination with chelated coppers, are effective on starry stonewort (Larkin et al. 2018). There are also no published studies assessing the impacts of herbicides and algaecides on bulbil production and/or germination. It is not possible to assess the need for control of starry stonewort operationally without first understanding its reproductive strategies and the factors affecting its spread and growth.

The simultaneous management of starry stonewort and other aquatic invasive species (AIS) lacks investigative data. This is important to note, as observational reports, including those made by Michael Greer of the USACE Buffalo District, suggest starry stonewort is occurring more

frequently in areas currently experiencing infestations of other AIS such as hydrilla (Mike Greer, pers. comm., October 26, 2018). In addition, there is concern that herbicide management for other nuisance species, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*), might exacerbate the spread of starry stonewort, particularly if it is already present (Aquatic Enhancement & Survey 2016).

4.2 Mechanical control

Some states use hand-pulling and mechanical removal (New York State DEC 2017) such as diver assisted suction harvesting (DASH) for managing starry stonewort (Bradley Steckart, pers. comm., September 7, 2018). These techniques can reduce biomass in small areas to treat pioneer populations; however, in the case of established populations, researchers recommend against hand picking and mechanical harvesting, as fragments could increase the spread of the macroalga in the lake (Minnesota DNR 2015). In addition, hand- and DASH-type techniques are labor intensive, expensive, and usually require repeated efforts for adequate control of submersed plants (Bailey and Calhoun 2008; Kelting and Laxson 2010). Large-scale harvesting is also impractical for controlling starry stonewort populations, since this macroalga is so bushy that harvesters quickly fill to capacity (German 2015).

4.3 Conclusions

Currently, outside of anecdotal reports, the management of starry stonewort in the field has had limited success. The general strategy consists of diquat- and endothall-based herbicides in combination with chelated copper. The combination of these fast-acting, contact products derives from the standard mixture used on other difficult-to-control submersed macrophytes. Tested mechanical methods are considerably more costly than chemical methods and offer little reprieve from starry stonewort infestations, while other mechanical methods seem promising but lack quantitative data on their effectiveness. The timing of starry stonewort treatment is likely important, but no data exists to inform optimal timing strategies for improved efficacy for any management strategy. Additionally, no evaluation of the efficacy of physical or chemical management tactics on bulbils exists, yet bilbil management is critical for ensuring complete and lasting starry stonewort removal. Ultimately, resource managers need more effective treatment methods and data on the precise timing of said treatments for established starry stonewort

populations. Ultimately, reducing the spread of this species within and amongst water bodies will require taking special care in its management and educating the public about its presence (Wisconsin DNR 2017).

5 Identifying Research and Management Priorities

Throughout the workshop, facilitators tasked participants with identifying and discussing in small-group break-out sessions areas for improvement and growth in the detection and monitoring of starry stonewort populations, novel applied research projects, and guidance for management. Small groups consisted of randomly selected applicators, researchers, and practitioners, and each group focused on each topic from a real-world perspective. The different perspectives included the researcher, the resource manager, an applicator (industry), and a concerned private citizen. The role-playing effort encouraged attendees to take a holistic perspective and start outside-the-box discussions. Workshop facilitators provided each group with scientific and social challenge questions ranging in scope and complexity. One of the objectives of the break-out sessions was to determine if common themes would emerge. Owing to the unique perspective of each group, important differences emerged at the same time interesting commonalities coalesced. Although there is some overlap in assembling the six topics below, the objective was to stimulate novel research and management approaches for addressing starry stonewort infestations in northern-tier waters. This list does not include all of the various ideas discussed, but it does capture areas of strong consensus.

5.1 Determine how starry stonewort infestations occur

- What are the sources and routes of new starry stonewort infestations?
 - Watercraft?
 - Waterbirds or other animals (epizoochory)?
- Where are new infestations likely to occur?
 - Boat launches?
 - Dock areas?
 - Anthropogenic management activities for other AIS, particularly herbicide treatments?
- How will projected climate change scenarios impact starry stonewort infestations?
- Further use of predictive models will help determine the rate of spread and ecological niche of starry stonewort.

5.2 Phenology and life cycle

- Analyze starry stonewort ecology and phenology to optimize timing and efficacy of management.
 - When is the best time to survey for starry stonewort?
 - How do sediment type, chemistry, and water quality influence growth?
 - Is starry stonewort associated with or benefiting from other AIS?
 - How can standardized cultivation techniques in the laboratory, growth chamber, and green house guide management strategies?
- Analyze bulbils' response to various stimuli.
 - How do they respond to freezing and desiccation?
 - How do they respond to current management strategies?

5.3 How invasive is starry stonewort likely to be outside of the Great Lakes Region (GLR)?

- What are the important factors affecting successful colonization?
 - water temperature and duration of growing season
 - water quality and chemistry
 - water depth and light attenuation (water clarity)
 - determining these factors to guide monitoring and EDRR efforts
- Is there variability in genetics of starry stonewort from different regions? Does this link to invasiveness?

5.4 New management strategies

- Which management strategies are the most effective?
 - What does a successful treatment mean?
 - Reduction in distribution and biomass?
 - Complete extirpation from the system?
 - Develop well-designed, replicated, controlled environment studies to address treatment efficacy.
 - Link timing of treatments to phenological events and weak points in life cycle.
 - Improve chemical control by combining herbicide concentration and exposure time studies with field verification studies.
 - Can nutrient management be used to control starry stonewort?
 - Pre- and postmonitoring (with appropriate controls) is critical for assessing efficacy of management actions.
 - Is biological suppression an option for management?
 - Need evaluation of potential vectors and their risks and efficacy.
- Address regulatory issues associated with herbicide and algaecide strategies.
- Investigate the role of nutrient management.

5.5 Is early detection/rapid response (EDRR) a practical technical objective?

- How best to monitor for starry stonewort?
 - Establish standardized EDRR programs at regional, state, and federal levels.
 - Establish protocols and methods tailored to detect starry stonewort while also collecting other parameters (that is, water chemistry) that will support science and future management.
 - Ensure monitoring efforts are standardized and data collections are quantitative.
 - Collect and preserve voucher specimens (press samples) for confirmation, validation, and genetic testing.
 - Standardize methods for collecting and sharing data.
 - Remove inconsistencies in data tracking and understand the limitations.
- What new technologies are available?
 - Compare cost effectiveness of new technologies with current monitoring and tracking methods.
 - Explore new options for increasing efficiency of search efforts to aid routine tracking and monitoring.
 - Assess feasibility of using underwater remotely operated vehicles, submersibles, GoPro cameras, and machine learning to monitor starry stonewort growth and spread
 - Assess feasibility of using drones underwater autonomous vehicles to analyze cover and biomass.
 - Train mechanical harvesters to identify starry stonewort or use videos to capture what's coming up (that is, flow-cam-type data).
- Can citizen science assist with monitoring?
 - Citizen Lake Monitoring Network (CLMN): valuable as rapid-response network but need to validate
 - fewer resources (that is, money and staff) to accomplish same amount of work, so there will be a greater need to rely on CLMNs, which will reduce the burden on research programs
 - phone apps for CLMN/tracking

5.6 Education and outreach

- Knowledge transfer
 - local media critical to getting information out sooner to interested stakeholders
 - water craft tours to engage public/inform about AIS
 - water fowl hunters for outreach
 - training citizens: both classroom and hands on
 - posts on Twitter, Instagram, and other social media.

-
- Facebook groups: existing Wisconsin sportsman groups and naturalist groups as potential targets, but need moderator to monitor social media pages
 - Messaging
 - Avoid use of solely negative media to help change public perception and encourage action.
 - Highlight successes and relay these to the public to show that treatments and monitoring are working.

6 Conclusions

The following conclusions outline key points identified by workshop participants. These conclusions can be used as a road map to prioritize and focus future collaborative efforts and significantly improve management of starry stonewort infestations in the United States and Canada.

- The workshop reviewed and discussed the current understanding of the biology, invasion ecology, and management of starry stonewort.
 - Much of the phenology of the plant is poorly understood, particularly with respect to linking those life-cycle events with management strategies.
 - Some information can be gleaned from work on other charophytes (especially *C. contraria*, Sleith, Wehr, and Karol 2018), but the uniqueness of starry stonewort (bulbils, aggressive invasiveness, difficulty to culture, etc.) will require developing new paradigms.
 - Controlled environments in laboratory cultivation for testing in nonconfounding environments, sediment and pore-water classification, and bulbil viability and treatment, require conducting replicated studies for growth and management applications.
 - Without this phenological-ecological understanding, successful and selective control of starry stonewort will be difficult.
- ERDC investigators first developed a successful model for Eurasian watermilfoil and hydrilla that links phenological and ecological understanding to improve management of submersed invasive plants . Clearly, the distribution and movement of starry stonewort is occurring on an accelerated basis across the Great Lakes Basin (GLB).
 - The macroalga is poised to become a major nuisance species in the region, perhaps replacing the niches occupied by valuable native plants and even by the invasive Eurasian watermilfoil, hydrilla, and curly-leaf pondweed.
 - Evidence continues to indicate that starry stonewort has the potential to cause significant negative ecological, recreational, and economic impacts in the GLB and has significant potential to invade US Army Corps of Engineers (USACE) lakes and reservoirs.
 - Likely impacts will include reduction in native plant abundance and diversity, decline in critical fish and wildlife habitat, interference with recreational water activities, increased management costs, and loss of tourism in lake communities.
- Starry stonewort population monitoring, applied research, and management strategies require a renewed emphasis. Crucial information gaps and innovative approaches to addressing this problematic species need much additional technical work

- Develop new and user-friendly technology to discover and routinely monitor starry stonewort infestations.
- Develop EDRR protocols and implement them within and across political boundaries.
- Renew emphasis on improving chemical control techniques.
 - Multiscale research programs that have tested treatments in laboratory, mesocosm, and field settings have greatly improved species-selective management of other submersed invasive plants (for example, for Eurasian watermilfoil and hydrilla).
 - Starry stonewort needs similar efforts.
- Encourage industry to develop and register new and effective products for treating starry stonewort infestations.
- Develop and test viable nonchemical treatment strategies
- Applied research efforts should be collaborative in nature, capitalizing on technical strengths and unique facilities from various groups. This process will maximize and accelerate work and fill critical information gaps.
 - Structure results from applied research efforts to provide technical guidance on starry stonewort issues for all appropriate stakeholders.
 - Include federal, state, and local agencies; academia; vegetation management practitioners; industry; and nonprofit organizations as collaborative stakeholders.
 - Establish a technical wheelhouse comprised of agencies, institutions, industry, and nonprofit groups for addressing starry stonewort, with a focus on minimizing duplication of research and development efforts and stimulating new collaborations..
 - Secure adequate annual funding levels to achieve management goals for research and development efforts and operational programs.
 - Engage the public through involvement and education in the overall process, especially from the perspective of limiting the spread of starry stonewort.
 - Provide education for young scientists and steer research into this area through student grants like the Graduate Student Research Grant supported by the Aquatic Plant Management Society.

7 Points of Contact

This special report was written by Dr. Kaytee Pokrzywinski, Dr. Kurt Getsinger, Mr. Bradley Steckart, and Dr. Jonathan Midwood. For additional information, contact Dr. Kaytee Pokrzywinski (601) 634-3716, Kaytee.Pokrzywinski@usace.army.mil, or the Program Manager, Aquatic Plant Control Research Program, Dr. Christine VanZomeran, Christine.M.Vanzomeran@usace.army.mil. This special report should be cited as follows:

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Acronyms and Abbreviations

Term	Definition
AERF	Aquatic Ecosystem Restoration Foundation
AIS	aquatic invasive species
APCRP	Aquatic Plant Control Research Program
CLMN	citizen lake monitoring network
DASH	diver assisted suction harvesting
EDRR	early detection/rapid response
EL	Environmental Laboratory
ERDC	Engineer Research and Development Center
GLB	Great Lakes basin
GLR	Great Lakes Region
UMN	University of Minnesota
USACE	US Army Corps of Engineers
UWEX	UW-Wisconsin Extension

Appendix A: Workshop Agenda

An Action Plan for Starry Stonewort: Aligning Research and Management Priorities

Workshop Objectives:

- Understand current research in starry stonewort (*Nitellopsis obtusa*) biology, invasion ecology, and management and determine key knowledge gaps and areas worth pursuing in more detail.
- Discuss current distribution and movement of starry stonewort and why it poses a significant threat to the Great Lakes.
- Identify and prioritize research, monitoring, and management needs for starry stonewort.
- Unite personnel from government, academia and industry to develop a wheelhouse for addressing starry stonewort with a focus on minimizing the duplication of efforts and stimulating new collaborations.
- Produce a summary report that highlights research and management priorities and details key discussions from this workshop to help educate resource managers, stakeholders, and legislators in the Great Lakes region.

September 7, 2017 - Morning Session

0800 – Welcome & Opening Remarks - Kaytee Pokrzywinski, ERDC

Aquatic Plant Control Research Program (APCRP) Overview – Al Cofrancesco, USAERDC

0830-0930 – Invited Presentations – The Scope: Species Distribution and Identification: Session chair – Paul Skawinski, UW-Steven's Point/University of Wisconsin Extension (UWEX)

0830 – Paul Skawinski, UW-Steven's Point/UWEX – Biology, identification, origin and dispersal

0845 – Jon Midwood, Fisheries and Oceans Canada – Starry stonewort in Lake Ontario

0900 – Hilary Mosher, Finger Lakes Institute – Addressing starry stonewort in New York’s Great Lakes Basin and Beyond

0915 – Brad Steckart, Washington/Waukesha Counties, WI – Starry stonewort in southeast Wisconsin: outreach and citizen involvement

0930-1000 – Refreshment Break – Sponsored by Aquatic Ecosystem Restoration Initiative (AERF)

1000-1130 – Breakout Session – Preventing the spread

1130-1215 – Breakout Session Summary

1215-1300 – Box Lunch

Afternoon Session

1300 – Session Remarks - Mike Greer, USACE Buffalo District

Great Lakes Research Initiative starry stonewort collaborative – Hilary Mosher, Finger Lakes Institute

1315-1430 – Invited Presentations – Tracking and monitoring a new invader: Session Chair – Dan Larkin, UMN–St. Paul

1315 – Dan Larkin, UMN–St. Paul – Using water chemistry to predict lake-level starry stonewort invasion risk in Minnesota and Wisconsin

1330 – Scott Brown, Michigan Lake & Stream Association – Ecological parameters associated with dense colonization by starry stonewort in Great Lakes region inland lakes

1345 – Robin Sleith, New York Botanical Garden - Starry stonewort bulbil research, starry stonewort distribution modeling and genetics

1400 – Michelle Nault, Wisconsin Dept. Natural Resources – Monitoring and response following the discovery of starry stonewort in Wisconsin

1415-1445 – Refreshment Break - Sponsored by AERF

1445-1615 – Breakout Session – Technologies and methods to enhance tracking and monitoring

1615-1645 – Breakout Session Summary

1645-1700 – Closing Remarks and Adjourn

September 8, 2017 - Morning Session

0800 – Arrive and Opening Remarks - Kurt Getsinger, USAERDC

AERF Overview – Carlton Layne, AERF

0815-0900 – Invited Presentations – Management Strategies: Session Chair – Kurt Getsinger, USAERDC

0815 – Bill Ratajczyk, Lonza/Applied Biochemists – A proactive approach for managing starry stonewort

0830 – Scott Van Egeren, Wisconsin Dept. Natural Resources – Management of starry stonewort in WI

0845 – West Bishop, SePRO Corp. – Research/control initiatives with starry stonewort

0900 – Paul Hausler, Progressive AE – An industry perspective on starry stonewort management by

0915-0945 – Refreshment Break - Sponsored by AERF

0945-1115 – Breakout Session – Identifying research to meet management needs

1115-1155 – Breakout Session Summary

1155-1200 – Closing Remarks and Adjourn



**US Army Corps
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Appendix B: Workshop Participants

Government Agencies

Al Cofrancesco, US Army Engineer Research & Development Center
Kurt Getsinger, US Army Engineer Research & Development Center
Linda Nelson, US Army Engineer Research & Development Center
Kaytee Pokrzywinski, US Army Engineer Research & Development Center
Mike Greer, US Army Engineer District, Buffalo
Greg Grabas, Canadian Wildlife Service
Jonathan Midwood, Fisheries and Oceans Canada
Maureen Ferry, Wisconsin Dept. Natural Resources
Michelle Nault, Wisconsin Dept. Natural Resources
Scott Provost, Wisconsin Dept. Natural Resources
Scott Van Egeren, Wisconsin Dept. Natural Resources
Tom Slawski, Southeastern Wisconsin Regional Planning Commission
Brad Steckart, Washington/Waukesha Counties, WI
Eric Fischer, Indiana Dept. Natural Resources
Erika Jensen, Great Lakes Commission
Sara LeSage, Michigan Dept. Environmental Quality
Tammy Newcomb, Michigan Dept. Natural Resources
Catherine McGlynn, New York State Dept. Environmental Conservation
Meg Modley, Lake Champlain Basin Program
Tim Plude, Minnesota Dept. Natural Resources

Academia

Tyler Geer, Clemson Univ.
Dan Larkin, Univ. Minnesota – St. Paul
Paul Skawinski, UW-Steven's Point/UWEX

Nonprofits

Scott Brown, Michigan Lake & Stream Association
Lisa Cleckner, Finger Lakes Institute
Ken Karol, New York Botanical Gardens
Carlton Layne, Aquatic Ecosystem Restoration Foundation
Hilary Mosher, Finger Lakes Institute
Robin Sleith, New York Botanical Garden

Industry

West Bishop, SePRO Corp.
Mark Heilman, SePRO Corp.
Pat Dalman, Eco Waterway Services

Gregg Joblonowski, Eco Waterways Services
Paul Hausler, Progressive AE
Amy Kay, Clean Lakes Midwest
David Nicholson, Lonza/Applied Biochemists
Bill Ratajczyk, Lonza/Applied Biochemists

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