Starry Stonewort Management Guide

Control, Monitoring, and Resource Guide

Starry Stonewort Collaborative | Finger Lakes Institute at Hobart and William Smith Colleges,
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Starry Stonewort Management Guide

Photo by Scott Brown

EXECUTIVE SUMMARY

Starry stonewort (*Nitellopsis obtusa*) is a highly invasive macroalga. It invades lakes, ponds, and slow-moving water bodies where it attaches to the sediment. Once established, it grows into dense mats that can have negative ecological and economic effects. The density of the macroalgae can outcompete native plants for resources, reducing biodiversity. They also reduce the area that fish have to spawn, harming fish populations. Additionally, starry stonewort can fill the water column, making recreational activities difficult. Control options include hand-pulling, mechanical harvesting, chemical applications (algaecides), and diver assisted suction harvesting (DASH). Hand pulling and DASH have the potential to eliminate very small infestations, but have not yet been proven as reliable methods for eradication. Because these methods can be costly and time consuming, they are best used on smaller infestations and when infestations are detected early. As such, prevention and vigilance with efforts like monitoring programs and watercraft stewards are of great importance due to their ability to stop infestations before they become problematic or even begin.

Cover photo by Scott Brown

Established in 2004, the Finger Lakes Institute at Hobart and William Smith Colleges is dedicated to the promotion of environmental research and education about the Finger Lakes and surrounding environments. In collaboration with regional environmental partners and state and local government offices, the Institute fosters environmentally-sound development practices throughout the region, and disseminates accumulated knowledge to the public.
Hobart and William Smith are nationally recognized liberal arts colleges defined by a longstanding focus on educating across academic disciplines and an intellectual environment that cultivates faculty and student connections. With a strong commitment to inclusive excellence, the Colleges have a distinguished history of interdisciplinary teaching and scholarship, curricular innovation and exceptional outcomes. Hobart and William Smith provide robust programs in career development, study abroad, service, leadership and athletics. There are 45 majors and 68 minors. With an enrollment of 2,061, morethan 60 percent of students study abroad through one of the top global education programs in the country and all participate in community service. Located in the heart of the Finger Lakes region, Hobart and William Smith enjoy a lakeside campus on the shore of Seneca Lake. Originally founded as two separate colleges (Hobart for men in 1822 and William Smith for women in 1908), Hobart and William Smith students share the same campus, faculty, administration and curriculum.

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INTRODUCTION

Starry stonewort *(Nitellopsis obtusa*) is an invasive species originating in Eurasia, where in some locations it is considered an endangered species. Its exact means and date of entry into North America are unknown, but the oldest records on the continent are from 1974 in the Saint Lawrence River, near Quebec. This first report was likely delivered via the ballast water of large tanker ships (Karol and Sleith 2017). Since then it has spread throughout the Great Lakes basin and beyond, reported as far west as Minnesota and as far East as Vermont (see distribution below for more information). It invades lakes, ponds, and slow-moving water bodies where it attaches to the sediment using rhizomes.

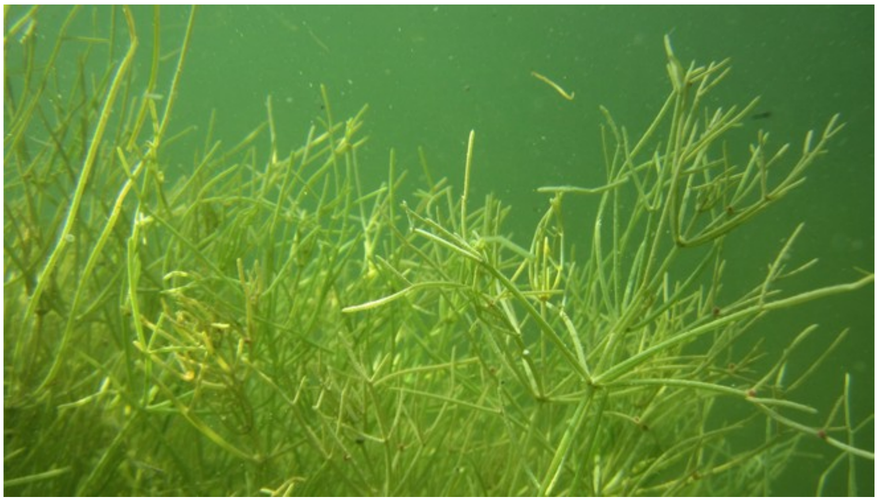


Photo by Scott Brown

BIOLOGY

Starry stonewort (SSW) is a macroalga from the family *Characeae* that closely resembles a vascular plant. However like all macroalgae, it lacks true leaves, roots, or a stem. Instead, it is comprised of a chain of nodes and internodal segments. Whorls of 5-7 branchlets extend from each node, with bract cells growing off branchlets, giving them a forked appearance. Color can vary from a bright green to greenish-brown.

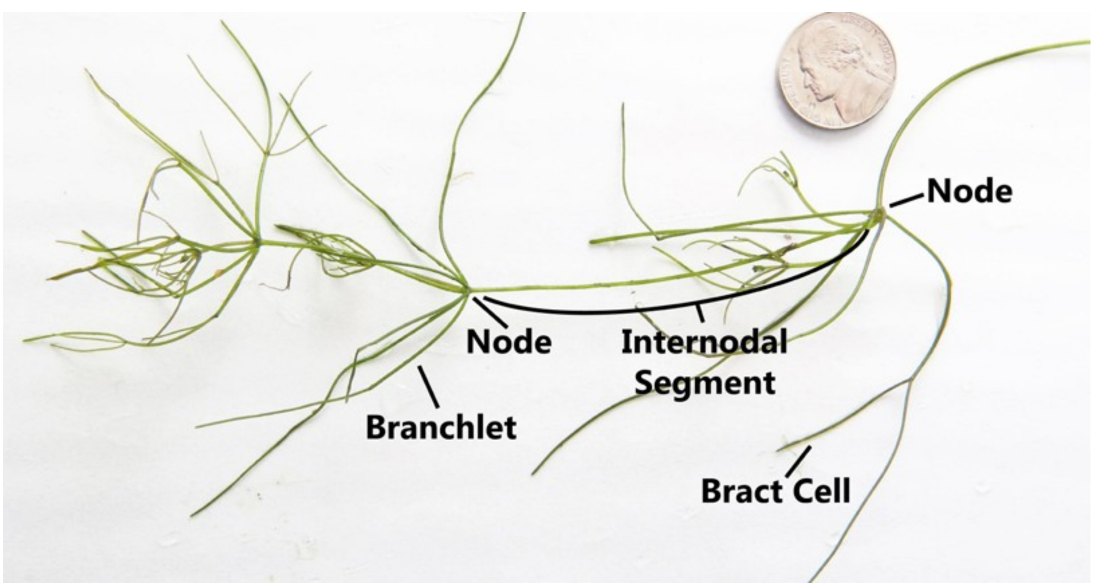


Photo by Paul Skawinski (modified)

SSW has both male and female individuals. As such, they produce unique reproductive organs, dependent on the individual's sex, at branchlet nodes. For males, this means orange antheridia, while for females it means bright red to light green oogonia. However, only sterile specimens or males have been found in North America thus far (Sleith et al. 2015). Here, SSW reproduces asexually from fragments of the macrophyte or bulbils produced beneath the sediment. Since fragments and bulbils can be small, this allows SSW to spread and reproduce easily.

To anchor themselves to the sediment, SSW uses clear, root-like rhizoids. From the nodesof these rhizoids, white, star-shaped bulbils are produced. It is from these bulbils that the name "starry" stonewort is derived. The star-shaped bulbils are also a distinguishing trait in most cases, asnative macroalgae rarely have them. Additionally, SSW lacks the musky smell of similar looking macroalgae from the family *Characeae*, also known as muskgrasses.

Close up of a bulbil.
Photo by Paul Skawinski.

Close up of an antheridium.
Photo by Robin Sleith.

POTENTIAL IMPACTS

Biological:

Research indicates that SSW may negatively impact the native plants in the invaded range (Brainard and Schulz 2017). Outcompeting them for nutrients, light and space, SSW can kill and replace natives thus reducing biodiversity. Additionally, anecdotal reports suggest animals can be negatively impacted by the invading plant (Pullman and Crawford 2010). Due to the loss of familiar native plants and the excessive density of SSW, many fish species are unable to find refuge or places to spawn.

Photo by Scott Brown

Economic:

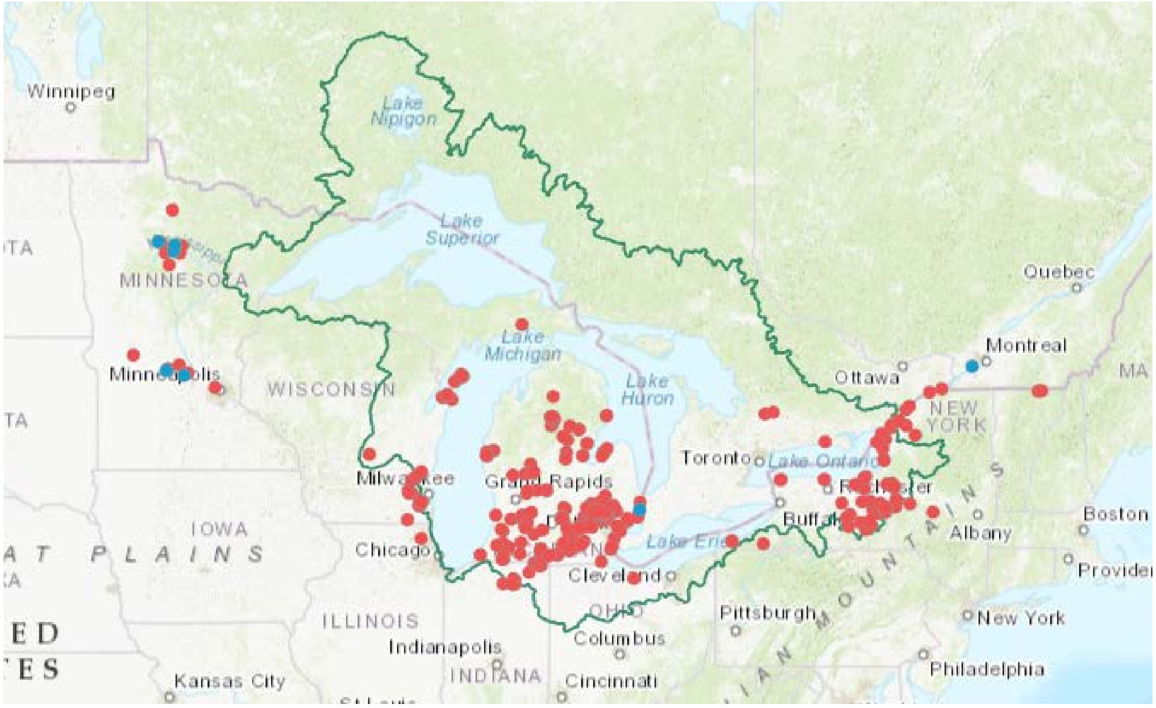
The macroalga has a negative effect on recreational activities. In addition to forming dense mats that cover the bottom of waterbodies, SSW fills the water column vertically. This makes swimming difficult and unpleasant. Boats are alsoimpeded, with thick infestations fouling boat propellers and causing significant drag on the hulls. Additionally, the eviction of native fish species reduces the viable area for fishing while hooks, lures, and other fishing equipment are easily caught in the vegetation.

Photo by Carol Cole

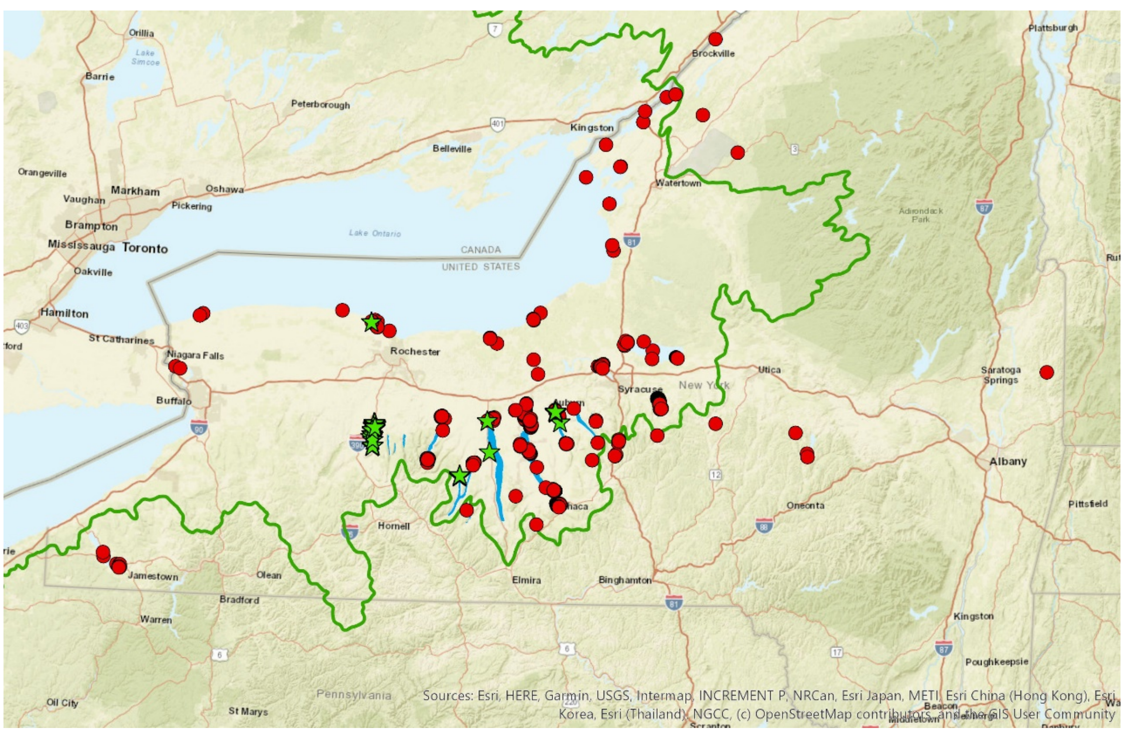
Fisheries and recreational boating represent valuable industries in all affected states. According to the Outdoor Recreation Satellite Account, U.S. and States, 2019 by the Bureau of Economic Analysis, fishing and boating were the most valuable conventional outdoor activities for the United States, at $23.6 billion. In the states where SSW is present, fishing and boating added millions of dollars in value to their economies. These are also valuable industries in Canada. According to a 2012 Marine Manufacturers Association Canada report, recreational boating contributed over $4 billion to the Canadian economy, with almost $2 billion coming from Ontario alone. As for fishing, the 2005 Survey of Recreational Fishing in Canada by Fisheries and Oceans Canada found that recreational fishing contributed $7.5 billion to the Canadian economy. In the Great Lakes, where SSW is currently spreading, it contributes $413 million to the economies of the region. As such, given the demonstrated negative effects SSW has on fishing and boating, the economic impact to these valuable industries could be impacted dramatically by the further spread of SSW.

Distribution:

As of July 2021, SSW has stayed mostly within the Great Lakes basin, though it continues to spread. Currently, it has been found within Minnesota, Wisconsin, Indiana, Michigan, Ohio, New York, and Vermont within the US. Outside the US, it has also been found in Southern Ontario, Canada. Studies indicate that the most likely means of transportation is via humans (Midwood et al. 2016, Sleith et al. 2015). As shown in the map below, major areas of infestation are in southern Michigan, the Finger Lakes region of New York, and the Saint Lawrence River between Ontario and Quebec.



Map of starry stonewort distribution as of August 2021 (USGS-NAS). Red dots represent locations of known infestations. Blue dots are reported, but unconfirmed locations.



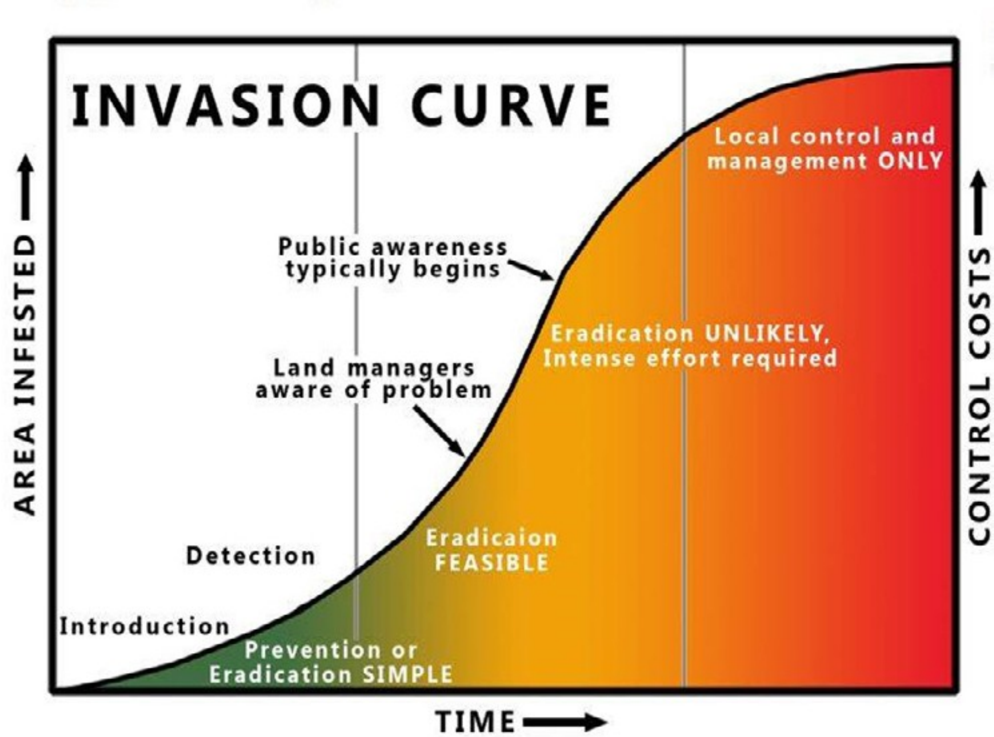
New York State starry stonewort distribution, September, 2021 (iMapInvasives). Red dots represent known locations, green stars are those confirmed in 2021

CONTROL METHODS

Method	Description	Advantages	Disadvantages	Best Suited For	Relative Cost
Prevention	Raise awareness, stop infestations before they start	Long-term strategy, lowest relative cost	Does not address current infestations	Non-infested waterways and waterbodies susceptible to starry stonewort spread	$
Hand Pulling	Remove starry stonewort by hand	Effective, little impact to other species, affordable, may eliminate infestations	Labor intensive, must be careful not to allow spread via fragmented pieces or bulbils	Small, localized infestations	$$
Diver Assisted Suction Harvesting (DASH)	Hand removal of starry stonewort utilizing scuba divers and specialized equipment	Effective, little impact to other species, doable at greater depths, may eliminate infestations	Expensive, require special equipment, labor intensive, must be careful not to allow spread via fragmented pieces or bulbils	Small, but deeper localized infestations	$$$
Chemical Control	Apply chemical treatments to exterminate starry stonewort	Reduces biomass when applied under the appropriate conditions and time of season, quicker than other methods	Expensive, regulatory restrictions, may impact non-targeted species, may not eliminate infestations	Large infestations	$$$
Mechanical Control	Remove starry stonewort using a harvester	Can greatly reduce biomass	Slow, expensive, limited by water depth and site access, may impact non-targeted species, may not eliminate infestations, must be careful not to allow spread via fragmented pieces or bulbils	Areas with concentrated starry stonewort populations or mats that are too large to physically control, with access for boats	$$$
Biological Control	Introduce an herbivore to control plant growth	Long-term control	Not yet available, still under research	Not yet available, still under research	Not yet available, still under research
Drawdowns	Lower water levels to expose and dry out plants	Effective at killing starry stonewort	Not feasible for most situations, leaves infestations in deeper areas untouched	Waterbodies where water levels may be manipulated	Not feasible for most situations

PREVENTION

The best management strategy for controlling any invasive species, SSW included, is to prevent them from establishing in the first place. As an invasive species establishes, spreads, and expands its population, it becomes increasingly difficult to eradicate, in terms of both cost and time, a concept known as the "invasion curve". Because there are more individuals, spread out over a larger area, more resources are needed to sufficiently address them all. As prevention precludes this problem, it is the cheapest and most efficient method of invasive species management. Additionally, studies have indicated that SSW's spread is well correlated to human activity. As such, stopping human-facilitated spread may largely contain the macroalga (Midwood et al. 2016, Sleith etal. 2015).



An illustration of the invasion curve by Southwest Montana Science Partnership, displaying the concept that resource and time costs for management increase with time.

Preventative measures can range from efforts to increase public knowledge and awareness of invasive species to more hands-on programs. Examples include: outreach events to inform people on how to identify invasive species and stop their vehicles from becoming vectors of spread; watercraft stewards at boat launches to inspect watercraft and to communicate to the public information concerning the identification, spread, and negative consequences of invasive species; placing signs on billboards and at boat launches to increase public awareness; and providing equipment at boat launches to allow boaters to wash down their boats and dispose of any invasive species.

Case Study:

The Finger Lakes Partnership for Regional Invasive Species Management (Finger Lakes PRISM) has deployed a variety of preventative measures within the region. For example, the Finger Lakes PRISM utilizes a network of boat launch stewards who provide information, educate boaters, and inspect their vehicles as they enter and exit the water. The Finger Lakes PRISM started their steward program in 2012 and has steadily grown in numbers since, with 29 stewards in 2021 spread across 25 launches. During that season, stewards performed 36,501 inspections, reaching a total of 82,716 people, and removing 4,016 invasive species. As they continue to grow, they scout for new locations where boat launch stewards would be most beneficial, based on boat launch traffic, previous steward coverage, and high priority invasive species present. To enhance their steward program, the Finger Lakes PRISM uses biweekly meetings in which they have conversations, quizzes, presentations, and lessons.

In addition to the stewards, the Finger Lakes PRISM also places signage and disposal boxes at boat launches to educate the public. The signs range from information on specific relevant species to broad lessons onhow boaters can prevent the spread of invasives. Disposal boxes display signage while also providinga place to get rid of any invasives that were attached to vehicles. Of the 184 boat launches in the area, a 2020 survey found that 82 had signage, while 53 had aquatic invasive species disposal boxes. The Finger Lakes PRISM has put signs on billboards for several years to extend their messaging to people they would not normally reach at boat launches, with 10 billboards in 2019 and 10 in 2020. In 2020, the billboards were seen over an estimated 3 million times.

To increase awareness among community members, staff participate in public events, host information sessions, and lead trainings including symposiums, conferences, festivals, meetings, banquets, fairs, forums, and soil and water conservation field days. In 2019, they attended 146 events and reached an estimated 90,000 people; in 2020 there were 68 events with an estimated 700 people; and in 2021, as of writing, therehave been 104 events with an estimated 38,000 people.

Early Detection

Early detection efforts can be used to supplement preventative measures. Regular survey programs can detect invasive species that evade prevention efforts while they are still at removable or manageable population levels. Similar to preventative measures, early detection is relatively inexpensive because it ensures that invaders can be dealt with before management becomes much more expensive. Survey programs can include but are not limited to visual surveys, rake tosses, and point intercept surveys.

If SSW is detected, it is imperative that the observer report the location. GPS coordinatesand photos clearly indicating the species and identifying features should be submitted to iMapInvasives.org, EDDmapS, or other similar apps for identification confirmation. Most of these applications can be accessed and used with a free user account. SSW populations grow quickly, so it is important to locate them in their early stages, so they are easier to control and require fewer resources for management.

To complement their preventative efforts, the Finger Lakes PRISM also engages in early detection efforts, running a program called the Macrophyte Survey. This program, started in 2017, utilizes trained citizen scientists who regularly conduct rake tosses at locations around the Finger Lakes. Additionally, the watercraft stewards are included in this effort and perform rake tosses when they are not inspecting vehicles. In 2020 alone there were 448 rakes tosses conducted across 34 waterbodies, of which 289 of the tosses included invasive species. This data is reported to both local organizations that track invasive species as well as the federal government and is used to help the Finger Lakes PRISM determine where to allocate resources.

A PRISM steward inspecting a boat with its owner.

A disposal box with PRISM signage.

A bi-weekly PRISM steward meeting.

HAND-PULLING

Hand-pulling is a management strategy that involves directly harvesting SSW by hand. Ideally, participants reach a few inches into the sediment and pull the plants up from the sediment, keeping the plant intact and pulling up its bulbils with it. This should be done very carefully to minimize the amount of plant fragments in the water column, as these fragments can easily become established in other areas thus further spreading the species. This method can be done by wading into the water, snorkeling, scuba diving, or from boats/kayaks, depending on the depth and location of the plants. If all parts of the macroalga are removed, along with their bulbils, this will leave them without a way to reproduce and eliminate the infestation. However, it may take several seasons of hand-pulling for complete success. This, along with diver assisted suction harvesting (DASH) are the only methods that can theoretically eradicate SSW (research is ongoing). Other management strategies will leave the bulbils untouched in the sediment, allowing the macroalga to return the next year. Notably however, while reports such as Jurek and Jacobs (2021) suggest hand-pulling to be effective at reducing biomass, they also indicated that it does not eliminate the infestations. In practice, it is too difficult to remove all bulbils and plant fragments.

A volunteer using a rake to pull up starry stonewort.

Case Study:

From 2017-2019, the Keuka Lake Association (KLA), Penn Yan, NY, has performed annual hand-pulls at their Sugar Creek infestation. Volunteers entered the water on foot, removed the SSW by hand and with rakes,and placed it in baskets. The baskets were then given to volunteers who were onshore. Once the vegetation was removed, it was moved via tractor bucket to NYS DEC Sugar Creek Fishing Access Site where it was then picked up for composting. In 2019, pallets were used for transport instead of a tractor bucket.

Despite the use of hand pulling, SSW has not been eliminated at this site and has continued to spread. Management of these locations is ongoing. To help decrease inadvertent spread and increase effectiveness, the KLA sought guidance from the SSW Collaborative Expert Panel. They advised to perform the removal overmultiple visits to let the sediment settle and to catch and regrowth; to focus on infestations that were manageable and not be discouraged by slow progress; to make sure that whole plants are being removed;and to use methods such as snorkeling, Self-Contained Breathing Apparatus (SCUBA) diving, or kayaking to minimize sediment disturbance.

DIVER ASSISTED SUCTION HARVESTING

As an alternative to hand-pulling, Diver Assisted Suction Harvesting (DASH) can be used. It utilizes a combination of SCUBA or surface-supplied (SNUBA) divers and boat-housed equipment to physically remove whole plants. The divers pull the plants out by hand and feed them into a suction line, which will transport them onto the boat. There, they are collected and the water is allowed to drain back into the waterbody. Like regular hand-pulling, this can be a theoretically effective method for removing infestations due to its ability to remove whole plants, including segments of the plants beneath the sediment. However in practice it is still only successful in reducing biomass because of the difficulty of removing all the bulbils and plant fragments (Jurek and Jacobs 2021). Additionally, the specialty equipment and training needed to perform this management strategy means that it also has an increased cost compared to hand-pulling.

Keuka Lake, NY 2021 DASH project (clockwise from the upper left): The harvesting equipment, DASH harvesting boat in action (diver in the water to the left), bags of harvested starry stonewort.

Case Study:

In August 2021, Integrated Lake Management Inc. (ILM) began DASH operations in Keuka Lake under contract with the KLA. In the weeks prior, KLA surveyed the area to establish the current extent of SSW within the lake. They then selected the locations for DASH based on which areas were likely to receive more boat traffic and SSW fragmentation, in hopes of preventing future spread. The DASH crew consisted of three team members and the vacuum system used was a venturi style vacuum. One team member did the harvesting in the water, using a suction hose to directly vacuum up the SSW without first removing it by hand. This method was employed after finding that removing it by hand and then feeding it into the hose was disturbing the sediment and greatly reducing visibility in the water. Further, there was greater potential for fragmentation while handling the plants. The team member used SNUBA in deeper areas and a snorkel in shallower areas. Once the SSW was removed and onto the boat, it was put through multiple screens to separate the SSW from the water and ensure that bulbils were not being put back into the lake. Other workers then sorted through what was collected to remove unintentional animal catches and return them to the water. Once it had been sorted, the SSW was moved into burlap sacks. To prevent SSW fragments from accidently escaping over the side of the boat, barriers were placed along the open edges of the boat. After harvesting was done, the SSW and burlap sacks were taken to be composted. Each day, the team removed about 2000 – 6000 ft^2 of SSW, depending on visibility conditions and the presence of desirable native species that needed to be avoided.
The results of this treatment have yet to be determined, but the harvesting team did note several

Above: The ILM boat. Keuka Lake, 2021.
Right: An ILM worker sorts through harvested SSW for by-catch to be returned to the lake. Keuka Lake, 2021.

lessons they learned from this treatment. First, it was useful to have an adjustable pump rate to help account for how much sediment was being vacuumed up and how fast water was draining through the filter. Second, it was useful to have multiple screen sizes to optimize containment and productivity. Finally it was a useful to have spare parts and tools on the boat so that productivity is not hampered greatly if something goes wrong.

CHEMICAL CONTROL

Chemical treatment involves the application of chemicals designed to kill specific macrophytes where they stand. Copper-based algaecides are commonly used, although any chemicals should be registered with the state and not in conflict with other regulations. The advantages of this method are that it is less labor intensive than physical control and is convenient when infestations are located a distance away from waterway access, which would otherwise make the process of physically removing the plant material difficult. However there may be unintended impacts to non-target species, as these chemicals are not species-specific. Jurek and Jacobs (2021) indicates that native species, especially native macroalgae, are also killed off in the process. The resulting die-off can also cause low dissolved oxygen concentrations by encouraging flurries of decomposer activity. This, in turn, can harm other species in the water and promote algal blooms due to releases of phosphorus that wouldnormally be locked in the sediment. It should also be noted that this method will not eliminate SSW. While it can reduce biomass, and therefore be used to manage the species, it leaves the bulbils in the sediment unharmed, allowing SSW to return afterwards. If native species are killed off in the process, this treatment may exacerbate the problem by clearing SSW competitors, allowing it to become even more dominant.

Copper-based algaecides, commonly used to treat starry stonewort. Little York Lake, 2020.

The application process for chemical treatments. Little York Lake 2020.

Case Study:

In 2020, the Little York Lake Preservation Society (LYLPS), Little York, NY began treating the SSW infestation in Little York Lake using Captain XTR algaecide. The infestation likely began in 1988 (webinar presentation by LYLPS member, 6/9/21) and confirmed in the early 2000s, most likely entering through the boat launch. Little York Lake is a 101-acre mesotrophic lake with a mean depth of 11.5 feet and a maximum of 75 feet, although SSW is mostly only found in the shallow areas. Approximately 15 acres of infested area received treatment. Prior to treatment, infestations were dense enough and high enough in the water column to hinder navigation. Although quantitative measurements were not taken for the results of the treatment, anecdotal evidence indicates that the algaecide was effective at reducing biomass. Areas that were treated showed less SSW than those left untreated, although some SSW did persist. Treatments cost $705 per acre, in addition to project overhead. A second algaecidede treatment was applied in July of 2021. At that time there was virtually no residual effects from the 2020 treatment and almost all the SSW had grown back. Given permitting restraints and the size of the areas to be treated the LYLPS will be trying mechanical harvesting in 2022.

MECHANICAL CONTROL

Mechanical control of SSW involves the use of an aquatic vegetation harvester, which cutsthe plants at a set water depth and removes the cut plants utilizing a conveyor system. The plant cuttings are then taken to shore and dumped, where they can be properly disposed. This method is capable of handling large and dense infestations with relative speed and offers immediate results for boating and other uses of the waterbody.

Studies show mechanical control also works well when followed up with chemical treatments, reducing biomass and bulbil viability (Glisson et al. 2018). However, this method will not eliminate the infestation, as it leaves the bulbils in the sediment intact, allowing SSW to repopulate following the treatment. Even if followed by algaecide treatment, most bulbils will remain viable. Also, it requires appropriate areas to launch and retrieve the harvesters, as well as calm waters deep enough to support a loaded harvester. Fragmentation of the plants may also occur, potentially furthering the spreadof the infestation within the waterbody. Additionally, since the harvester is not species-specific, any native species in the area will also be cut down.

An aquatic vegetation harvester cutting through starry stonewort. Keuka Lake, 2020.

Offloading the harvested plant mass for drying. Keuka Lake, 2020

Case Study:

Starting in 2017, the KLA Penn Yan, NY has performed annual mechanical harvests of SSW in Keuka Outlet through CNY Aquatic Harvesting. Keuka Outlet is the primary outlet river of Keuka Lake. The harvester was set to cut the SSW just above the sediment, as to get as much of it as possible without disturbing the sediment. Due to concern for fragments floating downstream, observers were placed further down the river. No such fragments were detected. Additionally, they were advised by experts from the Minnesota Department of Natural Resources that this should not be of great concern thanks to SSW's water content, which makes it more likely to sink than float. Collected SSW clippings were offloaded into a pile in the nearby boat launch parking lot several hundred feet from shore, where they were left to dry. After drying they were removed for composting. Based on non-quantitative estimates of harvest pile size and number of truckloads, from 2017 to 2018 the biomass harvested decreased. However, it increased slightly in 2019 and 2020.

To supplement this effort, signage instructing boaters to stop and reverse propellers was placed beyond the extent of the infestation in 2017 in the hope that reversing propellers would clear any attached potential plants before boaters could transport them further. This is of great concern as the outlet boat launch in village of Penn Yan, NY is a primary access point for boaters to enter Keuka Lake. These efforts have not stopped the infestations, as SSW continues to spread further within the outlet. To help monitor the infestation as it continues, surveys of the macrophyte communities within the outlet began pre-harvest in 2020. Results from 2020 indicate that SSW is both the dominant species in the outlet as well as the dominant species harvested. An estimated 45% of the harvest's volume was SSW, while 54% were native species. In comparison, pre-harvest surveys showed 30% SSW in the outlet and 59% native species.

DRAWDOWNS

Drawdowns consist of manipulating the water levels to expose previously submerged plants or seeds to adverse conditions. In this method, SSW is thoroughly dried and becomes unviable, unable to grow or sprout. Boissezon et al. (2018) indicates that desiccation is effective at killing SSW populations. As such, if water levels are able to be manipulated, a complete drawdown of an infested area could be effective if the seedbank becomes dry. However, this management option is not available in many of the infested waterways due to their connectivity to other waterbodies including lakes which often lack appropriate water control structures. This method is also not species specific and may impact native species as well.

BIOLOGICAL CONTROL

As of March 2021, no suitable organism has been found to biologically control SSW. Someresearch suggests that some animals, such as crayfish and waterfowl, feed on charophytes such as SSW, but no research has been conducted to test if they would be suitable species for biological control (Larkin et al. 2018).

REGULATORY INFORMATION

Each state has regulations on whether each control method can be performed. Check with your local regulators for more details.

New York: https://www.dec.ny.gov/63.html Department of Environmental Conservation

Minnesota: https://www.dnr.state.mn.us/rlp/index.html Department of Natural Resources

Wisconsin: https://dnr.wisconsin.gov/topic/lakes/plants/rules Department of Natural Resources

Indiana: https://www.in.gov/dnr/rules-and-regulations/invasive-species/ Department of Natural Resources

Michigan: https://www.michigan.gov/invasives/0,5664,7-324-71277---,00.html Michigan Invasive Species

Ohio: https://ohiodnr.gov/wps/portal/gov/odnr/home Department of Natural Resources

Vermont: https://dec.vermont.gov/watershed/lakes-ponds/aquatic-invasives/control Department of Environmental Conservation

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