Informal Review of Literature for the Starry Stonewort Collaborative

This document is the result of a 2019 effort by Finger Lakes Institute staff, as part of the Starry Stonewort Collaborative, to review current literature related to the ecology, outreach and control of invasive starry stonewort and determine which aspects were well covered, and which may require more research and study. Ideally, this could be used to help suggest the direction of research in the future and fill in some of the gaps of our knowledge of starry stonewort. It must be noted, however, that this is not an exhaustive formal review. It contains a number of readily available documents, including peer reviewed papers, presentations, and management plans. As such it is hoped that this information will be more accessible to citizen scientists and lake managers at the community level and be useful to support general knowledge and education about starry stonewort.

The first section contains lists of research topics, management techniques and methods presented in the documents and roughly ranks them in three categories: those showing consensus; areas of common research but minimal consensus and topics that are in need of more research (knowledge gaps). This is followed by the summaries of each paper/document reviewed, with keywords and citations. Citations are in Council of Science Editors format.

Research Consensus:

- <u>Short term control methods</u>: Diver Assisted Suction Harvesting (DASH), mechanical harvesting, and chemical controls have a good effect, if only temporary. They cause large reductions in biomass, essentially managing the portion of the macroalgae above the sediment. But, that still leaves the portion within the soil to regenerate shortly after. As such, these are only stop-gap solutions at the moment.

- Biocontrol methods: None is currently known but there are organisms that, in part, possibly consume SSW.
- Spreading of starry stonewort: Human transport is the most likely method of travel, as opposed to by animal. Forecasting models have shown good success predicting the spread of SSW based on several factors, such as abiotic conditions and boat travel.
- The impact of SSW: SSW has a negative effect on native macrophyte abundance and diversity.

Research With Partial or Minimal Consensus:

- The negative impact on fish.
- The current locations of SSW populations.
- The timing of the annual stages of SSW.
- Differences of niche between invaded and native.
- The possibility of early detection methods such as eDNA.
- The comparability of vertical rake use compared to quadrats

Areas Requiring Research (Knowledge Gaps):

- Sex differentiation and the lack of males in North America.
- An effective biocontrol method.
- Control methods that treat both above/below soil SSW.
- The effect of soil protection of bulbils from chemical treatments and different soil types.

- The effect of climate change.
- Impact on benthic macroinvertebrates.
- The variability of phenology.
- The effect of small scale abiotic factors.
- What kinds of biotic interactions SSW has.
- The effect of landscape factors.
- How SSW fragments would fare under on a moving trailer while exposed to high degrees of wind.
- Do herbivores/omnivores that consume SSW have any major effect on its abundance/biomass.
- How many strains of SSW have entered the US
- SSW's effect on water chemistry.
- The impact on the plankton community.
- The connection to zebra/quagga mussels.
- Why Michigan SSW differs temporally from elsewhere.
- The effect of water temperature.
- The degree of genetic variability.
- The long-term effects of treatments.
- Possible uses for more advanced technology.
- The factors that determine vertical rake method accuracy

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. Aquatic Botany 148:15–24. DOI: 10.1016/j.aquabot.2018.04.003

Funded by: Minnesota Aquatic Invasive Species Research Center (MAISRC); Michigan Invasive Species Grant Program (AKM, BC); International Phycological Society Paul C. Silva Student Grant for Research, Northeast Aquatic Plant Management Society Graduate Scholarship, Northeast Algal Society Student Grant to Support Research, and Phycological Society of America Grants in Aid of Research (RSS); Sarah K. de Coizart Article TENTH Perpetual Charitable Trust (KGK); the National Science FoundationDEB-1020660, DEB-1036466 (KGK), DEB-1701691 (KGK, RSS); and the Wisconsin Department of Natural Resources (PMS).

Keywords: Review, control, morphology, reproduction, dispersal, environment, disturbance, ecology, copper, flumioxazin, endothall, female, impact, knowledge gap, benefits, hand pulling, diver-assisted suction harvesting, harvesters, barriers, drawdowns, charophycean, invasion biology, macrophytes, plant diversity, water chemistry.

A review of previous literature, it covered basics of SSW biology, ecology, and where the knowledge gaps are. In its native range, SSW is actually considered an endangered species and a beneficial organism, providing food and shelter for other native species. It has also been linked to clearer waters. Impacts in the invaded range pose a knowledge gap, but it could potentially harm native diversity through light limitation, ecosystem engineering, nutrient restriction, and space competition. Cooper-based algaecides have been used to mixed results and need further study. Other herbicides such as flumioxazin and endothall have been used as well to mixed results. Mechanical methods can be used, such as hand pulling, diver-assisted suction harvesting, and mechanical harvesters, but these can leave fragments, rhizoids, or bulbils to recolonize from. Physical barriers have been used to mixed results and also require further study. Water drawdowns have the potential to work, but the ability of SSW to recover from freezing needs further study. Knowledge gaps include reason for lack of females in North America, niche differences in native and invaded ranges, biotic interactions, full range, ecological impact, and control methods.

Hackett RA, Cahill BC, Monfils AK. 2017 Dec. State of Michigan's Status and Strategy for Starry Stonewort (*Nitellopsis obtusa* (Desv. in Loisel.) J. Groves) Management.

Funded by: Michigan Department of Environmental Quality and Central Michigan University

Keywords: Review, control, morphology, reproduction, dispersal, environment, detection, eDNA, prevention, ecology, copper, flumioxazin, endothall, female, impact, knowledge gap, benefits, hand pulling, diver-assisted suction harvesting, harvesters, barriers, drawdowns.

A review of previous literature, it covered basics of SSW biology, ecology, and where the knowledge gaps are. In its native range, SSW is actually considered an endangered species and a beneficial organism, having been found to inhibit cyanobacteria growth and restrict phosphorus. In the invaded range, it’s been shown to reduce native diversity, but most examples are anecdotal. Cooper-based algaecides have been used to mixed results and need further study. Other herbicides such as flumioxazin and endothall have been used as well to mixed results. Mechanical methods can be used, such as hand pulling, diver-assisted suction harvesting, and mechanical harvesters, but these can leave fragments, rhizoids, or bulbils to recolonize from.

Physical barriers have been used to mixed results and also require further study. Water drawdowns have the potential to work, but the ability of SSW to recover from freezing needs further study. No biological means of control yet. Knowledge gaps include reason for lack of females in North America, niche differences in native and invaded ranges, biotic interactions, full range, ecological impact, early detection methods, and control methods. Michigan plans to look into these along with prevention, rapid response, and data networking.

Brainard AS, Schulz KL. 2017. Impacts of the cryptic macroalgal invader, Nitellopsis obtusa, on macrophyte communities. Freshwater Science 36:55–62. DOI: 10.1086/689676

Funded by: Cortland–Onondaga Federa-tion of Kettle Lake Associations, Edna Bailey Sussman Foundation, and the Northeast AquaticPlant Management Society (NEAPMS) Graduate Scholarship program.

Keywords: Research, ecology, impact, macrophytes, species richness, biomass, spread, displacement, invasive species, macroalgae, macrophyte, early detection

This study examines the impact of SSW on macrophyte density. While most previous reports were anecdotal, this one sought to provide actual data. At 40 sites across 4 lakes, they collected macrophytes in quadrats, identified them, and took their biomasses. They found that total species richness decreased as SSW biomass increased at all depths. At high SSW biomasses, richness approached 1. Among native species, richness decreased as SSW biomass increased. Non-native richness was unrelated to SSW biomass. As SSW biomass increased, non-SSW biomass decreased. In two of the lakes, mean SSW biomass exceeded non-SSW biomass.

In two lakes, SSW was found more frequently at depth, while there was no significant difference in the other lakes. This paper lends credence to reports that SSW was displacing native macrophytes instead of just filling in empty space. They speculate that differences between lakes may be caused by differences in recreational access since SSW is likely transported by boats. Other papers have noted that increased SSW can have detrimental effects on fish spawning locations. The authors note that more research is needed on the effects of SSW on benthic macroinvertebrates. The presence of SSW in deep water indicates it may go undetected by programs that can only survey in shallower waters. It can also be confused for other macroalgae.

Glisson WJ, Wagner CK, Mccomas SR, Farnum K, Verhoeven MR, Muthukrishnan R, Larkin DJ. 2018. Response of the invasive alga starry stonewort (Nitellopsis obtusa) to control efforts in a Minnesota lake. Lake and Reservoir Management 34:283–295. DOI: 10.1080/10402381.2018.1442893

Funded by: Minnesota Environment and Natural Resources Trust Fund and Outdoor Heritage Fund

Keywords: Research, control, copper, algaecide, mechanical harvesting, rake, biomass, bulbil density, in situ, liquid treatment, granulated treatment, aquatic plant management, Characeae, invasive species, macroalgae, mechanical

This study examines the efficacy of control efforts on SSW and its ability to regenerate from bulbils. They test how well chelated copper algaecide (both liquid and granulated) and mechanical harvesting worked as control agents, both separately and in combination, by comparing treated and untreated biomasses. They also tested bulbil density and viability before and after treatments. Samples were collected using a vertical rake. They found that chemical treatment was effective while mechanical was, statistically, not. A second treatment of algaecide in granulated form appeared to have the reverse affect, showing less biomass decrease than the control area, but this could be due to an already low biomass making detecting a difference difficult. For bulbil density, the results indicated that algaecide and mechanical harvesting had little effect while algaecide alone actually increased density. The combined algaecide and mechanical method resulted in lower bulbil viability while algaecide alone produced no difference. All of this indicates that neither algaecide nor mechanical control methods are effective at stopping SSW, only temporarily reducing it. Although biomass was significantly reduced, the bulbils in the soil allowed it to replace that biomass. That being said, mechanical + algaecide seemed like the best option and could potentially be used to control SSW over time. Whether bulbils have a resistance to algaecide or whether they were simply protected by the soil remains to be seen, although it is most likely the latter. The submersion in the soil also means that other methods that work ex situ may not work in situ unless soil is taken into account. As for the increase in bulbil density produced by the algaecide, two mechanisms were proposed: damage causing plants shifting production to focus on bulbils and the removal of conspecifics triggering the change. Differences in the amount of biomass lost between control methods is also a potential explanation for the differences between bulbil density, with the much larger reduction in the algaecide treatment triggering a larger reaction. It should be noted that this study was conducted in a single lake without replicates as a pilot study and could use further examination.

Midwood JD, Darwin A, Ho Z-Y, 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. Journal of Great Lakes Research 42:348–355. DOI: 10.1016/j.jglr.2016.01.005

Funded by: Unknown

Keywords: Research, ecology, phosphorus, nitrogen, nitrate, nitrite, ammonia, calcium, hardness, fetch, wind, docks, marinas, environmental factors, water quality, aquatic invasive, macroalgae, boosted regression tree, Great Lakes, marsh

This study examines the distribution of SSW in Lake Ontario and the environmental factors that it favors. They sampled at 218 sites within Presqu'ile Bay using rakes, identifying all plant species found. They also collected turbidity and conductivity using probes and water samples using a grab sampler, which they used to analyze TP, nitrogen, ammonia, and water hardness. Additionally, fetch, wave action, and exposure to wind were estimated. Finally, they analyzed the anthropogenic landscape, specifically where docks and marinas were. They found that SSW was found primarily on the North shore, in and around embayments. They also found that areas with SSW had higher conductivities, nitrite-nitrate, and hardness. Higher dock density along with lower mean fetch and distance to the nearest marina were also associated with SSW. They determined that the four most influential factors were dock density, conductivity, distance to marinas, and fetch. Although they found correlations in water quality and SSW, they noted that it would be hard to establish the cause and effect, as it was possible that SSW was modifying the environment instead of the environment being preferable to it. Also possible is the explanation that the presence of human activity is the cause for the water quality and that SSW is simply there because of the disturbances that humans create. Regardless, the correlation between anthropogenic structures and SSW suggests that human activity, whether it be by causing disturbance or by spreading SSW, has a strong link to the establishment of the macroalgae. As such, boaters and others should be made more aware of the species and the procedure to stop its spread. Consistent with previous literature on macrophytes, the negative correlation with fetch suggests a preference for low energy environments. Knowledge gaps still left by this study include the effects of differences in soil.

Pokrzywinski K, Getsinger K, Steckart B, Midwood J. 2018 Jun. Aligning Research and Management Priorities for Nitellopsis obtusa(Starry Stonewort): A Workshop Summary.

Funded by: US Army Corps of Engineers, Great Lakes Restoration Initiative (GLRI), and the Aquatic Plant Control Research Program (APCRP)

Keywords: Review, ecology, control, outreach, fetch, conductivity, dock density, distance to marinas, chl-a levels, pH, secchi depth, biomass, algaecide, herbicide, knowledge gaps

A review of previous literature, this covered the basics of SSW biology, ecology, and where the knowledge gaps are. Fetch, conductivity, dock density, distance to marinas, chl-a levels, pH, and secchi depth were all correlated with SSW presence. Control methods, both mechanical and chemical, were able to reduce biomass but not able to eliminate the problem, as the macroalgae would return following treatment. Chemical treatments that have been used thus far have utilized copper, diquat, flumioxazin, and endothall. The paper also covered numerous knowledge gaps: primary cause of SSW infestations, areas of most likely infestation, rate of spread, niche, effect of climate change, SSW peak time, effect of soil and chemistry, biotic interactions, behavior in controlled environment, bulbil tolerance to chemicals and environmental changes, effect of water temperature, effect of depth and light, genetic variability and history, the need for controlled studies, best time of treatment, more herbicide testing, effectiveness of nutrient management or biological suppression, the long term effect of treatments, best practices for early detection, and the possible use of more advanced technology. Additionally, they made suggestions for how to improve outreach efforts and the use of citizen scientists.

Escobar LE, Qiao H, Phelps NBD, Wagner CK, Larkin DJ. 2016. Realized niche shift associated with the Eurasian charophyte Nitellopsis obtusa becoming invasive in North America. Scientific Reports 6. DOI: 10.1038/srep29037

Funded by: Minnesota Aquatic Invasive Species Research Center

Keywords: Research, ecology, outreach, niche, modeling, spread, climate, temperature, precipitation, climate change, range

This study was aimed at determining and modeling the niche of SSW in both its native and invaded ranges. They did this by examining the abiotic characteristics of the areas that SSW has thus far occurred in such as mean temperature, diurnal range, isothermality, maximum/minimum temperatures, and precipitation. In its invaded range, SSW occupied niches not seen in the native range. However, these differences were found to not be statistically significant. The model also suggested that SSW had tolerances higher than the conditions it was currently being found in. These suggest that SSW is not fully realizing its potential niche in its invaded range. As such, the difference in invasion capability is likely due to factors not tested for here. Additionally, it's possible that human involvement is helping SSW cross biogeographic barriers that it would otherwise have not been able to surpass alone. The model also suggested that the macroalgae has a high potential to continue its spread within the US, as only 5 of the 29 predicted states have SSW thus far. Given these predictions, more resources should be devoted to early detection and awareness in these areas. The effect of climate change on the potential areas of SSW invasion is a subject that needs further research.

Wagner C, Glisson W, Larkin D. 2018 Sep. New phenology insights a year in the life of starry stonewort (Nitellopsis obtusa). DOI: 10.13140/RG.2.2.28417.30560

Funded by: Minnesota Aquatic Invasive Species Research Center

Keywords: Research, ecology, phenology, abundance, rake, bulbil, monitor, control

This poster examines the phenology of SSW. The researchers monitored SSW abundance and bulbil production over two years in two lakes using the spun-rake method. This shows that SSW abundance starts to increase in June, reaches its peak around September, and starts to decline in October. Bulbil production followed similar trends. Latitude appeared to have no effect on either variable. This suggests that late spring/early summer management efforts might be best in order to pre-empt to growth of SSW. It also suggests that the best time to monitor for it is from July to September, when SSW is at its highest, and therefore most detectable. It suggests no areas of further research but continuing this study in more areas and over more years could provide useful data.

Pullman D, Crawford G. 2010. A Decade of Starry Stonewort in Michigan. Lakeline:36–42.

Funded by: Unkown

Keywords: Review, ecology, control, macrophytes, fish, impact, biotic interactions, mussels, copper, endothall, chemical, mechanical, phenology

This review paper covers the history of SSW in Michigan. It covers basic identification, biology, and terminology at the start before moving on to its ecology. It finds that SSW will grow just about anywhere it can, but it prefers deep, still water. In contrast to what most other places report, Michigan's SSW appears to favor the non-summer months, actually becoming dormant or less active during the hottest part of the year. It is able to outcompete and displace all other macrophyte species, likely acting as a benthic barrier. Interestingly, bladderworts and coontail appear to benefit from the presence of SSW, possible due to a lower reliance on the soil. A correlation with zebra/quagga mussels potentially contributes to the clearer waters where SSW is present. Thick matts of SSW also hurt fish spawning by covering spawning locations and changing the biological landscape, making it difficult for fish to reproduce and survive. Sunfish appear to adapt, but all others do not fare as well. Both mechanical and chemical control methods have been used but none completely solve the problem, as the SSW just repopulates rapidly afterwards. Unable to penetrate the soil, the methods are referred to as "haircut treatments" because they simply reduce the amount above the bottom. The chemicals that have been used to good effect are copper and endothall based. The mechanical harvesters have also been noted to have problems with the "spongy" nature of SSW, as it will sometimes roll down the conveyor at the front, making collection difficult. One of the control methods being used in some areas is to simply do nothing and to let the species present compete. This helps reduce other invasive species with little to no effort while also somewhat keeping SSW in check. The wisdom of such a strategy is debatable, but it has utility nonetheless. The knowledge gaps they list are: how many different strains of SSW have entered the US, biotic interactions, how/if SSW is altering water chemistry, long term impacts on biodiversity, soil changes, impact on the plankton community, the connection to zebra mussels, impact on fisheries, other possible control methods, and what makes Michigan SSW different. Notably, this paper does not present data or cite many other sources for these statements, making this paper possible anecdotal.

Hackett RA, Cahill BC, Monfils AK. 2017 Sept. State of Michigan's Status and Strategy for Starry Stonewort (Nitellopsis obtusa (Desv. in Loisel.) J. Groves) Management.

Funded by: Michigan Department of Environmental Quality and Central Michigan University

Keywords: Review, control, morphology, reproduction, dispersal, environment, detection, eDNA, prevention, ecology, copper, flumioxazin, endothall, female, impact, knowledge gap, benefits, hand pulling, diver-assisted suction harvesting, harvesters, barriers, drawdowns

The September 2017 version of this review, as opposed to the December 2017 version. No major changes. A review of previous literature, it covered basics of SSW biology, ecology, and where the knowledge gaps are. In its native range, SSW is actually considered an endangered species and a beneficial organism, having been found to inhibit cyanobacteria growth and restrict phosphorus. In the invaded range, it’s been shown to reduce native diversity, but most examples are anecdotal. Cooper-based algaecides have been used to mixed results and need further study. Other herbicides such as flumioxazin and endothall have been used as well to mixed results. Mechanical methods can be used, such as hand pulling, diver-assisted suction harvesting, and mechanical harvesters, but these can leave fragments, rhizoids, or bulbils to recolonize from. Physical barriers have been used to mixed results and require further study. Water drawdowns have the potential to work, but the ability of SSW to recover from freezing needs further study. No biological means of control yet. Knowledge gaps include reason for lack of females in North America, niche differences in native and invaded ranges, biotic interactions, full range, ecological impact, early detection methods, and control methods. Michigan plans to look into these along with prevention, rapid response, and data networking.

Romero-Alvarez D, Escobar LE, Varela S, Larkin DJ, Phelps NBD. 2017. Forecasting distributions of an aquatic invasive species (Nitellopsis obtusa) under future climate scenarios. Plos One 12. DOI: 10.1371/journal.pone.0180930

Funded by: Unknown

Keywords: Research, ecology, modeling, Maxent, BAM, range, spread, climate, climate change, outreach

This study examined the current range of SSW and how it compared to predicated possible ranges along with its future range in several different climate scenarios. They used the program Maxent using a BAM framework. Three different calibration models were used based on the invaded range alone, its global range, and its global range but with a reduced dispersal potential. Climate was evaluated with five different climate models along with four different climate change emission scenarios. The predictions based on the different calibration models varied significantly, with the invaded range only underpredicting while the global range alone overpredicted. The third calibration produced results in between the two. The third model predicts that there are further areas that SSW has the potential to invade in the future. The climate models also varied, but in general they predicted that the suitable area for SSW will be reduced as the climate changes. These results suggest that calibration of the Maxent system should be done carefully in order to avoid generating erroneous results. But, this system, along with the BAM framework appear to offer a good method of niche prediction. The niche data generated in this study can be used to better allocate resources for monitoring and preventing the spread of SSW. Knowledge gaps for future research include: the effect of smaller scale abiotic factors, biotic interactions, dispersal potential, and the effect of landscape factors.

Glisson WJ, Wagner CK, Verhoeven MR, Muthukrishnan R, Contreras-Rangel R, Larkin DJ. 2019. Desiccation tolerance of the invasive alga starrystonewort (Nitellopsis obtusa) as an indicator of overland spread risk. Journal of Aquatic Plant Management:7–18.

Funded by: Minnesota Aquatic Invasive Species Research Center

Keywords: Research, outreach, control, desiccation, spread, wind, drying, viability, bulbil

This study examined the tolerance of SSW to desiccation to determine how it would fare in overland travel. They collected SSW in the field then allowed them to dry both in the lab and outdoors, removing the samples at 11 different times. They had both wet and dry controls, making a total of 13 different sample groups. Additionally, they separated them by size, with single fragments, small clumps, and large clumps. Finally they tested bulbil desiccation in the lab using the same drying time groupings. Based on mass loss following desiccation, mass recovery following rehydration, and physical recovery following rehydration, SSW is no longer viable after 2 hours for single fragments, 24 hours for small clumps, and 4 days for large clumps in a laboratory setting. This differed from the results found for the outdoor setting, in which the algae was no longer viable after 1 hour for single fragments, 6 hours for small clumps, and 6 hours for large clumps. Bulbils were no longer viable after 4 hours. These results differed significantly from previous macrophyte desiccation experiments, which took much longer to be rendered unviable. These differences are likely due to SSW being a macroalgae and the associated physiological changes causing them to lose water more easily. The difference between lab and outdoor results is most likely the product of exposure to the elements, chiefly sun and wind. As such, the outdoor results are more representative of what SSW would experience while traveling between bodies of water. Knowledge gaps: how SSW would fare when exposed to the increased wind from driving and how SSW would fare when hidden between the boat and the trailer.

Jessica E. M. Van Der Wal, Dorenbosch M, Immers AK, Forteza CV, Geurts JJM, Peeters ETHM, Koese B, Bakker ES. 2013. Invasive Crayfish Threaten the Development of Submerged Macrophytes in Lake Restoration. PLoS ONE 8. DOI: 10.1371/journal.pone.0078579

Funded by: Agentschap NL Innovation Programme Water Framework Directive (KRW08079)

Keywords: Research, ecology, control, crayfish, herbivore, omnivore, biomass, macrophytes, in situ

This study examines the effect of invasive crayfish on macrophyte populations. They divided a section of Lake Terra Nova in the Netherlands and sectioned off two “ponds” in part of the lake, which were then divided into 4 treatment areas: a full exclosure with no herbivores, a partial exclosure with crayfish and small fish, an enclosure with only crayfish, and an open section where all species had access. No macrophytes were present in the ponds at the start of the study. Six weeks later, macrophytes from all treatments were collected and measured. Crayfish gut analysis was also performed. Soil was tested in the lab to ensure that all treatments had viable propagules. Macrophyte growth and survival was significantly different between the treatments. The full exclusion treatment resulted in much higher plant survival and growth. Viable propagules were found in the soil of all treatments. As for the diet, crayfish appeared to favor eating meat but would also consume macrophytes. In the open access treatment, most crayfish were found to have both animal and vegetal contents in their stomachs. The results suggest that the crayfish could be used to control macrophyte species like SSW. Although SSW itself was not included in the study, another macroalgae was, indicating that the crayfish may be able to consume SSW as well. Knowledge gaps: does this apply for other crayfish, would the crayfish consume SSW, and would a similar effect occur on already established macrophytes.

Escobar LE, Romero-Alvarez D, Larkin DJ, Phelps NBD. 2018. Network analysis to inform invasive species spread among lakes. Journal of Oceanology and Limnology 37:1037–1041.

Funded by: Unknown

Keywords: Research, outreach, boats, watercraft stewards, survey, network, spread, GIS, nitellopsis obtusa, starry stonewort, lake, invasion

This study examined the relationship between boat travel to different lakes and the presence of SSW. They used watercraft stewards to survey boaters at Lake Koronis, a lake that had been invaded by SSW, on the most recent lake they had visited and the next lake they plan to visit. This data was then plotted in ArcGIS for better visualization. Four lakes, namely Rice, Horseshoe, Clearwater, and Green Lake were the lakes with the highest percentage of travel from Koronis Lake and would be the lakes at highest risk of SSW invasion respectively. Lake Mille Lacs was also fairly well traveled and would also be at greater risk of SSW invasion, despite a greater distance from Koronis. This study should serve as a pilot for programs aimed to predict the spread of SSW in the future, similar to other networking efforts for things like infectious diseases. A notable source of error in this study is the accuracy of responses, especially future predictions, as people may change their intended destination. Knowledge gaps include how representative this study is and how linked SSW travel is to boats. Additionally, lakes in this study should be surveyed for SSW to establish the effectiveness of this method.

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

Funded by: Sarah K. deCoizart Article TENTH Perpetual Charitable Trust

Keywords: Research, ecology, outreach, spread, range, distribution, wading, dredging, Characeae, Charophyceae, Charophyta, invasive, New York, Nitellopsis obtusa,

Starry Stonewort.

This study examined the distribution of SSW within New York State. Using statistical programs, they placed 400 points across the state and selected the nearest bodies of water with an area over 0.05 km^2. They then sampled 390 of these sites using wading and dredging. Water conductivity and pH were also measured. 13 of 23 previously recorded sites were confirmed to have SSW. The remaining 10 sites went unvisited, but sites nearby were visited and confirmed instead. Two previously recorded sites were unable to be confirmed but they represented large areas and could therefore have missed any SSW present. SSW was found at 7 new inland lakes, 5 sites in the St Lawrence, and 6 sites in Lake Ontario. However, it was not found in other areas such as the Adirondacks, the Catskills, and Long Island. Water chemistry testing showed that SSW inhabited a wider range of pH and conductivity than previously known for its invaded range, although more narrow than that of its native counterpart. This could be due to some physiological difference in the populations or the sample size not being large enough. All sites where SSW was found had substantial human development, supporting the idea that humans are the primary transporter of SSW. As such, more effort should be placed in the prevention of its spread. The distribution map should help in the formation of such strategies. Knowledge gaps include: how environmental and human variables contribute to the current distribution in North America.

Becker SD, Bosch NS. A study of potential treatments for effective management of starry stonewort (Nitellopsis obtusa) in Lake Wawasee, Indiana. :66.

Funded by: Indiana Department of Natural Resources Lake and River Enhancement program and the Wawasee Property Oweners Association

Keywords: Research, control, chemical, chemical treatment, herbicide, copper, endothall, Clearigate, Algimcycin, Clipper, Cutrine Ultra, Hydrothol, biomass, rake

This study examined the effectiveness of three different treatments on SSW in multiple different locations within a lake. The locations represented both open portions of the lake and more enclosed channel portions. Treatment 1 was Clearigate, (an aquatic herbicide), Treatment 2 was a combination of Algimcycin PWF (copper formulation) and Clipper (broad spectrum herbicide), and Treatment 3 was a combination of Cutrine Ultra (copper-based contact herbicide) and Hydrothol (endothall-based contact herbicide). Control treatments with no added chemicals were also used. They examined SSW biomass (dry weight) within 16 plots at three different times, using a vertical rake to obtain samples. They sampled before any treatments, after a first treatment, and after a second treatment. Treatments occurred on June 27th, 2016 and August 1st, 2016. Although the treatments overall show a general decrease in biomass, the results were very mixed. Treatment 1 reduced the average biomass in three of four plots but was not always effective upon the second treatment. Treatment 2 reduced biomass in all four plots but also did not always work with the second treatment. Treatment 3 reduced biomass in three of the four plots but also had the only plot in which a significant difference was seen after both the first and second treatments. With regard to location, Treatment 3 appeared to be most effective in a sheltered environment, where Treatment 2 also showed some effectiveness after the first treatment. In deeper, open water Treatment 3 appeared to be ineffective, with biomass actually increasing after the first treatment. Treatment 2 also appeared to be ineffective in this location, with biomass not changing significantly. Treatment 1 on the other hand reduced the biomass in this location. The more contained locations were inconclusive due to a lack of a control in one location and a significant change in the other, confounding the results. There were several possible confounding factors including: speed of chemical concentration decrease due to biomass or water movement, pH level, time of year, timing of application, and the error in the vertical rake method. To further understand these results, the interaction of these confounding results should be studied. This study indicates possible best uses of each treatment for more effective use of resources.

Karol KG, Sleith RS. 2017. Discovery of the oldest record of *Nitellopsis obtusa* (Charophyceae, Charophyta) in North America. Wood M, editor. J Phycol. 53(5):1106–1108. doi:10.1111/jpy.12557.

Funded by: Natural Science Foundation and Wisconson Department of Natural Resources

Keywords: Research, outreach, spread, earliest, Quebec, New York, Saint Lawrence, preserve

This study examines a new sample of SSW in North America dated to 1974, four years earlier than the previous earliest known sample. During a project to digitize all the samples in the New York Botanical Garden, this sample was discovered and identified. Based on morphology, it was positively identified as SSW. The previous earliest sample was from 1978, collected in New York. This newly discovered sample was collected somewhere in Quebec, along the Saint Lawrence River. This indicates that SSW has been on the continent since at least 1974. This also provides further evidence that the Saint Lawrence was the entry point for the species, although this still cannot be said with certainty. The overall spread of the species still remains to be seen.

Sayer CD, Burgess A, Kari K, Davidson TA, Peglar S, Yang H, Rose N. 2010. Long-term dynamics of submerged macrophytes and algae in a small and shallow, eutrophic lake: implications for the stability of macrophyte-dominance. Freshwater Biology. 55(3):565–583. doi:10.1111/j.1365-2427.2009.02353.x.

Funded by: Unknown

Keywords: Research, core samples, long term, macrophytes, England, abundance, richness, alternative stable states, aquatic macrophytes, plant macrofossils, resilience, shallow lake, radionuclide, dating

This study uses paleolimnology to examine the long term dynamics of submerged macrophytes and algae in an increasingly eutrophic lake. Six core samples were taken different locations within Felbrigg Lake, England. The cores were then analyzed using loss-on-ignition (LOI), radionuclide dating (^{210}Pb, ^{226}Ra, ^{137}Cs and ^{241}Am), core correlation, macrofossils, pollen, and diatoms. The cores show an increasing sedimentation rate, particularly in the last 20 years or so, during which the rate is doubled. The oldest sediment was found to be from 1797, although each core varied in the oldest date they contained, with the most recent being 1897. The plant communities changed in both richness and abundance over time. At first, plants were more abundant and had a higher richness, with *Chara spp., P. crispus, P. pusillus, C. demersum, R. sect. Batrachium* and in some cases *Z. palustris* and *Callitriche spp*. being common. Between the late 1800s and the mid 20th century, general abundance remains similar, but *M. spicatum* decreasing while *C. demersum* increases. Post mid 20th century, macrophytes decrease in both abundance and richness. *C. demersum* and *Chara* in particular have major decreases while *Z. palustris* increases. The cores also reflect how patchy the macrophytes can be, with some samples having high abundances in some locations but not others. Diatoms show an inverse trend to macrophytes, indicating that phytoplankton have steadily increased in the lake, most likely due to eutrophication. Indeed, there is a particularly large increase after roughly 1940. These indicate that a decrease in macrophyte abundance and richness has led to increases in phytoplankton, with the most likely cause being eutrophication. If this model is correct, then the loss of macrophytes may be a much longer process than other models suggest. Knowledge gaps include: possible interactions with zoologic organisms.

Boissezon A, Auderset Joye D, Garcia T. 2018. Temporal and spatial changes in population structure of the freshwater macroalga Nitellopsis obtusa (Desv.) J.Groves. Botany Letters. 165(1):103–114. doi:10.1080/23818107.2017.1356239.

Funded by: Unknown

Keywords: Research, ecology, native range, drawdowns, abundance, phenology, drought, degree-days, day duration, habitat, ecotypes, reproduction, sexual, clonal

This study focused on SSW survival and reproduction as various conditions in a lake change over time, such as water level. A lake in the French pre-Alps was monitored from 2009 through 2014, with data also being used from as far back as 2004. Water level was recorded every 4 hours using a data logger. Macrophyte species abundances were visually estimated as percent cover, measured once a year in mid-July. Macrophytes were also evaluated by the groups they formed and what other macrophytes they associated with. To describe SSW phenology, samples were collected every two to four weeks in 2009 and 2010 either by hand or with a heavy hook in order to obtain the whole plant. They were then preserved and examined in the lab, whereupon they were documented by “growing degree days” (GDD), which measures time since reaching adequate temperature for growth. Water level data showed that the shallow parts of the lake were exposed to prolonged periods of dryness at times, while the deeper parts were not. SSW was the dominant species in the lake during 2009, but was vastly reduced in 2010 and 2011, only appearing in the deepest part. As of 2014, it still had not recovered. The plants associated with each other changed over time, starting with SSW and *Potamion pectinati* in 2009, then switching to a mixture of all recorded macrophytes in 2010, then *Potamion pectinati* dominating in 2011, then a well-mixed community in 2013, and a dominance of *Charion vulgaris* and *Charion globularis* in 2014. Morphological values for SSW matched expected values. In 2009 and 2010, all SSW individuals were sprouted clonally, despite sections of mixed sexes. Early in the seasons, all new shoots were either male or sterile, with females emerging 400 GDD later. Antheridia ripening showed a bell curve, while the ripening oospores increased progressively over the season. These results indicate that lake bed drying has a large effect on the composition of the macrophyte community. The drawdowns coincided with SSW die-offs and its retreat into deeper waters. This is unsurprising considering that SSW prefers slow, deep water in its invaded range. The switching between sexual and asexual means of reproduction is also explained by these drawdowns the environment, with the SSW in the deeper, protected portion only using asexual reproduction while the SSW in the exposed parts used sexual, which produces the more durable oospores. However, it is unknown if this is due to phenological plasticity or ecotypes. Knowledge gaps include: Why no females have been reported in invaded range.

Pokrzywinski K, Sartain B, Greer M, Getsinger K, Fields M. 2020. Optimizing conditions for Nitellopsis obtusa (starry stonewort) growth and bulbil germination in a controlled environment. Aquatic Botany. 160:103163. doi:10.1016/j.aquabot.2019.103163.

Funded by: Aquatic Plant Control Research Program of the US Army Engineer Research and Development Center

Keywords: Research, ecology, Starry stonewort, Nitellopsis, bulbil, macroalgae, light, fluorescent, LED, metal-halide, darkness, medium, viability, growth

This study focuses on light conditions that are optimal for SSW growth, bulbil production, and bulbil germination. Bulbils were collected in the field in June then transported to the lab, where they were subjected to natural, fluorescent, LED, or metal-halide at different intensities for 41 days. They were placed in different mediums, including SB and FMII. A control with no light was also used. In addition to testing for associations between light and germination, they also examined the results for any correlations between bulbil size and germination. They also used cameras to examine the color and morphology of samples. The results showed that there was no statistical significance for a correlation between bulbil size and germination success or size and the amount of growth. The FMII media supported more growth and greater bulbil germination. The dark and metal-halide light treatments resulted in the greatest median growths, with high light resulting in the lowest median in regard to intensity. All other light treatments were similar in growth. The dark and low intensity metal halide groups were found to be not statistically different. Bulbil germination did not differ significantly by light treatment. The image analysis revealed that the emerging plants were under low stress. Additionally, it showed a litany morphological changes based on treatment including: high intensity fluorescent lights causing red meristems, LED light causing a brownish tint, and the dark light causing the deepest green. These indicate that SSW germination is mostly, if not entirely independent of light and that other factors should be explored. The lack of correlation between bulbil size and viability/growth indicates that the macroalgae may be a larger threat than previously perceived, making it a much better competitor than previously assumed. The FMII, which is high in calcium, having more growth supports the idea that this is a key factor to SSWs success in North America. The difference in light treatments means that light intensity should be a factor in field studies of SSW in the future, as well as suggesting why SSW does well in deeper waters. Additionally, these results will help researchers to grow SSW in the lab going forward. Knowledge gaps: How these variables interact with variables not tested, such as temperature or pH.

Christine Fritz, Thomas Schneider, Juergen Geist. 2017. Seasonal Variation in Spectral Response of Submerged Aquatic Macrophytes: A Case Study at Lake Starnberg (Germany). Water. 9(7):527. doi:10.3390/w9070527.

Funded by: Federal Minestry for Economic Affairs and Energy

Keywords: Research, ecology, reflectance, spectra, temperature, spectroradiometer, remote, climate change, phenology, submerged aquatic vegetation, phenologic variations, remote sensing reflectance modeling, spectral library, bioindication

This study examines the use of spectral signals to determine lakebed communities or the lack thereof and how water temperature changes affect the growth of macrophytes. An oligotrophic lake was monitored over the course of two year, 2011 and 2015. Water temperatures were taken hourly at a single site. At three sites, containing pure stands of *Elodea nuttallii, Chara,* and *Potamogeton perfoliatus*, reflectance spectra were remotely recorded with RAMSES spectroradiometers and underwater camera. Reflectance was measured each day up to 7 times, depending on local conditions. The data was then processed to account for sensor noise, phytoplankton, dissolved organic matter, and the backscattering of water of among others. The data was then interpolated and used to create reflectance models for each species of macrophyte. Then, a classification process was established with other spectral libraries to determine what the spectroradiometers were detecting and their phenologic stages. The reflectance models showed that there was definite differences between phenologic stages, date, and species. Species identification accuracy was 100% for *Chara*, but less for the other two. Variations in spectra gradients were higher in 2015, which was warmer than 2011. The classification process had 70% success in step 1 and 82% in step 2. Among the macrophyte species, phenologic classification ranged from 79% to 91% accuracy. These results suggest that spectroradiometers can be used to monitor water bodies easily and remotely. This approach needs further testing to establish a larger reflection library and to determine the effect of extreme weather.

Francoeur SN. 2017. Stimulation of Saginaw Bay charophyte photosynthesis by phosphorus. Journal of Great Lakes Research. 43(3):192–197. doi:10.1016/j.jglr.2017.03.015.

Funded by: Eastern Michigan University

Keywords: Research, ecology, control, phosphorus, limitation, light, photosynthesis, nutrient limitation, charophyte, chara, nitellopsis, benthic algae

This study examines the potential phosphorus limitation of charophytes, like SSW, in a nutrient-rich environment. On two dates, charophytes were collected from two sites (Sites 11 and 13) and sent back to the lab for testing and identification, Water samples were also taken for nutrient analysis. Additionally, benthic irradiance was measured at each site. In the lab, on the same day as collection, plants were put into two groups, with one group receiving phosphorus enrichment. They were then tested for photosynthetic performance using pulse amplitude-modulated (PAM) fluorometry rapid light curves. Charophytes surveyed consisted of *Chara* and SSW. For the site 11 macrophytes, photosynthetic performance was significantly boosted by phosphorus enrichments. Meanwhile, no statistically significant difference was seen for site 13, although the enriched samples were higher. There was no significant interaction between date and enrichment effect. These indicate that charophytes, including SSW, are phosphorus limited in this case. This suggests that controlling phosphorus could be an effective way of controlling SSW. However, these results cannot be used to predict in situ growth given a stimulus of phosphorus due to idealized lab conditions for testing. Although this may indicate phosphorus limitation, it is really only strong evidence for this body of water and should not be applied to all sites without further testing.

Johnson JA, Newman RM. 2011. A comparison of two methods for sampling biomass of aquatic plants. Journal of Aquatic Plant Management :1–8.

Funded by: Minnesota Department of Natural Resources

Keywords: Research, outreach, control, rake, quadrat, scuba, sampling, precision, accuracy, collection

This study examines the accuracy and precision of the vertical rake method of aquatic plant sampling in comparison to the quadrat method. At 38 vegetated sites, paired samples were taken using both vertical rake and quadrat methods, with pairs being collected directly adjacent to each other. Rake samples were collected using a 0.33-m wide, 14-tine, single-headed rake attached to a 3-m long pole which was lowered into the water until contacting the sediment then rotated 3 full turns. The rake was continuously spun while being risen to the surface to prevent the loss of collected samples. Quadrat samples were collected by scuba divers from 32x32cm PVC quadrats. Samples were broken off at the sediment by hand and placed in bags to be transported to the surface. In the lab, all samples were cleaned, drained, sorted, and dried at 105 C for at least 48 hours before weighing. The results and statistical analysis indicated that the number of taxa found by each method was comparable, although the rake did over represent Eurasian watermilfoil. The rake method consistently oversampled biomass, almost entirely due to the oversampling of two taxa, coontail and flatstemmed pondweed. As such, the two methods were similar in precision for taxa but not for biomass. The results also indicate that the rake and quadrats estimates for biomass were similar for individual taxa, but the rake did not sample all taxa equally well. This suggests that the comparability of the rake method is dependent on the taxa present. To achieve the same level of precision with regard to biomass, more rake samples would have to be taken. Even taking into account the extra samples needed to attain precision, the rake samples offer a valid alternative to quadrats do to the ease of use, lower amount of time needed, and increased safety. This does not take into account the sample processing time. Knowledge gaps: how different rakes affect sampling rates, how different macrophytes and densities affect sampling rates.

Bharathan S. 1987. Bulbils of some charophytes. Proceeding of the Indian Academy of Science (Plant Science) 97:257–263.

Founded by: University Grants Commission, New Delhi

Keyword: Research, ecology, bulbil, anatomy, whorl, branchlet

This study examined the bulbils of different charophytes, including SSW. Live specimens were collected and sent to a lab, where they were then grown and harvested for bulbils. Those bulbils were then placed in petri dishes with sterilized water to produce new plants. The sprouting bulbils were observed and dissections were conducted. SSW bulbils represent condensed nodes which split into 5 – 7 peripheral cells. Branchlets then stem from those peripheral cells. As such, this confirms that SSW has whorls of at least 5-7 branches. However, this only confirms that number of branchlets. It does not disprove numbers outside that range.

Knowledge gaps: Can there be whorls outside 5-7 branchlets.