Regional Invasive Aquatic Plant Control Prioritization and Needs Assessment

January 24-25, 2023

Workshop Proceedings

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Executive Summary

The need for multijurisdictional coordination and collaboration is essential to effectively implement invasive species prevention and control strategies across jurisdictional boundaries. Great Lakes resources continue to be compromised and are threatened by the introduction, establishment, and spread of invasive aquatic plant (IAP). Many agencies, nongovernment organizations, and private interests are implementing control measures for those IAP that impede recreation and navigation, degrade habitat for native species, and disrupt natural ecosystems. These entities are also working with research institutions and the private sector to develop new tools for management and improve the efficiency and effectiveness of control efforts. These activities are costing millions of dollars and are widespread throughout the Great Lakes region and across the United States; up to this point, there has been no regional approach to coordinate engaged entities, identify needs, share outcomes and lessons learned, and ensure future investments are directed towards the highest priorities. As part of an interjurisdictional project funded by the Great Lakes Restoration Initiative (F21AP00426), a workshop of Great Lakes stakeholders and aquatic plant managers was convened to improve coordination of IAP control method research and to prioritize research needs.

Based on prior work to prioritize IAP for which control is the highest priority, twelve species were selected for discussion over the course of this workshop:

- Hydrilla, *Hydrilla verticillata*
- European frogbit, *Hydrocharis morsus-ranae*
- Water soldier, *Stratiotes aloides*
- Didymo, *Didymosphenia geminata*
- Water hyacinth, *Eichhornia crassipes*
- Water lettuce, *Pistia stratiotes*
- Yellow floating heart, *Nymphoides peltata*
- Yellow flag iris, *Iris pseudacorus*
- Eurasian watermilfoil, *Myriophyllum spicatum*
- Starry stonewort, *Nitellopsis obtusa*
- Curly leaf pondweed, *Potamogeton crispus*
- Purple loosestrife, *Lythrum salicaria*

Throughout the workshop, baseline information on each of these species, including basic life history and reproduction information, available control tools, and management needs previously identified through literature reviews, was presented to attendees to ensure consistent knowledge among attendees on the management of each species. Presentations by species experts then followed, sharing additional insights and management knowledge/experience. Finally, attendees participated in smaller breakout group sessions to discuss the information presented and collectively identify additional research and management needs.

These proceedings are a record of the presentations and discussions held during the course of the workshop. Presentation files are available upon request. Information contained in these proceedings may serve as documentation of the current “state of the science” regarding management of these twelve species, and specifically identifies additional research needs and barriers to effective management in the Great Lakes region. This knowledge will be used to inform development of a forthcoming regional IAP research agenda that will detail key research questions for priority IAP species, capacity needs and obstacles to implementation that also need to be addressed, and associated timelines and funding estimates to guide future investments. The information outlined in the research agenda is intended to inform the development of proposals and work plans to submit under future funding opportunities.

Participating Agencies

Representatives from the following agencies participated during the course of the workshop. Not all agencies participated in every workshop session.

Chippewa Ottawa Resource Authority
Cleveland Metroparks
Crawford County (PA) Conservation District
Douglas County (WI)
Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS)
Illinois Department of Natural Resources
Illinois Natural History Survey
Illinois-Indiana Sea Grant
Indiana Department of Natural Resources
Invasive Species Centre
Lake County (IL) Health Department
Michigan Department of Environment Great Lakes, and Energy
Michigan Sea Grant – GLANSIS
Michigan State University
Minnesota Department of Natural Resources
Montana State University
National Oceanic and Atmospheric Administration
New York State Department of Environmental Conservation
Ohio Department of Natural Resources
Ontario Federation of Anglers and Hunters
Ontario Ministry of Natural Resources and Forestry
Pennsylvania Department of Agriculture
Parks Canada
Québec Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs
Trent University
U.S. Geological Survey
University of Minnesota
U.S. Army Corps of Engineers
University of Wisconsin Madison Extension
Wisconsin Department of Natural Resources
Wisconsin Sea Grant

Project work and knowledge up to this point

Call to order, roll call, agenda review

Ceci Weibert, Great Lakes Commission (GLC) & Lindsay Chadderton, The Nature Conservancy (TNC)

- Chadderton and Weibert reviewed the agenda for the workshop
- Chadderton and Weibert reviewed the goals of the workshop and the assumptions attendees should keep in mind while in discussion
    - Outcomes of the workshop will be used to inform development of a research agenda highlighting the most important areas of research needed to advance management and control of IAP
- Weibert commented that there is a parallel ongoing project addressing how community science can be leveraged for invasive aquatic plant (IAP) management. Weibert encouraged anyone interested in that effort to reach out to Tim Campbell (tim.campbell@wisc.edu)
    - Campbell noted that a graduate student will be sending emails inviting participation in a steering committee for this interjurisdictional project that will be addressing the outreach component of IAP management (e.g., to increase public awareness about what tools are viable and recommended for riparian/lake associations)
- Project overview slides will be shared as part of the workshop proceedings

Literature reviews (methods)

Alisha Davidson, GLC Contractor

- Davidson reviewed the criteria for species' inclusion in the project
    - The term "established" refers to species established anywhere in the Great Lakes basin, including inland populations
- Davidson reviewed the sources for the literature reviews and provide an overview of the literature reviews format and content
    - Literature reviews were emailed to workshop participants prior for review
- Davidson reviewed the general findings from the literature reviews, including:
    - The literature reviews are a starting point for identifying gaps and challenges with control of each IAP, but gaps and challenges will be further discussed in this workshop
    - Great Lakes experts were often hard to find, and the opportunity remains for more to self-identify and be listed on the reviews as an expert

Managers' survey results

Theresa Gruninger, GLC

- Gruninger reviewed the context of the managers' survey report, including the methods for conducting the survey and the results
- The goal of the survey was to understand each Great Lakes jurisdiction's priorities for the management of IAP as a supplement to the species inclusion criteria methods from the literature review process
- The definition of "management attention" as used in the survey and report refers to control/management activities, rather than any policy, prevention, or surveillance activities

Questions and Discussions

- For groups of species that co-occur, management should consider actions/strategies that address co-occurrence (e.g., *Phragmites/Typha* and European frogbit, Eurasian watermilfoil with curly leaf pondweed)

    - However, in some instances when IAP species co-occur, management of one can increase the population of the other
        - This has occurred in Ontario with Eurasian watermilfoil and starry stonewort replacing water soldier
        - Integrated management should be a topic to emphasize in an IAP research agenda
- "Known nontarget impacts" and "lack of knowledge about non target impacts" were clearly defined separately in the managers' survey to avoid convolution
- The definitions of the terms "Great Lakes" and "established" will need to be clearly defined in the research agenda; stakeholders are often most concerned about inland systems, so framing this work in the context of "Great Lakes" may not capture their attention
    - A disclaimer about lack of total coverage may also be useful to include
- Participants were invited to contribute any new content for the literature reviews to Davidson or Weibert

Emergent/expanding species

Species overview and information from literature reviews

Alisha Davidson, GLC Contractor

- Davidson reviewed the four species that are the focus of the emergent/expanding session (hydrilla, European frogbit, water soldier, didymo), and their management and knowledge gaps
- There may be a relationship between water quality/climate change and didymo, as an increase in phosphorous can increase didymo production
- Regarding differences between EFB response to *Typha* removal and *Phragmites* removal, the key difference in impact to EFB is the removal of biomass. A case study included in the EFB literature review noted that the removal of *Typha* biomass is what led to an EFB decline, which often does not happen with *Phragmites* treatment. *Phragmites* is often only treated with an herbicide, and the dead biomass still provides structure to EFB populations for growth

Hydrilla

Bradley Sartain, U.S. Army Corps of Engineers (USACE)

- Hydrilla rapidly increases within and between waterbodies. It is hard to predict future populations, as populations can almost triple within a year
    - Early intervention could delay rapid spread
- It is hard to have dedicated early detection and rapid response (EDRR) activities when the species is not present yet. Prepping for management takes time (e.g., permitting, etc.). It is easy to miss other new populations if managers are only able to focus on known population(s)
- Herbicide effectiveness depends on the populations' invasion state and hydrology
    - The Connecticut River variant of hydrilla is adapted to cool water systems. The Connecticut River is a tidal river, which makes it hard to achieve proper exposure time for chemical control
- Extensive treatment increases the likelihood of eradication. For example, for a one-acre infestation, you should treat two acres around the population site
- Management goals are important in determining how you should measure efficacy
- Dr. Dean Williams, Texas Christian University, is a good resource for genetic determination of hydrilla populations
- Although the herbicide Fluridone has been used extensively for the last several decades for monoecious hydrilla maintenance control and eradication, there are no documented populations of monoecious hydrilla showing resistance. The year-round or near year-round active growth of

dioecious hydrilla in Florida, its ability to overwinter in Florida and lack of senescence compared to monoecious hydrilla, and a few other environmental and management factors support a higher risk of a shift in herbicide response for dioecious in southern geographies versus monoecious hydrilla management programs using Fluridone. It is very important to keep herbicide resistance management principles (rotation or combination, strong scouting) in mind for monoecious hydrilla and any intensely-managed invasive plant species.

- Genetic analysis is the best way to confirm biotype. There are site-specific ways based on tubers, but to be sure, you should send a sample for testing, some sites have both biotypes
- The Connecticut River population is a new lineage and it could be from the aquarium trade. The Connecticut River is tidal, which means it could also be susceptible to shipping activity
- The lack of dioecious biotype populations may be due to prevention efforts. There is a lot of effort dedicated to education, boat washes, boat checks, etc. in the northern states
- There is not currently any research or literature specifically focused on the interaction between hydrilla and water chestnut, but Cayuga Lake in New York has both species
- Phenological studies have documented that both monoecious and dioecious biotypes do prefer warmer water for best growth despite showing tuber germination and slow growth in cooler water. The narrower windows of optimal growth temperature moving north may help slow hydrilla expansion in sites with new introductions but those seasonal windows are widening with climate change. As a plant with the ability to adapt and utilize many different environmental niches and re-establish from tubers after strong disturbance, it may not be as aggressive in colder northern waters compared to southern sites but its invasion projects to be persistent and opportunistic to expand its footprint when more established natives decline for natural or anthropogenic reasons.

European Frogbit

Billy Keiper, Michigan Department of Environment, Great Lakes, and Energy (ELGE)

- European frogbit is a free-floating emergent plant that spreads through turion and seed production. The species prefers emergent wetlands
    - European frogbit has spread up the eastern coastline of Michigan and was observed in west Michigan in 2016
- Michigan EGLE has often utilized hand-pulling as a removal method, but this method is very hard in complex habitats
- The herbicide Diquat has been used for management, although it is used less often now. The go-to herbicide is Flumioxazin, which is more selective and has minimal non-target effects
    - Flumioxazin needs at least one follow-up treatment
    - Imazamox (Clearcast) should have herbicidal activity on both cattail and EFB if dual control of both would fit management objectives
- The Standard Treatment Impact Monitoring Protocol created by the EFB Collaborative established a consistent methodology for evaluating the impact that treatments have on EFB
- Current EFB control and management challenges:
    - Physical access is often the biggest challenge. EFB can easily be hidden behind debris
    - After years of treatment, population abundance is often low. There may only be a few plants and thus difficult to detect, meaning it is possible for a population to rebound from a few missed individuals during follow-up monitoring
    - There are a lot of unknowns regarding the plant's reproduction. Are seeds or turions more important for annual population growth? What is their viability?
    - Multiple years of treatment are needed to get complete control. Michigan has yet to successfully eradicate a site

- It is unlikely that waterfowl eat EFB turions or seeds and then disperse them; turions/seed would not pass through the digestive tract, and there would likely be more extensive spread of the species if this was the case
- The size of EFB seeds is 1-1.3 mm, roughly the size of a bell pepper seed

Water Soldier

Rob McGowan, Ontario Federation of Anglers and Hunters (OFAH), Nick Weissflog, Trent University

- Water soldier has an emergent and submergent form. The plant reproduces via turions and offsets, and the seeds are not viable
- In 2008, when water soldier was first managed in Ontario, there were no registered herbicides available for use and management consisted of hand pulling
- Cost of hand removal is very high
    - Management of 0.25 acres would cost around $12,000 for the days of removal. The process needs structure (sein nets, etc.) so plants do not float away
    - 5x5 meters is about the maximum size for hand pulling
    - Management should occur between June and August
- OFAH has completed a lot of mechanical harvesting, but this management process also has its own complications, including obstacles in the substrate, weight of plants, and harvester size limitations in shallow water
- Diquat is the only herbicide used in Canada. Herbicide timing is important, best applied in early/mid-October. This minimizes non-target impacts, as everything native has senesced
    - Access to hard to reach places and limiting sediment disturbance are significant challenges to water soldier treatment. Airboats are a possibility, but they are hard to navigate in very shallow water
    - Endothall and flumioxazin are not effective herbicides
- Shading works for managing small areas
    - Jute fabric is not as effective as tarp
- In the future, ProcellaCOR could be used for management of small populations
- It is important to work on early detection with remote sensing/eDNA/drones
- It is not uncommon for water soldier to only have one sex present in a given area in its native range, making sexual reproduction impossible and its unlikely that seeds will become viable with enough genetic diversity
    - In Ontario, only the female (pistillate flowers) plants have been documented
- Does the floating type of water soldier can also root itself?
- Water soldier does not spread by fragmentation

Didymo

Matt Shank, Pennsylvania Department of Environmental Protection

- Didymo needs stable flow and a low nutrient environment to thrive. The species is showing increased ecological tolerance
- Didymo management gaps include:
    - Actionable management guidance for didymo below dams
    - Transferable guidance that can be applied using site-specific criteria
    - There is a need for an updated review of management gaps, as in Elwell et al. 2014
- Current didymo management/control efforts include:
    - River enrichment by adding phosphorus. With this effort, managers did see decreases in didymo populations for 0.5km. This treatment creates an undesirable eutrophication

    - Chemical controls by using chelated copper. Elimination of nonvisible infestations is possible, and suppression of early-stage infestations could be achieved after repeated applications but there are side effects on wildlife
    - Riparian canopy shading could be effective in smaller streams
- Prevention should include banning felt soled waders. Felt soles are a vector for many aquatic organisms, including didymo due to its porous nature and ability to retain moisture
- Didymo's polysaccharide-based stalks have some beneficial uses (metal-adsorption capacity allows them to have excellent wastewater remediation potential). Harvesting mats could be useful for industrial applications
- Stream restoration might be a good way to fund ecological restoration and manage didymo

Inconsistently regulated species

Species overview and information from literature reviews

Alisha Davidson, GLC Contractor

- Davidson reviewed the current regulating jurisdictions for this session's species (water lettuce, water hyacinth, yellow floating heart, and yellow flag iris)
- Integrated control strategies are effective for water hyacinth and most Great Lakes populations are small enough to hand pull
    - Current knowledge gaps include overwintering capacity, development of biological control tools, and evaluating the effectiveness of ProcellaCOR
- Water lettuce has effective control tools
    - Current knowledge gaps including overwintering capacity and life history information
- Yellow floating heart has some effective herbicides. Floodings/drawdowns have been noted as a possible tool. Treatment timing is important and most effective in late summer/early fall
    - Current knowledge gaps include investigating the effectiveness of ProcellaCOR and effects on seed viability, and better understanding of flooding/drawdowns as a control tool
- Yellow flag iris is currently controlled with herbicides (imazapyr and glyphosate) and manual control methods like digging and cutting below the waterline
    - Current knowledge gaps include how the absence of regulation may prevent management, and the long term efficacy of repeated mowing/cutting

Water Hyacinth and Water Lettuce

Bradley Sartain, U.S. Army Corps of Engineers

- The growing season in the Great Lakes is unlikely to be long enough for water hyacinth and water lettuce to impact the region to the extent that it has in the southern U.S.
- Management of the species can occur via mechanical/physical control, biological control, chemical, and integrated management
- Sartain reviewed the life history of water hyacinth
    - Seeds may be able to persist for 5 years or more
    - The species is able to survive moderate freezes under the water
- Sartain reviewed the life history of water lettuce
    - Water lettuce reproduces vegetatively (fragmentation) and by seed
    - Native range is unknown, possibly native to the southern U.S., Africa, or South America. Fossil records of the plant have been found in Florida

- Physical control can be selective, affordable, and provide immediate relief for small populations
    - This type of management is often slow and labor intensive. It can lead to plant spread (fragmentation), resuspension of sediments, and impacts to the ecosystem. Proper disposal of plants is often an issue as well
- Drawdowns can also be low-cost option. They reduce acreage requiring management, particularly in difficult to access areas. The plants desiccate in areas where they can completely dry out, and populations congregate where water remains making it easier to target management. Drawdowns prevent plant spread and increase water storage capacity
    - This control option may promote seed germination through the wet-dry-wet cycle
    - Drawdowns sometimes lead to stakeholder conflict through unwelcomed aesthetics, limited user access, and local economic impacts
- The purpose of biological control is to minimize invasive characteristics and decrease competitive advantage
    - A biological control agent is unlikely to establish in the Great Lakes region
    - The water hyacinth weevil can result in smaller plants, decreased flowering (i.e., less seeds), and overall less productivity
    - The weevil will not completely eradicate a species
- Flumioxazin is a fast- acting contact herbicide but can be systemic. It is a protoporphyrinogen oxidase inhibitor with good control on water lettuce but less effective on water hyacinth
    - Flumioxazin is highly selective but requires actively growing plants, which are necessary for root uptake of subsurface application
    - Cost of the herbicide is dependent on water depth if applying as in water injection
    - Flumioxazin is highly sensitive to pH. It will break down rapidly in more alkaline water (~9 pH)
    - Depending upon the severity of the infestation It is useful to wait a few weeks and treat half of the water body to prevent a crash in dissolved oxygen
- Carfentrazone has good selectivity and can be mixed with other products like Penoxsulam
    - It is less effective on water lettuce but more effective on water hyacinth than flumioxazin
- Penoxsulam is very slow acting and often takes over three weeks to take effect
    - The herbicide is active on both water lettuce and water hyacinth
    - The herbicide can be applied as a foliar or submersed application. Efficacy is still being evaluated for submersed application
    - The herbicide can have temporary non-target impacts
- Imazamox can be effective on water lettuce and water hyacinth
    - It is a very slow acting herbicide (2-6 weeks)
    - The selectivity of Imazamox is still under evaluation but is likely similar to Penoxsulam due to similar modes of action
    - Efficacy of submersed treatments is also under evaluation. There have been some effective static submersed treatment trials
- Florpyrauxifen-benzyl (FPB) “ProcellaCOR” can be used to control water hyacinth in either a foliar or submersed application
    - There are two different formulations for FPB and labeling varies by state
    - There are some seasonality issues with FPB on water hyacinth. Anecdotally, it has been seen to be less effective in colder temperatures
- 2,4-D is not utilized as much now as it has been in the past
    - The herbicide can give off a heavy odor
- Glyphosate is a broad-spectrum herbicide and efficacy can be sensitive to carrier volume

    - 20-50 gallons per acre may be better than 100
    - There are often public concerns over Glyphosate application
- Diquat is active on nearly all floating plants. The herbicide is fast acting (injury in less than 24 hours)
- Advantages of using herbicide as a control tool include:
    - Can treat small and large areas
    - Many herbicides have good selectivity
    - There are newer products that have excellent toxicology profiles
    - It is often the best tool for initially removing large amounts of invasive vegetation
    - Herbicide is compatible with other management options
- Disadvantages of using herbicide include:
    - It requires a commitment to long-term management
    - There are often use restrictions and those vary depending on location
    - There is often a negative public perception of use
- Developing an effective management plan for water lettuce and hyacinth should include:
    - Prevention – volunteer monitoring, signage, education, etc.
    - Identify the problem and keep good information
        - Keep detailed records of expenses, labor, time
    - Proper monitoring that includes distribution of target/nontarget species
        - Water quality records will indicate long term impacts
    - Establish reasonable management goals
    - Use site-specific management techniques
    - Use a quantitative survey method to evaluate control success
- The co-occurrence of Great Lakes populations of water lettuce and water hyacinth indicates introductions are likely aquarium dumps
    - Seems like the populations are able to flower and may be able to set seeds
    - Herbicide control prior to flowering to prevent seed formation is vital
- If treating with a fast-acting contact herbicide with a slow acting systemic one, the fast acting herbicide may be antagonistic, but a lower rate of fast acting herbicide can be used to prevent this

Yellow Floating Heart

Billy Keiper, Michigan Department of Environment, Great Lakes, and Energy

- There are residual yellow floating heart (YFH) populations in Michigan from when plantings were legal and new populations have been appearing as well
- YFH spreads via seeds and root fragments
- The plant is deeply rooted, making hand pulling difficult
- On average, it takes 1-3 years of control efforts (hand pulling, herbicides, or both) to meet Michigan's definition of eradication, defined as three years without regrowth
- Hand removal as a control tool is primarily used in lined ponds where roots cannot set
- Herbicides should be used to control larger populations and unlined ponds. The deep roots and large root masses allows the plant to fragment easily
- The herbicide ProcellaCOR is primarily used to treat YFH in Michigan. This herbicide results in very small regrowth, which is believed to be individuals from the seed bank
- For larger populations, herbicide control should be used until there is a small amount of re-growth and then hand pulling can be used
- Seed production via pods has been observed. The hydrophobic seed pods will float. The seeds are viable, but it is unknown if seeds can overwinter and remain viable

    - After flooding, some new plants do germinate after herbicide control. It is likely that they are coming form an established seed bank
- It is unknown if ProcellaCOR damages the seed pods in the same way as the rest of the vegetation
- Rooting from fragmentation has not been observed in Michigan, although the related species crested floating heart, is able to generate roots from leaf fragments and become a new plant

Yellow Flag Iris

Zach Stewart, Douglas County AIS Program (WI)

- Stewart briefly reviewed the ongoing yellow flag iris (YFI) control work that he has been involved in
    - Bois Brule River has a large population with ongoing manual management
- YFI seem to be able to utilize all types of substrates, emerges very early in the spring, and spreads heavily by seed
- Anecdotal evidence indicates that water flow may affect distribution, but Stewart has observed the plant growing in calm and fast flowing water
- There has been documented YFI herbivory by deer where resprouting is observed. It is unclear if new sprouts are occurring in response to herbivory, if sprout are emerging in the fall to overwinter, or if this is unique to warm fall events
    - This is a research gap that should be investigated. If fall sprouts are consistent, does this open a new option for control?
- Management knowledge gaps for YFI include:
    - Dredging/excavation is labor intensive and is dependent on removing the full rhizome
        - Douglas County has seen good results from this method and data from their study will be available soon
        - Digging results in a disposal challenge. The large plants are difficult to dispose of in remote areas
            - Stewart's team has been testing putting the plants on trees to allow them to fully desiccate (30+ days)
    - Cutting is only effective below the water line to prevent gas exchange
        - Could cutting/mowing above the waterline, when timed properly and performed annually, prevent seed production with minimal cost/time? How many years of repetition are needed to control an established mature cluster?
        - Additional research on cutting above water level and the timing of cutting is needed
            - Can we identify a phenological marker for mowing to aid management agencies?
            - What is the threshold population density below which annual management by mowing or seedhead cutting is effective in preventing spread/negative impacts?
    - Split/stem injection is a method in which an individual plant is cut and injected with a dilute herbicide (glyphosate). The method is cost effective and reduces non-target impacts
        - There is not much in the literature regarding how effective this method is with YFI
        - Split stem is a promising control method but needs more research

        - A team in Indiana is working on this type of control and Stewart has encouraged them to share their work, so more information is likely to be available soon
- There needs to be a standardized methodology for evaluating management efficacy, considering plant biomass, number of stems, #numberof vegetative fans, ability to flower, timeframe to monitor, etc.
- There is ongoing research into a biocontrol agent, a flea beetle

Discussion

- Genetic studies of these species could provide insight into whether/how often they are reproducing clonally versus via sexual reproduction. This is relevant to one or more of the questions regarding life history and persistence for these species
    - Genetic study may also shed light on the pathways for spread
    - A study published by Gaskin et al. (2016) uses genetics to address questions of reproduction in YFI
- Would fresh plant materials be needed for genetics? Or could you work with dried/herbarium materials?
- Fresh plant material is better for genetic studies, but dried materials (such as herbarium specimens) can often work for PCR-based markers (detection recombination via seed or clonal) and population genetics
    - A genetic evaluation of a time series of plants from a site may help to answer questions on clonal vs. sexual reproduction

Widespread species

Species overview and information from literature reviews

Alisha Davidson, GLC Contractor

- Davidson review each of the four widespread species in today's discussion
- Control strategies for Eurasian Watermilfoil (EWM) include:
    - Herbicides (Fluridone and ProcellaCOR). Many herbicides have significant re-growth
        - There is some research that the non-target effects of 2,4-D are more impactful than EWM
        - Hybrid strains of milfoil respond differently to herbicide treatment
    - Benthic mats and Diver Assisted Suction Harvesting (DASH) can be used for small populations
    - There are some variable results from biological control
- Gaps/challenges for EWM include:
    - It is important to understand that genetic variability effects herbicide response and how to set expectations
    - Better understanding of the long-term efficiency of Fluazifop-p-butyl (FPB)
    - Does cost of treatment (economic or non-target) warrant herbicide application?
        - This may be a good place for managers to give their guidance and experience
    - There are additional gaps in the EGLE EWM Status and Strategy report
- Control strategies for starry stonewort (SSW) include:
    - There are not many control efforts that are consistently effective
    - Hand removal and copper treatment have seen some effective results

    - States are working on various control projects
- Gaps/challenges for SSW include:
    - There is need to find an effective and available management tool
    - A better understand SSW invasion ecology
    - What is the most effective timing of treatment?
    - Are other IAP treatments exacerbating the spread of starry stonewort?
    - An EGLE Status and Strategy Report for starry stonewort is available
- Control strategies for curly leaf pondweed (CLP) include:
    - Diquat, endothall, and Fluridone are the most effective herbicides. Treatments in early spring are best
    - Water drawdowns can be effective
    - Multi-year treatments are often needed
- Gaps/challenges for CLP include:
    - A better understand turion viability
    - Effectiveness of herbicides 6-benzyladenine and gibberilic acid
    - Biocontrol options
    - Effectiveness of hemp bottom barriers
    - Additional knowledge gaps are in the CLP EGLE Status and strategy report
- Control strategies for purple loosestrife include:
    - Effective biocontrol agents, *Galerucella pusilla* and *G. calmariensis*
    - Herbicides are effective for multiple seasons
    - Mowing/cutting must be done before flower seeds and need to be repeated until energy stores are exhausted
- Although biocontrol does not eradicate purple loosestrife, it provides moderate long-term control. No management gaps/challenges were identified through the literature review

Eurasian Watermilfoil

Ryan Thum, Montana State University

- Thum and colleagues research EWM genetic markers to help inform best management practices
- Herbicides are generally effective (more on the whole lake level than spot level) but efficacy is limited
    - There are herbicide resistant EWM strains and a diagnostic approach is needed
    - Standing "natural" variation is not considered when developing herbicide use patterns. For example, the typical 4-6ppm for Fluridone did not account for variation of strains. Moving forward, this should be considered when developing herbicide formulations
    - It is important to understand the recolonization dynamics within and among lakes. What is the real management unit?
- Herbicide resistant strains should not be treated, and this could be better regulated by permitting. There are lakes with Fluridone resistant EWM strains that are treated with Fluridone
    - There are benefits of adaptive management with associated monitoring requirements, but one size won't fit all
- Additional investigation into ProcellaCOR is warranted but just like other herbicides, it will not be immune to a genetic variation response
- There has been insufficient research on utilizing integrated management approaches for EWM
    - All herbicides are effective in some ways, it would be a mistake to just choose one. we should not use a certain herbicide if resistant strains exist

- There needs to be a clear definition of management units and better monitoring and reporting. Diagnostics (variation and resistance) should be reported
- In the short term, it would be beneficial to build a catalog of EWM strains and where they are located
    - Many samples have been collected in the Great Lakes basin over the last few years to be catalogued
    - Additionally, they have developed a naming scheme for all strains
- In the future, Thum and team hope to modernize the process of strain identification
- Montana State University has a website that is a prototype database of genetic information with qualitative flags for herbicide response
    - This is a good resource to connect those who have the same EWM strain in their waterbodies together
- Thum and colleagues have found that the same three EWM strains are geographically widespread and all are pretty susceptible to Fluridone
    - Hybrid EWM are pretty localized. Most hybrids strains are found in only one lake. More than likely, if you are dealing with a hybrid strain, this is the only place you will see it. It is worth it for states to do more surveying to find these strains
    - Identifying herbicide response genes and developing markers is an important long-term approach
    - Thum's team has been crossing Fluridone resistant plants with the Fluridone susceptible genotypes. This process allows them to find an area of a genome that carries fluoridone resistance. Finding these spots narrows the genome down and hopefully Thum and team can find the mutation or molecular markers that cause this resistance
- In the long-term, the goal should be to create molecular markers to aid in herbicide response
- There are a few papers that are published on the Fluridone resistance strains
    - The 2,4D resistant strains are not published yet, but Thum is happy to provide more information

Starry Stonewort

Michelle Nault, Wisconsin Department of Natural Resources

- Nault gave a brief overview on the biology of starry stonewort (SSW). Starry stonewort is not a vascular plant but rather an algae, which ultimately makes it harder to control
    - Ecological impacts of the invasive are largely unknown
    - The species can survive in a wide range of habitats
    - SSW reproduces via asexual bulbils
- Identification of SSW is challenging, as it often looks similar to native algae species like *Chara*
- Starry stonewort has been slowly expanding in the Great Lakes basin
- The species can reproduce through fragmentation, but dispersal seems to be mostly from the asexual bulbils, which can easily be moved by watercraft and animals
- Genetic work has confirmed that most North American SSW populations are genetically identical
- Starry stonewort vegetative biomass peaks during late August through October, which is later than most native plants
    - Bulbil count peaks in the fall
- There have been few lab studies that have investigated herbicide's effectiveness on SSW, both in terms of vegetative biomass and bulbil viability

    - Research has shown copper based products have had various outcomes, although studies have found conflicting results
- States are struggling with effective ways to manage the species
- Wisconsin has tried chemical treatments in open water, barrier curtains, DASH/ hand-pulling, dredging and drawdowns
    - There are concerns regarding the repetitive use of herbicide applications
    - Management to date has not been successful in eradication
    - The control of other invasive plants (e.g., Eurasian watermilfoil) which results in the removal of the vascular plant canopy may impact starry stonewort's ability to establish and spread within an invaded waterbody
    - Barrier curtains are effective at keeping herbicide on site, but what herbicide to use remains unknown
- There is a need to better understand biology, invasion ecology and distribution and to investigate starry stonewort's interaction with other IAP
- States need to continue to share information. It might be good to bring back the Starry Stonewort Collaborative

Curly Leaf Pondweed

Michael Verhoeven, University of Minnesota

- CLP has a unique lifecycle, which influences management. The plant produces turions and successfully flowers, creating viable seeds
    - Turions germinate in the fall and survive through the winter. The plant grows to its nuisance conditions in March through June
        - Native aquatic plants, at least in Minnesota, do not have this type of life cycle. Spring herbicide management is able to be conducted without affecting native plants
    - Summer dieback of the plant may be contributing to algal blooms via nutrient release
- Direct control strategies through herbicide applications can drive populations lower through time. By treating the plant in the spring, managers can limit plant reproduction. As water clarity increases, CLP populations decrease, and winter snow cover can affect population density
    - Current control strategies are largely working
- It has been found that native plant communities did not respond positively to successful CLP management. This is likely due to CLP's winter growth; they are not competing with native plants but creating a niche
- Long-term control is hindered by a persistent turion/seed bank
- There are opportunities for novel control to take aim at their unique growth cycle

Purple Loosestrife

Robert Colautti, Queens University

- Coulitti briefly overviewed the biology of purple loosestrife
    - Loosestrife rootstocks can live for many years and the plant mostly produces through seeds
    - The species has a very broad distribution and can live in many environments
    - Many native species often look like this species, making identification difficult
- Mechanical removal is useful for small populations. Root stocks need to be fully removed but care must be taken with seedbank to avoid soil disturbance

    - Removing inflorescence before they begin to seed is necessary
- Many herbicides are effective and successfully control the species
- Biocontrol agents have been effective at controlling populations and purple loosestrife density has decreased since biocontrol release
    - Biocontrol is mostly successful through damaged root and leaf herbivory
- Herbivore control is variable, and genetic variation in the plants may be the reason. Climate has been shown to affect the phenology of the plant, which in turn seems to be affecting the success of the biocontrol agent
- Research needs for purple loosestrife include:
    - What determines biological control efficacy?
    - How do herbivores affect vital rates and population dynamics?
    - Are herbivore effects independent, synergistic, or antagonistic, and at what point in the CLP growing cycle?

DISCUSSION: Eurasian watermilfoil

- ProcellaCOR has been used at a larger scale for full littoral zone treatment. There has been an evolution towards larger scale treatments, but not yet at a full lake level
    - What is the potential for EWM eradication?
- ProcellaCOR gives managers another tool, but the challenge for controlling EWM is identifying the source of population recovery. Because populations are so widespread, management needs to be considered at a watershed level if eradication is the goal, especially if the risk of reintroduction is high
    - Scale is still important when thinking about impacts that are tolerable
- A whole lake treatment of ProcellaCOR would utilize a lower application rate, which is loosely captured on the product label
    - Lower rates may express a more tolerant milfoil, which is not how management of the species should progress
    - Thum suspects that lower rates will have less impact on natives, generally. Some EWM and hybrid strains are really sensitive to low rates, and others would require higher rates to achieve the same level of control. How low of a rate will still be effective may be a function specific population genetic dynamics
- Wisconsin has been actively collecting and analyzing data on ProcellaCOR use for EWM control
    - There are still questions about the scale of impact. There were a few treatments where herbicide was applied at a localized scale and managers found some natives were showing signs of impact outside target area
    - More research is needed to look into fluazifop-p-butyl (FPB) acid and how long it remains in a system
    - Wisconsin has not eradicated EWM from any lake (but have seen multi-year control). Three or more years of control for Fluridone is typical
- The recovery dynamics from management are relatively understudied, including where and how the plant is recovering (fragment, seeds). Understanding how EWM is sustaining itself needs more research
    - Recolonization from seeds is fairly easily to identify with molecular markers. One nuance is that the same genotype could come from survival and/or recolonization of the same genotype in a nearby lake.
        - Studying that question is easier in whole lake treatments

- In general, larger scale liquid 2,4D is the most cost-effective, followed by Fluridone and ProcellaCOR
    - Fluridone and 2,4-D have generic forms available, which may lower their costs. Whole lake Fluridone treatment can provide up to three years of control on susceptible strains, but not on resistant strains. So, in the case of a resistant strain, ProcellaCOR would be a more cost-efficient treatment, even if it's more expensive

DISCUSSION: Starry stonewort

- In Minnesota, for areas less than an acre in size, divers have successfully harvested SSW, collected sediment, and removed the bulbils. There has been success with that, This has not resulted in full eradication, but has lowered populations
    - Divers went out every month to check and harvest (which is expensive) and there were monthly hand-pulls from July through the fall. Some lakes will receive a follow-up copper treatment
    - Minnesota has data supporting that the SSW has not spread within 5 years of localized hand-pulling, and July was the best time for hand-pulling
    - Minnesota has been doing treatments in early July before SSW ramps up its production. Hand-pulling really only works on very small, localized sites. There is so much biomass that it becomes too labor intensive in the summer
- Bulbils can’t be completely removed from the sediment via hand pulling
    - There is a need for a management tool(s) that limit bulbil production (same as tubers and turions for other species)
    - There are some intriguing possibilities for gene silencing, etc. These will likely not be in the near future and probably full of regulatory/public issues and concerns, but certainly an intriguing possibility
- An integrated management approach seems to be critical to increase efficacy
    - When managing SSW, eradication may not be an achievable and short-term biomass decrease may just be the goal
    - Scale really matters in SSW management. Early infestations that are treated promptly have shown success
        - In populations larger than one acre in size, reducing bulbil production is hard
        - Early detection of the species is important
- There needs to be more insight into SSW phenology and timing of management activities
    - Basic insight into when they are producing bulbils (seems like June through August) but perhaps timing application to when biomass is at a minimum, algae can take up that copper herbicide fairly easily
- In areas that have chemical restrictions, managers can hand-pull and remove it from launches to prevent incoming/outgoing boats from transporting it

DISCUSSION: Curly leaf pondweed

- In Minnesota, an increase in CLP is associated with a decline in native plants
- Research in South Africa indicated that CLP provides nutrition for waterfowl
- CLP in large stands prevent mixing, promotes internal loading, and releases a lot of phosphorus when it dies

- The nine lakes featured in the Minnesota native plant community trend study had native plant data pre and post CLP management year (designed as a before-after-control-impact) study and included both abundance and distributions. There is not pre-invasion data for those study lakes. There is a negative effect of CLP on native plant populations evident by comparing repeated sampling of lakes that are unmanaged
    - Pre-invasion data would help define the impacts of CLP itself on the original, uninvaded plant community, or relative to pre-management data. Such data would help strengthen the conclusion that control efforts had minimal effects on native plants.
- In assessments of the propagule bank in those sites where CLP was controlled, turion densities were found to be affected by multi-year control, but the seedbank is variable, so removing the turions solely will likely not fix the problem
    - Lakes that have completed a drawdown and dredging can still experience massive CLP growth, which is suspected to be from seeds. There is evidence from Minnesota that CLP is setting both seeds and turion
- With Fluridone, there has been some evidence of a boost of sprouting from the treatment, which helps deplete the turion bank
- In terms of CLP management, has any other lake managers used large scale Diquat in early spring in the same areas 5-7 years consistently to reduce turion densities? Is there a different tool to reduce turion and seed propagation?
    - There are likely timing/phenological ways to limit production, this has been the traditional approach. In the future, gene silencing technologies could possibly be used to prevent/limit turion production. There are a lot of steps to getting there, but it is conceptually possible, and the general concept has been proven (silencing genes and delivering the silencer to them). This also has the potential to be more selective because you can target species' specific genes independently of other species
- Selective, early-season control of CLP usually relies on endothall for early-season control. Other selective approaches for managing CLP in early spring besides Diquat include the herbicide Panoxalin
    - Wisconsin has utilized hand-pulling, and mechanical control efforts for smaller populations with various levels of success
    - There are internal concerns with Diquat use on walleye fry in Minnesota, so Minnesota does have a policy surrounding this topic and would like to provide alternatives to lake groups
- There are a few instances in Wisconsin where CLP does not germinate from turions in a given year (i.e., its super dense for a few years, and then suddenly managers cannot find it anywhere for a year or two, without any active management occurring), raising questions about what drives the germination of CLP turions.
    - It is possible that the bottoms sediments in the lake may have gone anoxic and prevented germination
    - CLP "blooms" or growth explosions in lakes occasionally occur where densities are normally low for the plant, but this was only in mesotrophic systems with generally healthy native plant communities. The germination trigger was unknown. In eutrophic systems, CLP generally grows every season with some variability. Snow cover is an issue in all lakes
    - There can be significant seasonal fluctuations without any management. Work at the University of Minnesota indicates that both water clarity and snow cover affect spring

populations ,but populations overall are an integrated metric of turion abundance, germination, overwinter survival, and spring growth

DISCUSSION: Purple Loosestrife

- Wisconsin has noticed in the past few years that there have been more reports of purple loosestrife from the public. There seems to be more blooms in the last several years. The riparian zones tend to need beetles every year in hopes to control them
    - Wisconsin is currently working with local partners in Minnesota to establish beetle rearing areas
- In Minnesota, the biocontrol program has been a great success. But they also noted that lately loosestrife populations have been coming back. Particularly in northern Minnesota, there have been more public reports of purple loosestrife infestations in places where it had not occurred before
- Michigan state agencies do not coordinate a purple loosestrife biocontrol program. Ultimately that work happens at a local level, but it's small if it is happening at all
    - In Michigan, an environmental firm does sell pots of loosestrife with beetles for individuals or communities to use for biocontrol. It is not a coordinated program
    - Anecdotally, there are indications that purple loosestrife populations have increased in the last three years. There has been an increase in grant application and all-around interest in purple loosestrife control
        - Biocontrol for purple loosestrife is not at the highest priority for Michigan right now
- In New York, insects were released on a provincial scale between 1994 and 2004. There is a commercial company that still sells beetles for release, but this is conducted more at the local scale; there are no watershed level initiatives. There was some work in the 2000s to follow up on the early releases and document impacts but there would be great value for a broader basin wide assessment of the efficacy and principles for success for biocontrol program for loosestrife
- There is not a coordinated program in Pennsylvania for loosestrife, control is left to local resource manager and associations
- It tends to be easier and more effective to lead a larger biocontrol effort at a local scale and coordinate volunteers/partner organizations than for individuals to release a few thousand beetles on their own

Final Discussion

- The topic of evaluating management and management endpoints are an important consideration for development of the research agenda
- There is interest in seeing studies that document an absence of impacts of SSW on other lake species or any beneficial use
    - Rob Colautti noted that he has a grad student looking at the efficacy of purple loosestrife biocontrol and would love to coordinate with others if they are interested

Breakout Group Notes

Hydrilla

Research needs

- **Research need: continued exploration and testing for selective and effective biocontrol agent for both monoecious and dioecious strains of hydrilla**
- What often makes or breaks successful control is the type of water body
    - **Research need: tools that work in flowing habitats and for small populations**
- Because the time of year when monoecious hydrilla puts down tubers, it is possible time treatments around when new tubers will emerge. Timed applications significantly lower the number of plants that can produce tubers and prevent it from establishing in new areas
    - **Research need: an effective systemic herbicide with a relatively short exposure time requirement**
        - There are many that are effective, but they are unfortunately require a long exposure time (which often means two applications)
        - Research is ongoing examining the application of systemic herbicides via a drip application
        - There is also talk of using light to disrupt tuber formation. This method could be used for a high-priority management area, and involves floating fish lights on timers to disrupt the cycle
- Hydrilla at a low density is difficult to detect and diving in clear water lakes is often best
    - **Research need: develop of eDNA tools for detection**
    - **Research need: general monitoring tools**
- Maintenance and control requires a lot of active management or tubers will continue to pop up. Containing the species is very difficult
    - Increasing management scale often gets a lot of pushback due to the increase in cost
    - **Research need: effective tools or methods for containing populations**
- **Research need: further research on the Connecticut River strain**
    - With the Connecticut River hydrology, there are still many unknowns. The strain does not seem to be producing viable seeds. It is believed to be monecious and there are still many traits that need to be investigated
- **Research need: methods to facilitate trigger sprouting to aid in herbicide application**

General discussion-biocontrol

- There are a number of selective biocontrol agents that are in development for hydrilla but none that have been successful in the field
    - No biological control agent has been effective at reducing plant growth, and is likely only effective as a maintenance management tool
        - Impediments to biocontrol success include overwintering ability, nutrient availability, is the plant able to host all of the biocontrol's' life stages and allow for reproduction, natural predators
- There are four USDA APHIS approved agents for hydrilla control in the US*:* two weevils (*Bagous hydrillae, Bagous affinis*) and two flies (*Hydrellia pakistanae*, and *Hydrellia balciunasi*)
    - Only the two flies (*H. balciunasi* and H. *pakistanae*) are widely established, and only in the southeastern US. Neither of the weevils seemed to establish initially, but there was a population of *B. hydrillae* was found in Los Angeles several years ago

    - Unfortunately, none of the agents provide much control on their own. The two flies can establish and damage both dioecious and monoecious hydrilla in the southeast US, but can be heavily parasitized by a native North American parasitoid wasp
    - The flies' persistence on monoecious plants also seems to be limited because they require intact stems to overwinter and monoecious hydrilla at many sites senesces back to the sediment/root crown
    - Overseas exploration for hydrilla agents has shifted away from a dioecious focus (the target for most of the last 50+ years) towards agents for monoecious hydrilla. Recently, a *Hydrellia* fly was collected from monoecious hydrilla in South Korea, but was not host specific enough (it also attacked *Elodea canadensis* during host-specificity testing) so was scrapped from consideration
    - There are a few other insects of interest to test on monoecious hydrilla, but things are moving slowly right now with international travel restrictions. Of note, because of travel issues, and because a main collaborator is there, searches have expanded in Australia, where they consider hydrilla a native plant
        - *H. balciunasi* was also originally found in Australia
    - Nathan Harms can be contacted for more info on this work: nathan.e.harms@erdc.dren.mil

<u>General discussion-chemical control</u>

- Chemical control tools right now are the most effective at managing abundant populations
    - Grass carp is likely not ideal for the Great Lakes, as species richness of native plants would severely be impacted and Lake Erie is actively trying to remove the species
    - Harvesting has not been really effective and just fragment the plant (can be good for maintenance but will not help with eradication)
    - Integrated management options will depend on the end goal (maintenance or eradication)
- There are only a few products that can treat hydrilla with a small exposure time, which makes full eradication hard
    - Diquat and copper are often the quickest acting, but they have broad impacts on co-occurring vegetation
- Herbicide selection should be based on your goals and treatment locations/habitat types
- Regulatory requirements of herbicide often slow down rapid response and adaptive management activities
- Field demonstrations of ProcellaCOR were conducted to test efficacy for hydrilla. There are two variations of the herbicide: EC and SC. In Pennsylvania, EC was trialed with pretty good results eight weeks after treatment. Treatments were well timed. A one-year post survey monitoring will occur
    - In the field study, dye was used to visualize the water exchange in the area. For areas that had a high-water exchange and a short exposure time, ProcellaCOR was not that effective
- Selectivity of ProcellaCOR EC is based on rate. Around 6-9ppb is effective for Eurasian watermilfoil treatment with high selectivity at those rates, but for hydrilla higher application rates are needed
    - Several species (eelgrass, pondweeds) have been shown to be resilient
    - More field demonstrations are occurring to get more information on field selectivity data
        - Mark Heilman can be contacted for more information

General discussion

- The smaller the population, and the more sporadic it is in the water body, the more difficult it is to control
- Hydrilla can tolerate the low brackish range but 3 or 4 ppt salinity is about the limit
- Is there a good time to manage the plant?
    - Yes, should focus management seasonality when tubers begin to sprout and essentially prevent new tuber growth for the next season
    - This is a great reason to find a systemic herbicide that is effective
        - There are many that are effective, but they are unfortunately require a long exposure time (which often means two applications)
        - Research in the works at looking at applying systemics via a drip application
        - There is also talk of using light to disrupt tuber formation. Would be used for a high-priority management area, floating fish lights on timers to disrupt the cycle
- Are there any other outstanding questions on the biology or phenology of hydrology?
- Bathymetry tools are helpful to create survey efforts to delimit the extent of a newly discovered population and narrow in on certain depth ranges. For example, shallow littoral zones (9ft or less) should be surveyed the most

European Frogbit

Research needs

- Populations are fairly easy to remove (physical removal with a garden rake), but getting access to the plant is usually more challenging since it co-occurs with emergent vegetation
    - Mostly co-occurs with narrow leaf cattail (but not *Phragmites*); can use mechanical harvester with a cutter on it too for the emergent stems
    - Controlling cattail and removing biomass is critical. If you remove structure, the habitat is unavailable for EFB and will be unlikely to regrow
    - Glyphosate is not effective on EFB, but does control cattail. However, chemical control leaves plant litter, leading to an increase in EFB in those treated locations
    - Flumioxizine controls EFB but not cattails/phragmites. No known overlap between chemical control tools for these species
    - **Research need: integrated management strategies of emergent vegetation and EFB**
- **Research need: herbivory/biocontrol.** There is likely a weevil, some aphids have been present, some evidence of aquatic lepidoptera
    - A leaf has been found folded in half with a lepidoptera cocoon in it
- **Research need: why is there less flowering in sparse population and more flowering in dense populations?**
- **Research need: what level of control/effort is needed to get to eradication of this species?**
    - It may be helpful to examine other eradication frameworks, and understand how that applies to a leafed AIS
- **Research need: testing the herbicide penoxsulam**. Penoxsulam is similar to fluoridone, and maintains concentration and residuals in the system. This herbicide has never been tested in open water in Michigan
    - May be easier to get support for use in a detention pond rather than true open water
- **Research need: need a better understand seed viability and germination requirements.** This would inform when control needs to happen, particularly in relation to flowering timelines
    - Seeds are viable, but unsure about overwintering or germination success rates
    - Seed pods are roughly the size of a tic tac and contain 30-50 seeds each. Could move via feathers, fur, other waterfowl
- **Research need: how significant of a pathway is spread via waterfowl, and what to do about waterfowl as a vector?**
    - Not currently as strong of a pathway as human-mediated (boat ramps, etc.), but may be a factor
    - Can look at pattern of migration to inform surveillance efforts
- **Research need: viability of turions and plants out of water/desiccation rates**
    - Some of this work has been conducted in an unfinished MS thesis
- **Research need: unsure about how control methods affect turions**
    - Late application of herbicide still controls adult plants, it varies on if this is sufficient for the turion bank. Anecdotally, see a reduction either way
- **Research need: unsure about the impact of control methods in use, particularly when sprouting EFB are sprayed**
    - Anecdotally, have not seen resurgence in populations but unknown if that's direct impact to turions or if population was just controlled before turions produced
- **Research need: unknown how drawdowns may impact EFB as a potential control measure**

    - If the water level changes and the plants become stressed, turions can be produced earlier than expected – as early as June
    - How much drawdown is needed for how long? And at what time of year? What would a winter drawdown be more effective?
    - Drawdowns are particularly relevant for wetland environments
    - Possibly may be studying this in MI
    - Flood events may also be relevant to control efforts. EFB follows water level into other areas, but hasn't persisted in years without as much of an increased water level
- **Research need: evaluate mechanical control methods for other free-floating plants (like water lettuce and water hyacinth) to understand if these methods may be effective for EFB**
    - Michigan has been planning a trial study based on tools used in Florida to manage water lettuce and water hyacinth
    - These methods may be useful for areas where herbicide use isn't realistic
    - Some of the technology developed for skimming trash off the surface of waters could be useful - except in the cases where the EFB is growing among emergent vegetation
- **Research need: when do you start treating vs. how much do you need to survey?** Relevant to preventing spread
    - Is there value in focusing on suppression activity? Remove what is in the population, then control and try to manage spread to prevent drift out of that population
        - Residual surfactant? To prevent drift
        - Physical barrier would also work to create a controlled zone for management

<u>General discussion</u>

- This plant can root if the population is on a mud flat, but is generally free floating. Can sometimes appear rooted in the water column, but this is usually the plant tangled in filamentous algae
- There is some data on EFB occurrence over time to indicate how its reproducing, but seems to be primarily turions in MI

<u>General discussion-physical control</u>

- Backpack DASH harvesters haven't been used yet, but could be. Mechanical harvesters haven't been employed in a study yet, but Michigan is hoping to trial some this summer
    - A DASH harvester works like a reverse leaf blower, water spits out but vegetation is kept
    - Could be used on airboats
- There is less interest in herbicide usage other control methods that may be appropriate include:
    - Backpack DASH, small mechanical harvester (1 person)
    - Even hand-pulling has negative impacts. 10-15 people walking through marsh to pick plants, disturb sediment and there's now EFB in the trails left
    - Native plant restoration as a control tool? Native water lilies preventing extensive growth of EFB in western New York
    - EFB doesn't grow substantially within spatterdock – may still be present, but won't gain a stronghold. More so in the edges where there is more open area

<u>State control efforts</u>

- NYSDEC working on a treatment project for drawdown, herbicide, and clear-cutting for EFB, with post-treatment native species restoration. This project is due to begin in 2023 season

    - Dam rehabilitation at same location will result in a drawdown, trying to build on that to keep drawdown down a little longer to incorporate this as a control methods into this project
    - March to November drawdown for dam, trying to keep the drawdown longer for over winter and into early spring
    - Can pull turions out of the seedbank periodically throughout the drawdown to understand germination rates after set periods of time
- Coastal marshes in Ohio with EFB may have drawn down over the summer months (2-3 months, soil is likely still well-hydrated through the seedbank) to manage for waterfowl. Also an intentional drawdown over winter (Sept-May). In both situations, once wetlands were flooded, EFB returned quickly. Good control in first few months but turion persistence in seed bank seemed to be extensive
    - Possibly need to drawdown, flood, then drawdown again to pull out turions in seedbank during that flooding period

Water Soldier

Research needs

- **Research need: will water soldier seeds become viable with enough genetic diversity, like *Phragmites*?**
    - It is not uncommon for water solider to only have one sex present in a given area in its native range making sexual reproduction impossible. Only females are present in Ontario
- **Research need: could a drone application of herbicide be used in areas airboats can't access?**
    - Drones have been used to treat a site of flowering rush – expensive but possible. Had a 5 gallon capacity with a licensed commercial applicator. Suspect it would work for submerged form, have seen spray gun on the surface work.
    - There may be regulatory concerns with using drones to apply aerial herbicides
- **Research need: How to transition from large scale to small scale control**
    - When you go from high density to very low density of plants, detections of those becomes difficult.
- **Research need: how do we improve residency time of herbicides in a flowing system?**
- **Research need: could it spread in a serious wind event or flood?**
    - How does it spread? Was industry plant. Spreads via offsets and turions. Because of this, likely to spread via water garden trade. But
- **Research need: What tools do we need to be able to respond to a new invasive species as efficiently as possible?**
    - New detections should always be treated at least two years in a row; sometimes this leads to full eradication
    - A barrier curtain around it when removing, or some sort of floating structure (WI has done), will help reduce drift and vegetative spread
    - A private pond treated with ProcellaCOR had hardly any plants within 2 months. ProcellaCOR shows promise; conditions drives outcomes. ProcellaCOR in consideration for approval in Canada.
- Drones have been used for surveillance over the last 3 years, with manual identification
    - **Research need: an identification algorithm would be extremely useful**

General discussion

- Multiple new populations have been identified in local, private water bodies. Small treatments have been successful because lack of flow. Great success with closed environments.
- The Trent-Severn population is 75 km long; there has been great control success but no decrease in 2019 – at the low end of abundance, eradication is difficult. Control is hard to do when system is bordered by wetlands, hybrid cattails. Have been doing grid square monitoring by boat, but drone aerial application of herbicide is a potential option.
- The majority of growth is in shallower littoral zone. It is rakeable, but so heavy at 14 kg/m2

General discussion-chemical control

- Reward (diquat) is not labelled for aerial application in Canada. Due to formulation/registration issues, its use is being discontinued in Canada

General discussion-biocontrol

- Active restoration to mitigate impacts may also be a potential control tool. Wild rice has been seeded in Minnesota in response to starry stonewort

Didymo

Research needs

- **Research need: do blooms impact early life history stages of other species**
    - NZ studies suggest benthic invertebrates are smaller but abundant in didymo mats, and that they may not be accessible or energetically important for adult trout, but does this also impact smaller juvenile or larval fish?
    - **Research need: water upwelling may mean mats are not impacting dissolved oxygen within beds where eggs are present in redd/nests, but could they impede emergence?**
    - Where blooms are observed is not always predictable from year to year, so often no blooms are seen in subsequent years
- All existing treatment options primarily kill the diatom but having limited effect on polysaccharide stalks and mats
    - Recovery of diatoms is likely to be rapid, and none of existing treatments are ideal or able to be used in a wide range of habitats
    - **Research need: ways to disrupt or break the polysaccharide stalk to speed up or enable removal of mats / blooms**. How do you attack the structure of the stalk?
- In the absence of any effective treatment systems the only management options are containment and slowing the spread
    - **Research need: define the value of containment measures if the species already likely widespread?**
- **Research need: do we really have a good idea of distribution of didymo, and are we conflating presence of blooms with current range** – based on fact that sediment cores, presence dating back to the last ice age, and genetics data is suggesting Didymo was present and is probably a nuisance native, and New Zealand response survey data – it is possible that Didymo is already widespread but sparse and low levels of detection until it forms nuisance blooms.
    - **Research need: is there a need to conduct more sensitive regional delimitation surveys for Didymo using RNA and drift net sampling approaches adopted by Biosecurity New Zealand (BNZ)?**
- **Research need: if didymo is not widespread and we are observing some range expansion from blooms, is the only management option prevention: check, clean, dry etc…**
- **Research need: efficacy of felt wader ban**
    - Why have states adopted or not adopted felt sole wader bans. What is the thinking and rationale? Felt soled waders are likely a vector for other AIS other than didymo.
- **Research need: what triggers blooms?**
    - May be a stress response to low phosphorous (<0.5ppm, often below detection limits)
    - How much of a phosphorous addition to the system would be needed to prevent stalk formation?
    - What are low limits of a phosphorous release that would impede bloom development?
        - Unlikely to be acceptable in high quality trout streams. Could experiments be undertaken in lower quality streams with blooms but where phosphorous addition might be more acceptable?
- **Research need: access to more of grey literature** – unpublished studies like NZ biosecurity response work that is not in general literature. Area of interest included:
    - Trace elements in spring heads and North Island of New Zealand that may be preventing blooms

General discussion

- A priority of management of nuisance blooms is their impacts on fisheries values and aesthetics (couched under banner of water quality), including impacts on:
    - Fisheries (Biological resource) and impacts on critical habitats like salmonid spawning habitats or juvenile/larval fish nursery habitat that can be impacted by Didymo blooms.
    - The fisheries experience (impacts of blooms on aesthetic and fishing – fouling of hooks and flies etc).
- When making management decisions, we need to consider temporal aspect and whether blooms occur when they will impact fall or spring spawners.
    - Also longevity of blooms, in uncontrolled rivers or coastal habitats of Great Lakes – are storm or flood events likely to occur in following months that could remove mats and hence impacts could be short term
    - Is there overlap between blooms and critical life stages of species in the location you're treating?
    - BNZ polysaccharide study that investigated enzymatic or chemical breakdown of stalks.

Water Hyacinth and Water Lettuce

Research needs

- **Research need: definitive knowledge of overwintering seed set and viability in both species**
    - There are no certain latitudinal limits but likely anywhere that freezes the first few inches of the waterbody would be fatal
- **Research need: is it important or relevant to treat populations in fall months if the vegetation is just going to die in the winter?**
- **Research need: a genetic study to determine how often a plant will reproduce by seed vs clonally**
- **Research need: viable options for managing a seed bank**
    - Seeds are released (water hyacinth releases pods) and then seeds settle on the sediment, forming a seed bank
    - This management would likely take several years. Managers need to actively manage new plants that occur and eventually wear out the seed bank. The key will be to manage plants before seed production, so they are not adding new plants
- **Research need: establishing best practices for removal efforts**, including timing of when removal of plants is not need (should plants be removed in the fall months?) and where to spend resources
- **Research need: synthesizing water lettuce and water hyacinth introductions across the Great Lakes basin, whether populations are persisting, and what management efforts are being or were done**
- **Research need: ability for these plants to bring along other hitchhikers**. Warmer fall weather may increase flowering and seed production. Are nuisance conditions (seed and expansion) possible when growing from seeds only?
- **Research need: seed production, germination rates, etc.** There are not many studies out there regarding seed production; water hyacinth and water lettuce seed banks are universally understudied
    - Stable, relatively clear shallow water would be best to test this in
        - Would not need a lot of plants to test this, as self-fertilization is common
        - Would eDNA have any promise looking for seed material?
            - Likely not tell you viability of the seed, and it's been suggested that viability is more important than just presence
        - Would seed viability in the Great Lakes (due to the cold water), last longer than the typical 5 years?
            - Unsure, but soil temperature could very likely have an impact on longevity
- Dr. Hugh MacIsaac (University of Windsor) has conducted overwintering survival and seed viability studies on water lettuce and water hyacinth.
    - From personal communication with Dr. MacIsaac: "neither hyacinth nor lettuce survived 2 winter survival experiments - one a severe winter, the other a mild winter. We don't think the winters are warm enough yet for this. We found no evidence of in situ reproduction (other than by fission) of water lettuce. We did find hyacinth producing seed pods, and we were able to germinate these seeds (28C or 35C). Minimum reported germination temp in the literature for hyacinth is apparently 20C. We think they could produce a batch of seeds on year, then die, and the seeds germinate in a following

year. Essentially the plants might behave like annual terrestrial plants. I think states and provinces around the GL should prohibit water hyacinth sales."
    - Sue Galatowitsch at the University of Minnesota has also conducted research on cold winter hardiness on several aquatic invasive plants
    - **Research need: there is value in repeating these studies and perhaps over a longer duration**
- **Research need: Understand, via genetic analysis, if some populations are more cold adapted than others**
    - Genetics could help us understand if we are seeing repeat introductions or seed production

General discussion

- The robust roots of the plants may encourage additional plant infestation when the introduction comes from aquarium dumps
    - In the south, Cuban bulrush hitchhikes on water hyacinth
- It will depend on the conditions of growing year, but the type of monocultures that are seen in the south are unlikely in the Great Lakes basin, due to the longer winter months
- The idea of sleeper populations does raise a concern. It could continue not being a problem until that one weird summer/fall that does make it a problem and changes the system.
    - https://news.wisc.edu/invasive-species-often-start-as-undetected-sleeper-populations/
- The time from flowering to seed production like differs with the specific conditions of the weather and waterbody, but plant production is pretty rapid after seed production (as quick as two weeks)
    - The plants produce clonally as well, which dominates growth and spread in the southern US, as the growing season is so long
- How much effort should we put in post treatment monitoring, is this something to standardize?
    - Cleveland Metroparks monitors for hydrilla and yellow floating for four years after management
    - Michigan has recorded 27 locations with water lettuce and water hyacinth since 2014. Only five of those have had reoccurring populations. Three infestations have been larger (acres in size with hundreds or thousands of plants). Control activities are conducted on all reports with follow-up monitoring at the large populations. Follow-up monitoring is generally not conducted for small populations, the state relies on local partners to report if there is regrowth or spread
    - encourage some states to regulate this plant if they are not already
- Wisconsin prohibits both water lettuce and water hyacinth, and at the time of listing, there was significant pushback from water gardeners and industry as water lettuce has a lot of functional use in a water garden system (removing nutrients from the water)
    - These plants are also popular because they are so easy to propagate and so hard to kill, which makes them popular with growers and hobbyists. Sometimes nurseries give them away for free with purchase (because the plants continue to propagate after they've been delivered as stock)
- How would we go about testing seed viability?
    - A paper published in 2011 in South Africa took sediment samples for water hyacinth seeds, and germination was about 50%
- There have been several sites within New York where water lettuce and water hyacinth co-occur (including in the Erie Canal alongside the hydrilla infestation), but there has never been a re-

appearance post-treatment. The only exception is within the Erie Canal, which is occurring adjacent to an ornamental pond and appears to be consistent reintroduction rather than seeding. They have never seen the species flower

- Indiana has not seen seeding but rather individuals that were intentionally adding seeds to water for them to germinate and also had them falling off barges originating from the southern US
- It is critical to ensure that water lettuce and water hyacinth populations do not expand to areas that are warmer (e.g., water discharge, power plant areas) as water would not freeze in those areas and may serve as a refuge
- Another relevant article: https://onlinelibrary.wiley.com/doi/abs/10.1002/rra.3362

Yellow Floating Heart

Research needs

- **Research need: regrowth possibly from seeds, OR from rhizomes?** Unknown
  - It is also possible that root masses are also regrowing from soil
- **Research need: reproduction of leaf fragmentation? Need to confirm if this is true of YFH**
  - Leaf with a part of a stem (node) may be sufficient – Michelle Nault to find source
- **Research need: unknown potential for spread via seeds (sticky Velcro seeds)**
  - May not be playing as big of a role in spread/growth as possible, since spread is so easy
  - If YFH were present in a larger system, the potential for spread would be significantly different. Growth/spread would be extensive
- **Research need: identify possible control methods based on tools used to control other species in the genus**
  - Possibly partner with researchers on crested floating heart in southern US? Michigan has worked with them to explore control tools and develop management plans based on experience, but no conversations about seeds
- **Research need: better understanding how climate change may impact suitability for seed germination/viability** – primarily *Pistia*, *Eichhornia*, *Nymphoides*
  - Interest in enhanced ERSS with climate – if included in research agenda, this also validates FWS efforts to continue this work
- **Research need: seed germination rates and requirements**
  - Seed unknowns are the biggest concern in Michigan. Knowing that seeds are being released into the system, but unknown if there's regrowth
  - Seed viability questions have been a need for a number of years – so why hasn't it been picked up yet?
    - Still trying to identify the right group to conduct some of these studies – need to build networks of experience
    - Considering MSU/horticulture program
    - Partner with master gardener programs?
  - Anecdotally, seed pods don't seem to be affected by low dose ProcellaCOR

General discussion-physical control

- Hand removal has been successful in smaller lined ponds. Landowners are more resistant to herbicide use. Success largely depends on how high the liner runs up the sides of the pond – roots can get caught under rocks and regrow in subsequent years
- Wisconsin populations are also present in small private ponds with no connection. To control the population, staff are draining and relining pond, dredging, removing rocks and spraying them down
  - Staff have begun to incorporate FPB into strategies, including treating individual plants popping up on the edges of populations treated with FPB
  - Seeds may have some longevity and remain viable until conditions are right – particularly in high/dry mud flats that become inundated

General discussion-chemical control

- Most treatments take place in July/August
  - Herbicides have quick uptake time, so timing of application is critical, there needs to be no wave action in the system

- Fluoridone treatment for hydrilla did not affect YFH. Freezing/drawdown didn't seem to affect either. Would like to do soil cores to test germination rates, but regrowth tends to be minimal
- The EC form of ProcellaCOR is what's registered for use in the Great Lakes

General discussion

- In Wisconsin, there is one population that has not been observed to be flowering
    - Could be shaded, could be nutrient limited due to lined pond not providing nutrients via roots, could be a cultivar bred to be surface cover
- YFH overwinters well due to deep root structure (easily several feet)
- The systems in which YFH has been found in Michigan have all been stagnant systems, not flowing
- New discoveries primarily through education efforts about the invasive quality of the plant and how to identify it
- YFH has only seen once in a Michigan natural waterway (i.e., not a lined water garden) and was clearly a bucket dump – plants still in the shape of the bucket
- When landowners report populations to Michigan, the state will assume the cost of removal. Good win-win to encourage reporting and early treatment
- In one inland lake in Michigan, a small patch was found, like as secondary spread via fragments/seeds moving through storm drain
    - If YFH were being moved on feathers/fur, we would expect to see more populations in natural systems

Yellow Flag Iris

Research needs

- Populations are often isolated, but can form monoculture and have impacts
    - **Research need: Unsure why forms monocultures** – temperature? Appears to prefer more organic substrate, but could be another reason. Or maybe in a robust native community
    - This approach will never reduce existing population, but will contain its spread
- **Research need: Lack of quantitative, standardized pre- and post- treatment efficacy, relative to each method**
    - Also, comments on cost for each method
- **Research need**: **Decision-support tool for this, and all, species**
    - This is a priority. There is collective knowledge out there
    - Funding needs, differences in treatment between rural/urban, treating different densities, etc.
- **Research need: is there a phenological marker for knowing when to cut plant off at base? Can you deplete reserves via above ground mowing?**
    - No permitting is required for mowing and is easy for landowner to do

General discussion-chemical control

- One participant is planning to try herbicide wicking in high quality wetlands
- For new populations, what is the best approach? Glyphosate and imazapyr tend to be the most effective herbicides

General discussion-physical control

- Engagement with volunteers is important – digging is very labor intensive
- It is hard to dig up. Cutting seed heads is a low effort control strategy. Primary literature suggests seed spread is main vector (over rhizome)

General discussion

- One management challenge is the difficulty in identification between blue and yellow flag iris when not in bloom
    - One approach is to wait to go out during bloom, and generate GPS points for any flowering blue iris. In future treatments, these GPS points can be referenced later with confidence
- Three ways to differentiate yellow and blue flag iris: flower color, seed pods, large leaf mid-vein
- Wisconsin is actively managing yellow flag iris populations, but most states aren't
    - Ontario did some hand pulling in a small pond with liner over several years
    - Not a lot of concern in MN, although populations are spreading in MN
- The plant is mildly toxic, but not actively managed/considered a problem by the public for several reasons
    - Beautiful, grows right at shoreline, people like to plant
    - There is a cultural belief that this plant has been here for hundreds of years. A story that it was planted by French voyagers to mark portages
- A colorful native mix could be promoted to landowners as a favorable replacement

Eurasian Watermilfoil

Research needs

- **Research need: It's unknown if the effectiveness of ProcellaCOR differs between "pure" and hybrid EWM**
    - Resistance comes from "resistance alleles"
    - Tolerance is a description of species – versions of genes where all copies of gene have that property
    - Since hybrid EWM is not a species, there's nothing that makes it distinct from "pure" EWM, so ProcellaCOR response will be a function of both environment and alleles. There may be general patterns of difference with hybrids (e.g., grow faster) but would caution against treating "hybrid" watermilfoil as fundamentally different as a cohesive unit. Hybrids are dependent on which individuals (with which genomes/alleles) have crossed. One size does not fit all with hybrid control and should not be treated as such. How do you diagnose whether something is going to work or not?
- Stakeholder interest and resources are going to drive management – broad stakeholder group interest and funding is critical
    - **Research need: data collection is a key and often missing component due to capacity as a limiting factor**
- Low dose fluoridone treatments started as a model trial with MAISRC's involvement. 2-4 ppb reduced negative impacts to native species while still effectively controlling EWM.
    - **Research needs: using ProcellaCOR at a lower dose for lakewide levels is an interesting question – and which tool is better for a lakewide treatment?**
- **Research need:** technology is widely available to screen agricultural pests for known resistance mutations. **There would be a lot of management value in a tool like this for EWM**
    - Can already be done with Hydrilla fluoridone resistance
- **Research need: there hasn't been a lot of research on EWM weevils**; WI has had some success in a smaller lakes with enclosures to prevent fish from eating weevils
    - **Research need: should examine/trial alternate control tools that haven't been used as frequently**
- Are there ways to demonstrate that eradication (or long-term suppression) is possible on a whole lake scale? This might change the perceived paradigm and could encourage agencies and states can start funding EWM treatment more
    - **Research need: a mutual public/private partnership to discuss common goals will help to move the needle**
    - On the public side, there are good education programs to prevent moving IAP from lake-to-lake
        - Keeping public access sites clean of invasive plants as a form of a management is an important strategy to eliminate a vector of spread
    - **Research need: do we need to look at this at a landscape scale and identify the lakes that might be a key vector (and manage or eliminate those populations)?**
        - In MN, there are key lakes that get a lot of boat traffic. And unfortunately, they tend to be very large lakes that are probably not feasible for lake wide treatments
- **Research need: how much EWM is tolerable in the plant community? Many in the community would rather see EWM than no plants. What level should we try to manage to?**
    - Mark H.: The fishing community just wants to see vegetation in general and often does not care whether it is invasive or native. This gets into a challenging place where you're a

pseudo encouragement for an IAP and the ecosystem service it is providing. Having a common vision to reconcile that an IAP is not a good thing ever is important. Leaving EWM just because it is the only plant that will grow in a disturbed lake seems like an easy out, especially with the additional tools

- **Research need: is anyone working with fungicides?**
    - This was a research topic at one point, but no attendees were aware of current research
- **Research need: gene silencing on EWM is an intriguing tool that should be investigated**It's strongly recommended that managers screen EWM populations before treatment to understand if it's a fluoridone resistant strain
    - There's currently no evidence of presence in MN, but doesn't mean there aren't any strains with that gene

General discussion-mechanical control

- Are there any methods besides chemicals that have been successful at a lake wide scale in terms of management?
    - Mechanical harvesting removes the top five feet of growth, provides nuisance relief and extra light for native plants
    - There are a handful of lakes in the northwest that have done DASH work. This method requires a lot of money/energy, but does seem feasible even on large water bodies
    - The milfoil weevil approach still has some supporters, but it can be a lot of work
        - A lake in MN did build an enclosed cage to rear weevils so they didn't have to bring them in

General discussion-chemical control

- There was full agreement that we want to use the lowest rate possible, and the higher the rate, the more separation there will be between wild type susceptible plants and mutant resistant plants. Low rates will result in much greater variability in efficacy between lakes

General discussion

- The chapters in AERF book on definitions of control (http://aquatics.org/bmpchapters/BMP4ed.pdf) may be a good perspective on the difficulties of how to define control and measure it – and how should we measure it?
    - Another chapter on lake management plans is useful here
- The questions that should guide management decisions include:
    - What do we want the lake to look like and why?
    - Why does that matter to us and the ecosystem more broadly?
- Integrating active restoration into the active management of a widespread species may help reduce reinvasion risk
    - Chesapeake Bay as an example
- How could we achieve better management results?
    - Some states are driving EWM funding and work, but there is also a lot of private funding (from lake associations, etc.). This can lead to a disconnect between eradication and maintenance goals
    - Some states have public grant funds for EWM management, but not all. When funding comes exclusively from a local level, there's no a lot of coordinated management
    - There can be issues with what management activities the people who live on that waterbody are comfortable with and a realistic management goal. Accommodating

waterfront homeowners is still a challenge. The more tools we have, the more management scenarios we can try

- MN often tries to disperse their funding between more lakes instead of just focusing on full lake efforts. They are also restricted on treating less than 15% of littoral water with herbicide, which pushes them to do smaller treatments

Starry Stonewort

Research needs

- **Research need: At what population level do management goals shifts from eradication to maintenance?**
- **Research need: tools to keep growth at a manageable level that managers feel comfortable recommending to stakeholders for local control**
    - Indiana is managing starry stonewort at 25 lakes, <5 acres in size because beyond that, the population seems totally out of control
- **Research need: leverage information on "failed" establishments to better predict when/where to intervene?**
    - Some lakes in Indiana; Pike Lake, Wisconsin; Lake St. Clair
    - A lake in Weshara County, Wisconsin, has had no intervention and they've seen no spread of starry stonewort
    - **Research need: What are the precipitating factors for explosive growth?**
- **Research need: is it possible that active management of other species (e.g., Eurasian watermilfoil) may exacerbate starry stonewort spread, abundance, or density?**
    - Maybe starry stonewort is present at deeper depths and treatment creates new open niche for starry stonewort to infill
    - More diverse native communities could be more resilient/resistant to starry stonewort, but lakes with more Eurasian watermilfoil might be more susceptible
    - The interactions between starry stonewort and other species are not well studied (e.g., removing Eurasian watermilfoil allows light penetration). More long-term data is needed from lakes treating both species
- **Research need: is biocontrol viable?**
- **Research need: future potential of gene silencing to limit bulbil production**
    - There may be regulatory and public relations issues related to genetic manipulations, but this could be a key for a species with limited control tools
    - The best case scenario for successful management would be the development of highly selective techniques that disrupt bulbil formation. Gene silencing is an intriguing idea. Chemical cues might also still be examined
    - **If just one longer-term research effort were funded for starry stonewort management, focusing it on the genetics/physiology of bulbil formation and how to suppress it would seem to make sense.**
- **Research need: Does hand pulling work? And under what conditions?**
- **Research need: Is hand pulling and herbicide use better than herbicide only? Why?**
- **Research need: Can phenology help to optimize treatment timing?**
    - Biomass and bulbils tend to peak in September and be at their lowest in mid-summer
- **Research need: What do we know about bulbil viability/resting period? And best practices to manage that bank of propagules?**
- **Research need: variation of growth patterns within lakes between years.**
- **Research need: would be good to explore the 'do nothing' approach with public. Trying to frame that as a tool in the toolbox.**
    - There can be an emotional response from the public related to desire for management – there can be the short-term view that any aquatic plants (including native) are "bad" and thus a hesitation to development a management plan for that lake, and instead favoring a lakewide herbicide approach to "kill everything"
- **Research need: utilization of starry stonewort beds by wildlife**. There is anecdotal evidence that crayfish utilize it well, but also that it ruins fish spawning habitats
- **Research need: is starry stonewort allopathic?**

General discussion

- Managers may need to focus on being more efficient in maintenance management efforts
    - Limiting spread from boating accesses is key; perhaps in some cases that is the correct management endpoint for starry stonewort?
    - There has been some success with hand pulling (supplemented with DASH) at boat ramps in Wisconsin and Minnesota, but populations may then occur in other locations of the lake. Beyond 2-3 acres hand pulling isn't feasible, and so management shifts to biomass reduction and limiting surface area
        - Hand removal protocols can be shared
- Given starry stonewort in North America is all male, presumably the genetic implications that are so important for Eurasian watermilfoil are not for starry stonewort? Though recent reports of females suggest this could be an area of inquiry
- There was some interest in reviving the Starry Stonewort Collaborative as means to share information
- There have been some observations of natives *Chara* species in shallow, and starry stonewort occurring in deeper waters – do they have separate niches?
- What is better management? In the absence of effective control tools, and absence of impacts, does better management look like more cautious treatment and 'do nothing' with ongoing monitoring?
    - The consideration of effective management will vary lake by lake, and it may be more efficient to focus on limiting spread