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More Than Mattresses: Community-Based Adaptive Management for Floating Treatment Wetlands in the North and South Twin Lakes

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Senior Project Submitted to

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by

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Dedication

I would first like to dedicate this project to the FONASTL group and to the larger Twin Lake community. I hope that my research and observations can be of use to preserve your beautiful lakes.

Acknowledgements

First I would like to thank my parents for making my existence a possibility. My genetic material would not be here without you, so my collective cells and I are grateful for everything you have done for me.

Thank you to Kathryn Anderson for taking me on as my SPROJ advisor. The R and statistics present in this SPROJ is thanks to Dr. Anderson's code and collaboration.You really changed the game for me with R, and I really appreciate the career advice!

Thank you to Robyn Smyth for giving me an opportunity to research for you. Your guidance on this project has taken me from places of panic to focused optimism. Your patience is greatly appreciated.

Thank you to Emily White for sharing your knowledge, lab equipment, and connecting me to more resources.

Thank you to Lea Stickle and everyone involved at the Bard Field Station for providing me with a space. Sorry if it looked like a witches' corner with the bizarre plant set up.

To my incredible friends, thank you for your support, love, and humor. Special thanks to Margaret and Misha for the drives to the site. Margaret, our library sessions were a saving grace to this project. To Marxe and Itzel, your dedication to your work has been a great inspiration and I just wanted to acknowledge how much I have grown from being friends with you.

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Introduction

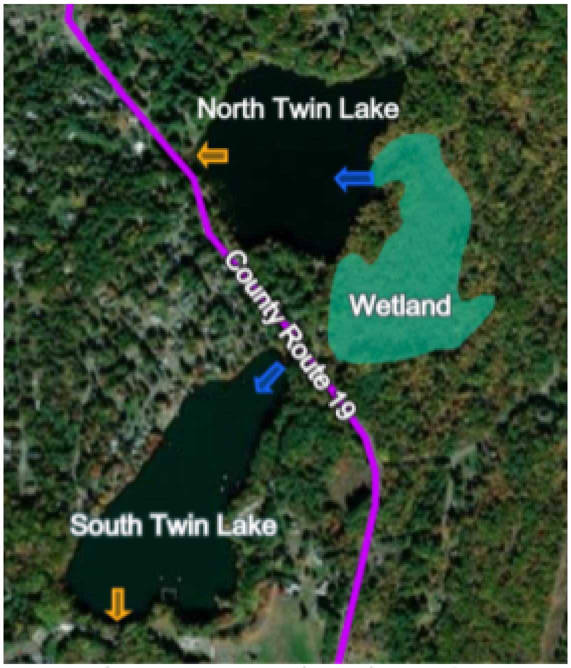
Abstract

The impacts of climate change have caused significant changes in temperature, precipitation, and ecosystems. Recent studies have begun to indicate that climate change is impacting the rate and size of algal blooms globally. Sea surface temperature has been rising, which can stimulate algal blooms. Total global bloom-affected areas have expanded by 13.2% from 2003 to 2020, a tremendous increase (Dai, Y., Yang, S., Zhao, D. *et al.* 2023).

One of the major concerns for the future is the health of water bodies. Amongst the visually striking, are the increase in global algae blooms. Lakes are important to studyas they provide drinking water, food, recreation, and are homes to complex ecosystems. Excess nutrients like Nitrogen and Phosphorus (coming from fertilizers and septic systems) get into lakes through runoff and create the perfect conditions for algae and cyanobacteria to grow in overabundance. Likewise, road salt and septic waste have a serious negative impact on water quality. Algae blooms decompose and remove oxygen from the water, creating a potentially deadly environment for aquatic life. Understanding algae blooms in small/medium lake ecosystems is a good chance to test solutions and dynamics of larger water bodies. My Senior Project is built off of the prior studies done by Ben Harris, Glennys Aileen Romero Medina, and Dr. Robyn Smyth on the Twin Lakes site in Elizaville, NY. The North and South Twin Lakes are located in Elizaville, NY in the southern end of Columbia County. The two lakes are located less than five hundred meters apart. The South Twin Lake is private, accessible only through resident properties. Both lakes are quite deep for their size and are estimated to have a maximum depth of 24 meters (Romero 2020). There is also a camp called Camp Scatico which is active during the summer and off season for conferences.

The goal of my study was to follow the process of a pilot project of floating treatment wetlands (FTWs) as a mitigation strategy of algal blooms. Having done prior research with Robyn Smyth, I was aware of testing being done in the Twin Lakes. There was an incredible opportunity to work with the community on this project. Whenever I showed people photos of the S1 FTWs, I was told most of the time that they looked like mattresses, hence the title. The Friends of the South and Twin Lakes (FONASTL) are a community group which consists of residents from both lake sites. Their collaboration with Dr. Robyn Smyth had led the investment in FTWs to try a low-end cost strategy to prevent serious algae blooms from occurring. The study will be accessing the survivability and biological output used for the first growing season. It will also discuss how adaptive management strategies create a feedback loop for lake management in real time.

It is important to note that most literature concerning FTWs focuses on streams, ponds, and retention ponds for. This creates a lack of data and makes it hard to compare results. The community aspect included observations beginning from spring of 2022, when materials were ordered and constructed. I performed an analysis of the growing and harvest season. The second part of the study continues past spring of 2023. This includes the next trial run for the FTWs for the Summer of 2023. This project is a way to combine academically sound research with community science that can be useful to a wider audience. Small scale, local steps residents can take to engage with their environment, and how this can translate to policy to make concrete differences for the Twin Lakes. I also include a protocol using adaptive management strategies. This will combine recommendations and adaptive management techniques to be used as a resource for the community to continue researching the Twin Lakes.



North and South Twin Lake and inflow-outflow map (source: Ben Harris)

Fig. 1 Aerial view of the Twin Lakes (Columbia County). The County Route 19 goes between these lakes, which is an important feature to note as it is a major contributor of road salt due to winter de-icing (Harris, 2021).

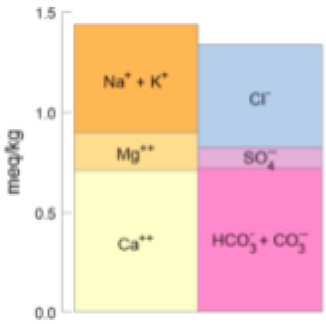
Background on Twin Lakes

Houses on the Twin Lakes were historically used for seasonal fishing, or seasonal housing. This is still the case for some homeowners, however many community members now reside in the surrounding homes year round. Decades ago, it may have been sufficient to have septic systems for the plumbing. With year round residence and modern appliances, septic systems can become overwhelmed. Age of the septic system can be a factor as well. Septic systems treat wastewater, which then moves into a septic tank, and is released into a drainfield. The wastewater leaches into the ground and eventually finds itself in the lakes through subsurface runoff. In the winter, road salt is applied to county route 19 and neighborhood roads. This ends up running off into the creek that feeds into the North Lake and directly goes into both lakes through precipitation.

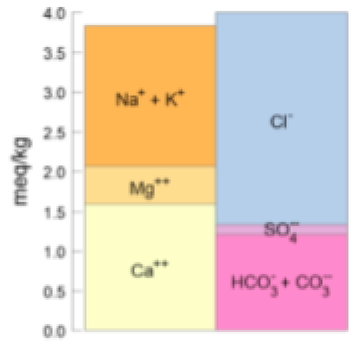
Previous studies have used YSI testing to create profiles of the Twin Lakes. This testing included temperature, conductivity, acidity, dissolved oxygen, and detergent tracing. The YSI tool is a digital water quality meter with a sensor attached by a cord, allowing you to take several measurements at different depths.

Lake Eutrophication and Algae Blooms

Lakes provide essential resources and ecosystem services like drinking water and biodiversity. Lakes are one of the most extensively altered freshwater ecosystems on Earth in terms of physical, chemical, and biological transformations (Harris, 2021). Human activity such as modern agriculture, septic systems, modern appliances, urban pollution, and nearby housing development play a role in Lake ecosystem degradation. Eutrophication is the phenomenon that results in excessive and dense algae growth and the death of plants/animals due to the resulting low oxygen conditions it creates in a lake. Eutrophication comes as a combination of rich nutrients; nitrogen (N) and phosphorus (P), temperature, and other conditions (Paerl, H et. al. 2016). Accumulation of phytoplankton, protists, and microalgae in water bodies can create red, brown or green tides as scum or foam. The biomass lowers oxygen levels through overgrowth and decomposition. This process of oxygen depletion is called hypoxia when the biomass sinks to the bottom of the lake (Watson, S. B. et. al. 2016). Commonly referred to algal blooms, these blooms occur from natural processes like circulation, upwelling of nutrients, or water body flow (Kevin G. Sellner, Æ Gregory J. Doucette, and Gary J. Kirkpatrick, 2003).



North Twin Lake ionic balance diagram. Source: Cabrera and White (2022)



South Twin Lake contains a higher percentage of sodium and chloride compared to the North Twin Lake. Source: Cabrera and White (2022)

Fig. 2 A study done by assessment from the Bard Research Institute during the 2022 Summer, the growing season for the floating wetlands. Researchers Cabrera and White were able to conclude that road salt was contributing to the sodium and chloride levels, particularly in the South Lake.

Regular testing shows some concern for the lakes. South Lake salt levels are triple the levels shown in the 1970s and 1980s (FONASTL End of Summer report 7/30/2022). North Lake has a high bacteria level. There was seasonal monitoring for levels of enterococci and E. coli, bacteria indicative of fecal matter during the summer of 2021. There were a few cases of enterococci and E. coli and levels exceeding the threshold. This was connected to rain events, and one septic system replacement (White, 2021). The table below includes those events.

Table 1. Source: Robyn Smyth and Emily White. Condensed snapshot of monitoring fecal-indicating bacteria.

Lake	Location	Date Collected	Enterococci (MPN cells/100 mL)	E. coli (MPN cells/100 mL)	Total Coliform (MPN cells/100 mL)
STL	Beach	5/13/21	3	10	109
NTL	Beach	5/13/21	2	10	2489
STL	Beach	6/10/2021	29.2	20	1850
NTL	Beach	6/10/2021	12.1	<10	1467

STL	Beach	6/24/2021	156.5	<10	7701
NTL	Beach	6/24/2021	12.1	10	2481
STL	Beach	7/1/2021	11	10	3441
NTL	Beach	7/1/2021	3.1	10	3448
STL	Beach	7/8/21	14.2	<10	1624
NTL	Beach	7/8/21	148.3	86	4352
NTL	Beach	9/11/21	12.2	20	4352
NTL	Storm Drain	9/15/21	>2419.6	>24196	>24196
NTL	Storm Drain	10/9/21	18.6	201	1521
NTL	Storm Drain	10/16/21	>24196	>24196	>24196
NTL	Storm Drain	11/13/21	6.3	<10	265
NTL	Center	11/13/21	3.1	<10	464
STL	Beach	5/31/22	113	75	6653
NTL	Storm Drain	5/31/22	150	85	1471
STL	Beach	6/9/22	21.6	10	6131
STL	Center	6/9/22	18.9	<1	135
NTL	Beach	6/9/22	866.4	148	>24196

Over time, researchers have increasingly understood that nutrients play a major role in the development of eutrophic lakes (Bhagowati, B., & Ahamad, K. U. 2019). Besides smelling bad and clouding up lakes with scum, algal blooms are often harmful. They can lead to mortalities, respiratory or digestive tract problems, memory loss, seizures, lesions and skin irritation, or erosion of coastal habitat (Carmichael, W. W., & Boyer, G. L. 2016). Algae in itself is not harmful. Phytoplankton utilize light nutrients to produce biomass through photosynthesis. This becomes a food source for zooplankton, snails, and insects, which are then eaten by fish (Paerl, H. et. al. 2001). Cyanobacteria are prokaryotic, so they have no nucleus or organelle. These are the blooms that are more problematic. When it comes to severe health impacts, Cyanobacteria is what creates Harmful Algal Blooms (HABs).

The health impacts of HABs are still not fully known . There have been past and current bloom events in great lakes. Increased reporting has happened since the 1990s (Carmichael, W. W., & Boyer, G. L. 2016). Cyanobacteria such as microcystis can potentially cause negative health symptoms. HABs can also lead to poisoned seafood, another reason to care about this issue. It also reduces resilience and biodiversity in aquatic ecosystems (Paerl, H et. al. 2016).

Lake depth, size, exposure to light, and temperatures can impact a lake's algal bloom response to nutrient loading and climate change. How algal blooms respond can help evaluate mitigation strategies (Janssen, A, 2019).

Stratification is the separation of layers in water because the density of water varies depending on its temperature. Denser, and often more saline water stays at the bottom, while water warmed by the sun stays above (CDRG, 2019). There is a separating layer called the thermocline, which changes depth according to seasons. Stratification plays a role in why nutrients upwell from the bottom of lakes to encourage algal bloom. Salt can also increase stratification. All temperate lakes that stratify during the summer will have some loss of Dissolved Oxygen (DO) which can lead to hypoxia (WOW, 2004). Prevention of hypoxia can include creating educational outreach or campaigns to reduce P loadings from sources of fertilizers, litter, sewage, and urban environments.

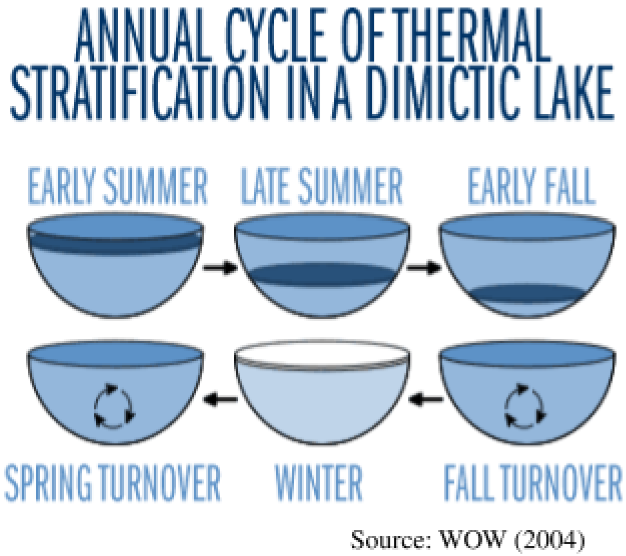


Figure 3. Diagram of lake stratification. Dimictic lakes are classified by thermal change in the fall and spring. This is what allows the layers to turnover. Algae become exposed to light and nutrient availability. In the spring turnover, nutrients upwell which become available for algae in the summer (Harris, 2021).

The problem of algae blooms, however, can be mitigated through physical strategies; pipes, diffusers, aeration; chemical including enzymes, algaecides; and biological strategies through the introduction of species and construction of wetlands both onshore and floating.

Mitigation Strategies

There are different types of strategies for managing lake health. These include physical, chemical and biological (Romero, 2020). I was given marketing pamphlets which had been passed around in prior meetings for FONASTL and the Town Board. This outlines the strategies the community has considered, but also the way Lake Management products are marketed. It should be restated that community members are not going to be digging into academic literature, nor would they have access to it unless affiliated with an institution. Therefore, the communication of Lake Management companies provides a good idea of public understanding of lake health. These marketed strategies offered primarily physical and chemical strategies which offered immediate results. These companies also made visually compelling advertisements, and included very accessible communication, something that is often missing from academic literature.

Physical

Physical mitigation techniques have all involved lake stratification, such as artificial circulation, where compressed air from a pipe or ceramic diffuser is injected into the hypolimnion layer (NYSFOLA, 2009). This strategy is limited because the aeration only occurs in the narrow radius surrounding the pipe. It does not provide a way to remove the excess nutrients or salinity. Solitude Lake Management: “Restoring balance. Enhancing beauty”. They provide Aquatics in Brief. This is a newsletter/ advertising that showcase how the treatment controls

Aquatic weed and algae:

- Fisheries management
- Reservoir management
- Aeration
- Fountains

The pictures provided in the newsletter show trim lawns in front of lakes with a fountain spraying from the center. It becomes part of the horticultural design, rather than a nuisance to customers.

Chemical

Bio augmentation is another buzz word used by Solitude Lake Management. The services the company promises to provide are listed as:

- Nutrient remediation, phosphorus locking
- Invasive species management
- Wetland health
- Lake mapping tools (bathymetry)
- Water quality testing
- Mosquito control
- Mechanical harvesting
- Hydro-raking/sediment removal

The pamphlets had sleek pages with blue framing to draw attention to the blurbs. There were also pictures of employees hard at work installing the Solutions. Pictures of healthy lakes, ponds, and plants surrounding the beautiful scenery. There are just enough graphs and color coded maps that make this company scientifically righteous. But more than anything, the message stresses that this affordable service is preparing for the future. And of course one more showcase of compelling before and after pictures of sites.

Another company was Kasco aeration:"The green approach to cleaning up your pond". Kasco promises to:

- Reduces excess nutrients and sediments
- Removes pond scum and odors
- Safe and non toxic
- Improves water quality
- Keeps for 2 years
- Easy to use, cute names like much pucks

These "Pucks" are enzyme products which are supposed to kill excess cyanobacteria and prevent lake greening from occurring. Earthtec algaecide/bactericide offers similar results: "Clean water for the Planet" and "2 Problems 1 solution"

- Check boxes of what solutions are covered
- Beautiful lake with a majestic mountain in the background
- NSF certification stamp (very compelling)
- More specific product, molluscicide
- Pictures of happy attractive kayakers. Before and after picture of cyanobacteria on a log. "Unsightly algae" is a floating quotation on a vivid lake background.

What I notice is that the focus is on the aesthetics of lakes, but also the idea of ownership over natural resources. The manicured country clubs with a reputation to uphold. The perfect lake for recreation and for a waterfront property. These solutions offer quick and visually effective strategies, however, especially with mass chemical treatments, there must be more scrutiny on the long term effects. While algaecides provide results quickly, they are described as "a temporary poison for a permanent problem,". Because of algae's fast growth rate and build up of resistance, these chemical treatments may actually create even more harmful blooms. The chemicals themselves may also have negative side effects on the food web living in the lake, making it essentially poison (NYSFOLA, 2009).

Fig 4 marketing pamphlets for previously mentioned companies

Biological

This strategy is also called bioremediation, or biomanipulation. It is the introduction of biological control to manage ecological conditions (NYSFOLA 2009). This can look like constructed wetlands, Floating Treatment wetlands, and introducing plant and fish species. I will discuss Floating Treatment Wetlands as the primary focus of the biological mitigation strategy. With it, I will pair adaptive management as a crucial monitoring strategy for this project. This strategy is usually lower cost, but takes longer in for implementation and results.

Floating Treatment Wetlands as management strategy

There are benefits to looking towards solutions found in nature. Floating treatment wetlands (FTWs) are artificially constructed floating platforms released into water bodies with macrophytes serving as an uptake for the overabundance of nutrients as a way to prevent algal blooms through ecological engineering (Ijaz, A. et. al, 2015. Macrophytes are plants with structures more physically substantial than algae, which can create habitats for fish and invertebrates (Colares, G. S., et al. 2020). The root systems are a natural filter. There is already evidence to show this is a relatively low cost scale, yet removes N and P. FTWs may provide an appealing alternative to the more conventional wetlands to solve problems associated with eutrophication because they do not claim additional land area (Keizer-Vlek, H. E. 2014). FTWs can enhance performance in retention ponds and pollution mitigation of urban areas (Romero, 2020).

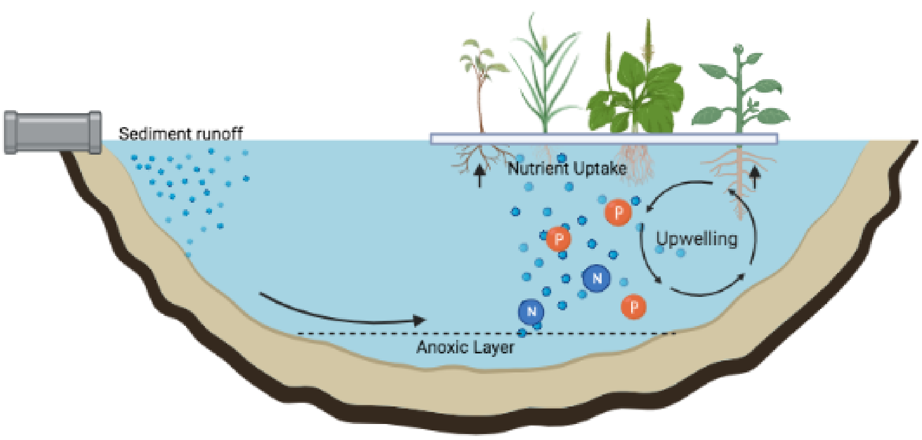


Fig 5. Created using Bio Render, based on Spangler, J. T., Sample, D. J., Fox, L. J., Albano, J. P., & White, S. A. (2019).

Through the root system, there is the chemical process of N and P uptake. Oxygen is also released into the water from the roots via photosynthesis. In a smaller body of water, the platforms lower the aerobic zone, and impact the rate of sediment/nutrient turnover by altering the mixing of layers in the lake (Hu, G. J., Zhou, M., Hou, H. B., Zhu, X., & Zhang, W. H. 2010).

N is nestled in the biomass then removed through biomass. P is captured by sorption (gas trapped by solids or liquids). Metals are trapped by biofilm, binding to clay, particulate matter, ion exchange. Plants are harvested to prevent pollutants from getting back into the water. Biofilms are slimy bacteria, fungi, and algae which also protects the plant against disease. (Koehl et. al, 2008).

The downside to FTWs as bioremediation is due to the multiple design and installment parameters. Studies have presented a wide range of results, making them difficult to compare and standardize from widespread implementation (Wang et al., 2014).

The next section discusses plant species that have been used for FTWs. Because the Twin Lake study used a plant selection based on the Lake Champlain Basin Program (LCBP), I decided to focus more on studies which used the plants mentioned (Tharp, B., & Dipietro, T. (2018). As a disclaimer, the finalized plant list was done after I joined in on the project. The plant order was also impacted by the plant availability at the nurseries.

The most common macrophytes applied in FTW are from the genera *Canna*, *Carex*, *Cyperus*, *Juncus* and *Typha* (Colares, G. S., et al. 2020). Native and non-invasive species are preferred. When considering which plants to purchase, it is important to consider several things.

a) Preferably native and non-invasive species;
b) Perennial species;
c) Terrestrial plant species or emergent wetland plants capable of adapting to and thriving in hydroponic conditions;
d) Plants with aerenchyma for higher oxygen diffusion from aerial parts to roots and rhizomes;
e) Plant species that contribute to aesthetics;
f) Plants with high nutrient uptake

(Colares et al., 2020; Wang & Sample, 2013)

These need to be wetland plants, capable of adapting to hydroponic conditions. There should be a high oxygen diffusion in roots and rhizomes to have as successful results as possible. Aesthetics are also important to include. Having floating platforms in the middle of a lake can interrupt a scene which residents are used to. Residents' wish for recreation or for a beautiful view can be a point of resistance as some may consider FTWs an eyesore.

Aerial tissues of the plant above water accommodate translocated pollutants. Peak N and P accumulation *in J. effusus* occurred in September (Sharma, R., Vymazal, J., & Malaviya, P. 2021). According to the study, FTWs having floating vegetation cover between 5% and 10% have the same removal efficiency which suggests that even 5% coverage is sufficient to remove nutrients significantly. Even though this was in reference to pond surface coverage, it is worth asking if this can be applied to lake surface.

The Lake Champlain Basin Project was the most notable inspiration for the project. I will discuss more of the methodology later. The species that were recommended were Pontederia cordata (pickerelweed), Schoenoplectus tabernaemontani (Softstem Bulrush), Carex comosa (Long haired Sedge), and Juncus effusus (Common Rush) (Tharp, B., & Dipietro, T. 2018). While not all of the species were selected for the Twin Lakes project, the mix of sedges, rushes, and flowering plants was very similar to this study.

Other studies were very robust through technical control, but not necessarily in wider application. One study used styrofoam, not a realistic material for a platform if it was being released in a lake. These platforms were in buckets in a lab, with measured out N drops. After removal of the plants from the tanks, the shoots were separated from the roots. The dry weight of roots and shoots was determined after drying to constant weight (at least 48 h) in a fan-circulated oven at 70 °C. The total biomass of shoots and roots was determined per tank (total of 12 plants). A selection of dried roots and shoots were taken, ground, and analyzed for N and P (Keizer-Vlek, H. E. 2014).

Another study used Iris and Typha. The average biomass of the *Iris* increased threefold, and the *Typha* doubled. Interestingly, the bulk of the increase in the *Iris* was through the shoots, while the *Typha* had an increase in both root and shoot biomass (Van de Moortel et al. 2010).

Table 2. Compact meta analysis of plant species used in previous studies.

Species	Nutrient removal	result	source	
Iris Typha	-removal efficiency ranging from 6% and 83% for P and between 25% and 40% for N	-avg. Iris biomass increased 3x, mainly through shoots -avg. Typha biomass increased 2x through roots and shoots	(Van de Moortel et al. 2010).	
J. effusus	Peak N and P accumulation occurred in September	suggests that even 5% coverage is sufficient to remove nutrients significantly	(Sharma, R., Vymazal, J., & Malaviya, P. 2021)	
Acorus calamus (Sweet Flag)		-promise of FTWs for shallow turbid eutrophic lakes -strong anti-pollution and fast-growing abilities	(Hu, G. et. al. 2010).	
Carex Stricta (Tussock sedge)	-arsenic uptake	-performs C3 photosynthesis typically experience maximum photosynthetic efficiency at temperatures below 20°C	Rofkar, J. R., & Dwyer, D. F. (2011).	
Schoenoplectus tabernaemontani (Soft stem bulrush)	-Seasonal changes in biomass -P resulted in the maximum removal in June.	-survived ice encasement	Wang, C. Y., Sample, D. J., Day, S. D., & Grizzard, T. J. (2015)	
-Typha latifolia (broadleaf cattail) -Phragmites australis (common reed)			(Marecik, R et. al, 2013)	

-Acorus calamus L. (sweet flag)				
-Pontederia cordata (pickerelweed), -Schoenoplectus tabernaemontani (Softstem Bulrush), -Carex comosa (Long haired Sedge), and -Juncus effusus (Common Rush)	-The data indicate that overall, FTW did not have a positive impact on stormwater pond performance. No difference was noted in TN levels	-96% survival rate for long haired sedge -22% survival for pickrelweed -97% for common rush -95% for bulrush	(Tharp, B., & Dipietro, T. 2018).	
-Agrostis alba (red top) -Canna × generalis 'Firebird' (canna lily), -Carex stricta (tussock sedge) -Iris ensata 'Rising Sun' (Japanese water iris) -Panicum virgatum (switchgrass),		-covered 80.3% of the water surface area	(Spangler et. al, (2019)	
-Eutrochium purpureum (Joe Pye weed) -Hibiscus moscheutos (swamp rosemallow) -Juncus effusus (soft rush) -Lobelia siphilitica (great blue lobelia) -Rudbeckia laciniata (green headed coneflower) -Sagittaria latifolia (broadleaf arrowhead) -Symphyotrichum novaeangliae (New England aster) -Vernonia noveboracensis		-Attract butterflies	(Lubnow, F. S. 2014)	

(New York ironweed) -Asclepias syriaca (common milkweed) -Asclepias tuberosa (butterfly weed)				

There was a treatment for polluted lakes by using dredged lake sludge as the platform base. The goal was to limit algal growth by competing with nutrients and sunlight. The study highlighted the promise of WTFs for shallow turbid eutrophic lakes. Acorus calamus (called sweet flag), was planted on the ESFB functioned as a nutrient assimilation species because it has strong anti-pollution and fast-growing abilities (Hu, G. et. al. 2010).

A combination of native wetland plant species might perform better than a monoculture in wetlands designed for arsenic remediation by supplementing weaknesses. Carex stricta and Spartina pectinata were used in hydroponic experiments, primarily to measure arsenic uptake. *C. stricta* (tussock sedge) is a cool-season, perennial sedge Rofkar, J. R., & Dwyer, D. F. (2011).

Roots were harvested after 4 hours (this time was selected based on preliminary experiments). The harvested tissues were rinsed first with tap water, then HCl (10%), with tap water again, then dried (55°C; 48 h), and weighed. This is a good way to remove excess dirt to be able to digest the roots for N and P levels. The timespan for plant immersion however, is not realistic for the project since the plants would be left in the lakes for months.

The lengthy growing season of *C. stricta* might be reflected in its ability to maintain uptake through both the spring and summer treatments. In addition, organisms like *C. stricta* that perform C3 photosynthesis typically experience maximum photosynthetic efficiency at temperatures below 20°C (Rofkar, J. R., & Dwyer, D. F. 2011). This makes Tussock Sedge a good candidate to be used in this project.

Based on a study by Wang, C. Y., Sample, D. J., Day, S. D., & Grizzard, T. J. (2015), Soft stem bulrush was able to survive ice encasement and regrow in the second year. Seasonal changes in biomass and P resulted in the maximum removal in June. Harvesting was optimal in September before the plant released P with deterioration. Observation of wildlife indicated eight classes of organisms inhabiting, foraging, breeding, nursing, or resting in the FTWs.

For a sixteen week trial, FTWs were used to treat runoff from commercial nurseries(Spangler et. al, 2019). The plants were supported by Beemat rafts. Five monoculture treatments of Agrostis alba (red top), Canna × generalis 'Firebird' (canna lily), Carex stricta (tussock sedge), Iris ensata 'Rising Sun' (Japanese water iris), Panicum virgatum (switchgrass), two mixed species treatments, and an unplanted control were assessed. covered 80.3% of the water surface area (Spangler et. al, (2019). Plugs or bare root liners of the plant species were purchased. Before planting, the root balls of each plug were rinsed to remove the original planting media. The bare root liners were also rinsed. 80% is an impressive amount. It doesn't translate over to this project, but it was worth mentioning another material and method for floating wetlands.

The experiments were carried out using rhizomes of sweet flag (Acorus calamus L.), broadleaf cattail (Typha latifolia), and common reed (Phragmites australis) obtained from the commercial market. Plants were taken out of pots and the soil was carefully removed by washing them under running water several times. Afterward, the plants were transferred to hydroponic containers (Marecik, R et. al, 2013).

Lobelia siphilitica (Great Blue Lobelia) and Lobelia cardinalis (Cardinal Flower) were the two flowering plants that were chosen for the Twin Lakes Project. Pickerelweed was the original choice but the nurseries did not have it so Lobelia and cardinal flower were the flowering plant alternative. Pickerelweed was also the top choice in Romero's Senior Project recommendations, and showed great promise through modeling the nutrient uptake (Romero 2020). However Pickerelweed does not seem to be a viable plant choice for Northern climates (Tharp, R., Westhelle, K., & Hurley, S. 2019).

In a collective review, Joe Pye weed (Eutrochium purpureum), swamp rosemallow (Hibiscus moscheutos), soft rush (Juncus effusus), great blue lobelia (Lobelia siphilitica), green headed coneflower (Rudbeckia laciniata), broadleaf arrowhead (Sagittaria latifolia), New England aster (Symphyotrichum novaeangliae), New York ironweed (Vernonia noveboracensis), common milkweed (Asclepias syriaca), and butterfly weed (Asclepias tuberosa) were the recommended species. The study favored milkweeds and flowering plants to attract butterflies (Lubnow, F. S. 2014). For this selection of plants, the author referenced the Mid-Atlantic states as being the prime locations. The area spans from New York to Virginia. That is quite a difference in average temperatures through the seasons.

The success of effluent removal has a wide range, from 6%-83% for Phosphorus and 25%-40% for Nitrogen (Van de Moortel et al. 2010). This is bearing in mind that the scale of the studies vary as well. Furthermore, because the Twin Lake project will be taking place on residential lakes, the tradeoff of accuracy with control will demand different methodology and management. In order to implement such a mitigation strategy as FTWs, this requires stakeholders involved to be on board with such a project. Any push for solutions involving climate change will always require tapping into people's value system to get them to care and provide support. Likewise, for a pilot project, there will be a lot of mistakes and unpredictable variables that come along. This requires a flexible response.

Adaptive Management

Adaptive management monitors how natural resource systems change over time in response to uncertain environmental conditions. Management strategies include flexible decision making and making adjustments after outcomes (Russell et. al, 2001). It is also important to engage appropriate stakeholders. There needs to be an agreement about the scope, objectives, and management alternatives before making a decision to go with a strategy. Without this agreement, the management strategy is likely to be viewed as having biased objectives which increases the chance for failure (Williams, B. K. 2011). Monitoring is a way of putting theory into practice and learning from it. Model based predictions can be compared to the results, and changed to better fit the situation. Another word for this is double loop learning. It involves monitoring indicators and comparing results to projected models. With an improved understanding every round, appropriate changes can be made, and observe the result (Williams, B. K. 2011).

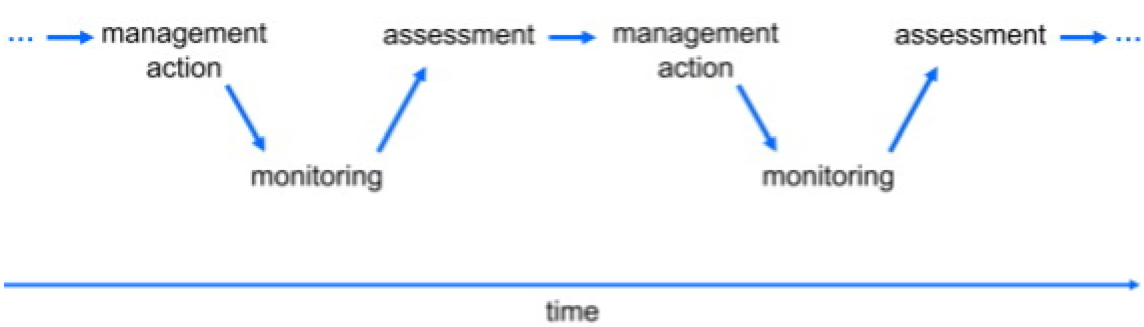


Fig. 6 Source: (Williams, B. K. 2011). The double loop of monitoring and assessment over time.

Adaptive management requires the acknowledgement that there is no golden “fix” to manage ecosystems. There is simply not enough information. The goal is to learn from mistakes and surprises.

This is a different setting than a laboratory experiment, where a controlled observation can be replicated, but have less applicational opportunities. It is also not just trial and error, where solutions and observations are about a specific problem (Lee, K. N. 2001).

Perhaps most importantly, the community in which the experiment or project takes place must be treated as stakeholder. As a valuation exercise, there can be several things that get people on board. For instance, if this project is a comparatively low cost solution to an ecological problem. If people feel they are making a difference, it can create a lot of opportunities. Several community members in early gatherings were talking about growing up in the area and seeing how the lakes changed over the decades. Some community members mentioned kids or grandkids, wanting to leave a better legacy to later generations.

Depending on individuals, the willingness to pay (WTP) can be defined as chipping in monetarily or through time. Some people will be more invested in others, while some might hold back and see if the project is worth investing into (Russell et. al, 2001). Enough community members decided this project was worth investing into, and so the Twin Lakes FTW project was on its way.

Twin Lakes FTW Project (S1)

The Twin Lakes in Elizaville have been experiencing an increasing amount of algae blooms during the summer time. Due to the partnership between Dr. Robyn Smyth and the Twin Lakes community, this project was motivated from a place of prevention, rather than remediation. This pilot project was agreed upon as a method of adaptive management. The residents wanted to see if FTWs could create a form of outflow which could potentially take out Nitrogen and Phosphorus out of the water. Because the project was guaranteed to run for at least two growing seasons, Another goal of this study was to create and collect data about FTW in colder climates. It is important to understand the maintenance needs and longevity of these systems. The community also wished to know if the plants begin to regrow in the spring, to understand the renewable value of the wetlands. Another benefit of the FWTs is that they adapt to changing water levels, which could vary significantly during summer months.

During the summer of 2022, the precipitation in the area was lower than usual, according to residents and the director of Camp Scatico. The increased variation in weather over the last decade creates another advantage for floating wetlands. The element of floatation can allow for the vegetation to be exposed to a comfortable amount of water, instead of ground based wetlands which are more reliant on the weather. The plan was to have four main mats, one large and small mat per site. Each mat would be placed around the areas which have had higher levels of conductivity based on the YSI readings. Residents were given the option to purchase and participate with smaller kits that they could release in front of their homes.

The following content is tracking the study through its first season (S1) which spans from March 2022- November 2022. I will be classifying S2 as the data gathered from overwintered plants, and the groundwork for the next round of the study. Chronologically, this would be from February 2023- and continuing past the submission of this Senior Project.

Methods (S1)

Glennys Romero's Senior Project culminated in FTW recommendations, some of which were followed, but the primary literature guiding this project was based on a study by the Lake Champlain Basin Project. The materials and plants were picked primarily from this resource. They were designed with two layers of pollyflow, with marine foam to ensure the floatation. Holes drilled into one layer of polyflo created pockets to install the plant plugs. The material allowed for roots to grow into the water and uptake nutrients without the risk of the whole plant falling through . The LCBP focused on storm drains in ponds. The study covered 25% of the surface with the treatment to have optimal results (Tharp, R., Westhelle, K., & Hurley, S., 2019). The North and South have a far greater surface area to work with. There are limited outflows, and the shape of the lakes effectively makes them like bathtubs. The placement of the FWTs were picked from the shape of the lakes. Through wind and stratification, nutrients would travel across the lake, be pushed to one end, then upwell at the surface.

The plant species had been selected for their survivability during a growth season and over a winter in the LCBP. Two of the plant species from that project were selected for this pilot study: Softstem Bulrush and Common Rush. The rest of the plants purchased were Hardstem bulrush, Tussock Sedge, Sweet Flag, Cardinal Flower, and Great Blue Lobelia. There were mixtures of flowers and grasses, partly as an aesthetic decision. The study would include releasing the FTWs during spring, having them grow throughout the summer, and to harvest biomass in fall right as the growing season ends before the plants begin to decay for winter. The biomass would be weighed for growth and the remaining plants on the platform would be observed over winter into spring to see if they were able to survive and sprout back.

Pre-release weighing

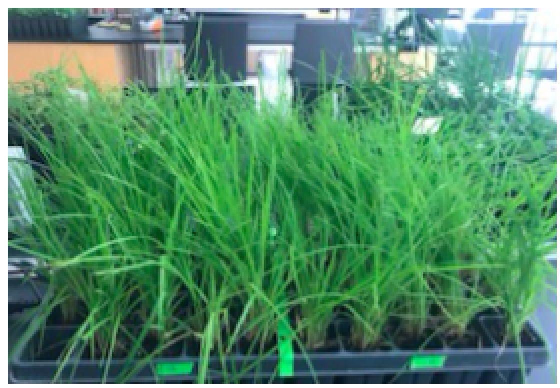
The plants were divided by species into sections which would determine which lake they would be deployed to. Each plant was individually weighed on a standard lab scale in grams. After taking individual measurements, the totals per lake group would be averaged out. Then the species total would combine both averages.

Some trays were ordered by community members and left outside to acclimate. Most species were stored in an RKC biology lab which provided partial but constant sunlight. The hardstem bulrush arrived looking very sparse and barely alive. It was disappointing since previous studies indicated that it would be one of the best plants for nutrient intake and hardiness.

Fig. 7

Cardinal flower above left, Soft stem bulrush, swamp milkweed below 5/14/22

Hard stem bulrush 5/14/22



Construction

There was a reference video for building the polyflo mats posted by Rutgers University Agricultural Experiment Station.

The video started by listing the needed equipment:

1. Roll of 5 ft by 90 ft poly-flo biological filter material
2. Two part marine floatation foam
3. Utility (Exacto) knife
4. Long thin bladed (filet) knife
5. 21 inch zip ties
6. Drill
7. 2-inch hole saw (circular drill component to create uniform plug holes)
8. Plastic drop cloth

To begin, the roll of poly-flow is to be measured and cut to create the appropriate sizes for the large and small platforms. For each platform, two mats are stacked together. The thin knife creates small holes around the perimeter in order to put zip ties through. The video instructed to drill holes for the plant plugs, through both layers of poly-flo ideally 1 ft. apart. Then a third layer is placed on top and the zip ties are looped through to bind the three mats, each zip tie placed about 1.5 ft. apart from each other. Then, having the three layers over a dropcloth, mixing equal parts A and B of the aquafoam together. When the foam starts to expand, slowly pour 1 to 1.5 cups of the mixture between the approximate hole placement. The liquid foam will flow through all the layers. When the foam hardens, the platform will be flipped over so the solid layer is at the bottom and the plant holes are at the top.

The platform is moved to the shore to begin the planting process. The holes are filled ¾ of the way with soil. The plant plugs are placed in the holes and nestled snugly within. Anchors are tied to the platforms to release when the boat reaches the desired location. The anchor is actually a bit tricky because it must have enough slack to adjust to water levels.

A quote from Robyn Smyth gives a good preface of how the Twin lake building and release was expected to differ and replicate the video, “We have ordered a 90 ft roll of this poly-flo material and are awaiting a tracking number to see when it will arrive. These platforms will be used to grow 288 of the 500 plants we have ordered. The poly-flo is expensive so we are also planning to make 7-9 smaller platforms of lower cost materials. We are expecting some trial and error in getting these smaller platforms to work”.

On the day of the platform building and release on May 14 2022, the community volunteers were split among the North and South lake shore. The South lake launch site was on the boy’s side beach of Camp Scatico. The North lake launch location was the Elizaville public beach. The first step was to cut apart the roll of poly-flo and distribute it evenly to the launch locations. The polyflow mat measurements were 10 ft. by 4.5 ft. for the large platforms, and 5 ft. by 4.5 ft. for the small platforms.

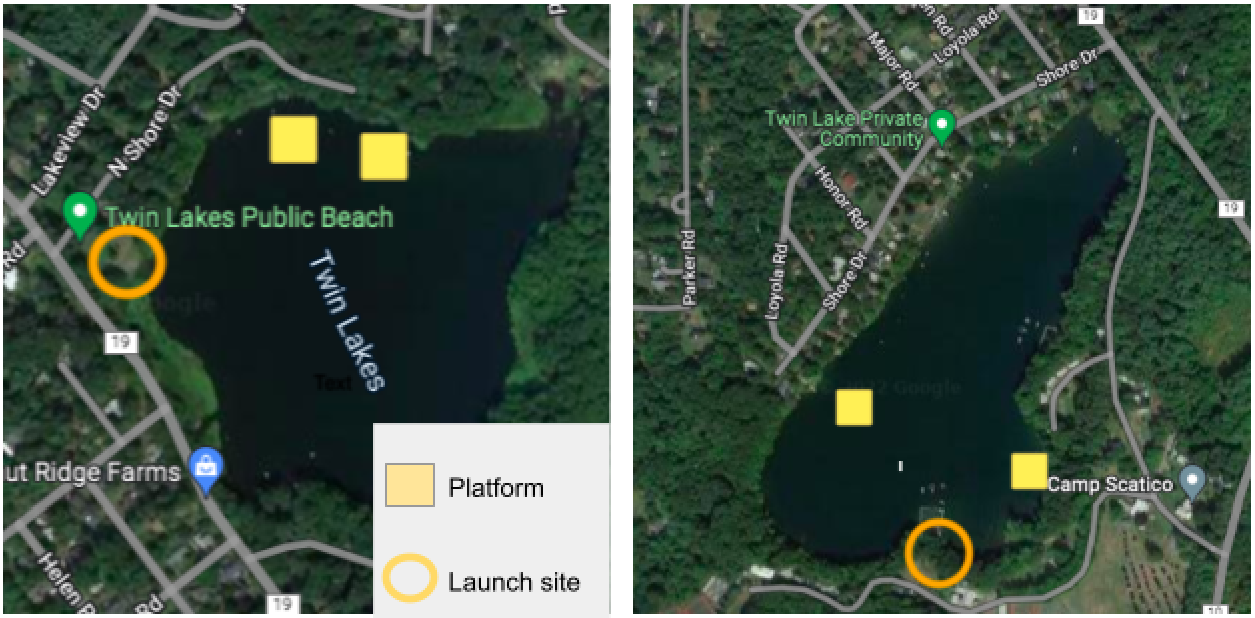
The next step was to drill the holes using the hole saw. This proved challenging, as the resistance from the polyflow fibers caused the drill to overheat. An hour or so into drilling at the South lake, the drill had to be replaced because the batteries died. Luckily a resident had another they could retrieve.

The video tutorial advised using aquafloat, a foam which acts as non-toxic floatation. The aquafloat was accidentally applied on the top of the platforms, instead of the bottom, which created a need for extra buoyancy. The mats were supplied with plastic jugs and pool noodles. The use of pool noodles was not ideal, as it had the risk of disintegrating into the lake, especially if exposed to the sun.

The North Lake team had pvc pipes, bamboo, and coconut coir along with what polyflow mats. Along with making the original design, some community members were trying to make a pvc pipe structure. The pvc pipes would provide the skeleton, while the coir mats would serve as the mat. There were also black cones to put the plant plugs in. There was a special purple plumbing glue. It was later found out that the dry time was 24 hours, but the structure was only left out for two hours maximum. The aquafloat ran out before it could be distributed to the North lake, so the floatation was primarily pool noodles and plastic jugs.

There had to be a re-organizing of plant species to make sure each species was designated to two rows next to each other. With plant shortages due to some plants dying during the shipping and acclimation process, there was a bit of creativity with the row design, but species were placed to ensure that any rows that mixed were between two distinct species to avoid confusion.

Fig. 8



Platform Sites on the North and South lake, respectively. The launch site were on NL public beach and Camp Scatico. Aerial view from google maps.

Fig. 9

Polyflow mat unloading SL, 5/14/22

Graduate student Ben Harris drilling plugs SL, 5/14/22

Community members bringing finished mats down to the beach to install plants SL, 5/14/22

Nearly finished platform with plants and floatation NL, 5/14/22

The distribution of the plants is shown below in the diagrams. Due to some losses during the delivery of the plant orders, there were variances in the amount per species released in each mat. Due to material and building issues, the small North lake platform had trouble staying afloat, and there were several replacements from alternate materials. Due to this, the small platform is observed but not calculated into the results. The large platforms for both lakes were incredibly hard to take out, having so much drag.

Fig. 10

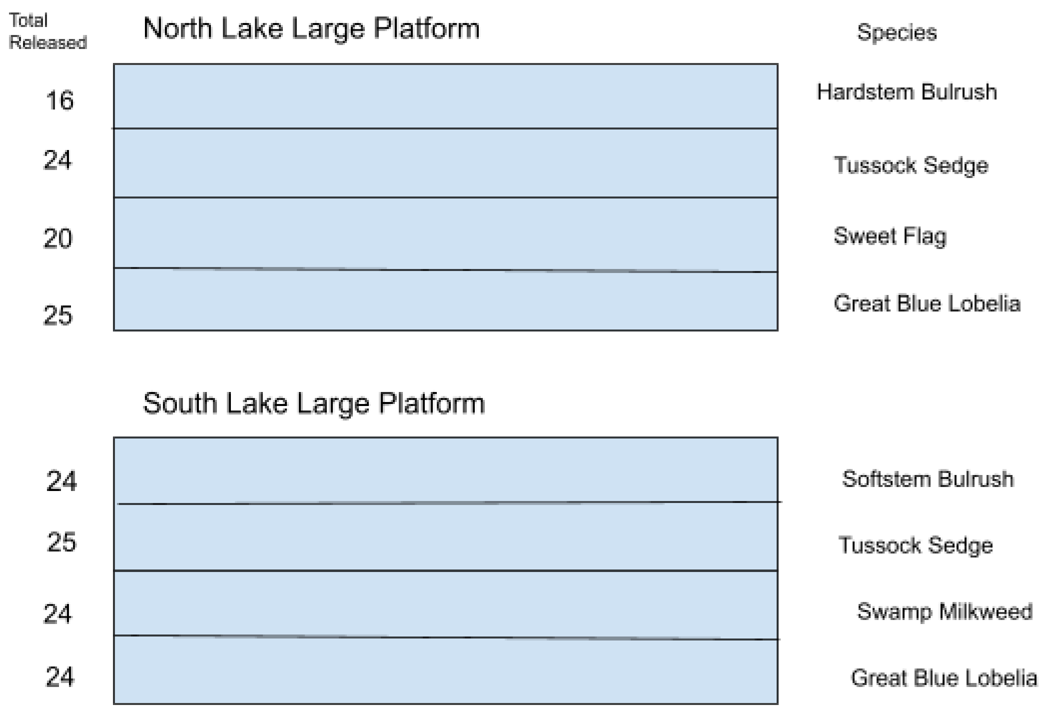

Total Released
North Lake Large Platform
Species
16
Hardstem Bulrush
24
Tussock Sedge
20
Sweet Flag
25
Great Blue Lobelia
South Lake Large Platform
24
Softstem Bulrush
25
Tussock Sedge
24
Swamp Milkweed
24
Great Blue Lobelia

Fig 11.

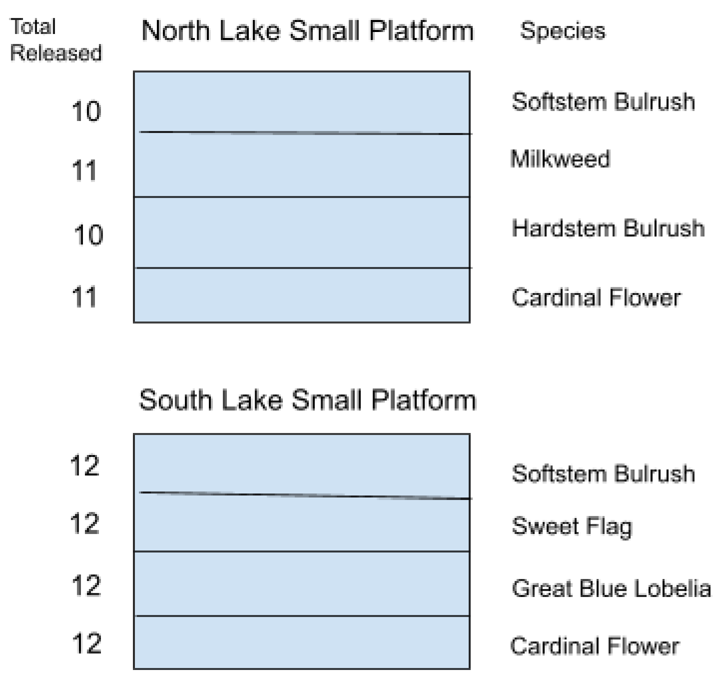
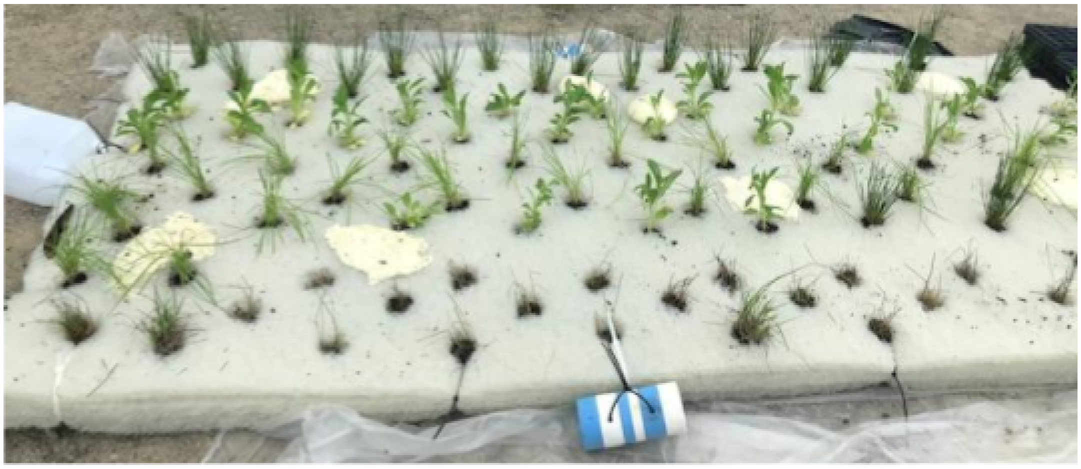

Total Released
North Lake Small Platform
Species
10
Softstem Bulrush
11
Milkweed
10
Hardstem Bulrush
11
Cardinal Flower
South Lake Small Platform
12
Softstem Bulrush
12
Sweet Flag
12
Great Blue Lobelia
12
Cardinal Flower

Fig. 12



Finished large platform SL, 5/14/22

Finished and released small platform SL, 5/14/22

Finished large platform NL 5/14/22

Seasonal Check in, Thursday September 22, 2022

Rachel Ephraim (who was community coordinator at the time) and I went out to the lake to check in on the platforms. The South small platform had a painted turtle lounging on it. It got alarmed and dove in with the canoe approaching. There were also droppings, which suggested the presence of muskrats. The platform had a few columns left with living grasses, but they had yellowing tips, suggesting that they were beginning to decay. The large platform was facing a similar situation, but some of the grass seemed to be growing still. The lobelia was completely absent, save for two stems.

The North lake was a trickier assessment. The small platform had no remaining plants from the original release. It seems it was colonized by saplings and other seeds. Interestingly, they were doing quite well. The large platform grasses along the border were beginning to decay. There were lobelia stems present, but they were husks. Resident M, the resident who kindly lent his kayaks to use for collecting data had observed muskrats eating the plants.

Fish were visible from the boats for every location. They would dive under the platforms, possibly using the roots as nurseries. Insects were hopping around on the platforms. This may provide a food source for fish.

Fig. 13

Small platform SL, 10/5/22

Large Platform SL, 10/5/22

Small platform NL, 10/5/22

Large platform NL, 10/5/22

Harvesting steps

Three random plants from each species were selected to be fully harvested (roots, soil, stems). The rest harvested at the stem Citing from study: by cutting at the surface of the mat. Plant samples were kept separate by species and mat location (Tharp, R., Westhelle, K., & Hurley, S., 2019).

First harvest on Thursday October 5, 2022

The weather was in the high 60s, sunny, the beginning of autumn leaves. Rachel Ephraim, the community coordinator had an essential role in harvesting the samples and updating the community. Rachel and I planned to get the small platform on the South lake, but discovered that the pull of the platform was massive. It took us a good 20 minutes to cross the short side of the lake and ten more to dock it, not including the harvest time. The plants were looking a bit frail overall. We collected at least three whole plant samples from each species (including roots) and cut the tops of the rest. I noticed an abundance of lettuce looking tops. They did not seem to fit the description or identification of plants purchased, but were too organized to seem like an invasive plant. One guess is that the species came with some seed mix which may have outcompeted the plant on the platform.

One community member's house has an aerator, to prevent ice forming at the plastic shore wall. The reason for moving the South lake small platform was to prevent the roots from completely freezing over. This would hopefully allow for regrowth in the spring.

The North lake had a collection of smaller home kits. We could only find the large platform for the lake. There were a few lobelia stems, but they were husks. The lobelia was effortless to remove from the soil, and the root system was only a few inches long. The grasses did exceedingly well. We left the platform as is since it was quite close to the shore.

Second harvest on Tuesday October 18, 2022

The temperature was in the mid/low 60s, sunny. The goal for Rachel and I was to dock the large platform at Lucille's as well but we actually moved backwards with the wind if we weren't straining to paddle. We had to leave the platform where it was, and were curious to see how the plants would fare over winter. The south lake large platform from a qualitative standpoint had grown best. The grasses were lush and green. There were three blue lobelias that still had a bud or flower. The root systems were similar to the other platforms. The roots for grasses and sedges were incredibly intricate. To harvest the entire plant, we had to loosen the roots from the bottom and scoop from the top of the mat, trying to dig and grab hold of the root bundles. Even then, because roots were intertwined with each other we still lost root mass with each full plant we attempted to harvest. The roots had a fibrous texture, like coir. There were finer root rhizoids which made it harder to detach if they were growing within and through the mat.

The LCBP cited studies which would oven dry the samples. Because this resource was not available, the samples were air dried. The drying and measuring was done in the wet lab of the Field station. The humidity and air was constant. The first harvest batch was separated by species and location. The tops were bundled and hung or left to dry on a counter. The tops would be measured as well. The full plants would be measured by length of the tops and the roots. The full plant samples would be bundled and left to hang up. The weight measurements would be taken after, to allow for roots to be folded or wrapped to ensure the entire plant fit on the scale without the risk of impacting the length in case any material was damaged.

Unfortunately, with fall break and access to the field station, the samples were left to dry for 4 days. They were fully dry, which throws off accuracy, as preharvest weighing was done with plants in soil that was moist enough to be handled without crumbling.

The second batch had 48 hours to dry before weighing. The tops dried. The full samples had similar moisture levels to the preharvest samples. This skews the results, and makes it hard to compare even the two harvest batches. However, because each wetland had such different rates of growth and survivability, qualitative data may provide a better idea of how well the plants did.

Fig. 14

Rachel Ephraim holding plastic cup plug next to pvc homekit (SL, 10/18/22)

Tussock sedge laid out before beginning root measurements (NL, 10/5/22)

Lobelia sample suspended to dry (NL, 10/5/22)

Lobelia sample with flower bud (SL, 10/18/22)

Results (S1)

This is a summary of plant plug pre-weights by species (table or bar chart), report on survival percentages by species/lake, summary of post-weights and root lengths.

I used R and excel to analyze the survivorship rates between species, and across lakes. Because milkweed, and cardinal flower did not survive, they were not included in the statistical tests because it was confusing the program. Likewise, the invasive lettuce looking plant was excluded because it had not been an input for the start period. The goal of these tests was to find out the proportion of return of plant material to starting plant material. The start period is the plant mass that was weighed prior to launching the platforms. The end period is the mass data collected with the harvest plants. Site is comparing the North Lake (NL) to South Lake (SL).

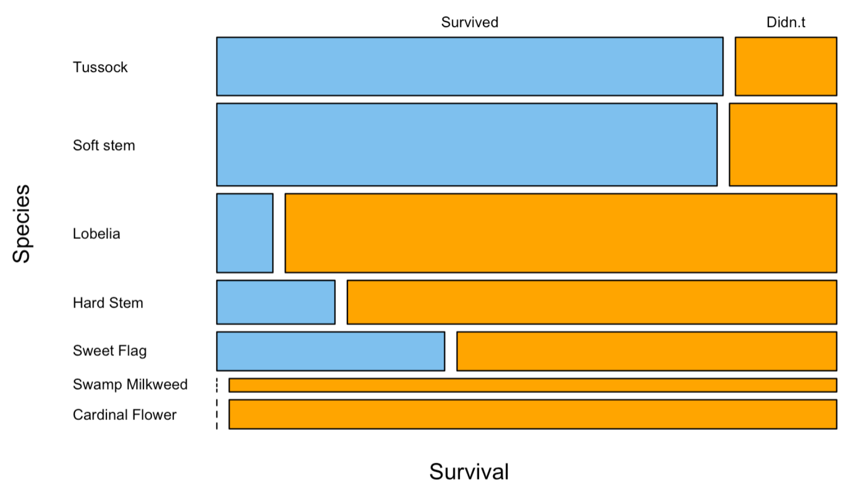


Fig. 15

This figure is accessing overall species survival, combined across both lakes, all platforms. Swamp milkweed and cardinal flower did not make it.

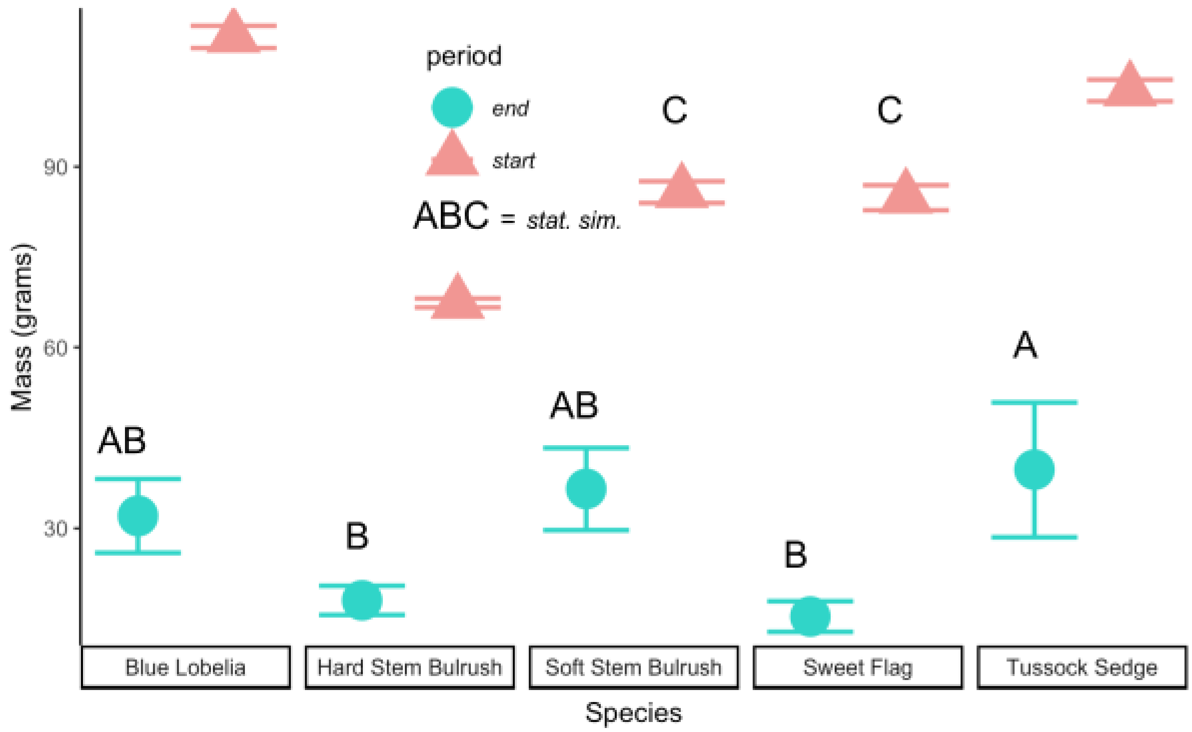
Table 3. Analysis of Variance

	Degree freedom	Sum squared	Mean squared	F value	P value
species	4	60734	15184	109.6457<	2.2e–16
period	1	81886	81886	591.3227<	2.2e-16
site	1	869	869	6.2743	0.0129590
species:period	4	2896	724	5.2286	0.0004801
species:site	4	2432	608	4.3910	0.0019444
period:site	1	1278	1278	9.2289	0.0026636
spec:per:site	1	76	76	0.5494	0.4593450
residuals	225	31158	138		

The P and F value for comparing Species, Site, and Period showed that there was no third term interaction, or where all three variables would impact each other at once. This makes the rest of the tests significantly less complicated. period affects how we interpret species, species effects site, site impacts period. This can be flipped around as well, because there is no causality.

A single-factor ANOVA can show that at least one group has a different meaning from another group, but it does not inform which group means are different from which other group means (Whitlock, M., & Schluter, D. 2015). A Tukey-Kramer tests for the null hypothesis of no difference between the population means for all pairs of groups. When comparing by site, the end period for NL and SL are statistically the same.

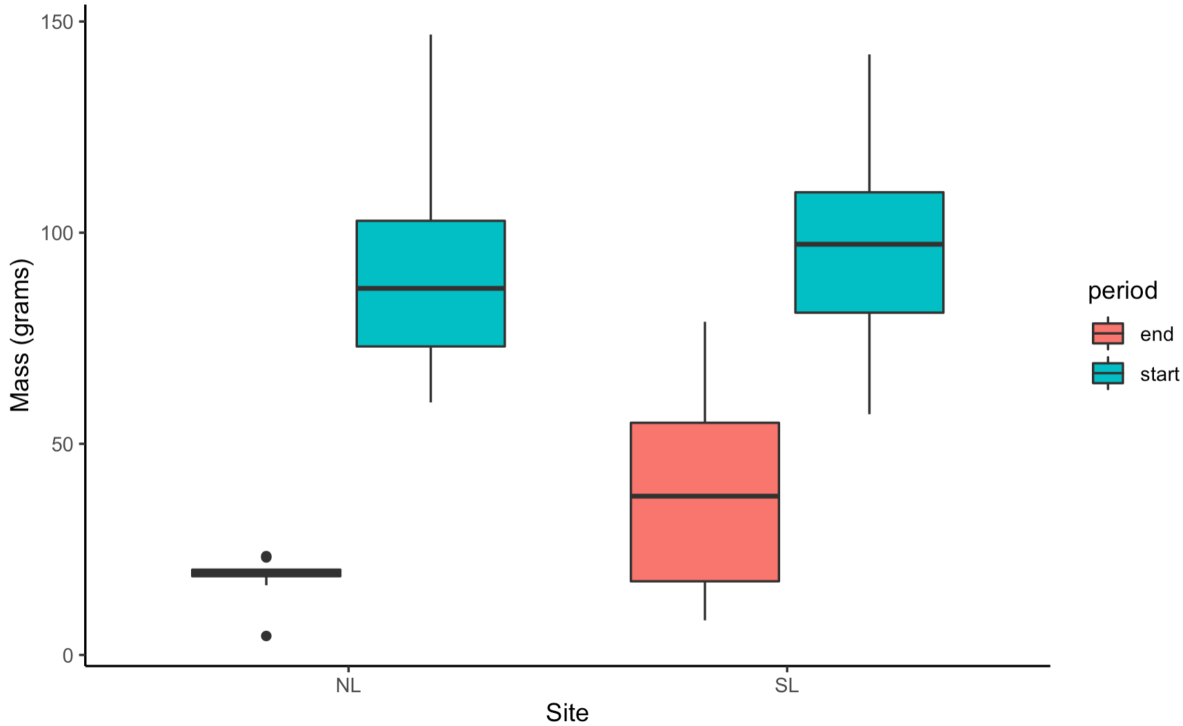
In Fig. 16. Species by period graph. Compares each of the surviving species from their start period to end.



It is important to point out that different species started with different starting mass. What the program is testing is how similar species are compared to each other. Figure x visualizes the relationship. Soft Stem Bulrush is the same as Sweet flag in the start period. Blue Lobelia, Soft Stem Bulrush, and Tussock sedge are statistically the same in their end period. However, when comparing the end period with Sweet Flag and Hard Stem Bulrush; Blue Lobelia and Soft Stem Bulrush are still statistically similar, while Tussock Sedge is not.

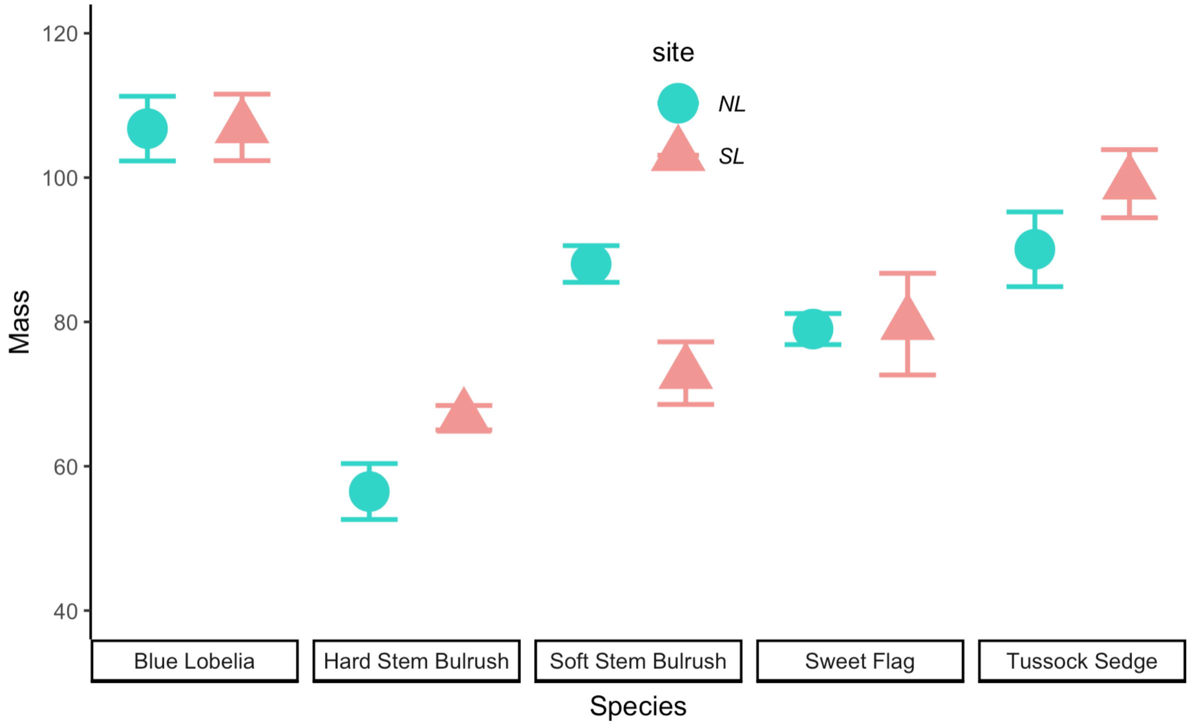
Start period for NL and SL starts at the same place, but the magnitude of difference between start and end period is diff. Larger diff btw periods is more for North Lake, pattern is true regardless of which species we consider

Fig. 17



The program interpreted the start period for NL and SL as being statistically the same. The end period for both sites are the same as well. Visually, it is clear that the magnitude of difference between start and end period is diff. There is a greater difference between periods for NL. This pattern seems to be true for most of the species we consider. It is interesting why the program seems to label the end periods to be the same. Differing sample size of the species may impact this. There are few reasons for why NL has a greater difference between periods. Firstly, based on results from previous studies collected on the Twin Lakes, the NL is colder, and has less runoff coming from the surrounding properties. Secondly, the muskrat problem could be having a significant impact on the mass of the plants. There were several reports from homeowners spotting muskrats hanging around the NL platforms or even munching on the stalks.

Fig. 18. Species by site. Except for Soft Stem Bulrush, every other species did better in the South Lake than the North Lake.



Overall, every species on both lakes lost mass from the launch date to the harvest collected.

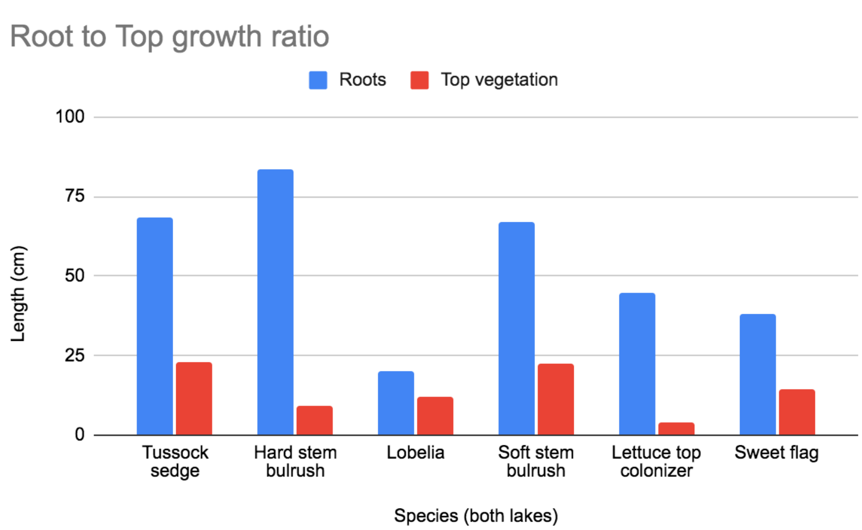


Fig. 19.

Root growth may be more indicative of the plants' success. The harvested plants had thick and complex root systems.

Tussock, Softstem, and Sweetflag had the best survivability, but blue lobelia outperforms sweet flag in terms of mass. This could be due to the sample size for the collection of each species. Only Lobelia had a complete collection, but there were only two individuals remaining. The Lobelia had thicker stalks, being a flowering plant (with flower buds as well) An important question to ask, is how is it that the root mass did not contribute to overall mass? This could be due to the soil the plugs lost being submerged underwater. The pre-release plugs had a varying level of soil moisture, which could have contributed to a greater mass from the beginning.

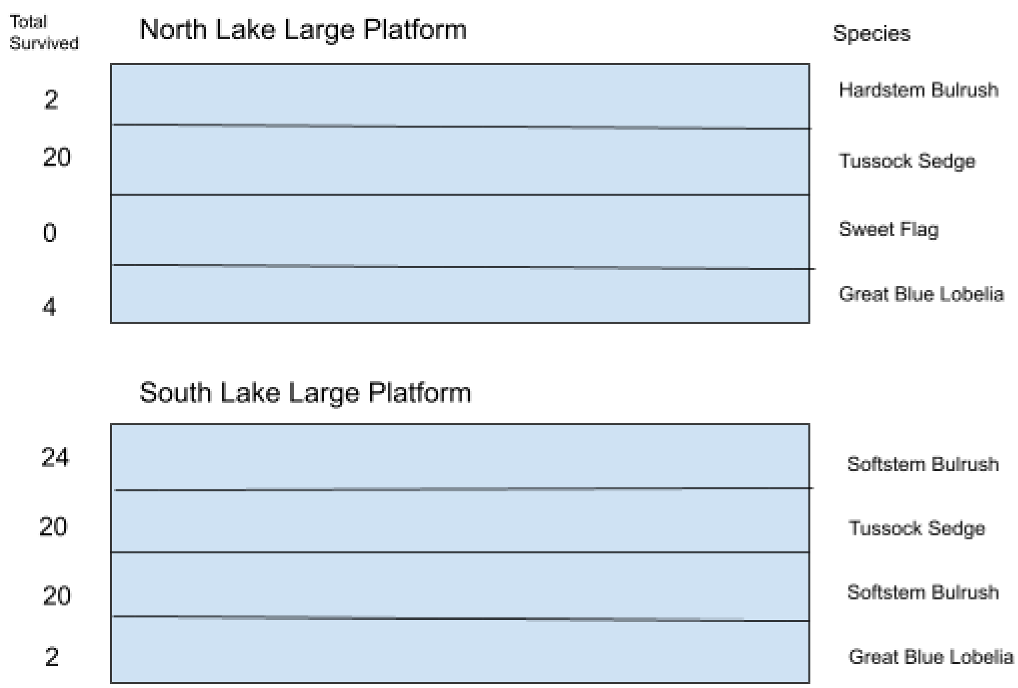
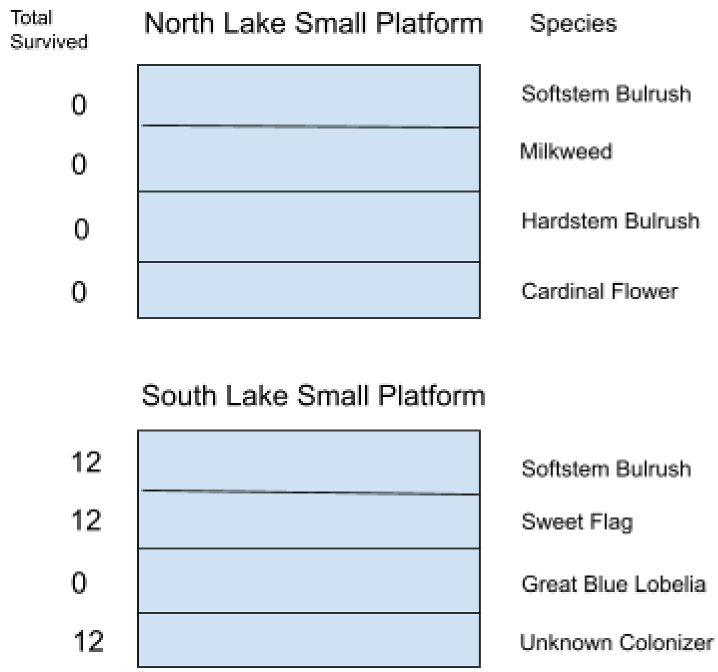


Fig 20 and Fig. 21. Individuals counted during harvest period by platform.



Discussion (S1)

The weighing process did not align with the methodological rigor I had hoped for. What I should have done was draft a lab protocol so that the drying period would be uniform. Unfortunately, I was also constrained by transportation. It is embarrassing to admit I did not have my drivers license, growing up in a city. Thankfully, my wonderful friends, Robyn Smyth, and Rachel Ephraim were able to help me in that department. This did however make me think about the relationship between Bard and other communities. Bard has labs where we can process data, and students who can do this work. However, this creates a tension because communities working with Bard have to, at some level, rely on getting this knowledge from a school that is removed from their community. What about when students graduate? Unless there is a permanent or semi-permanent faculty member with the time, energy, and dedication to keep the relationship going, it is an unsustainable model. Emily White, who is involved in multiple EUS, chemistry, and community science initiatives, has suggested implementing more citizen science elements to the community. For instance, there is a pH and basic conductivity water sample kit, which looks like a large thermometer and is able to run a quick test from a water sample collected in a cap. This equipment, though far from cheap, is small and can be a way to get a reliable snapshot of the lakes. Something I would potentially propose is a form that residents can submit to the Friends of the Twin Lakes and/or the government of Elizaville. They could take a picture, the weather conditions, and if there is any equipment available, then some data. This way, information can be passed and stored remotely. The many voices are far more effective than the few. It could also encourage more community members to get involved in learning more and appreciating the lakes they live near.

As mentioned in the methods section, the North lake ended up with several smaller platforms. The small polyflow mat used bamboo and aquafloat for floatation. This was constructed after the official launch day. The polyflo is incredibly hard to move around, even without the added drag of roots and weight coming from plants. Having pool noodles as floatation aids outweighs any benefits floating wetlands may have because of microplastics created by polyethylene foam. It is not biodegradable material.

It should be noted that community members got involved in the project using alternative methods. On the North lake, there was a bamboo and coconut coir mini platform which was able to float decently.

On the South lake, there was a simple pvc structure with one open pipe to hold the plugs and two perpendicular pipes on either side to create buoyancy and balance. The plugs were stored in plastic cups which had to be removed and disposed of because they were disintegrating.

A community member used beemats held together by metal wiring. Whether it was because of the location of the mats (right by a shore dock), the plant selection, or the mat itself, the flowering plants did exceptionally well there. It seems that this material is being considered for next year. If Beemats (the thinner mats) are the next main platform material, this could allow for the polyflow to be re-used or cut apart to create smaller, more manageable platforms. Either way, this adds cost to the project, but is certainly part of the adaptive management strategy. Change is slow and costly, but changes can be made along the way to ensure better results.

Recommendations (S1) for (S2)

Overall, soft stem bulrush outperformed every other plant in survivability, and despite technical gaps in the weighing procedure, gained mass through vegetation and root growth. Tussock sedge had similar results. It is unclear how hardstem bulrush would have performed had it arrived in better condition. Sweet flag had third top survivability. It would be another plant to invest in for the next planting season. I was able to have a conversation with Erik Kiviat, head of Hudsonia (a non profit environmental research institute based in the Bard Field Station. He suggested having taller species like cattails (in the genus Typha). For taller wetland plants, the risk is stem structure, and the lack of proximity on the FTWs. There would not be the usual support from other plants for factors like wind. This does, however, bring up a good point. The species purchased were relatively young. This was done to see how the plants could adapt and grow through the full seasonal cycle. A recommendation would be to purchase full grown plants, or have a mix of smaller and full grown. The full grown plants would have a bit more hardiness and offer an immediate aesthetic benefit.

Flowering plants were originally ordered as a way to bring aesthetic consideration into the project. The blue lobelia did have a few flowers in budding form on the large platform in the South lake. One of the community member's platforms had many of the lobelia blooming. Perhaps this is a species that can be installed in home kits as long as it is closer to shore. A few studies cited the success of Iris in temperate water bodies.

Muskrats are another consideration. There isn't anything that can be done about them, but this needs to be a communicated risk. The Rueger's instructional video gave the option for fencing to keep out waterfowl. This could be a potential solution to keep the muskrats out, but would then prevent turtles from seeking out the platforms.

Moving forward with SPROJ

I would like to host a feedback session with the Twin Lakes community to give a mass update, but to also get a sense of what they have observed through the summer and fall. The community is already planning to keep with this study going. They are looking at beemats to be the main platform material for the next season. I would also ask about the potential survey form and see if anyone would be interested and the feasibility. When the weather begins to warm in the spring, I plan on doing a few more site check-ins to see how the plants and platforms are doing. If the plant conditions look dismal, this could really inform how the study should move forward for next year. I would also create a protocol that students or residents should be able to follow to collect length and weight data for the harvesting.

Twin Lakes FTW Project (S2)

Updates

A petition was submitted to the Livingston Town Board oversees Elizaville) on September 8th, 2022. FONASTL was trying to vote for a "No Road Salt" area for County route 19 during the winter, and surrounding roads bordering the lakes (FONASTL End of Summer report n.d). Lowering the speed limit along the lake side was also included in order to ensure road safety during the winter and lower emissions. It was confirmed that the town agreed to change from a 40:60 salt-sand ratio to a 10:90 ratio. With the winter of 2022-23, this change has begun to be implemented. Because the winter was quite low in snow days, there were not many opportunities to see the outcome, but this is a huge boon to the lakes. There is a very interesting opportunity to observe how the decrease in salt impacts the lakes over time. It may be an immediate positive change, or it might take years to see significant results.

2023 Growing Season Groundwork

I had a call with one of the stakeholders, Claire Redes, who is one of the chairpeople of FONASTL and the one in charge of making sure the order for the materials goes through. The general feedback from residents is that they were upset with the "mattresses", or the bulkiness of the white polyflo. I explained the pros and cons of full harvesting versus the partial harvest with overwintering. Ultimately, full harvesting was chosen to prevent nutrients from going back in the lake once the plants started decomposing for winter. The other plus is that there would be more robust data for plant mass after harvesting. It would also ensure that the community could collect this data without unnecessary complications.

I was also informed that a community member had her own platform, and had quite a successful growing season with Blue Dart rush, Juncus tenuis. No literature that I could find had Juncus tenuis as part of a FTW study. However, this species is known to be resilient to trampling and often thrives in flood plains (McCurdy, J. et. al, 2022). Claire herself had a platform on the South lake with Blue Lobelia near her home, which ended up flowering for the majority of the season. It may have been that the shore had warmer temperatures. Perhaps there was less wind, which created more optimal growing conditions. Having community members participate with their own platforms created engagement. It also allowed for a larger variety of plant species to be tested with smaller stakes. Essentially, it widened the scope of monitoring natural resource systems change over time in response to uncertain environmental conditions (Russell et. al, 2001).

Figure 22. (Cred. Vicky Spinola).

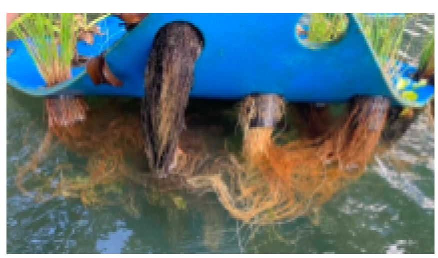
A community member had her own platform on the South Lake and had quite a successful growing season with Blue Dart rush, Juncus tenuis. South Lake. A photo of the platform with a Blue Heron perched on top of it.

The design of the floating wetlands would be changing to Beemats. These mats come in different dimensions, with holes for plant plugs already installed. The plant plugs themselves come in a plastic casing that clicks into the hole. The beemats would be a thinner material and rollable, a feature which makes storage, transport, and removal more manageable. Claire also said that there was a company based in New Jersey. This company partners with Beemats, so it makes aquatic plants that can be installed as plugs. Unlike the earlier black Beemat model which was used for a community member's waterfront, the color of the platforms is bright blue, which will stand out in the water. This is an aesthetic factor which is important to consider. People have also been very receptive about making their own. The diversity of floating wetland designs was very encouraging as residents were willing to engage in the project and test materials.

The Beemats would come in two distinct designs. For the platforms that community members can order, it would be 3 sq. ft. hexagons, for $25 each. They would come with 7 holes, including baskets for the plant plugs. The plants for the smaller platforms would cost around $25 as well. The rest of the materials, such as ropes, cinder blocks for the anchors would be the resident's own responsibility. The larger platforms would be 40 sq. ft., with 90 holes for plants. The cost would be $315 before shipping, with the plants it would be $500 total per platform. The mailing cost was around $300 for the S1 platforms, so it was safe to assume it would be similar for both plants and platforms for S2.

Fig. 23. Example of personal Beemat kit

Cred. FONSASTL



Cred. FONASTL

Table 4. Recommendation list submitted to FONASTL for the plant order:

Species	Key attributes	Drawbacks
Schoenoplectus tabernaemontani (Soft Stem Bulrush)	-Performed the best in survivability- least mass lost from pre-post harvest -hardy root system -definitely order this plant	
Carex stricta (Tussock Sedge)	-top survivability -quite a bit of literature backing up	
Juncus effusus (Common/Soft rush)	-Overwinters very well -When in group plant studies, outperforms -Would recommend this plant over Sweet Flag	
Acorus calamu (Sweet Flag)	-has light stripes on the border of each blade, can offer visual contrast -literature which highlights Sweet Flag performance	-Did not do as well as Soft stem bulrush and Tussock Sedge in survival
*C. comosa (*Longhaired Sedge)	-Did very well in other studies -Could be interesting to look at how the two Sedges compare in the Twin Lakes	-Similar to Tussock, if looking for visual mixture
Typha latifolia (broadleaf cattail)	-Hardy plant, can withstand colder temperatures -Consistently high uptake of effluent	-Wind on the lakes is far stronger than streams or ponds, because the genus tends to have tall stalks, it may not be the best combination
Juncus tenuis (Wire Grass/Path Rush) (As a wild card option if the plant distributor has a limited selection)	-Did very well in resident's floating wetland -Juncus genus does well in colder climates and wet conditions	-No extensive literature, is common around North America but most data in North Carolina

Claire submitted a proposal to the Columbia County Land Conservancy to cover two large rectangular mats with 96 plants for each lake. FONASTL also drafted a proposal for the mat orders and presented it to the Town Board. As of Thursday April 13, the Livingston Town Board voted to fund 500$ for mats and plants in this project. Because the Columbia County Land Conservancy grant did not go through, the Town Board donation replaced the funding amount. Given that the shipping costs are incredibly high, the goal would be to have another association to purchase a 5'x8' mat, which would reduce the shipping costs overall.

If this is possible there will be two mats on the South Lake, and one mat for the North Lake. Camp Scatico made a $600 donation and another $600.00 from Twin Lake Improvement Association (TLIA) at the first meeting in May. May 6 is the first FONASTL and TLIA meeting, which will go over the assembly details, finance, and plans for the project moving forward. It should also be a good time to share my findings and recommendations in person before the official assembly day.

The assembly and launch date is still scheduled for May 20th. The Town Board has confirmed May 20 for a 9:30 am assembly launch at the North Lake. The South Lake launch date is subject to change for May 27, but as it stands, it seems that both lakes will have their launch on the 20th. I will be able to assist with the May 20 launch. I will also be attending the first FONASTL meeting of the season sometime in May.

Along with the launch, this will be a good opportunity for community members to bring the first platforms out of the water. It would require two boats or more than two people on a canoe to remove the South Lake large platforms. I can also observe if the plants whose tops were harvested were able to a. Survive winter and b. If the vegetation was able to regrow.

Protocol for Launch Days

The goal for this season's launch day is to have more organized tasks for volunteers, and an easier way to keep track of the species being put into each platform. This task might be even trickier with more people participating by building their own home kits. Since each platform is contributing to nutrient uptake, it will be important to get residents with their own kit onboard with a shared place where they can keep track of their data. This protocol will definitely undergo revision as the launch date approaches.

- On the day of harvesting, start on one site with all plants, make sure that each box/tray is labeled with masking tape that clearly outlines the species and count.
    - Last March, some trays were stored in an RKC lab, while others that were ordered by community members were stored outside to acclimate.
    - To ensure that every plant is acclimated, and weighed, battery powered scales should be available, either borrowed from the biology department or purchased
- If mat materials arrive in one order, have all necessary materials at the same site. This will allow for all volunteers to get a rundown of the construction.
- Costs and orders should be scanned and collected and the day of construction. Cost-benefit analysis was not performed for the last round. However, having cost explicitly stated and officially written up will be better for transparency and understanding
- Have diagrams drawn up for each platform with count and type.
    - Have color coded rings to clip into each corner, or zip tie with water resistant fabric attached. This will provide a way to locate rows based on approximation to each color. In a sense, this will create a compass. What is important is to create a system where all platforms will follow the same rule. For example, green top left, red top right, blue bottom left, yellow bottom right.
    - The other reason is that because the platforms may move around or spin, it has made plant identification tricky. Even if orientation by cardinal directions for data collection such as wind direction will still be useful, this can still provide a safety net.
- Once the overview of construction is done, with questions answered, plants will be divided up for each platform.
- Plant plugs should be laid out on the ground to mimic a condensed version of each platform. If there are trays, then strings can be taped up to act as plant dividers.

- Routine check ins would be incredibly helpful from any community member boating out on the lakes. Even glance observations build a better picture of how the FTWs are doing.
- To harvest the plants ideally around late September: have gallon zip lock bags and sharpies at hand. Identify the plants according to the diagram and zip lock color system.
    - On the zip lock, write date, lake, platform type, and plant species
- Make sure that there is a designated site where plants can be dried. Preferably indoors, or somewhere that can be somewhat separate from the elements.
    - If hanging, lightly bind each individual in string to secure. If laying out, make sure vegetation has enough room to air out.
    - Let air dry for 24 hours, or another interval, but all harvested plants must have same drying time
- To get weight, weigh each individual plant, and add up species averages later.
- For other measures, use a yardstick or measuring tape to access root growth.
- Take plenty of photos!

Conclusion

The weather in the Hudson Valley area has varied quite a lot in the past few years. The Summers of 2019 and 2020 were quite hot, with several algae blooms reported (Romero, 2020). The Summer of 2021 saw heavy thunderstorms, raining almost every week. That season resulted in regular algae blooms, particularly in the South Lake. Sampling for bacteria also showed quite a few high recordings. By contrast, Summer of 2022 was classified as a drought. Scum was present, but only on shore ends.

Though Robyn Smyth's collaboration with the Twin Lakes community had been considering FTWs for several years, late spring of 2022 was the first time theory and planning was able to be put into practice. Being a real world, community effort meant that assembly and research would not be as tidy as if it were done in a lab setting. As I mentioned before, there have been tangible results from Smyth's research as the Town of Livingston passed a road salt limit on County Rt 19, particularly in the areas next to the Twin Lakes. This could have had a significant impact on the lakes starting this year, or could take many years to see a decline in chloride and sodium.

Another factor to consider is the realistic durability of this project. The model posited by Dr. Smyth has been her long standing relationship and pro bono research on the lakes, with her students undertaking research of these sites for their SPROJ. Seeing as Dr. Smyth is no longer working at Bard, it does not seem likely that another student will take up the mantle.

The beemats will guarantee durability for several years, and will be easy to store out of the water outside of growing seasons. However, plants are not cheap. That is a factor that must be considered by the community and town. It seems unreasonable to continue this study if there is no promise of citizen science to help analyze the biomass and understand the result of each growing season. If the season of Summer 2023 was to go smoothly, in order to have truly robust results, I would argue this study would need more research. This would mean at least two more growing seasons after summer 2023 to have data on the Beemat platforms and the revised plant list. The question remains of whether or not FTWs are a sufficient biological mitigation strategy for the Twin Lakes? Are more platforms needed to make a significant difference, and would this be acceptable for stakeholders? Does the overall biomass loss of the first growing season signify that the plants arrived in poor condition, that muskrats are to blame, or that lake conditions are less than ideal for growth?

With this coming growing season, I hope that the plan to have full plant harvesting will create a nutrient sink (Wang et al., 2014) and will give a clearer picture of changes in biomass. Long term, perhaps this community could pioneer citizen science efforts for bioremediation, and create an established monitoring system. The example that comes to mind is Bard's Sawkill sampling project. The Twin Lakes had been randomly selected as part of DEC's lake survey list, meaning that there will be further opportunities to apply for research grants. Given the increased attention for researching algae blooms of larger water bodies, the demand for studies like this FTW project will increase. As of October 2022, NOAA awarded $18.9 million dollars for Harmful Algae Bloom research and monitoring (NOAA). This is focused on U.S coastal and Great Lake water bodies, but it is a sign of a turning tide (pun intended) when it comes to national and even global attention to water quality.

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