Raquette Lake,
Lake Management Plan

FOREWARD

The Raquette Lake Preservation Foundation (RLPF) welcomes the reader to Raquette Lake, a very special and unique place in New York's Adirondack Park. Raquette Lake is a vital and significant natural resource. It hosts diverse aquatic habitats, provides important environmental benefits, and is a basis for activities that drive the local economy. Invasive species represent a threat to the lake's health and economy. Because so many Raquette Lake properties, businesses and functions are dependent on water-based access and activities it is imperative we prevent the introduction of invasive species and not allow them to inhibit lake use or displace native species. We must do our best to maintain Raquette Lake's water quality and variety of aquatic habitats so that future generations may continue to enjoy its many recreational opportunities, cottaging on the lake, and its wildness. It is RLPF's hope that this report, for the management of aquatic invasive species in Raquette Lake, is the foundation for future actions necessary for the protection of this unique and valuable resource.

Raquette Lake is the largest natural lake in the Adirondacks. Much of its shoreline is undeveloped and part of the NYS Forever Wild Forest Preserve, as are the surrounding woods and mountains. The lake size is approximately 5,333 acres. With many inlets from area streams Raquette Lake is part of the 82,000-acre St. Lawrence River Drainage Basin. The lake is the source for the Raquette River which flows north to the St. Lawrence River and is the second longest river in New York State. Downstream of Raquette Lake includes Forked Lake, Long Lake and Tupper Lake.

The lake is about five miles in length with numerous bays and nineteen islands creating many miles of shoreline. Maximum depth is around 85ft at the north end. This provides a large zone of cool water and is home to a native strain of Lake Trout which are important for fisheries management in the Adirondacks. The NYS Department of Environmental Conservation (DEC) collects eggs from these Lake Trout to raise in their hatcheries, with eventual stocking in Adirondack lakes and ponds. The many shallow bays and shorelines provide excellent habitat for warmwater fishes.

Raquette Lake provides a perfect setting for dozens of nesting Loons, and their calls are a reminder of the lake's wildness. Osprey, Bald Eagles, Kingfishers, Mergansers, ducks, geese, and other water birds are frequently seen. During spring and fall the lake provides a stopover for migratory birds. The water quality in Raquette Lake is generally excellent and has been monitored for years by the RLPF and Hamilton County Soil and Water Conservation District.

Over one hundred years ago wealthy industrialists recognized the beauty and serenity found at Raquette Lake and several Great Camps were built or owned by the names of Durant, Carnegie, Stott, Collier and Huntington. Around the same time two churches were built, one on St. Hubert Island, and St. Williams on Long Point - both water accessible only and still in use. Today over three hundred and fifty homes and cottages dot the shoreline. Most of these require a boat trip for access as there is no road around the lake. Being a large lake, float planes also utilize Raquette Lake.

The State University of New York College at Cortland operates two large educational facilities at Raquette Lake, providing an important experience for several degree programs. One of the facilities is boat access only. For over one hundred years Raquette Lake Camps have operated summer girls and boys camps, the boys camp being accessible only by boat. NYS DEC operates two very popular campgrounds on Raquette Lake. Golden Beach Campground is at the east end of South Bay and Tioga Point Campground is in the northern area of the lake and is water accessible only.

Raquette Lake provides a diverse number of opportunities for visitors and is a popular area for tourists. Scenic excursions and dinner cruises are available aboard the W.W. Durant. Among accommodations available are: local cottages to rent, the two DEC campgrounds, and lean-tos and primitive tent camping on the Forest Preserve.

All kinds of watersports are available along with excellent fishing for bass and trout. Boating, canoeing, kayaking, sailing, water skiing and swimming are common activities. Raquette Lake is part of the water routes for both the 700-mile Northern Forest Canoe trail from New York to Maine and the Adirondack Canoe Classic - 90 Miler Race from Old Forge to Saranac Lake.

With so many properties and facilities on Raquette Lake being water accessible only there are several marinas that provide the necessary sales, service and docking. And of course, the Raquette Lake General Store is very busy in the summer providing groceries and supplies to cottagers, campers and tourists.

The RLPF monitors aquatic vegetation changes in the lake and has taken aggressive action to remove tons of the invasive plant, variable leaved milfoil (VLM), where it is problematic to recreational use of the lake. RLPF has been proactive in preventing the introduction of invasive species to the lake and sponsored one of the first boat launch steward programs in the Adirondacks to inspect watercraft for invasives and to educate boaters on what they can do to prevent the spread of invasive species. RLPF is active in addressing other invasives like purple loosestrife.

To repeat for emphasis, it is clear Raquette Lake is a vital and significant natural resource. It hosts diverse aquatic habitats, provides important environmental benefits, and is the basis for activities that drive the local economy. We must do our best to maintain Raquette Lake's water quality and variety of habitats for future generations. It is RLPF's hope that this report, for the management of aquatic invasive species in Raquette Lake, is the foundation for future actions necessary for the protection of this unique and valuable resource.

Raquette Lake Preservation Foundation

Board of Directors, 2021

Raquette Lake,
Lake Management Plan

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The following management plan was made possible by the dedicated Raquette Lake Preservation Foundation (RLPF) volunteers. Their continued advocacy, community organization, and widespread partnerships have provided vital information and communication needed to make informed lake management planning decisions. RLPF is a Not-for-Profit Charity 501(c)(3) dedicated to protecting, promoting, and preserving Raquette Lake.

Partner Organizations

Town of Long Lake
Hamilton County Soil and Water Conservation District (HCSWCD)
NYS Department of Environmental Conservation (NYS DEC)
NYS Adirondack Park Agency (NYS APA)
Paul Smith's College Adirondack Water Institute (PSC AWI)
Adirondack Park Invasive Plant Program (APIPP)
Adirondack Lake Alliance (ALA)
Adirondack Council
NYS Federation of Lake Associations (NYSFOLA)
Adirondack North Country Association (ANCA)
Northern Forest Canoe Trail (NFCT)
Local Businesses
SUNY Cortland

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1.0 Introduction

This plan was funded by a State of New York Department of Environmental Conservation (NYDEC) lake management planning grant from the Environmental Protection Fund. The Raquette Lake Management Plan is the culmination of a two-year project with the Raquette Lake Preservation Foundation (RLPF). While there are certainly additional components that could go into a lake management plan, such as detailed watershed analyses, specific land-use goals, wetlands-management goals, or high-level fisheries recommendations, this plan covers core objectives proposed in initial discussions with NYS DEC and as identified by the RLPF. A major focus of this plan is Aquatic Invasive Species (AIS) management, since AIS present the most visible and immediate threats to Raquette Lake.

Balance for Raquette Lake

Raquette Lake embodies the unique Adirondack wilderness. There are few northeastern lakes that possess such a powerfully peaceful atmosphere. The expansive 5,333+ acres of water and irregular lake shape provide nearly 47 miles of shoreline and various littoral habitats. A large section of the shoreline is only accessible by boat, which enhances the wild essence that one senses in remote sections of the lake. The State of New York owns large tracks of waterfront and watershed land in the northern and southern basins, land that is set for long-term preservation and is presently barred from development. NYDEC perimeter lands also extend to the land beneath the water surface in shallow waters, classified as Forest Preserve land. Such land ownership has implications for aquatic plant management. Like many lakes in the Adirondack Park, the State of New York and residents of local communities recognize that they are, and forever will be, responsible for pursuing balance between development pressures and inherent preservation of wild land and water.

At its core, lake and watershed management attempts to achieve harmony between nature and anthropogenic resource use, including associated effects from human interaction with the environment. Similarly, aspects of lake management may also attempt to thwart or slow down the rate of ordinary landscape and waterbody change. Many lakes in the agricultural or suburban/urban regions of New York have succumbed to widespread ecological damage from humans. The ideal balance has been toppled to the point where lake management in these regions now resembles restoration, rather than conservation or preservation. Prior to the 1970s, there was little forethought on how human development could possibly harm lakes. The science of limnology was still in its infancy at this time; and today, more than ever before, society collectively understands that both watershed and in-lake management is perpetually required for a sustainable water resources future. Adirondack lakes have been partially shielded from historical and present overuse, primarily due to the creation of the Adirondack Park in 1892 and more stringent land conservation and private-use regulations beginning in 1973. The Adirondack Park Agency (APA) assumed responsibility over wetlands in 1985. But the 2020 pandemic stimulated record recreational activity in the Adirondack Park, reminding us all that lake and watershed management is an evolving and timeless effort.

This Raquette Lake Management Plan (RLMP) was created with the intention to guide stakeholders through the long-term pursuit of ecological, recreational, and economic goals. This plan also serves as an assessment of historical water quality and aquatic plant survey data. The plan provides professional recommendations for improvements to the data collection process and various aspects of lake management at Raquette. Recommendations for record keeping, data collection, and future research accompany both the water quality and aquatic plant management sections - an effort to ensure the Raquette Lake Management program does not fall victim to *landscape amnesia,* or *creeping normalcy* – as brilliantly termed by Jared Diamond in his novel *Collapse*. Lake management requires unbiased and standardized information over time, as anecdotal accounts leave room for lost details and unconscious shifts in normalcy.

The Planning Process

As part of the Lake Management Plan (LMP) development process, the RLPF organized and distributed a public survey questionnaire. This survey aimed to define the resident priorities, primary lake uses, concerns, property uses, and overall perception of the lake and prior management. The survey indicated that the majority of the lake residents have a long history of visiting the lake, and that many people value the *remoteness* and *peacefulness* of the lake. Residents were also concerned about *acid rain, algae blooms, aquatic plant growth, climate change,* and *invasive species.* This LMP emphasizes invasive species management, which was the most common stakeholder priority.

The results from the public survey can be found at:
https://rlpf.org/wp-content/uploads/2020/10/LMP-Survey-data.pdf

Over 60% of the respondents answered that they had observed changes in the aquatic plants in the lake over the last few years. Roughly one third of respondents were unsure if change has occurred or not. This perceived change over the years highlights the importance of plant management record-keeping. This topic is revisited in the Aquatic Plant Survey Results Section.

The RLPF also hosted a public presentation on August 25, 2020 where Northeast Aquatic Research consultants were able to discuss the lake management planning process, initial plant survey results, and solicit questions from the audience. A recording of the presentation is posted on the RLPF website.

Additionally, the RLPF participated in conference calls and rough draft brainstorming sessions throughout the two-year period. Initial thoughts, concerns, and recommendations were discussed prior to this draft submittal. Representatives from the Adirondack Watershed Institute also provided helpful comments and suggestions that have been incorporated into this draft plan.

Lake Uses & Inherent Values

Raquette Lake, like many of the large Adirondack lakes, has many uses and inherent values. The lake is used for power-boating, jet-skiing, paddling, sailing, fishing, swimming, and camping. There are also numerous hiking trails than span the watershed.

Of the total public survey respondents, 56% said they actively fish in the lake. A total of 77% of respondents answered that water sports and recreational usage of the lake is ‘Very important’ or ‘Extremely important.’ But there were a large number of comments that attempted to clarity what types of recreational use that they deemed important. There were a high number of public comments that distinguished preference towards kayaking and canoeing over power boating. There were many comments regarding concerns over large, noisy, and potentially dirty motorboat usage. People also expressed concerns over excessive wakes and disturbance of the naturally peaceful environment of the lake. There were several comments about the potential dangers and disruptions of jet-skiing, particularly the threats to shoreline erosion and long-distance swimmers, who also use shallow waters. Swimming was also one of the most commonly listed important recreational activities.

In the general comments section of the public survey, many people expressed how the *wildness* and lack of shoreline development at Raquette Lake were their favorite qualities. Respondents are extremely concerned with maintaining good water quality and managing aquatic invasive species because they know that the lake's future depends on present actions. Seventy percent of survey respondents indicated that family ties, and preserving the lake for their family's future generations to enjoy was 'Very Important.' Roughly 50% of the respondents have been visiting or living around the lake for 50+ years. Another 42% said they had been visiting Raquette for at least 25 years.

Over 30% of survey respondents answered that they use the lake water for household use, including a fraction that use the lake water for as a drinking water source. Less than 40% of respondents had a well.

Defining "Management" for Raquette Lake

The term "management" is subjective, and its definition is based on a particular lake's existing conditions, the community perceptions and beliefs, and the desired uses of a waterbody. Management depends on the state, regional, and local permitting framework – as well as local funding opportunities. Like in any natural resource management program, compromise is required. Competing interests and differing economic opinions can obstruct management efforts. This Lake Management Plan aims to communicate information, hone in on local priorities, and to set specific goals that will guide the community through years of adaptive management.

The goals that have been established for Raquette Lake management will persist into the future. But the year over year, actionable items will revise the approach to reaching those goals. While tentative costs and future funding mechanisms are proposed as part of this plan, there is no proposed overall lake management budget. In nearly every case where a specific management budget has been proposed for many years into the future, there is something that occurs that makes the estimated budget no longer reasonable. For instance, access to funding will change over time depending on state programs, local tax and reimbursement policies, level of volunteer enthusiasm and labor support, and generous donations. Market costs are also subject to change and there are often wide price differences for materials, labor, and expert involvement. Similarly, if the RLPF waits to manage certain areas that presently have very low quantities of VLM, then management costs will increase as VLM populations grow over time. Small manageable beds are capable of growing into large dense beds over the course of several years, and the rate of growth and spread at Raquette is unfortunately not yet understood.

The RLPF must approach achieving their goals based on reasonable annual budgets, and if a budget year is insufficient to achieve stated goals, members must pursue avenues to increase access to lake management funding. Budget estimates are included in the Funding for Plan Implementation section.

2.0 Lake Management Plan Objectives

Goals for the Raquette Lake Management Program

A LMP requires goals that provide a framework for both long-term and immediate actionable measures. The goals presented below are intended to be adaptable over time, but they draw upon aspects of lake management that will require persistent future effort.

1) Prevent new aquatic invasive species (AIS).
2) RLPF should partner with educational and governmental institutions to conduct scientific research of issues core to the lake's continued well-being. Of immediate interest is to study the current VLM population in the lake, its rate of growth and its expansion capability, to guide resource management decisions.
3) Prevent human-caused deterioration of Raquette Lake water quality.
4) Increase public education and awareness of aquatic sciences.
5) Prevent the spread of Variable-leaf milfoil (VLM) in existing and new areas of Raquette Lake and to other waterbodies.
6) Manage VLM and invasive species in order to preserve Raquette Lake habitats, species diversity, and to achieve balance between recreational opportunities, navigation, and ecological integrity.
7) Improve methods to track management success; track all expenditures and volunteer labor.
8) Use new information and political change in the Adirondacks to advance RL management, including permitting changes, new legislation, regional priorities, and funding opportunities.
9) Embrace partnerships for local land-use planning, and work towards changes to regulations that would benefit Raquette Lake.
10) Work towards a detailed watershed management strategy.
11) Commit to adaptive management with regularly updates to the RLMP. Commit to annual revisions of the specific VLM short-term action strategies provided in Appendix C.

These proposed Raquette Lake management goals build upon existing statewide and Adirondack Park goals for conservation and development, as well as aquatic nuisance species.

Regional Plant Management Goals

The New York State Department of Environmental Conservation (NYS DEC) and Adirondack Park Agency (APA) has made great strides in state-wide terrestrial and aquatic invasive species management over the last 15 years. The NY Partnerships for Regional Invasive Species Management (PRISM) were formed and funded under state statute to coordinate invasive species management regionally in NY. The Adirondack Park Invasive Plant Program (APIPP) PRISM is administered by the Nature Conservancy. Select publications have relevant information about Aquatic Invasive Species (AIS) management in NY and the ADKs. Key components of two major reports are quoted below. The statewide goals must be applied to Raquette Lake, and such established goals demonstrate how Raquette Lake management will fit into the overarching regional plans. There is no regional water quality or watershed management plan for Adirondack Lakes, as these types of plans are very waterbody-specific.

Adirondack Park Aquatic Nuisance Species Management Plan (2006)
https://www.adkwatershed.org/files/adk_ans_final.pdf

The goals of the Adirondack Park Aquatic Nuisance Species Management Plan are to:
1) Prevent new introductions of ANS into waters of the Adirondack Park
2) Limit the spread of established populations of ANS into uninfested waters of the Adirondack Park
3) Abate negative ecological, socioeconomic, and public health and safety impacts results from infestations of ANS within the Adirondack Park

New York State Invasive Species Comprehensive Management Plan (2018)
https://www.dec.ny.gov/docs/lands_forests_pdf/iscmpfinal.pdf

This publication documents the state-wide commitment to and plan for the following eight core initiatives. While these NYS DEC initiatives are state-wide, they can be applied to a local level at Raquette Lake and overlap with some of the Raquette goals.

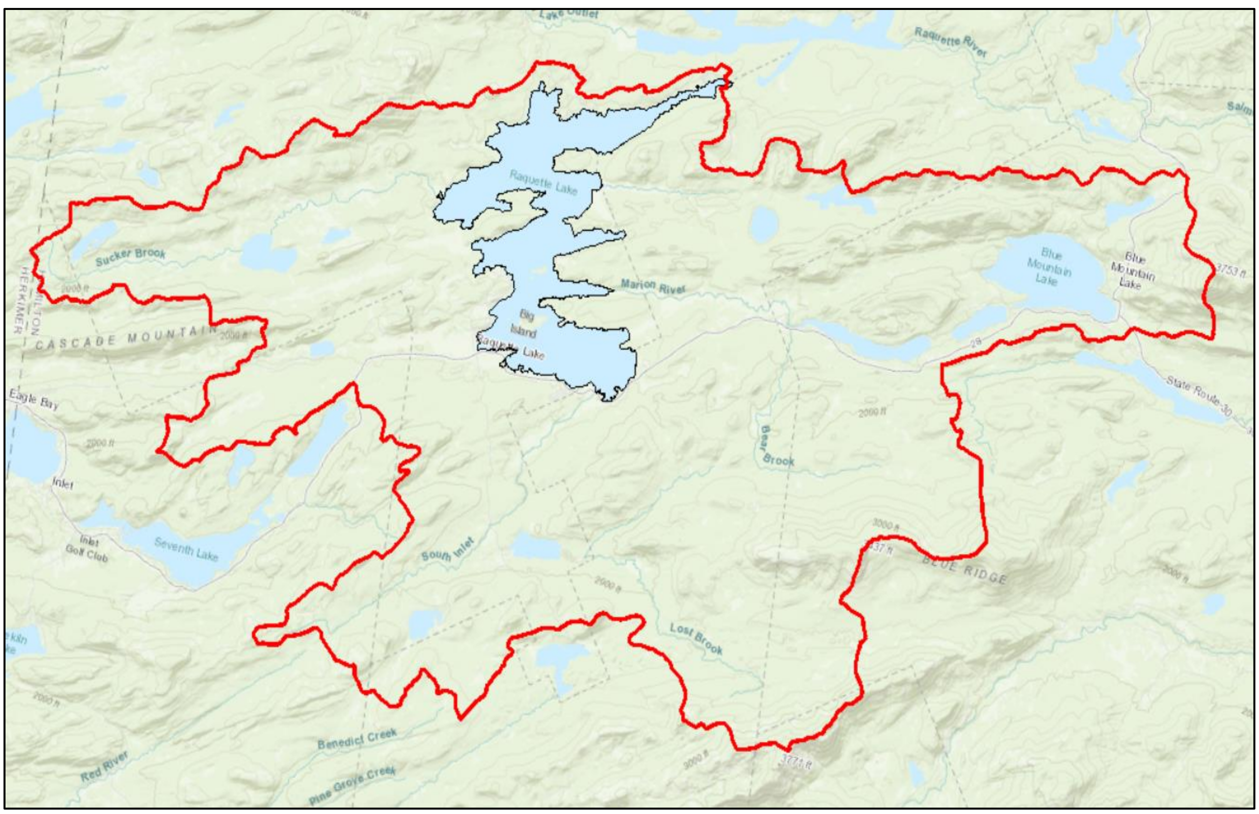
1) Continue to build partnerships and capacity
2) Commit to a centralized framework for sharing invasive species information
3) Set priorities for invasive species management & advance preparedness
4) Engage & inform the public
5) Advance prevention & early detection
6) Improve the response to invasive species
7) Recover ecosystem resilience
8) Evaluate success

3.0 Waterbody Characteristics

Watershed & Lake Morphology

Raquette Lake is located in the Town of Long Lake, in Hamilton County, NY. The lake is located in the center region of the Adirondack Park. According to the Adirondack Lake Assessment Program (ALAP), the lake is roughly 5,372 acres (2174-ha), and has approximately 47 miles (76 km) of shoreline. The lake volume is approximately 231,670 acre-feet (285,759,848 cubic meters). The ALAP estimated flushing rate is 0.91 times/year, with a 1.11-year retention time (Laxton et al. 2018[1]). This flushing rate estimate may or may not account for evapotranspiration, which is expected to be high given the densely forested watershed. The ALAP watershed area reported in the 2019 report was 33,123 ha (76,906 acres[2]). The USGS Stream-Stats 10m LIDAR topographical watershed calculated the Raquette watershed acreage to be 79,360 acres (*NAD 1983 StatePlane New York Central FIPS 3102 Feet* projected coordinate system). Previous watershed area estimates were upwards of 81,000 acres. ALAP estimates that the Raquette watershed is roughly 59.5% forested, 13% surface water, 25.1% wetlands, and 1.2% residential development.

Map 1 – Raquette Lake Watershed



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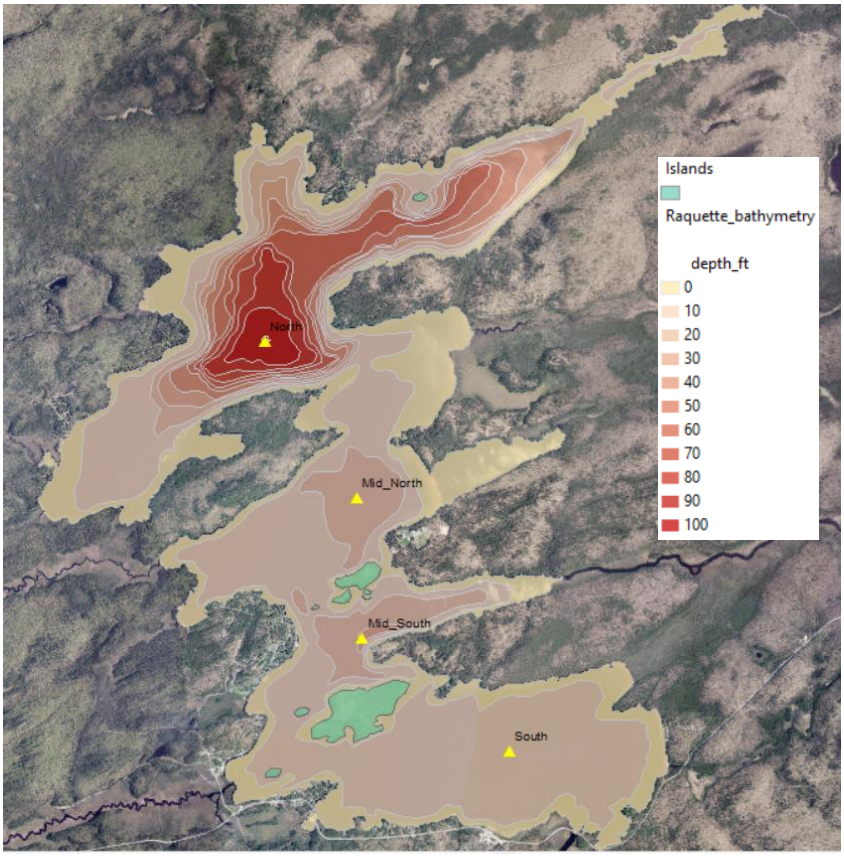
[1] Laxton, C., Yerger, E., Favreau, H., Regarlado, S., and D. Kelting. 2019. Adirondack Lake Assessment Program: 2018 Report. Paul Smith's College Adirondack Watershed Institute.

[2] Laxson, C., Croote, L., Stewart, C., Regalado, S., and D. Kelting. 2019. The State of Hamilton County Lakes: A 25-year Perspective, 1993 – 2017. Paul Smith's College Adirondack Watershed Institute.

The NYSDEC bathymetric map was retrieved and georeferenced in ArcGIS. The main long-term monitoring station is located in the center deep-hole area of the north basin. Additional monitoring locations were added to the two middle bays and the south bay (Map 2). Very infrequent monitoring was conducted in Sucker Brook Bay, Beaver Bay, and the mouths of the Marion and South inlets. The maximum depth of Raquette Lake is roughly 82 feet (25 meters). The lake mean depth is 21ft.

Map 2 - Raquette Lake Bathymetry



The bathymetric data was separated out into depth strata and is displayed in the hypsographic curve below. Note that nearly 70% of the lake's total surface area is shallower than 20ft deep.

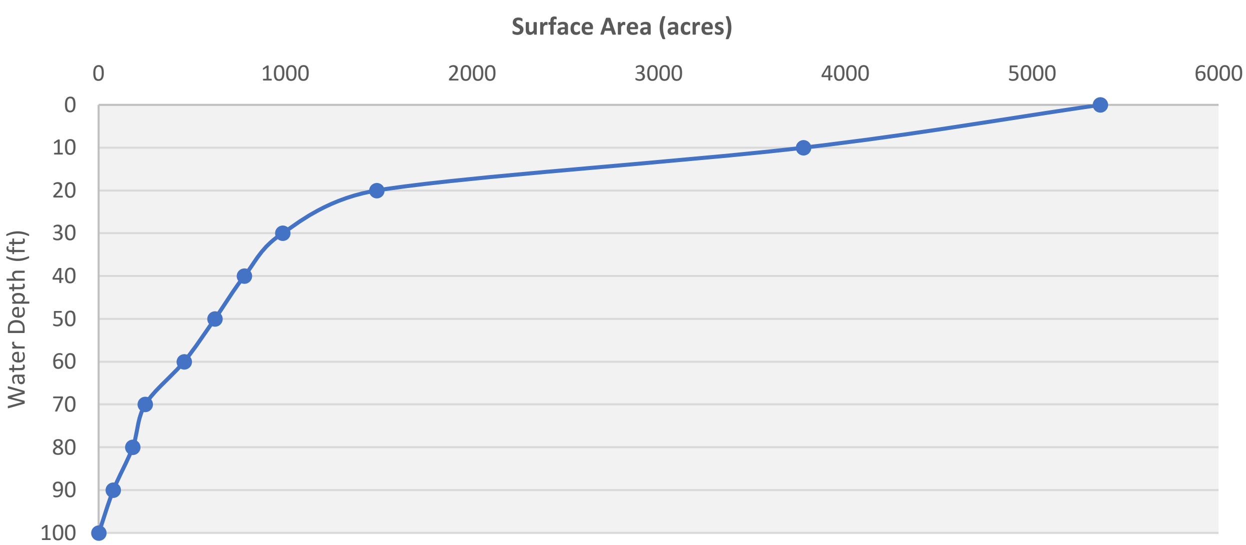


Figure 1 Surface Area to Depth Curve of Raquette Lake

Lake Access Points

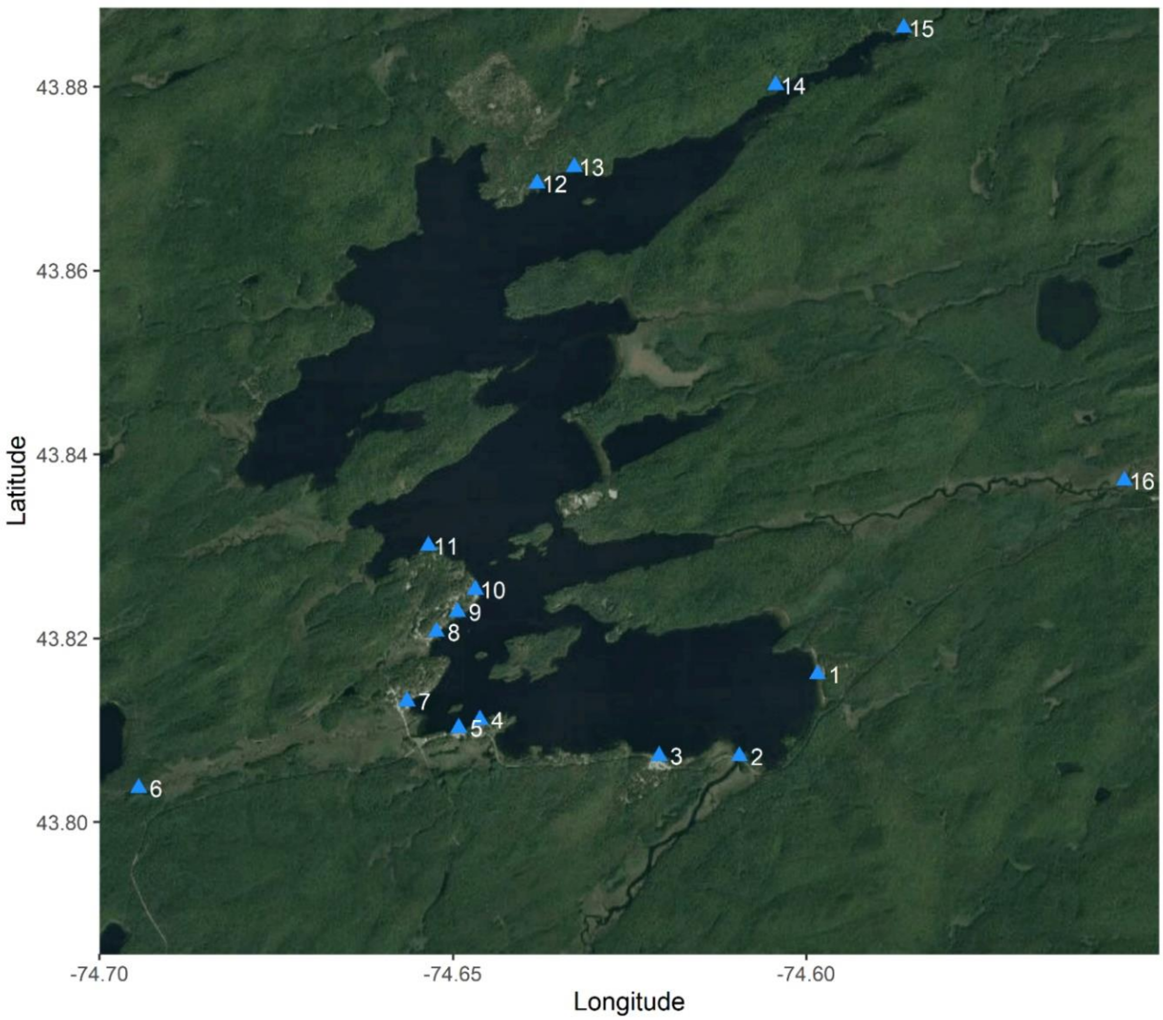
The following table lists the known boating access points to Raquette Lake. The associated details mention if the access point is public, private, and if it is for trailered versus only "paddle" boats, referring to canoes, kayaks, and other personal carry-in water craft. Of all the access points, the Raquette Lake public boat launch at the Village General Store (#7) is the most frequently used. This is the access point that is frequently monitored by boat-inspection stewards. Other priority access points for boat-inspector stewards are Burke's Marina (#5), Golden Beach (#1, in partnership with NYSDEC), and the South Inlet (#2).

The RLPF aims to connect with a representative from every access point to ensure adequate communication about the risks of non-native and invasive species infestations. AIS are commonly transported by trailed and motorized boats, but kayaks and other small personal boats can also transport AIS. The boat ramp inspections by paid and volunteer stewards are the first line of defense against new AIS.

Table 1 - Boating Access Locations

Site #	Access Point Name	Details/Notes
1	Golden Beach	Best for 'paddle' boats. Too shallow for boats of any size.
2	South Inlet	Currently 'paddle' boats only. DEC had plans for a launch ramp.
3	Burke's Marina	Stewards are present as available. RLPF used to cover Friday night peak. Burke's do keep an eye out as best they can.
4	Levi's	Mainly private.
5	Bird's Marina	Checks the boats they service. Very few launches of boats they do not maintain.
6	Brown's Track Outlet	Paddle boats only. Stewards/RLPF volunteers cover '90 Miler'.
7	Village General Store	Full time stewards 8AM to 4PM. Can shift hours to cover Friday peak.
8	Raquette Lake Camps	Very close monitoring and inspection of their boats. Outsiders are not allowed to use the launch ramp.
9	SUNY Antlers	Limited capability and no outsiders.
10	Antlers	Association controlled.
11	Hunter's Rest	Limited capability and no outsiders.
12	North Point	Association controlled.
13	Greylock	Association controlled.
14	Raquette River	Snowmobile trail. 'Paddle' boats only.
15	Raquette River Carry	Paddle' boats only. Private property with Right of Way.
16	Marion River	Private property.

Map 3 - Boating Access Points



ACCESS POINT RECOMMENDATIONS

Increase visibility of boat ramp steward calendar via weekly social media posts. Resident volunteers have busy lives and may have difficulty committing to regular volunteer time slots. Allowing residents to see and to sign up for empty time slots on a last-minute basis will increase boat-ramp steward coverage at the Village access ramp.

Appropriate signage mitigates the risk of potential new AIS infestations to Raquette Lake, and will simultaneously minimize the spread of invasive Variable-leaf milfoil to other Adirondack Lakes.

4.0 Water Quality

The entire Raquette Lake Water Quality Assessment report is included in this LMP as **Appendix A.** Important aspects of the assessment report are summarized below.

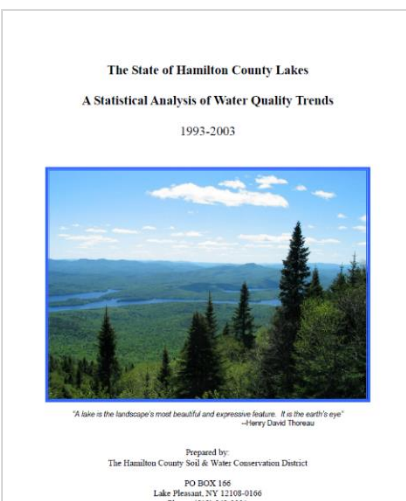
Review of Past Reports

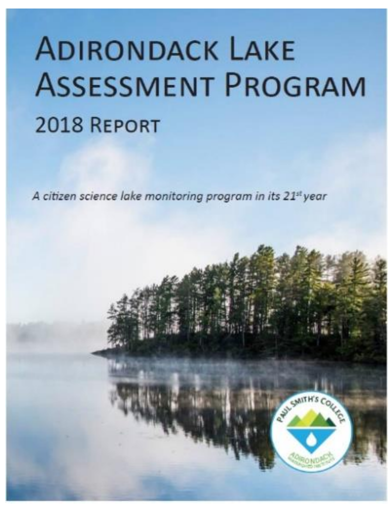
The earliest water quality monitoring data were from a New York Department of Environmental Conservation (DEC) study in 1934. There was no data available from 1935 through 1973. Sporadic water clarity measurements were recorded in the 1970s and 1980s, but consistent monitoring did not begin until 1993. Almost all of the data collected was from the central deep area in Raquette's north basin.

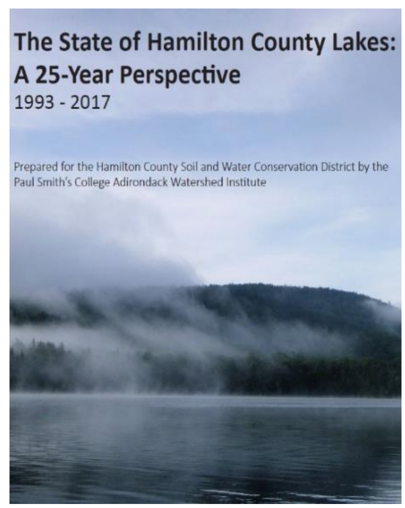
Three main water quality reports were reviewed:

1. The State of Hamilton County Lakes: A Statistical Analysis of Water Quality Trends, 1993-2003 (2005). Hamilton County Soil and Water Conservation District[3]
2. *ALAP 2018 Report.* Paul Smith's College Adirondack Watershed Institute[4]
3. The State of Hamilton County Lakes: A 25-year Perspective, 1993 – 2017. Paul Smith's College Adirondack Watershed Institute[5]

Cover Pages of Historical Reports Reviewed during the Raquette Lake water quality assessment







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[3] Publication alternatively cited as:
Cedar Eden Environmental, LLC, (2005). A Statistical Analysis of Water Quality Trends in Hamilton County Lakes, 1993-2003.

[4] Laxson, C.L., Yerger, E.C., Regalado, S.A., and D.L. Kelting. 2019. Adirondack Lake Assessment Program: 2018 Report. Paul Smith's College Adirondack Watershed Institute. 181p

[5] Laxson, C., Croote, L., Stewart, C., Regalado, S., and D. Kelting. 2019. *The State of Hamilton County Lakes: A 25-year Perspective, 1993 – 2017*. Paul Smith's College Adirondack Watershed Institute.

Key Water Quality Findings

The key points derived from the long-term water quality data analysis are listed below. Please note this this section includes technical terminology and relies on the reader having a basic knowledge of limnological science. Readers can refer to **Appendix A** for the Description of Monitoring Component Handouts and explanation of certain types of measurements.

Water quality findings that are considered "Good" for Raquette lake are marked with a green thumbs-up. Unmarked points are simply information that was included in the Water Quality Assessment in **Appendix A.** All water quality assessment details and data figures are provided in this supplemental report. There were generally no alarming water quality data trends for Raquette Lake.

Raquette Lake has overall excellent water quality and can be considered Oligotrophic. Certain publications consider the lake to be Mesotrophic due to its limited Secchi clarity (< 5m), but the analysis demonstrated that Secchi clarity was not a good measure of Raquette Lake trophic condition.

For the depth of the lake and size of the watershed, Raquette Lake has excellent overall oxygen conditions in deep water.

There does not appear to be a dramatic worsening of oxygen conditions over time, but hypoxia in the deep waters may become more common in the next few decades, as the oxygen demand of the sediments and decomposing organic matter could increase over time.

The thermocline exhibits interesting oxygen dynamics that are not yet explained but are likely related to zooplankton populations, lake thermal and density structure, or oxygen demand of shallow waters.

The watershed is relatively undeveloped and close to pristine conditions, yet the high wetland percentage likely contributes high colored dissolved organic matter loads. Adirondack lake "browning" has been documented in research literature.

Water clarity values greater than 5-meters are excellent. The high dissolved organic matter and high color at Raquette Lake causes naturally lower water clarity than other 'clear-water' Oligotrophic lakes.

Clarity measurements among data sources are variable. The decrease in water clarity over time as measured by ALAP is complicated and is not reason for alarm. The north basin deep hole long-term quartile range values are: 3.55m (25th percentile), 4.25m (50th percentile), 4.97m meters (75th percentile).

Nutrient (nitrogen and phosphorus) concentrations appear to be decreasing, and have been very low in the last several years – less than 100 µg/L Nitrate + nitrite nitrogen and 10 µg/L Total Phosphorus, indicative of excellent water quality.

Alkalinity appears to be increasing, which signifies that the lake is recovering from past acid rain pollution. Researchers are engaged in the study of ecological effects from increasing alkalinity.

Conductivity is not obviously increasing over time at Raquette lake, which indicates that the lake is less influenced by road salts than many other lakes in the northeast. Conductivity at hundreds of lakes in the northeast has been steadily increasing over time, but is not dramatically increasing at Raquette Lake.

The water quality assessment included in Appendix A includes data through the end of 2019. The 2020 data was reviewed prior to publishing the RLMP draft. New 2020 information added the ability to perform profile monitoring of Chlorophyll fluorescence, which confirmed the presence of high amounts of phytoplankton present in the middle of the water column. This phenomenon is common in deep clear-water lakes. To view the updated Hamilton County Lakes monitoring program 2020 summary report, please visit: https://storymaps.arcgis.com/stories/5f57d2c22363461e9fe325fd7ab62e64

KEY WATER QUALITY PRESERVATION & MONITORING RECOMMENDATIONS

1. Historical phosphorus testing did not use methods with a low enough limit of detection, which has been acknowledged by Hamilton County and AWI as the primary reason for the wide range in seasonal (Total Phosphorus) TP values historically. **The open water concentration at Raquette Lake should remain below or close to 10 µg/L TP**, as has been measured in recent years, using more accurate laboratory methods.

2. Volunteer monitoring, conducted at the Deep Hole station, added nutrient testing at the lake bottom through the CSLAP program in 2019. This addition is essential to long term monitoring at Raquette Lake. Phosphorus values at the beginning and the end of the growing season are the most valuable to demonstrate a potential seasonal increase. After years of watershed loading, lakes begin to develop large stores of phosphorus at the lake bottom. Some of that phosphorus can be recycled in the lake from year to year. In nutrient-rich lakes, the bottom of the water column almost always has the highest phosphorus due to this internal load/recycling process and settling from the water column.

3. **Include monitoring of major inlets and inlet basins to better detect water quality change**, in addition to the North Bay traditional monitoring. RLPF can spearhead a systematic inlet testing plan to establish baseline inlet conditions, such as mean summer TP and Total Nitrogen (TN), as well as general observations about plant growth, sedimentation, diffuse or channelized flow, etc. Baseline photos taken in 2020 will help track potential change over time. Inlet testing is not necessary every month or year because it is generally cost prohibitive for large lakes, **but field notes *and* photos are very valuable if nutrient testing is not possible**. There is currently no baseline data for the Raquette Lake inlets or watershed.

4. Because the water volume of Raquette is so enormous, the first instances of water quality change are likely to be observed in the basins with major inlets, where the inlet areas serve as settling chambers for sediment and organic material over time. This settling will affect aquatic plant densities as sediments become more nutrient-rich over time. **It is highly recommended to track oxygen loss in bottom waters of the southern two basins, particularly in summer and fall**.

5. The lake is in good condition, but **it would be wise to invest in Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC) to establish baseline values for relevant parameters for Adirondack Lakes**. True Color values can be used as a proxy measurement for organic material in the water column, but True Color trends were variable and appear less reliable. DOC and TOC levels appear to be increasing, resulting in an effect termed “lake browning,” and reduced water clarity.

5.0 Aquatic Plants in Raquette

Most of the available historical aquatic plant information for Raquette Lake comes from the 1934 NYS DEC survey and the 2016 survey conducted by the Adirondack Watershed Institute (AWI) through the Adirondack Park Invasive Plant Program APIPP). These surveys were the only two historical assessments that documented all native and invasive aquatic plant species found in the lake. Volunteers from the Raquette Lake Preservation Foundation have also recently scanned large sections of the shoreline for invasive Variable-leaf milfoil. The SUNY and Lebanon Valley College efforts reproduced the transects of Dr. John Titus (SUNY Binghamton) and documented the change in plants and plant density from their original surveys in 2005 to 2015. In addition, they had a grant from the DEC to study the practical value and effectiveness of biodegradable benthic barriers. RLPF donated the barrier material used in the study.

Historical Surveys

NY DEC 1933 Survey[6]

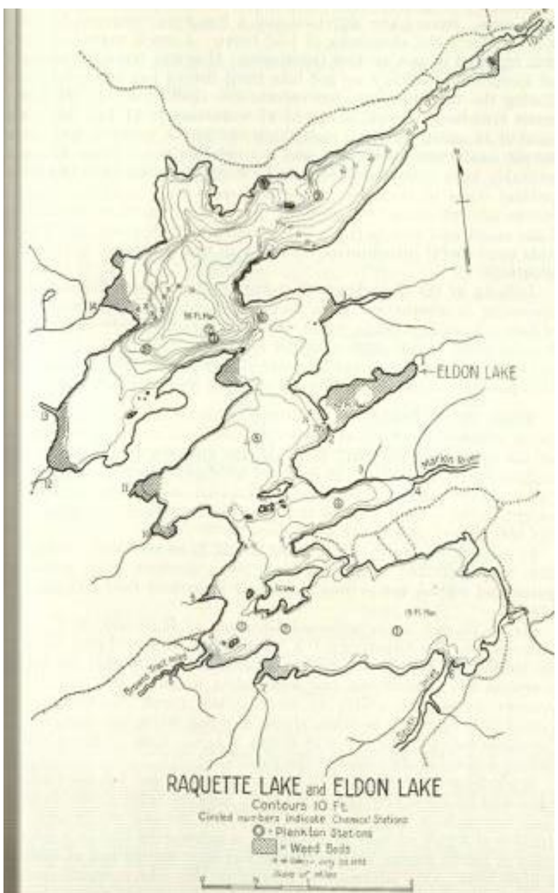


Chart 7. Raquette Lake and Eldon Lake

The 1933 study was conducted by the New York State Conservation Department (now the NYS DEC) and was a part of a significant effort to document the ecology and water quality of Adirondack lakes in the late 1920s to early 1930s. The survey documented roughly 12 aquatic plant beds of varying size, including in Eldon Lake. Based on the available data, it is also unclear if areas that are left blank are blank because there were no plants present, or that those areas were not surveyed.

Thirty-nine species were documented during the study (Table 3, p22). Plants were classified as abundant, common, frequent, and rare, which without further explanation makes quantifying abundance difficult. The 1934 plant map does not delineate different species locations within the plant beds, making long term comparisons of species distributions impossible. There does not appear to be any associated 'raw' survey data that could be used to glean information on the densities and abundances of specific species in various areas throughout the lake.

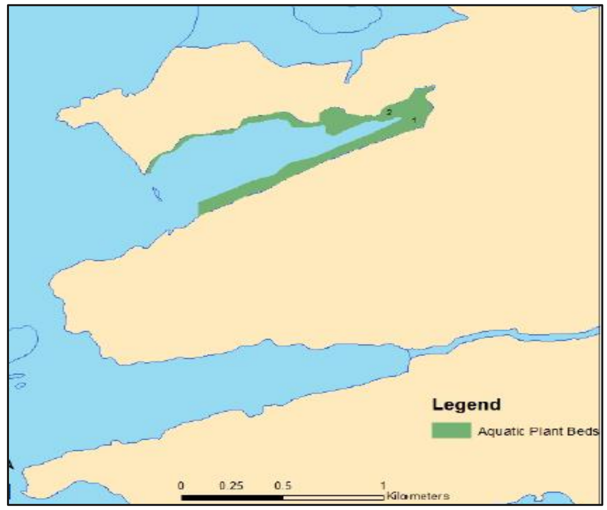
This study is primarily useful in establishing the locations of general plant beds throughout the lake, and for creating a baseline for aquatic plant species list.

[6] Muenscher W. C. 1934, Aquatic Vegetation of the Raquette River Watershed, p 209-221. In a Biological Survey of the Raquette Watershed, State of New York Conservation Department, Biological Survey No VIII, J. B. Lyon Co, Albany N.Y.

2013 AWI Rake-Toss Survey of Eldon Lake

Survey results can be accessed at the following link:
https://www.adkwatershed.org/files/eldon_lake_aquatic_plant_survey_2013_dlk.pdf

Map 4. AWI 2013 Eldon Lake Survey - Plant Beds



In 2013, the AWI performed a point-based rake-toss aquatic plant survey of Eldon Lake.

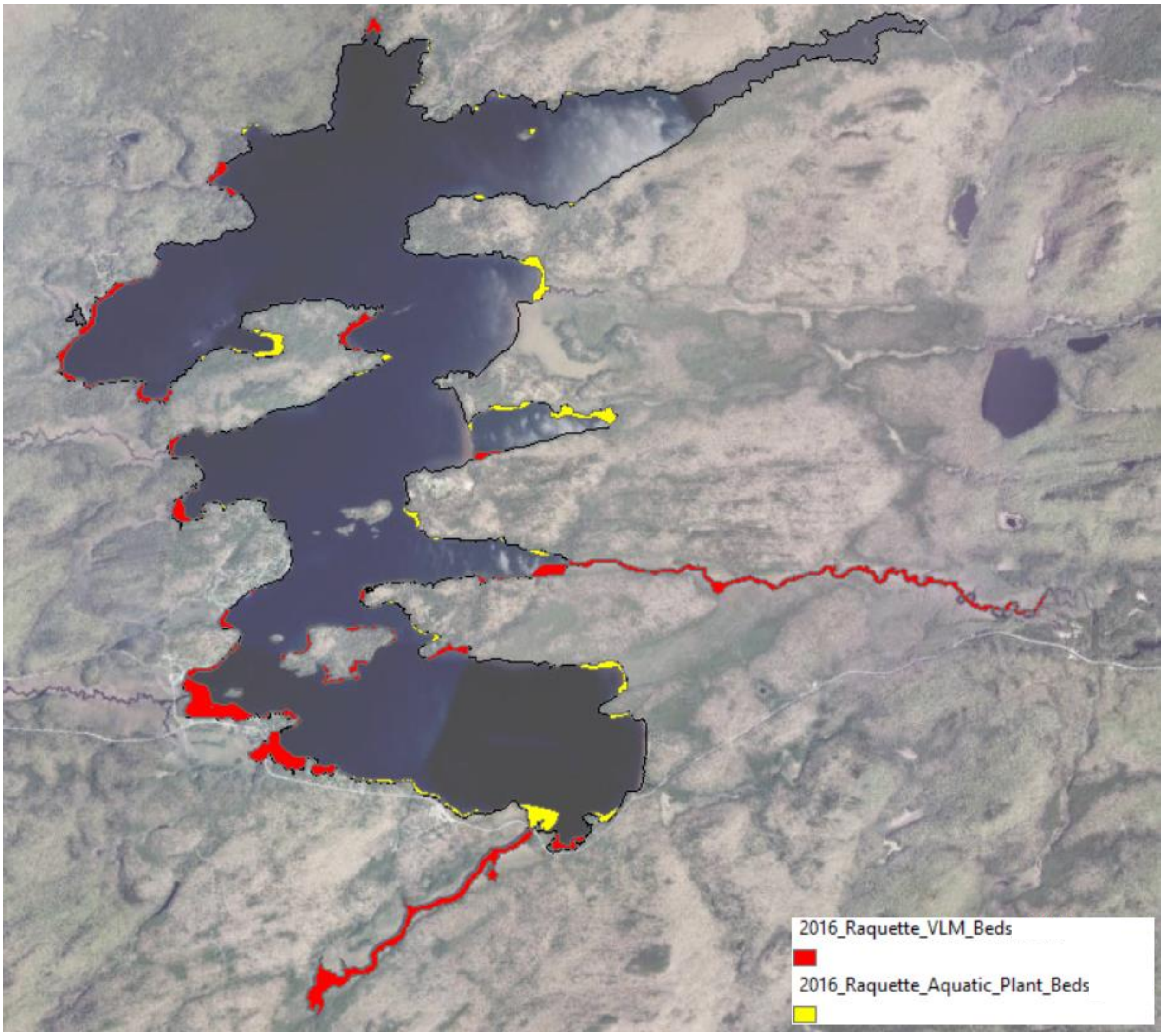
The results of this survey are quite interesting and provide enough detail to be able to make limited species presence and density comparisons to the 2020 survey. A total of 13 different aquatic plant species were found in Eldon Lake during this 2013 assessment. The most common species were recorded as Water shield (*Brasenia schreberi*), White-water lily (*Nymphaea odorata*), and Hairgrass (*Eleocharis sp*.). VLM (*Myriophyllum heterophyllum)* was present at 3 of 27 littoral-zone sampling points.

2016 AWI Survey

A study was conducted in 2016 by the Adirondack Watershed Institute in conjunction with APIPP. Ninety-two plant beds were documented during the 40 hours of surveying. Approximately 25 aquatic plant species were recorded, but based on 2020 survey data it appears that this was not a true reduction in species since 1933 and that 2016 results were likely limited. One limitation to data interpretation similar to the 1934 survey is the lack of specificity on plant locations. The shapefiles from 2016 show the general locations of plant beds, but not the individual points themselves. The raw plant data likely exists, but it would take considerably more effort to organize the raw all-species point data into a similar format to the 2020 survey and that was not done as part of this analysis.

The 2016 survey shapefile data is organized into two layers: VLM shown in red and native plants in yellow (Map 5). The native plant beds were assigned one total abundance ranking for all of the species present. There polygons are general areas of presence, not actual acreage of VLM present. For example, the survey documented 18 species within the south inlet, but there is only one polygon for the entire inlet, which shows that Variable leaf milfoil (VLM) was common throughout the entire area. This provides information about general abundance, but it provides little insight on species distribution is not directly comparable with the 2020 survey data.

Map 5. Raquette Lake 2016 AWI Survey - VLM & Native Plant Areas



Secondary Surveys & Studies

Evaluation of Benthic Mats by SUNY Cortland and Lebanon Valley College

In 2018, SUNY Cortland and Lebanon Valley College evaluated the impacts of matting on several aquatic plant species including (VLM) and Swollen Bladderwort. Their work documented an increase in Swollen Bladderwort in areas with light plant-density matting efforts as opposed to heavy density matting efforts. We find this result interesting because bladderworts are not rooted and should not be affected by benthic matting of any kind. The effects of the benthic matting seem to be inconclusive at this moment, as there were only marginal decreases in aquatic plant individuals from 2017 to 2018.

The Invasive Freshwater Macrophyte Utricularia inflata - Titus & Grise, 2009[7]

This publication compared the initial plant survey results from 1933 NYS DEC survey to underwater transect surveys in Eldon Lake and Beaver Bay in 1983 and 1999/2000. Swollen/inflated Bladderwort (*Utricularia inflata*) was documented within 13 beds at percent covers ranging from rare to present (0 to 25%). Titus 2009 documented this plant for the first time in the lake in 1999. New York does not consider this plant to be an invasive species, however it is highly aggressive and is considered a nuisance species in surrounding areas and has rapidly colonized new areas within Raquette Lake. The species was added to the Native Pioneer Plant Watch List in 2010, as the NY Natural Heritage Program decided the species was exhibiting a range expansion. Future surveys should focus on the potential expansion of Swollen bladderwort. The design of the 1983 and 1999/2000 surveys, as underwater transect surveys, are excellent for small scale community ecology studies, but less comparable to lake-wide distribution assessments. This publication also lists a number of species that were not listed in the 1933 species list table.

After discussions with Dr. Titus, we discovered that the additional species mentioned in Titus & Grise study were listed as being present in Raquette Lake and the Raquette Lake watershed circa 1933, despite not being included in the main table of species in the 1934 NYDEC publication.

*Megalodonta (*now *Bidens) beckii – "infrequent in bays of Raquette & Tupper Lakes"*
Myriophyllum farwellii (current NYS protected species) – "bays of Raquette Lake"
Utricularia minor – "infrequent in Lonesome Bay, Raquette Lake"
Nuphar microphylla – "very local in deep water, Beaver Bay, Raquette Lake"

[7] Titus, J.E. and David J. Grisé. 2009. The Invasive Freshwater Macrophyte Utricularia inflata (Inflated Bladderwort) Dominates Adirondack Mountain Lake Sites. The Journal of the Torrey Botanical Society, Vol. 136, No. 4, pp. 479-486.

2020 Aquatic Plant Species

As part of the Raquette Lake Management plan formation, NEAR performed an aquatic plant survey covering as much of the littoral zone as possible within a period of 6 long survey days. All areas surveyed by APIPP in 2016 were revisited. Table 2 presents the total list of species found. Invasive species are colored red, and state-listed natural heritage species are listed in blue. The "Nothing present" is listed as Common, but is not counted as a species. It is important to track the areas of the lake where there were no aquatic plants to determine if more lake shoreline is becoming colonized over time.

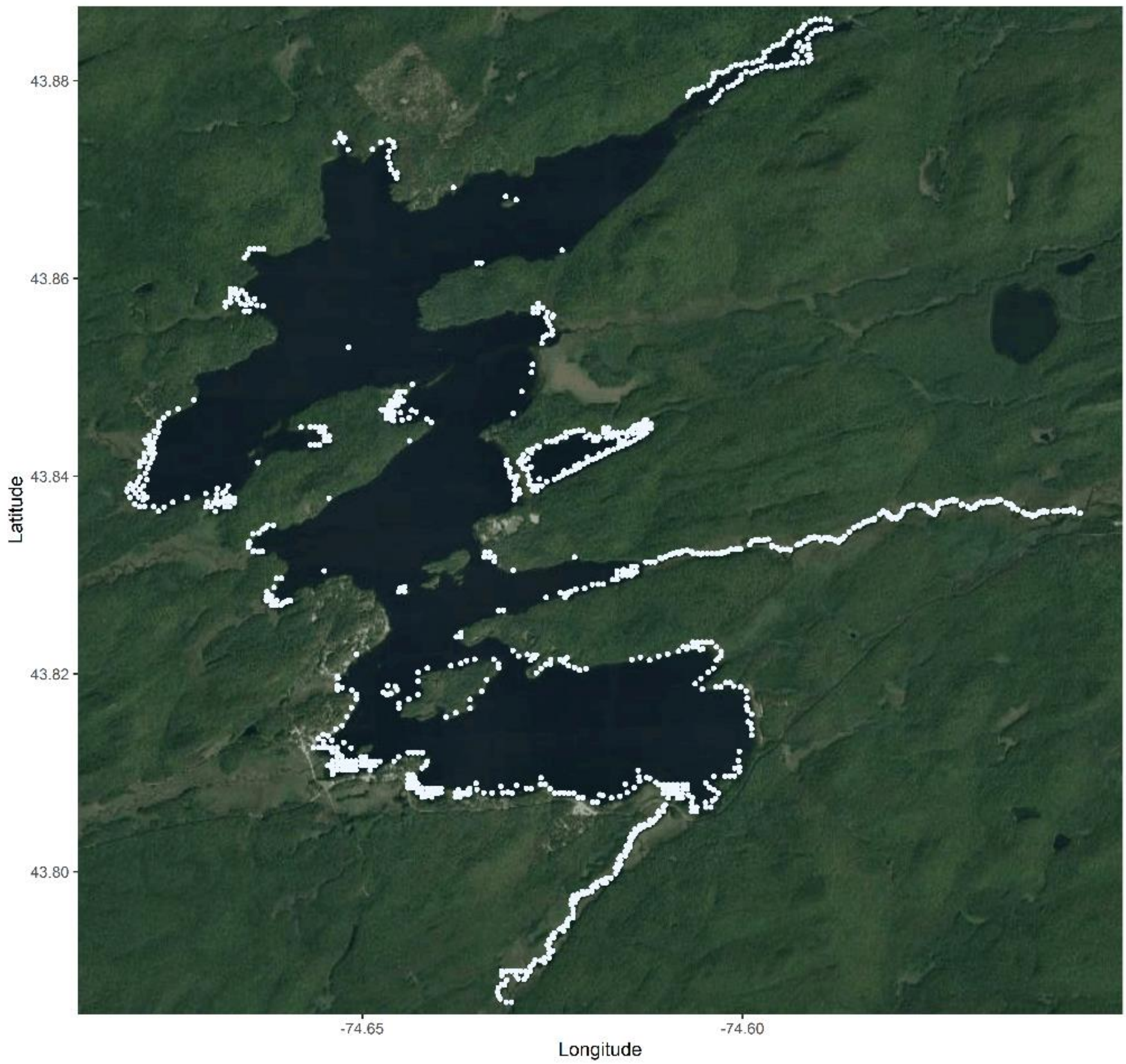
Table 2 - List of Species Present 2020

Rare	**Frequent**	**Common**	**Abundant**
(<10 observations)	**(10-50 observations)**	**(50-200 observations)**	**(>200 observations)**
Elodea sp	*Najas flexilis*	*Brasenia schreberi*	*Juncus sp.**
Equisetum sp	*Nitella sp*	*Eleocharis acicularis*	*Schoenoplectus subterminalis**
Filamentous algae	*Potamogeton natans*	*Eleocharis robbinsii**	*Myriophyllum heterophyllum*
Isoetes sp	*Sagittaria sp (2)*	*Eriocaulon aquaticum*	*Nymphaea odorata*
Lobelia dortmanna	*Utricularia macrorhiza*	*(Nothing present)*	*Pontederia cordata*
Myriophyllum alterniflorum	*Utricularia resupinata*	*Nuphar variegata*	*Sparganium sp (2)*
Myriophyllum humile		*Nymphoides cordata*	*Schoenoplectus sps.*
Myriophyllum tenellum		*Potamogeton amplifolius*	
Potamogeton pusillus		*Potamogeton epihydrus*	
Potamogeton robbinsii		*Potamogeton perfoliatus*	
Typha sp		*Utricularia inflata***	
Utricularia geminiscapa		*Utricularia purpurea*	
Utricularia gibba			
Utricularia intermedia			
Utricularia minor			

*Note that *Eleocharis robbinsii* and *Schoenoplectus subterminalis* are very difficult to distinguish from one another, particularly in the field where they occupy the same aquatic habitats. The rapid pace of the plant survey did not allow extensive amount of time to distinguish one from the other, and thus, results of the two of these species are often overlapping, based mostly on the growth habits of the plants observed. Both species appear frequently present. Similarly, Juncus species are difficult to identify and occasionally hybridize. Most of the Juncus found was identified as *J. militaris*, but there were several shorter patches in Sucker Brook Cove and Eldon Lake that were tentatively identified as *J. pelocarpus* and/or *J. brevicaudatus.*

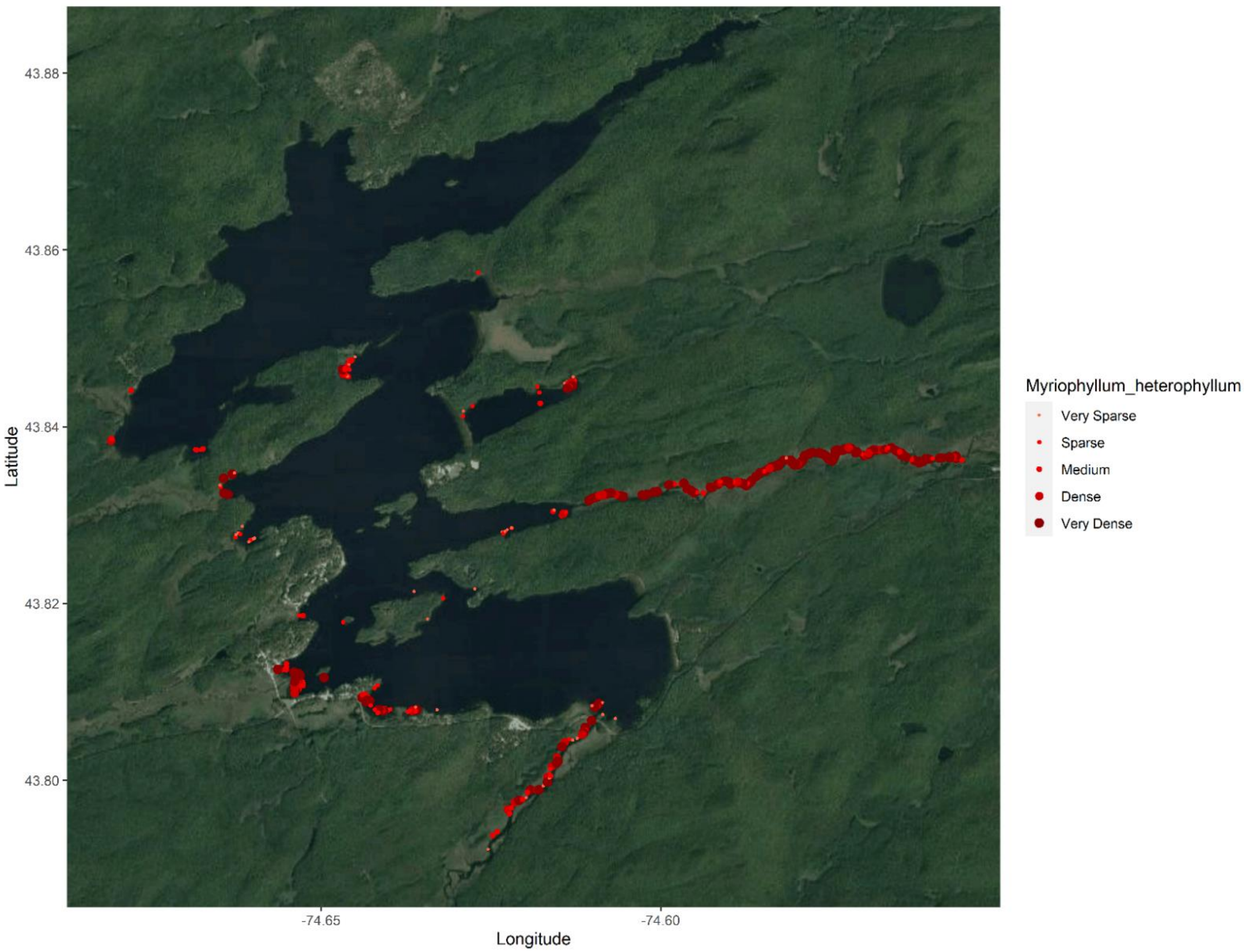
**The initial survey results shared with the RLPF board members distinguished between *Utricularia radiata* and *U. inflata*. *U. radiata* is sometimes referred to as a sub-species of *Utricularia inflata*, but most taxonomists believe them to be two distinct species. The major observable difference between the two species is the size of the plant, and the growth habit. *Utricularia radiata* tends to be more delicate and greener, with smaller branches, where *U. inflata* is large and robust and usually very brown with purplish upper-coloring. The major distinguishing feature is the plant's surface float and flowers, which are not commonly present. After careful consideration, all of the questionable *U. radiata* plants were considered to be *U. inflata*.

Map 6. All NEAR 2020 Survey Waypoints



2020 Invasive & Nuisance Plant Species Survey Results

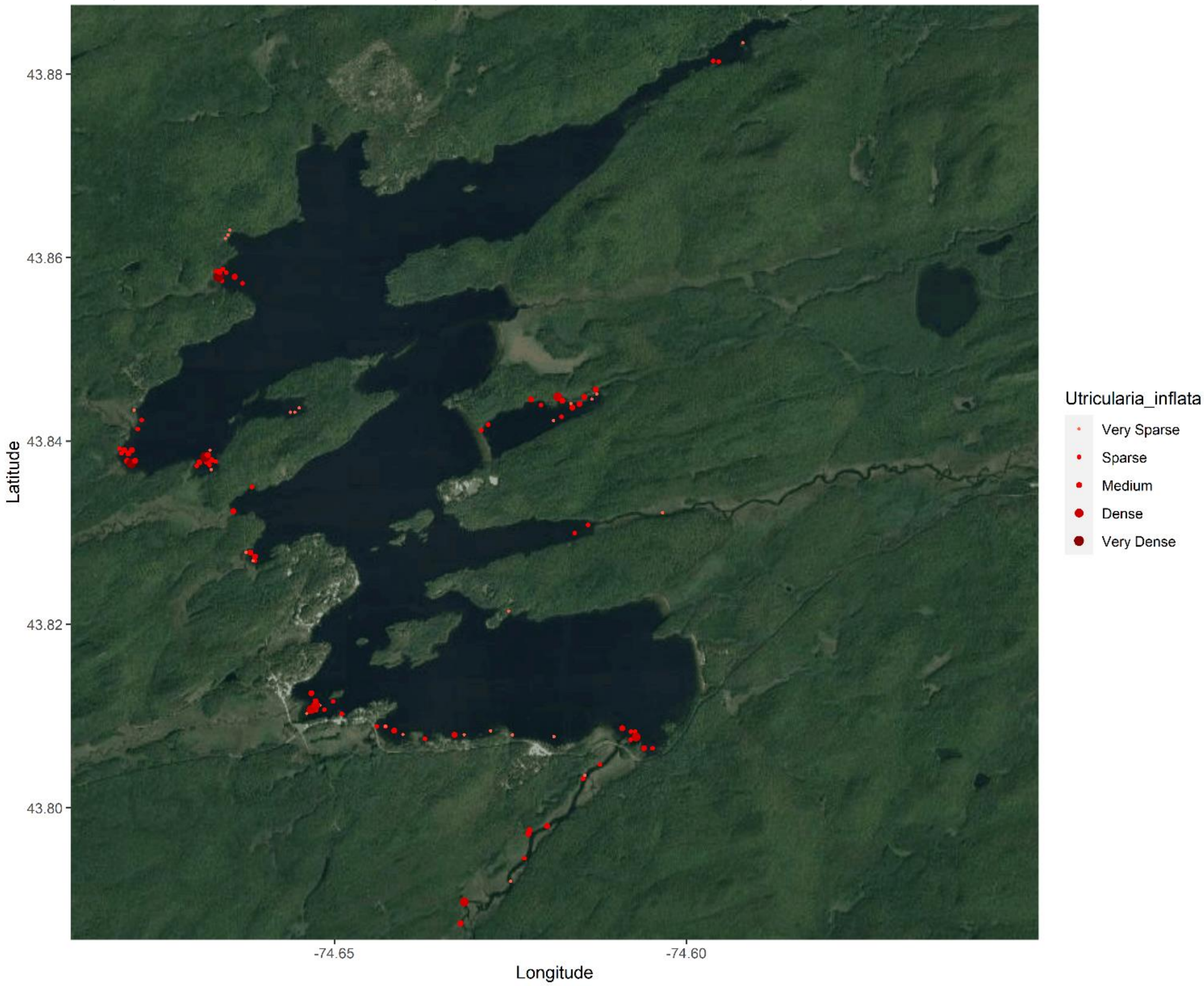
Map 7 - NEAR 2020 Invasive VLM Locations



Map 8. Raquette Lake: **<u>Marion River</u>** – Variable milfoil (*Myriophyllum heterophyllum*)

Map 9. Raquette Lake: **<u>South Inlet</u>** – Variable milfoil (*Myriophyllum heterophyllum*)

Map 10 - NEAR 2020 Nuisance Inflated Bladderwort (*Utricularia inflata*) Locations



Inflated Bladderwort (*Utricularia inflata*) is not classified as an invasive species in the state of New York, despite it being considered non-native and potentially invasive in other regional northeastern states. There is still debate about how long the species, which is native to the southeastern United States and westward to eastern Texas[8], has been present in northeastern areas. The species has been potentially introduced and found in multiple places in Massachusetts, New York State, and Connecticut. There are very few records of the species in VT, ME, NH[6]. In some lakes in the Adirondack Park, it is a dominant species[9]. The potential impact of *U. inflata* in New York and New England is uncertain. It is a competitive plant that has the potential to impact and outcompete other plant species, reduce biodiversity, and impede recreation. Its rootless, sprawling growth-form allows it to cover and shade out other macrophytes. Continued monitoring of this plant will provide valuable information as to its future success, spread, and ecological impact.

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[8] https://www.mass.gov/doc/swollen-bladderwort-0/download

[9] Titus, J.E. and David J. Grisé. 2009. The Invasive Freshwater Macrophyte Utricularia inflata (Inflated Bladderwort) Dominates Adirondack Mountain Lake Sites. The Journal of the Torrey Botanical Society, Vol. 136, No. 4, pp. 479-486.

Overview of Survey Results Comparison

This section serves as an overview of the historical plant survey data comparison to the 2020 survey results. Additional details and descriptions from the 2020 survey results are woven into the Habitat-Specific Management & 2020 Survey Results section, as it is important to discuss survey results in terms of aquatic plant management.

It is critical to acknowledge the differences in survey and mapping methods between the 2020 and historical surveys. The 2020 survey methods are explicitly detailed in Appendix B, so that these methods can be reproduced in future survey years. The waypoint-specific classification of density employed in the 2020 survey is somewhat of a subjective measurement, with error ranges from person to person. The framework for defining plant density is provided in the methods description, but ideally one individual should be responsible for density determinations across an entire survey and across survey years. It may not always be practical, but that is the best way to ensure consistency and comparability from year to year.

Overall, the 1933 survey did a phenomenal job of establishing a baseline species list. Unfortunately, however, the 1933 results do not have distribution information on native aquatic plants. It provides good overall relative abundance data for the lake as a whole, but one cannot say definitively if the 1933 frequency categories compare uniformly to the 2020 frequencies. Regardless, all species found during the 2020 NEAR survey are compared in the table below. The species marked with an * in the 2020 column were not recorded, but are likely still present – these species are shoreline wetland plants that NEAR considered not "in" Raquette Lake. Abundance category rankings for 2020 are defined in Table 2.

Table 3 - Comparison of All Plant Surveys

	NYDEC	Titus & Grise, 2009[10]		AWI	NEAR
Grand List	**1933**	**1983**	**1999/2000**	**2016**	**2020**
Brasenia schreberi	Frequent	Present	Present	Present	Common
Carex rostrata	Common				*
Dulichium arundinaceum	Common				*
Eleocharis acicularis	Common	Present	Present	Present	Common
Eleocharis palustris	Common				
Eleocharis robbinsii		Present	Present	Present	Common
Elodea (canadensis)	Rare	Present	Present		Rare
Equisetum (limosum/fluviatile sp.)	Rare				Rare
Eriocaulon aquaticum (septangulare)	Abundant	Present	Present	Present	Common
Gratiola aurea	Rare				
Isoetes (sp./echinoepora)	Frequent	Present	Present	Present	Rare
Juncus sp. (militaris)		Present			Abundant
Juncus sp. (brevicaudatus)	Frequent				NA
Juncus sp. (perlocarpus)	Common	Present			NA
Lobelia dortmanna	Common	Present	Present	Present	Rare
Mariscus mariscoides	Frequent				*
Megalodonta beckii (now *Bidens beckii)*	Rare				

[10] Surveys confined to Beaver Bay and Eldon Lake, snorkel surveys (did not document emergent wetland species)

Myriophyllum alterniflorum	Rare				Rare
Myriophyllum farwellii	Rare				
Myriophyllum heterophyllum		Present	Present	Present	Abundant
Myriophyllum humile (possibly M. farwellii)		Present	Present		Rare
Myriophyllum tenellum	Common	Present	Present	Present	Rare
Najas flexilis (sp.)	Frequent	Present	Present	Present	Frequent
Nitella sp.				Present	Frequent
Nuphar microphyllus	Rare				
Nuphar variegata	Common	Present	Present	Present	Common
Nuphar (Nymphozanthus) advena	Common				
Nuphar (Nymphozanthus) rubrodiscus	Frequent				
Nymphaea odorata	Common	Present	Present	Present	Abundant
Nymphoides cordata (lacunosum)	Frequent	Present	Present	Present	Common
Pontederia cordata	Common	Present	Present		Abundant
Potamogeton amplifolius	Rare	Present	Present	Present	Common
Potamogeton bicupulatus		Present			
Potamogeten dimorphous (spirillus)	Rare	Present	Present		
Potamogeton epihydrus	Frequent	Present		Present	Common
Potamogeton gramineus				Present	
Potamogeton natans	Frequent			Present	Frequent
Potamogeton perfoliatus		Present	Present	Present	Common
Potamogeton praelongus		Present			
Potamogeton pusillus	Rare	Present	Present	Present	Rare
Potamogeten richardsonii	Frequent				
Potamogeton robbinsii	Frequent	Present		Present	Rare
Ranunculus reptans	Frequent	Present	Present		
Sagittaria sp (graminea)	Frequent	Present	Present	Present	Frequent
Sagittaria sp (latifolia)	Frequent				Frequent
Schoenoplectus (Scirpus) americanus	Rare	Present	Present		Abundant
Schoenoplectus (Scirpus) subterminalis	Common				
Sparganium sp (americanum)	Common				
Sparganium angustifolium	Common	Present	Present	Present	Abundant
Sparganium sp (fluctuans)	Common				
Typha sp					Rare
Utricularia geminiscapa					Rare
Utricularia gibba					Rare
Utricularia inflata			Present	Present	Common
Utricularia intermedia			Present	Present	Rare
Utricularia macrorhiza (vulgaris)	Frequent	Present	Present	Present	Frequent
Utricularia minor	Present				Rare
Utricularia purpurea	Common	Present	Present	Present	Common
Utricularia resupinata	Frequent	Present	Present	Present	Frequent
Vallisneria americana	Rare	Present	Present		
60 (including several wetland plants)	**46**	**33**	**29**	**27**	**39 (42)**

Plant abundance is defined for each management area in the 2016 survey, and although several attempts were made to compare 2016 abundance data to 2020, it was not possible to draw reasonable conclusions on lake-wide species frequencies and density changes. The abundance categories published per "Bed ID" do not proportionally translate to the lake-wide frequency or specific waypoint abundances tabulated from the 2020 survey.

Without putting too much weight on the lake-wide abundance data comparisons, it does appear that shoreline emergent plants, and plants associated with growth in less than 2ft of water, are becoming more abundant. This is to be expected over nearly ninety years of lake change. Species like *Pontederia cordata* (Pickerel weed), *Nymphaea odorata* (White water lily), Juncas spp. and Schoenoplectus sp. (shoreline rushes) appear to have become more abundant. In terms of rarer species in Raquette Lake, it is extremely difficult to compare these surveys. The ability to find and sample rare species in a lake is heavily dependent on the survey effort, how hard one looks, and the ability of a surveyor to spot unique plants from a distance or from knowledge of specific habitats (knowing where to look). Similarly, there have been some taxonomic changes since the 1933 survey, and there are also chances of misidentification, particularly among narrow-leaf pondweeds in the Potamogeton genus or more rare native Milfoils.

In terms of comparing invasive Variable-leaf milfoil across the 2016 and 2020 surveys, it is not straight forward. The difficulty with the 2016 survey is the method used to draw polygons of the native and invasive species coverages in certain areas. The 2016 survey employed the "polygon" mapping method, which maps an entire cove or bay littoral zone with a single species density rating. When a species is extremely variable in its growth across a bay or shoreline, this type of polygon mapping is common. Polygon maps have varied degrees of accuracy. In many cases, instead of drawing a polygon around a bed of VLM (like in the 2020 Marion River survey maps), the polygon is drawn to cover the entire area, with a significant buffer zone around where the AIS is actually documented. The 2020 survey results were intended to be displayed using point-data – not interpolating VLM growth between waypoints by drawing large polygons that misrepresent the size of a continuous VLM bed. In the Marion and South Inlets, 2020 polygons were drawn, but aimed to stick to less than a 5ft buffer around the actual VLM beds and indicated which parts of beds are more or less dense. Even still, these inlet polygons are only as accurate as one's field measurements, notes, and ability to translate point data into polygons in GIS programs.

Prior surveys provided inadequate information to be able to track the expansion of VLM since its documentation in 1983. The 2016 VLM polygons are too coarse to compare to 2020 VLM abundance. Recent 2018-2019 volunteer survey efforts have refined the survey process and the new 2020 survey guidelines from APIPP are sufficient to track the expansion or decline of VLM from now on. https://adkinvasives.com/data/files/Documents/APIPP-AQUATIC-INVASIVE-SPECIES-Manual-2020.pdf

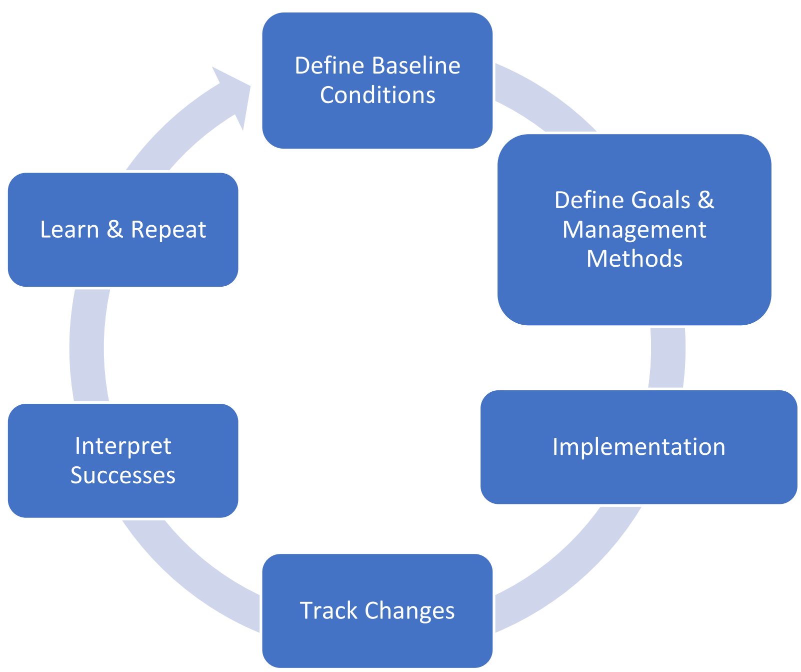
It is also important to acknowledge the difference in survey quality resulting from volunteers versus experts. There was concern among RLPF board members regarding the 2021 volunteer surveyors not finding certain VLM patches that were found by NEAR in 2020. It is improbable that VLM patches have been reduced without management intervention, particularly in water less impacted by ice scours (deeper than 2.5ft). It is more likely that volunteers were unsuccessful in finding certain VLM patches – sometimes sunlight, water clarity, presence of other native species, and lack of a depth sounder make it extremely difficult to find AIS, even in areas where populations are known to occur beneath the surface.

Sometimes small patches of AIS need to be surveyed underwater because they are too difficult to find during boat-surveys. Volunteer surveys can influence future Raquette AIS management, but the 2020 survey results are the foundation of the plant management plan presented in section 7.0. If the VLM patches are at all determined to be "disappearing" or highly variable from one year to another for unknown reasons, the periodic updates to the RLMP will reflect updated survey information and area-specific management goals based on current conditions. It would also present an extremely uncommon phenomenon to be studied in detail through research partnerships and improved annual VLM growth-tracking in specific areas.

6.0 Aquatic Plant Management for Raquette Lake

Adaptive management is the process of continuous learning and adjustment. It requires a community to be open to change when new information becomes available. Adaptive management uses science and objective reason to continuously improve their plant management program over time. This Lake Management Plan (LMP) attempts to define the baseline Raquette Lake plant conditions, and provides recommendations for the most reasonable steps towards defined plant management goals. When it comes to implementation, the RLPF will need to stick to distinct methods to track changes and interpret success. Methods for tracking change and evaluating success are revisited in the Evaluation of Past VLM Management section.

Figure 3. Adaptive Management



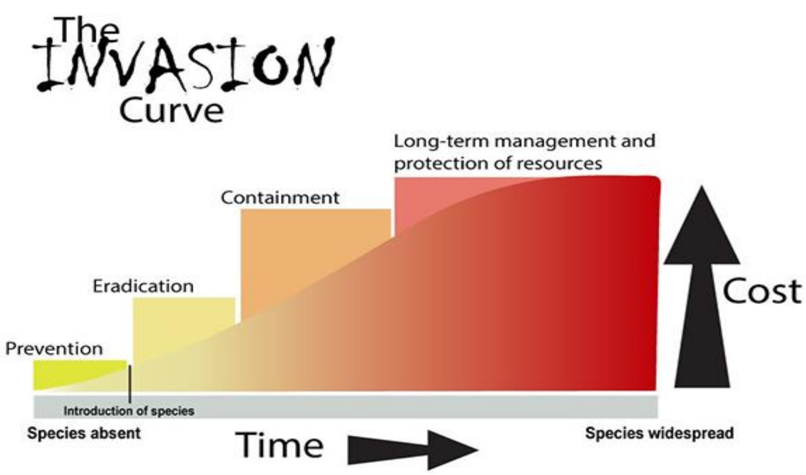
Why Manage Aquatic Invasive Plants?

Like aquatic invasive animals, it is well understood that aquatic invasive plants pose a severe risk to New York lakes. The state of NY collectively spends millions of dollars annually to combat the spread and mitigate the impact of invasive aquatic species. Many NY lake residents are also acutely aware of environmental, recreational, and aesthetic detriments that aquatic invasive plants have on waterbodies. If left unmanaged, it is common for invasive plants to out-compete native species and to expand in range and density to dominate entire littoral zones. Invasive plants diminish recreational opportunities, harm aesthetic lake value, and negatively impact local ecology. The pace and intensity with which such negative changes occur is dependent on the specific invasive species, natural background conditions, and the effectiveness of plant management efforts.

Increased use pressure on Adirondack lakes over the past two decades has dramatically increased the risk of AIS spread. Once established aquatic invasive plants are also particularly well adapted to thrive in worsening water quality conditions, which is a parallel threat that comes with increased waterbody-use pressures. In other words, as watershed and shoreline development increases in the Adirondacks, existing invasive plants will take advantage of high nutrients and disturbed littoral areas. Thankfully, Raquette Lake has a very large percentage of its shoreline that is owned by the NYS DEC and classified as Wilderness or Wild Forest lands.

The “Invasion Curve” is a commonly used infographic that aims to explain the relationship between time and cost, when dealing with new AIS infestations. There is a narrow time window where AIS is manageable and can be potentially eradicated. That time frame for total eradication is usually a couple years at maximum. There are many instances where AIS have been successfully eradicated when they have been found and managed within the first year of invasion. The only way to catch new AIS and to employ rapid response management is to have boat ramp stewards and active AIS surveys on an annual basis.

Figure 4. AIS Invasion Curve (National Park Service Graphic)



https://www.nps.gov/subjects/invasive/prevention.htm
http://senecacountycce.org/natural-resources/invasive-nuisance-species/invasion-curve

Annual surveying will, for the most part, rely on volunteers from RLPF. The ADK volunteer Lake Protectors survey program (akdinvasives.com) is quite possibly one of the best in the country. This level of organized citizen science makes natural resources management possible. It took many years for science to recognize the pervasive threat of non-native and invasive species in aquatic environments, which tend to be much more difficult to access and survey. Once the threats became well-known, and nearly overwhelming in many parts of the state, it took another several decades to allocate appropriate funding towards a cohesive public education and management effort. The people of New York recognize that their lakes, particularly the relatively pristine Adirondack lakes, need protection. That protection relies on continued state and community efforts.

Unfortunately, many of the Adirondack lakes already have at least one invasive species. The VLM at Raquette Lake was first recorded in 1983, though the actual date that the species was established may have been earlier but is undocumented. VLM was not present in 1933. In approximately 40 years, VLM has spread to many areas of the shoreline, and has come to dominate multiple bays and inlets. Similarly, potentially invasive Inflated bladderwort was first found in the late in 1999, and has since spread to large areas of the shoreline. Managing now, will prevent continued spread and further decline in Raquette Lake's uses and inherent value.

AIS Prevention, Early Detection, & Rapid Response

Boat-ramp inspection stewards are the ultimate form of prevention. Public education and use of boat washing stations are also major forms of AIS prevention that need to be prioritized for Raquette Lake users. There are three nearby boat-washing stations that should be used prior to launching a boat at Raquette Lake. The purchase of a fourth boat-wash station specifically for the Raquette Village launch does not need to be an immediate priority. The resources exist nearby for people to adequately clean their boats, and boat inspection stewards at the Village launch should continue to be prioritized. Stewards can also encourage people to wash at neighboring stations.

With the numerous boating access points at Raquette Lake, a well-defined early detection and rapid response plan is the backup to prevent new AIS from becoming established. Early detection requires dedicated time for annual surveys near public access points, and a full-lake survey at least every five years. Surveys must be designed to cover as much area as possible, in transect patterns throughout the littoral zone.

If any new aquatic invasive plant is ever found in Raquette Lake, the rapid response plan must include immediate deployment of benthic barriers (or hand-remove a small patch and then cover with barriers). Follow-up surveying will be required to ensure that a plant has not already spread to multiple patches. Certain invasive plant species spread faster than others. Prevention is the key because once a species gets into a lake, it is difficult to control, as has been seen with VLM and non-native Inflated bladderwort. Right now, Raquette Lake's alkalinity is very low and the lake is thankfully not highly susceptible to invasive Zebra mussel takeover.

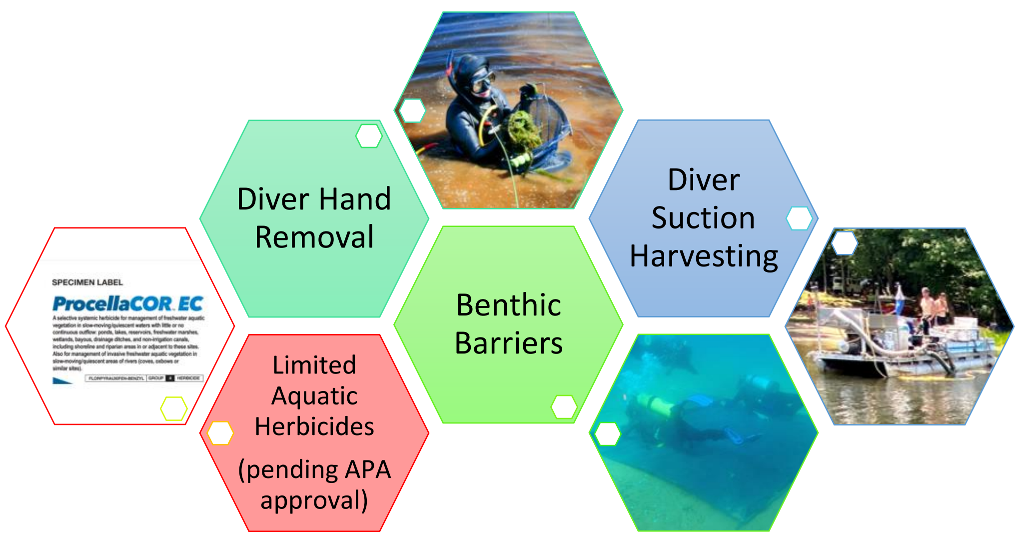
Additional prevention and public education recommendations are made in the Lake Access Points (3.0) discussion on page 8.

Plant Management Techniques

Raquette Plant Management 'Tool-Box'

There are limited options for aquatic plant management, and in many cases, it is necessary to take advantage of multiple methods as part of an integrated AIS management program. The APA has a general permit application for diver-removal and benthic-barriers use. The APA has permitted a few uses of aquatic herbicide in the Adirondack Park. Triclopyr was approved for use in Lake Luzerne in 2010. Aquatic herbicide use is evaluated on a case by case basis. The first use of ProcellaCOR, a relatively new Milfoil-specific herbicide took place in 2020. The future of ProcellaCOR use and permitting in the park is unknown, but ProcellaCOR has performed well in Variable milfoil treatments across the northeast in the last few years.

Figure 5. Available In-Lake AIS Management Techniques for Raquette Lake



APA and DEC Permit Requirements

To undertake a benthic barrier or hand harvesting project within the Adirondack Park, the APA general permit 2015G-2 is needed. Raquette Lake currently has two general permits in place (2019-66 & 2016-59). The permit information is available online at: (https://apa.ny.gov/Forms/FormDetails.cfm?recordID=52). Within 15 days of application receipt, the APA reviews applications for completeness, and if complete, the agency will issue a signed permit by mail within 10 days. Note that if a site visit is deemed necessary by the APA, the authorization timing may be longer. It is reasonable to expect that the issuance of a new permit will take at a minimum 30 days from initial submission, depending on completeness and site visit timing. The permit has several detailed stipulations and monitoring requirements and should be carefully reviewed prior to submission. It is recommended to engage APA staff prior to application submission to make sure all requirements are understood and questions are answered thoroughly.

Descriptions of AIS Control Practices

Diver Removal

Both diver hand-removal and diver-assisted suction harvesting have been used at Raquette Lake. Diver hand-removal involves underwater weeding of the lakebed and systematic removal of plants by the roots. Plants are placed into mesh bags for later disposal. This practice is best suited to small patches and single VLM plants. It is less suitable for very large VLM patches because it is labor-intensive and often cost prohibitive. Diving contractors typically charge at least $70/hour per diver and often require a minimum number of underwater labor hours. Particularly skilled divers charge upwards of $200/hour for their time.

Diver-assisted suction-harvesting (DASH) is similar, but instead of an underwater catchment bag, a suction device is used to pump the removed plants onto a platform. The plants are screened and collected onboard. Suction-harvesting is usually used in larger areas that are impractical for hand-removal. The efficacy of both diver hand-removal and DASH depends on the quality and care of diving contractors. It is easy for divers to rip AIS plant stems or to leave large patches of roots that will regrow in the following season. Due to the nature of suction-removal, there is also a certain amount of sediment disturbance that may make it difficult for divers to see what they are doing underwater. The APA general permit prohibits suction-harvesting from being used for sediment suction and the hose has to be kept sufficient distance from the bottom. For those combined reason, it is imperative that each site is revisited after the first clearing, when any sediment has settled and divers are able to see where the remaining roots and stems are located. Both diver hand-removal and DASH are moderately effective on VLM. Both techniques are not usually effective on dense growth of other AIS like Fanwort, Hydrilla, and even Eurasian milfoil, because these species have fine root structures and readily fragment when disturbed. VLM has thicker stems and slightly stronger roots, making it feasible as a plant management technique in moderately soft sediments. Sandy and gravelly sediments make it more difficult to adequately remove VLM roots.

Diver removal generally costs roughly $2,000 per day, and daily coverage and success depends heavily on plant density and sediment type. Large DASH projects are often able to negotiate lower daily rates for a higher number of work days, but rates also depend on the number of diver-crew persons used per day.

Benthic Barriers

Benthic barriers are appropriate in relatively flat, non-rocky areas. The use of benthic barriers is most common in the 4-12ft depth range. The presence of rocks, boulders, or steep slopes make barriers unable to adequately cover aquatic vegetation, particularly if the benthic barrier has a ridged frame. Both a NYDEC permit and the APA general permit are required for all uses of benthic barriers, depending on the water depth. Prior to the application of a benthic barriers, the area must be surveyed and no NY-listed Endangered, Threatened, or Rare species can be present. There are specific types of benthic barriers with holes and vents that allow sediment gas buildup from decomposition to pass through the barrier. There are other types of non-woven geotextile materials that are **semi-permeable and have been used with high success (US Fabrics 160NW geotextile)**. Based on prior experience at Raquette Lake, it is necessary to leave the barriers in place for a whole year to effectively kill VLM.

Barriers must also be appropriately weighted down with steel rebar rods or cement weights, so they do not move or become raised and billowy. Benthic barriers are most suitable for VLM patches less than 30ft in diameter, though they have been used on larger patches in many lakes with relatively good success. Barrier use on larger VLM beds will require approximately a foot of overlap in successive side-by-side barriers. Benthic barriers must ideally remain in place for at least one year to be effective in killing plant roots, but the length of time that benthic barriers are in place depends on DEC Forest Preserve lands regulations and authorizations. The closer the barrier is to lying flat and near the sediment surface, the better it will work as a VLM control technique. If the barrier does not adequately cover the edges of the VLM bed, it is possible for the plants to grow up and around the edge of the barrier. It is common for divers to remove plants around the edges of benthic barriers. Benthic barriers are also commonly used to cover areas that have been previously harvested by divers, to minimize regrowth after a large biomass removal effort, but this is not an authorized use under the APA general permit and would likely require an additional permit.

The use of barriers is very case specific and should always consider the practical difficulties and chances of success. Barriers typically cost around $2,000 per 1,000 sq. ft., depending on the type of barrier material used and cost of install. Homemade tarp-like benthic barriers are much cheaper, but are often not as effective as the heavier types of geotextile fabrics. Cheaper tarp materials are best used in very flat moderately sandy/mucky bottoms. To reduce costs, it is possible for volunteers from the RLPF to install and maintain their own benthic barriers on an annual basis.

Aquatic Herbicides

While aquatic herbicides remain controversial in society, they are incredibly effective at short-term control of invasive aquatic plants. Aquatic herbicides are used frequently in New York lakes and all other states. Aquatic herbicide use is infrequent in the Adirondack Park. The APA has approved 4 of the total 5 permit applications it has received thus far. In 2020, the APA approved a permit for the control of Eurasian milfoil in Minerva Lake, using a relatively new herbicide called ProcellaCOR.

People often flinch at the use of aquatic herbicides because they fear unintended consequences of chemical use in the environment. These fears are not unfounded, but residents are often surprised to realize that aquatic herbicides are the most well-regulated and most widely researched methods of aquatic plant control. Because all herbicide products must be first approved by the EPA, there is continuous rigorous testing and evaluations conducted on the implications of herbicide use on human health and the environment. If the same level of testing and research were to done on other non-chemical forms of plant management techniques, it is very likely that unintended consequences would be found. On top of the EPA registration, states have their own aquatic herbicide registration programs and requirements. Many states require even more rigorous testing on aquatic invertebrates and fish to ensure that there are no significant impacts to non-target species. ProcellaCOR has passed these stringent requirements and there is ample research on the very low-level toxicity within label use-restrictions.

Aquatic herbicides can be divided into two classes: contact and systemic. Contact herbicides are fast-acting and tend to be more board-spectrum, affecting a higher number of aquatic plant species. Contact herbicides only kill the actively growing leafy parts of the plants. Contact herbicides rarely provide more than one year of plant control. Systemic herbicides, however, are translocated into the roots. Depending on the maturity of the plant beds, systemic herbicides may eradicate a species entirely. Usually, systemic herbicides will at least provide 2-3 years of complete plant control. Systemic herbicides like Sonar (fluridone) are often used to target specific species of aquatic plants. For instance, both Hydrilla and Eurasian milfoil are sensitive to low doses of Sonar that are relatively harmless to most native species. Fluridone treatments, supervised by the US Army Corps of Engineers, have been used multiple years in a row at low concentrations to eradicate Hydrilla from certain California lakes. Sonar has not yet been used in the Adirondack Park, but the APA will review any proposal put before it in accordance with its established permit application review processes.

ProcellaCOR, the herbicide permitted for Eurasian milfoil treatment in 2020 in Minerva Lake, is considered a systemic herbicide for milfoil treatments, but it acts much quicker than Sonar. The state of New Hampshire Department of Environmental Conservation has researched the multi-year effectiveness of ProcellaCOR on VLM and found good control at low dosages. If residents are interested in learning more about ProcellaCOR the state of Massachusetts has well-researched public information about toxicity testing and potential impacts the environment and non-target species.

*Plant Management Techniques **NOT** Recommended for Raquette Lake*

It may seem strange to include a section that describes various aquatic plant management techniques that are NOT recommended for Raquette Lake. Though, experience from other lake communities suggests that it is important to provide information and reasoning against certain techniques that are not appropriate for a specific lake. The following techniques for aquatic plant management are very common. These techniques are practiced widely in New York and many other states, but are not appropriate for Raquette. Raquette is a relatively pristine waterbody with overall low aquatic plant growth and high species richness. The following techniques are usually used as a 'last resort,' where a lake has become entirely consumed by aquatic plant growth and invasive species.

These techniques are discussed for informational purposes only.

Mechanical harvesting –NOT Recommended

Mechanical harvesting involves a truck-sized floating lawn-mower-like machine that cuts plants beneath the water line. Mechanical harvesters are usually used as a last resort plant control method, where biomass is so great that boating access is severely limited. Mechanical harvesting is extremely messy and creates fragments that will spread to new areas of the lake. This technique is not species selective, and effects are short lived. Constant mechanical cutting is required because aquatic invasive plants have high regrowth rates when cut. There are many different types of mechanical harvesting machines in existence, but cutting and roller machines work similarly.

Triploid Grass Carp –NOT Recommended

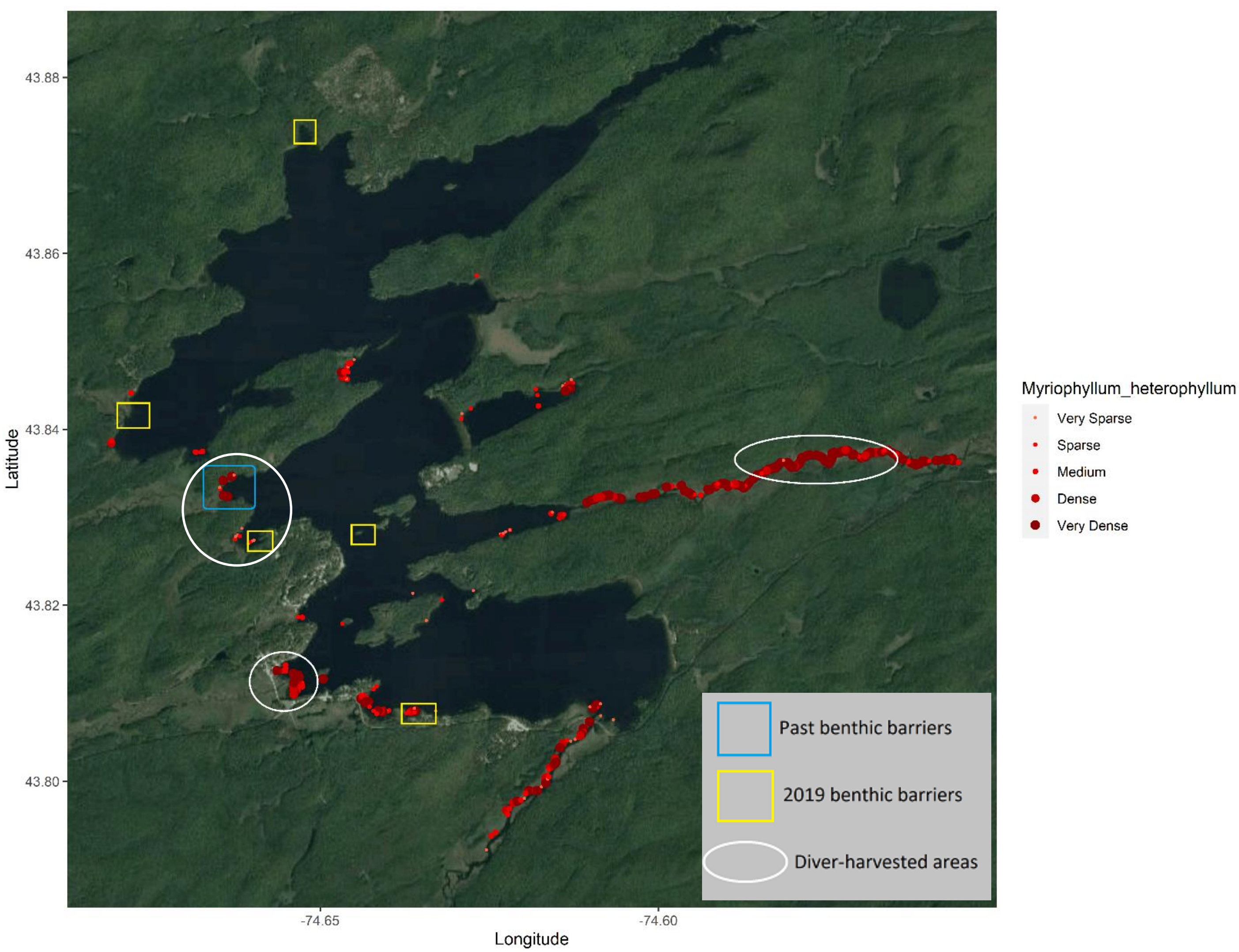
Sterile triploid grass carp use is controversial. Grass carp are widely used in large artificial reservoirs or smaller man-made lakes/ponds to control invasive aquatic plant growth. However, some northern states do not allow their use. Grass carp are currently not permitted in lakes in MA, RI, NH, VT, or ME. Triploid Grass carp are permitted for use in CT and NY. NY has much wider use of grass carp than CT, however, and many of the early stocking in NY occurred in the 1990s resulted in complete eradication of all aquatic plants. Over-stocking these fish can have severe ecological consequences and the efficiency of grass carp to control invasive aquatic plants in NY is very understudied. Both invasive Variable milfoil and Inflated Bladderwort are generally considered unpalatable species for grass carp. Despite widespread use in NY, it is ecologically harmful to stock grass carp in large biodiverse natural lakes.

Evaluation of Past VLM Management Efforts

In most Adirondack lakes, the top priority is to prevent the infestation of any new aquatic invasive plants. This is achieved through boat-ramp stewards and inspections, as well as increased public education about AIS. RLPF, AWI, and APIPP have a phenomenal program for preventing new AIS. Boat-washing and inspections are key.

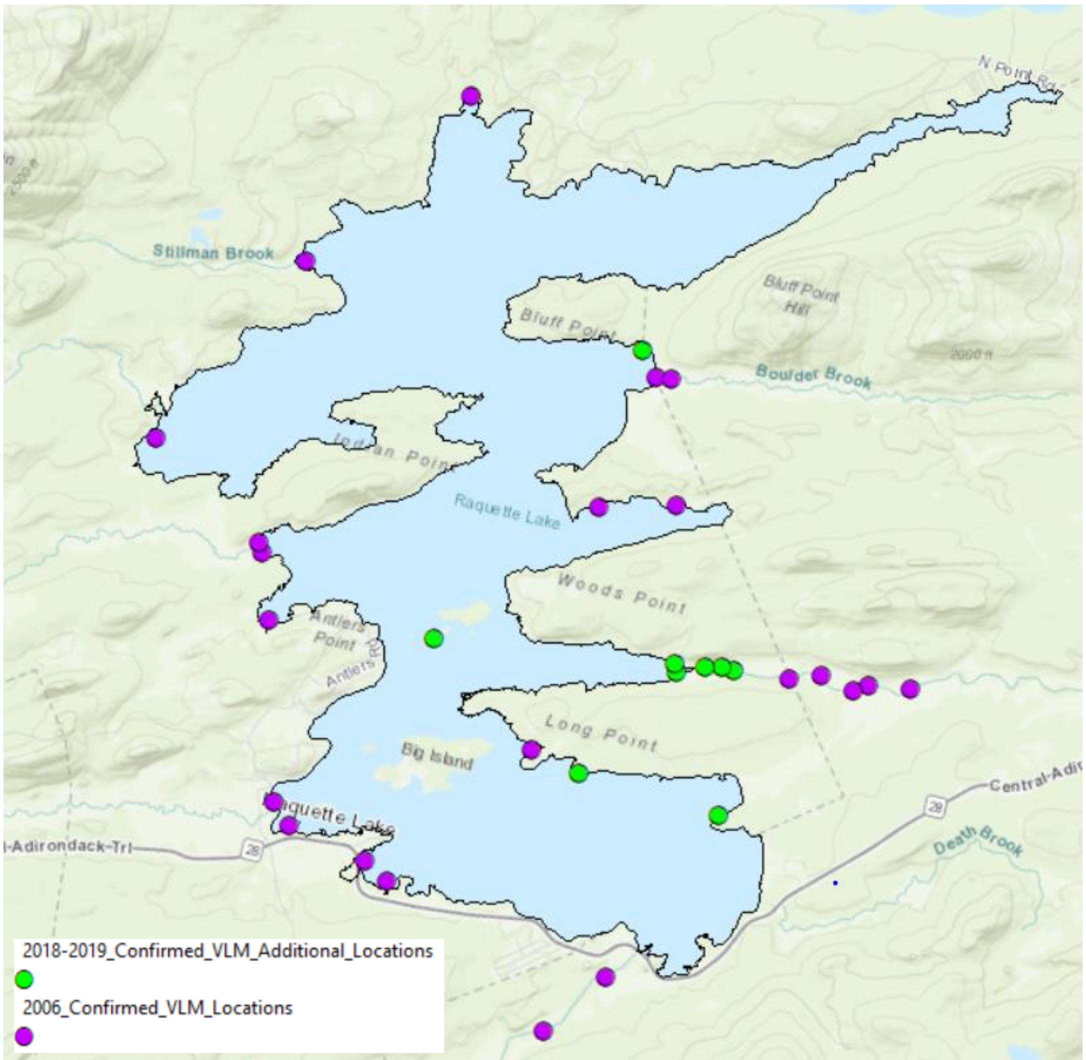
The RLPF has also put considerable effort into benthic barrier placements and diver assisted removal of invasive VLM over the past decade. The following map shows the overlay of previous areas where benthic barriers have been used (2017-2018) and/or are still present (2019-2020), on top of the 2020 VLM survey map. The map also shows the two main diver-removal areas in the Village Bay and Marion River. The two areas where benthic mats were previously used and no VLM was found were in the north central bay (Pug Bay) and Strawberry Island.

Map 11 - VLM 2020 Locations - Past Management Areas Overlay



Based on the historical documents provided by the RLPF, VLM was known to exist in the following locations in 2006 (purple points). Several additional beds were confirmed by volunteers in 2018-2019 (green points).

Map 12 - Historically Known VLM Areas from 2006 & 2018-2019 Volunteer Surveys



Based on the descriptions of benthic barrier use provided by the RLPF, barriers were used in 2017-2018 in the following amounts and locations, all placed by volunteers:

2017:

- Lonesome Bay – 3 mats
- Beaver Bay – 3 mats
- Otter Bay – unknown # mats
- Sucker Brook Bay – 3 mats
- Pug Bay – 2 biodegradable mats, and 4 non-degradable mats

2018:

- Lonesome Bay – 3 mats removed; 1 mat moved
- Beaver Bay – 3 mats moved
- Strawberry Island – 3 mats placed
- Otter Bay – unknown number of mats moved
- Sucker Brook – 3 mats removed, 100% 'kill rate'
- Pug Bay – biodegradable mats degraded, 4 mats moved to SUNY study area in 2020, good VLM control observed

In addition to the benthic barriers work, the RLPF reported approximately 15 days of Diver Assisted Suction Harvesting (DASH) VLM removal, performed by AquaLogic. Approximately 13+ tons of VLM were removed in the bay to the southeast of the Village launch site, also known as Browns Tract Inlet Bay. It is unknown how the weight of VLM was tracked. It is unknown if there were any pre- and/or post-harvesting surveys of the area. No known photos or specific data exist. Additionally, divers spent a day and half suction-harvesting in Lonesome and north Beaver Bays but there were no specific records. The 2017 diving contract work budget was reported as $12,500. Approximately $15,000 was spent on diver harvesting in 2018. Areas harvested from 2015-2018 are in the RLPF 2018 report to APA/DEC. In 2019, approximately $17,500 of diving VLM-removal contract work was performed over four weeks. The 2020 VLM-removal work was concentrated in the Marion River.

Relative Success of VLM Work to Date

The RLPF appears to have had good success with VLM control through volunteer placement and use of benthic barriers in several areas. Based on the 2020 survey data, VLM has been eradicated from the north central bay and is no longer present in Stillman Bay. Unfortunately, it is impossible to make more detailed assessments of past benthic barrier use and relative successes because there is no specific VLM survey data to evaluate. Future benthic barrier use should involve very specific VLM tracking details. GPS locations of the barriers (volunteers can use Google Maps if necessary). Place multiple GPS points/'dropped-pins' when mats are installed in more than one location within a bay, and take careful notes about the approximate sizes of the VLM beds that are being covered. VLM bed sizes can be estimated by comparing the patch sizes to the boat length.

Maintain a master word document and file to record all of the past and future benthic barrier work, including the survey/VLM patch data, GPS coordinates, dates, bottom types, observations, etc. RLPF has been tracking the diver-harvesting budget, but there are less records of the materials costs for barriers that have been used. If that information is easily accessed, RLPF should spend the time to tabulate materials costs thus far. RLPF is also encouraged to continue tracking the number of volunteers and approximate amount of time spent in each area. Volunteer time records are a great metric to track success vs. the amount of effort, which is just as important as costs tracking.

It was obvious that the 2020 Marion River DASH effort has cleared certain sections of the river, but there are unfortunately no good records of specific VLM bed sizes to compare to. As previously noted, the 2016 AWI survey VLM polygon maps are not specific enough to use to evaluate the potential changes in density and/or bed sizes after suction harvesting. Similarly, there are no formal maps of where the divers have worked in previous years.

Because diver-harvesting work is so expensive, it is absolutely critical to track the exact areas where harvesting has taken place. Surveyors must include as much observation data as possible. For instance, notes like, '*VLM bed began as a continuous band approximately 50ft long and 20ft wide, plants reached the surface and were flowering, see geotagged photos…*" help evaluate success. Follow up notes like, '*divers spent four days in BLANK area; VLM bed no longer clearly visible from the surface; in-water snorkel surveys indicate that divers did a good job removing root; only a few remaining roots were visible.*' And then the following season, it is important to note the amount of regrowth, "*One season after diver VLM removal work, roughly 30% of the original bed appears to have small regrowing VLM* *plants so far*." For future reference 20-30% regrowth after the first year of VLM removal in dense and very dense beds is common. We have seen as high as 70% regrowth in the first year after sub-optimal removal efforts.

There is no sense in spending tens of thousands of dollars on diver-harvesting of VLM unless RLPF and volunteers are prepared to document the relative effects and success. This type of pre- and post-harvesting surveying takes just a couple days per year and is invaluable information for long-term plant management.

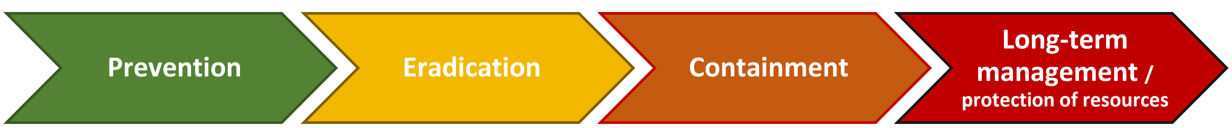
Habitat-Specific Management & 2020 Survey Results Discussion

The large size and unique shape of Raquette Lake allow for various types of littoral habitats. There are wide differences between the chemical and physical characteristics of a cove versus an exposed shoreline. These natural differences result in varied biological conditions, such as the diversity and density of aquatic macrophytes. Developed and disturbed shorelines also influence littoral areas, often by adding nutrients or through sediment disturbances or clearing of woody debris.

The littoral habitats of Raquette Lake can be separated into six main categories:

1. Riverine/Major Inlet Areas
2. Protected Coves
3. Highly Wind-swept Sandy Shores
4. Rocky / Boulder-filled Shallows
5. Exposed Shorelines with Steep Drop-offs/Narrow Littoral Zone
6. Unique Isolated Areas

This section describes the current conditions of each habitat and proposes an aquatic plant management plan – with varied degrees of recommended effort, given the ecological and recreational value of certain habitats. The plan lays out how to contain VLM without excessive use of financial resources. Certain types of littoral habitat are more vulnerable to VLM spread and dominance than others. For that reason, **each type of habitat designation and respective locations in Raquette Lake were assigned a management "Phase" or "Goal" based on the US National Parks Service modified invasion curve**. These goals are suggestions, and are designed to be revised over time.



The AIS invasion curve typically refers to a waterbody as a whole, but the process of infestation and strategy of management equally applies to specific areas within a lake. Assigned "Phases" should be revisited and tracked over time based on future efforts to control VLM. This plan does not include widespread management of non-native Inflated bladderwort because there is still confusion as to if it should be managed as an invasive aquatic plant species. When two VLM "Phases" are given to a site, it indicates that a site may change between Containment and Eradication efforts based on available resources in a particular year – time and money. Keeping AIS from regrowing or spreading requires annual effort. Similarly, a site may be considered in the "Long-term management" phase, where the goal is to minimize negative impacts to ecology and recreation while protecting limited resources. Such "Long-term management" will have to draw upon strategies of "Containment" in a way that is economically reasonable. In areas where Prevention is the main goal, there will be years where a new VLM plant is located and eradication becomes necessary. Lake managers must appreciate that waterbodies are dynamic systems, and area-specific plant management goals will shift slightly from one "Phase" to another in the future.

Major Inlets: Marion & South Rivers

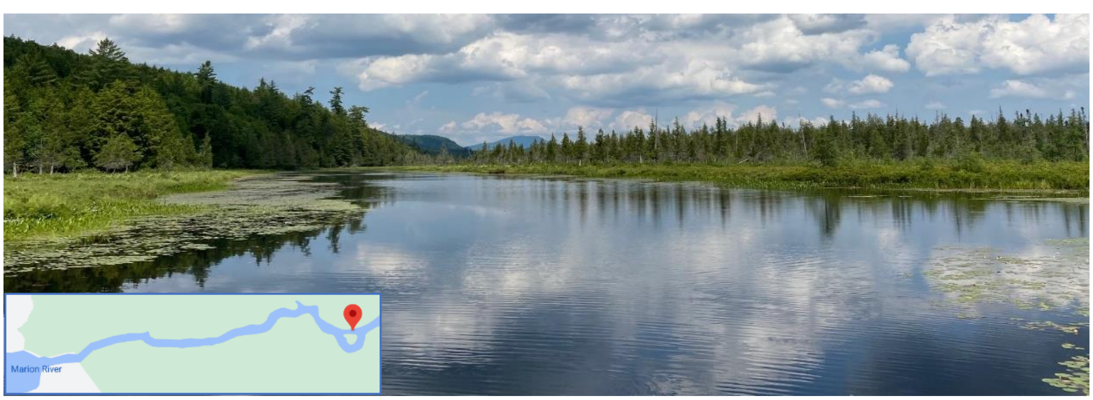
VLM Long-term Management / ***Containment***

The Marion River and South Inlet are the two major riverine habitats. Both are heavily infested with VLM (Maps 8 and 9, pg. 20). Though smaller, the Brown's track and Beaver Bay inlets also fall into this category. The smaller inlets were unfortunately not surveyed due to limited funds in 2020, but can be assigned a management "Phase" in the future.

The mouths of both the Marion and South inlets are shallow and are characterized by resilient aquatic plant species that thrive in semi-deltaic mucky areas. Species diversity in wetland-dominated slow-moving riverine habitats tends to be high, which is exactly what was observed at Raquette. The Marion River contained 17 different species, and the South Inlet contained over 25 species of aquatic plants, of 39+ species that were found during the entire Raquette survey. For clarification purposes, there were two species of Sagittaria and two species of Sparganium that were found during the 2020 survey, but the total species list combines those species in each genus because positive species-level identification was not possible in the field. Most of these plants lacked certain identifying characteristics but were almost certainly *Sagittaria graminea*, *S. latifolia*, and *Sparganium fluctuans*, *S. americanum*.

Photo 1. South Inlet Plant Community, just upstream of Rt. 28

Photo 2. Marion River, dense shoreline vegetation along wetland transition edge



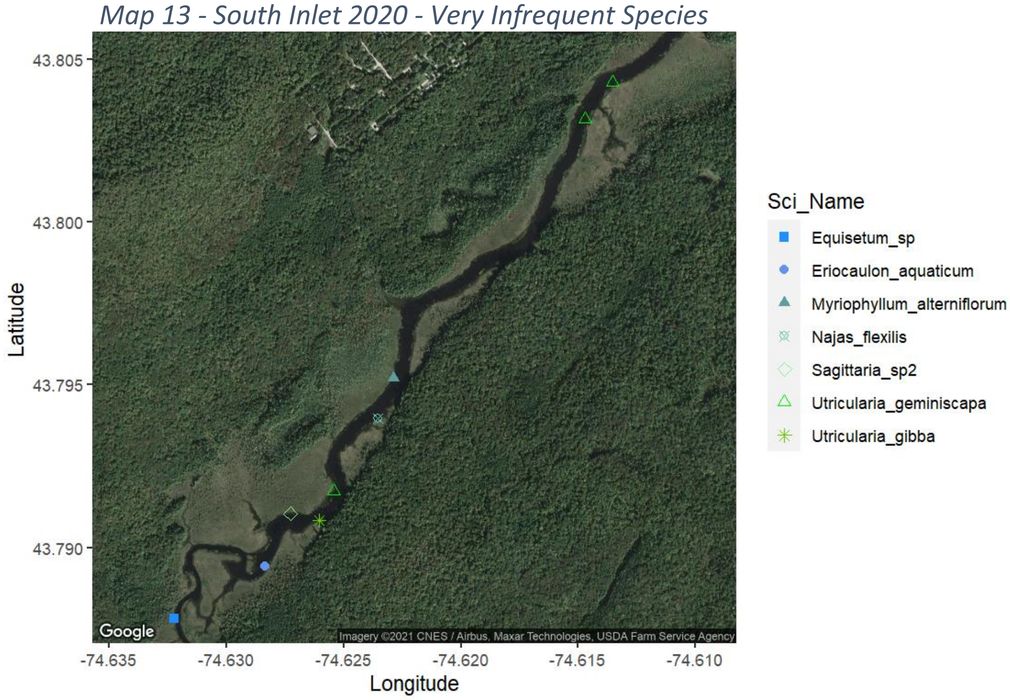
Both inlets are unfortunately infested with large populations of invasive Variable-leaf milfoil (VLM) and are classified as long-term management zones because there is a very low likelihood of eliminating VLM from these inlets, and both areas will quickly use up financial resources. The inlets are somewhat on the cusp of being classified as "containment zones" because there is still ample area in both inlets that does not have VLM, but such containment requires better long-term monitoring to periodically assess the expansion of VLM and impact on both navigation and native species. It is uncertain if the potential ecological harm is worth the very high inevitable expenditures for these areas.

The high species diversity in each of the inlets is encouraging, and suggests that the large biomass of the other aquatic plant species has slowed total take-over of VLM over time. Because management of VLM in both of these rivers is extremely cost-prohibitive, and the recent impacts of VLM on these inlets are not fully understood, we recommend that the RLPF stop management in the Marion River for the next few years and use funds for management of in-lake areas. The 2020 survey, with the specific maps of VLM coverage in each inlet, will serve as a baseline assessment. Methods employed in the 2020 survey should be repeated for future surveys.

Protecting the high species diversity of the Marion and South Inlets should be considered a long-term ecological management goal. Eight species in the South Inlet were found at just a one or a couple waypoints; these species were also found in locations where VLM was not located. The Marion and South inlets should be surveyed frequently enough, potentially every three years, to ensure that the species richness and diversity is not declining over time due to continued VLM takeover. Species richness is often used as a metric of ecosystem stability. The 1933 aquatic plant survey found many of these species, but the historical information is not specific enough to determine if these species are becoming more or less frequent over time.

Similarly, the VLM data prior to 2020 was not specific enough to determine if invasive VLM is continuing to expand in the Marion or South Inlets, or if VLM had been majorly reduced after extensive Marion River diver suction-harvesting efforts. Future surveys should be designed to answer those questions. Refer back to the Overview of Survey Results Comparison section for a discussion about past and present data.

Map 13 - South Inlet 2020 - Very Infrequent Species



Protected Coves

Otter Bay

Containment

The Otter Bay area is considered a medium priority. Otter Bay is close to the highly trafficked area of the Raquette Village Cove. The VLM beds in this bay were not consistent, some were very large and dense, and other VLM patches were small and manageable. Diver-assisted suction harvesting can be used to remove dense beds of VLM in this area, but it is unrealistic to expect to achieve long-term VLM eradication in this area with suction harvesting or hand-removal. Dense beds of VLM will continuously regrow from broken stems and root structures, particularly if divers are not making at least two follow-up trips in a season. It is possible to eradicate smaller patches of VLM, usually less than 30ft in diameter. But large continuous swaths of VLM are extremely resistant and will regrow annually, albeit usually with less biomass for a year or two after a large-scale diver-assisted removal effort.

To conserve resources, it would be best of RLPF used benthic barriers to continue to tackle smaller VLM patches in this cove. It is unrealistic to expect to cover such a large area with benthic barriers at one time and this will be a multi-year *Containment* effort. All the while, volunteers must continue to survey the area annually to ensure that the VLM does not continue to expand or become a severe hazard to lake uses – mainly swimming, fishing, and boating in this cove.

In 2021, there was a question as to if certain Otter Bay patches of VLM had been naturally reduced, or if they were even present, as volunteers had a difficult time finding the patches documented in 2020. This is likely a result of water level fluctuation, poor survey conditions (clarity and cloudy weather), and the fact that volunteers did not use a depth sounding device or strategic transect search pattern in the Bay. It is improbable that any VLM patch would 'disappear' naturally. RLPF will have to reevaluate the *Containment* strategies in Otter Bay on an annual basis and make adaptations as needed.

Photo 3. Otter Bay Waterlilies and Very Dense VLM next to Sparganium sp.

Raquette Village Bay

VLM Long-term Management / ***Containment***

The Raquette Village Bay and the Browns Tract Inlet area are considered high-priority "Long-term management" zones, but management will draw upon "Containment" strategies. It will be critical to use financial resources wisely when combatting VLM in this area. Managing VLM in the village area benefits navigation and recreation, and decreases VLM transport to other areas of Raquette Lake and other waterbodies. The sediments in much of the Browns Tract Inlet area are soft and high in organic matter, which promotes prolific growth of VLM at the outer edge of the Water-lilies. The high use of the public boat launch leaves Dense and Very Dense VLM beds open to rampant fragmentation, which will ultimately continue to spread VLM to other areas. There are areas in this bay that do not currently have VLM but that could support significant VLM growth. Managing VLM in the village area gives the greatest benefit by improving navigation, recreation and by decreasing its transport to other areas and other lakes.

Like in Otter Bay, diver harvesting may be used to reduce VLM biomass and to remove VLM growing in the direct path around the boat launch. But for Sparse to Moderate VLM patches in water deeper than 4ft, we recommend using benthic barriers. Barriers are most cost effective and tend to have better control on smaller patches than suction-harvesting. The Village Bay is the only area that could be considered a future herbicide treatment zone. This area is already highly disturbed from human use, and the native species found would be resilient to treatments.

The near-continuously Dense and Very Dense bed of VLM at the mouth of Browns Tract can be harvested by divers around the outer edge. A good harvesting strategy begins at the deepest and more scattered VLM patches. Divers can then slowly work in towards shallower water where the beds become more cumbersome. This plan of preventing edge expansion will prevent the VLM bed from increasing over time because VLM spreads primarily through root runners. It is also recommended to harvest a narrow paddling access channel through the VLM so that the Browns Tract inlet remains accessible. Divers should do a throughout underwater search in a transect pattern across the entire littoral zone of the Village Bay. There is a high chance that single VLM plants, or very small patches, exist that were not found during the formal survey, particularly in around the 5-8ft depth range. Conserve financial resources and modify this plan on an annual basis based on access need and financial constraints.

The 2020 survey in this area was complicated by very high boat traffic. It was not possible to do as many back and forth search transects in deeper water. In the future, begin the VLM search and removal work in early June before peak boating season. VLM plants at this time will be smaller and easier for divers to remove underwater. Divers should focus on root structures and plan to return to harvested areas to scan for regrowth and remove any half-removed VLM stems or roots. In a perfect world, it is best to return to a harvested site, two weeks after the initial removal, and then two months after the second follow-up visit. These follow-up visits will remove much less biomass, but will be extremely valuable for preventing regrowth in the following seasons. Without follow-up efforts, VLM will typically regrow to moderate amounts (~30+%) after less than one season.

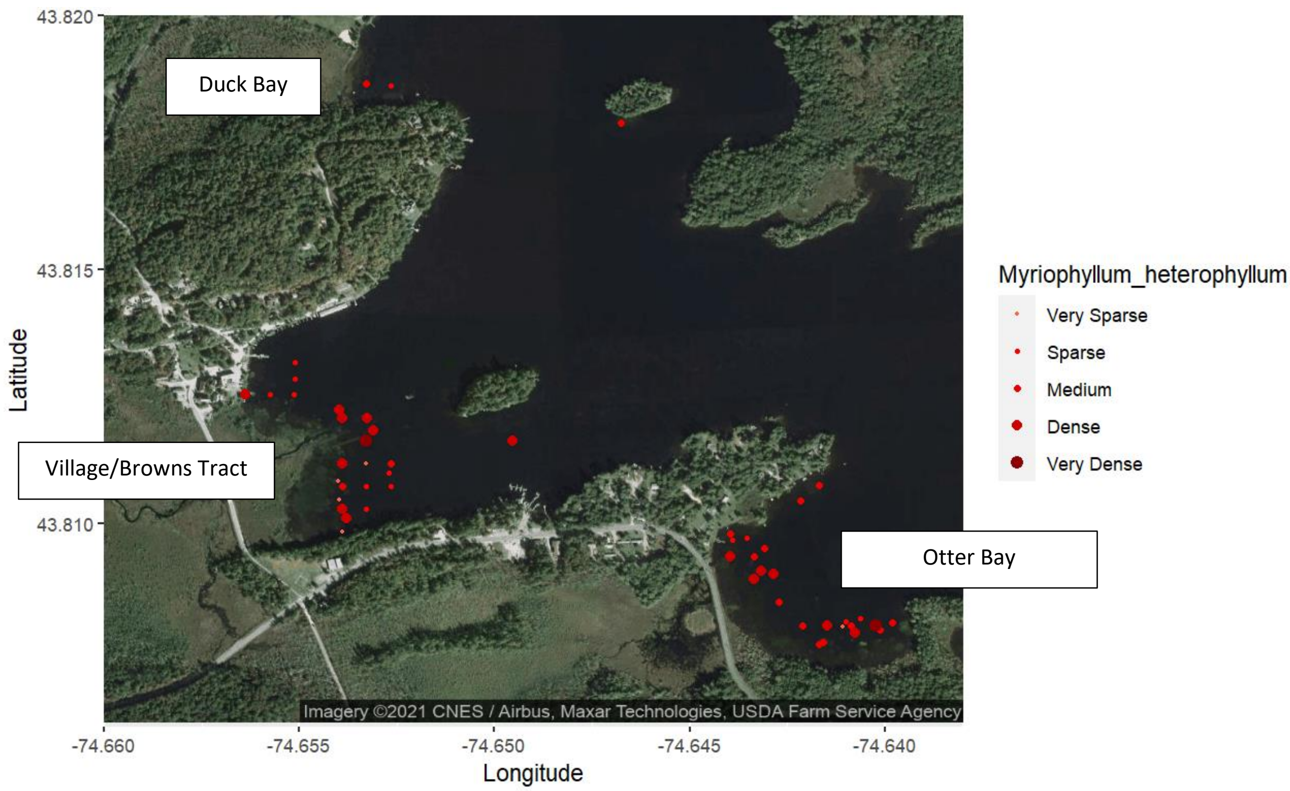
Divers must record the dewatered wet weight of the plants removed on a daily basis, as well as the number of divers in the water and hours worked. RLPF should inform divers that they are not being judged based on the amount of biomass removed, because in some cases, less biomass per day is a good thing – indicating progress in a particular area over time. Emphasis should be on adequate removal of VLM root structures, not on how much area can be incompletely cleared.

Duck Bay

VLM Eradication* / *Containment

Duck Bay, the small bay to the north of the Village Bay, should be a medium priority. It currently has a very low quantity of VLM that is fairly manageable. The Sparse and Moderate beds could be covered by benthic barriers. Benthic barrier placement in Duck Bay may take volunteers just one full day. This area is classified primarily in the "Eradication" phase because minimal effort and financial expenditures will ensure great ecological benefits long-term.

Map 14 - Otter, Village/Browns Tract, & Duck Bays 2020 - VLM



Lonesome & Beaver Bays

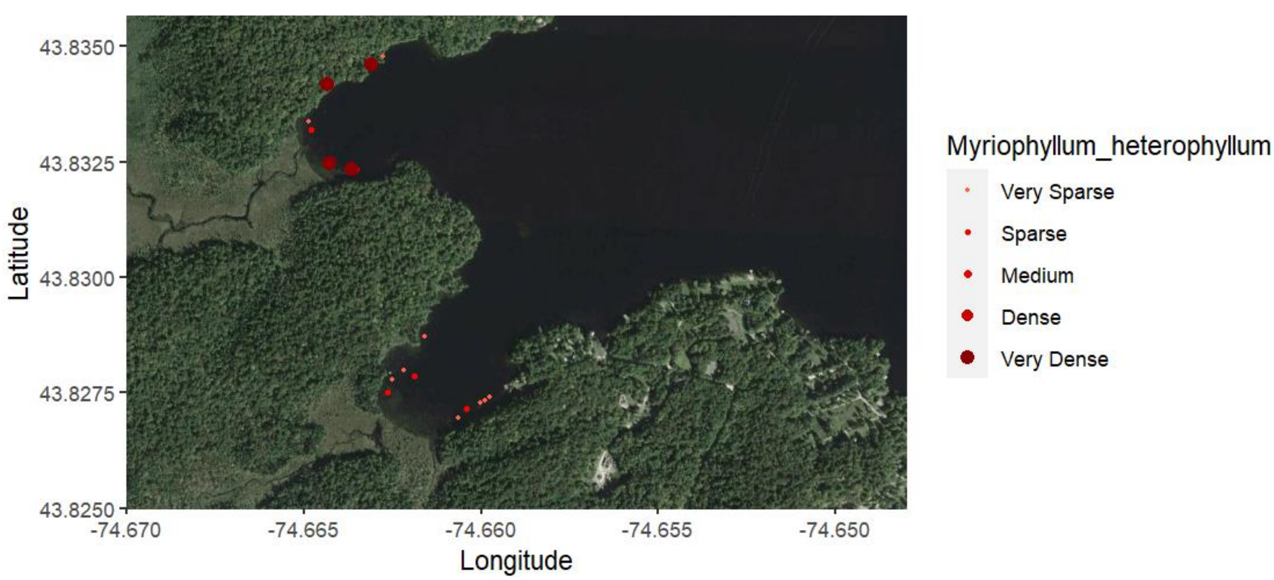
VLM Eradication / ***Containment***

The inner coves of Beaver and Lonesome Bays have sandy sediments with moderately high organic matter. Both coves have consistent inner bands of dense White waterlilies (Nymphaea odorata), and there is a very strong wetland edge transition habitat with dense beds of emergent and semi-emergent aquatic plant species. Additional dominant species across the bays are displayed in Map 15.

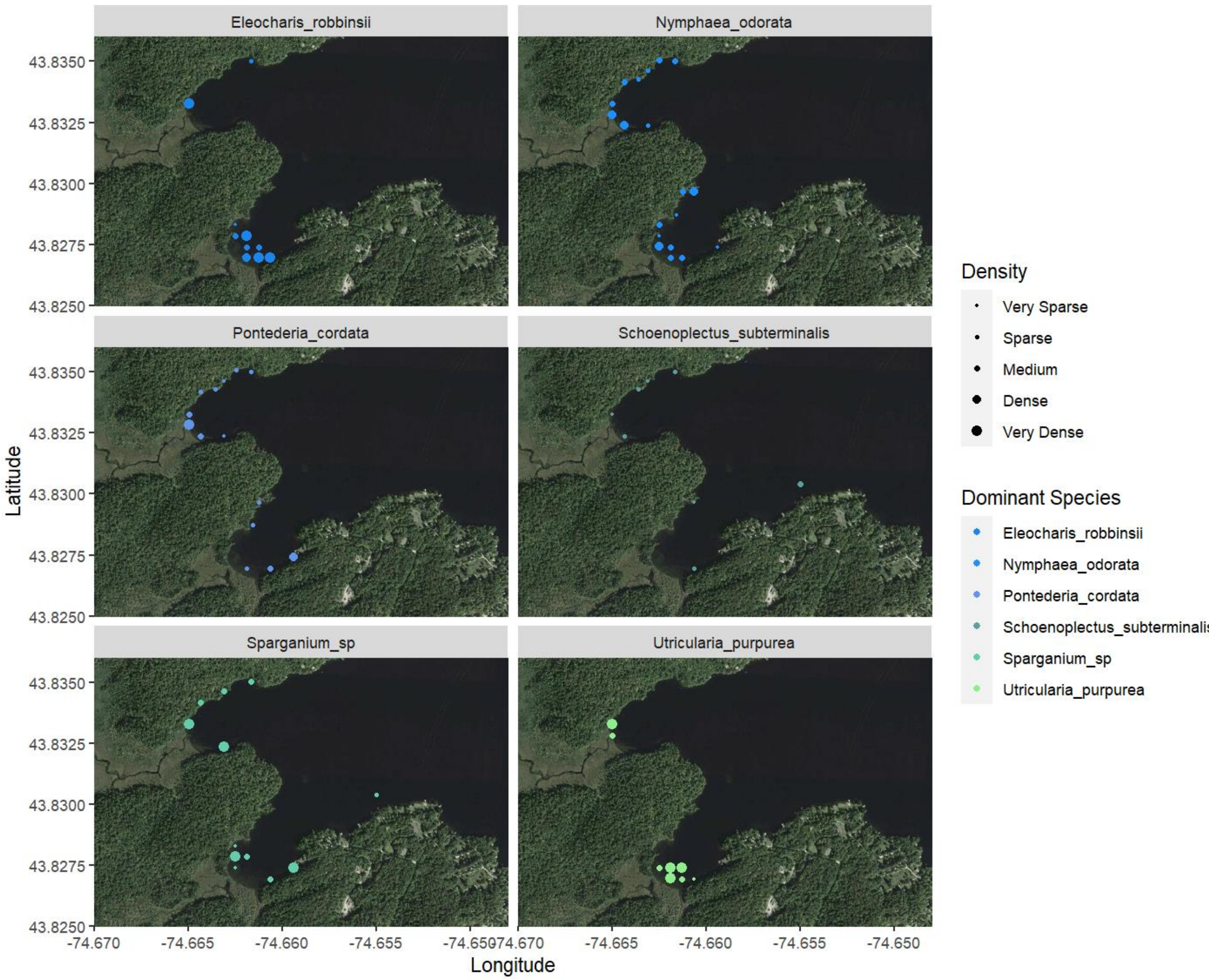
VLM management in the Lonesome Bay cove will be easier than in the northern Beaver Bay Cove because the existing Lonesome Bay VLM patches are less dense and smaller. Benthic matting is the best option for the Sparse and Very Sparse VLM patches. The Very Dense VLM beds in Beaver Bay are a secondary priority for this zone, meaning that these areas should be scanned annually to ensure the larger VLM beds are not expanding, nor feeding more frequent small patches via VLM fragmentation and nearby re-rooting. The key to VLM eradication in Lonesome Bay is to cover small patches before they grow to unmanageable sizes, which is when a ”Containment” management strategy becomes more reasonable than “Eradication.”

The benthic barriers in Lonesome Bay can be installed by volunteers and non-divers, as all patches were found in less than 6ft of water. Most of the VLM was in less than 4ft of water. Snorkeling will be required to install the deeper barriers, and it may be helpful to have one or two divers assist for a day. The Lonesome Bay benthic barrier effort should take less roughly one full weekend, depending on the number of volunteers. The barriers should be left in place for at least one year.

Map 15 - Beaver & Lonesome Bays - VLM



Map 16 - Beaver & Lonesome Bays - Dominant Species



Birch Bay

VLM Eradication / ***Containment***

There was considerable VLM found in Birch Bay, just west of Needle Island. Fortunately, many of the VLM patches were Sparse and Very Sparse. RLPF should attempt to eradicate these smaller patches of VLM before the patches are able to expand in size. Like all the other shallow protected coves, the VLM in Birch Bay has the potential to rapidly expand and outcompete native species. The presence of several Moderate, Dense, and Very Dense patches indicates that VLM coverage in Birch Bay will likely increase dramatically if left unmanaged. VLM patches and beds in Birch Bay ranged from 2.5ft to 6.5ft deep. Roughly half of the VLM patches are in less than 5ft of water, which are accessible to volunteers laying benthic barrier. Because the patches are scattered, most with relatively low biomass, benthic barriers are most appropriate. Again, the barrier must remain in place for at least one year. Effort to combat the VLM grow in Dense and Very Dense patches will necessitate more of a "Containment" strategy over time. The priority in Birch Bay is to prevent small patches from expanding and becoming less manageable.

Map 17 - Birch Bay - VLM

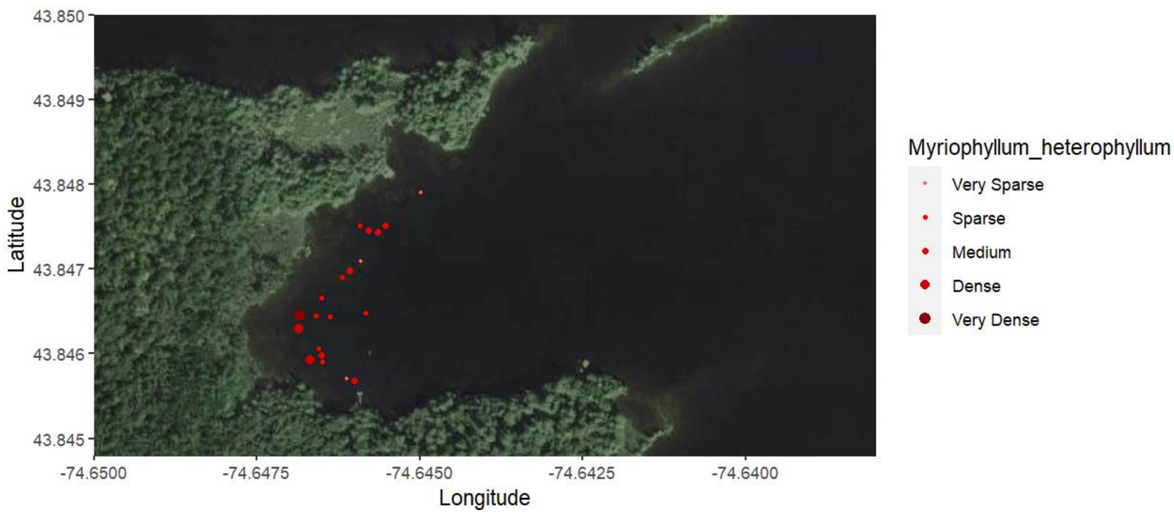


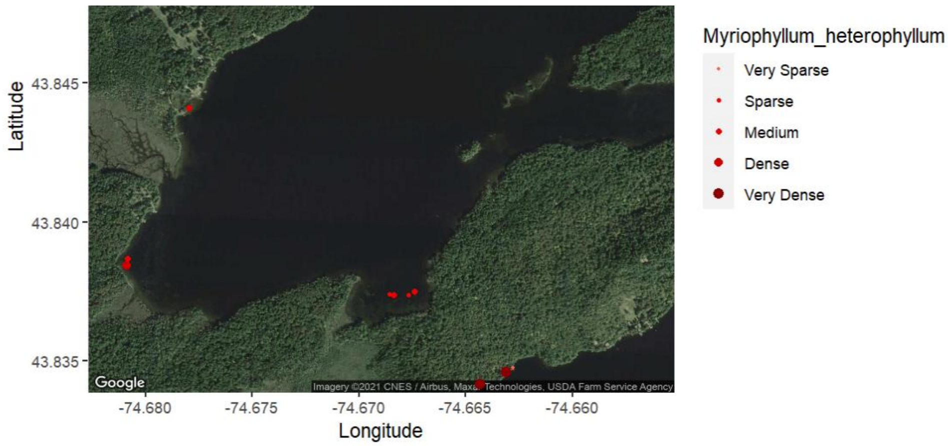
Photo 4. View Small Cove Before Birch Bay

Sucker Brook Bay

VLM Eradication

VLM was found in three distinct areas in the large Sucker Book Bay. Despite some of the patches being Medium to Dense, benthic barriers would still be appropriate in Sucker Brook Bay. Similar to other bays with moderately organic and sandy sediments, these VLM patches have the capacity to grow and become larger and denser over time if left unmanaged. An "Eradication" management strategy would help protect the natural ecology of this remote bay, without large expenditures.

Map 18 - Sucker Brook Bay 2020 - VLM



Other species in Sucker Brook Bay are Inflated bladderwort (*Utricularia inflata*) -potentially non-native and may require future management, Purple bladderwort (*Utricularia purpurea*), Pickerelweed (*Pontederia cordata*), Bullrush (*Schoenoplectus subterminalis*), Hairgrass (*Eleocharis* sp), Rush (Juncus sp), and White waterlily (*Nymphaea odorata*). Other species were also present and can be viewed in the supplementary maps provided to the RLPF. Overall, the Sucker Brook Bay is a low priority for recreational management, but VLM eradication is feasible and would provide inherent ecological benefits. <u>"Eradication" of VLM from the northern half of Raquette Lake is a good long-term ecological goal.</u>

Photo 5. Beds of Very Dense Juncus species

Additional smaller bays that were not explicily disucssed in this section can be managed similarly. The fact that no VLM was found in the small central North Bay cove is proof that benthic matting for VLM control and eradication is effective.

Wind-Swept Sandy Shores

South Bay Eastern Shoreline

VLM Prevention

The South Bay eastern shoreline has a very large section that is owned and maintained as a NYS DEC campground, Golden Beach Campground. The naturally sandy and very shallow shoreline is poor habitat for most aquatic plants. The northern mini-cove above the Golden Beach area did have a coverage of native emergent species like Bulrush (*Schoenoplectus subterminalis*), Pickerel weed (*Pontederia cordata*), Sparganium species, and Water Lobelia (*Lobelia dortmanna*). There were also several patches of Yellow water lily (*Nuphar variegata*) and Large-leaf pondweed (*Potamogeton amplifolius*).

Photo 6. NYSDEC Golden Beach Campground

https://www.dec.ny.gov/outdoor/24468.html

Rocky/boulder-filled shallows

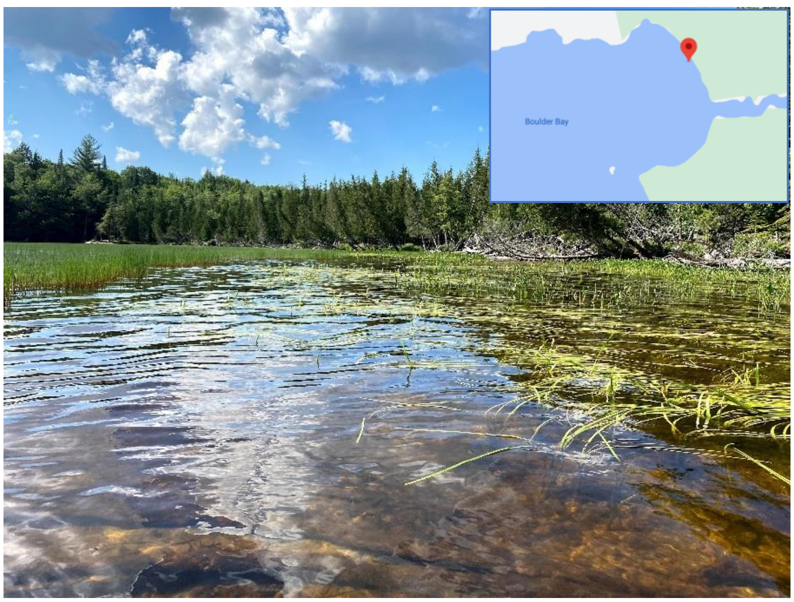
Boulder Bay

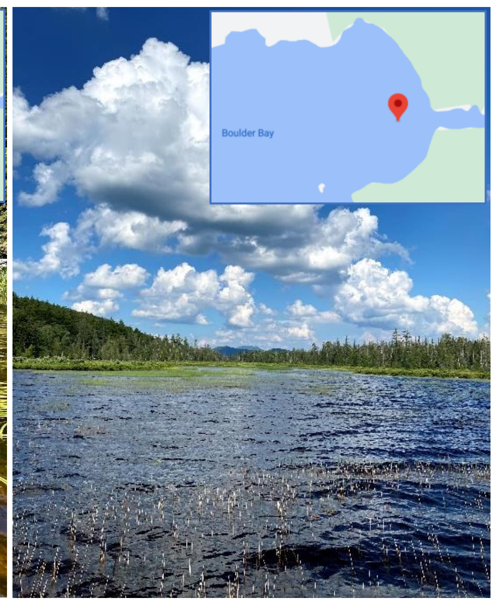
VLM Prevention / ***Eradication***

There was only one small Very Sparse patch of VLM found in Boulder Bay. The patch was in very shallow water, right next to the shore. This patch can be hand-removed without much effort. Volunteers can navigate to the patch in using provided GPS coordinates. For the entire Boulder Bay, the long-term goal is VLM prevention. Prevention involves surveying this shoreline every two years to ensure that no VLM has become established. There are historical records of VLM in the Boulder Bay inlet channel and this area should also be inspected to ensure VLM is not expanding, or to verify if it is still present. The inner cove is canoe or kayak access only.

VLM is not expected to spread significantly in the entire cove, making it a low overall management priority zone. The Boulder Bay habitat for VLM is poor, due to rocky bottom substrate. Navigating Boulder Bay is tricky and most of the area is not readily accessible to motorboats.

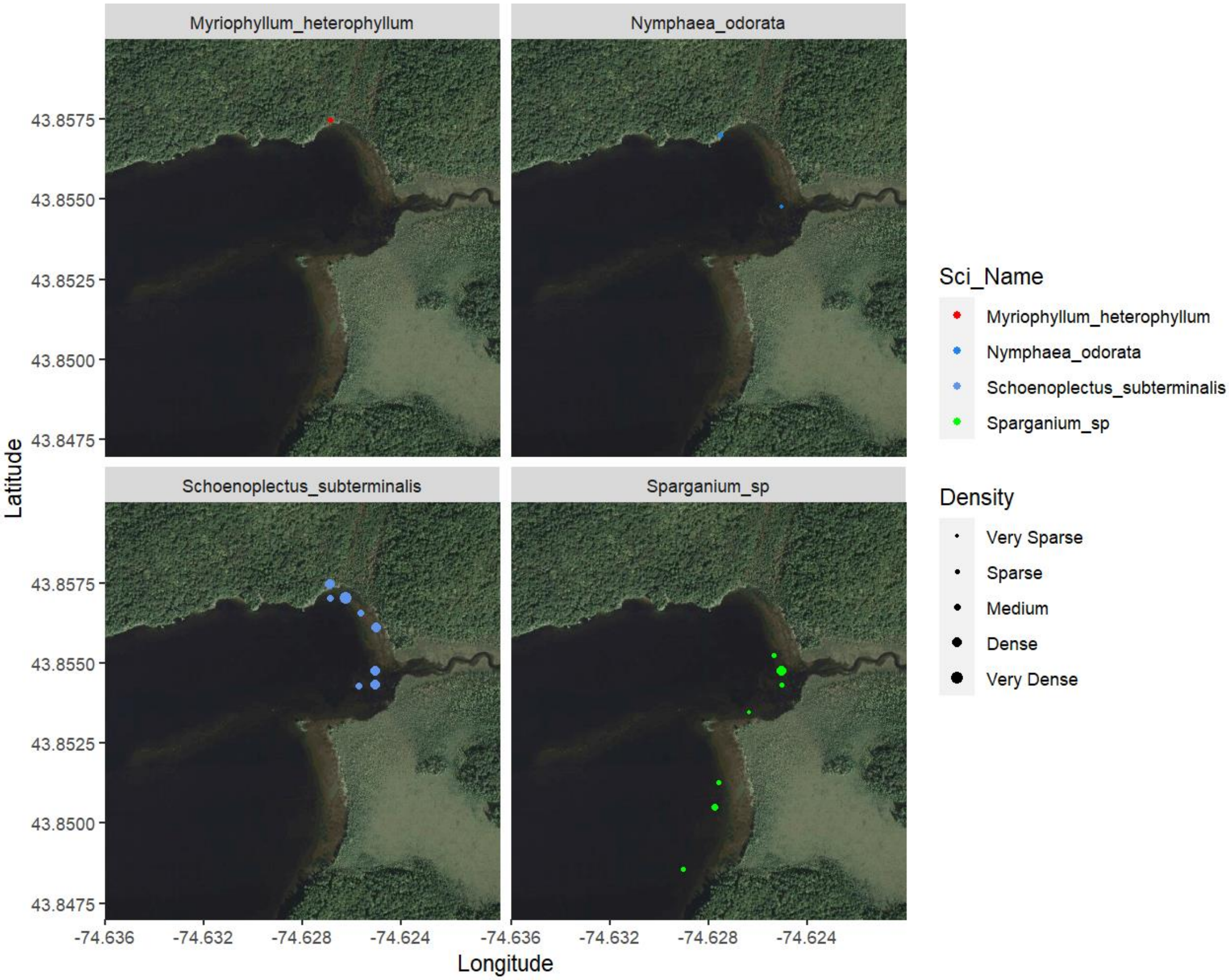
Photo 7. (A) Northern Shallow Emergent Vegetation Band in Boulder Bay; (B) View into Mouth of Boulder Brook





Note that Boulder Bay has much less organic matter in the near-shore sediments, and that the bay is more heavily windswept and exposed than the previously described bays. The gravelly sediments in Boulder Bay make it more difficult for VLM to become established, and will limit growth to lesser biomass than seen in other bays. Boulder Bay did not yet have many White waterlilies (*Nymphaea odorata*), likely because it is difficult for the lilies to become established given current sediment characteristics. Future increased prevalence of Water lilies may signal that the bay's sediments are slowly becoming more enriched with organic matter, which is a natural process over hundreds of years.

Map 19 - Boulder Bay 2020 - VLM & Other Notable Species



North Bay Outlet Channel

VLM Prevention

The long and narrow channel-like bay, on the eastern side of North Bay, eventually turns into the Raquette River. The end point is where water flows out of Raquette Lake to the north. This bay had no VLM at the time of the 2020 survey, likely because it is very far from the areas where VLM has become established. The channel is very rocky and full of large boulders. At first glance the area appears to have little VLM habitat. However, there were bands of mixed density White waterlily, Pickerel weed, and Sparganium plants. The presence of these floating-leaf and emergent species indicates that this area has pockets of shallow water that are adequate for aquatic plant growth. After decades of emergent plant growth and organic matter deposition, areas that are more protected from winds and water motion may begin to form adequate VLM habitat. AIS fragments also frequently get blown and stuck in beds of floating leaf native species, allowing fragments to then root beneath floating-leaf species during periods of calm weather.

If VLM were to infest this area of the lake, it would be able to grow around the other existing native species. The key to long-term VLM prevention in this area is to educate residents that live there. Residents should be able to identify VLM, and they can become familiar with the plants that they see around their shores from season to season. Similarly, this area should be surveyed in full roughly every two years. VLM prevention relies on early detection and rapid response.

Exposed Steep Drop-offs

VLM Prevention / ***Eradication***

Exposed shorelines with steep "drop-offs" at Raquette Lake are common along the northern shores of Northern Bay, South Bay, and Middle Bay ("The Crags"). This type of littoral zone is also common along Antlers Point, Strawberry & Osprey Islands, and some shores around the Big Island in South Bay.

These areas are characterized by relatively narrow littoral zones, where the drop-off to greater than 10ft provides less area for VLM to become established. Not all of these areas were surveyed in 2020, but VLM was found at several locations around the Big Island and a couple scattered plants around the small island to the west. VLM was difficult to see from the surface, but the down-scan SONAR was able to pick up on small patches between the rocks. These types of shores are heavily-sloped and rocky. Therefore, benthic barriers would be very difficult to place. Volunteers must evaluate each area individually when VLM is found. Diver hand-harvesting can be used for VLM eradication between the rocks. Similarly, RLFP should continue to support resident volunteers to scan these areas for VLM. Exposed steep areas are not a high priority for VLM management, because the species has limited ability to expand. Financial resources to control VLM via diver harvesting should be allocated to other priority locations in 2021, but these areas can be eradicated over time and are suspected to spread slowly.

Unique Isolated Areas

Eldon Lake

Containment / ***VLM Eradication***

Eldon Lake is a truly unique area. The lake is mostly isolated from the rest of Raquette Lake, in that there is a very shallow connected channel access to the southwestern side. There is a barrier peninsula/sandy island that separates the western side of Eldon from Raquette Lake.

After all pre-determined point-intercept waypoints were visited and surveyed, the field crew realized the importance of finding VLM that was likely lurking in the 4-8ft depth range. Eldon Lake was visibly less tannic and likely has consistently better water clarity. Such expanded light penetration will increase the littoral zone, making it easier for VLM to grow unnoticed in deeper water. Therefore, the 2020 survey spent extra time searching for VLM patches using narrow back and forth meander transects. The result was 20 variably-sized patches of VLM, mostly confined to the innermost cove.

The VLM patches that are Very Sparse, Sparse, and Medium density can be targeted for future eradication. Start by evaluating if the Eldon Lake VLM is actively spreading, which appears to be the case based on prior survey data. Benthic barriers are the most appropriate and targeted approach for small VLM patches in Eldon Lake. VLM beds that are Dense or Very Dense, are more appropriately managed via a “Containment” strategy in Eldon Lake, where large beds are inspected annually to ensure that they are not dramatically increasing in size or range, and then contained via benthic barriers or suction harvesting as needed. If the VLM from the Dense and Very Dense beds continues to grow, resources should be allocated to minimize the expansion. The 2016 APIPP survey did not find VLM in the locations found in 2020, and there was no VLM found in the 2020 survey in the location found in Eldon Lake in 2016. Eldon Lake is small enough that it should be surveyed every year. “Containment and Eradication” goals for Eldon Lake are primarily ecological and aim to preserve the unique character of Eldon Lake. It would also be advantageous to partner with a research institute or university to better study the species and change in Eldon Lake over time.

Map 20 - Eldon Lake 2020 - VLM

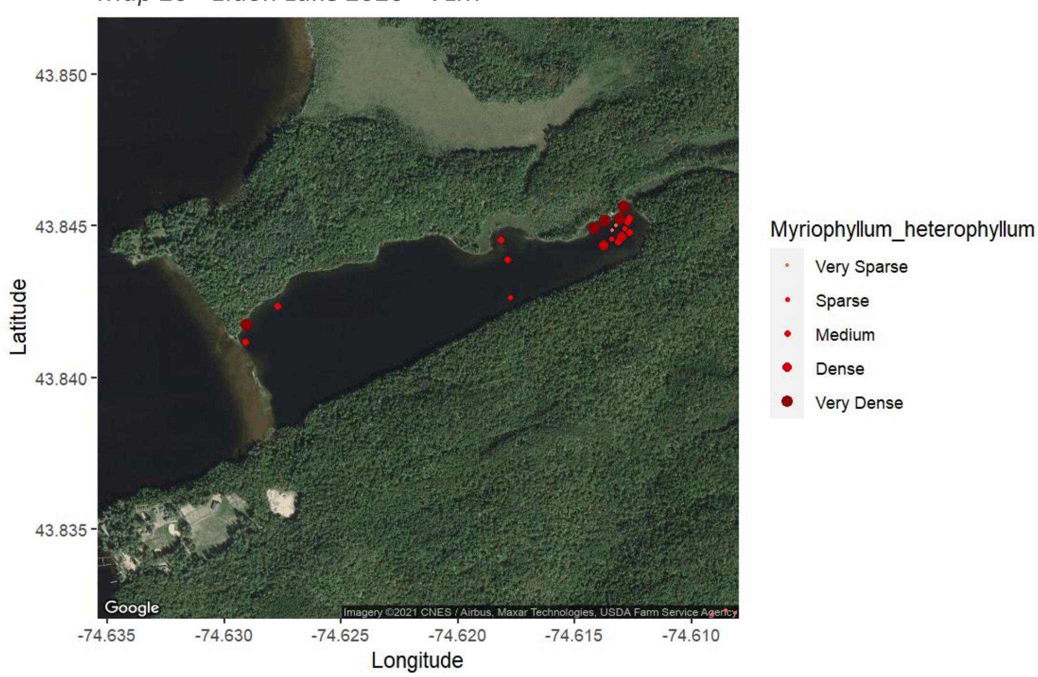
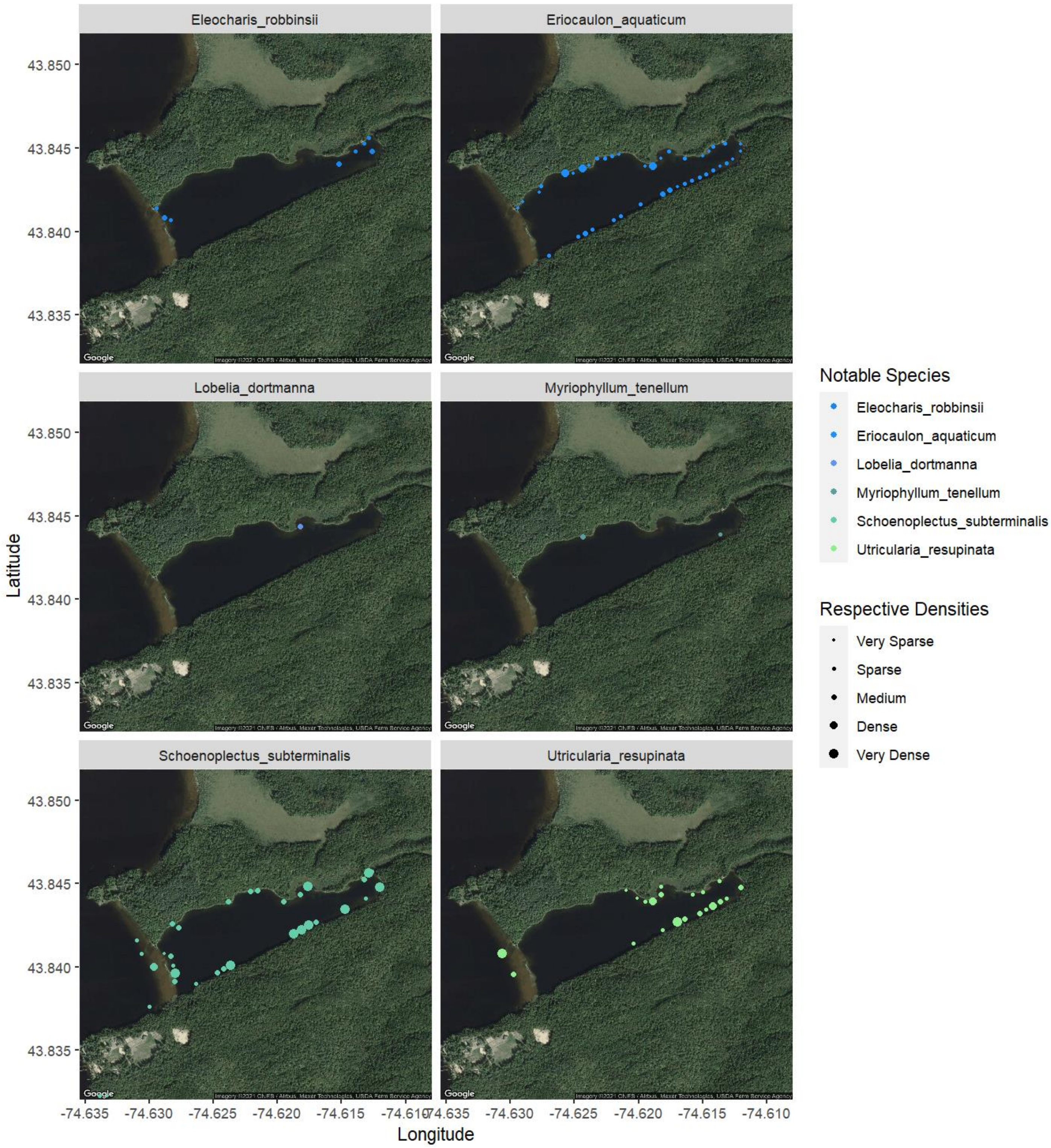


Photo 8. Eldon Lake Northern Rocky/Gravelly Shore

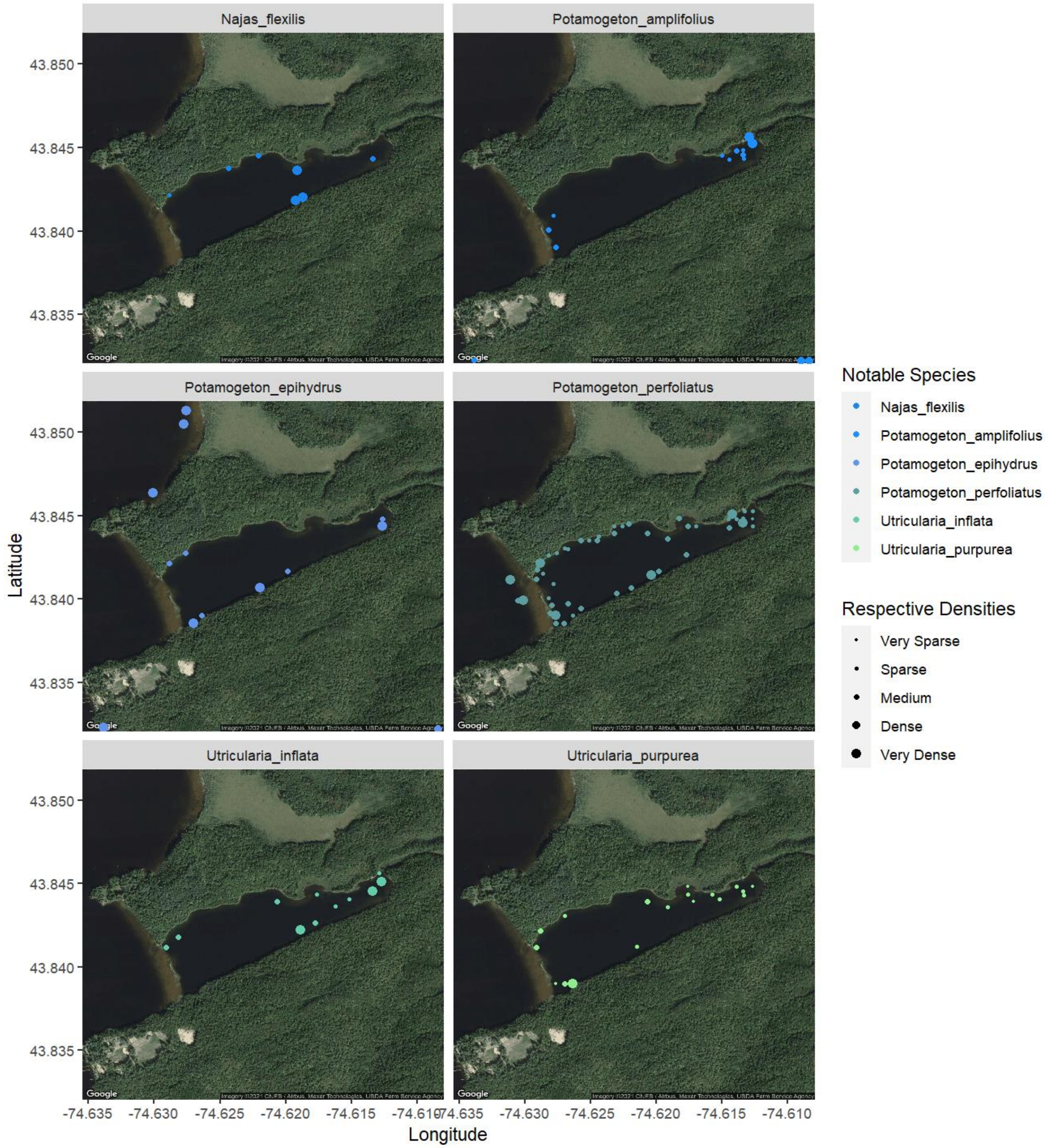
Both photos were taken along the northern shoreline of Eldon Lake, to document the exposed stony shoreline that transitions into gravelly-sandy sediments in the 1-2.5ft depth range. This northern Eldon Lake shoreline is prime habitat for Pipewort (*Eriocaulon aquaticum*), Hairgrass (*Eleocharis acicularis/robbinsii*), Threadlike grass (*Schoenoplectus subterminalis*), and Low-Bladderwort (*Utricularia resupinata*), as well as several other small infrequent species like Leafless-milfoil (*Myriophyllum tenellum*) and Water Lobelia (*Lobelia dortmanna*). Protecting the high species biodiversity is important for Eldon Lake (Map 22).

Eldon Lake was the one area where we noted a very frequent and potentially expanding coverage and increasing density of Clasping-leaf pondweed (*Potamogeton perfoliatus*). Other Potamogeton species that are also known to rapidly increase in area and density found in Eldon Lake are Ribbon-leaf pondweed (*Potamogeton epihydrus*) and Large-leaf pondweed (*P.* amplifolius). Several other species that are known to increase in frequency and density as lakes become more mesotrophic over time are shown in Map 23.

Map 21 - Eldon Lake 2020 - Unique Habitat Species



Map 22 - Eldon Lake 2020 - Dominant Species Capable of Rapid Range Expansion



Summary of Recommendations for AIS Management

Public Education & AIS Prevention - Use moderated social media and email communications to disseminate information and to increase access to, and flexibility of, the existing volunteer boat steward program. Include download-able pdf handouts about prevention of AIS spread on the RLPF website. It is important to continue to share existing materials from APIPP, DEC, and AWI. A surprising number of visitors will take advantage of available resources prior to their summer vacations.

RLPF should continue to participate in APIPP's Lake Protectors survey program. Additional resources are found at: https://www.adkinvasives.com/Get-Involved/Volunteer-With-APIPP/Lake-Protector-Corps

VLM Management in Raquette Lake

Work to **ERADICATE** VLM from Sucker Brook Bay, Boulder Bay, the Outlet Bay, exposed steep drop-off areas.

Work towards **CONTAINMENT** and possibly eventual **ERADICATION** of VLM in Eldon Lake, Duck Bay, Lonesome & Beaver Bays, and in Birch Bay. Establish strong methods of monitoring changes in VLM populations and distribution in these areas. If VLM is confirmed to be spreading and increasing in density in these bays, work to prevent the takeover of VLM in these areas.

Use **CONTAINMENT** strategies for **LONG TERM MANAGEMENT** of VLM in the Marion River, South Inlet area, the Raquette Village Bay, and Otter Bay. Prioritize navigation and boating access, which will limit the fragmentation and further spread of VLM. Pause suction harvesting efforts in the Marion River and South Inlet for several years in order to prioritize the Village and Otter Bays. Place large and clear signage for boaters at the mouths of the Marion and South Inlet, indicating boaters should clean propellors when leaving the rivers. Lean on research to determine if VLM is actively spreading in and at the mouth of the inlets.

Maintain permits for diver-harvesting and benthic barriers in VLM management zones. Inflated bladderwort (*Utricularia inflata*) is not listed as a species that can be managed under the Adirondack Park Agency General Permit 2015G-2. Any change to this legal determination must include conversations with the NY Natural Heritage Program and their determination of the species' native status.

Have divers commit to better record-keeping of weight of VLM removed from harvested areas. Ask the contractors to mark their exact work locations on a Google map and keep records for annual re-evaluations of diver harvesting successes. Continue to track all annual AIS management and adapt actions as needed.

Tracking Plant Management Progress

Standardize the reporting structure for ease of year-over-year comparisons. If diver-harvesting continues, the divers should continue to report wet weight, as a proxy for tracking biomass removal. Wet weight tends to be a more accurate metric than area. It is easy for a diving operation to claim that an area has been 'cleared,' but depending on the original VLM biomass, an area should be covered more than once in a single season. The second removal effort focuses on missed root-structures, partial stems, and any regrowth. VLM shoot length should be recorded as supplemental information during re-harvesting.

Tabulate all past and future benthic barrier work in a long-term working document. Record the square footage of benthic barrier used, the approximate sizes of the respective VLM beds before covering, and the dates. Additional photos and notes are essential metadata.

Surveying & Follow-up Monitoring

Regular surveying of management zones is required for adaptive long-term plant management. The RLPF should rely on its strong and active volunteer base to become intimately familiar with certain areas of shoreline. Any future volunteer surveying should utilize the published standard methods, as presented in the APIPP Aquatic Invasive Species Manual:
https://tnc.app.box.com/file/827975280694?s=63jhz9ga2mjuysqwnzky4xt6wh0g9gju

The survey methods described in the APIPP manual are almost identical to the meander style survey that was used to search for additional VLM between pre-determined waypoints during the 2020 survey. They also specify how to record approximate sizes of VLM beds and patches. Calm sunny days are the best days for survey visibility. Volunteers should refer to the APIPP AIS manual for tips for identification, when needed.

7.0 Funding for Plan Implementation

Lakes that are the size of Raquette Lake typically **require at least an $80,000 annual budget** for plant management, routine water quality monitoring, and limited professional oversight. Additional funds will be required for public outreach and boat-ramp AIS prevention efforts. There are many lakes that are 20 times smaller than Raquette Lake that spend $50,000 per year on lake management. In certain years, Raquette Lake may need more funds than others.

Cost Estimates for VLM Management

Estimates for Benthic Barrier "Eradication" Plan Costs

These materials costs are estimated on the high end using the US Fabrics 160NW geotextile, cheaper benthic matting materials do exist, but are not quite as effective, durable, or negatively buoyant. Similarly, size of the barriers will be different given the size and distribution of the VLM patches in each area. Small beds will not need a full 15x15ft barrier and the material can be cut to minimize material costs. Larger VLM beds will likely require larger barriers and the size of the barriers will be more determined by the ability of volunteers or laborers to transport and install the material. There may also be cost savings if material is purchased in bulk. Crew labor hours depend on the ability of the volunteers and/or contractors. Almost all of the barrier locations can be done without diving services (except roughly half of the Eldon Lake effort). RLPF could reasonably approach this entire benthic barrier plan over a three to five year time period.

Table 4 - Benthic Barrier Investment Estimates

Location	**Estimated # of Benthic Barriers (15ft+)**	**Approximate Materials Costs** (US Fabrics 160NW geotextile, framing, weights)	**Estimated Labor Hours** (for crew of 3 people)
Duck Bay	5	$4,000	8-20
Eldon Lake	20+	$16,000	24+
Lonesome & Beaver Bay	30+	$24,000	36+
Birch Bay	25	$20,000	30+
Sucker Brook Bay	10	$8,000	16-24
Isolated "Steep" Shores	6	$4,800	8-24 – location dependent
Total	**~96**	**$76,800**	***Variable***

Proposed Costs for Diver Harvesting

The harvesting strategy outlined for the Village Bay will vary substantially from year to year based on the amount of regrowth. Start with a $16,500 diver-harvesting annual budget and a very specific plan for evaluating the success of harvesting over a one-year period. The success of harvesting in the Village Bay needs to be adequately measured before expanding the diver harvesting budget and/or resuming harvesting in the inlets.

Access to Funding

The RLPF currently subsists on a combination of membership dues, donations, and limited local and state government contributions. The road ahead will require a constant source of annual income to adequately manage Raquette Lake. Raquette Lake should remain eligible for state-sponsored grant opportunities.

NYS Environmental Protection Fund

AIS & Lake Management

In 2019, the State of New York awarded over $2.8 million dollars to lake management and AIS projects through the Environmental Protection Fund. Raquette was awarded $25,500 – to fund this plan. Many other lakes of similar size received upwards of $100,000 for their lake programs and management. The State allocations for the Environmental Protect Fund (EPF) vary annually, but have been generally increasing as NY recognizes the value of protecting its natural resources.

Smart Growth

In addition to the AIS projects the NYS EPF program has a Community Smart Growth Fund, specific to the Adirondacks and Catskill regions. This type of municipal grant can be used to improve and enhance watershed development on public lands in the Raquette watershed.
https://www.dec.ny.gov/lands/103864.html

NY Adirondack PRISM / The Nature Conservancy APIPP

The Nature Conservancy (TNC) administers the NY Adirondack PRISM. TNC operates the Adirondack Park Invasive Plan Program (APIPP) and will continue to be a valuable resources for RLFP.

Local Funding

The Hamilton County Soil and Water Conservation District has provided annual resources towards water quality monitoring. This is an enormous benefit that cannot not be understated. Hamilton County SWCD also has a cost-sharing program in place to help cover the costs for landowners to implement environmental land-use practices. https://www.hamiltonswcd.org/byc-cost-share.html

The Town of Long Lake is a current financial supporter of the RLPF. As Towns with a tourist-based economy, the Town of Long Lake and the Town of Arietta should support the annual RLPF budget. It is possible to set up a special Lake Management tax district for waterfront properties and businesses. Many lakes in southern NY rely entirely on tax district funds to support their annual budget.

Donations from Local Businesses

Local businesses that derive the majority of their customer base from the local Raquette Lake economy will be allies in the ongoing effort to manage AIS and water quality. RLPF can continue to hold semi-annual fundraising rounds and solicit donations from the local business. Even small donations greatly enhance the mission of RLPF. Encourage residents to support local businesses in return.

Large Private Philanthropic Organizations

Smaller lakes are less likely candidates for grant funding from large or national philanthropic organizations. But Raquette Lake is a large and unique waterbody that should have national-level protections. The Adirondacks themselves are a rare opportunity for philanthropic dollars to make an enormous environmental impact. It is worth searching for private competitive environmental conservation grant opportunities.

NRCS RCPP

The Natural Resources Conservation Service, a branch of the United States Department of Agriculture, has a Regional Conservation Partnership Program. These grants usually focus on regional conservation priorities around the United States. While most of these partnerships involve agriculture or private forest management, the NRCS RCPP determines project eligibility based on conservation practices that improve public lands. The NRCS has recently invested in mapping sub-aqueous soils (soils formed and presently underwater), which means that the NRCS has interest the land underneath water. It is worth pursuing an inquiry to the RCPP for a potential Adirondack AIS-management partnership program.
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/rcpp/

8.0 Conclusions

This Raquette Lake Management Plan establishes long-term goals that are centered around research, public education, AIS prevention, and in-lake management. The plan provides water quality thresholds and methods to track change over time. The report presents guidance on how to limit the ecological and recreational impacts of AIS and watershed development over time, and it focuses heavily on Variable-leaf milfoil management (VLM) in key areas. Additional short-term suggested action items for VLM management are included in Appendix C. These items must be reevaluated over time, as part of the implementation of this RLMP.

Raquette Lake Preservation Foundation has the opportunity to open discussions with the NYSDEC and APA about possible Inflated bladderwort management in the future. The plant is not considered invasive in New York, and there are differing scientific opinions about if the plant is or is not actually native to the Adirondack region. It is not native to Raquette Lake or the upland watershed, which can be considered a semi-closed ecosystem. The species is rapidly spreading in Raquette Lake since its introduction roughly twenty years ago, and is known to exhibit growth patterns that arguably meet the NYS statutory definition of an *invasive species*.[11] It is possible to discuss the interpretation of law with the Invasive Species Council and Advisory Committee of New York State. Future conversations about *Utricularia inflata*, should also involve the NY Natural Heritage Program.

Overall, Raquette Lake has excellent water quality, but the lake is starting to show signs of increased productivity and deep-water hypoxia that can be carefully monitored in the future. Partnerships with universities and research institutions will become increasingly valuable. Graduate students provide a uniquely qualified labor market for large lakes.

Climate change is an ongoing threat that will exacerbate existing human impacts on land and water, including in ways we do not yet understand. The frequency and intensity of rainfall events will alter the natural flows of water, especially in areas with increased development. Despite the economic benefit of development around Raquette Lake, future lake and watershed management needs to aim for ecological and economic balance.

Conservation and development are conflicting priorities. Future development in the Raquette watershed must be approached thoughtfully, armed with environmental strategies and best management practices for sensitive land use. Lakeside living comes with a responsibility to minimize environmental damage through use of sustainable Low Impact Development techniques. A unified and persistent community effort is the best defense against declining lake conditions. More than ever, Raquette Lake requires the attention and care of the entire community.

[11] https://www.nysenate.gov/legislation/laws/ENV/9-1703

Appendix A - Raquette Lake Water Quality Assessment Details

Review of Past Water Quality Reports

The State of Hamilton County Lakes: A Statistical Analysis of Water Quality Trends, 1993-2003 (2005). Hamilton County Soil and Water Conservation District

[Cedar Eden Environmental, LLC, (2005). A Statistical Analysis of Water Quality Trends in Hamilton County Lakes, 1993-2003.]

The 2005 Cedar Eden report recognized inconsistencies in eleven years of analyzed data. The author cautions that limited data may lead to inaccurate conclusions.

The most interesting takeaway from this report is that all of the Adirondack lakes in the Hamilton County Soil and Water Conservation District program had very similar long-term trends in mean seasonal values. This could be related to the fact that Adirondack lakes are relatively pristine, with very little watershed development, and are more heavily influenced by weather than clusters of lakes in more developed regions. Clusters of highly developed lakes rarely share such similar trends over time, particularly with nutrient or chlorophyll concentrations. Weather and climate seem to be a major driver of water quality in Adirondack lakes. It should also be acknowledged that water quality parameters are typically performed in batches of samples, and there may also have been some laboratory analysis bias that was similar across lakes on an annual basis.

Mean annual alkalinity across all studied lakes was consistently higher than the mean annual calcium. The long-term regional trends across the two parameters are not visibly similar, despite calcium being a major factor in alkalinity. On a regional scale there was a very weak negative correlation between Secchi transparency and both Total Phosphorus (TP) and Chlorophyll-a (CHL) - pg. 26 of the report. Generally, there is a much better correlation, albeit not linear correlation between these variables. This lack of correlation could be related to the suspicious historical TP measurements and/or to the fact that Secchi transparency is more limited by dissolved organic matter than phytoplankton in many Adirondack lakes.

The Cedar Edan 2005 Hamilton County 10-year empirical data analysis classifies Raquette Lake as *Mesotrophic*, presumably because of low Secchi clarity and few high TP values. However, the oxygen levels at the lake bottom suggest that the lake is *Oligotrophic* (high water quality) and that observed clarity is more a natural factor of high dissolved organic matter from the watershed, despite overall low lake productivity.

NOTES ON COUNTY INTRUMENTATION & LABORATORY PROCEDURES RELEVANT TO DATA QUALITY

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pH: 1993-1997 monitoring used an Orion meter, 1998-2003 used a YSI multi-probe

Phosphorus: 1993-1998 tests used a Hach DR/3000 spectrophotometer. The report appears to have a typo that misstates the accuracy range of this device. The detection limit of this device is not low enough to test lake water samples. Although the water quality assessment did use the Hamilton County data, the historical phosphorus values prior to 1998 are extremely suspicious and likely inaccurate. The switch to the DR/4000 in 1998 was also not accurate enough to test for low-level lake water phosphorus. The DR/4000 manual estimates the detection level of orthophosphate to be 0.031mg/L. Historical Hamilton County phosphorus values did not provide suitable accuracy to detect low levels of phosphorus in the water column.

Nitrogen: There are similar low concentration concerns with historical Hamilton Country nitrogen data.

Other parameters: Chlorophyll, calcium, and aluminum were outsourced to a laboratory, indicating accurate results.

ALAP 2018 Report. Paul Smith's College Adirondack Watershed Institute

Laxson, C.L., Yerger, E.C., Regalado, S.A., and D.L. Kelting. 2019. Adirondack Lake Assessment Program: 2018 Report. Paul Smith's College Adirondack Watershed Institute. 181p

Similar to the Hamilton County SWD report, all lakes appeared to follow similar trends in water quality parameters over the years.

The State of Hamilton County Lakes: A 25-year Perspective, 1993 – 2017. Paul Smith's College Adirondack Watershed Institute

Laxson, C., Croote, L., Stewart, C., Regalado, S., and D. Kelting. 2019. *The State of Hamilton County Lakes: A 25-year Perspective, 1993 – 2017*. Paul Smith's College Adirondack Watershed Institute.

This study documented decreasing (worsening) regional Secchi clarity, yet approximately 90% of the study lakes showed a decrease in Total Phosphorus (TP). That fact alone seems to imply that many of the historical TP values are not reliable measurements. The authors acknowledge that the TP reduction is likely a result of various method changes since monitoring began, as more recent measurements are more suitable for low limits of detection necessary for lake water testing. The TP trend was not aligned with notable regional change in chlorophyll over time.

The report states that many of the Adirondack lakes are, "exhibiting a clear signal of recovery from acid deposition, including elevated pH and acid neutralizing ability." Raquette Lake is among those Adirondack lakes that appears to be recovering from acid deposition.

25-YEAR REVIEW AWI PUBLICATION HIGHLIGHTS

The AWI 2019 report provides excellent background information and descriptions about limnological principals and data types. Report visuals are very easy to understand; this report is a great public resource.

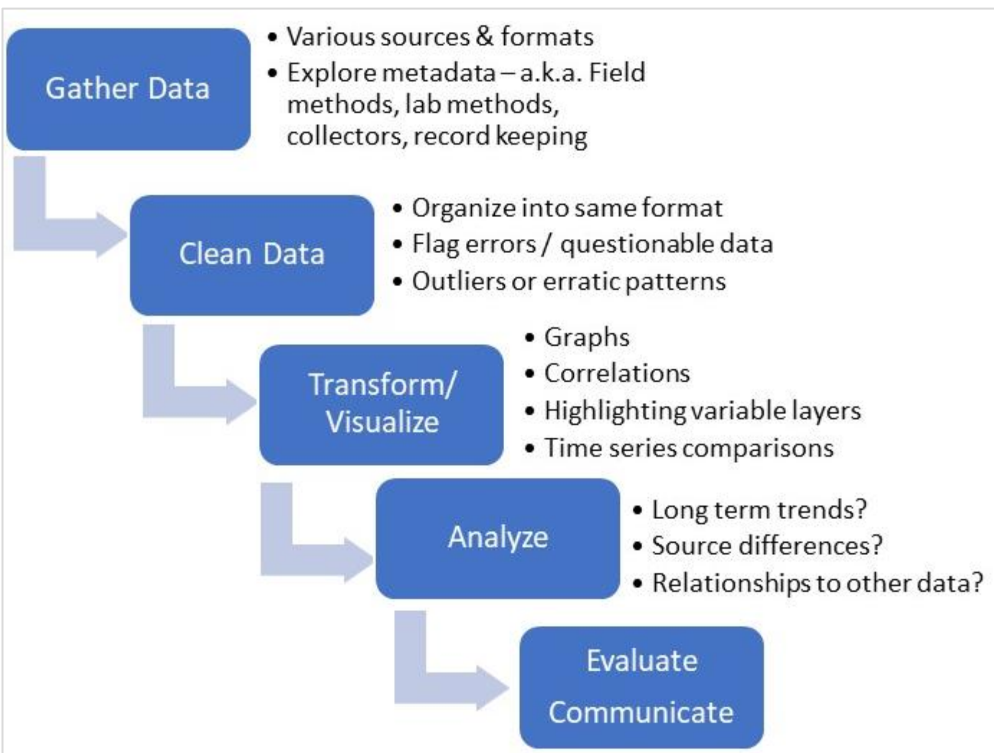
The report classifies Raquette Lake as *Mesotrophic*, based on the calculated Trophic State Index (TSI) index from Secchi, TP, & Chlorophyll-a, but the Carlson TSI (Carlson, 1977) is more or less an index of algae biomass, and is generally less useful for lakes with high color and high non-algal turbidity, like Raquette. Given other characteristics, Raquette can also be classified as *Oligotrophic* and potentially trending towards *Dystrophic*.

Raw Data Organization & Analysis Methods

A standard format of data organization is essential to good record keeping over time. A large part of the Raquette Lake water quality assessment entailed amassing data from various sources into a series of master spreadsheets. Key steps in the data analysis process are outlined below. Data that don't pass the 'cleaning' process are removed and not used for analyses. Examples of data that may be removed or changed are: typos, erratic values indicative of probe or laboratory problems, improper units/conversions, redundant data, questionable dates, etc.

Long-term lake monitoring datasets often have thousands of data rows and tens of thousands or more of individual measurements. It is very easy for spreadsheet errors to appear over time, usually resulting from data entry typos, inconsistent units or labeling, or mistaken copy and pasting.

Lake data is complicated and measurements are subject to procedural error, equipment malfunctions or improper use, and laboratory errors. It is common for pH or conductivity probes to give questionable readings resulting from a slight variation in calibration. It is also common for laboratories to make analysis or reporting errors. Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP) in lakes are naturally present in very low concentrations, specifically in Raquette Lake. This requires the lab tests are more rigorous to ensure accurate measurements. There is wisdom in careful review of every data point that gets entered into a long-term dataset. The difficulties in collecting, analyzing, and processing data necessitate a certain level of speculation and appropriate critique.



The following table summarizes the main data sources and monitoring parameters that were included in this study. There were several additional data sources with scattered historical data, mostly prior to the 1980s. The smaller data sources that were not explicitly associated with a university, state, or county agency were not included in the analysis discussed in this report. There were several inconsistencies in the smaller data sources that each require careful consideration, such as improper units or oxygen values that did not make sense for natural lake conditions.

Table 5 Water Quality Data Sources & Parameters Used in Assessment

Source	#Years	Profiles?	Secchi	pH	SpCond	Color	Chla	CDOM	Alk	TN	NO3	NOX	NH3	TP	SRP	Cl	Na	SO3	Ca	Al
ALAP	16	No	✓	✓	✓	✓	✓		✓		✓	✓		✓		✓	✓		✓	
Hamilton County SWD	26	Yes	✓	✓	✓	✓	✓	✓	✓			✓		✓		✓	✓	✓	✓	✓
SUNY Cortland	28	Yes	✓	✓	✓															
CSLAP	1	Yes	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓					
NYDEC 1933	1	No	✓	✓	✓	✓	✓							✓						
*Note that not all years have records of indicated data for each source, but each source includes at least one year of checked parameters.																				

It is not unusual to be suspicious of, or "throw out," large sections of historical data when conducting a long-term analysis. Doing so means that science is improving and that a monitoring program now has enough data to decide if errors exist. Consistent data collection of lakes in the northeastern United States only began in the 1970s, and many lakes today are still very under-monitored. The fact that Raquette Lake has decades of historical data is, in itself, a leap above many northeastern lakes in need of management and protection.

The result of this data cleaning process is four separate master spreadsheets:
1. Raquette_historical_profiles.csv (25 variables and 2430 observations)
2. Raquette_nutrients.csv (42 variables, 250 observations)
3. Raquette_Secchi.csv (10 variables, 160 observations)
4. plankton_2019.csv (12 variables, 139 observations)

RECOMMENDATIONS FOR FUTURE DATA MAINTENANCE & RECORD KEEPING

If adding to the clean master spreadsheets, save a renamed copy. Do not alter the original spreadsheets delivered as part of this analysis.

When copying over spreadsheet data into the master spreadsheets, make sure that units are the same for each variable.

Ensure the date format is the same.

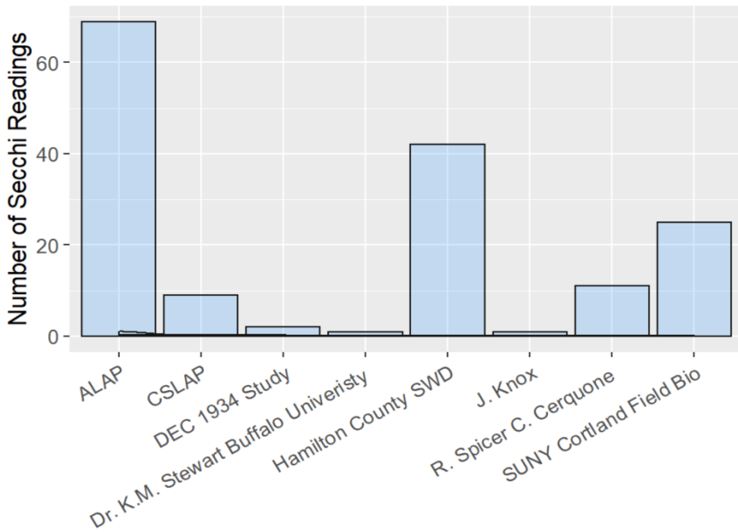
Check for spelling errors and make sure that the monitoring stations are named consistently with exact names spellings and capitalization.

Keep a word document to note any changes that are made and by whom, with the person’s contact information.

Water Clarity Assessment

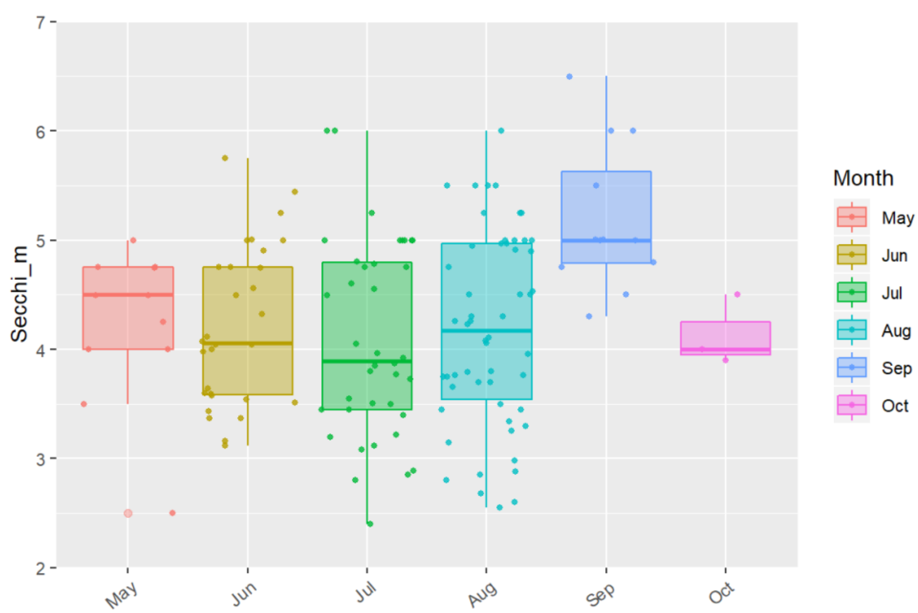
The total dataset analyzed for water clarity, measured as Secchi disk transparency, consisted of 160 observations across seven months, including one February under-ice measurement recorded in 1974. Eighty three percent of the water clarity observations were recorded during the months of June, July, and August. Fewer samplings occurred in spring and fall.

The number of readings per data source are included in the figure below.



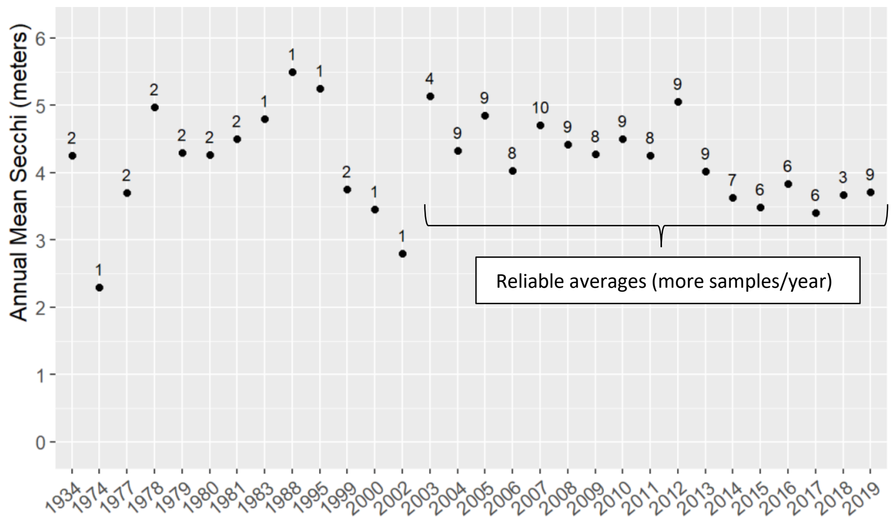
Appendix A Figure 1

At the 'Deep Hole' station, the minimum Secchi measurement was 2.3 meters, recorded under ice in February 1974. The maximum Secchi measurement was 6.5 meters, recorded at the end of September 2005. The Deep Hole long term quartile range values are: 3.55m (25th percentile), 4.25m (50th percentile), 4.97m meters (75th percentile). Water clarity tended to be best in September, and there was a wide range in summer clarity values. With the exception of generally improved clarity in September, there does not appear to be a consistent seasonal trend in clarity across all monitoring years.



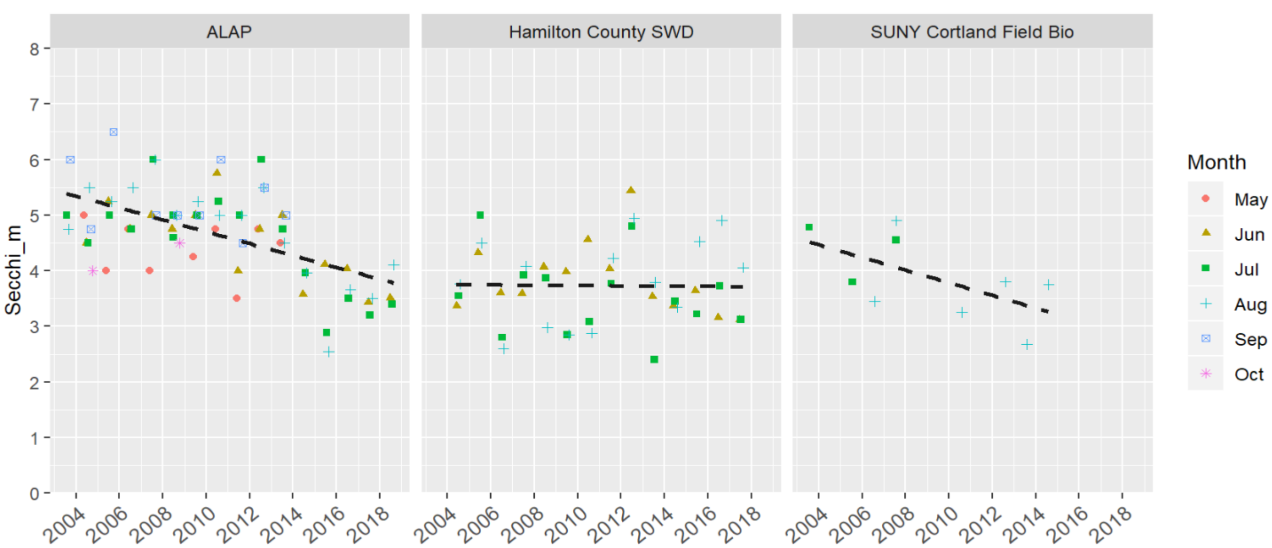
Appendix A Figure 2

Long term annual mean water clarity values are shown below (Appendix A, Figure 3). The number of measurements per year that were used to calculate the mean values are displayed above the data point. Means calculated from a higher number of measurements are more reliable. For instance, mean values calculated from just one or two Secchi readings per year are less robust than a mean calculated from 10 separate measurements. Prior to 2003 there was not a good seasonal representation of water clarity. From 2003 to 2019 there are many more measurements per year, making the data from the last two decades more reliable. Note that the timeline on the bottom is not of equal units, and only years with data were included on the graph's bottom axis (prior to 2003).



Appendix A Figure 3

The figure above demonstrates that there is a decreasing trend in mean annual water clarity from 2003 to today. The decreasing trend since 2003 is statistically significant with a strong R^2 value = 0.57. However, there were multiple poor clarity measurements less than 4 meters (4 values) from 1999-2002. All of the poor clarity measurements during this time were recorded by SUNY Field Bio personnel. The low 1977 values were also recorded by SUNY Field Bio personnel. The 1974 value can be ignored because it is an under-ice value. Further exploratory analysis of the Secchi data demonstrated that the measurement sources differed from one another.



Appendix A Figure 4

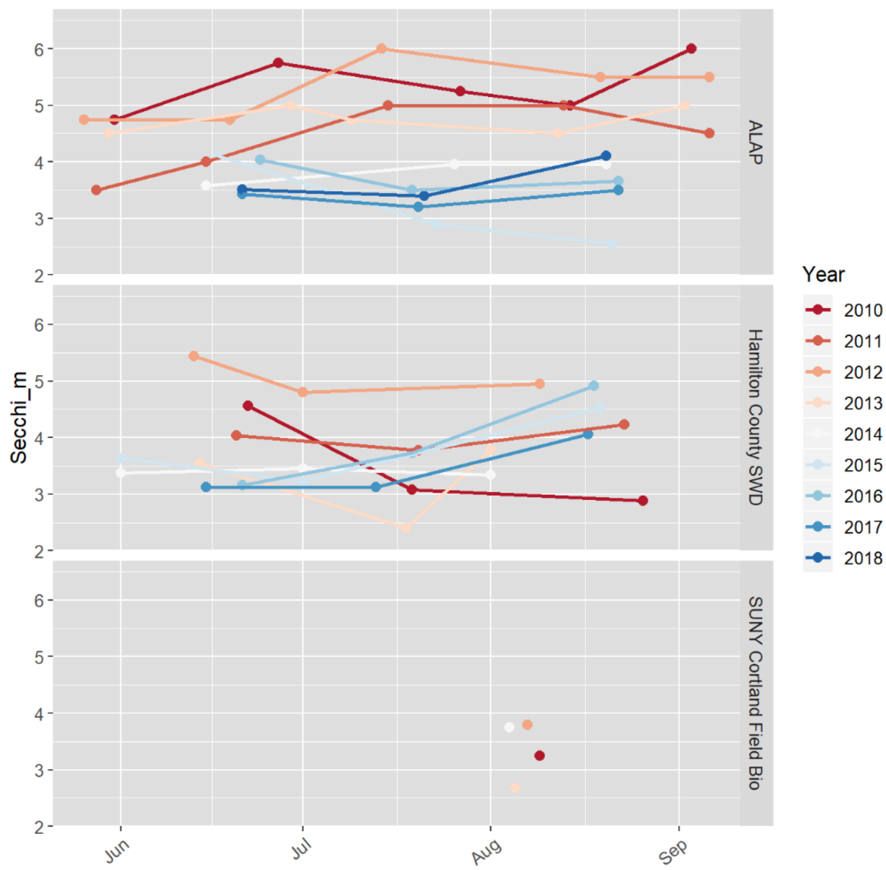
The ALAP and SUNY Cortland Secchi data distinctly show a decreasing trend over time using all collected values. However, this decreasing Secchi trend is not present when looking at the Hamilton County data during the same time period. The trend shown in the ALAP data is statistically significant with a good fit $R^2 = 0.33$, $p < 0.0005$. They SUNY Cortland is not statistically significant ($R^2 = 0.35$, $p = 0.091$), but does show a similar decreasing trend.

It is important to recognize that the ALAP trend is influenced by the fact that 4 of the 7 historical Secchi values > 5.5m are from September, and September was not sampled from 2013-2018. Had September clarity over the last five years been greater than the seasonal average, as was the case in prior years, the trend would be less dramatic. However, a look at the seasonal trends in clarity across sampling sources shows a clear difference in July and August ALAP concentrations measured over time. Data collected roughly a week apart by Hamilton County in 2010 and 2011, however, had dramatically different Secchi clarity readings. Similarly, all measurements taken by the SUNY Cortland Field Bio team in August 2010-2013 were below 4 meters, on par with current ALAP measurements. It is possible that the differences in viewer sight and weather conditions on a particular sampling day are major factors in the discrepancy in water clarity measurements among sources over time.

SECCHI CLARITY RECOMMENDATIONS

Take historical clarity readings with a grain of salt. The large variation between data sources within the same time period indicate that the methods of Secchi clarity collection were likely inconsistent across sampling individuals – i.e., time of day, use of a view scope, consistency of sampling person.

Improve future Secchi clarity readings by including more information and implementing standard practices. Using a Secchi view scope (to take two separate measurements with and without the scope) will minimize error from variable weather conditions like cloud cover and/or wind surface disturbances. Record the names of individuals taking readings.



Appendix A Figure 5

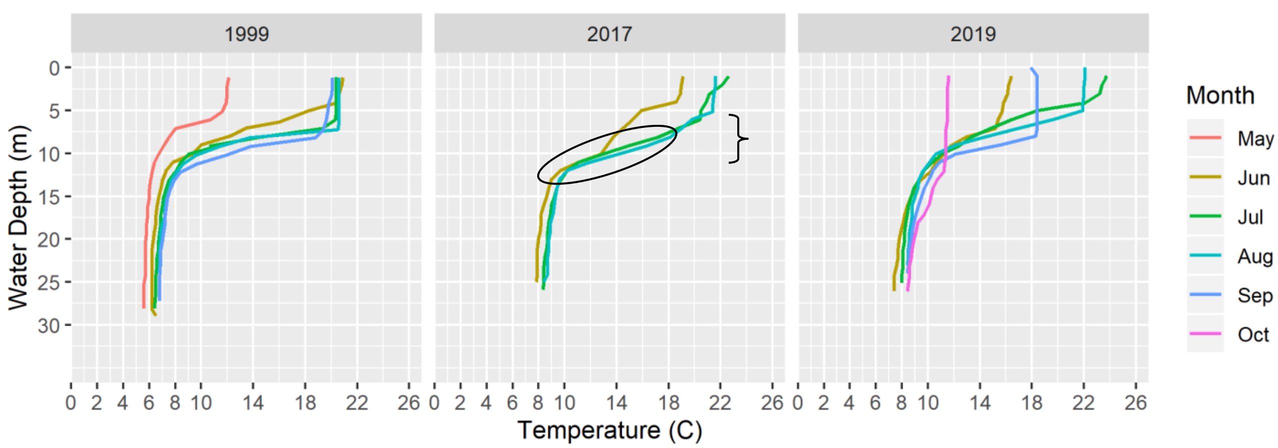
Profile Data Analysis

Profile data consists of parameters that can be measured in-situ with calibrated meters and probes in at least 1-meter increments from the lake surface to the lake bottom. Because lakes undergo thermal stratification, the conditions at the top, middle, and bottom are often quite different. Lake data commonly collected in profile format includes temperature, dissolved oxygen, pH, specific conductivity, and total dissolved solids.

Temperature

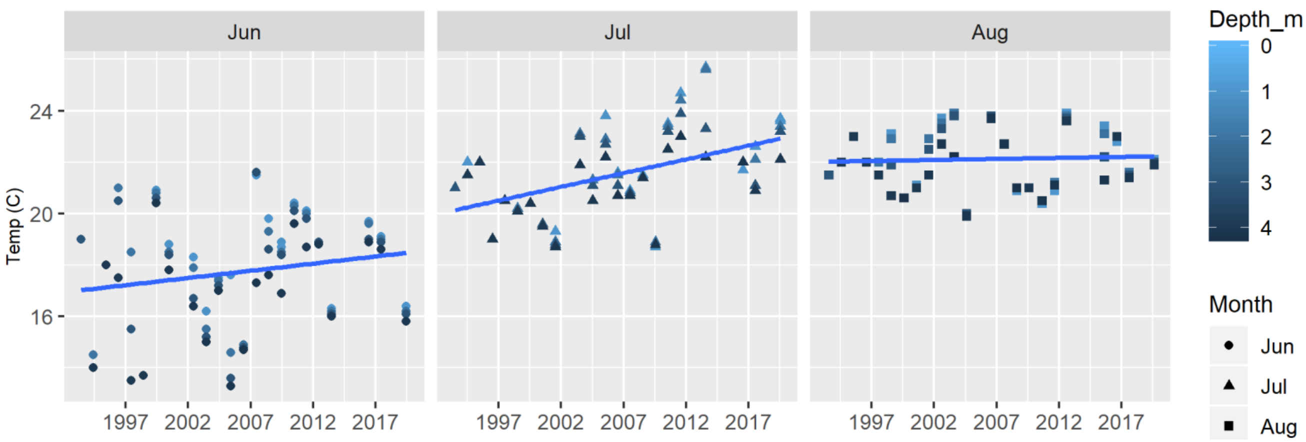
An introductory explanation of lake temperature is included in the Monitoring Components Handouts. The main concept to remember is that lake temperature goes through seasonal patterns, and that the surface water warms much faster than the bottom waters, which causes a temperature gradient somewhere in the middle of the water column. That gradient is called the thermocline. The placement and intensity of the thermocline influences oxygen levels and water chemistry in deep waters. It is also a major factor in the mixing of nutrients and the biological activity of lakes.

The Figure 6 below examines just three years of temperature data from 1999, 2017, and 2019. These years had consistent monthly monitoring, where some years had only a few sampling dates. The 1999 and 2019 data also provide good comparison across a decade of lake change. As one can see from the graphs below, the lake gains heat rapidly in the top ~5 meters of water from spring to summer. By September the surface begins to lose heat. Temperature should be more or less the same from top to bottom in the spring and fall, referred to as "lake turnover." The graph also shows that the lake gains a small amount of heat throughout the season below the thermocline. There is roughly a 2 degrees Centigrade change at the lake bottom across the season. The summer thermocline at Raquette Lake hovers around 5 to 10 meters deep.



Appendix A Figure 6

The second temperature figure (Appendix A, Figure 7) demonstrates the long-term trend in epilimnetic (surface waters) temperature over summer months. The 0-4.5m profile measurements were defined as the epilimnion because 5m is often the top of the thermocline/metalimnion (middle waters). Collectively Figure 7 shows increases in epilimnetic heat throughout the years. Trends are variable. Only July is significant.



Appendix A Figure 7

The increase in Raquette Lake's July epilimnetic temperature corresponds to the data published in the State of Hamilton County Lakes 2019 report[12], which demonstrates that the number of growing degree days is increasing over time. Warmer July temperatures and longer growing seasons due to climate change are projected to further strengthen and lengthen lake thermal stratification in the future.

Strengthening stratification would lead to thermal isolation of the hypolimnion earlier in the season, potentially resulting in a longer period of oxygen consumption beneath the thermocline. Similar results have been found in Connecticut reservoirs. The risk of hypolimnetic hypoxia (low oxygen conditions) would then increase, regardless of nutrient changes.

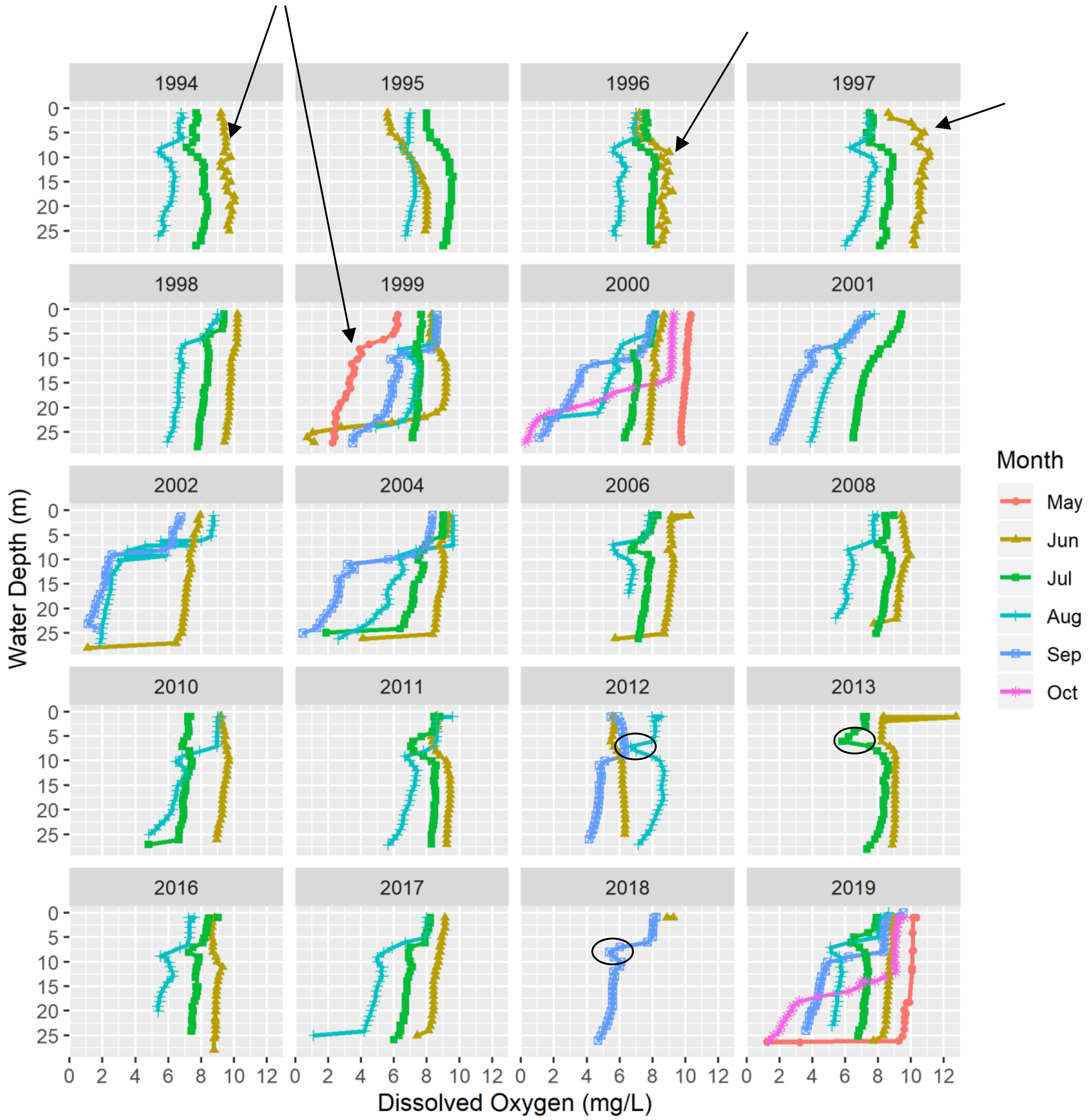
Dissolved Oxygen

Dissolved oxygen (DO) values ranged from roughly 13mg/L all the way to less than 1mg/L, which is considered anoxic. Values greater than 13mg/L were highly supersaturated (> 130% oxygen saturation) at their respective temperatures and were marked as potentially erroneous measurements. Such saturated oxygen conditions do exist in nature, but are usually limited to extremely productive and algae-dominated waterbodies. Suspect values were removed for the purposes of this analysis.

The DO profile graphs below depict measurements collected from 1994 to 2019, excluding several years with only one or two sampling dates. The black arrows point to a very strange back and forth pattern of

[12] Cedar Eden Environmental, LLC, (2005). A Statistical Analysis of Water Quality Trends in Hamilton County Lakes, 1993-2003.

DO with depth. This pattern could be a result of built-in error of the DO meter, but we have seen similar oscillations of DO with depth in another large deep lake like Raquette. The exact reason is unclear without further field investigations, but DO profile measurements since 2000 have less unusual back-and-forth variation.



Appendix A Figure 8

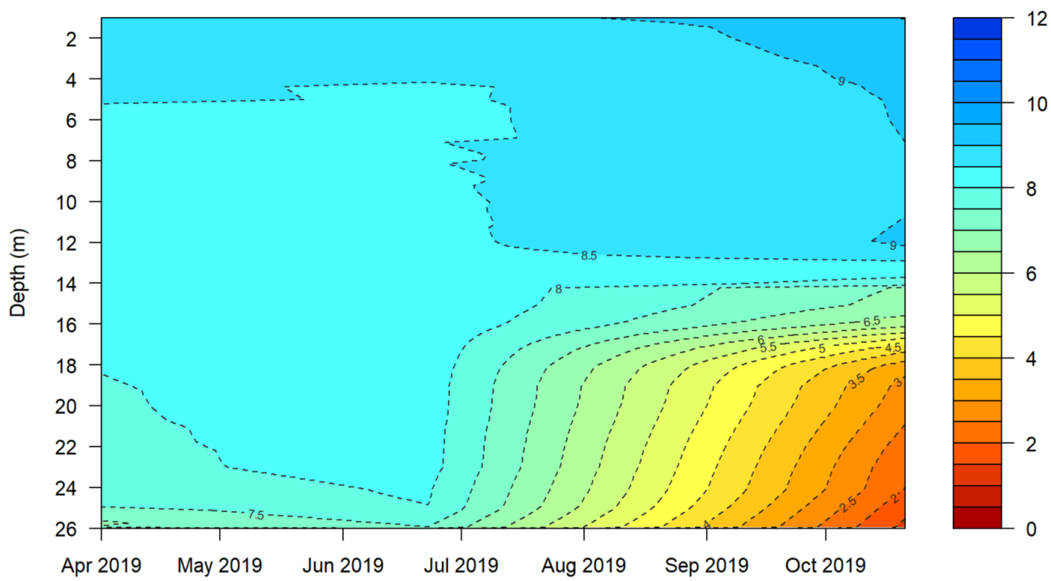
This graph also demonstrates that bottom water oxygen loss is not consistent from year to year. There is always some seasonal oxygen loss in deep waters, but the timing and amount of oxygen loss is not the same every season. More consistent seasonal data is required.

The late 1990s data show an Orthograde oxygen curve in June and July. The lake generally exhibits a negative heterograde oxygen curve and a metalimnetic oxygen minimum (MOMin) that is not just a function of temperature-controlled oxygen saturation potential. An example of a MOMmin is circled in

Figure 8 above in 2012, 2013, and 2018 - though it exists to some extent in other years. MOMins are sometimes related to settling rates of organic matter and water density changes (Kreling et al. 2017). Some MOMins have also been related to zooplankton grazing at the top of the thermocline, or a strong shallow water oxygen demand (Weck, 2017). A strong shallow-water oxygen demand is frequently linked to dense aquatic plant growth and/or sediment oxygen demand of shallower basins that mixes horizontally into the deeper basin waters (NEAR observations supported by Wetzel, 2001*).*

Since Hamilton County SWD profile monitoring began in 1993, October sampling occurred in 2000 and 2019 (2 years); September sampling occurred in 1999, 2000, 2001, 2003, 2004, 2012, 2019 (7 years). May DO sampling occurred in 1999, 2000 (2 years). Few oxygen profile measurements exist prior to the 1990s. Sporadic measurements taken in 1934, 1975, 1977, 1978, 1979, and 1980 are compared to measurements from 2000 and 2019 below. Note that even in 1975, loss of bottom-water oxygen was recorded in April, just after ice-melt.

The isopleth in Figure 9 is included to demonstrate the reduction of hypolimnetic oxygen and the development of hypoxia (orange to red colors) at the lake bottom in September to October 2019. This was not visible during all years of monitoring, but hypoxia and/or anoxia may become more common in future years as the lake continues to accumulate sediment, organic matter, and nutrients, while also adjusting to climate change. Prior to the use of nutrient concentrations in Trophic Status development, lake and wetland productivity was tracked using dissolved oxygen (Walker, 1979).



Appendix A Figure 9

Nutrient enrichment and oxygen loss is likely to happen faster in the south, as nutrients and large organic particles from roughly a third of the watershed end up settling in the southern basin, long before the material can be carried to open water over the northern deep hole monitoring site. Oxygen profile monitoring conducted by NEAR staff in the center of the south basin (Sandy Bay) on July 6, 2020 measured less than 3.0mg/L DO at 5-meters (35% saturation), and oxygen loss was apparent below 4-meters. Similarly, a profile measured on July 8, 2020 in the deep section of the Marion River Bay showed oxygen loss below 3-meters and anoxic conditions in the bottom 1-meter of water (8.0 to 8.5m; 26.2ft). Measurements taken at the deep hole North Bay station on the same day, 7/8/2020, showed 8.0mg/L

DO and water that was still 73% saturated with oxygen). Hence, profile monitoring of the southern bays is essential for understanding the slow eutrophication process – exhibited in shallower-water oxygen loss during summer months.

WATER PROFILE MONITORING RECOMMENDATIONS

A higher proportion of the direct watershed load enters the lake from the southern inlets. The Raquette Lake monitoring program should expand to include a long-term monitoring station in the center of the southern two basins, particularly during summer months.

September and October profile monitoring at the North Bay deep hole station are essential for capturing potential seasonal increases in water clarity.

Seek research partnerships and leverage data acquisition funding opportunities. Consider partnering with a graduate student to study the presence and causes of Metalimnetic Oxygen Maximums and Minimums.

High resolution temperature and dissolved oxygen sensors are revolutionizing the lake science world. Work with the AWI to set up a custom continuous monitoring buoy with sensors at multiple depths. It is also possible to install single sensors at various locations, such as the bottom waters of the two monitoring stations proposed in the Marion Bay and South Bay.

Additional Profile Parameters

There has been no significant change in <u>conductivity</u> since 2001. For the purposes of this analysis, values that were above 80 or below 25 µS/cm were determined to be erroneous data points, based on the spread of the data. Of the annual maximum conductivity measurements, 60% are lake-bottom values. Bottom-water outliers are attributed to the meter probe coming close to the sediment surface. All other conductivity profile measurements were clustered between 25 to 40 µS/cm over time, with a median of 36 µS/cm. The 2017 and 2019 measurements were more precise, with a much narrower range in seasonal conductivity. This may be due to more accurate calibrations in recent years. The lack of significant increase over time indicates that Raquette Lake is less impacted by road salting that some other Adirondack waterbodies that have seen increases over time. Sodium and chloride in lakes are highly correlated with conductivity (Laxton et. al. 2018), and that paved road density is positively correlated with increased sodium and chloride in Adirondack lakes (Kelting et al. 2012).

Over the course of the Raquette Lake monitoring history, <u>pH</u> measurements were taken by SUNY Cortland, ALAP, Hamilton County SWCD, and NY Citizens Statewide Lake Assessment Program (CSLAP) volunteers. Surface water pH measurements from Hamilton County appeared widely variable across sampling years, and may not be reliable information. Hamilton County results may be influenced by the accuracy of the pH probe used in certain time periods (1993-1997 used Orion pH meter, 1997-2003 used a YSI meter; the county is believed to have used a YSI pH meter into current monitoring years). pH values greater than 8 in low alkalinity lakes are generally associated with surface phytoplankton blooms. Though there are fewer values, the ALAP and SUNY Cortland surface pH data appears to be more consistent over time. There were overall no significant trends in surface pH across data from all monitoring sources. Available pH profile data shows a general decreasing pH trend with depth, which is considered normal. Water column pH remained relatively circumneutral, with pH of roughly 6 below the thermocline. Epilimnetic pH values tended to be 7-8.

Turbidity measurements taken by the Hamilton County were determined to be mostly unusable. With a total of 260 measurements over time, only 51 were positive measurements within range of normal lake water. Eight of the measurements were way above what should be present in open lake water, and were taken at the very bottom of the profile. Presumably these high measurements were recording probe muck disturbance at the lake bottom. The remaining values were all consistently negative, which indicates either a problem with the meter or the blanks used for meter calibration.

The next profile parameter to be measured in recent years is Total Dissolved Solids (TDS), which encompasses minerals, salts, ions, organic material, and other compounds small enough to pass through 0.45-micron filter. Only three years of TDS data exists and there were no measurable increases over that time period. The top-to-bottom water column measurements are more or less the same, ranging from 21 to 27 mg/L. One unusually high value at the lake bottom in 2017 is likely due to the probe being close to the bottom muck.

RECOMMENDATIONS FOR ADDITIONAL MONITORING PARAMETERS

Continue monitoring and keep good records of the model of meter used, as well as calibration data for pH and for conductivity. RLPF can be responsible for maintaining copies of probe calibration logs from each monitoring group.

Seek partnership with a graduate student to take a full season of monthly measurements at the major watershed inlets to establish baseline data. It would be wise to also perform inlet measurements before, during, and after a major rain event to establish a baseline storm curve values.

Results Discussion

The Raquette Lake Water Quality Assessment reviewed historical laboratory samples data from the ALAP, CLSAP, Hamilton County SWCD monitoring program, and from SUNY Cortland researchers.

The majority of the historical nutrient data, including surface water Total Phosphorus (TP), Nitrate + Nitrite Nitrogen (NOx), Chlorophyll-a, and Alkalinity, was from Hamilton County. ALAP monitoring of TP and Chl-a began in 2010. It's important to note that the Hamilton County program samples pre-2008 were performed in the Hamilton County laboratory, but since 2008 all Hamilton County TP, NOx, and Chl-a samples have been analyzed by the Adirondack Watershed Institute (AWI), the same lab that performs the ALAP monitoring laboratory analyses. AWI took over the alkalinity analysis for Hamilton County in 2010. A detailed historical account and discussion about procedures and timelines is included in the Hamilton County 25-Year report (Laxton et al., 2019). CSLAP monitoring begin in 2019 and includes additional parameters such as Total Nitrogen (TN), which captures all forms of particulate, dissolved, and reactive nitrogen, rather than just a fraction of the inorganic nitrogen as NOx. Almost all of the historical True Color values came from ALAP data.

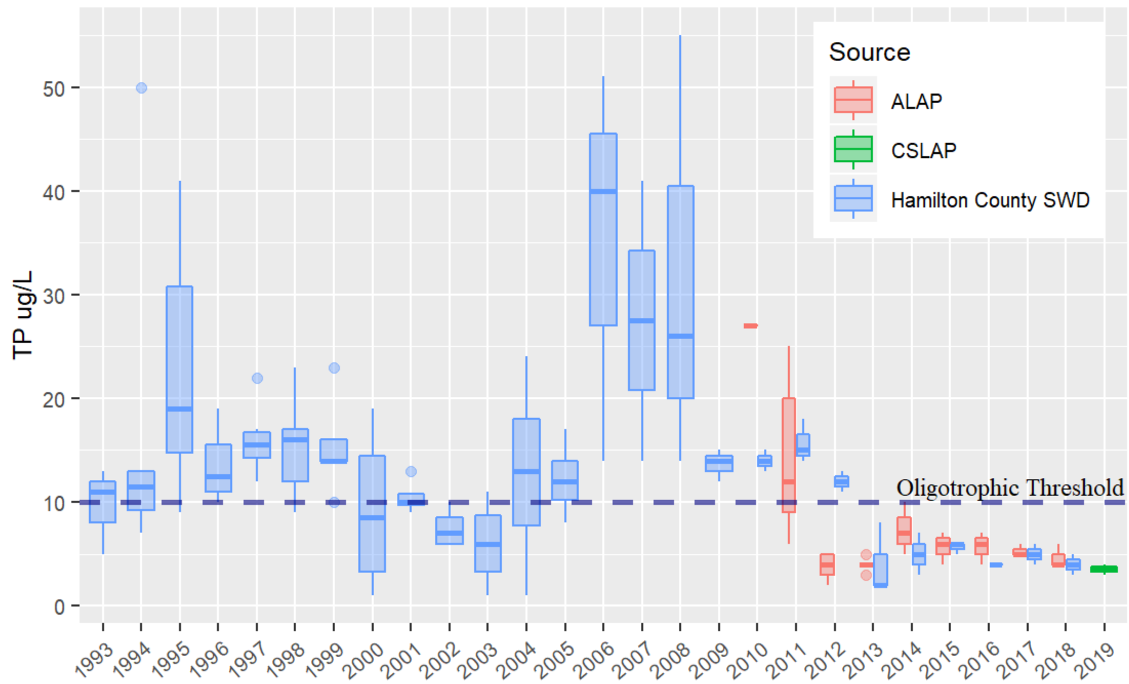
There are often correlations between TP and Chl-a in lake data, because it is widely understood that phosphorus concentrations drive phytoplankton productivity in freshwater systems. Nitrogen concentrations are sometimes co-limiting in eutrophic systems (Paerl and Otten, 2012), but generally phosphorus tends to be the limiting nutrient – in least supply for algae growth - in lakes. Similarly, there are often correlations between Secchi transparency and the TP and Chl-a variables. The Carlson Trophic State Index (TSI) relies on the TP, Chl-a, and Secchi interactions to classify lakes based on their nutrient enrichment and algal abundance. The available data suggests that Raquette Lake does not readily fit into the TSI categories, which is often true of colored waterbodies (Nurnberg, 1996; Brezonik et al., 2019).

The data analysis found:

- No significant correlation between TP and Chlorophyll-a.
- No significant correlation between TP and Secchi.
- No significant correlation between Chlorophyll-a and TrueColor.
- No significant correlation between TrueColor and Chlorophyll-a.

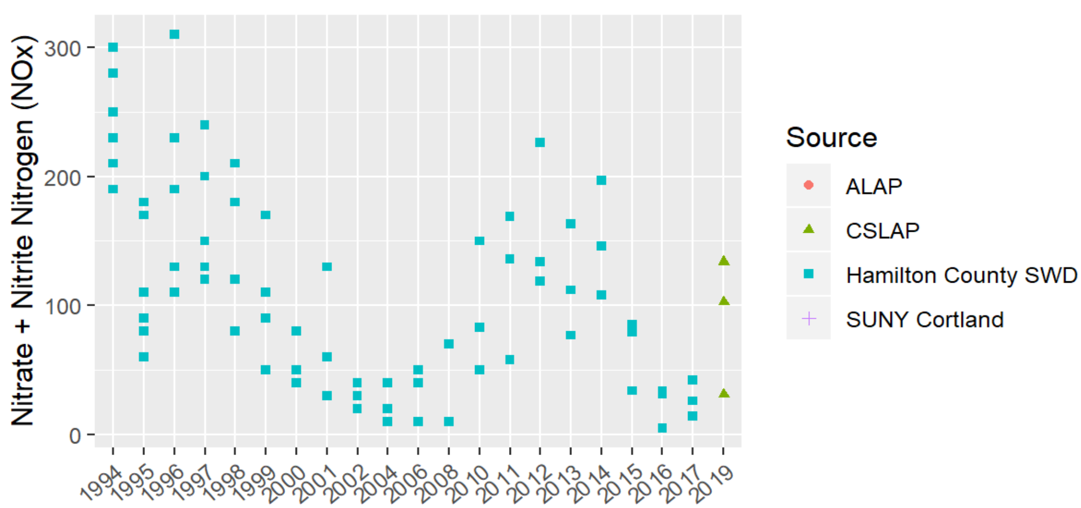
Furthermore, the patterns visible in the TP and NOx data are likely more related to the difficulty of getting accurate low-concentration data. The 2005 to 2008 time period measured very high TP across the Hamilton County lakes, including Raquette Lake. These values are suspicious and likely inaccurate. This same issue of low limits of detection laboratory methods are what has driven the State of New York to focus on a nutrient-testing certification program for laboratories that want to test lake water – under the Environmental Laboratory Approval Program (ELAP). The CSLAP works with an accredited laboratory, and AWI ALAP is currently working towards ELAP approval. Hamilton County SWCD is no longer performing nutrient tests in-house.

The Total Phosphorus (TP) concentration trend, Figure 10 below, demonstrates the improved accuracy and precision of phosphorus testing since about 2010. Since 2013, all samples have been below the Oligotrophic ("Good") threshold of 10 µg/L.



Appendix A Figure 10

Similarly, NOx measurements at Raquette Lake are generally low ("Good"), despite a change in laboratory procedures in 2010. Generally, less than 200 µg/L of NOx is considered normal for large Adirondack Lakes. The Hamilton County data suggests that there may be a regional decrease in NOx over time, as a result of reduced nitric acid deposition from acid rain (Laxton et al., 2019; Strock et al., 2014).

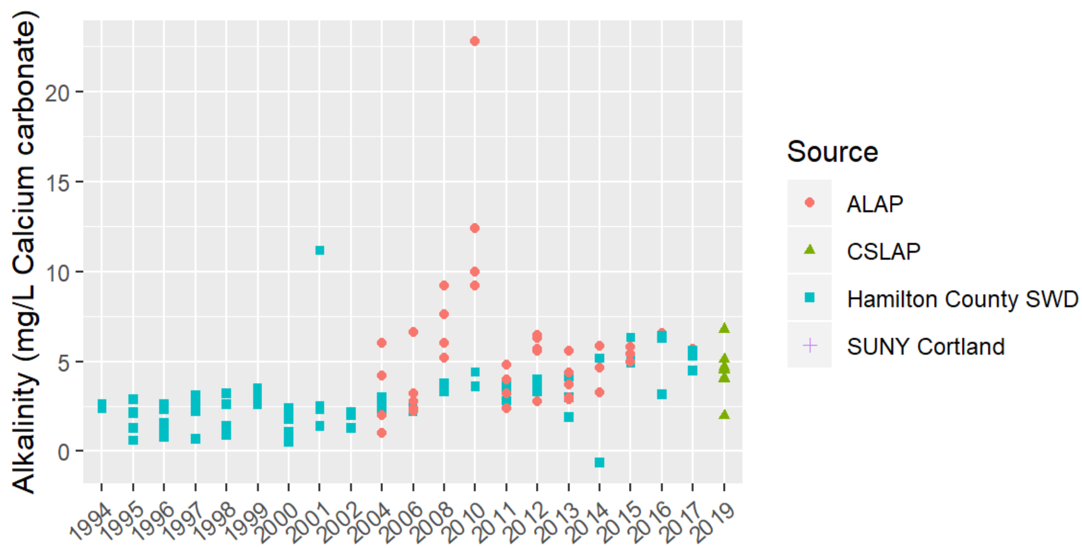


Appendix A Figure 11

Surface water Chlorophyll-a at Raquette Lake appears to be decreasing across the decades, suggesting there may be less open-water phytoplankton production today as in the 1990s. There is usually a seasonal component to chlorophyll-a in lake systems, where the highest values are frequently seen in peak summer, when phytoplankton accumulate in the surface layers. Overall, Chl-a is low at Raquette Lake, which typically translates to overall “Good” water clarity.

Appendix A Figure 12

Despite a few extraneous and questionable values, Alkalinity is increasing over time. The trend is statistically significant, and suggests that the lake may be recovering from impacts of historical acid rain. This increase in Alkalinity was apparent at many Adirondack Lakes (Laxton et. al., 2019). Alkalinity is still generally low, however, which makes the lake less vulnerable to invasive zebra mussels that thrive in greater than 20 mg/L Calcium carbonate. There were no long-term trends visible for True Color at Raquette Lake.



Appendix A Figure 13

NUTRIENT MONITORING RECOMMENDATIONS & RESEARCH INTERESTS

The historical TP and NOx values pre-2010 are inaccurate. The difficulty in getting accurate nutrient results, with very low limits of detection, for Oligotrophic lakes monitoring is one of the major reasons why bottom-water dissolved oxygen or inlets concentration data can be better long-term parameters to track change at Raquette Lake using historical data. The results from AWI and CSLAP monitoring today are reliable and will continue to track open-water nutrient concentrations into the future.

CSLAP monitoring requires sampling the bottom waters for nutrient concentrations. Bottom TP and TN will provide indications if the lake starts to exhibit signs of internal recycling of nutrients from bottom sediments. This is a key addition to the long-term monitoring program.

Consider partnering with a geochemistry research lab to take sediment cores in South Bay and Marion Bay to better understand how watershed nutrient inputs have affected Raquette Lake over time in bays with major inlets. Sediment cores with phosphorus extractions and total organic matter analyses provide a window into the past and may help predict future plant and algae growth patterns.

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Appendix B - 2020 Aquatic Plant Survey Methods

2020 Survey Methods

The Raquette Lake 2020 survey was conducted from July 5-11th. A total of 1072 waypoints were made. The majority of the total survey waypoints were predetermined using a 50x50 meter grid throughout the vegetated areas documented by the 2016 APIPP survey, including the Marion River and South Inlet. No other inlets were surveyed. There were several instances where the APIPP survey area that was used to create the predetermined waypoints did not extend to the full depth of the littoral zone, and great effort was made to search for additional invasive Variable milfoil beds in areas that have not been recently examined.

At each survey waypoint, aquatic plant species were observed and/or sampled. In areas where the lake bottom and aquatic plants were clearly visible from the surface, the surface observation became the major method of documenting species' densities. Visual assessments were common in water less than 4ft deep. In water that was less clear, typically deeper than 4ft, either a long-handled (16ft) rake, or a 14-tine double-sided garden rake attached to a 10m rope, was used to collect specimens of all species.

Plant density was determined using a combination of methods. The first, visual determination, is based on what is visible from the surface. This method involves using a hypothetical quadrat. In this method, one visually assesses an estimate of how much area is covered by the plant in question. The use of actual survey quadrats in the field is not appropriate for the large scale of most aquatic plant surveys, so surveyors must visualize a rough hypothetical quadrat overlaying the area and estimate percent coverage accordingly. The second way to estimate the percent coverage of vegetation is to use the raking density estimates. Rake-density estimates are semi-quantitatively recorded as a percent cover based on standard rake-toss density categories: Very Sparse/Trace (<1-10% cover), Sparse (11-19% cover), Medium/Moderate (20-59% cover), Dense (60-79% cover), Very Dense (80-100% cover).

The rake density estimates are also verified with SONAR down imaging. SONAR provides scrolling images of bottom features and water depth, which also allow for accurate estimates of invasive species plant height in the water column. When possible, both ways of estimating the percent cover are used at each waypoint, and the resulting estimate is recorded on the datasheet. Invasive Variable leaf milfoil was also given a growth form score, which indicates its relative height in the water column. The growth score form is as follows:

GF#	Growth Form Description
1	Laying on bottom, almost parallel with sediment.
2	Just coming off the bottom, but only occupying ~20% of the vertical water column.
3	Occupying ~50% of the vertical water column.
4	Occupying 60-90% of vertical water column, often just under the surface.
5	Plants parts breaking the surface, flowers and seeds are usually out of water.

Extra care was taken in areas where benthic mats were present. Minimal raking was done in these areas and the assessment of species presence and density relied on visual observation using the Secchi view scope, as well as very careful hand-raking around the edges of the benthic matting. SONAR depth sounder readings also verified the lack of aquatic plants growing on or around the exact location of benthic mats.

Between the pre-determined survey points, the surveyors used visual and SONAR searches to attempt to find invasive Variable-milfoil (*Myriophyllum heterophyllum*), utilizing the meander style survey. Additional VLM search time was spent in:

North Bay
Stillman Bay
Sucker Brook Bay (all coves)
Beaver Bay (North)
Lonesome Bay
Birch Bay
Browns Tract Bay
Otter Bay
South Inlet
Marion River Bay
Marion River
Eldon Lake

Additional patches or beds of Variable milfoil were marked with GPS points, totaling 81 separate occurrences in addition to the presence documented at the pre-determined waypoints. When comparing frequency of all species across the entire survey, one must remove the extra 81 waypoints where Variable milfoil was explicitly documented for search and management purposes.

Appendix C – VLM Short-term Recommendations

Variable-leaf Milfoil Short-term Recommendations

Village Boat Launch & Browns Tract Inlet Bay Plan

Reduce biomass with June harvesting. Emphasize the importance of divers to revisit/re-clear the regrowth of VLM later in the season. Success is not about tracking area if it is not sufficiently cleared and root fragments are able to regrow the following season.

Start in deeper water with less dense VLM patches and work towards shallower water. Benthic mats are generally not appropriate for areas where there is heavy boat traffic and danger for the mats being snagged by propellors or anchors, but may be appropriate for deep-water small patches, if any additional VLM is found by divers. All matting must be performed under existing or newly acquired permits and conditions.

- This area should be surveyed in June prior to the divers beginning their work, and should be inspected just after the divers are finished. Photos and notes will be key in evaluating the success of suction harvesting and if it should be continued.
- Have divers better evaluate the sediment substrate in this area. Sediment substrate will determine if root-removal if possible/probable.
- Depending on 2021 and 2022 results, VLM control in the Village Bay may require aquatic herbicides, pending APA permit approval. There is precedent for ProcellaCOR treatments for invasive milfoil in the Adirondack Park. Gauge the community's perspective on potential future herbicide use, it may require years of conversation before a community is even ready for a small test case.

Otter Bay Plan

VLM biomass in Otter Bay is high. If resources are available, this site is a secondary option for long-term diver-harvesting. Otter Bay will likely require a combination of diver-harvesting and benthic barriers. Benthic barriers are the more cost-effective way to control VLM spread, by targeting and eradicating smaller VLM beds before they become denser. RLPF must keep track of bed sizes before and after benthic barrier placement and use benthic barriers within existing permit conditions.

Plan for the Bays in the Northern Half of the Lake

The RLPF should have a long-term goal of eradicating VLM from the northern half of the lake using primarily benthic barriers. This is an ecological goal. Benthic barriers are appropriate in the low sloping and non-rocky areas such as the Sucker Brook Bays, Beaver Bays, and Needle Bay. The one location in Boulder Bay with VLM should be hand-removed.

Many of the VLM patches in these bays are shallower than 5ft deep, making them accessible to volunteers. In many cases divers are not needed to lay benthic barriers, but it may be helpful to have a couple volunteers who are good swimmers/snorkelers or divers. RLPF should also be able to hire a pair of divers to help for a weekend of laying benthic barriers.

Prioritize the removal of the Lonesome Bay patches – there are many very small patches of VLM, documented by GPS coordinates. Larger patches can be either covered using multiple overlapping barriers, or by partially covering the center of the bed. The latter case can also use hand-harvesting around the edges of the barrier to minimize bed extension.

Small patches in the northern bays need to be addressed for removal or benthic barriers before the patches grow to unmanageable sizes. The best benthic barrier material is medium-thickness geotextile fabric. It is naturally porous and negatively buoyant, making it easier to work with than the plastic barriers. Good benthic barrier material can be purchased in bulk and assembled on ridged PVC frames with steel rebar inside the PVC. The US Fabrics 160NW geotextile fabric (https://www.usfabricsinc.com/products/us-160nw/) is puncture and tear resistant and can be used for multiple seasons. In areas where large ridged frames are not easy to place, due to boulders or other obstacles, this fabric can also be cut into the desired shape. Benthic barriers will require an APA permit. Again, details pre- and post-management survey are needed.

Eldon Lake

Focus on small VLM patches that were found during the 2020 survey. These patches are very manageable and most of them can be covered with benthic barriers. In areas where native species grow densely around the VLM, it may be more appropriate for diver hand-harvesting to carefully remove the VLM without harming the native species. Protect the unique Eldon Lake habitat by minimizing spread of VLM. There is ample habitat and it is evident that the existing dense patches are fragmenting to cause multiple smaller patches in the same area. It is possible to get ahead of the spread in the next few years.

Marion & South Inlets

The VLM has a stronghold on a large amount of the river edge. Suction harvesting will not be adequate to eradicate VLM from these inlets and it should only be used to maintain an open channel in areas that VLM has started to encroach and restrict navigation. Suction-harvesting efforts should be moved to other areas in 2022 if RLPF proceeds with resumed suction-harvesting.

Pick several locations in each of these inlets and carefully track the VLM over time to see if it is spreading laterally. The high native species richness in both inlets seems to somewhat combat the VLM complete takeover, but the change is likely very slow and difficult to see. The 2020 survey put considerable effort into accurately mapping VLM patches on both sides of the river channels. The 2020 polygons are more precise than those drawn from the 2016 survey data and the two cannot be compared.

Previously Eradicated VLM Areas

Continue annual surveys of the areas where VLM has been successfully eradicated: North Bay central cove & locations in Sucker Brook Bay.

RLPF may reach out to the Maine Lakes Environmental Association to get more perspective on using benthic barriers specifically for VLM control as part of a volunteer program.

Appendix D - Aquatic Invasive Species Photos

High priority aquatic invasive plants to become aware of and familiar with. Please refer to NYSDEC and APIPP resources for more tips for identification and to learn how to distinguish invasive species from native look-alikes.

Myriophyllum heterophyllum

Variable-leaf milfoil **Invasive**

https:// gobotany.nativeplanttrust.org /species/ myriophyllum /heterophyllum /

Myriophyllum spicatum

Eurasian watermilfoil **Invasive**

http:// fingerlakesinvasives.org /invasive_species /eurasian-watermilfoil/

Trapa natans

Water chestnut **Invasive**

Photos by Northeast Aquatic Research staff

Potamogeton crispus

Curlyleaf Pondweed **Invasive**

https:// www.outdooralabama.com /submersed -aquatic -plants/curly -leaf-pondweed
https:// nas.er.usgs.gov /queries/ FactSheet.aspx?SpeciesID =1134

Cabomba caroliniana

Fanwort

Invasive

https:// shoalcreekconservancy.org /no-fans-of-the-wort/

Hydrilla verticillata

Hydrilla

Invasive

https:// www.reddit.com /r/invasivespecies /comments/28qk9i/ this_is_a_devastating_photo_of_a_hydrilla /
http:// nyis.info /invasive_species /hydrilla/