The state of Lake Forest and Lake Allure, NY 2020 and a plan for the management of Lakes Forest and Allure

Samantha R. Carey

Occasional Paper No. 74
State University of New York
College at Oneonta, 2020

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Acknowledgements

First, I would like to thank my parents, Dennis and Joanne. None of this would have been possible without their continued encouragement and their inherited love for the natural world. A special thank you goes to my family for the constant support and frequent phone call/text message check-ins!

I am extremely grateful for an amazing group of friends and colleagues who have accompanied me on sampling trips, helped collect field data and who pushed me along the way. I would like to especially thank Raymond Nellis, Lyndon Watkins, Abbey Holsopple, Samantha Wooley, Stephanie Iberger, Matthew Best, Zachary Diehl, Monica Matt, Dave Andrews, Stradder Caves and Kyle Olivenca.

I would like to express my deepest appreciation to my graduate committee members, Matthew Albright, Dr. Willard Harmen and Dr. Daniel Stich. Matt and Bill, thank you for your technical assistance, expertise and encouragement along the way! Dan, thank you for being an outstanding graduate advisor, committee chair and friend. Your guidance, patience, support and knowledge has helped me grow both academically and personally. Thanks should also go to the faculty and staff of SUNY Oneonta and the Biological Field Station, specifically Holly Waterfield and Dr. Jeffrey Heilveil.

I'd like to recognize the Northwood Lake Association for the assistance, help and continued support that I received throughout the course of my study! I am extremely thankful for their understanding of my crazy schedule and I am excited to present these wonderful folks with a plan they are excited to receive. A special thanks goes to Rosalba O'Boyle and the rest of the NWLA executive committee. Both Lake Forest and Lake Allure will hold a special place in my heart from now on.

Many thanks!

Samantha Carey

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Preface

Lake Forest and Lake Allure are two private waterbodies situated in the "Forever Wild" Adirondack Park. The impoundments were formed in the early 1900s when dams were constructed on Stewart Brook and Stewart Creek by Earl Woodward. Soon after, the Northwoods Lake Association (NWLA) was founded to serve, protect and manage these resources. NWLA members serve as vested lake stewards who are invested in the care of these lakes.

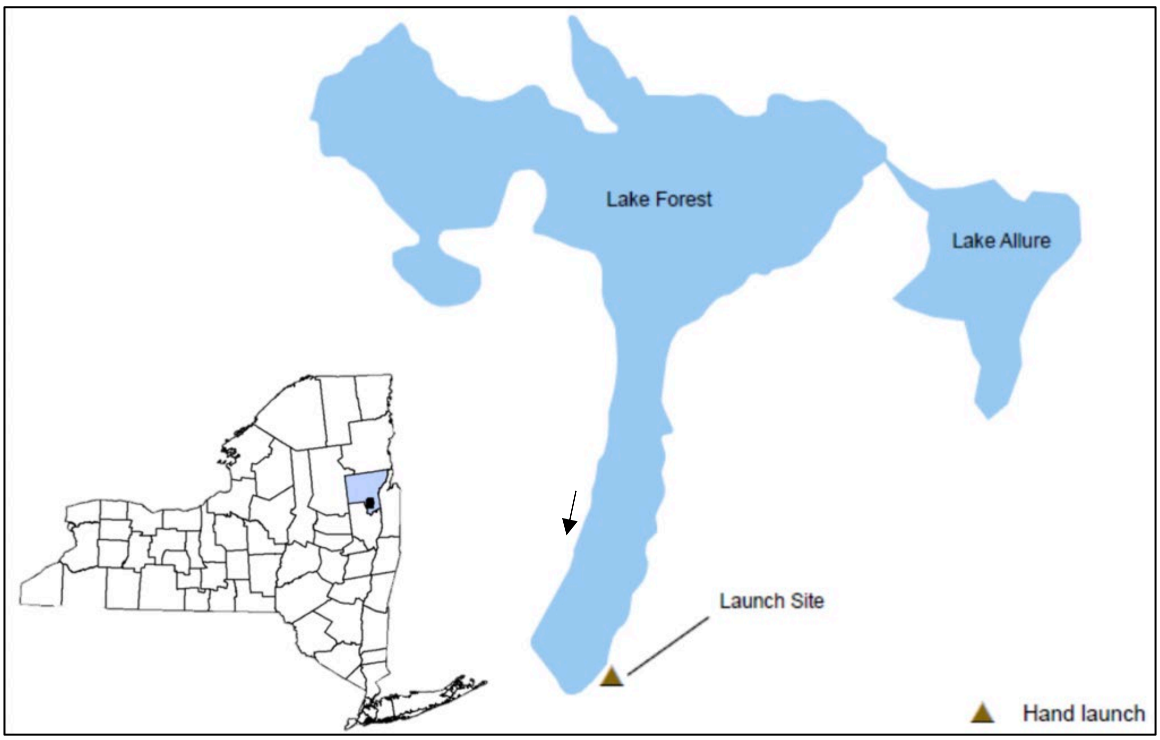
These impoundments are cherished by residents, visitors and the Northwoods Lake Association, who strive to both manage and protect the resources. The State of Lake Forest and Lake Allure, NY and Comprehensive Lake Management Plan for Lakes Forest and Allure was created to provide the above parties with the information, tools, resources and recommendations to help preserve and protect the lakes for future generations.

Chapter 1: Introduction to Lake Forest and Lake Allure

Lake Morphology and Classification

Lake Forest and Lake Allure are two privately owned impoundments located in the Town of Lake Luzerne in Warren County, NY (Figure 1.1). The lakes are encompassed by a 761-acre (3.08 km^2) watershed which eventually drains into the Hudson River. Lake Forest is 24.3 acres (0.10 km^2) in size with a maximum depth of 2 m and a mean depth of 1.2 m. Lake Allure is 4.5 acres (0.02 km^2) with a maximum depth of 2 m and a mean depth of 1.6 m (Table 1.1). Both lakes are polymictic, primarily because of their shallow depths.

Figure 1.1: Map of Lake Forest and Lake Allure, NY, with the outflow denoted by an arrow.



Both lakes are moderately productive and are classified as mesotrophic (Table 1.2). Lake Forest is classified as a Class B lake by the New York State Department of Environmental Conservation (NYSDEC 2019). A class B lake is a waterbody best used for swimming, fishing and other recreational activities. Class B waterbodies serve as suitable habitats for fish, shellfish, and wildlife (NYSDEC 2019). Lake Allure has not been classified by the NYSDEC.

Table 1.1: Morphological characteristics of Lake Forest and Lake Allure September 2017-October 2018.

Parameter	**Value**	
	Lake Forest	**Lake Allure**
Maximum length	0.55 km	0.21 km
Maximum width	0.46 km	0.10 km
Maximum depth	2 .00 m	2.00 m
Average depth	1.20 m	1.60 m
Shoreline length	2.33 km	0.85 km

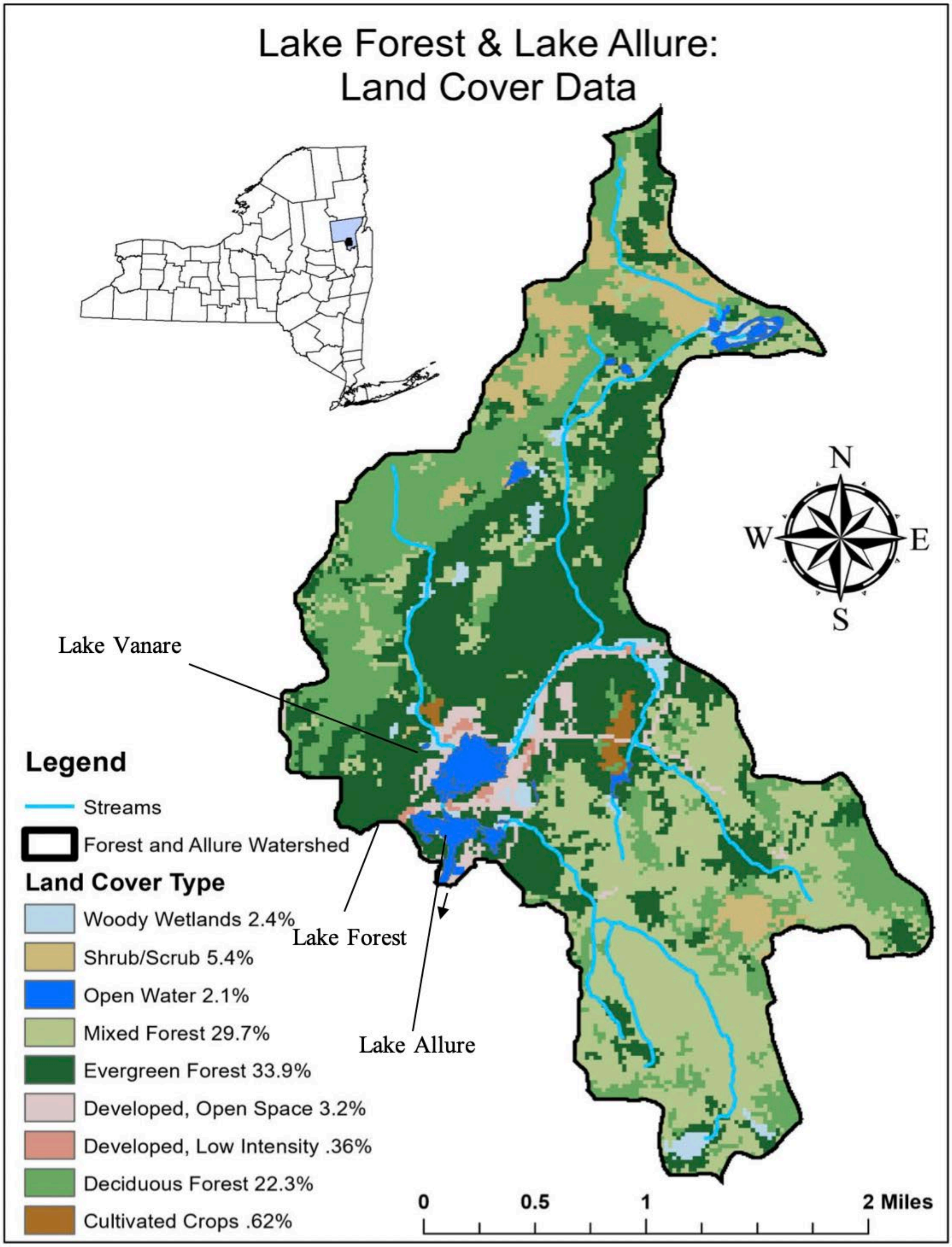
Table 1.2: Long term trends in Lake Forest (NYSDEC 2018), yearly averages for Lake Forest and Lake Allure 2017-2018, and trophic status classification parameters (NYSFOLA 2009).

Trophic Status	**Transparency (m)**	**Total Phosphorus (μg l^{-1})**	**Chlorophyll a (μg l^{-1})**
Lake Forest CSLAP Data 2001-2016	2.6	12	4.2
Lake Forest 2017-2018	1.95	12	4.1
Lake Allure 2017-2018	2	14	4.4
Oligotrophic	> 5	< 10	< 2
Mesotrophic	2 - 5	10 - 20	2 - 8
Eutrophic	< 2	> 20	> 8

Watershed Characteristics

The lakes are encompassed by a 761-acre (3.08 km^2) watershed, dominated by forested land (91%) (Figure 1.2). Lake Forest and Lake Allure are artificial impoundments created by dams constructed in the early 1900s by Earl Woodward. In 1929, Earl built dams on Stewart Brook and Stewart Creek with the intent to form Lakes Forest and Allure (D. J. Slovak, Northwoods Lake Association, personal communication). Water enters Lake Allure from a single tributary on the east shore and exits on the west shore over a type "B" (intermediate) dam into Lake Forest. Lake Forest has two major inlets, a pipe culvert at the north, draining Lake Vanare and a dam on the west shore from Lake Allure. The outlet of the system is in the southernmost portion of the lake, over a concrete spillway (Figure 1.3). Water flows through a sequence of lakes along route 9N and eventually drains into the Hudson River.

The land within the watershed is mainly undeveloped forest with little input from agricultural land use or residential development (Figure 1.2). Fine, sandy loam soils make up most of the watershed, which is a characteristic of undeveloped forest land. The shoreline soil is primarily composed of very sandy soil, which can result in excellent percolation and poor filtration of water and septic effluent (Figure 1.4). Septic tank absorption fields in the watershed are categorized as “somewhat limited” and “very limited. A “somewhat limited” rating indicates that the underlying soils have features that are moderately favorable for septic tank absorption and the “very limited” rating indicates that there are one or more unfavorable characteristics which preclude the use of a conventional system for wastewater treatment. The shoreline composition of both lakes is a mix of sandy beach, mowed grass and forested land.



https://www.mrlc.gov/finddata.php

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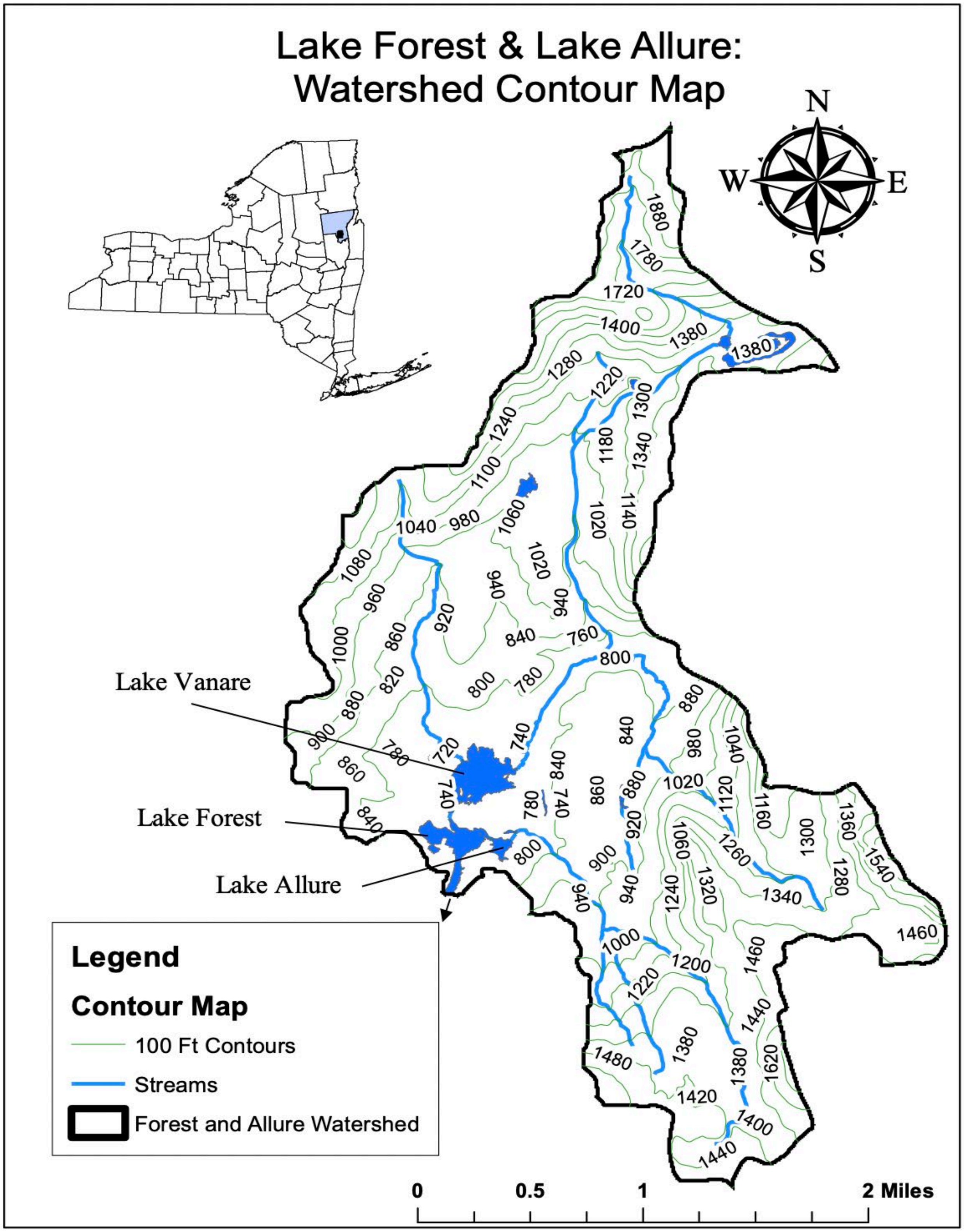

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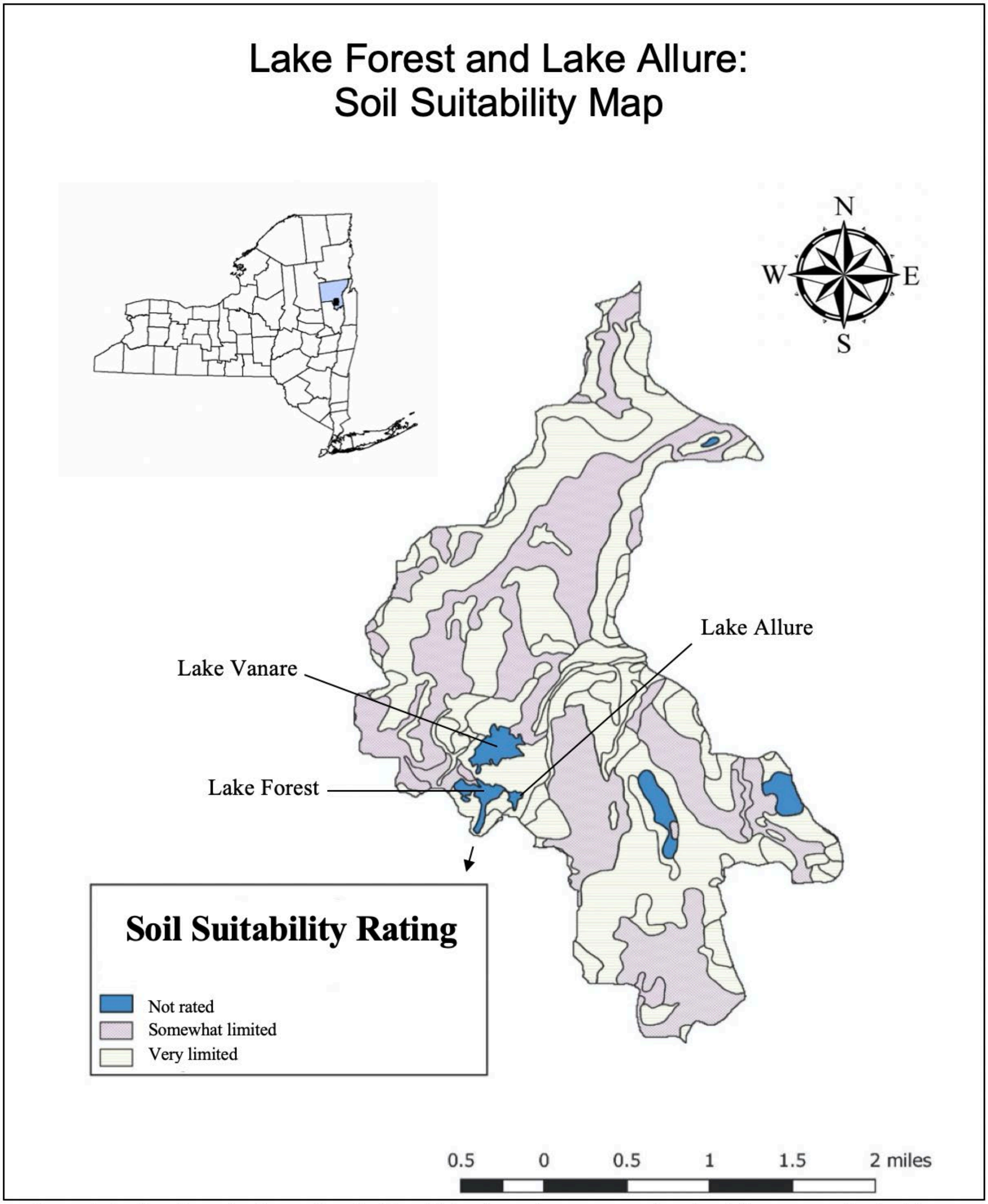

Figure 1.4: Soil suitability ratings within the Lake Forest and Lake Allure watershed with the outflow denoted by an arrow (NRCS 2017).

Lake Management History

The Northwoods Lake Association (NWLA) monitors the limnological characteristics of Lake Forest through the Citizens Statewide Lake Assessment Program (CSLAP) to understand long-term and seasonal changes in physical and chemical characteristics of the lakes. Samples have been taken over 17 years, in 2001-2010, 2012, 2013, 2015-2019 (R. O'Boyle, Northwoods Lake Association, personal communication). The NWLA has been extremely interested in the current condition of the lakes, the condition and management of the surrounding forested land, and the future of the waterbodies. The executive committee of the NWLA distributes a bi-annual newsletter informing current members of association news including past, current and future management efforts.

Aquatic plant surveys were conducted on Lake Forest and Lake Allure in 2000, 2002, 2004, 2009, and 2013 by the Darrin Freshwater Institute (Eichler 2013). A total of 27 native aquatic plants were identified during dive surveys of the lakes. Additional plant surveys were conducted in the summer of 2018 to identify and monitor seasonal aquatic plant growth and the changes in community composition. The Northwoods Lake Association was granted a bi-annual water level drawdown permit by the Adirondack Park Agency in 2001 (APA) to control excess plant growth. Additionally, a watershed assessment of Lake Forest and Lake Allure was conducted in June 2001 to evaluate the condition of the watershed and to identify potential point and non-point sources of pollution (Warren County Soil and Water Conservation District 2001).

The NYSDEC has not examined the fish communities in either lake due to the lack of public access. According to NWLA members and anglers, largemouth bass, chain pickerel and bluegill were historically common in Lake Forest and trout were prevalent in Lake Allure. As of 2019, no targeted management actions had been implemented in Lake Allure.

Stakeholder Survey

A stakeholder survey was distributed to the members of the NWLA in fall 2017 to help guide management of both lakes. Similar surveys have been distributed to lake residents in the past, with limited interest and a 30% return rate. Current stakeholder survey results have guided the management suggestions found in the comprehensive lake management plan following this document.

A total of 17% of households participated in the 2017 stakeholder survey with 41% of residents either vacationing or residing in the area for more than 30 years. Many of the residences are equipped for year-round living with 100% of homes and camps using well water. Northwoods Lake Association members use the surrounding forested land for hiking, snowmobiling, and logging and use both Lake Forest and Lake Allure for fishing, swimming, and other recreational activities. The average number of days spent at or on either lake is 63 days a year. In the fall 2017 survey, more than half of the respondents did not notice a change in water quality during the most recent 5-year period, but did report noticing a change in the aquatic plant community. Comments from stakeholders described "an increase in surface growth, floating vegetation, and a tremendous decrease in lake depths".

Stakeholder meetings in fall 2017 and 2018 allowed for the discussion of questions and concerns of lake association residents who may or may not have completed the survey. A group discussion approach helped prioritize concerns of residents. Excessive plant growth, understanding the water quality, fish community composition, mammal control and the decrease in lake depths were the top four concerns of lake residents.

Goals and Objectives

The goal of this work was to collect and report data necessary to make informed management decisions for the lakes, as related to problems identified through the stakeholder survey. To do this, I compiled historical information about the lake and current monitoring data into a "State of the Lakes Report". The report was used to support the creation of a lake management plan guided by stakeholder concerns identified during fall 2017. The state of the lakes report will describe the general state of both Lake Forest and Lake Allure, highlighting aquatic plant communities, water quality monitoring, fish communities, invertebrate communities, and lake depths from historical and current data. The comprehensive lake management plan will outline the best management practices for the lakes and the encompassing watershed.

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Chapter 2: Physical Limnology and Water Quality

Introduction

Both physical and chemical limnological parameters have important effects on the function of aquatic ecosystems. Monitoring and analyzing specific water quality parameters helps resource managers understand the “state” or current condition of a lake, pond or reservoir. Mixing, stratification, anoxia, rainfall, nutrient input, turbidity and extreme temperature changes are just some of the processes that can affect water quality in lakes and therefore the aquatic biota that live there. Plants, macroinvertebrates, plankton and fish may each respond differently to the variety of changes in water quality throughout the year. Continuous year-round water quality monitoring can help inform the use of specific management practices in lakes and surrounding watersheds.

Through the NYSDEC and NYSFOLA, trained volunteers collect valuable long-term water quality data, including pH, temperature, chlorophyll *a,* and nutrients (phosphorus, nitrogen) through CSLAP. New York State has more than 7,500 lakes, ponds and reservoirs that are enjoyed by residents and visitors year-round (NYSDEC 2018). CSLAP monitoring by lake volunteers allows the NYSDEC to gather vital information on waterbodies across NY that may not have been regularly sampled by a state agency survey. Information gathered can be used to educate the general public about lake, pond or reservoir management, help identify changes in water quality and to compile data from multiple state waterbodies. The members of the NWLA began to participate in CSLAP monitoring in June 2001. Samples were collected during summer months in Lake Forest from 2001 - 2010, and again from 2012 - 2019 as part of the CSLAP monitoring program (NYSDEC 2018). Lake Forest is currently categorized as mesotrophic, and water quality parameters have not significantly changed over the last 15 years (NYSDEC 2018). Lake Allure, which flows into Lake Forest, has not been sampled or studied through CSLAP monitoring.

The goals of this study were to characterize current limnological conditions in Lakes Forest and Allure through collection of in-depth information, and to examine trends in long-term CSLAP datasets. To do this, I 1) analyzed important physical and chemical limnological parameters in both lakes over a 1-year timespan, and 2) examined long-term trends in dissolved oxygen, temperature, total phosphorus, specific conductance, pH, and total nitrogen within Lake Forest using 15 years of historical CSLAP data.

Methods

Field sampling occurred monthly from October 2017 through October 2018 on both Lakes Forest and Allure. Samples were taken at 0.5 m (1.6 ft) intervals at the deepest portions of each basin from the surface to bottom (Figure 2.1). Temperature (C°), dissolved oxygen (mg l^{-1}), specific conductance (mS cm^{-1}) and pH were recorded using a YSI® 650 MDS with a 6-series multiparameter sonde. The YSI was calibrated following manufacturer instructions and protocols before each sampling event. Water depth was recorded using a Vexilar LPS-1 LCD Portable Sounder and a handheld Garmin GPS was used to record and relocate sampling locations.

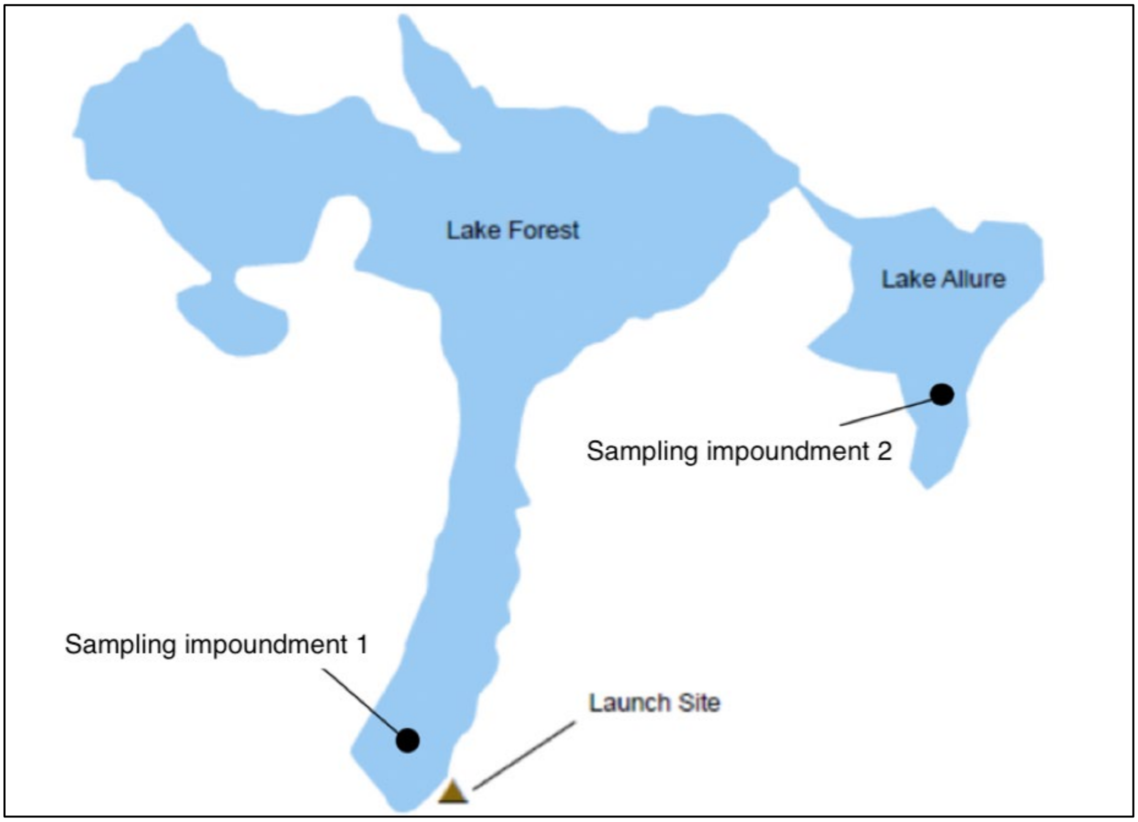

Figure 2.1: Lake Forest and Lake Allure in-lake sampling map from the APIPP.

A Secchi disk was used to determine water transparency at sampling locations on Lakes Forest and Allure. The disk was lowered into the water column from the shaded side of the boat until it vanished, and the depth was recorded. It was then raised up until the disk reappeared and the depth was recorded. Depths were averaged to estimate Secchi depth in Lake Forest and Lake Allure.

Water samples for nutrient analysis of total phosphorus (TP), total nitrogen (TN), nitrate and nitrate ($NO_3^- + NO_2^-$), calcium hardness (mg l^{-1} $CaCO_3$) and alkalinity (mg l^{-1} $CaCO_3$), were collected using a Wildco© 1.2 L opaque PVC Kemmerer Sampler. Chlorophyll *a* was collected and analyzed as part of CSLAP monitoring in Lake Forest and samples were collected for Lake Allure in summer 2018. Samples were collected at the surface (0 m), 1 m and at the bottom of each sampling basin (2 m). Additional water samples were collected from the inlet of both Lake

Forest and Lake Allure and from the outlet of Lake Forest for analysis of total phosphorus, total nitrogen and nitrate + nitrate. Samples were collected from the inlet of Lake Allure at Chuckwagon Trail, the inlet of Lake Forest from Lake Vanare under NY-9N, and from the outlet of Lake Forest at the corner of Northwoods Road and Pinewoods Road (Figure 2.2).

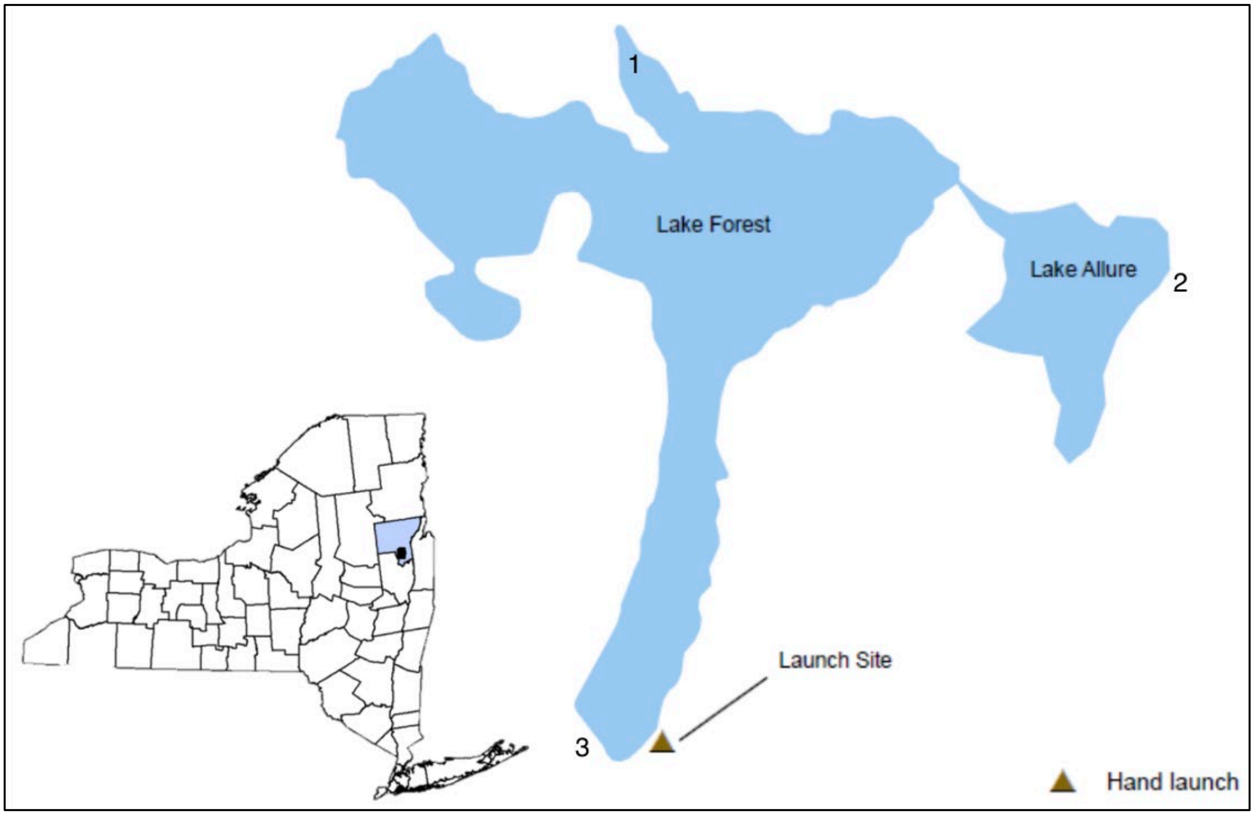

Figure 2.2: Lake Forest and Lake Allure nutrient sampling map.

Water samples for the analysis of TP, TN and NO_3^- + NO_2^- were transported on ice in 125 ml acid washed sample bottles and preserved to pH < 1.0 using ml sulfuric acid (H_2SO_4) at the SUNY Oneonta laboratory. Samples for calcium hardness and alkalinity were collected and stored in 1 L sample bottles under refrigeration for future analysis. Total phosphorus, total nitrogen, and nitrate + nitrite concentrations were determined using a Lachat QuickChem FIA + Water Analyzer 8000®. Laboratory analysis followed standard protocols at the SUNY Oneonta Biological Field Station (Table 2.1).

Surface and bottom water samples were collected on October 28, 2017 (fall), January 11, 2018 (winter), May 26, 2018 (spring) and July 21, 2018 (summer) to quantify seasonal changes of alkalinity and calcium concentrations. Both alkalinity and calcium were estimated using titration methods and calculated using the following equations:

$$\text{Calcium (mg l}^{-1}\text{ Ca}^{2+}\text{) = ml 0.0100 N EDTA titrant} \bullet \frac{\text{1000 ml}}{\text{50 ml of sample}}$$

$$\text{Alkalinity (mg l}^{-1}\text{ CaCO}_3\text{) = ml of titrant} \bullet \frac{\text{1000 ml}}{\text{100 ml of sample}}$$

Chlorophyll *a* samples were collected from Lake Allure on June 23, July 21 and September 1, 2018. Chlorophyll *a* was analyzed by filtering a known volume of sample water through a 47 mm, 0.7 pore size GF/A glass filter. Filtering rates were determined using 100 ml of sample per 1 m of Secchi depth from the day of water sample collection. Filters were cut into small segments and were placed in a 15 ml grinding tube with 10 ml of buffered acetone (10% magnesium carbonate and 90% acetone) for three hours according to Arar and Collins 1997. Soaked samples were then placed in a Thermo Scientific Sorvall Legend XI centrifuge and centrifuged for 10 minutes at 10,000 x g. Fluorescence was measured using a Turner Design Trilogy fluorometer and chlorophyll *a* concentrations were reported based on the filtered water sample volume. Lake Forest chlorophyll *a* concentrations were taken from the 2018 CSLAP report.

To understand vertical dissolved oxygen and temperature trends, visual isopleths were created using data from monthly water quality monitoring of Lakes Forest and Allure. The Akima package (Akima et al. 2015) in R statistical program (R Core Team 2017) was used to create the visual graphs over one year's time.

Table 2.1: Laboratory methods for nutrient analysis for calcium hardness ($CaCO_3$), alkalinity ($CaCO_3$), total phosphorus (TP), total nitrogen (TN), and nitrate + nitrite ($NO^{3-} + NO^{2-}$) with preservation procedures, references and detection limits.

Parameter	Preservation	Method	Reference	Detection Limit
Calcium (Ca^{2+})	Store at 4ºC	EDTA titrimetric method	EPA 1983	If low, use more sample
Alkalinity ($CaCO_3$)	Store at 4ºC	Titration to pH = 4.6	APHA 1989	If low, use more sample
Total phosphorus (TP)	H^2SO^4 to pH < 2	Persulfate digestion followed by single reagent ascorbic acid	Liao and Marten 2001	4 µg l^{-1} P
Total nitrogen (TN)	H^2SO^4 to pH < 2	Cadmium reduction method following peroxodisulfate digestion	Pritzlaff 2003; Ebina et al. 1983	0.04 mg l^{-1}
Nitrate & Nitrite ($NO_3^- + NO_2^-$)	H^2SO^4 to pH < 2	Cadmium reduction method	Pritzlaff 2003	0.02 mg l^{-1}

Results

Both Lake Forest and Lake Allure are polymictic systems, meaning that the lakes mix regularly throughout the ice-free season. Continuous mixing events occurred because of shallow lake depths, wind, and wave action. Both lakes inversely stratified during winter months due to ice cover from January to March 2018. As ice forms and floats on the lakes surface, warmer, denser water sinks to the bottom. There is no well-defined epilimnion, hypolimnion or thermocline in either Lake Forest or Lake Allure for most of the year due to constant mixing (Figure 2.3 and 2.4).

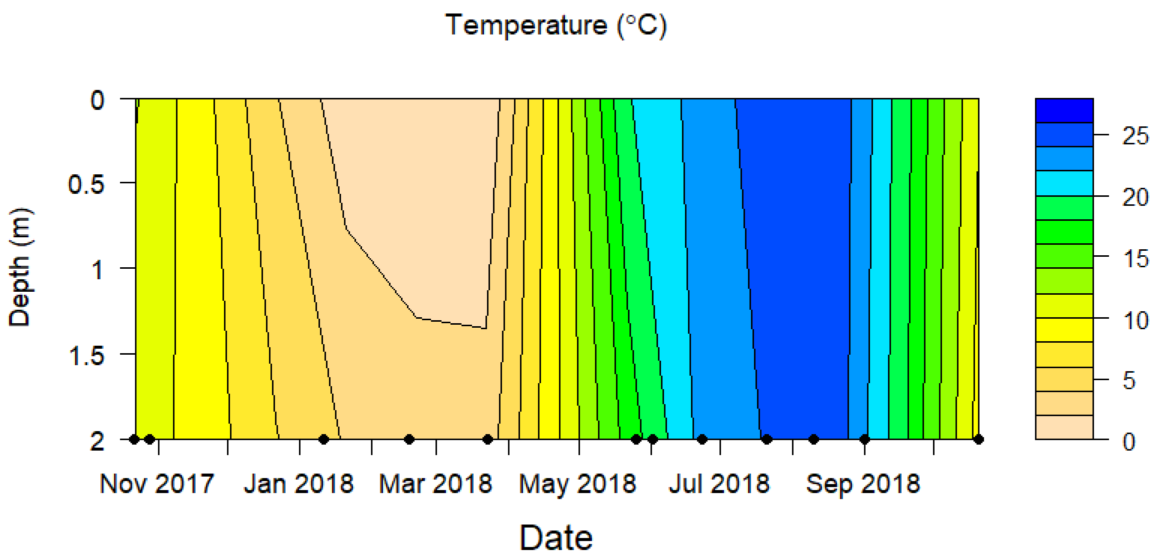

Figure 2.3: Temperature °C isopleth for Lake Forest between October 2017 and October 2018. Black dots mark sampling dates.

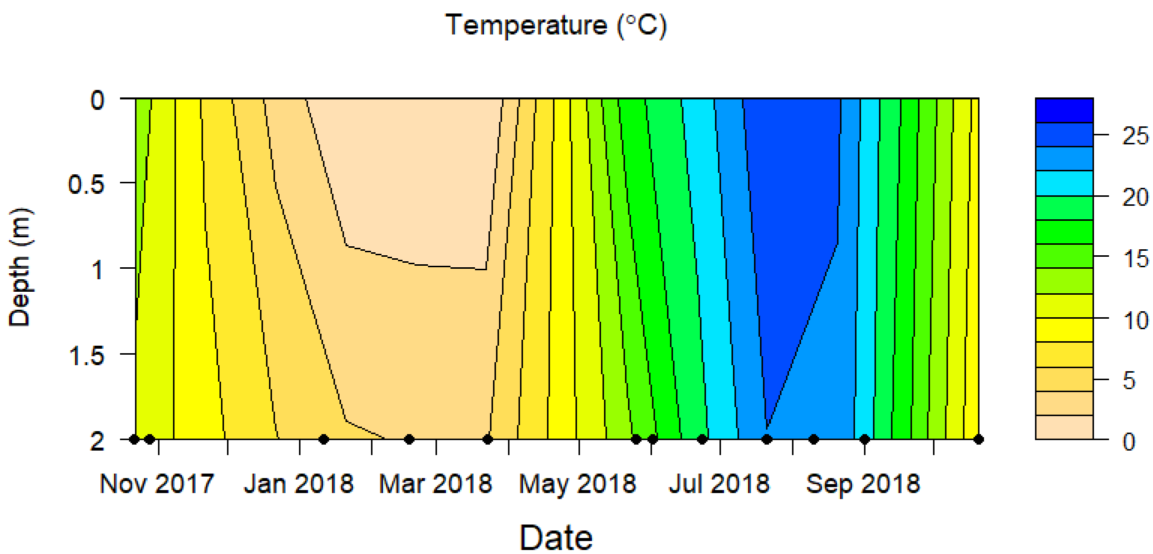

Figure 2.4: Temperature °C isopleth for Lake Allure between October 2017 and October 2018. Black dots mark sampling dates.

Dissolved oxygen concentrations in Lake Forest varied from < 2 mg l^{-1} to > 12 mg l^{-1} within the water column throughout the year. Lake-wide oxygen levels were lowest during January and February 2018 (< 5.00 mg l^{-1}) under ice cover (Figure 2.5). Lake Allure exhibited uniform dissolved oxygen concentrations throughout the water column during the ice and ice-free season (Figure 2.6).

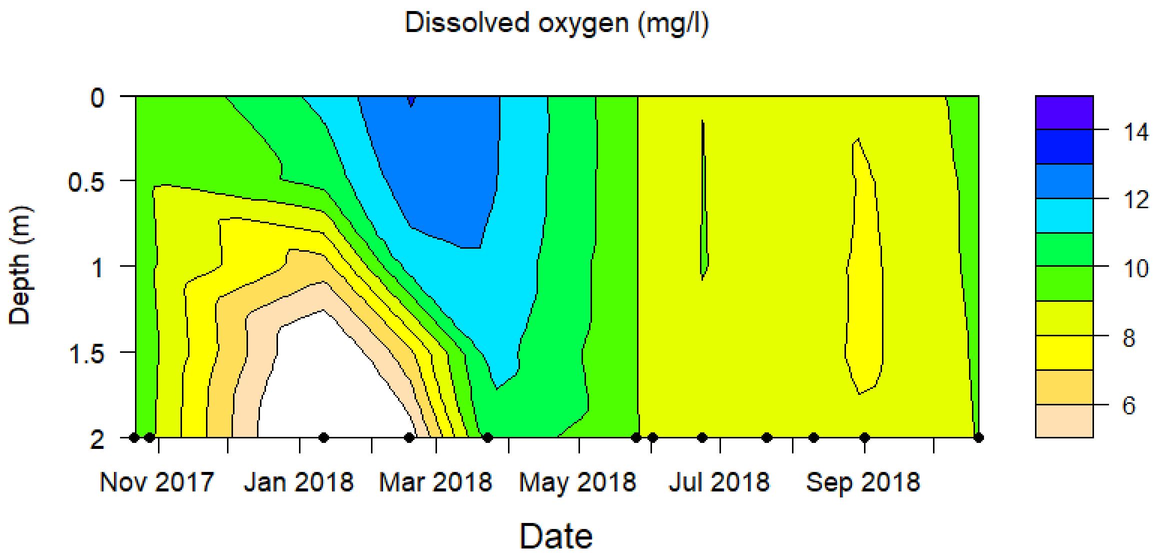

Figure 2.5: Dissolved oxygen (mg l^{-1}) isopleth for Lake Forest October 2017-October 2018. Black dots mark sampling dates. Black dots mark sampling dates.

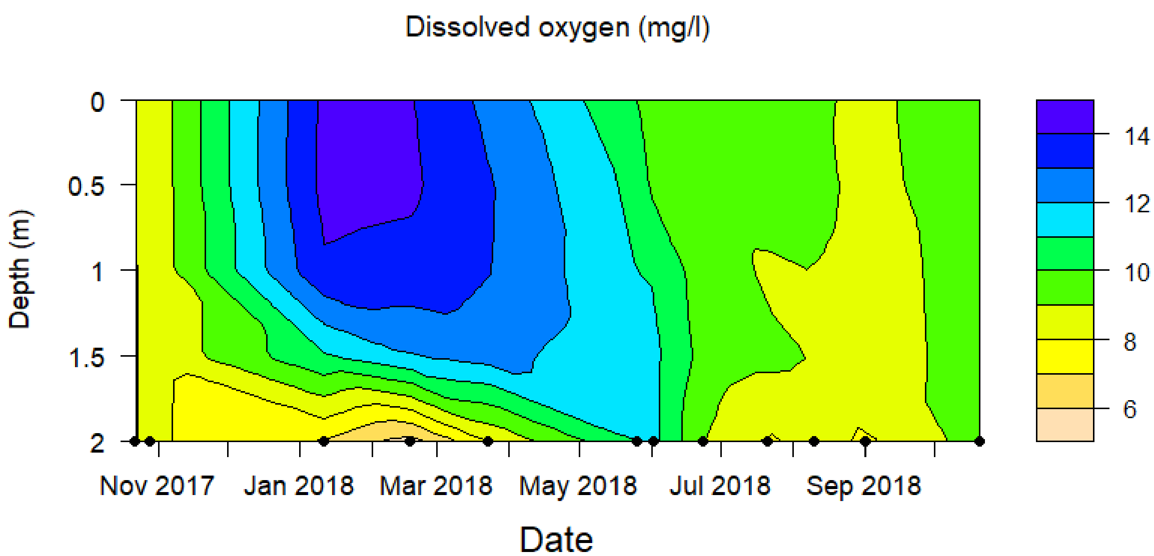

Figure 2.6: Dissolved oxygen (mg l^{-1}) isopleth for Lake Allure between October 2017 and October 2018. Black dots mark sampling dates.

The pH or the "power of hydrogen" is an exponential scale representing the measure of the free hydrogen (H^+) ion concentrations in a solution. The pH scale ranges from 0 – 14. A pH of 7.0 is neutral, a pH greater than 7.0 is basic and a pH less than 7.0 is acidic. pH levels in aquatic systems should range from 6.5 to 8.5 to adequately support aquatic organisms (NYSDEC 2018). The pH in Lake Forest ranged from 6.9 to 9.1, with a yearly mean pH of 7.5 (Table 2.2). The pH in Lake Allure ranged from 6.1 to 10.1 with a mean pH of 7.1 (Table 2.3). The annual average pH fell within the optimal range indicating that it does not currently infringe on biological processes.

Specific conductivity is the ability of water to conduct an electrical current and it is a coarse index for the concentration of dissolved ions found in water. Specific conductance is typically affected by the geology and topography of the surrounding watershed. The mean specific conductance in Lake Forest during 2018 was 0.116 mS cm^{-1} (Table 2.2). Concentrations fell within the optimal range from 0.100-0.300 mS cm^{-1}, but on the lower end of the ideal range. Specific conductivity measurements in Lake Allure were low for most of the sampling period with a mean measurement of 0.049 mS cm^{-1} (Table 2.3). The lack of dissolved ions in Lake Allure can be attributed to the forested nature of the surrounding watershed and underlying geology of the region. Unlike Lake Forest, Lake Allure is not subjected to additional inlets or increased turbidity. Low specific conductivity can be the result of low calcium or magnesium inputs from the surrounding watershed, both which are essential for aquatic life.

Total phosphorus (TP) in Lake Forest ranged from 4 – 26 µg l^{-1} (Table 2.2) with an average surface concentration of 12 µg l^{-1} and a bottom concentration of 15 µg l^{-1} (Figure 2.7). Lake Allure TP levels ranged from 5 – 36 µg l^{-1} (Table 2.3) with an average surface concentration of 17 µg l^{-1} and bottom concentration of 16 µg l^{-1} (Figure 2.8).

Table 2.2: Mean concentration, standard deviation and range of surface chemical parameters of Lake Forest from October 2017 – October 2018.

Parameter	Mean	Standard Deviation	Range
Calcium (mg l^{-1} Ca^{2+})	9.25	0.96	8 – 10
Alkalinity (mg l^{-1} $CaCO_3$)	21.50	3.42	17 – 25
*Chlorophyll *a (*µg l^{-1})	3.90	0.56	3.3 – 4.4
pH	7.51	0.52	6.9 – 9.12
Specific Conductance (mS cm^{-1})	0.13	0.02	0.07 – 0.17
Total phosphorus (µg l^{-1})	11.78	5.16	4 – 26
Total nitrogen (mg l^{-1})	0.29	0.11	0.12 – 0.52
Nitrate & Nitrite (mg l^{-1})	0.07	0.08	0.02 – 0.23

*Gathered from 2018 CSLAP data

Table 2.3: Mean concentration, standard deviation and range of surface chemical parameters of Lake Allure from October 2017 – October 2018.

Parameter	Mean	Standard Deviation	Range
Calcium (mg l^{-1} Ca^{2+})	7.50	0.58	7 – 8
Alkalinity (mg l^{-1} $CaCO_3$)	15.00	2.94	12 – 19
Chlorophyll *a (*µg l-1)	3.67	0.55	3.1 – 4.2
pH	7.07	0.93	6.13 – 10.07
Specific Conductance (mS cm^{-1})	0.05	0.01	0.04 – 0.06
Total phosphorus (µg l^{-1})	16.26	8.29	5 – 36
Total nitrogen (mg l^{-1})	0.13	0.05	0.07 – 0.27
Nitrate & Nitrite (mg l^{-1})	0.04	0.03	0.02 – 0.12

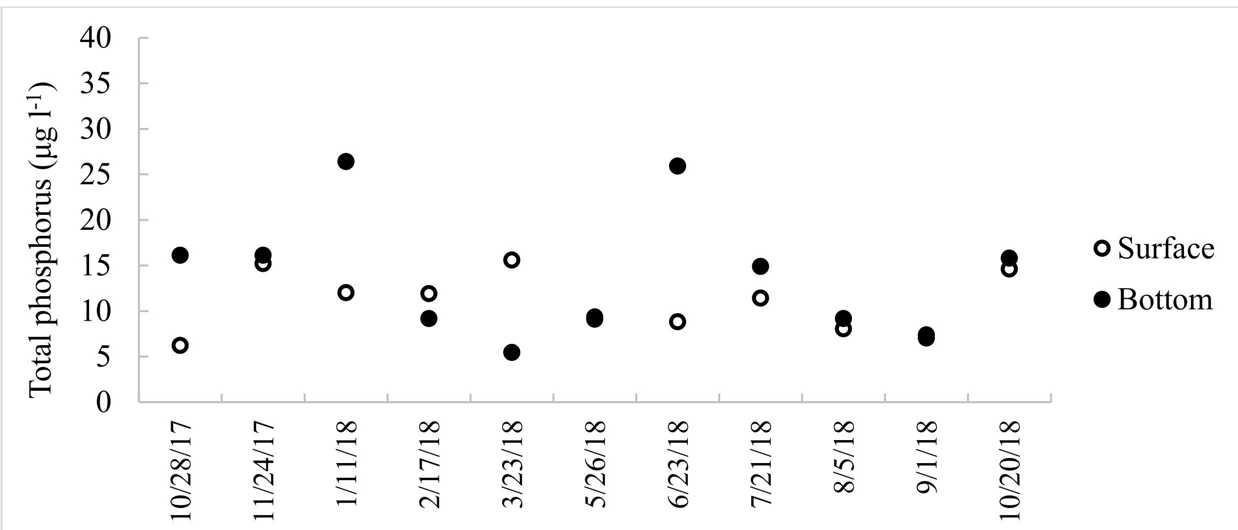

Figure 2.7: Lake Forest surface (0 m) and bottom (2 m) total phosphorus (µg l^{-1}) concentrations from water quality sampling dates.

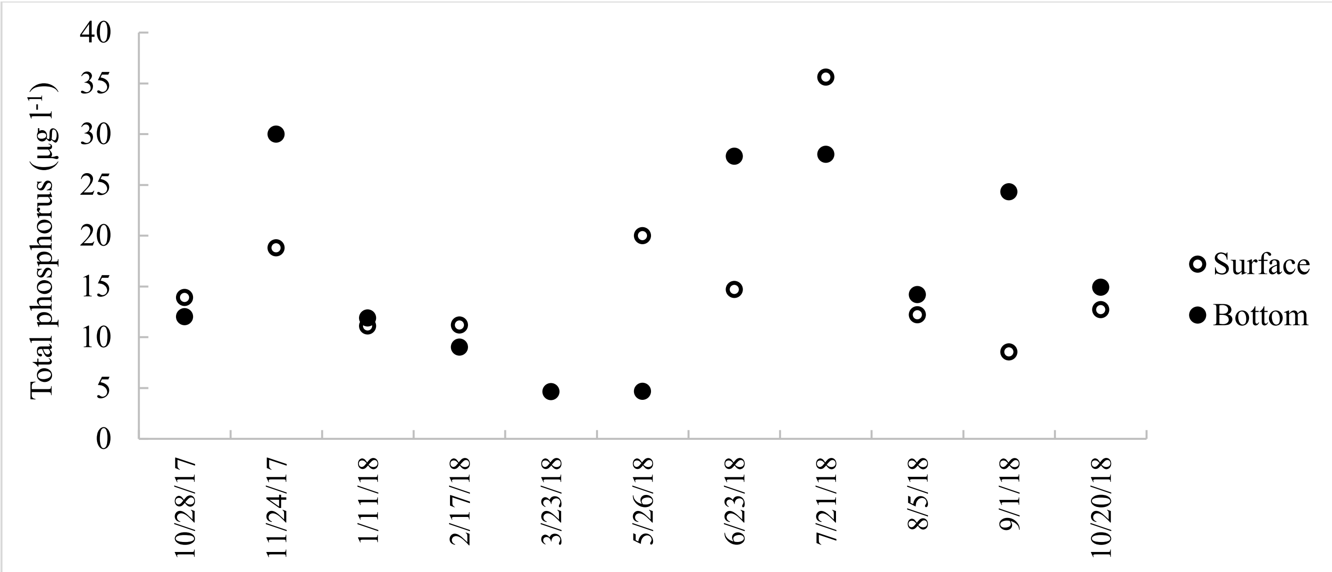

Figure 2.8: Lake Allure surface (0 m) and bottom (2 m) total phosphors (μg l^{-1}) concentrations from water quality sampling dates.

Total nitrogen levels in Lake Forest averaged 0.29 mg l^{-1} on the surface and 0.27 mg l^{-1} on the bottom (Figure 2.9, Table 2.2). The highest concentrations of total nitrogen were found under ice cover in January, February and March 2018. Lake Allure total nitrogen levels averaged 0.13 mg l^{-1} at the surface and 0.15 mg l^{-1} on the bottom (Figure 2.10, Table 2.3).

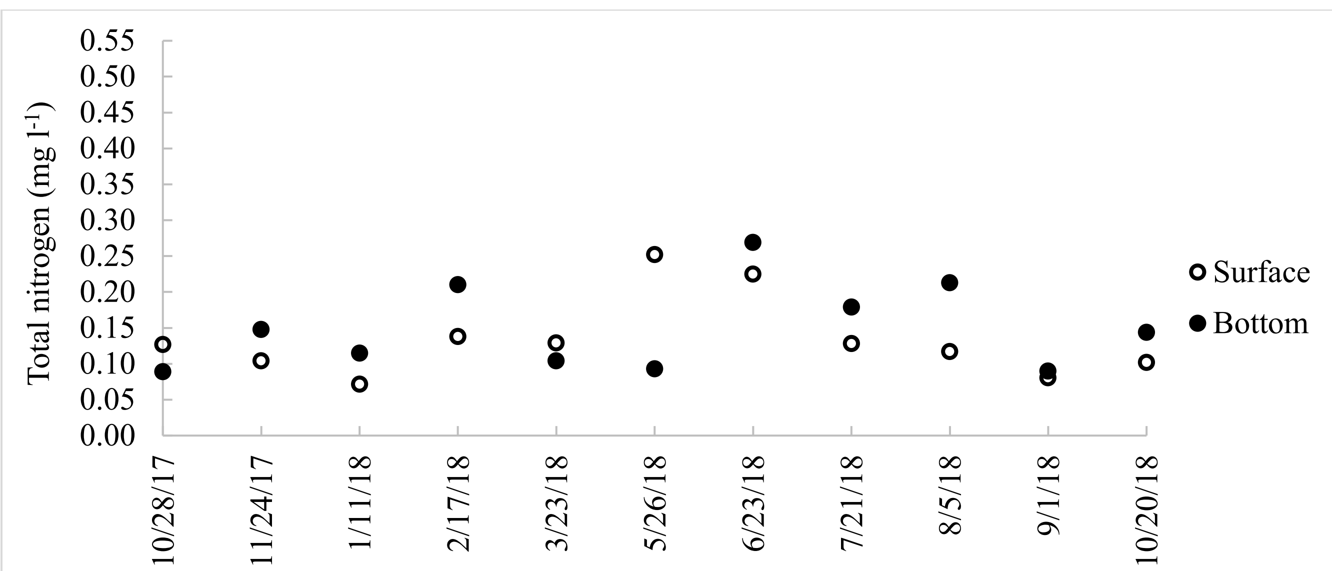

Figure 2.9: Lake Forest surface (0 m) and bottom (2 m) total nitrogen (mg l^{-1}) concentrations from water quality sampling dates.

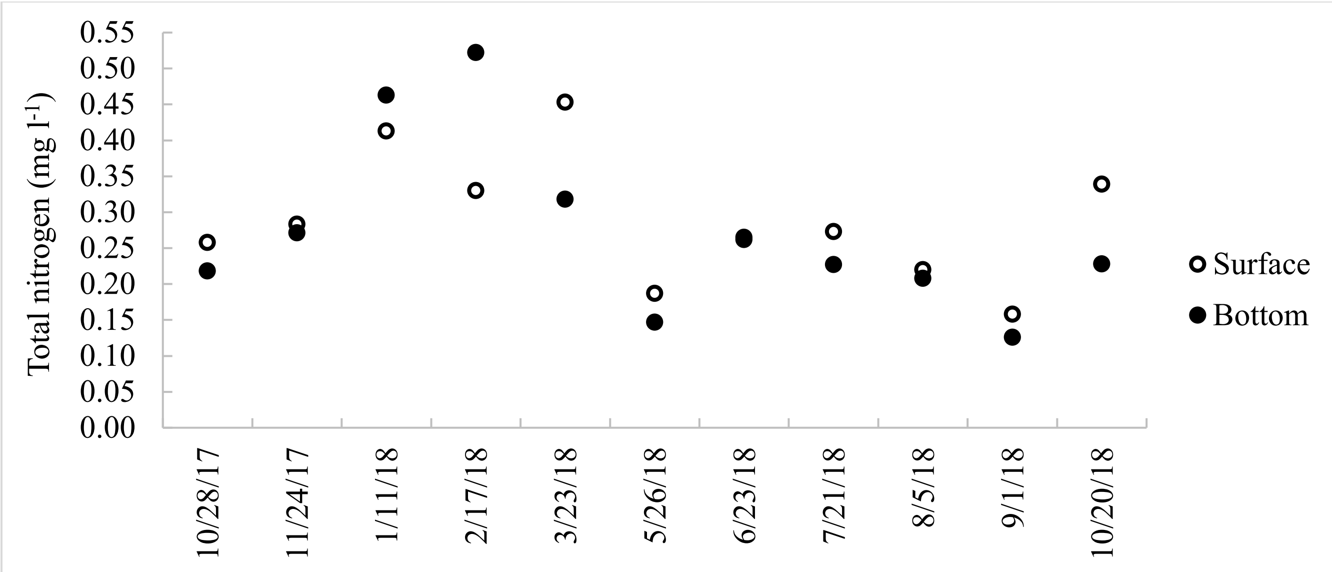

Figure 2.10: Lake Allure surface (0 m) and bottom (2 m) total nitrogen (mg l^{-1}) concentrations from water quality sampling dates.

Nitrate + Nitrite concentrations stayed at or below minimum detection levels in fall, spring and summer 2017-2018. Concentration levels increased during times of ice cover for both Lake Forest and Allure. Nitrate + Nitrite concentrations were 0.07 mg l^{-1} on the surface and 0.07 mg l^{-1} on the bottom of Lake Forest and 0.04 mg l^{-1} on the surface and 0.02 mg l^{-1} bottom of Lake Allure (Table 2.2 and 2.3).

Calcium (mg l^{-1} Ca^{2+}) values showed little variability over the four seasonal sampling events in both lakes. Lake Forest surface concentrations ranged from 10 – 8 mg l^{-1} with a mean concentration of 9.25 mg l^{-1} (Figure 2.11, Table 2.2). Lake Allure surface concentrations ranged from 8 – 7 mg l^{-1} with a mean concentration of 7.50 mg l^{-1} (Figure 2.12, Table 2.3).

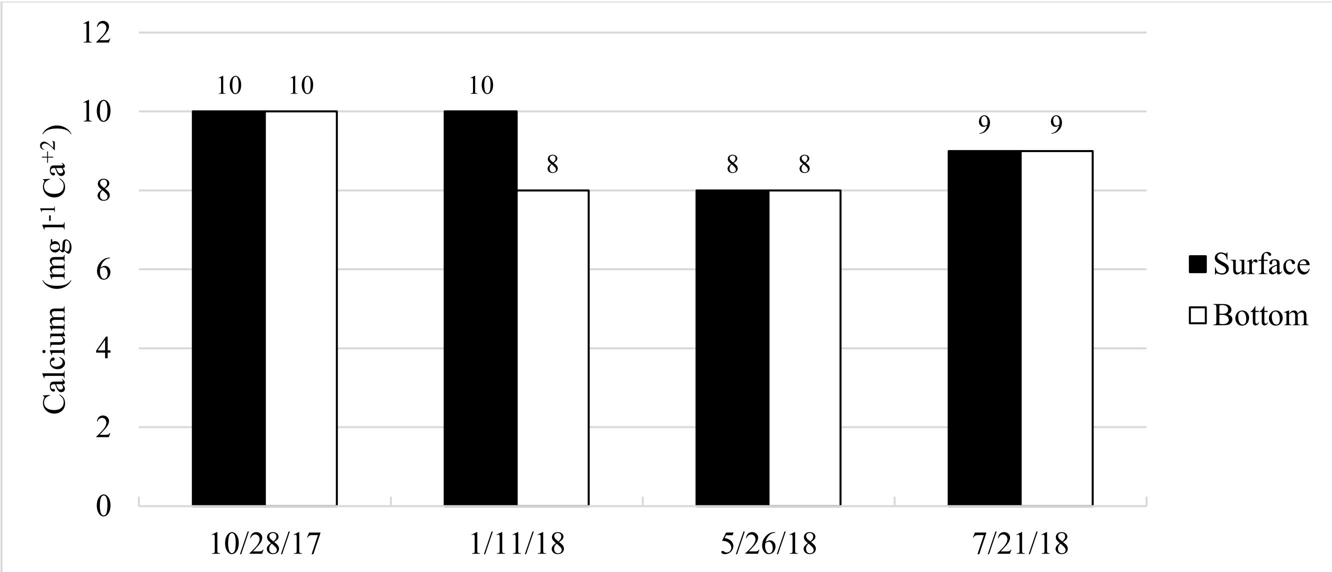

Figure 2.11: Lake Forest surface (0 m) and bottom (2 m) calcium (mg l^{-1} Ca^{2+}) concentrations from seasonal water quality sampling dates.

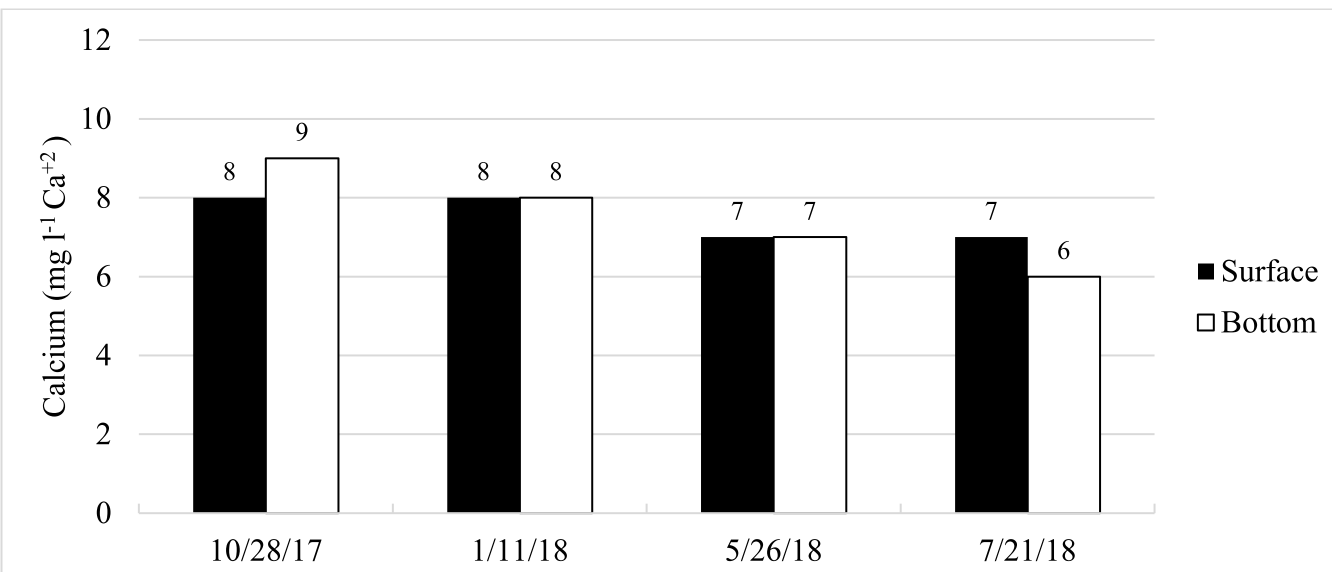

Figure 2.12: Lake Allure surface (0 m) and bottom (2 m) calcium (mg l^{-1} Ca^{2+}) concentrations from seasonal water quality sampling dates.

Alkalinity (mg l^{-1} $CaCO_3$) values fluctuated slightly during seasonal sampling events. Lake Forest surface concentrations ranged from 17 – 25 mg l^{-1} with a mean of 21.50 mg l^{-1} (Figure

2.13, Table 2.2). Lake Allure concentrations ranged from 12 – 19 mg l^{-1} with a mean of 15.00 mg l^{-1} (Figure 2.14, Table 2.3).

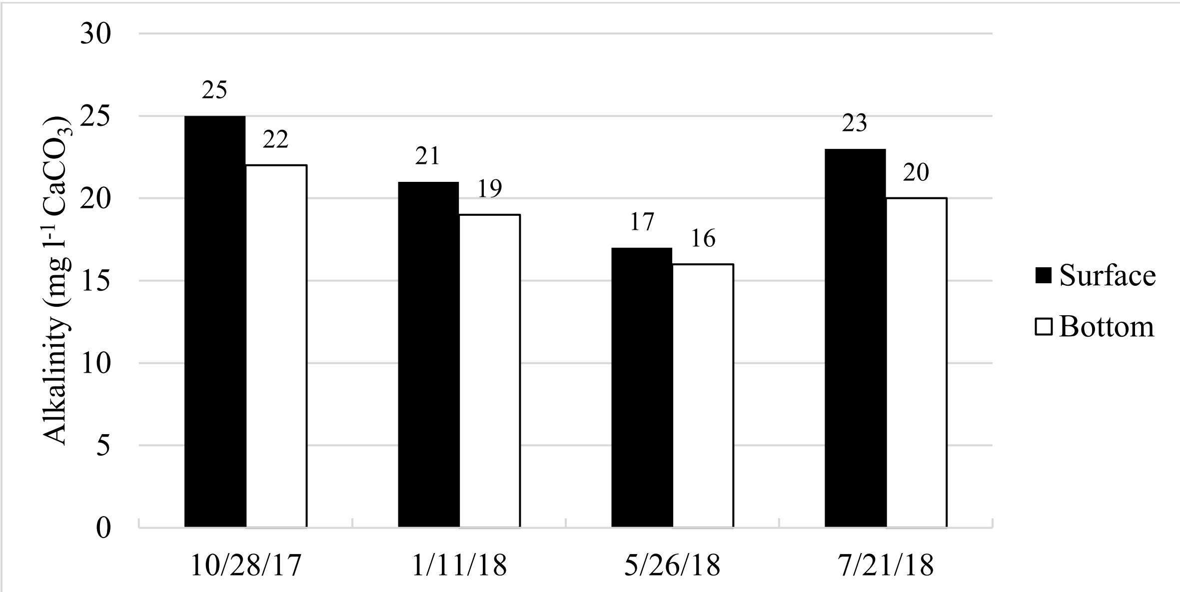

Figure 2.13: Lake Forest surface (0 m) and bottom (2 m) alkalinity (mg l^{-1} $CaCO_3$) concentrations from seasonal water quality sampling dates.

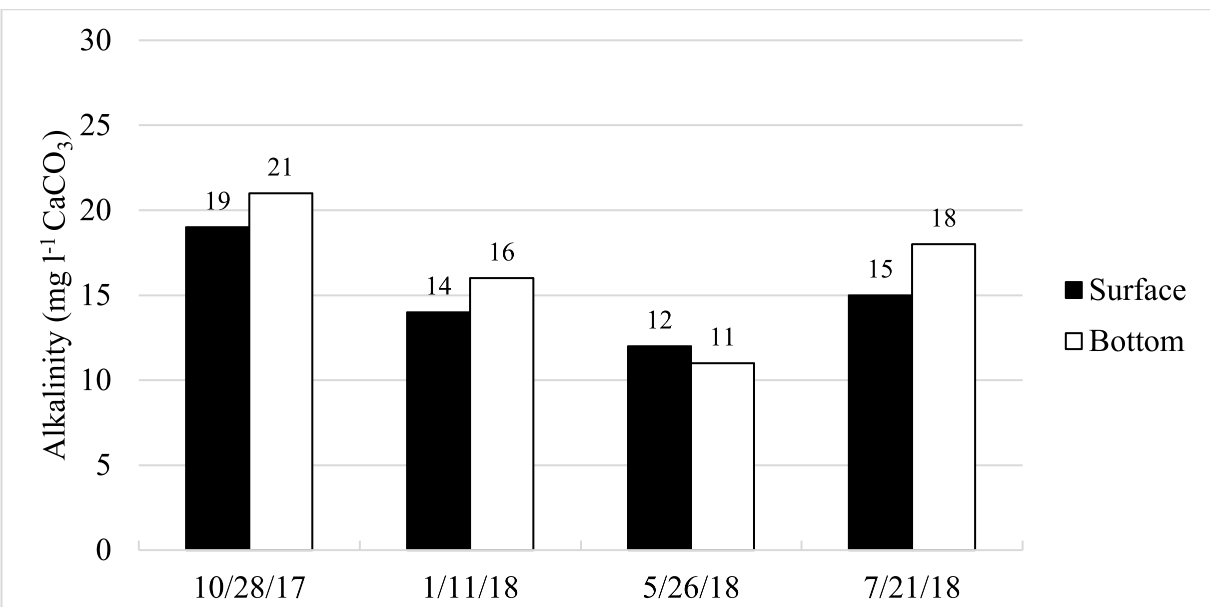

Figure 2.14: Lake Forest surface (0 m) and bottom (2 m) alkalinity (mg l^{-1} $CaCO_3$) concentrations from seasonal water quality sampling dates.

Lake Forest chlorophyll *a* concentrations ranged from 3.3 – 4.4 µg l^{-1} with a seasonal average of 3.90 µg l^{-1} (Figure 2.15, Table 2.2). Lake Allure chlorophyll *a* concentrations ranged from 3.1 – 4.2 µg l^{-1} with a seasonal mean of 3.67 µg l^{-1} (Figure 2.15, Table 2.3).

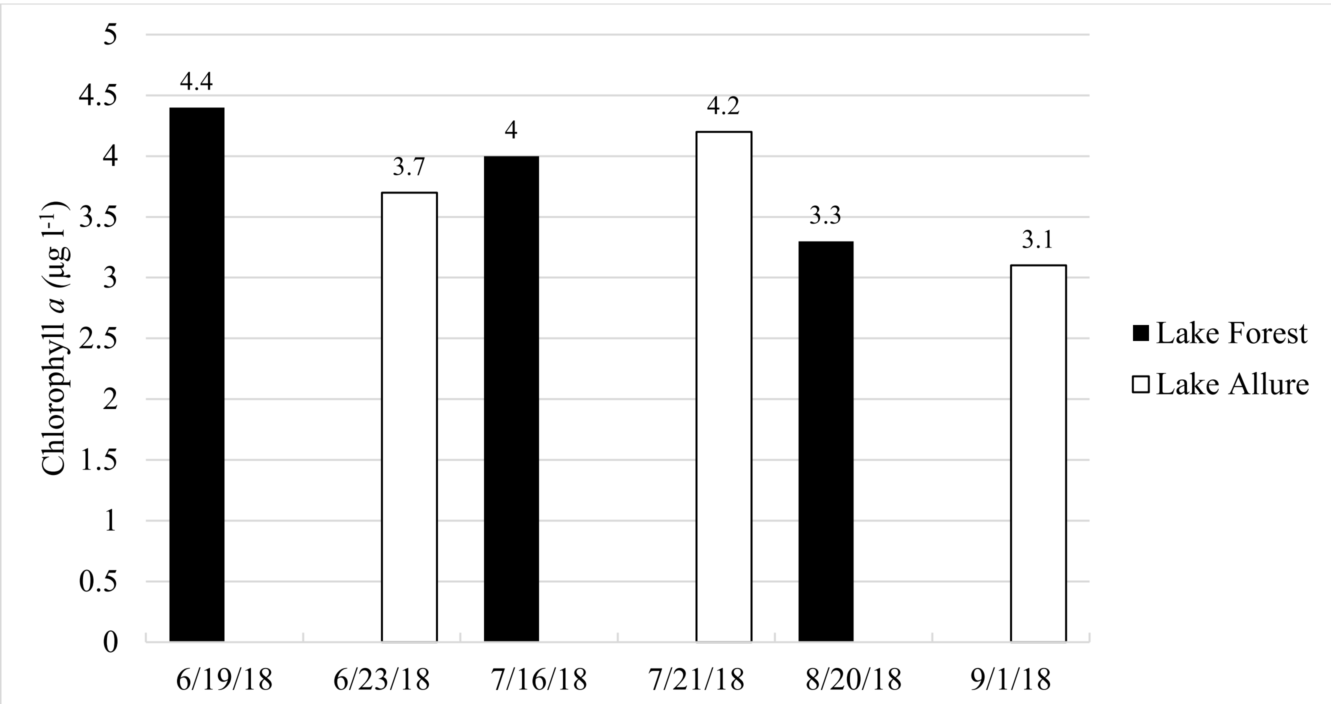

Figure 2.15: Lake Forest and Lake Allure surface (0 m) chlorophyll *a* (µg l^{-1}) concentrations from seasonal water quality sampling and CSLAP monitoring dates.

The true Secchi depth of both Lake Forest and Lake Allure exceeds what is reported because the disk was visible at the lake bottom on 90% of the sampling dates. The mean Secchi depth of Lake Forest was 1.92 m (Figure 2.16). Lake Forest Secchi depth has not drastically changed since the start of CSLAP monitoring in 2001 (CSLAP 2018). Historically, Secchi depth of Lake Forest was measured at 2.4 m but, due to natural succession, sediment load has increased about 1 ft. in depth at the sampling location. Mean Secchi depth of Lake Allure was 1.94 m (Figure 2.17). Unlike Lake Forest, previous water quality and Secchi depth data were unavailable for Lake Allure. Water quality parameters of the inlet and outlet sites of Lake Forest and Lake Allure are summarized in Table 2.4.

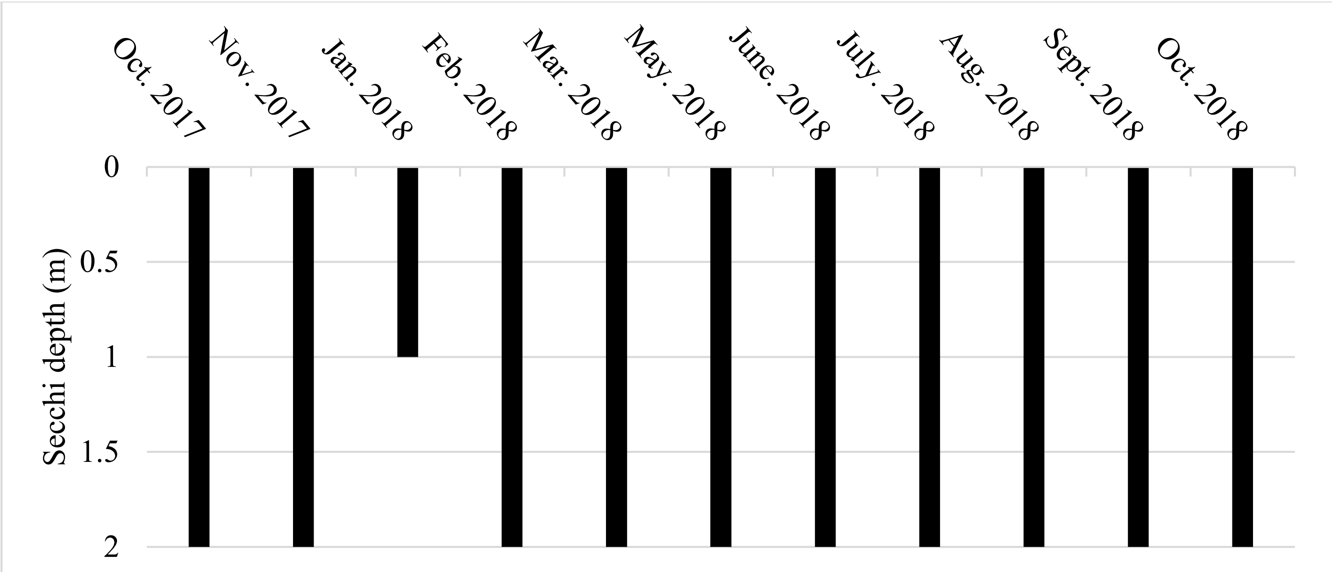

Figure 2.16: Lake Forest Secchi depth (m) from October 2017 – October 2018. Secchi depth was not collected in December 2017 and April 2018

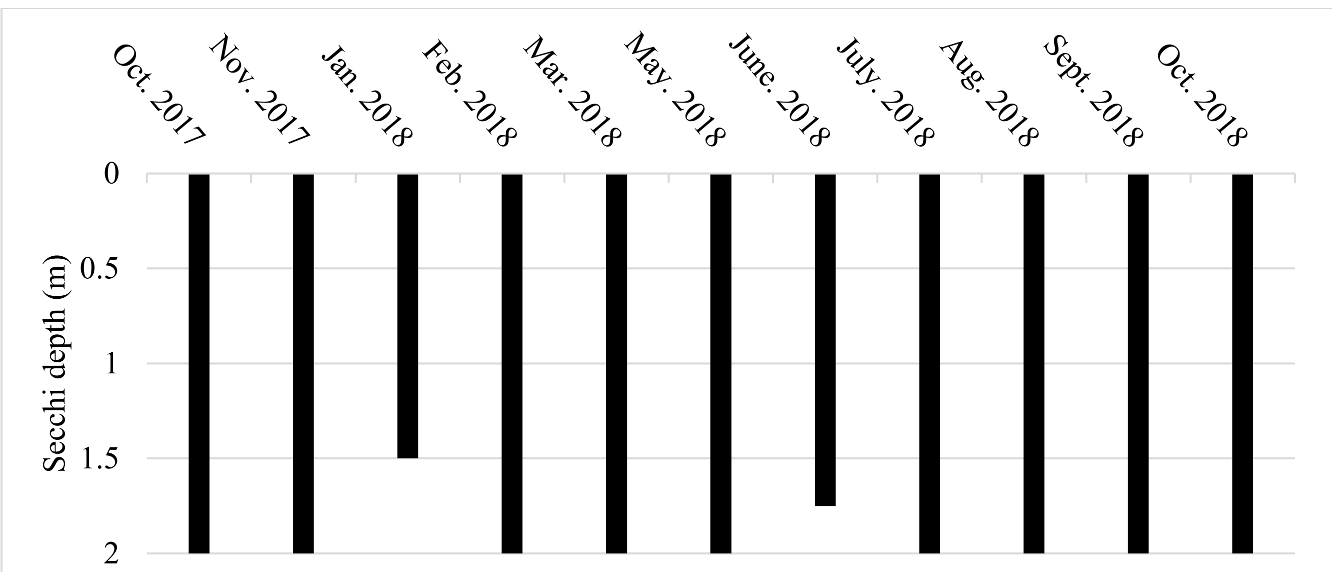

Figure 2.17: Lake Allure Secchi depth (m) from October 2017 – October 2018. Secchi depth was not collected in December 2017 and April 2018.

Table 2.4: Mean and range of nutrients from the inlets and outlet of Lake Forest and Lake Allure. (See figure 2.2 for reference of nutrient sampling locations).

Parameter	Site 1 Lake Forest Inlet	Site 2 Lake Allure Inlet	Site 3 Lake Forest Outlet
Average total phosphorus (μg l^{-1})	9.85	14.58	17.78
Range of total phosphorus (μg l^{-1})	9.00 – 11.00	7.00 – 20.00	7.00 – 45.00
Average total nitrogen (mg l^{-1})	0.21	0.12	0.24
Range of total nitrogen (mg l^{-1})	0.17 – 0.25	0.09 – 0.20	0.13 – 0.43
Average nitrate & nitrite (mg l^{-1})	Below detection	0.18	0.13
Range of nitrate & nitrite (mg l^{-1})	Below detection	Below detection – 0.57	0.04 – 0.31

Discussion

The chemical and physical limnology of both Lake Forest and Lake Allure points to mesotrophic systems that are moderately productive based on transparency, chlorophyll *a*, and total phosphorus levels (Table 2.5).

Table 2.5: Trophic status classification (TSI) parameters for oligotrophic, mesotrophic and eutrophic bodies of water (Carlson 1977, NYSFOLA 2009).

Parameter	**Oligotrophic**	**Mesotrophic**	**Eutrophic**
Transparency (m)	> 5	2 - 5	< 2
Total Phosphorus (μg l^{-1})	< 10	10 - 20	> 20
Chlorophyll *a* (μg l^{-1})	< 2	2 - 8	> 8

By examining historical CSLAP data of Lake Forest, it seems clear that trophic status has not changed drastically during the last 15 – 20 years. Water quality parameters such as total phosphorus, chlorophyll *a* and transparency from Lake Allure closely mimicked Lake Forest throughout the sampling period. It could be assumed, even with the lack of historical data, that Lake Allure has also not considerably changed trophic status over the last two decades.

Lake temperatures in polymictic systems during the summer are typically uniform throughout the water column. Average summer temperatures in Lake Forest and Lake Allure are typical of warm-water, shallow lakes in this and other temperate regions (Pearson and Jones 2008; Anderson et al. 2017). Constant in-lake mixing prevents stratification during the ice-free season. Shallow lakes can experience rapid rates of cooling and heating due to changes in air temperature, solar radiation, wind speed and other meteorological conditions (Woolway et al 2017). Due to constant mixing, the lakes lack distinct stratified layers typical of deeper waterbodies (Imburger 1985; Gorham and Boyce 1989; Anderson et al. 2017). Water temperature plays a vital role in aquatic systems because changes in water temperature can influence stratification which can dictate whether or not deoxygenation occurs. Temperature can also affect biological and chemical processes which determines the success of aquatic organisms (Gillooey et al. 2001; Yvon-D 2012, Martinson et al. 2019).

Dissolved oxygen concentrations in Lake Forest stayed above levels required by most aquatic organisms (5.00 mg l^{-1}) for most of the year (see Figure 2.5). Prolonged ice cover in January and February inhibited the addition of oxygen via diffusion and photosynthesis, reducing oxygen levels below biological thresholds. Lake Allure exhibited optimal dissolved oxygen concentrations throughout the study (see Figure 2.6). Wind-exposed lakes typically exhibit uniform dissolved oxygen concentrations during periods of mixing (Kalff 2002). Most aquatic organisms require dissolved oxygen concentrations above 5.00 mg l^{-1} to carry out important biological processes. When dissolved oxygen levels drop below this threshold, organisms can become stressed and it can result in a death for fish and other aquatic biota (Robarts et al. 2005). The decomposition of organic matter by aerobic bacteria can use up most, if not all of the oxygen within the water column during periods of stratification. Primary production from plants and algae can temporarily increase dissolved oxygen levels through photosynthesis but, as plants and algae respire or when they die and bacteria begin to break down organic matter, oxygen loss occurs. High rates of photosynthetic activity from aquatic macrophytes, epiphytes and algae can yield high daytime dissolved oxygen concentrations but as nighttime community respiration occurs, shallow lakes can develop anoxic conditions by early morning (Kalff 2002). When ice and snowpack cover the lake surface during winter months, the ability for plants and algae to photosynthesize decreases. Without adequate sunlight penetration, wave action or surface diffusion, there is the possibility of hypoxic or anoxic conditions to arise. Hypoxia is a decreased level of dissolved oxygen within the water column and anoxia is the complete loss of dissolved oxygen throughout the water column. When a lake becomes hypoxic or anoxic there is the potential for the aforementioned winter or summer fish kills. Dissolved oxygen levels in Lakes Forest and Allure are something for which many lake associations strive.

Alkalinity and calcium are two chemical qualities that are used to determine the buffering capacity of water. Both alkalinity and calcium are closely linked to pH in freshwater aquatic systems. pH is the measure of the free hydrogen ion concentration in water, whereas alkalinity is the buffering capacity of water to changes in pH, and is usually expressed as a measure of the carbonate and bicarbonate ions found in water. Alkalinity is influenced by calcium and magnesium ions found in water. Both are based upon a few factors, most of which are driven by the geology within the watershed (Wetzel 2001). Inputs from limestone can increase alkalinity through the addition of calcium ions, for example. Both Lake Forest and Lake Allure had slightly basic pH throughout the year. These basic conditions (pH > 8.5) could be from an influx of particles from the surrounding watershed after snow melt, flooding or heavy storm events. Average alkalinity of Lake Forest was 21.50 mg l^{-1} $CaCO_3$ and 15.0 mg l^{-1} $CaCO_3$ in Lake Allure. This low alkalinity can allow for rapid fluctuations in pH which was observed in both water bodies (Table 2.2 and 2.3).

Specific conductance is the measure of the dissolved ion concentrations in a body of water or the ability of water to conduct an electrical current. Conductive ions include salts, alkalis, and chlorides from the surrounding watershed. High conductance is observed when there are large quantities of conductive ions within a waterbody, and low conductance occurs when these ions are sparse. Storm events and snowmelt can have a direct effect on specific conductance in lakes. Specific conductance changed minimally in Lake Forest throughout the year with a mean specific conductance of 0.13 mS cm^{-1}. Specific conductance in Lake Allure was much lower when compared to Lake Forest, with a mean of 0.05 mS cm^{-1}. Specific conductance, like alkalinity, is typically affected by the geography and topography of the surrounding watershed (Wetzel 2001). The lack of dissolved ions in Lake Allure can be attributed to the forested nature of the surrounding watershed and the single lake inlet. Unlike Lake Forest, Lake Allure is not subject to excessive road salt, additional inlets, erosion and sedimentation.

Water transparency, usually measured as Secchi depth, is an indicator of sunlight penetration into the water column. Transparency plays a vital role in determining the trophic status of lakes and other waterbodies (Carlson 1977). Reduced water clarity can often be an indicator of excess external nutrient or sediment loads entering a waterbody. However, low water clarity may also be the baseline expectation in lakes with large watersheds and/or shallow maximum depth. True Secchi depth measurements exceed what is reported in both Lake Forest and Lake Allure because the disk was typically at the lake bottom during most sampling events. It seems reasonable to assume that mean Secchi depth in both lakes may be greater if Lake Forest and Lake Allure were deeper. Therefore, while Secchi depth is a useful for monitoring these systems, in the event of reduced transparency, other metrics such as chlorophyll *a*, total phosphorus may provide more resolution with respect to changes in trophic status.

Total phosphorus is the measure of both dissolved and suspended phosphorus in a system (NYSDEC 2011). Phosphorus is found in virtually every waterbody. In addition to natural inputs from the watershed; agriculture, lawn fertilizers, and septic waste from homes and water treatment plants all are commonly cited sources of anthropogenic phosphorus. High levels of phosphorus in aquatic systems can contribute to increased intensity or frequency of algal blooms and increased aquatic plant growth. Freshwater systems in NY are considered nutrient rich or eutrophic if phosphorous concentrations exceed 20 μg l^{-1} and nutrient poor or oligotrophic if concentrations are below 10 μg l^{-1} (Carlson 1977, NYSFOLA 2009). Systems that fall between these concentrations are considered moderately productive or mesotrophic. Total phosphorus concentrations in Lake Forest remained between 10 μg l^{-1} and 15 μg l^{-1} during the last 15 years, according to historic CSLAP data. Consistent values indicate that there have not been any major changes to the watershed or the lake to increase eutrophication during this time period. Although historical data for Lake Allure are not available, phosphorus concentrations indicate a similar mesotrophic status.

Typically, chlorophyll *a* concentrations are used to examine primary production within a waterbody. Chlorophyll *a* is the prevalent form of chlorophyll that facilitates plant and algal photosynthesis as it absorbs energy from light waves. Chlorophyll *a* concentrations can provide insight into algal production within a lake, reservoir or pond (Arar and Collins 1997). Algal production can come from either green alga, harmful cyanobacteria or the other divisions of algae. Average chlorophyll *a* concentrations were 3.90 μg l^{-1} in Lake Forest and 3.67 μg l^{-1} in Lake Allure, both being below 10 μg l^{-1} which is considered the threshold for excessive algal growth.

To help understand trophic status, chlorophyll *a*, total phosphorus, and Secchi depth are often used to determine eutrophication in freshwater basins (Carlson 1977). Trophic status indices (TSIs) can be calculated using the following formulas:

$$TSI(SD) = 60 - 14.41 \ln(SD)$$
$$TSI(TP) = 14.42 \ln(TP) + 4.15$$
$$TSI(CHL) = 9.81 \ln(CHL) + 30.6$$

According to the TSI calculations, both Lake Forest and Lake Allure fall within the mesotrophic state (Table 2.6). Trophic status indices were in the range of 40-50. Typically, this range is associated with Secchi depths of 2 – 4 m, chlorophyll *a* concentrations of 2.6 – 7.3 μg l^{-1} and total phosphorus levels between 12 and 24 μg l^{-1}.

Table 2.6: TSI calculations for Lake Forest and Lake Allure looking at secchi depth, total phosphorus and chlorophyll *a*.

Parameter	Lake Forest	Lake Allure
Secchi depth (m)	50.38	50.01
Total phosphorus (μg l^{-1})	43.95	43.35
Chlorophyll *a* (μg l^{-1})	39.72	44.36

Total nitrogen includes all forms of nitrogen including, nitrite, nitrate and ammonia and that contained in organic compounds. Nitrogen is an essential nutrient for plant growth. Excessive total nitrogen concentrations can enable excessive aquatic plant growth, decrease dissolved oxygen levels and negatively impact aquatic organisms (EPA 2013). Nitrogen can enter aquatic systems either through the atmosphere or from the encompassing watersheds (Kalff 2002). According to the EPA, an acceptable range of total nitrogen falls between 2 mg l^{-1} and 6 mg l^{-1} within any fresh body of water (EPA 2003). Total nitrogen concentrations increased under ice cover in Lake Forest but barely reach the EPA threshold for aquatic systems. Both Lake Forest and Lake Allure fell below the optimal ranges which can eventually impact the aquatic plan community, as well as other aquatic organisms.

Nitrate + nitrite fell below the detection level for most of this study. Nitrates and nitrites can enter an aquatic system through agricultural run-off in the form of fertilizers or livestock manure (WQA 2013). These nutrients not only originate from agricultural land but, from natural deposits and leeching of home septic systems. Nitrate concentrations greater than 10.0 mg l^{-1} and nitrite concentrations greater than 1.0 mg l^{-1} are considered dangerous according to the EPA (WQA 2013). Average nitrate + nitrite concentrations were well below EPA guidelines with an average surface concentration of 0.07 mg l^{-1} in Lake Forest and 0.04 mg l^{-1} in Lake Allure.

Further lake monitoring is recommended as it can help guide future management decisions for Lakes Forest and Allure. Continued limnological monitoring of Lake Forest through CSLAP is highly encouraged and it is recommended to utilize CSLAP to gather yearly data for Lake Allure to help better understand the impoundment.

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Chapter 3: Aquatic Macrophytes of Lake Forest and Lake Allure

Introduction

Lake Forest and Lake Allure support a diverse community of aquatic macrophytes, which includes aquatic plants and macro-algae (Block and Rhoads 2011). Aquatic plants are critical for sustaining freshwater biodiversity as littoral zones (where plants grow) and provide habitat for many organisms such as waterfowl, amphibians, fish, and mammals (Kalff 2002, Scheffer 2004, NYSFOLA 2009, Akasaka and Takamura 2011). Stands, or beds, of macrophytes may also provide spawning areas for adult fish and nursery habitat for their young (Wiley et al. 1984). Macrophytes oxygenate water through photosynthesis, they sequester nutrients and provide bank and sediment stabilization (Kalff 2002). Ecological services from aquatic macrophytes such as sediment stabilization from root mass, can help decrease shoreline erosion and decrease the number of suspended particles within the water column.

Although aquatic plants play an important role within the ecosystem, excessive plant growth can alter human perception of the resource and can be considered a nuisance to recreational users as they can interfere with swimming, boating, fishing and aesthetic enjoyment. Overabundance of aquatic macrophytes can cause concern among lake stakeholders as it can interfere with a multitude of activities and dense stands can damage watercraft motors, obstruct swimming areas and inhibit other recreational activities (Kalff 2002). A major management concern for many lakes is not only excessive native plant growth but, the growth, overabundance and transport of non-native plants known as aquatic invasive species (AIS). Non-native plants can dominate areas in the waterbody where native species once grew and may not provide many essential in-lake functions that native aquatic plants provide.

The distribution and species richness of aquatic macrophytes is directly related to the physio-chemical state of water, surface area, water depth and sediment type (Rorslett 1991, Akasaka and Takamura 2011). Factors such as available nutrients or water clarity play an important role in determining species richness as plants rely on sunlight, nutrient uptake and temperature to grow and reproduce. Floating leaved macrophytes rarely experience physio-chemical limitations because they grow on the surface where sunlight is always available for photosynthesis but, can be limited by water depth. In contrast, submergent macrophyte growth can be hindered by reduced water clarity, and shading caused by well-established floating-leaved plants (Akasaka and Takamura 2011). Aquatic plant growth is limited to the littoral or photic zone where sunlight penetration to the bottom is sufficient for growth. As day length decreases, most aquatic plants in the Northeast senesce, or die, seasonally and they decompose at the bottom of the waterbody. The organisms that decompose plants and algae use dissolved oxygen from the waterbody for respiration. Therefore, the decomposition of plant material by aerobic bacteria can cause decreased levels of oxygen at the lake bottom, which can result in hypoxic or anoxic conditions in extreme cases. Excessive decomposed organic matter can also accumulate as a bottom layer of flocculent material above lake consolidated sediments.

Aquatic plant surveys were conducted by the Darrin Fresh Water Institute (DFWI) on both Lake Forest and Lake Allure in 2000, 2002, 2004, 2009, and 2013 (Eichler 2013). Past surveys of each waterbody were designed to provide information to the Adirondack Park Agency (APA) for an aquatic plant management permit, which allows the lake level to be drawn down during the winter. Surveys were conducted in conjunction with a watershed management plan for Warren County, New York. Surveys documented the current status of aquatic plant populations, and then provided management strategies for each waterbody. Previous aquatic plant studies of Lake Forest and Lake Allure have solely focused on identifying common macrophyte species within each body of water to determine water-level drawdown permitting and identification of AIS. Bi-annual winter water level drawdowns have been the only means of aquatic plant control in Lake Forest. In 1993, the NWLA was granted an overwinter permit to drop water levels 6.8 ft from the top of the dam spillway. The permit was amended in 2017 which authorized three additional water level drawdowns of 3 ft over a five-year period. Residents at Lake Allure do not currently use any other type of aquatic plant control.

The Adirondack Park Invasive Plant Program (APIPP), administered by the Adirondack Chapter of the Nature Conservancy, conducted early detection AIS surveys of Lake Forest in the summer of 2015 and 2018. While surveying for aquatic invasive species, native aquatic macrophytes were identified and a comprehensive list was compiled. In 2015, the most abundant species collected were bigleaf pondweed (*Potamogeton amplifolius*) and ribbon leaf pondweed (*Potamogeton epohydrus*), with 100% coverage of the lake bottom at known survey locations (Schwartzberg et al. 2015). Surveys in 2018 determined that bigleaf pondweed and bladderwort species (*Utricularia* sp.) were the most abundant (Schwartzberg et al. 2018). No AIS were detected during either survey. Native aquatic plant beds cover most of the lake bottom with most of the native vegetation biovolume over 50% (Figure 3.1).

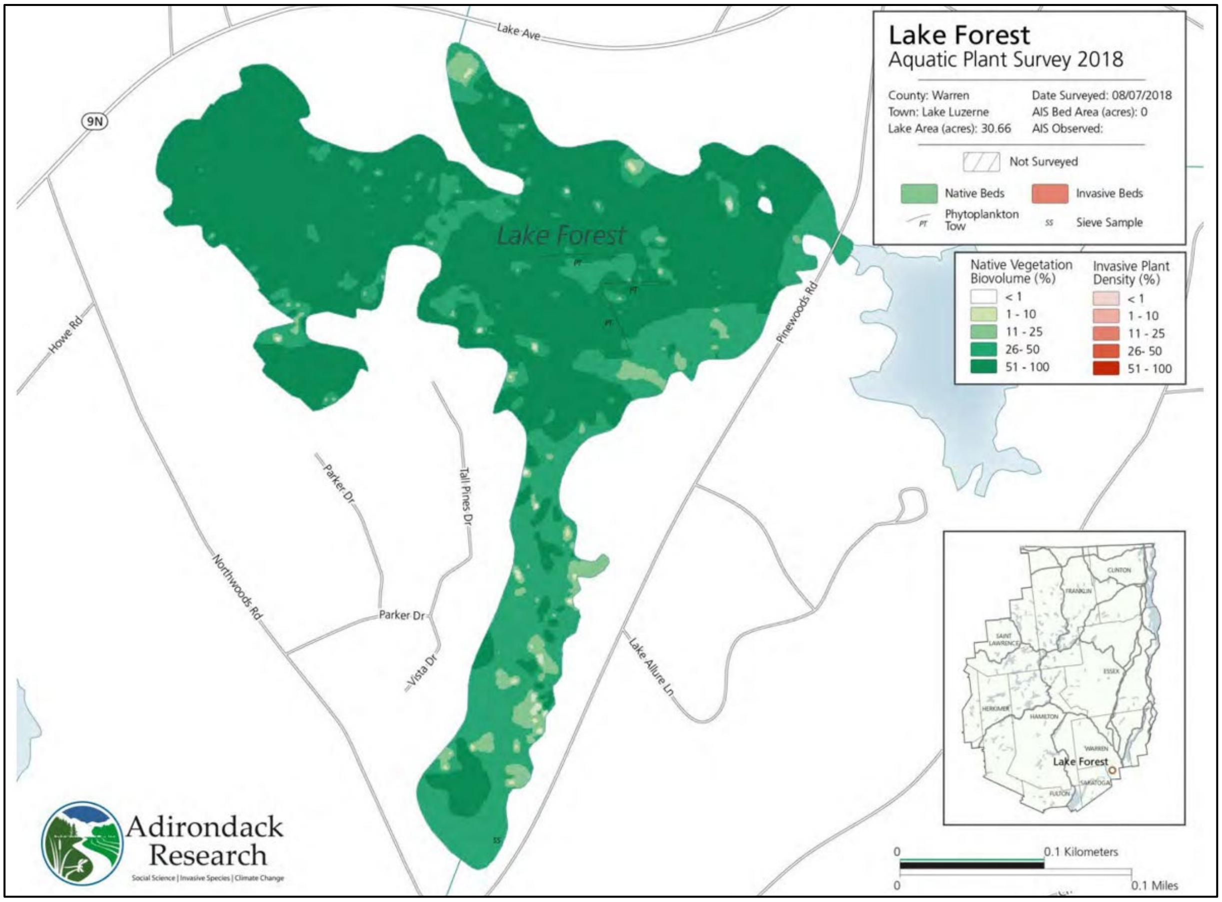

Figure 3.1: Lake Forest native vegetation biovolume map completed by the APIPP 2018 (Schwartzberg et al. 2018).

To establish potential management strategies for aquatic plant control in Lakes Forest and Allure, three objectives were determined to 1) identify the current aquatic macrophyte communities in Lake Forest and Lake Allure, 2) evaluate seasonal changes in aquatic macrophytes, and 3) provide the NWLA with baseline data to use for future lake and watershed management.

Methods

Plant surveys were conducted on June 23, July 21, and September 1, 2018. Surveys were conducted using the Point Intercept Rake Toss Relative Abundance Method (PIRTRAM, Lord and Johnson 2006). Sampling sites were determined using a 15 × 15 m UTM grid in Google Earth™ (Figure 3.2). Due to their size, each waterbody was sampled at all sites, which were located using a Garmin handheld GPS. In total, 39 locations were sampled in Lake Forest and 12 locations were sampled in Lake Allure (Figure 3.2).

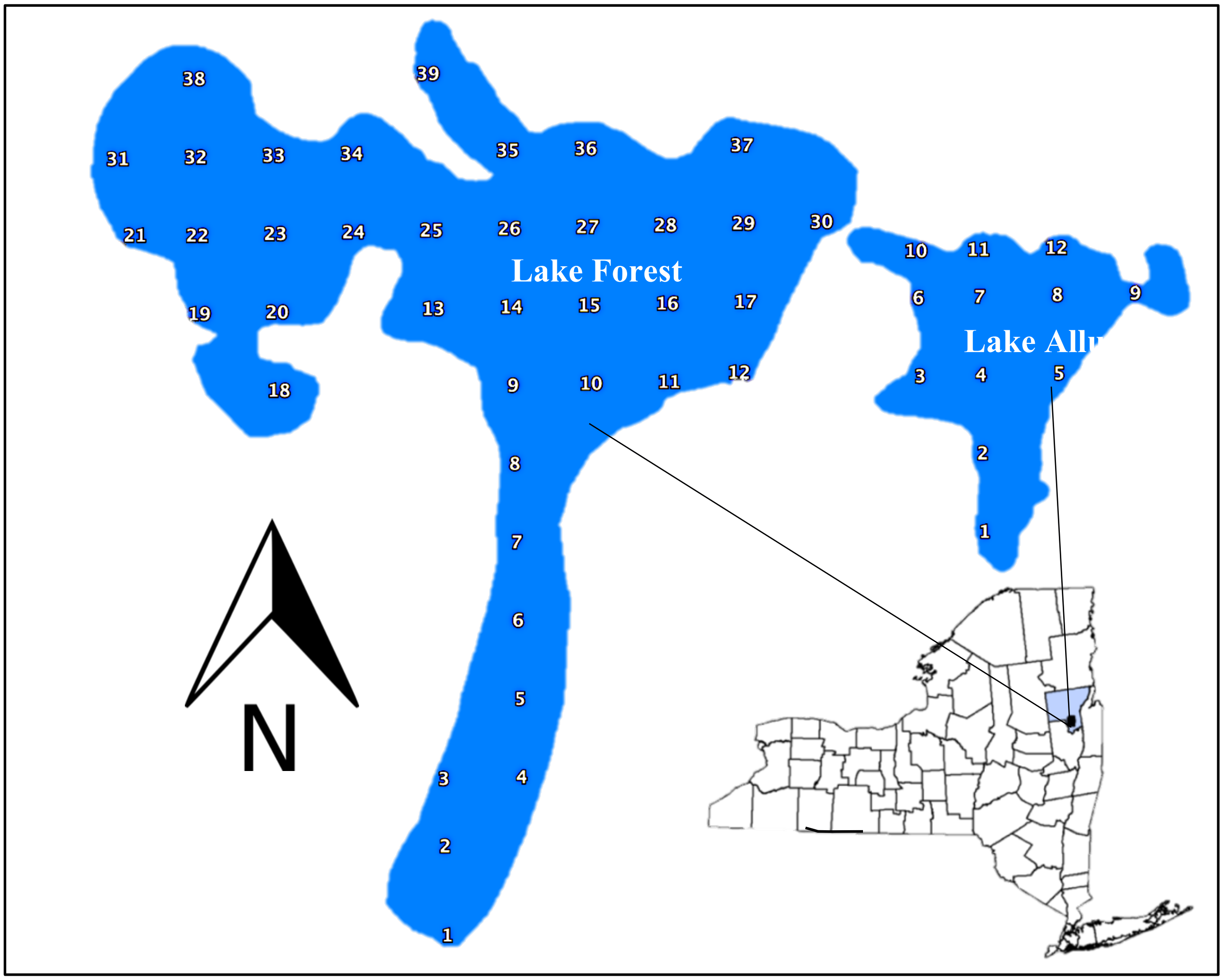

Figure 3.2: Map of sampling locations used for aquatic macrophyte surveys in Lake Forest and Lake Allure, NY June 23, July 21, and September 1, 2018.

A double-sided 0.33 m metal rake head attached to 12 m of rope was tossed three times at each sampling location: once each from the starboard, port and bow of the boat. The rake was allowed to settle to the bottom and was slowly pulled back to the boat. Aquatic macrophytes were identified to species using Block et al. (2011) and Borman et al. (2014) and total relative abundance was recorded for each species at each site. Plants were recorded in 5 abundance categories (Table 3.1).

Table 3.1: Categories used to classify plant abundance and associated range and midpoints for estimated dry weight (g/m^2) for each category (Lord and Johnson 2006).

Abundance category	Field measurement	Dry weight range(g/m^2)	Dry weight midpoint (g/m^2)
"Z" = no plants	No plants	0	0
"T" = trace plants	Fingerful of plants	.0001-2.000	1.00005
"S" = sparse plants	Handful of plants	2.001-140.000	71.0005
"M" = medium plants	Rakeful of plants	140.001-230.000	185.0005
"D" = dense plants	Difficult to bring into boat	230.001-450.000+	340.0005

Results

Lake Forest

Plant densities were mapped at 39 locations around Lake Forest (Figure 3.2). Nineteen native species were identified in Lake Forest with the most common being big leaf pondweed (*Potamogeton amplifolius*), bladderwort (*Utricularia* sp.), tape grass (*Vallisneria americana*), stonewort (*Nitella* sp.), waterweed (*Elodea* sp.), watershield (*Brasenia schreberi*) and variable pondweed (*Potamogeton gramineus*) (Table 3.2). June plant densities were categorized at sample sites as sparse (n = 20) and moderate (n = 15) (Figure 3.3). Plant densities increased throughout the growing season as expected, with increasing daylength and temperatures. July abundance increased to moderate (n = 24) and dense (n = 9) with five additional species observed in July (Figure 3.4). Watershield, northern water nymph (*Najas flexilis*), ribbonleaf pondweed (*Potamogeton epohydrus*), snailseed pondweed (*Potamogeton spirillus*), water bulrush (*Scirpus subterminalis*) and lesser bladderwort (*Utricularia minor*) were present in both July and September 2018. September surveys categorized Lake Forest with moderate (n = 24) and dense (n = 13) vegetation at sample sites (Figure 3.5). The highest densities of aquatic plants were found at sites 15 – 38 (Figure 3.3) where water depths were less than 1 m (3.28 ft) in depth. The most abundant species collected throughout the growing season were tape grass, watershield, stonewort, and bigleaf pondweed. Based on PIRTRAM dry weight midpoints, average plant biomass in Lake Forest was 322 g/m^2 in June 2018 (Figure 3.6), 133 g/m^2 in July 2018 (Figure 3.67) and 669 g/m^2 in September (Figure 3.8) per site. Average summer biomass ranged from 0.700 to 340 g/m^2 across sites. No AIS were identified in surveys of Lake Forest.

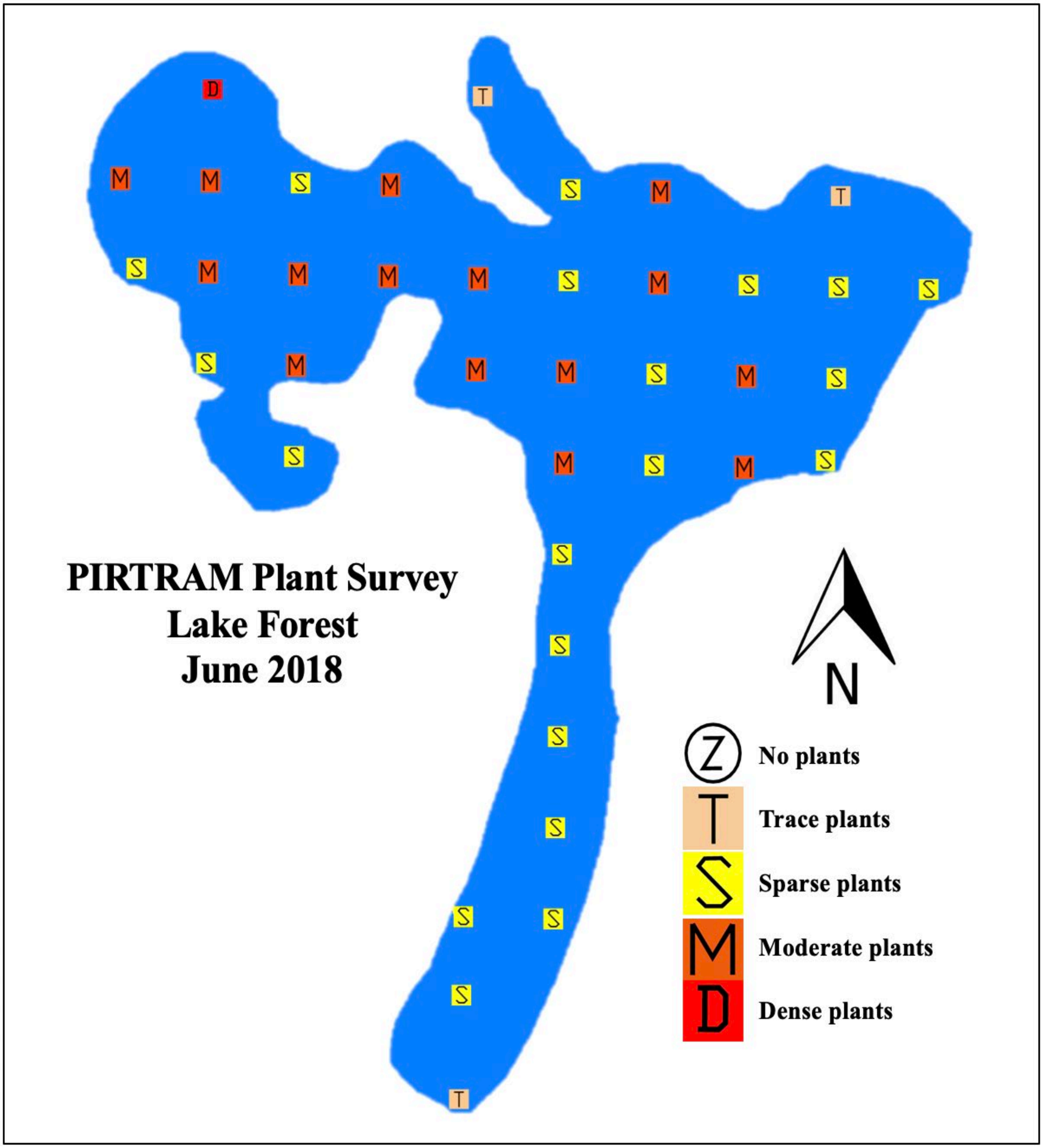

Figure 3.3: Map of Lake Forest seasonal plant density from June 2018 at PIRTRAM sampling locations.

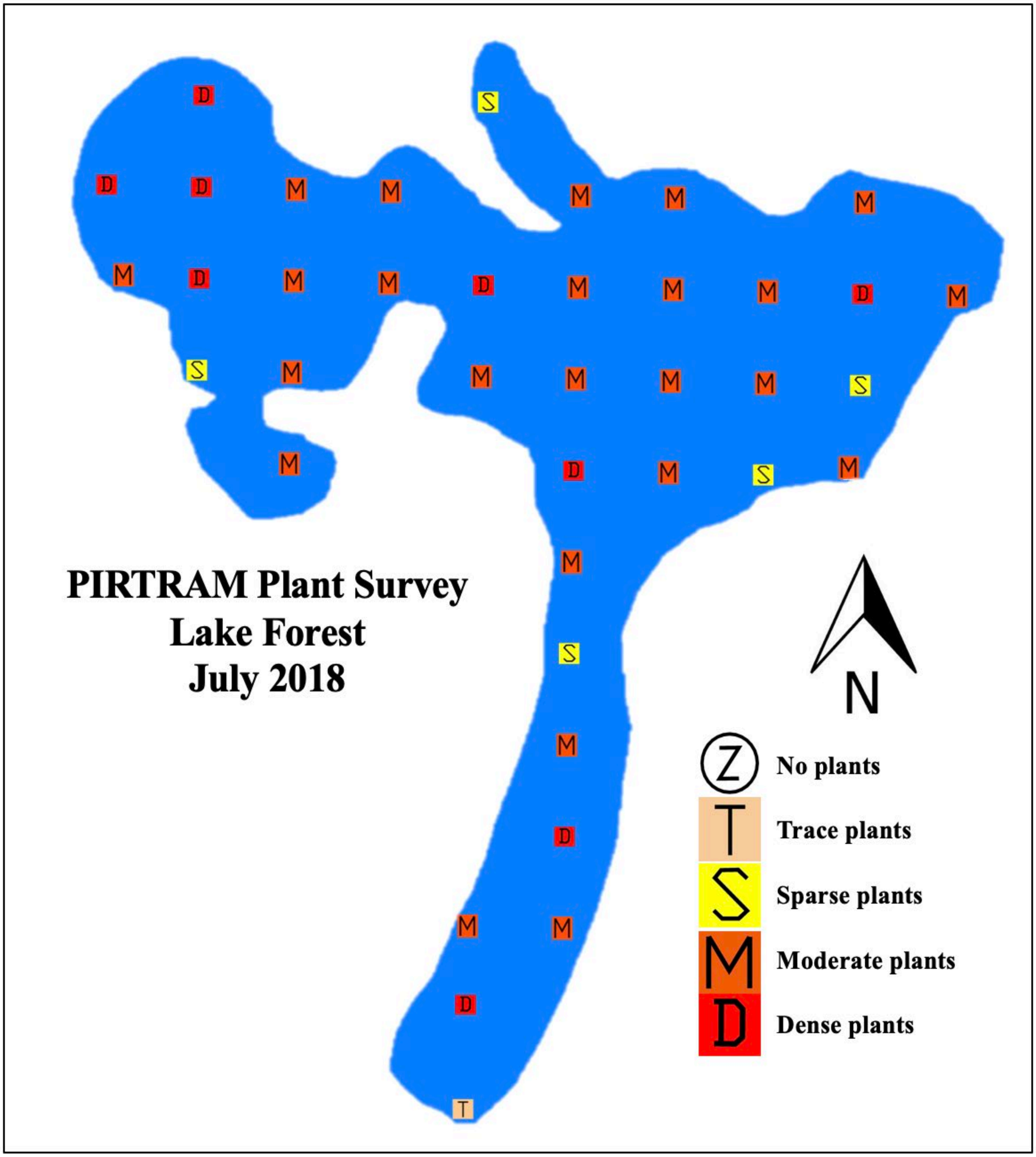

Figure 3.4: Map of Lake Forest seasonal plant density from July 2018 at PIRTRAM sampling locations.

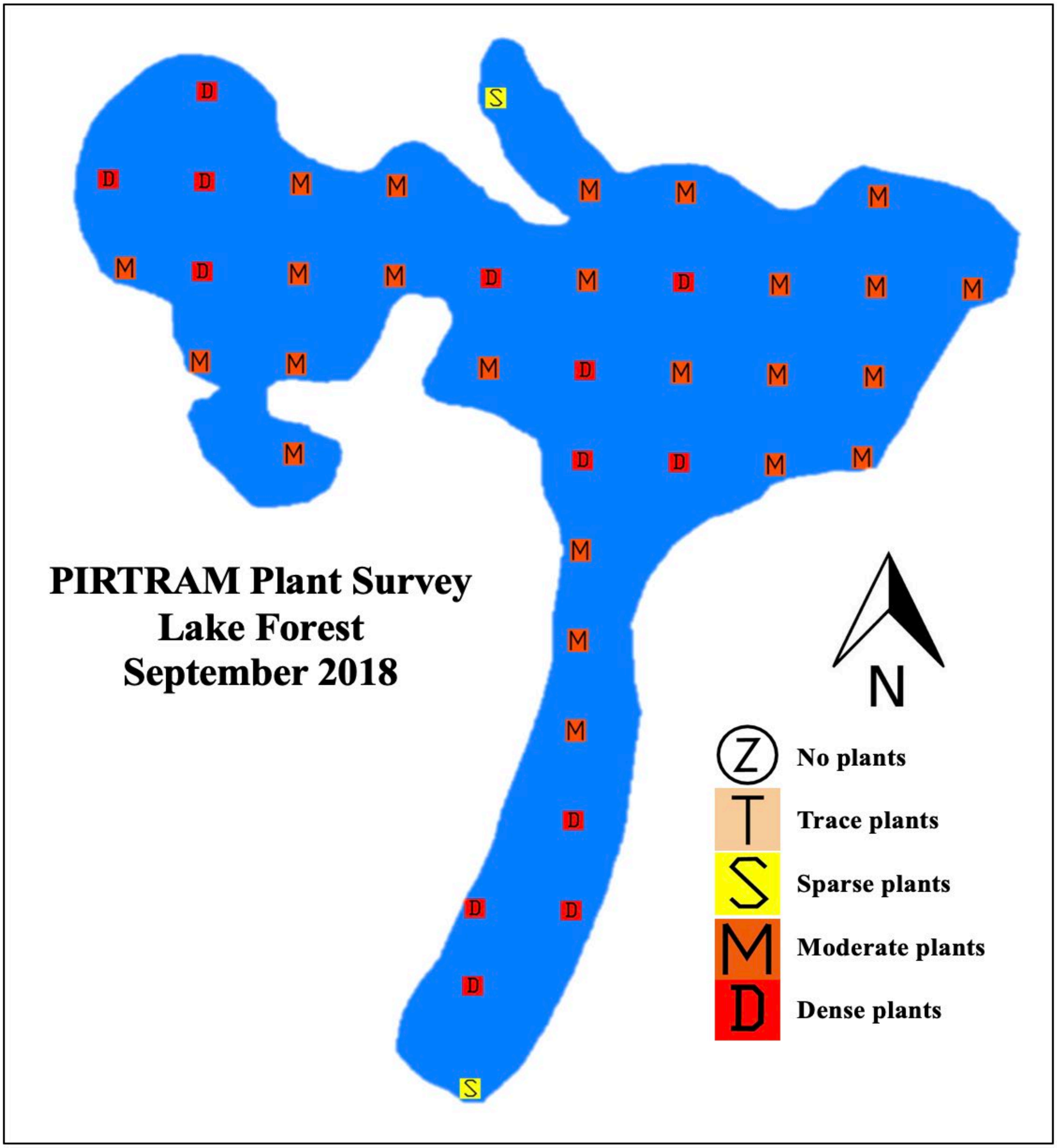

Figure 3.5: Map of Lake Forest seasonal plant density from September 2018 at PIRTRAM sampling locations.

Table 3.2: Aquatic plant species found in Lake Forest during summer 2018 aquatic macrophyte surveys during June, July, and September 2018.

Scientific Name	Common Name	June 2018	July 2018	September 2018	Notes
Chara sp.	Musk grass	X	X	X	Submergent, free-floating, macroalga
Nitella sp.	Stonewort	X	X	X	Submergent, free-floating, macroalga
Fontinalis sp.	Aquatic moss	X	X	X	Submergent
Elodea canadensis	Common waterweed	X	X	X	Submergent, Perennial
Elodea nuttallii	Slender waterweed	X	X	X	Submergent, Perennial
Najas flexilis	Northern waternymph		X	X	Submergent, Annual
Brasenia schreberi	Watershield		X	X	Floating-leaf, Perennial
Nuphar variegata	Yellow water lily	X	X	X	Floating-leaf, Perennial
Nymphea odorata	White water lily	X	X	X	Floating-leaf, Perennial
Potamogeton amplifolius	Bigleaf pondweed	X	X	X	Submergent, Perennial
Potamogeton epohydrus	Ribbonleaf pondweed		X	X	Submergent, Floating-leaf, Perennial
Potamogeton gramineus	Variable pondweed	X	X	X	Submergent, Perennial
Potamogeton robbinsii	Fern pondweed	X	X	X	Submergent, Perennial
Potamogeton spirillus	Snailseed pondweed		X	X	Submergent, Perennial
Scirpus subterminalis	Water bulrush		X	X	Emergent or Submergent, Perennial
Utricularia intermedia	Flat leaved bladderwort	X	X	X	Submergent, Perennial
Utricularia minor	Lesser bladderwort		X	X	Submergent, Perennial
Utricularia vulgaris	Common bladderwort	X	X	X	Submergent, Perennial
Vallisneria americana	Tape grass	X	X	X	Submergent, Perennial

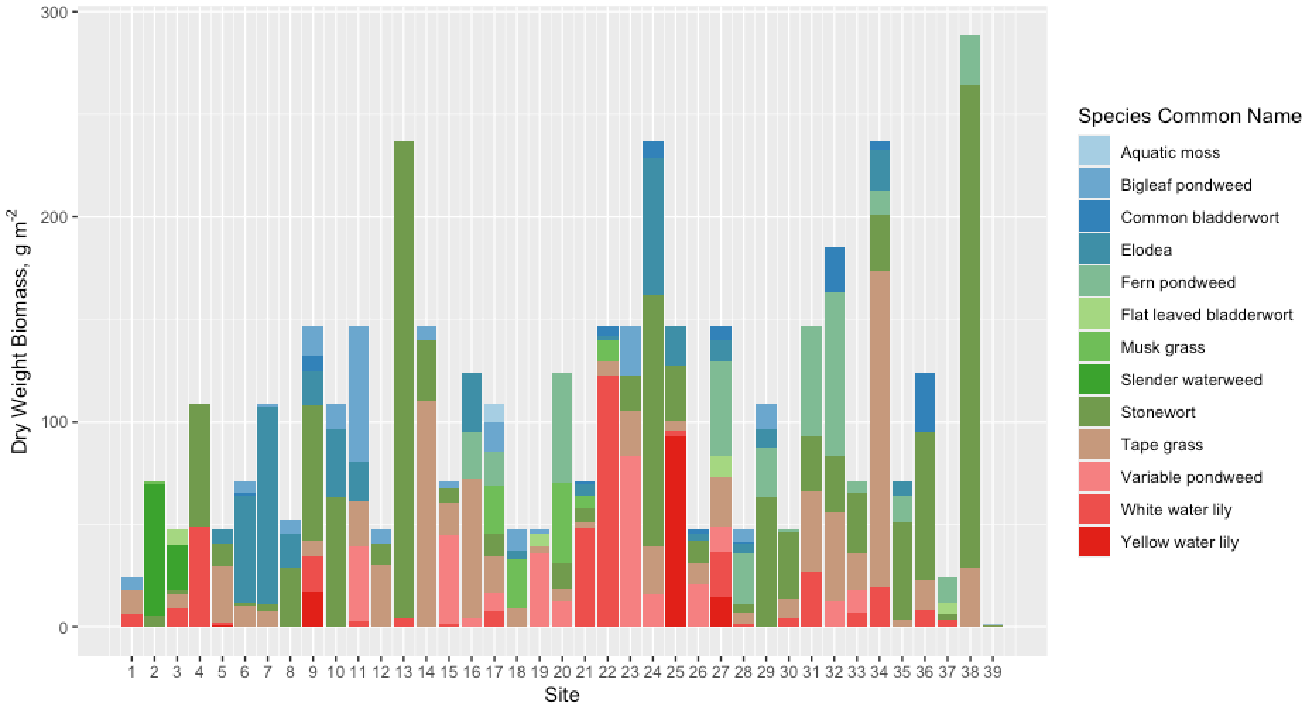

Figure 3.6: Dry weight biomass (g/m^2) of collected macrophytes from sample sites in Lake Forest, June 2018. Biomass is based on the midpoint PIRTRAM designations (Table 3.1).

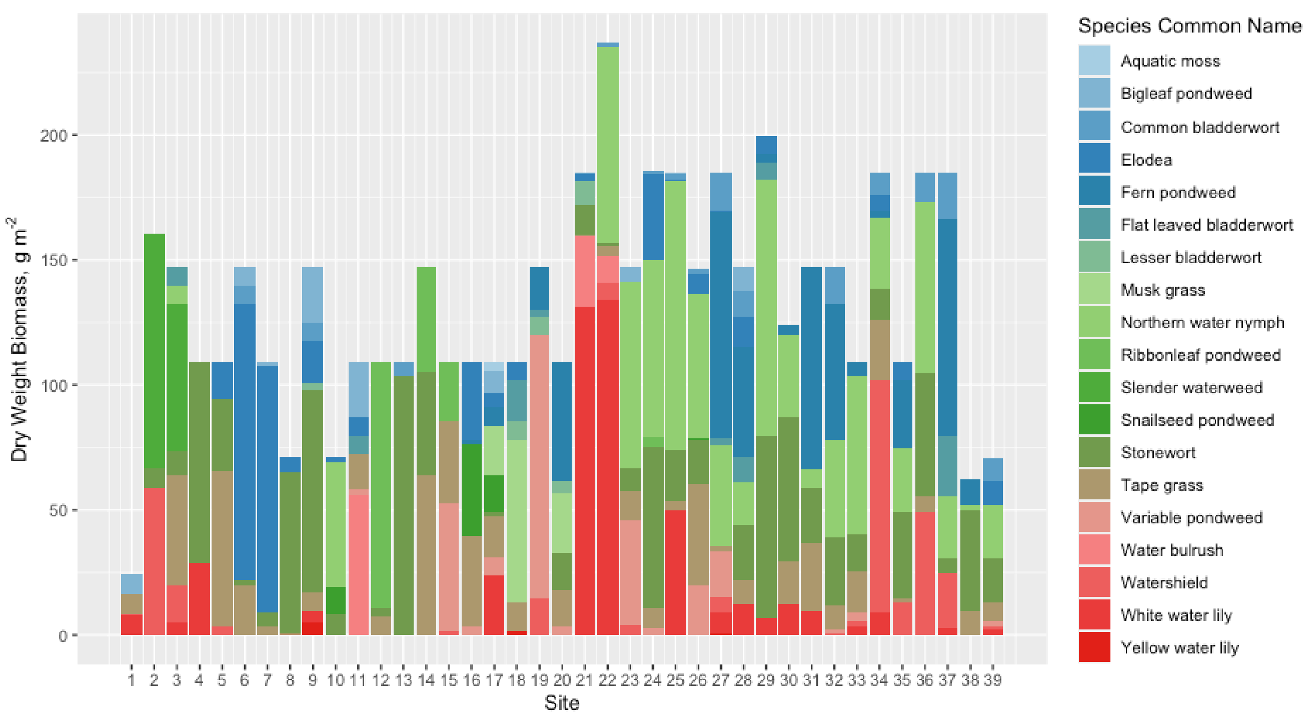

Figure 3.7: Dry weight biomass (g/m^2) of collected macrophytes from sample sites in Lake Forest, July 2018. Biomass is based on the midpoint PIRTRAM designations (Table 3.1).

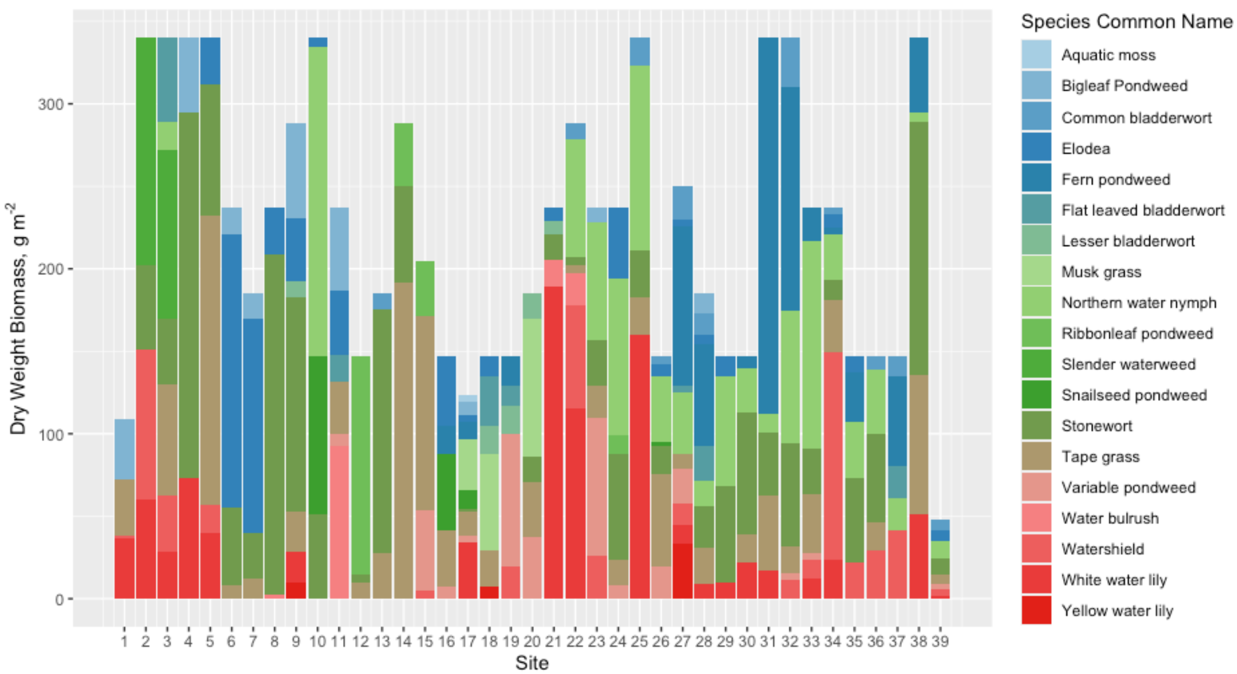

Figure 3.8: Dry weight biomass (g/m^2) of collected macrophytes from sample sites in Lake Forest, September 2018. Biomass is based on the midpoint PIRTRAM designations (Table 3.1).

Lake Allure

Eight plant species were identified across 12 sites in Lake Allure throughout the year (Figure 3.2). Aquatic moss (*Fontinalis sp.*), elodea, stonewort and floating leaf pondweed (*Potamogeton natans*) were the most common plants found (Table 3.3). June plant densities were categorized as zero (n = 3), sparse (n = 6) and moderate (n = 3) (Figure 3.9). Densities increased in July to sparse (n = 5) and moderate (n = 4) (Figure 3.10), and in September to moderate (n = 4) and dense (n = 2) (Figure 3.11) with the addition of two new species: spiny-spored quillwort (*Isoetes echinospora*), tape grass and floating leaf pondweed. The most abundant species collected were aquatic moss and elodea, which were found in 9 of the 12 study sites. Based on PIRTRAM dry weight midpoints, average plant biomass in Lake Allure was 48 g/m^2 in June 2018 (Figure 3.12), 128 g/m^2 in July (Figure 3.13) and 408 g/m^2 in September per site (Figure 3.14). Average summer biomass ranged from zero to 340 g/m^2 across sites. No AIS were discovered during any of the surveys on Lake Allure.

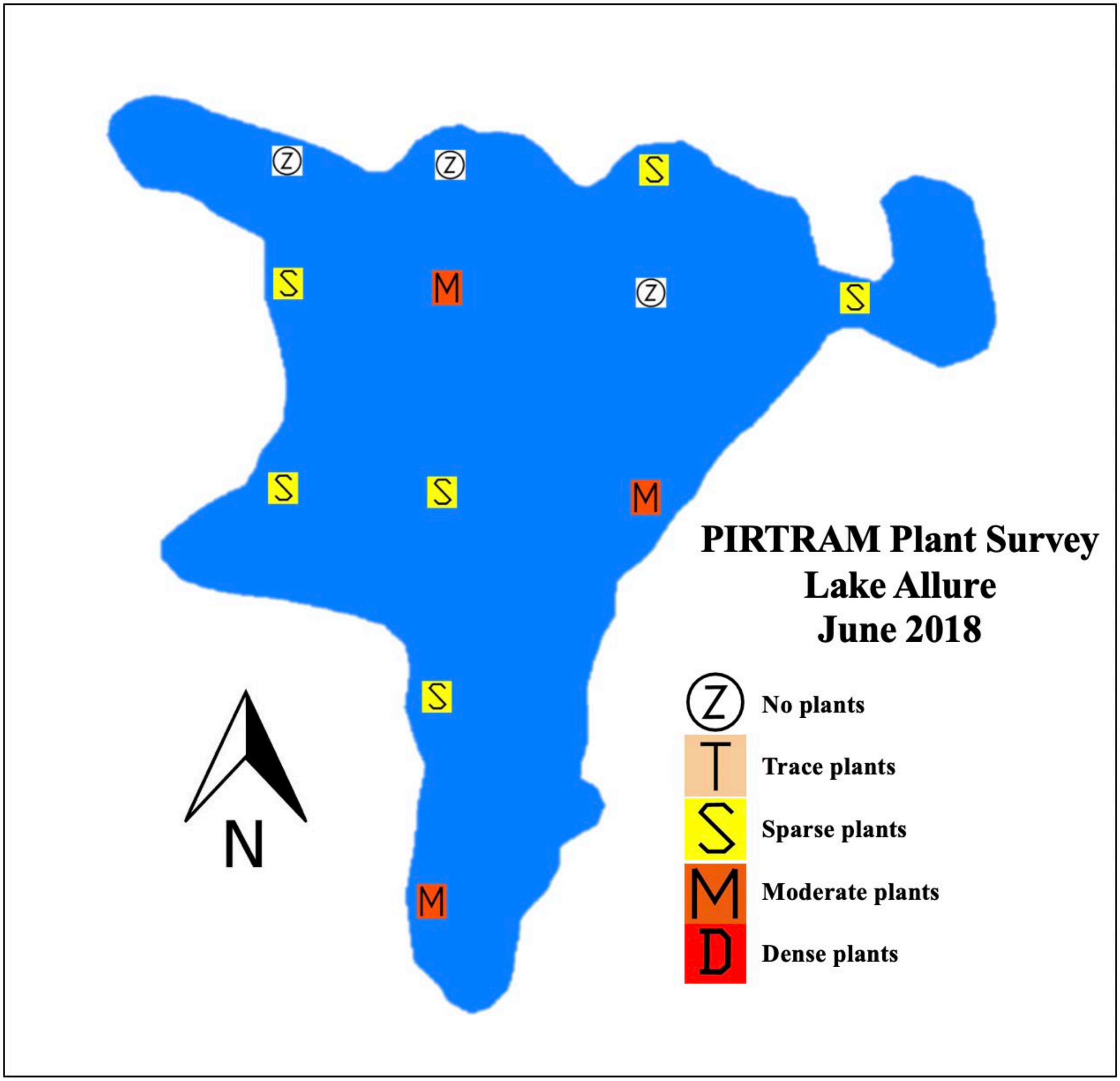

Figure 3.9: Map of Lake Allure seasonal plant density from June 2018 at PIRTRAM sampling locations.

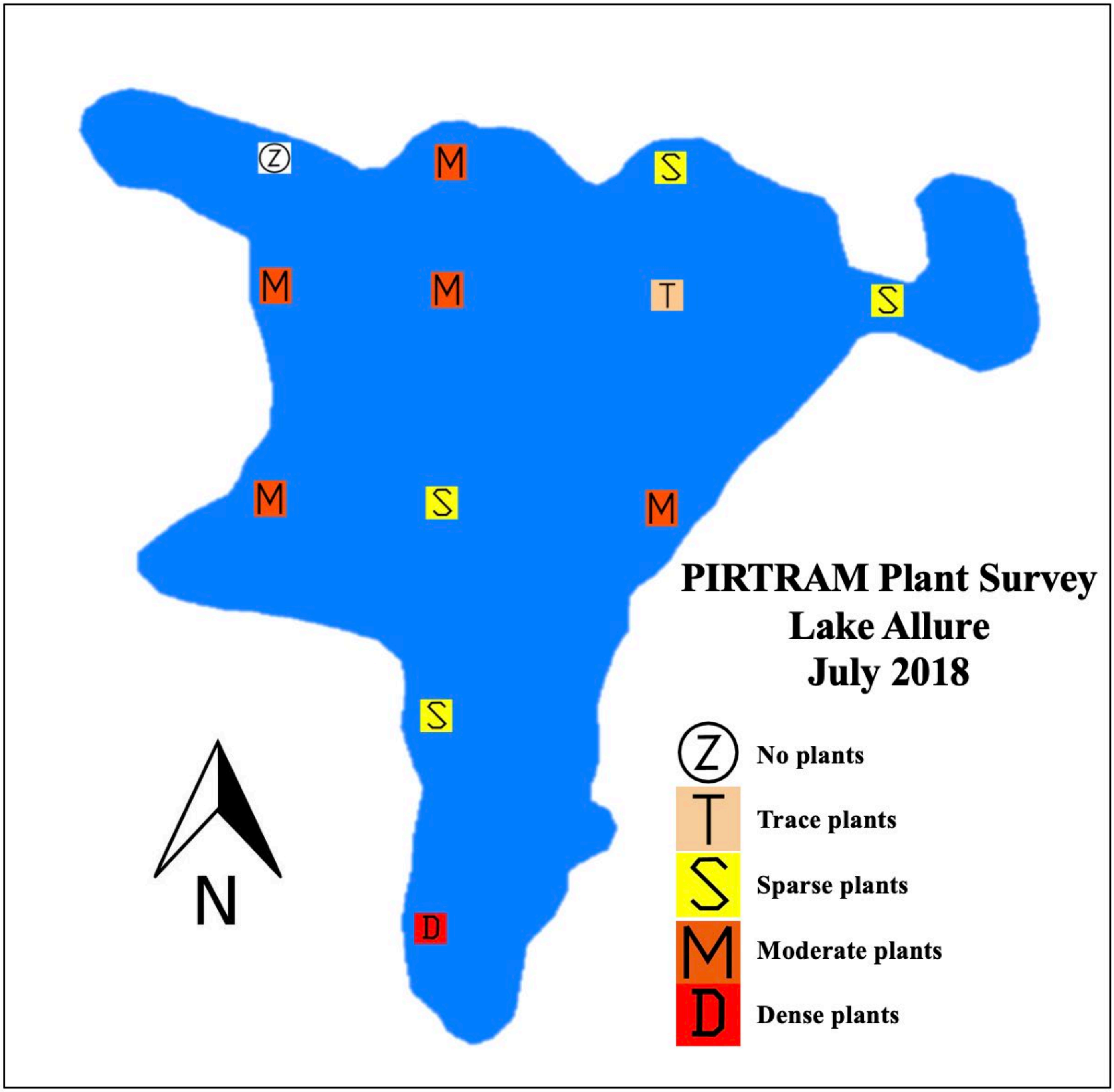

Figure 3.10: Map of Lake Allure seasonal plant density from July 2018 at PIRTRAM sampling location

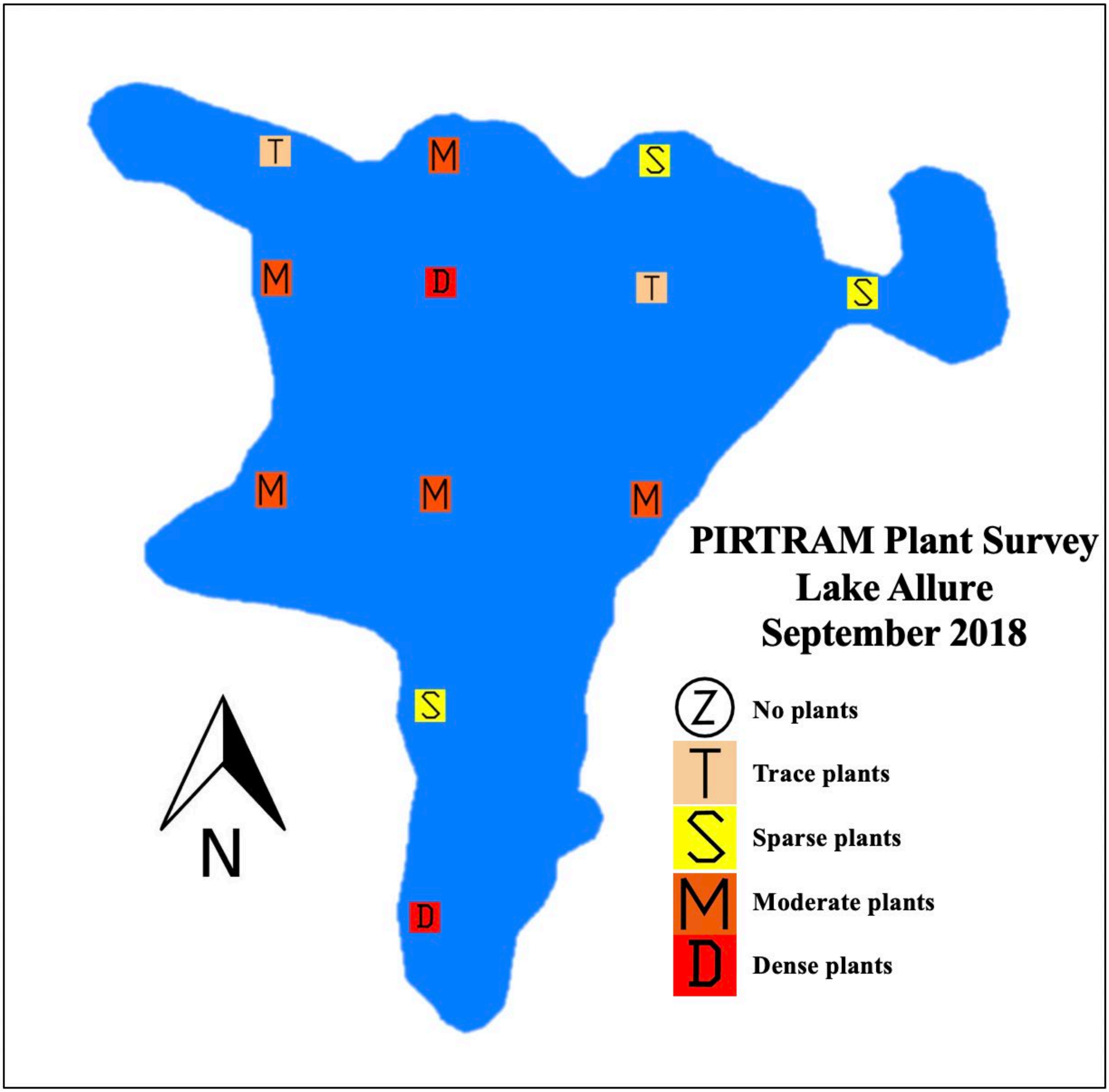

Figure 3.11: Map of Lake Allure seasonal plant density from September 2018 at PIRTRAM sampling locations.

Table 3.3: Aquatic plant species found in Lake Allure during summer 2018 aquatic macrophyte surveys.

Scientific Name	Common Name	June 2018	July 2018	September 2018	Notes
Nitella sp.	Stonewort	X	X	X	Submergent, free floating, macroalga
Fontinalis sp.	Aquatic moss	X	X	X	Submergent
Elodea canadensis	Common waterweed	X	X	X	Submergent, Perennial
Najas flexilis	Northern waternymph	X	X	X	Submergent, Annual
Potamogeton amplifolius	Bigleaf pondweed	X	X	X	Submergent, Perennial
Potamogeton natans	Floatingleaf pondweed		X	X	Submergent, Floating-leaf, Perennial
Potamogeton spirillus	Snailseed pondweed	X	X	X	Submergent, Perennial
Isoetes echinospora	Spiny-spored quillwort		X	X	Submergent, Perennial
Vallisneria americana	Tape grass		X	X	Submergent, Perennial

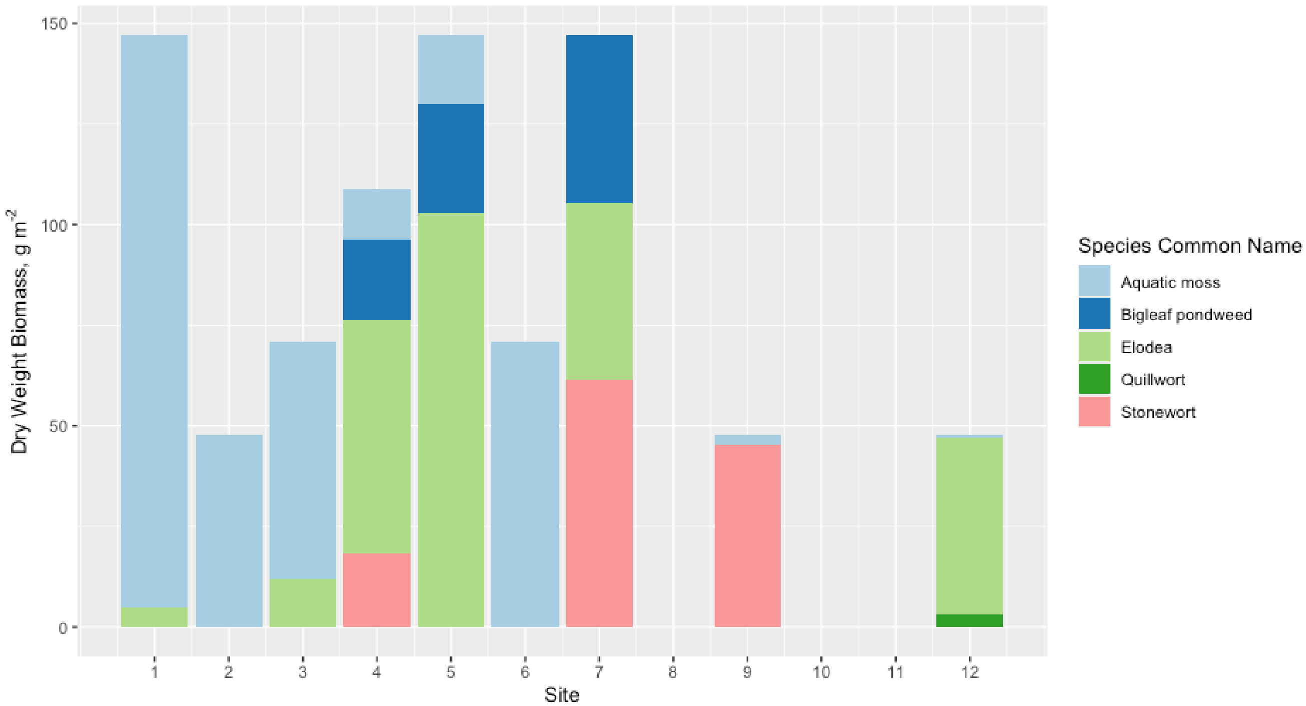

Figure 3.12: Dry weight biomass(g/m^2) of collected macrophytes from sample sites in Lake Allure, June 2018. Biomass is based on the midpoint PIRTRAM designations (Table 3.1).

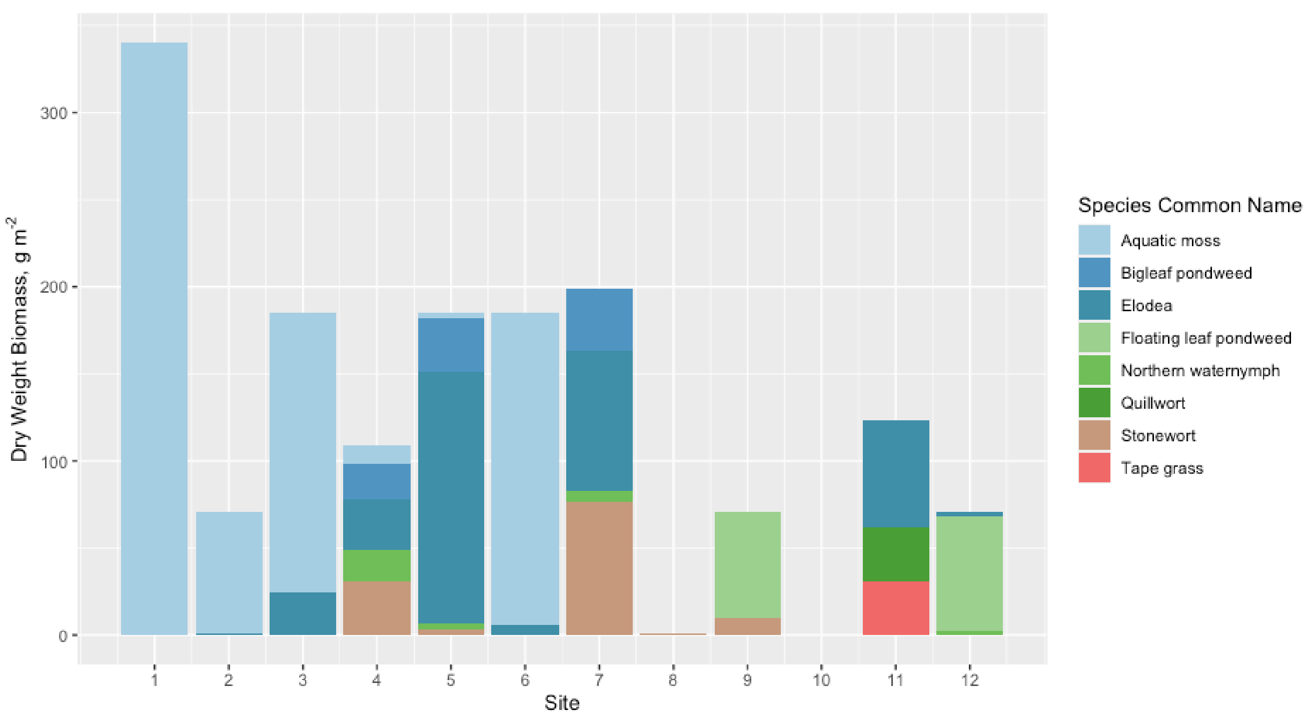

Figure 3.13: Dry weight biomass(g/m^2) of collected macrophytes from sample sites in Lake Allure, July 2018. Biomass is based on the midpoint PIRTRAM designations (Table 3.1).

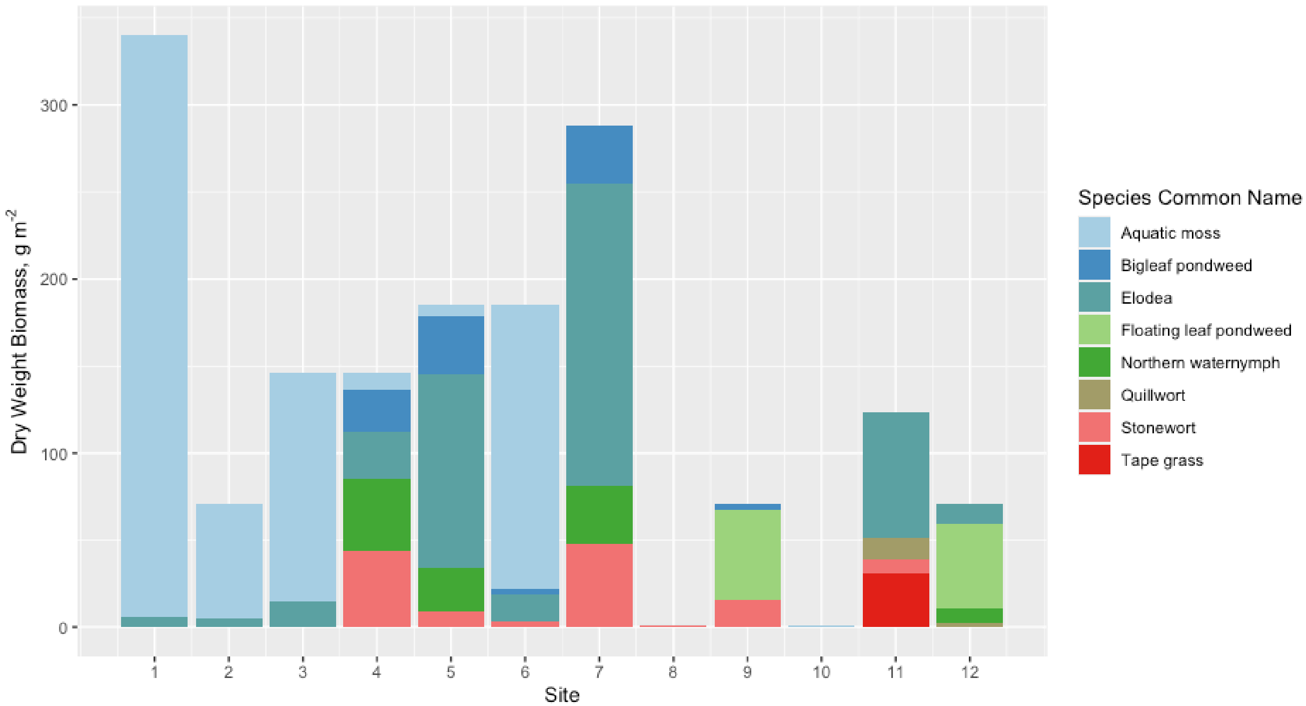

Figure 3.14: Dry weight biomass(g/m^2) of collected macrophytes from sample sites in Lake Allure, September 2018. Biomass is based on the midpoint PIRTRAM designations (Table 3.1).

Five species of aquatic plants were found in both lakes. Elodea, northern waternymph, stonewort, bigleaf pondweed, and snailseed pondweed were found in both impoundments throughout the growing season from June to September 2018.

Discussion

Lakes Forest and Allure support abundant, diverse, native aquatic plant communities that provide many essential ecosystem services to the surrounding habitats. Shifts in macrophyte density, occurrence, and abundance were observed throughout the growing season, which can be expected from May to September. Despite seasonal changes, species composition and abundance has remained relatively steady when compared to previous macrophyte studies.

The plant community of Lake Forest is extremely diverse with a total of 19 native species collected. Established macrophyte stands make up more than 80% of the bottom cover. Pondweeds and lilies were some of the most abundant species surveyed. A total of 8 native aquatic macrophytes were collected in Lake Allure. Aquatic moss was the most abundant species found. Aquatic moss rarely impacts recreation as it grows on the bottom of the waterbody. Lake Allure had fewer submergent and emergent aquatic macrophytes than Lake Forest. A few additional species were collected from Lakes Forest and Allure in previous studies, such as small pondweed (*Potamogeton pusillus*), duckweed (*Lemna* sp.) and Vasey's pondweed (*Potamogeton* *vaseyi*). It is important to note that these and other species may be present within the impoundment but not collected during PIRTRAM studies. Plant densities have remained relatively constant over the last 20 years (Eichler 2013).

Excessive growth can impair the use and reduce the aesthetic quality of the impoundment, while high plant densities can decrease available oxygen and habitat heterogeneity (Wiley et al. 1984). Plant growth can also interfere with predator-prey dynamics, causing slow growth and higher population densities of fish when macrophyte cover is greater than 40% of the lakes surface area (Durocher et al. 1984). Small impoundments are prone to excessive aquatic plant growth as many are shallow and receive most of their water from runoff, which can be high in nutrients (Arthaud 2012). Shallow ponds or impoundments typically have extensive littoral zones where there is adequate light penetration to the lake bottom. In addition, plants can spread easily across the water by a variety of mechanisms such as wind, wave action, waterfowl or watercraft. Both Lake Forest and Lake Allure also have an abundance of unconsolidated sediments that promote plant growth. Average unconsolidated sediment depths in Lake Forest were 0.79 m (2.59 ft.) and 0.57 m (1.89 ft.) in Lake Allure (Chapter 5). The abundant plant growth has made swimming, fishing and kayaking problematic for residents. Plants may clog motor props, make paddling difficult and impact swimming areas.

While plant growth may impact aesthetic value and recreational use, a moderate amount of macrophytes are an important component within aquatic ecosystems as they affect a variety of in-lake dynamics. The preservation of the native aquatic plant comminutes of Lakes Forest and Allure is a top priority. Aquatic plants play an essential role in ecosystem functions as rooted plants species take up nutrients, especially nitrogen and phosphorus, from the sediments. Roots can also bind sediments and prevent erosion, which can increase water clarity (NYSFOLA 2009, Anda et al. 2016). Plant beds can produce oxygen and provide essential habitat for juvenile fishes, macroinvertebrates, and other aquatic organisms (Hanson et al. 2015). Therefore, elimination of all aquatic vegetation is undesirable because it can cause major in-lake challenges such as increased algal blooms and predation, or decreased water clarity and dissolved oxygen levels (NYSFOLA 2009). The key to preserving native diversity will be to prevent accidental introduction of aquatic invasive species. Aquatic invasives are known to negatively impact the ecosystem through mechanisms such as competition with native species, as well as impacting swimming, fishing, water quality and property value (Zhang and Boyle 2010).

The aquatic plant communities of Lakes Forest and Allure should be monitored and follow-up surveys should be completed to assess any changes in condition. These surveys will provide valuable long-term data and can also be used to influence plant management in these systems. The comprehensive lake management plan (LMP) highlights a few management strategies to help control aquatic macrophyte growth in Lakes Forest and Allure without eliminating this important part of the lake ecosystems (see LMP Section 1.0). Plant management may also help improve the fish communities relative to desired uses, as well as in-lake water quality.

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Chapter 4: A comparison of benthic macroinvertebrate communities between the inlets and the outlet of Lake Forest and Lake Allure, NY

Introduction

Much ecological research has focused on studying and understanding biotic communities and their structures (Keddy 1992). Changes in water quality and environmental parameters can influence community structure and diversity of macrobenthos (Heino 2013). Benthic macroinvertebrates serve as important indicators of ecosystem health (Duan et al. 2011; Hernandez-Suarez and Nejadhashemi 2018). Macrobenthos assist with multiple ecosystem services from nutrient cycling to the decomposition of organic matter (Covich et al. 2014). Many aquatic macroinvertebrates are extremely sensitive to environmental changes, which makes them an important ecological component in freshwater systems. Community structure or richness can provide insight with regard to habitat quality. Sensitive taxa such as mayflies, stoneflies and caddisflies are used to assess changes in water quality and habitat (Shi et al. 2017). Environmental pollution from road salts, siltation, fertilizers and human waste can impact macroinvertebrate community structures, depending on specific organismal tolerance levels (Nedeau et al. 2003). High flow events, low oxygen levels, excessive nutrients or high temperatures can result in lower family diversity, altered community composition and decreased habitat diversity in lakes and streams (Dauer et al. 2000). Both lake inlets and outlets serve as habitat for organisms throughout the stream continuum (Vannote et al. 1980). Lakes and streams link one another, which can then impact nutrient loads, effecting the organisms inhabiting the areas (Jones 2013). All of these dynamics influence biological communities, so understanding the communities themselves can help us understand changes within ecosystems over space and time.

A macrobenthic study was conducted for the NWLA at 3 different locations on Lake Forest and Lake Allure. The study was formulated to examine differences in community structure at each site. The goals of this study were to: 1) collect macroinvertebrates at 3 separate locations on Lake Forest and Lake Allure 2) examine differences between sites using non-metric multidimensional scaling 3) compare Pielou's evenness and Bray-Curtis dissimilarly index between sites 4) better evaluate water quality using community composition and richness and 5) establish a baseline community structure to be used in future studies.

Methods

Lake Forest and Lake Allure are in the Town of Lake Luzerne, Warren County, NY (Figure 4.1). Lake Forest has two major inlets, one drained by a culvert at the north end from Lake Vanare (Site 1) and another by a spillway on the east shore from Lake Allure. Lake Allure has one single inlet coming from the northeast from a small mountain stream (Site 2). The outlet at the most southern portion of Lake Forest is a concrete spillway which then flows into a small wetland pond (Site 3). Sampling was conducted in March 2019 and samples were taken at three separate locations around the lakes (Figure 4.1). Samples were taken at each sample site using a D-frame aquatic dip net. Habitats at each site were assigned into one of three categories: run, riffle or pool. Samples were taken haphazardly within a 5-meter reach for a total 5 minutes. Samples were sieved (#30 mesh) and preserved in 70% ethanol. Samples were taken back to the lab and most organisms were identified to family level (n=27) of taxonomic organization based on Cummins and Merrit (2008), although others were identified to subclass (n=2) or order (n=1).

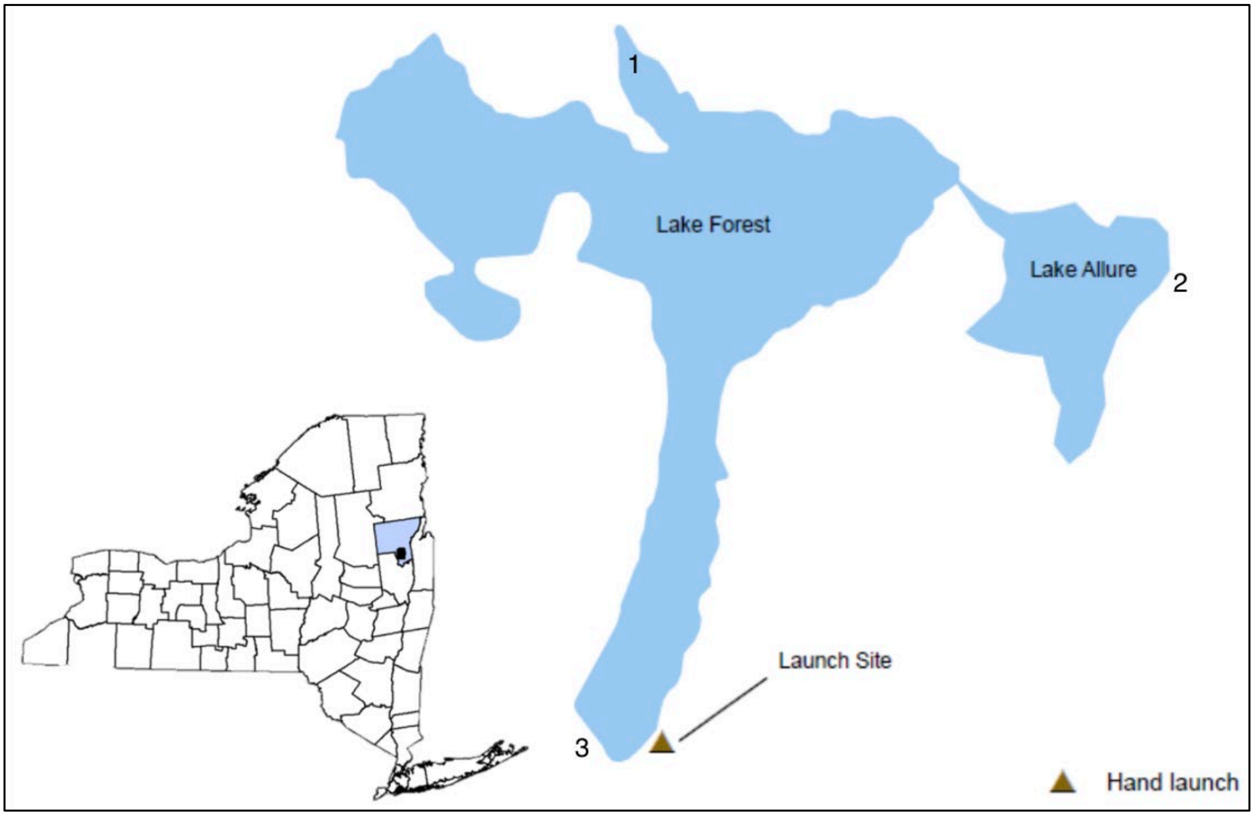

Figure 4.1: Map of the macroinvertebrate sampling locations of Lake Forest and Lake Allure.

Statistical analyses were conducted in the R statistical software package (Version 3.4.4; R Core Team 2017). Non-metric multidimensional scaling (NMDS) was used to examine differences between invertebrate communities in the Lake Forest inlet (1), the Lake Allure inlet (2) and the Lake Forest outlet (3). Data were organized into a site × taxa matrix and the ordination was conducted using the metaMDS wrapper function from the vegan package in R (R Core Team 2019) to find the best arrangement of points in ordination space. To evaluate NMDS mapping, a stress plot was used.

Ordination plots were created to show both family and site correspondence. Ellipses were added to the plot to show the 95% confidence intervals. Analysis of similarities (ANOSIM) was used to determine whether the dissimilarities between groups were statistically greater than the dissimilarities between taxa within groups. Pielou's evenness, a measure of diversity and richness was calculated as:

$$J' = \frac{H'}{H'_{max}}$$

where H' represented the number derived from the Shannon diversity index and H'_{max} was the maximum possible value of H'. Evenness was calculated to show the similarities or "evenness" between sampling sites in regard to the identified taxa. All taxa were grouped similarly across samples, but depth of taxonomic identification varied between groups based on expertise and available dichotomous keys (Cummins and Merrit 2008).

Results

A total of 224 macroinvertebrates were collected during the study, representing 26 families. The greatest number of individuals were collected in Site 1 with a total of 115, and the fewest were collected in Site 2 with a total of 47, with Site 3 being intermediate between the two with 62 individuals. Other clear trends in the raw data were difficult to detect; however, several trends were readily apparent through ordination.

The stress level from the NMDS ordination indicates how well the actual sample or raw data similarities were preserved in the statistical analysis. Stress values can range from 0-1. High stress (< 0.3) is a poor representation of reduced dimensions and low stress (< 0.05) is an excellent representation of reduced dimensions (Vegan 2019). The stress level was 0.154 for the ordination used in this study, indicating an excellent representation of reduced dimensions. A stress plot was used to examine points around the regression line to visualize the distances in each of the sites against the original dissimilarities. Little scatter around the regression line in the stressplot suggests that original dissimilarities are well preserved in the reduced dimensions (Figure 4.2).

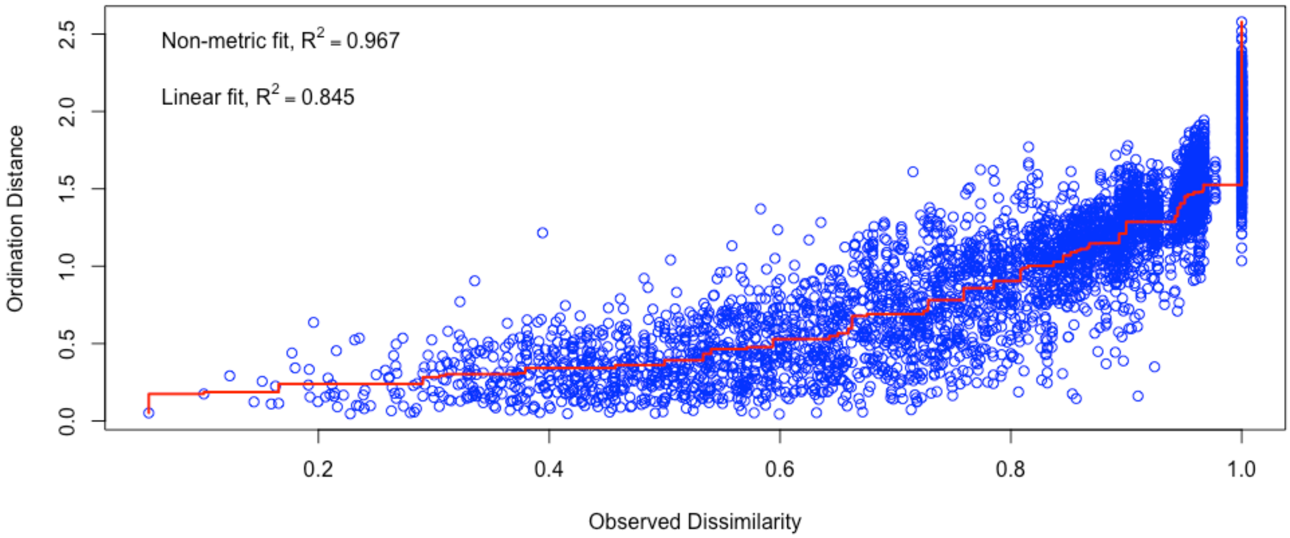

Figure 4.2: NMDS stressplot of the 3 sites of Lake Forest and Lake Allure.

Statistically significant differences were detected between sites (ANOSIM, R = 0.96, p = 0.001). These differences appeared to be associated with presence and abundance of specific taxa within each of the sites (Figure 4.3). At Site 1, a total of 115 individuals were collected representing 16 different taxa (Table 4.1). Amphipods (scuds) alone accounted for about 31% of the invertebrate community at this site and mayflies in the family Heptageniidae with the second highest number of individuals. The fewest taxa (11) and individuals (47) were captured at Site 2 during the study, however in some cases these included whole taxonomic orders. Oligochaeta (aquatic worms), Limnephilidae (case caddisflies), and the Hydropsychidae (net-spinning caddisflies) all were common at this sample site. At site 3, 62 individuals were collected from 14 different taxa. Hydropsychidae were the most abundant group, with 26 individuals. Chironomidae (nonbiting midge), Oligochaeta and Amphipoda were all found in the depositional areas of the outlet. Site evenness scores were 0.31 at site 1, 0.35 at site 2 and 0.31 at site 3 (Table 4.1).

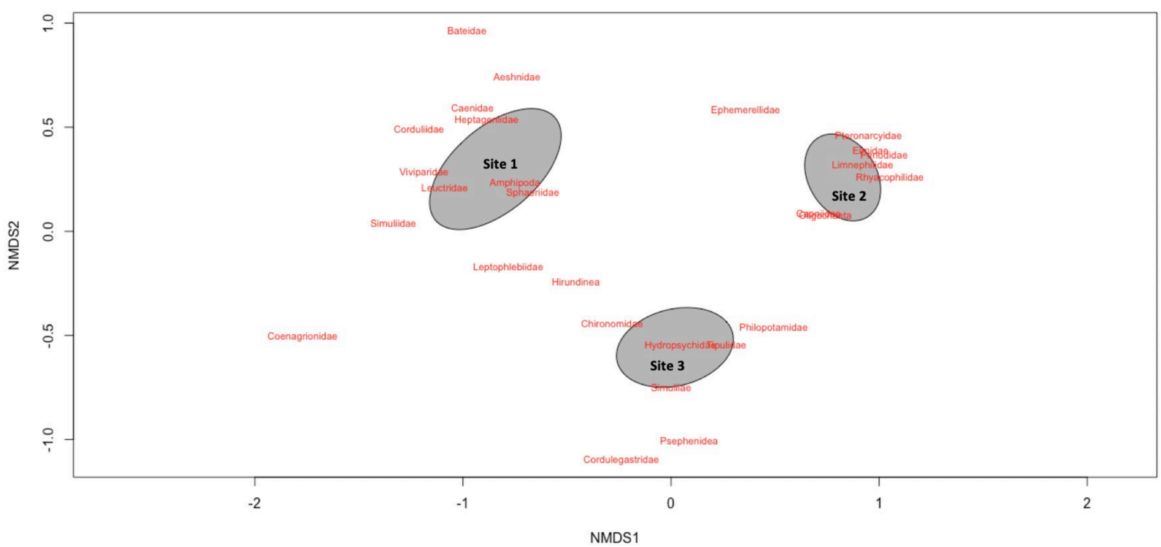

Figure 4.3: Visual plots of NMDS to show both family and site correspondence. Ellipses were added to the plot to show the 95% confidence intervals.

Table 4.1: Evenness among dominant taxonomic groups collected from three different sampling sites in the inlets of Lakes Forest (Site 1) and Allure (Site 2), and the outlet from Lake Forest (Site 3) during March 2019.

Site #	Dominant organisms	Evenness
1	Amphipoda and Heptageniidae	0.31
2	Oligochaeta and Limnephilidae	0.35
3	Hydropsychidae and Chironomidae	0.31

Discussion

Results of NMDS showed that invertebrate community composition and diversity varied between sites (Figure 4.3). Combined with the fact that taxonomic evenness was low across sites, these results suggest that the differences between sites were associated with a small number of primary constituents within each community. Site-specific differences in habitat could explain the variation between each of the sampling sites. Sites with high abundance of specific taxa likely have favorable habitat for those groups. Alternatively, the absence of sensitive taxa may indicate environmental disturbances.

A nearby body of water, Lake Vanare, flows into Lake Forest from a connecting culvert pipe (Site 1). The inlet contains many riffles and slack water depositional areas which serve as habitat for macroinvertebrates. According to the NYSDEC, total phosphorous levels are just within the moderately productive category with levels reaching 10 µg l^{-1} (Carlson 1977 and NYSDEC 2010). The abundance of macrobenthic invertebrates was highest at this site out of the three considered. Amphipods were dominant, making up 31% of the entire sample. Most amphipods are tolerant of both environmental pollution and stressors (Voshell 2003). Large cobbles and boulders were found at this sampling site, the preferred substrate of the Heptageniidae. Members of this specific family of mayflies are considered “scrapers”, which feed on detritus and attached algae. The silty depositional areas of Site 1 provide adequate habitat for three different families within the order Odonata. Most larva are found in slack water areas comprised of soft substrates with an abundance of allochthonous input (Voshell 2003).

The Lake Allure inlet starts as a small forested stream with dense canopy cover (Site 2). This stream travels about 1.5 miles until it reaches the inlet of Lake Allure. The average total phosphorus level at the Lake Allure inlet is 14.5 µg l^{-1}. The moderate concentration of nutrients here is most likely due to high levels of organic matter and detritus that decompose within comparable streams (Mulholland et al. 1985). The most abundant macroinvertebrate group at this site was the Oligochaeta, followed by the families Limnephilidae and Hydropsychidae (Trichoptera; caddisflies). Individuals in Limnephilidae make protective cases from plant materials found within the stream from allochthonous (external) inputs provided by surrounding canopy cover (Voshell 2003). The Hydropsychidae can tolerate areas with moderate concentrations of nutrients, which may explain the high relative abundance of individuals in this location (Voshell 2003).

The macrobenthic invertebrate community composition in the outlet from Lake Forest (Site 3) was primarily composed of tolerant taxa such as the Hydropsychidae and Chironomidae. The Hydropsychidae are a family of net-spinning caddisflies which are known to inhabit areas with moderate levels of organic matter or environmental pollution (Dodds and Whiles 2020). If the Hydropsychidae make up most of the community sampled, this can be an indication of environmental pollution from excess nutrients, waste, or sedimentation. The second most abundant group were the Chironomidae, or nonbiting midges. This is a family found as larvae in aquatic environments. They are known to tolerate, and even thrive in, areas with excessive levels of nutrients and in constantly changing environments. The outlet is subject to some nutrient loading, with an average total phosphorous level of 18 µg l^{-1}. This is considered moderately productive, according to the NYSDEC (NYS DEC 2015) and may be one possible reason for a tolerant community composition of macrobenthic invertebrates in the outlet.

Site evenness scores were relativity consistent across sites. Pielou's evenness ranges from zero to one, with zero being no evenness within sample sites and one being complete evenness within sample sites. The low evenness at all three sampling locations suggests that patterns in family abundance were driven by a few select taxonomic groups at each sampling site.

The macrobenthic invertebrate communities in this watershed varied between inlets and the outlet of the system. Differences in communities appear to reflect differences in environmental conditions at each site. Therefore, monitoring these different communities over time may help stakeholders and biologists understand changes or responses to management and conservation activities in the watershed.

Conclusion

This study examined the community composition changes between study sites. Pollution, rapid water quality changes and habitat degradation can alter the macrobenthos communities. Macrobenthic invertebrate communities varied among study sites (1, 2, 3). These differences can be attributed to the source water, nutrient concentrations and available habitat and thus represent diverse assemblages that may change in different ways in the future.

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Chapter 5: Sediment Depth Pilot Study

Introduction

Sedimentation in lakes is a concern among stakeholders because it limits volume of useable water for recreation (e.g., boating and swimming) and can influence lake ecology. Lake succession, or the process of a waterbody filling in, occurs naturally overtime. Lake succession can decrease lake depth, contribute to habitat loss, and can increase turbidity levels (Prakash 2005). As lakes age and begin to fill in, changes in the physical and chemical parameters can disrupt the aquatic biota. Sediment build up may reduce the aesthetic value and viable fish spawning habitat, limit boat access and restrict water bird feeding and nesting (Hoyer et al. 2008). Lake sediments are composed of both organic (plants and algae) and inorganic (clay, sand, silt) matter from a multitude of sources. Both organic and inorganic matter can be produced within a waterbody known as autochthonous material or externally as allochthonous material.

Lake succession, and filling, can occur at accelerated rates if the lake is susceptible to increased levels of decomposition of organic matter, urbanization, increased flows or other anthropogenic inputs (Prakash 2005). Stakeholders typically notice the sedimentation process occurring as inlets become laden with inorganic particles of sand, silt and clay or organic particles such as leaf litter and tree limbs which can be washed downstream after heavy storm or flow events. Benthic environments may also develop “fluffy or mucky” flocculant organic materials from the decomposition of plants and algae. Flocculant material can accumulate as plants and other organic material decompose at the bottom of the water column (Kalff 2002). The accumulation of sediments and flocculant materials can reduce lake depths which can ultimately disrupt swimming or boating and serve as newly created habitat for increased macrophyte growth.

The goals of this study were to: 1) determine unconsolidated sediment depths at randomly generated locations within Lake Forest and Lake Allure and 2) provide a baseline sediment depth to guide future management decisions for Lakes Forest and Allure.

Methods

Unconsolidated sediment depth (USD) was collected from Lake Forest and Lake Allure on June 8, 2019. Sampling locations were determined using locations that were randomly generated for this survey and the aquatic macrophyte survey. A total of 15 unconsolidated sediment depths were measured in Lake Forest (Figure 5.1) and a total of 7 were measured in Lake Allure (Figure 5.2).

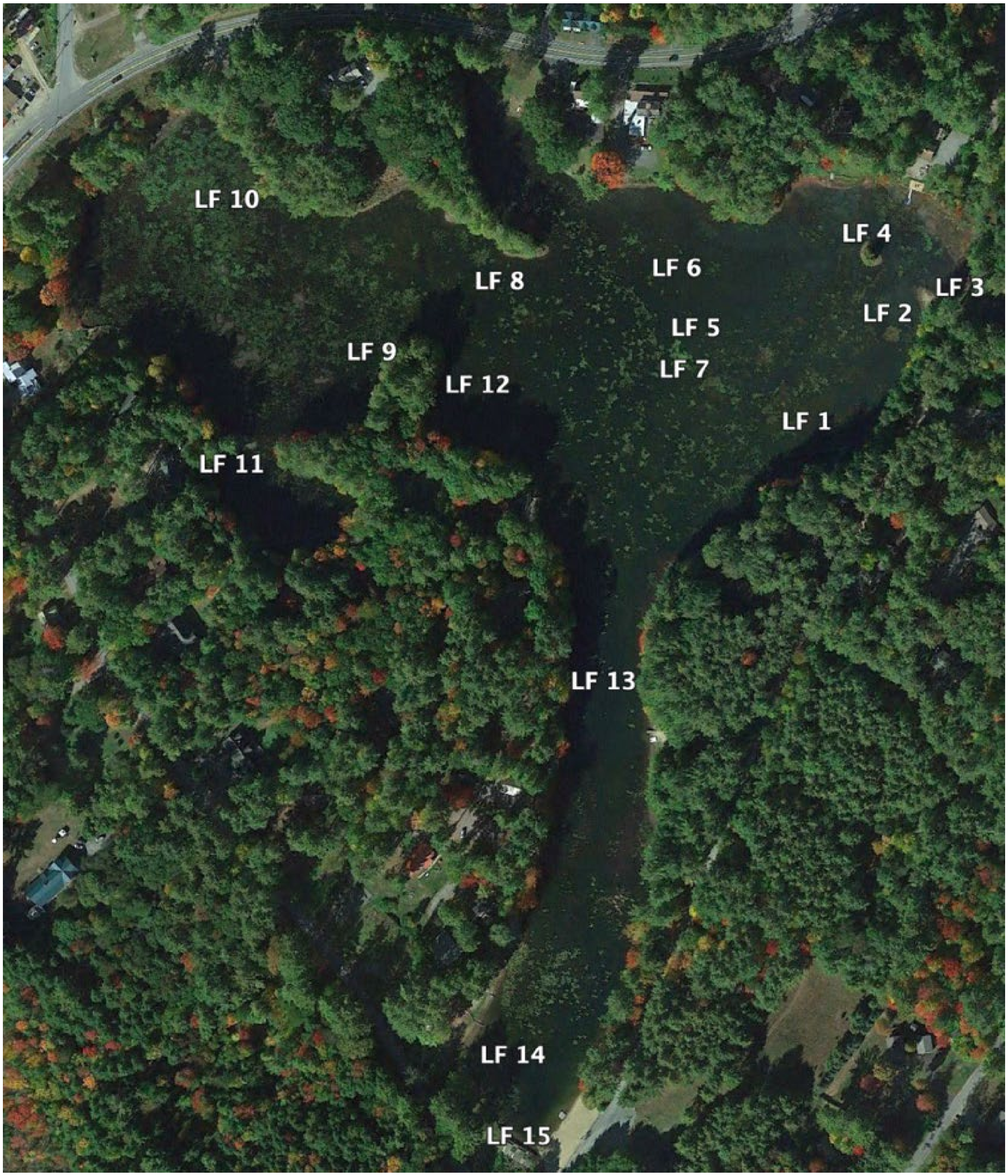

Figure 5.1: Randomly generated unconsolidated sediment depth sampling locations, Lake Forest, Lake Luzerne NY.

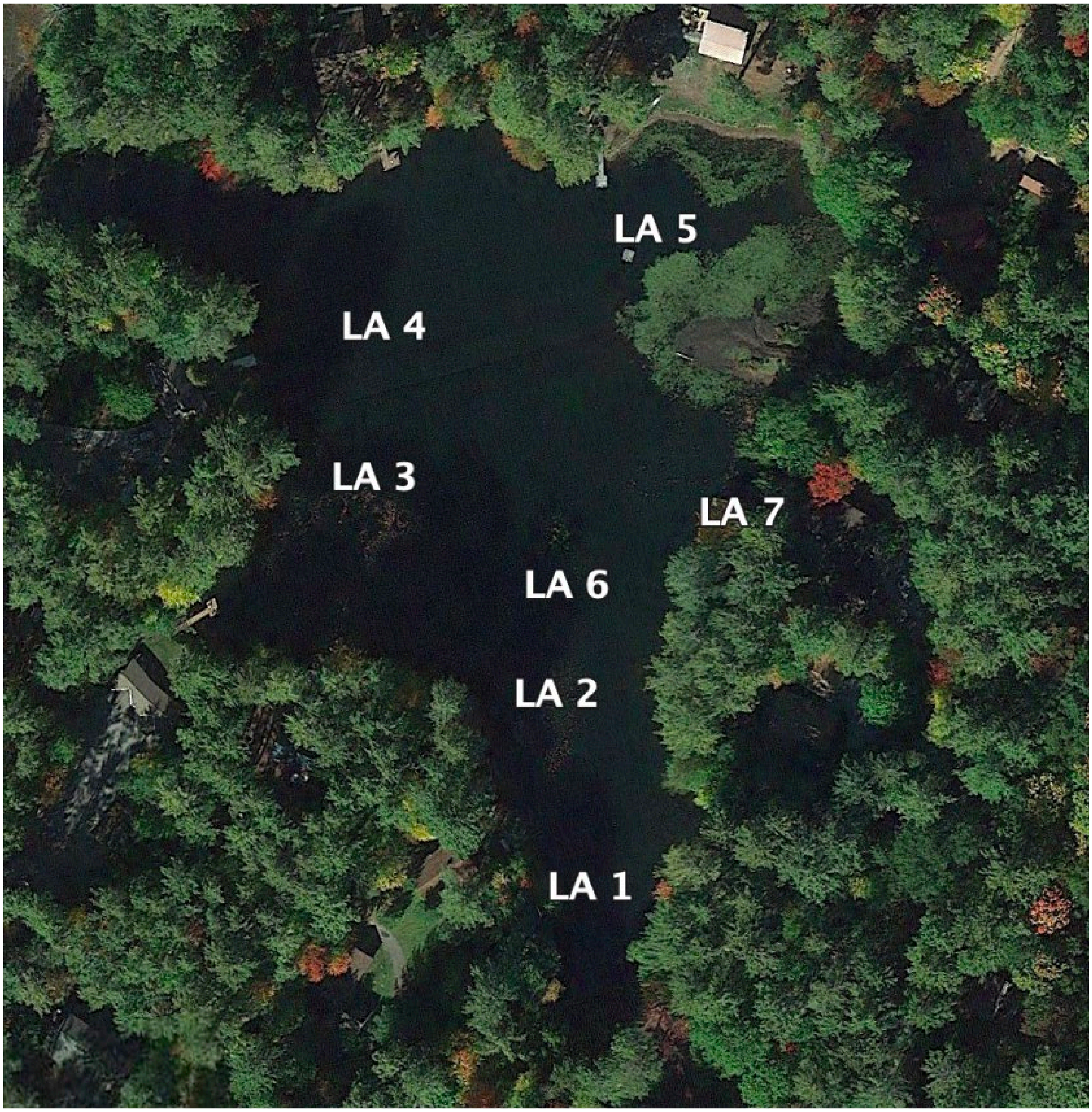

Figure 5.2: Randomly generated unconsolidated sediment depth sampling locations, Lake Allure, Lake Luzerne NY.

Unconsolidated sediment depth was measured using an incremented 10-foot aluminum sediment rod. The sediment rod was driven into the unconsolidated sediment until it reached consolidated or hard sediments and was unable to proceed further. Current water depth was recorded using a Vexilar LPS-1 LCD Portable Sounder. Unconsolidated sediment depth is calculated using the total rod length and subtracting the current water depth and the excess rod length above the water (Figure 5.3):

Unconsolidated Sediment Depth = (Total rod length) – (Water depth) – (Excess rod length)

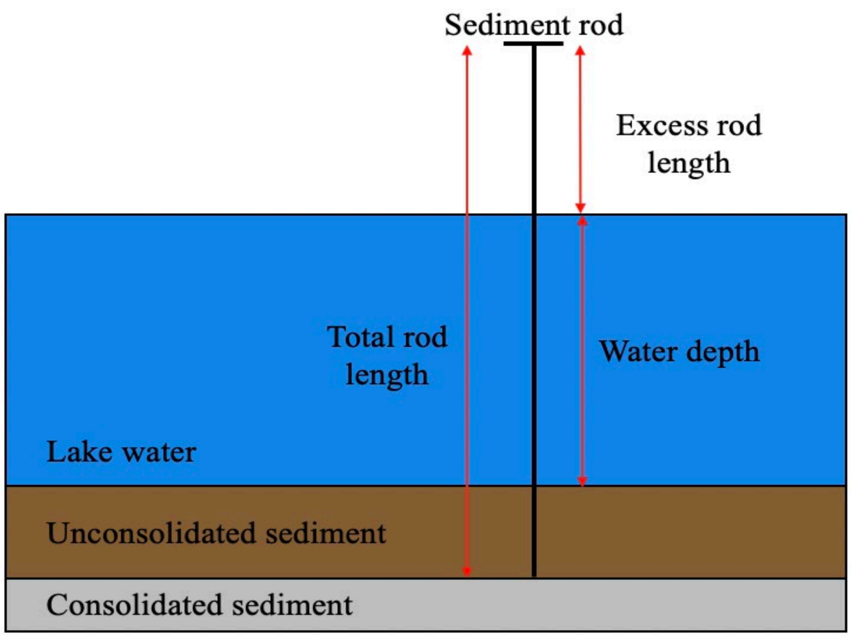

Figure 5.3: Unconsolidated sediment depth schematic.

Results

Unconsolidated sediment depths in Lake Forest averaged 2.59 ft at 15 randomized sampling locations. The maximum USD was recorded at site 12 with a depth of 4.70 ft and the minimum was recorded at site 3 with a depth of 0.40 ft (Table 5.1).

The average unconsolidated sediment depth in Lake Allure was 1.89 ft at the seven randomized sampling locations. The maximum USD was recorded at site 7 (Lake Allure inlet) with a depth of 4.70 ft. The minimum USD was recorded at site 5 with a depth of 0.70 ft (Table 5.2).

Table 5.1: Average, range and standard deviations for unconsolidated sediment depth measured at 15 randomized locations in Lake Forest, Lake Luzerne, NY.

Sampling Location	Unconsolidated sediment depth (ft)	Unconsolidated sediment depth (m)
LF-1	2.50	0.76
LF-2	1.60	0.49
LF-3	0.40	0.12
LF-4	2.70	0.82
LF-5	3.90	1.19
LF-6	2.90	0.88
LF-7	3.30	1.01
LF-8	1.90	0.58
LF-9	2.70	0.82
LF-10	4.50	1.37
LF-11	3.90	1.19
LF-12	4.70	1.43
LF-13	2.30	0.70
LF-14	0.90	0.27
LF-15	0.70	0.21
Average depth	2.59	0.79
Range	0.40 - 4.70	0.12 - 1.43
Standard deviation	1.33	0.41

Table 5.2: Average, range and standard deviation values for unconsolidated sediment depth measured at seven locations in Lake Allure, Lake Luzerne, NY.

Sampling Location	Unconsolidated sediment depth (ft)	Unconsolidated sediment depth (m)
LA-1	0.90	0.27
LA-2	1.80	0.55
LA-3	2.50	0.76
LA-4	2.20	0.67
LA-5	0.70	0.21
LA-6	0.90	0.27
LA-7	4.20	1.28
Average depth	1.89	0.57
Range	0.70 - 4.20	0.21 - 1.28
Standard deviation	1.24	0.38

Discussion

As waterbodies age, they naturally fill with sediments from the surrounding watershed and from in-lake decomposition of plants and algae. Increased sediment depths can lead to murky or turbid waters, a reduction in water depth or excessive aquatic plant growth (Kalff 2002). Each of the aforementioned problems can impact boating, swimming and the aesthetic value of a water body.

Lake Forest is a shallow waterbody with an average depth of 3.9 ft. Excessive unconsolidated sediments can be found at sites 9 – 13, where water depth was about three ft. With shallow water depths and unconsolidated sediment depths of two or more feet, it provides prime habitat for excessive aquatic macrophytes to flourish.

Lake Allure has less unconsolidated sediment at the bottom of the impoundment. The location with the greatest amount of sediment was at the mouth of the inlet. Even though the watershed is mainly forested, years of storm and increased flow events can cause a buildup of sediments at the mouth of the inlet. By addressing the root of the increased sediment in the watershed, watershed management strategies may help reduce this source of sediment over time.

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Chapter 6: Zooplankton

Introduction

Zooplankton include microscopic crustaceans, rotifers, and in some systems molluscan larvae. They are critical links within the food chain between micro-organisms and larger organisms found in almost every aquatic ecosystem (Berggern et al. 2014). A simplified example of a food chain that includes zooplankton might look something like the following:

Phytoplankton → Zooplankton → Planktivorous/Larval Fish → Piscivorous Fish → Birds

Zooplankton community composition and abundance vary both horizontally and vertically within the water column because they continuously drift passively while impacted by wind and wave action, water agitation and in some cases diel vertical migrations (Kalff 2002). Zooplankton can serve as indicators for changes in lake ecology as most are sensitive to environmental changes. Lake depth, fluctuations in water quality, organismal interactions and lake trophic status can influence zooplankton community composition, relative abundance and individual size. Phytoplankton, or algae and cyanobacteria, are usually the most abundant prey items for zooplankton followed by allochthonous inputs from the surrounding watershed (Berggern et al. 2014) even though some can serve as predators. They are also an important food source for planktivorous and larval fishes.

In negatively impacted plankton communities, trophic interactions and trophic status of lakes may be compromised. Large-bodied zooplankton continuously feed on phytoplankton within the water column. If their biomass is depleted, phytoplankton populations can increase or "bloom". Increased algal production generally is associated with increased rate of nutrient cycling due to the rapid cohort turnover. Large blooms can cause oxygen depletion when individuals die along with unpleasant odors, and human health impacts. Oxygen depletion reduces fish habitat and can also cause release of phosphorus from sediment (internal loading), which can propagate further algal growth.

Community composition of freshwater zooplankton is generally dominated by 3 groups: rotifers, copepods and cladocerans. Each plays a unique and important role within the ecosystem. Rotifers, while small, have extremely diverse morphologies and often can be identified by a rotating wheel of cilia at the anterior end, known as the corona, which is used for locomotion and feeding (Kalff 2002). Copepods are a part of a group of large bodied crustaceans that can exceed 2 mm in length. Copepods can be carnivorous or omnivorous, having the ability to change feeding habits based on a multitude of factors such as age, season, sex and food availability (Kalff 2002). Cladocerans are another large bodied crustacean group that are covered in a fused chitinous exoskeleton known as a carapace. Many cladocerans exceed 1 mm in length as adults. The majority are filter feeders that eat algae, although others are carnivorous and some even eat decomposing organic matter (Kalff 2002). The filtering rate, or the volume of water filtered by the average individual zooplankter per unit of time, is dependent on a multitude of factors including community composition, relative abundance and size distribution of zooplankton (Kalff 2002).

There is little known about the zooplankton communities of Lake Forest and Lake Allure. Despite the lack of historical information, a few objectives were determined. The objectives of this study were to 1) determine the current state of the zooplankton communities of both Lakes Forest and Allure and 2) calculate relative abundance, mean length and dry weight of collected zooplankton.

Methods

Zooplankton samples were collected at the deepest sampling locations in both Lakes. Vertical zooplankton tows were conducted in May, June, and July 2018. Samples were gathered using a 63 µm zooplankton net with a 0.3 m opening. The net was lowered then retrieved from 2 m (bottom) to the surface in both lakes. Samples were preserved in Rose Bengal dissolved in 90% ethanol, doubling the sample volume. For each lake, each sample was analyzed using 1 ml of sample on a gridded Sedgwick Rafter cell until at least 100 individuals were counted and measured (µm). Dry weights were calculated according to taxa-specific biomass/length relationships provided by Watkins et al. (2011).

Results

Cladocerans, copepods, and rotifers were found in both lakes throughout the summer of 2018 in varying abundances (Figure 6.1 and 6.2). In Lake Forest, rotifers were numerically the most abundant organisms ($n = 195$), followed by copepods ($n = 67$) and then cladocerans ($n= 38$). Rotifers were also the most abundant organisms in Lake Allure ($n = 123$), closely followed by copepods ($n = 104$) and then cladocerans ($n = 73$). Shifts in community composition and relative abundance were observed over the sampling period in both impoundments. The relative abundance of rotifers varied monthly but consistently made up more than 50% of the zooplankters found in each sample. Rotifer relative abundance spiked in June 2018 with individuals making up 89% of the sample (Figure 6.1). Lake Allure exhibited a more diverse and balanced zooplankton community with large bodied zooplankters occurring more regularly in monthly samples. The monthly relative abundance of copepods decreased as the relative abundance of rotifers and cladocera increased. Dry weights were highest among copepods in both lakes, followed by cladocerans and then rotifers (Figure 6.3 and 6.4).

Monthly length data were combined to create boxplots of lengths within each group of zooplankters found in each lake (Figure 6.5). Cladocerans and copepods were larger in Lake

Allure when compared to those in Lake Forest. Rotifers in both impoundments were similar in size.

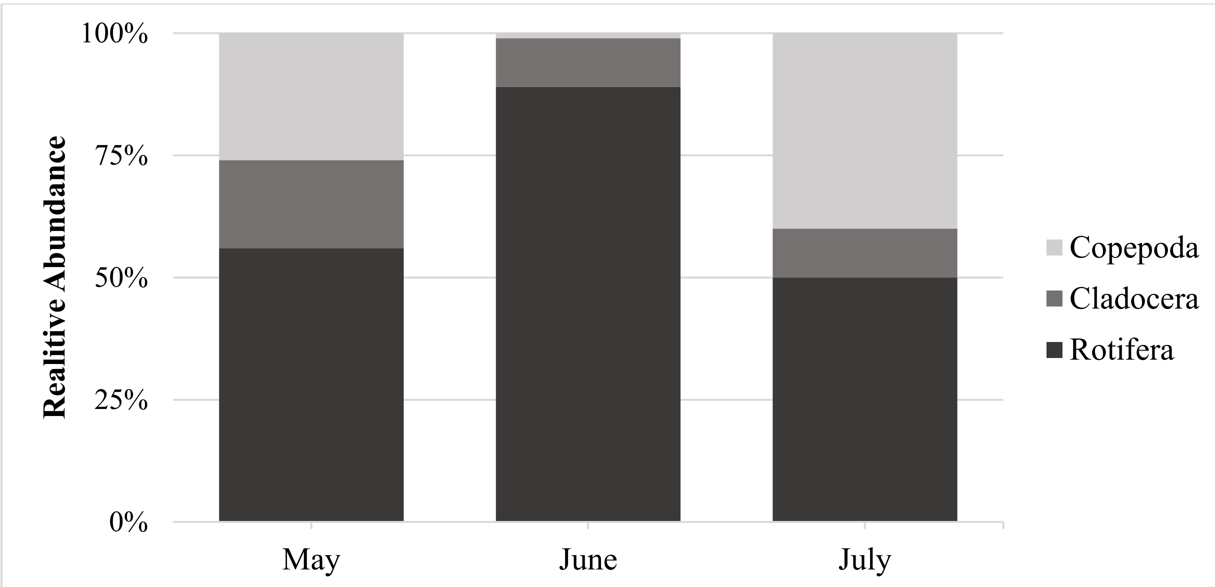

Figure 6.1: Relative abundance of zooplankton groups from Lake Forest sampled in May, June and July 2018.

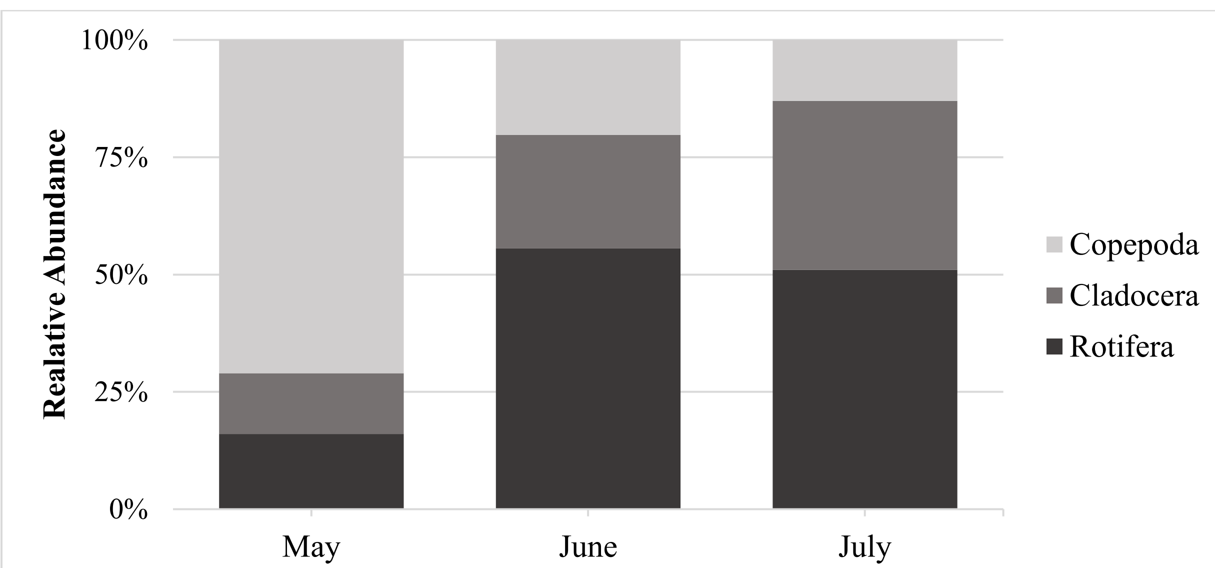

Figure 6.2: Relative abundance of zooplankton groups from Lake Allure sampled in May, June and July 2018.

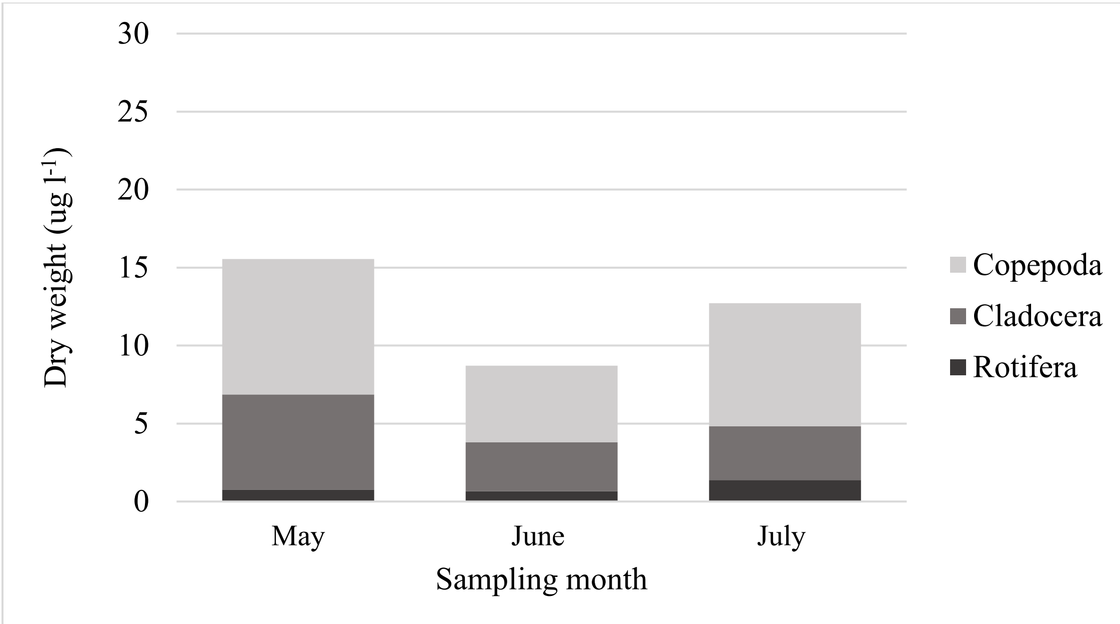

Figure 6.3: Dry weight (ug l^{-1}) of zooplankton groups in Lake Forest summer 2018.

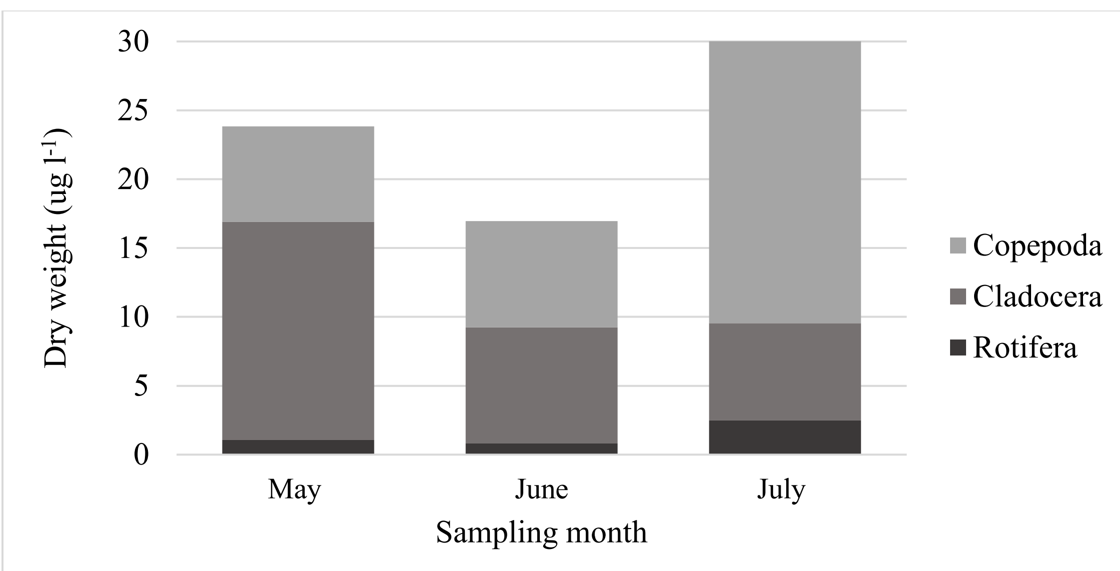

Figure 6.4: Dry weight (ug l^{-1}) of zooplankton groups in Lake Allure summer 2018.

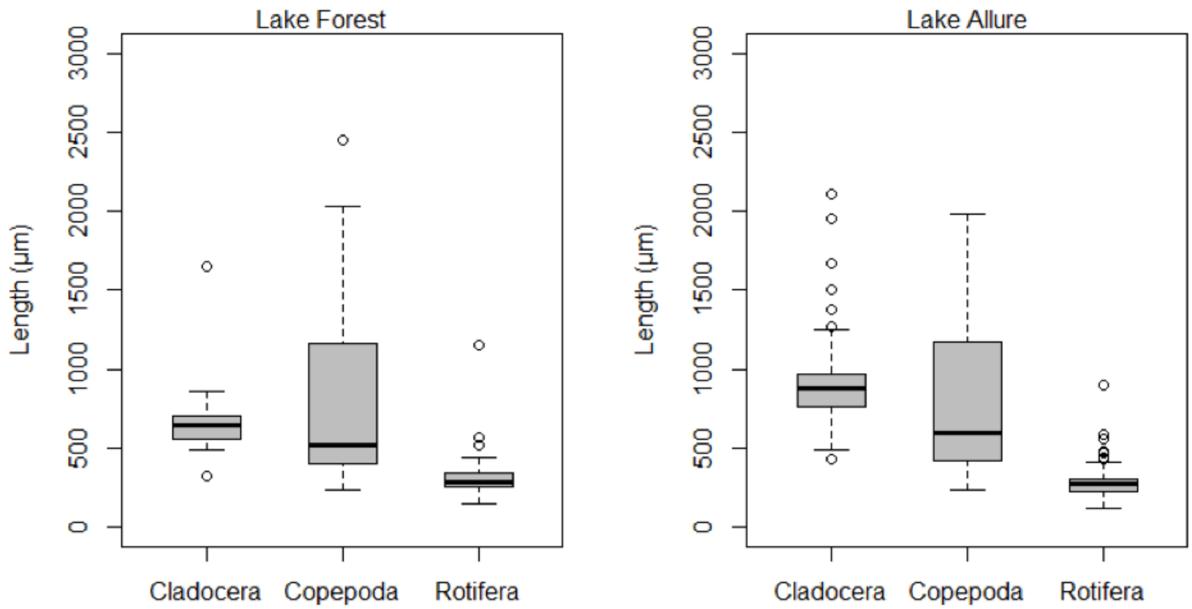

Figure 6.5: Length distributions of combined zooplankton groups in Lake Forest and Lake Allure. The mean is represented by the black line, the gray box is the interquartile range, hollow circles are outliers and the dashed lines extends to represent the 1^{st} and 99^{th} percentiles.

Discussion

The analysis of the zooplankton communities of Lakes Forest and Allure suggests that there are multiple important differences between the two communities. These results can be used to determine in-lake and watershed management strategies.

The relative abundance of zooplankton in Lake Forest shows that there is a lack of large-bodied zooplankton, such as copepods and cladocerans, which are essential for juvenile fish growth and algae population control within an aquatic system (Figure 6.1). Juvenile fish typically feed on a multitude of different zooplankton taxa (rotifers, copepods and cladocerans) which are all nutritionally and calorically different (Taipale et al. 2018). Prey quality is dependent upon many environmental factors such as water quality and eutrophication which can both influence juvenile fish development and growth (Taipale et al. 2018). The low densities of large-bodied zooplankton in Lake Forest could be subject to increased predation by planktivorous juvenile fishes within Lake Forest (Post et al. 2008). Increased planktivory can cause shifts within the zooplankton community, increasing the number of small-bodied zooplankton such as rotifers (Rinke et al. 2009). Copepods were nearly absent in June 2018, which can be the result of increased predation by juvenile fishes after spring spawning seasons for species such as largemouth bass. Rotifers made up more than half of the organisms collected in Lake Forest, followed by copepods and then cladocerans. Rotifers can become dominant when large-bodied copepods and cladocera experience high predation or other unfavorable conditions, but are naturally regulated by large-bodied plankton through competition when conditions are favorable. For example, cladocerans can suppress rotifer densities through a combination of competition for shared food sources and predation (Gilbert 1988, Diéguez and Gilbert 2011). Due to their small size, rotifers are less efficient at grazing phytoplankton stocks (algae) than large-bodied crustacean zooplankton. Balance between taxa in the zooplankton communities, therefore, is necessary to maintain water clarity and reduce the potential for algal blooms.

The zooplankton community of Lake Allure was characterized by a high abundance of rotifers followed by copepods and then cladocerans (Figure 6.2). Unlike Lake Forest, copepods and cladocerans appeared more frequently during monthly zooplankton sampling. The increased counts of large-bodied zooplankton could be due to differences in factors such as impoundment size, fish predation, or localized environmental conditions during sampling. More work would be needed to understand whether these apparent differences are due to limited sampling or meaningful ecological differences between the lakes.

Overall dry weights (biomass) of zooplankton were lower in Lake Forest then Lake Allure (Figure 6.3 and 6.4). Copepod dry weight was highest in both lakes, followed by cladocerans and then rotifers. Dry weights are closely linked to the varying sizes of each taxon along with the feeding and capacity of zooplankton in a lake to filter out algae and other organic matter (Peters and Downing 1984). Rotifers, copepods, and cladocerans all feed and filter at different rates and filtering rate also varies within taxa based on size. Therefore, dry weights provide a more meaningful representation of the zooplankton communities than relative abundance or length alone (Dodson 1974, Havens and Beaver 2011).

Mean length distributions of copepods and cladocerans were smaller in Lake Forest when compared to Lake Allure (Figure 6.5). Copepods collected from Lake Allure were 1.3× larger than individuals from Lake Forest and cladocerans were 1.5× larger in Lake Allure than Lake Forest. Mean rotifer lengths from both impoundments were relatively similar with a mean of 308.7 μm in Lake Forest and 310.4 μm in Lake Allure. Predation from juvenile fishes may be responsible for the decreased lengths of large-bodied zooplankton in Lake Forest. With the lack of historical data, it is hard to determine if zooplankton lengths have changed over time.

In summary, zooplankton communities are essential components within a lake's ecosystem as they serve as important links between primary production (algae) and predators (e.g. fish) within the food web. Grazing by zooplankton can also reduce algal standing crop, thereby maintaining higher transparencies and oxygen concentrations then would otherwise exist. Therefore, understanding the make-up and filtering capacity of zooplankton in a lake can provide insight into the trophic state of a waterbody. This study provides a baseline description of the zooplankton communities of Lakes Forest and Allure during the growing season. Continued monitoring of zooplankton communities will allow assessment of long-term trends. These groups can also be used as biological indicators to understand responses to in-lake and watershed management.

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Chapter 7: Fisheries

Introduction

Fish are an integral component within an aquatic ecosystem as they confer many ecosystem functions, and provide economically and culturally important ecosystem services, such as recreational opportunities for anglers. Fish can serve as environmental indicators of changes within the ecosystem while also providing important functions such as nutrient transport and food-web connections as predators and prey of other aquatic organisms (NYSFOLA 2009). Freshwater angling not only impacts in-lake biological dynamics, but also benefits the local economy bringing in revenue to the surrounding communities from state license, tackle, bait and food sales. New York State is home to more than 7,600 lakes and more than 70,000 miles of rivers and streams (NYSDEC 2020) many of which are managed as public resources by the NYSDEC. While public lakes and rivers are managed by the state, the management of privately-owned waterbodies is usually controlled by local property owners and lake associations (NYSFOLA 2009).

Fish communities are overarchingly structured based on local environmental and ecological processes. For example, individual species may have different tolerances to temperature and dissolved oxygen concentrations. Salmonids (e.g. trout) thrive in well oxygenated cold-water systems, while other species, such as largemouth bass (*Micropterus salmoides*), flourish in warmer waters. Biologically, the presence of a given species may preclude or influence another due to inter-specific interactions such as competition and predation. In fishes, these interactions also occur within species (populations) due to intra-specific competition for food and resources and through cannibalism as a form of predation. The inter- and intra-specific interactions play a vital role in fish community abundance, recruitment and diversity (Dochtermann and Peacock 2013). These interactions can determine the predator/prey interactions and the size structure of fish populations in a waterbody.

Proportional size distribution (PSD) is an index that is used to describe the relative proportion of fish of different sizes in a population (Gabelhouse 1984). Changes in "size structures" in a population can be used to make inference about ecological processes such as growth and mortality, and also to understand how these translate to human benefits like frequency and size of fish caught. This index uses species-specific fish lengths to classify fish into five categories: stock (S), quality (Q), preferred (P), memorable (M) and trophy (T) size groups (Table 7.1). Stock size is the size at which a fish begins to have recreational value (Willis et al. 1993). Each of the subsequently larger size categories are defined loosely based on world-record catches for a given species. In most multi-use lakes and ponds, the proportion of quality to stock-sized fish (PSD_Q) is used to assess balance within and between species. The value of PSD_Q is calculated as:

$$PSD_Q = \frac{\text{Number of fish} \geq \text{quality length}}{\text{Number of fish} \geq \text{stock length}} \times 100.$$

Populations are considered to be “balanced” between large and small fish when PSD_Q values fall between 30 and 70 (Anderson et al. 1983). Similarly, if both predator and prey PSD_Q fall within this range, the fish community is said to be in balance. Low PSD_Q values indicate that there are few larger fish in the population, and high PSD_Q values indicate that there are few smaller fish within the population (Anderson 1976, Anderson et al. 1983, Gabelhouse 1984). PSD_Q values are useful, but they should be examined alongside other information such as length-frequency histograms and/or fish condition indices to understand changes in size structure because a given PSD_Q or combination of values can have multiple interpretations.

Table 7.1: Length classification of common freshwater species in millimeter and inches according to Gabelhouse 1984.

Species	Stock		Quality		Preferred		Memorable		Trophy	
	mm	in	mm	in	mm	in	mm	in	mm	in
Bluegill	80	3	150	6	200	8	250	10	300	12
Chain pickerel	250	10	380	15	510	20	630	25	760	30
Largemouth bass	200	8	300	12	380	15	510	20	630	25
Pumpkinseed	80	3	150	6	200	8	250	10	300	12
Yellow perch	130	5	200	8	250	10	300	12	380	15

Length-frequency histograms can provide insight into the number of fish in narrower size-bins (e.g. 10 mm or 0.5 in) that may not be visible from the broader PSD indices. Length-frequency histograms allow biologists to examine fine-scale patterns in size distributions that are related to important population dynamics such as recruitment, predation, mortality and missing year classes (Anderson and Neumann 1996). Likewise, use of multiple data collection methods (e.g. haul seine, shore seine, angler surveys) improves information available because each of these provides snapshots of different parts of fish communities (seines will tend to collect small fish whereas anglers tend to catch larger fish).

With a lack of historical information about fish communities in Lakes Forest and Allure, it is important to gather community data to understand the state of the fishery. This information can help guide the management of both impoundments for recreational and ecological value. The goal of this study was to provide a baseline understanding of the fish community and the select populations (species) of fish in Lake Forest and Lake Allure. To do this, I 1) examined the current fish community using a haul seine, shore seine and angler surveys, 2) estimated PSD_Q

and created length frequency histograms for species collected and 3) described species interactions to understand ecological and recreational balance in fish communities.

Methods

Field Data Collection

A survey of fish communities in Lake Forest and Lake Allure was conducted on 13 August 2020 using a haul seine and a shore seine. Lake Forest was surveyed using a 100 ft x 4 ft (30.5 m x 1.20 m) haul seine with 1-inch mesh and Lake Allure was surveyed using a 25 ft x 4 ft (7.6 m x 1.20 m) fine mesh shore seine to capture fish. Seine pulls were walked for 5 m increments. All fish captured were placed in holding totes, identified to species, measured to total length (mm) and returned to the waterbody from which they were collected.

Angler surveys were conducted from May to June 2018 and in March 2019. Anglers were encouraged to fish Lakes Forest and Allure and to record catches on a data sheet provided. Anglers could fish during the ice-free season with rod and reel, and during ice cover with tip-ups and jigging.

Data Analysis

Proportional size distributions were estimated in R using the fisheries stock assessment package, *FSA* (Ogle 2017, R Core Team 2018). Length-frequency histograms were created with Gabelhouse lengths overlaid to help visualize size distribution within each species and understand recruitment to consecutive size groups. Predator and prey interactions were analyzed using PSD_Q estimates to create "tic-tac-toe" plots that help visualize and interpret PSD_Q between species.

Results

Lake Forest

Lake Forest supports a warm water fishery that is typical of many other shallow lakes and ponds in New York. A total of 99 fish were captured during haul seine surveys of Lake Forest. This included six species from four different families (Table 7.2).

Table 7.2: Common name, scientific name, number caught and mean total length (mm and in), TL of species collected by seine efforts of Lake Forest, August 2020.

Common name	Scientific name	Number caught	TL (mm)	TL (in)
Bluegill	*Lepomis macrochirus*	7	115	4.5
Chain pickerel	*Esox niger*	12	268	10.6
Golden shiner	*Notemigonus crysoleucas*	1	113	4.4
Largemouth bass	*Micropterus salmoides*	2	186	7.3
Pumpkinseed	*Lepomis gibbosus*	53	105	4.1
Yellow perch	*Perca flavescens*	24	111	4.4

The most common species collected from Lake Forest was pumpkinseed (n = 53) with an average length of 105 mm (4.1 in) and a range of 61 – 170 mm. Pumpkinseed had a PSD_Q of 2, which indicates that most fish captured fell under quality size (Table 7.1). The length frequency histogram suggests presence of at least three year classes, with an abundance of fish (n = 45) in the stock size category (Figure 7.1). Yellow perch were the second most abundant species with a total of 24 individuals, and an average length of 111 mm (4.4 in) ranging in length from 92 to 163 mm (Table 7.2). A minimum of two year classes are observable in the length-frequency histogram with many individuals shorter than stock size, suggesting that fish captured are young-of-the-year (YOY) likely from the spring spawning season (Figure 7.2). All chain pickerel (n = 12), bluegill (n = 7), and largemouth bass (n = 2) collected were smaller than quality size, representing two year classes each in the histograms (Figures 7.3 – 7.5). A single golden shiner was captured at 113 mm (4.4 in). The PSD_Q for these species, therefore, could not be estimated simply due to a small sample size and a lack of larger fish.

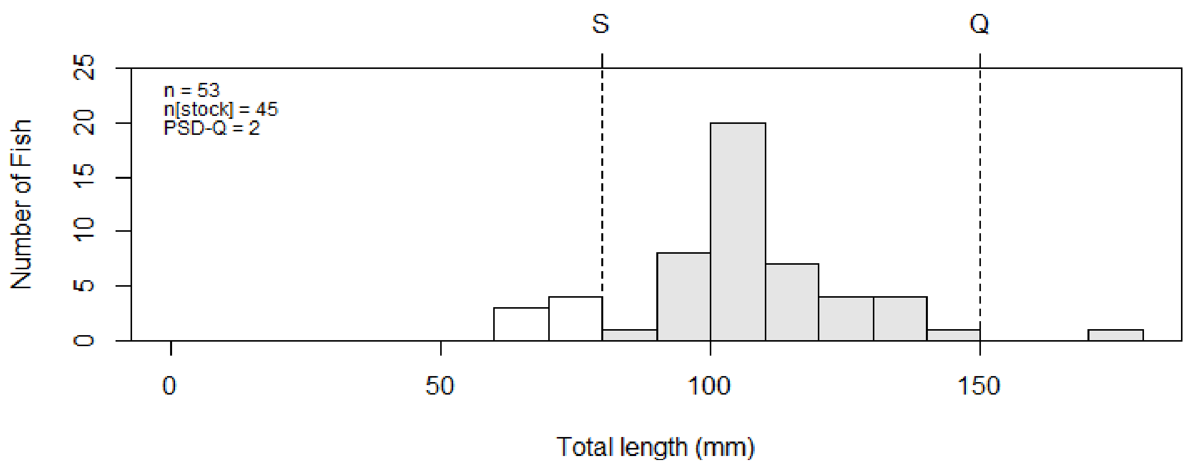

Figure 7.1: Length frequency histogram of pumpkinseed in Lake Forest with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

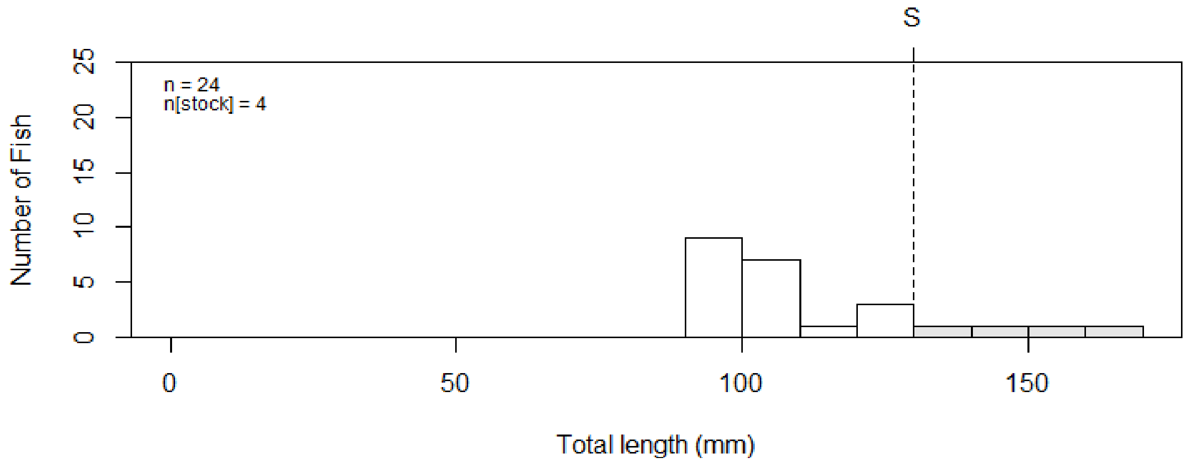

Figure 7.2: Length frequency histogram of yellow perch in Lake Forest with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

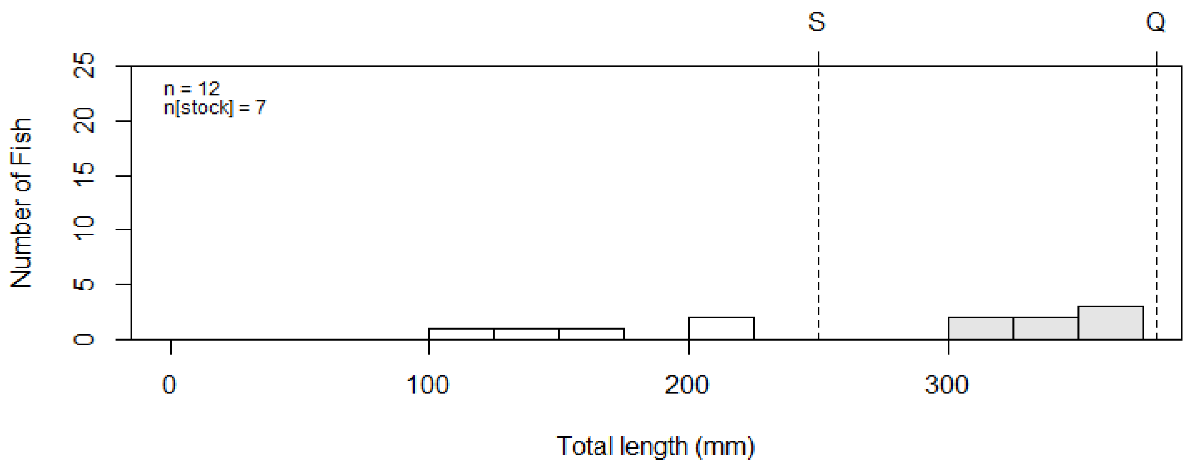

Figure 7.3: Length frequency histogram of chain pickerel in Lake Forest with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

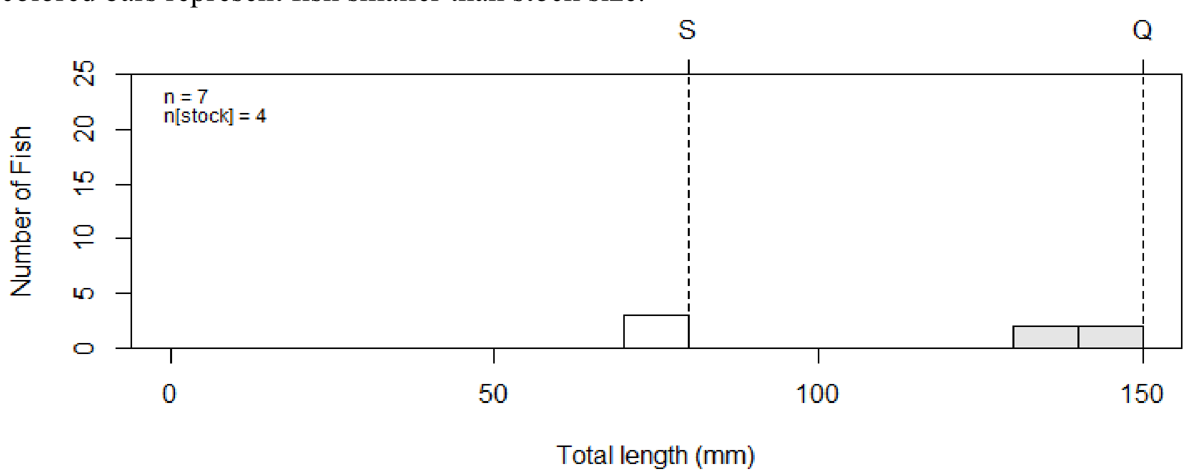

Figure 7.4: Length frequency histogram of bluegill in Lake Forest with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

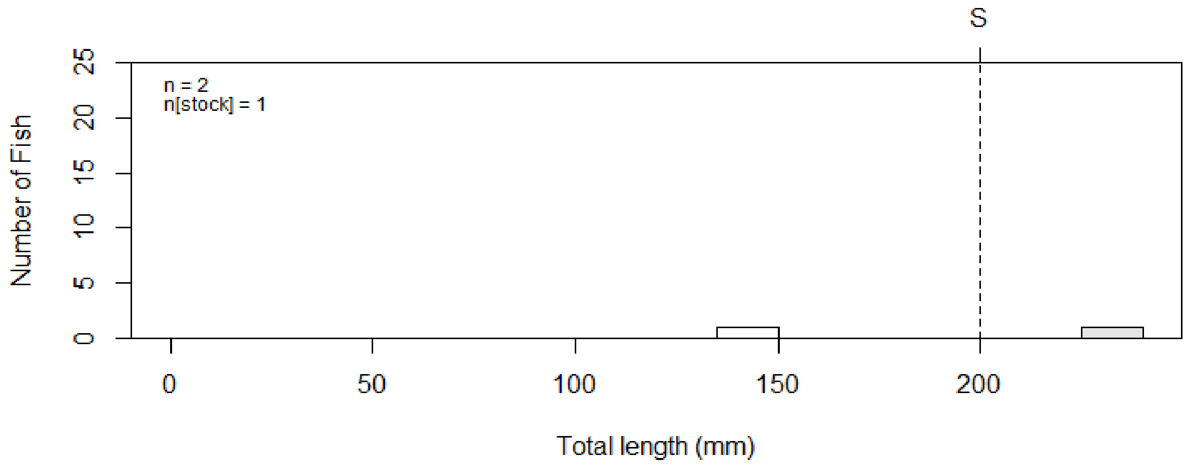

Figure 7.5: Length frequency histogram of largemouth bass in Lake Forest with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

Lake Allure

Lake Allure supports a warm water fishery dominated by centrarchids (sunfishes). A total of 69 fish were captured during shore seine surveys with a total of 3 species captured from 1 family (Table 7.3).

Table 7.3: Common name, scientific name, number caught and mean total length (mm and in), TL of species collected by seine efforts of Lake Allure, August 2020.

Common name	Scientific name	Number caught	TL (mm)	TL (in)
Bluegill	*Lepomis macrochirus*	8	137	5.4
Largemouth bass	*Micropterus salmoides*	21	67	2.6
Pumpkinseed	*Lepomis gibbosus*	28	100	3.9

Pumpkinseed were the most abundant species collected from Lake Allure (n = 28). The average total length of pumpkinseed was 100 mm (3.9 in) with a range of 58 – 151 mm. All fish were stock size or smaller, representing two year classes (Figure 7.6). Largemouth bass were the second most abundant species collected (n = 21) with an average length of 67 mm (2.6 in). Largemouth bass ranged from 37 to 202 mm in total length representing two year classes with a majority of individuals in the sub-stock size class (Figure 7.7). Bluegill were the least abundant species collected (n = 8), with an average length of 137 mm (5.4 in). Bluegill ranged from 114 – 155 mm representing the largest size class of species captured in Lake Allure. Bluegill had a PSD_Q of 12, which indicates that most fish captured fell under quality size (Figure 7.8). Bluegill were represented by only one year class in this collection. PSD_Q estimates for pumpkinseed and largemouth bass could not be calculated due to a small sample size and a lack of larger sized fish.

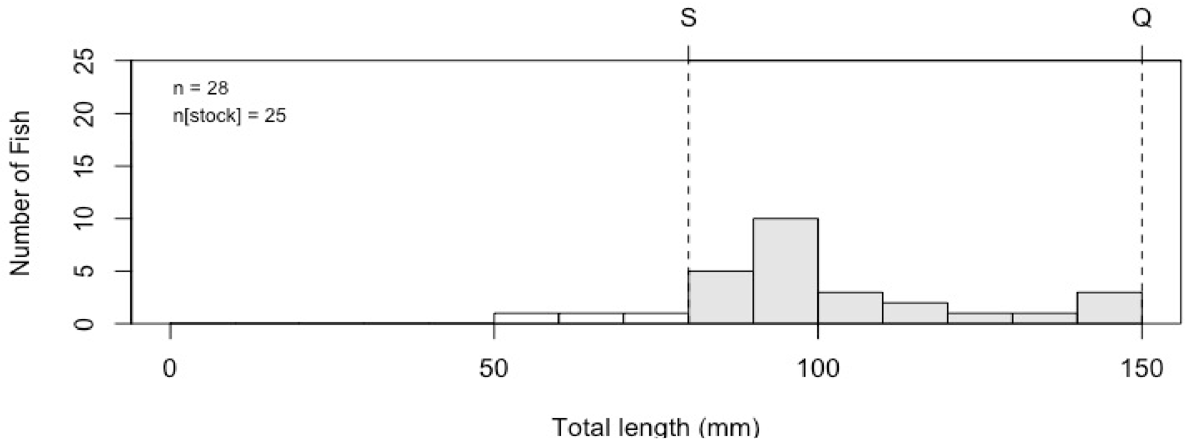

Figure 7.6: Length frequency histogram of pumpkinseed in Lake Allure with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

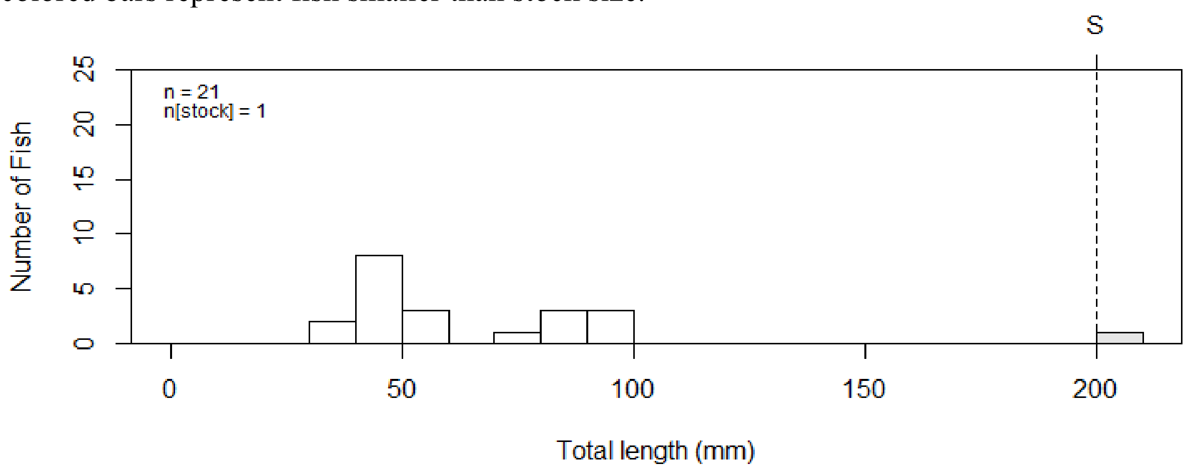

Figure 7.7: Length frequency histogram of largemouth bass in Lake Allure with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

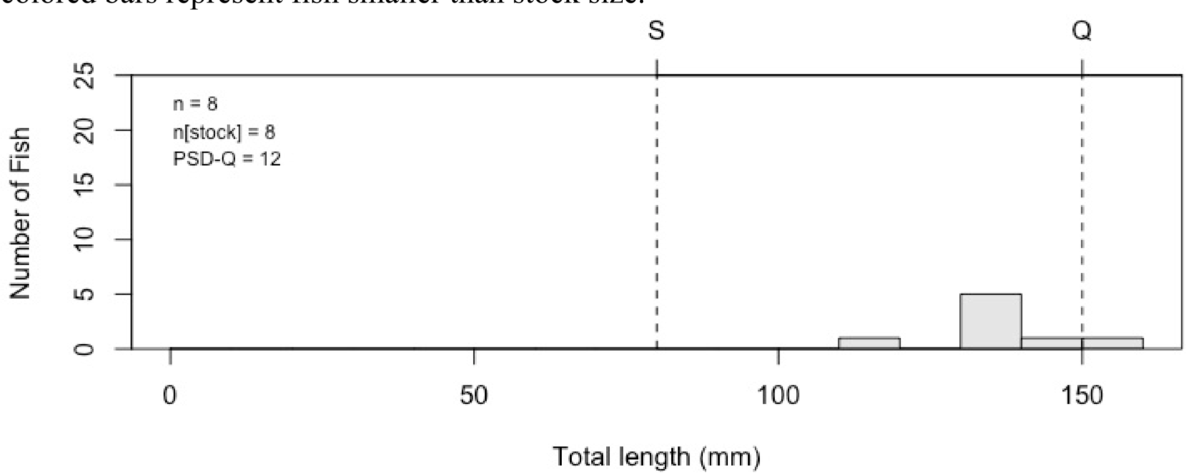

Figure 7.8: Length frequency histogram of bluegill in Lake Allure with vertical lines displaying Gabelhouse lengths for stock (s) and quality (q) size fish (Gabelhouse 1984). White colored bars represent fish smaller than stock size.

Angler Surveys – Lake Forest

Three species were collected during angler surveys of Lake Forest in the spring of 2018 and the winter of 2019. These included chain pickerel, largemouth bass and yellow perch. A total of 65 fish were caught during the ice free and ice-covered seasons combined (Table 7.4). Both rod and reel and tip up were used to catch individual fish.

Table 7.4: Common name, scientific name, number caught and mean total length (mm and in), TL of species collected by angler efforts of Lake Forest, August 2020.

Common name	Scientific name	Number caught	TL (mm)	TL (in)
Chain pickerel	*Esox niger*	59	352	13.8
Largemouth bass	*Micropterus salmoides*	3	381	15.0
Yellow perch	*Perca flavescens*	3	220	8.6

Chain pickerel were the most abundant species (n = 59) caught by anglers in Lake Forest. Creeled pickerel were generally larger than fish captured during haul seine efforts with an average total length of 352 mm (13.8 in) and a range of 158 – 533 mm (Figure 7.9). Fish captured represented four year classes. A total of three largemouth bass and three yellow perch were caught in spring 2018. Average total length of largemouth bass was 381 mm in size (15.0 in) with a range of 355 – 406 mm, likely representing a single year class (Figure 7.10). Yellow perch collected by anglers had an average total length of 220 mm (8.6 in) and a range of 117 – 254 mm (Figure 7.11). The limited number of individuals and wide range of sizes for yellow perch precludes any inference about year classes.

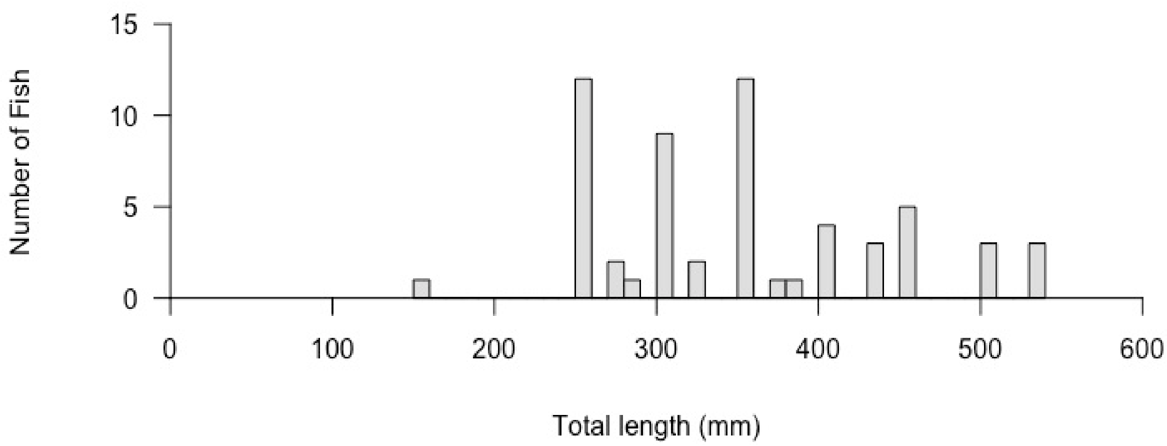

Figure 7.9: Length frequency histogram of chain pickerel in Lake Forest caught by rod and reel.

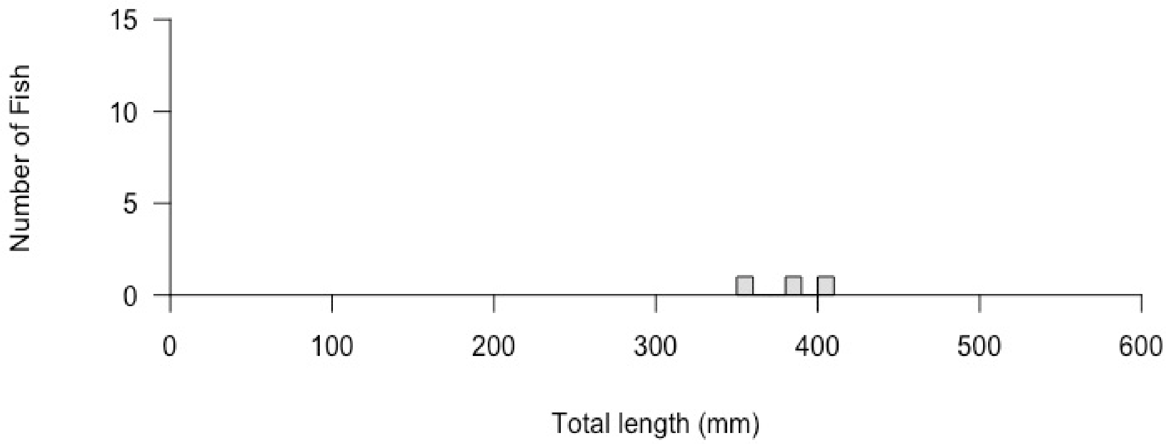

Figure 7.10: Length frequency histogram of largemouth bass in Lake Forest caught by rod and reel.

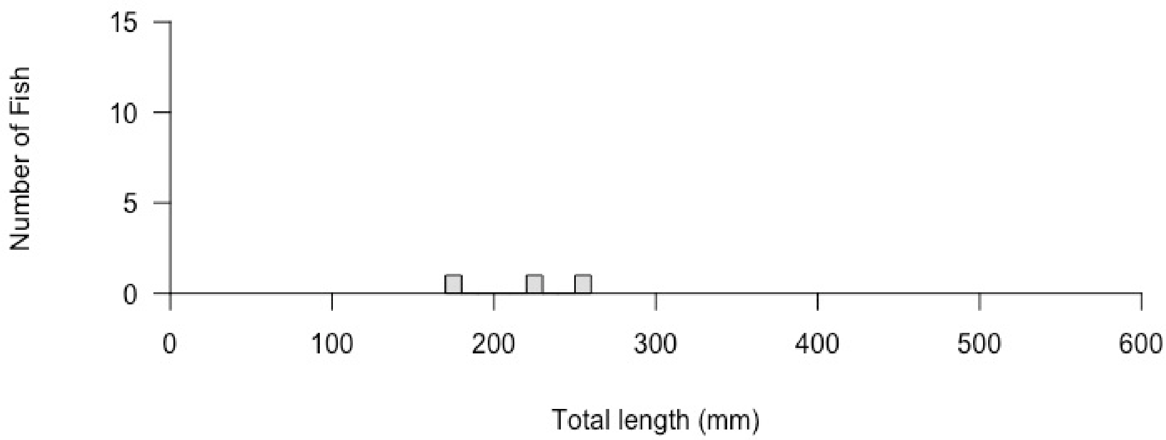

Figure 7.11: Length frequency histogram of yellow perch in Lake Forest caught by rod and reel.

Predator-prey Interactions

Tic-tac-toe plots were created using PSD_Q estimates from combining haul seine and angler survey data to help better understand the main predator-prey interactions between chain pickerel, largemouth bass, pumpkinseed and yellow perch in Lake Forest. The tic-tac-toe plot for chain pickerel and pumpkinseed suggests below average quality of both predators and prey within the impoundment. When points plot in the lower left quadrant of the graph, it is representative of a mediocre quality of fish with low PSD_Q estimates. Chain pickerel and yellow perch interactions are slightly more balanced as prey have higher PSD_Q estimates when compared to collected pumpkinseed (Figure 7.12). While fewer individual largemouth bass were collected during surveys, bass had higher PSD_Q estimates than chain pickerel. Largemouth bass are considered to be of recreational value at 200 mm (8 in) in size, compared to chain pickerel at 250 mm (10 in) in size. Largemouth bass populations are composed of larger individuals while pumpkinseed and yellow perch population are skewed toward smaller individuals (Figure 7.13).

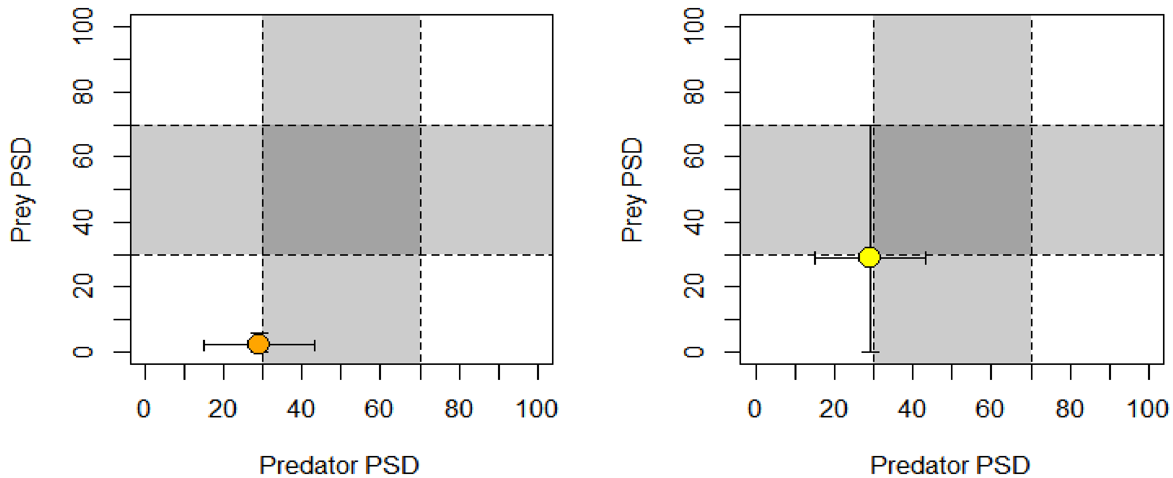

Figure 7.12: Tic-tac-toe plot displaying predator (chain pickerel) and prey (pumpkinseed and yellow perch) interactions in Lake Forest from haul seine and angler survey data. The x-axis on the left graph represents chain pickerel PSD_Q values and the y-axis represents pumpkinseed PSD_Q values. The x-axis on the right graph represents chain pickerel PSD_Q values and the y-axis represents yellow perch PSD_Q values. Solid black lines are the 95% confidence intervals of the predator (x-axis) and prey (y-axis) species.

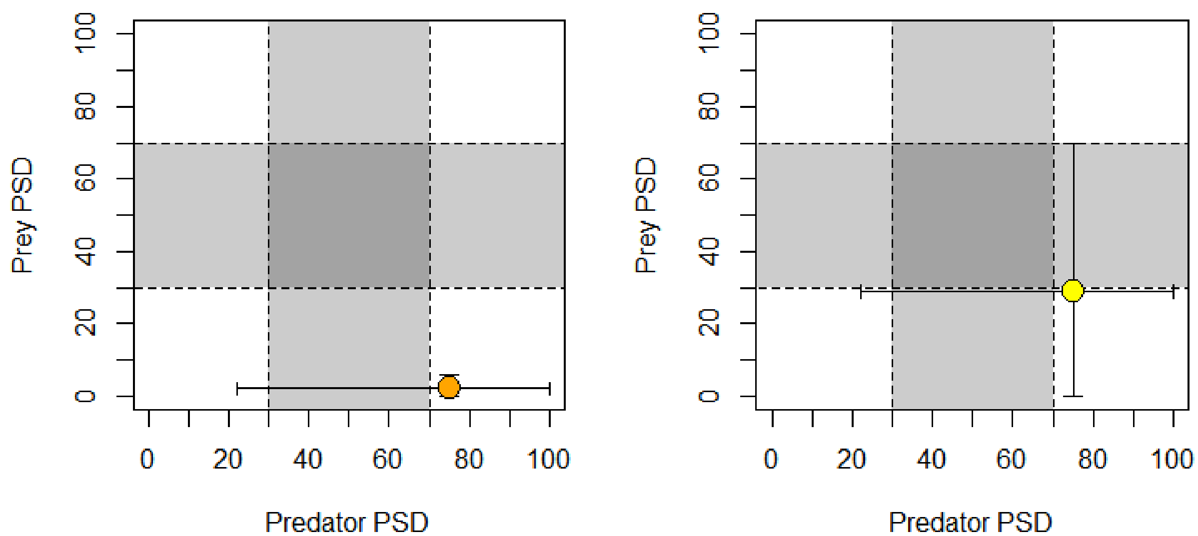

Figure 7.13: Tic-tac-toe plot displaying predator (largemouth bass) and prey (pumpkinseed and yellow perch) interactions in Lake Forest from haul seine and angler survey data. The x-axis on the left graph represents largemouth bass PSD_Q values and the y-axis represents pumpkinseed PSD_Q values. The x-axis on the right graph represents largemouth bass PSD_Q values and the y-axis represents yellow perch PSD_Q values. The orange and yellow circles represent the relationship between the two species. Solid black lines are the 95% confidence intervals of the predator (x-axis) and prey (y-axis) species.

Discussion

Currently, Lake Forest supports a panfish and pickerel fishery, while Lake Allure supports a small panfish fishery. Both are typical of shallow lakes and ponds throughout upstate New York. Gear selectivity and species catchability need to be taken into consideration when interpreting survey results and it is important to note that seasonal effects may influence fish behavior and physiology and thus interpretation of size-structure indices such as PSD and length-frequency histograms (Pope and Willis 1996). Additional data would result in greater confidence in PSD estimates and interpretation of length-frequency histograms in the future. However, with the lack of historical data, these angler and seine surveys do provide the Northwoods Lake Association with important baseline community data about the fisheries of Lakes Forest and Allure. The data from these surveys can be compared with results of future fisheries monitoring across impoundments, and are readily built upon by stakeholders in the future.

The forage (prey) fishes in both waterbodies were primarily sunfishes. Pumpkinseed were the most abundant species captured in both lakes during seine surveys. Pumpkinseed play a vital role in the ecosystem as they are an important prey item for predatory fishes such as chain pickerel and largemouth bass. The high proportional abundance of juvenile sunfishes and perch indicate that this prey base is in-tact within these systems. The low PSD_Q for these species is likely due to the fact that seining selected for smaller individuals and these species were not commonly targeted in angling surveys. In the future, targeted angling for a wide range of sunfishes would allow stakeholders to better understand whether this trend is due to sampling bias or lack of recruitment of these small fish to adult sizes. Likewise, it would allow for calculation of PSD_Q values for a wider range of species and sizes.

Species such as largemouth bass and chain pickerel are the main predators within lakes Forest and Allure. PSD_Q estimates of predators in Lake Forest suggest that size distribution of individuals changed with the use of different gear types. Larger predators were selected for during angler surveys and selected against during seine surveys. Chain pickerel were the dominate predators captured in Lake Forest followed by largemouth bass. Unlike Lake Forest, the only predator collected from Lake Allure was largemouth bass. Bass collected from Lake Allure were small in size, but larger individuals may have been selected against during shore seine surveys.

The tic-tac-toe plots (Figure 7.12 and 7.13) represent the relationship between predators and prey in Lake Forest. When community structure between both predator and prey falls within the bottom left corner of the plot, it signifies a mediocre quality of gamefish and panfish (Anderson and Newman 1996). Low PSD_Q values of panfish can reflect low densities of gamefish, ineffective predation of prey or both (Anderson and Newman 1996). Even based on the limited data collected here, in conjunction with observations of dense plant growth (Chapter

3) and stakeholder concerns related to fisheries and aquatic plants, it seems most likely that this trend represents challenges associated with predator access to prey. In other words, the abundant aquatic vegetation provides excellent nursery habitat and refuge for small fish, which makes it difficult for predators to forage and can result in "stunted" prey fish populations due to resource competition within species and between species (e.g. bluegill, pumpkinseed, juvenile largemouth bass) that use the same or similar resources. Additional data points can help understand the in-lake, predator-prey interactions.

Both the quality and quantity of habitat can affect the recruitment and foraging abilities of fishes within an aquatic ecosystem (Wiley et al. 1984). The density of fishes, such as a largemouth bass, are directly correlated to the percent cover of aquatic macrophytes or the lack thereof. Likewise, the size of individuals is limited by the density of fish per unit of food. Peak density and coverage of macrophytes within an impoundment should be approximately 40% of the bottom surface area to help maintain a balanced fishery (Wiley et al. 1984). In waterbodies with low densities of aquatic vegetation, spawning and recruitment success of fishes may decrease (Durocher et al. 1984). Slow growth and increased population density of fishes can be the result of > 40% percentage macrophyte cover in an impoundment because there is more competition for food due to increased survival of small fish. Added cover and density can increase species recruitment, but may decrease the foraging ability of fishes and result in patterns such as those observed here.

The size-efficiency hypothesis, from Brooks and Dodson (1965), explains that while under foraging pressure from planktivorous juvenile fishes, large bodied zooplankton such as cladocerans, can be depleted and smaller zooplankton (rotifers) can dominate. Lake Forest and Lake Allure both appear to be dominated by relatively small zooplankton (Chapter 3), and high densities of juvenile fish or stunted adult fish may also contribute to grazing pressure on large zooplankton. The lakes could benefit from a top-down management approach to improve the zooplankton and the fisheries communities. Fish < 200 mm can have a negative effect on the zooplankton community as most fish are planktivorous for the beginning stages of life. These fish deplete large stocks leaving smaller, less efficient zooplankters (Brooks and Dodson 1965). The lack of large bodied zooplankton may affect clarity and chlorophyll *a* levels when phytoplankton stocks cannot be controlled through predation. To help control grazing, a large predatory species of fish, such as a largemouth bass or walleye, can be stocked to reduce and control small prey species. However, this may also require concurrent reduction of aquatic plant density to be successful. If densities of small, planktivorous fish populations can be controlled, large-bodied zooplankton stocks of cladocerans (e.g. *Daphnia* sp.) would increase in theory, and this would provide a natural buffering against nuisance algal blooms and help maintain water clarity.

It is also important to note here that bi-annual water level drawdowns may negatively impact perceived quality of the fish communities of Lake Forest. Water level drawdown, especially in shallow lakes, can deplete available oxygen and reduce available habitat (NYSDEC 2005). This could be manifested as slower growth, earlier maturation, and/or increased annual mortality of fishes depending on the severity of impacts.

This study provides a preliminary characterization of the fishes in Lake Forest and Lake Allure. Management actions related to reducing aquatic plant biomass can impact fish abundance and recruitment in the lakes. Continued monitoring should examine community structure as well as predator-prey interactions within the impoundments. This could be easily employed through targeted angling surveys by stakeholders.

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Conclusion

Lake Forest and Lake Allure are two small impoundments that are both aesthetically and recreationally pleasing to residents and visitors. These lakes currently support a variety of organisms as well as a plethora of recreational activities for residents. The state of Lakes Forest and Allure was determined by understanding the physical, chemical and biological components that make up the lakes and encompassing watershed through a variety of sampling techniques. The condition of the lakes is favorable, considering reports of excessive aquatic macrophyte growth and decreased lake depths. The water quality is within optimal ranges; the plant community is comprised of native species; and there are few algal blooms. The NWLA has invested both time and money into the protection and management of the lakes over time. The data collected can and should be used to make important, informed management decisions and as reference data for future studies.

In both lake and watershed management, it is important to consider information like that generated in the state of the lake report to understand potential consequences of management techniques along with other pros and cons. The management plan that follows provides stakeholders with recommendations and management techniques that can be used to address current concerns and maintain favorable conditions. Lakes are forever changing and it is important to note that management techniques expressed in this plan may also change as new regulations, technologies and environmental conditions develop. However, maintaining the current trophic status while controlling aquatic macrophyte growth is an attainable management goal.

A Plan for the Management of Lakes Forest and Allure

Introduction

Lake Forest and Lake Allure are two privately owned, artificial impoundments located in Lake Luzerne, New York. The lakes are encompassed by a 761-acre forested watershed located in Warren county. Both waterbodies are shallow in nature with a max depth of 2 m. Lake Forest has an average depth of 1.2 m and Lake Allure has an average depth of 1.6 m. Due to the shallow depths, both systems are polymictic and are classified as mesotrophic based on water quality parameters.

Lakes Forest and Allure are managed by the NWLA, who has worked with the SUNY Oneonta Lake Management graduate program to develop a State of the Lakes Report and a Comprehensive Lake Management Plan. Current physical and chemical data are available including water quality monitoring, aquatic macrophyte surveys, fish and macroinvertebrate community composition studies and analysis of zooplankton abundance can be found in the State of the Lake Forest and Lake Allure, NY. The NWLA currently monitors the limnological parameters of Lake Forest through CSLAP monitoring and have contracted previous studies in the watershed as well as aquatic plant communities.

The goal of the management plan is to provide the NWLA and stakeholders with the necessary information to make educated, management decisions for Lake Forest and Lake Allure. This management plan highlights the highest concerns among stakeholders along with the tools to address these matters. A key component within lake management is continued monitoring of in-lake conditions to evaluate the success of management actions moving forward. The information gathered here can help mangers match the needs and wants of stakeholders.

1.0 Watershed and Water Quality Management

1.1 Overview

Watersheds can be defined as the area within which all of the rain, surface water, or groundwater drains towards in a specific area such as a lake. Lakes, ponds, and rivers would not exist without their watershed, which is why watershed management it is an important component in the management of a waterbody. Watershed characteristics such as geographic extent (size), geology and land cover can determine the terrestrial influences on an aquatic system. With regard to terrestrial influences, pollutants of various types are generally the primary concern. Pollutants may be contributed to the watershed through both point and non-point sources. Non-point sources of pollution are linked to precipitation, snowmelt, drainage and land runoff from agricultural land, impermeable surfaces, lawns, septic systems, and logging sites that are de-centralized and thus difficult to relate to a given point in space. Point source pollution is recognizable as direct input from an identifiable source such as a waste-water treatment plant or industrial factory. Watershed pollutants can also include constituents such as organic matter, sediments and excessive nutrients such as nitrogen and phosphorus in addition to synthetic or anthropogenic toxics that we usually associate with pollution.

To manage the influx of watershed pollutants into Lakes Forest and Allure, a variety of strategies, referred to as best management practices (BMPs) can be used to achieve specific water quality and plant management goals. The stakeholder survey helped determine concerns among residents regarding water quality and watershed management for future generations.

1.2 Management concern: Protect and maintain the water quality of Lakes Forest and Allure.
1.2.1 Objective 1: Promote the use of BMPs to limit non-point source pollution within the watershed.
Action Item 1: Educate and encourage residents to implement watershed BMPs in homes and on personal and NWLA property.

Several BMPs have been established for a variety of land-use activities to help control runoff, erosion and excess nutrients from entering lakes, ponds and impoundments. Ground cover and skid trail management are two important practices used for logging or forested properties. Ground cover management can help reduce runoff and soil erosion by maintaining or adding cover to exposed soil after logging. Cover can be added by a combination of hay, seedlings or re-planted saplings, shrubs or grasses. Skid trail management should focus on log skidding paths used by equipment operators and loggers. These trails can be a major source of loose, eroding sediments in a forested watershed. Weather conditions should be monitored to avoid logging during heavy rain or storm events and skidding on dry or frozen trials/roads may prevent soil runoff and erosion from occurring. It is also important to ensure that any logging trails do not directly wash into streams, as turbidity and sedimentation can increase.

Phosphorus-free products such as fertilizers and detergents can greatly reduce import of this nutrient that can contribute to eutrophication in lakes. New York State has enacted the Nutrient Runoff Law that restricts the use of phosphorus-containing fertilizers on lawns or non-agricultural turf. The environmental conservation law prohibits the use of phosphorus containing fertilizers from December 1 through April 1, annually. Additionally, the law states that no person shall apply phosphorus fertilizer to any lawn within 20 ft of surface water without a continuous, natural, vegetative buffer at least 10 ft wide. Funding may be available through the NYS Water Quality Improvement Program (WQIP) to help implement BMPs locally:
https://www.dec.ny.gov/pubs/4774.html and
https://www.dec.ny.gov/docs/water_pdf/wqipr14rfa0714.pdf. All watershed BMPs can be most effectively implemented with the use of zoning laws. Zoning laws allows for enforceable legislation in regard to local land use or septic system maintain.

Action Timeline: Educational literature should be passed out at the next association meeting to better help stakeholders implement BMPs and can be made available and updated through the NWLA website.

Action Item 2: Encourage the use of septic system BMPs.

Septic system BMPs are relatively easy to follow and can benefit both the homeowner and environment. It is important to regularly inspect and pump septic tanks to ensure proper functions and to limit the probability of clogging or overflow. The EPA and NYSDEC suggest pumping septic tanks every 2 to 3 years dependent on use. Absorption (leach) fields should be free of rooted vegetation and excess weight from cars or building structures. Other easy to implement septic system BMPs are to conserve water use with low flow toilets, use phosphorus-free detergents, avoid use of garbage disposals in sinks, ensure proper disposal of nondegradable products and to avoid harsh septic tank additives marketed to help break down tank waste. Additional information on septic system care and maintenance can be found through the United States Environmental Protection Agency (USEPA; https://www.epa.gov/septic/how-care-your-septic-system) and the New York State Department of Health (NYSDOH; https://www.health.ny.gov/publications/3208/index.htm).

Action Timeline: Educational literature should be passed out at the next association meeting to better help stakeholders implement BMPs. Each household should sign a contract pledging to implement at least two BMPs into their home life.

1.2.2 Objective 2: Continue CSLAP monitoring of Lake Forest and implement a CSLAP volunteer for Lake Allure.

Action Item 1: Encourage residents to engage in CLASP monitoring to gather long-term data and preserve the water quality of Lakes Forest and Allure.

The Citizens Statewide Lake Assessment Program is a volunteer monitoring program that is managed by the NYSDEC and NYSFOLA. In-lake monitoring by citizens scientists can help identify problems, such as water quality changes or harmful algal blooms, while collecting valuable long-term data of public and private NYS waterbodies. Lake Forest should continue volunteer monitoring to add to existing data and Lake Allure should identify a citizen scientist to become a trained volunteer. Continued and future monitoring can help gauge the success of prospective or existing management strategies in the lakes. The following link provides residents with more information regarding CSLAP monitoring: https://www.dec.ny.gov/chemical/81576.html.

Action Timeline: New and additional volunteers should be determined before the next CSLAP sampling season (Spring/Summer 2021).

2.0 Aquatic Macrophyte Management

2.1 Overview

Aquatic plant management is one of the most common management concerns among lake users and managers. Stakeholders typically prefer low densities of aquatic macrophytes so they do not impact recreation and aesthetics. Although plants can be considered a nuisance, aquatic macrophytes are an integral component within lake ecosystems as plants perform numerous ecological functions such as nursery habitat for fish or nutrient uptake, and important ecosystem services that benefit humans directly such as sediment stabilization (Kalff 2002). Excessive aquatic macrophyte growth was the top concern among 95% of the Northwoods Lake Association stakeholders. Lakes Forest and Allure sustain abundant, native aquatic plant growth throughout the year. Excessive growth has continually impacted recreational activities such as boating, swimming and fishing. Previous studies indicate that nuisance aquatic plant growth has been an ongoing challenge for stakeholders. The 2018 aquatic macrophyte study (SOL Chapter 3) determined that plant abundance was high in both impoundments. Nuisance aquatic plants included watershield, bigleaf pondweed, aquatic moss and floating leaf pondweed.

Currently Lake Forest follows a bi-annual water level drawdown of 3 ft. This method is used to freeze and eradicate shoreline aquatic macrophytes and roots to improve recreation and aesthetics.

2.2 Management concern: Excessive and increasing aquatic macrophyte growth impacting recreation and aesthetics.

2.2.1 Objective 1: Educate stakeholders on the benefits of native aquatic macrophyte communities and help stakeholders identify aquatic invasive species for early detection.

Action Item 1: Create educational handouts, brochures or flyers for association members that describe and identify the native aquatic plants in Lake Forest and Lake Allure.

Use handouts to educate members on the benefits of aquatic plants and help residents identify common aquatic invasive species for early detection. Handouts should include management options for recreational areas (beaches, docks, etc.), along with best practices for residential property management (e.g., fertilizer application, riparian buffers, septic tank BMPs) for stakeholders. For those not in attendance, educational information should be made available on the NWLA website.

Action Timeline: Hand out literature at the next annual meeting (Summer 2021).

2.2.2 Objective 2: Control nuisance aquatic plant growth.

Action Item 1: Use the best suited physical control techniques to reduce plant growth around docks and in critical swimming areas.

Authorization of the following physical control techniques are approved under the NYSDEC General Permit 0-15-005 (https://www.dec.ny.gov/permits/106121.html) and a joint application through the US Army Corps of Engineers (https://www.dec.ny.gov/docs/permits_ej_operations_pdf/jointapp.pdf).

Benthic Barriers

Benthic barriers are a common, inexpensive method for aquatic plant control. Physical barriers made from inorganic or biodegradable materials are placed on the lake bottom to prevent plant growth by blocking sunlight and covering existing stands. Benthic barriers not only prevent growth, but can reduce turbidity from soft benthic sediments. There are some restrictions based on presence of threatened species, but there are otherwise few restrictions to their use under NYS general permit, GP-0-15-005 (NYCRR 2020). While benthic mats are an ecologically benign option, mats can be labor-intensive and may cause anoxic conditions to accumulate at the sediment-water interface. Porous materials that allow gases to escape are recommended to prevent barrier uplift and displacement during seasonal deployment. Cost varies by size and material and is dependent on instillation. Mats are to be placed after June 30th to protect vital fish spawning habitat and are to removed annually to prevent sediment buildup.

Hand Harvesting

Hand harvesting is one of the most widely used plant management techniques in New York State. Hand harvesting is labor intensive, comparable to garden weeding, and is typically the only plant management strategy that does not require a permit through the NYSDEC or APA. Hired help or volunteer stakeholders can collect nuisance plants by hand and remove the entire root from the sediment. Costs are relatively low, usually $1,000 per acre or less. Alternatively, divers can be hired to perform this work seasonally. Fragmentation is the main disadvantage of hand harvesting as plant fragments can settle on the lake bottom and regrow or drift to new areas and generate new stands. Hand harvesting should occur yearly to prevent re-infestation. Due to the size of Lakes Forest and Allure, cost can be reduced if harvesting targets only nuisance areas.

Hydro-raking

Hydro-raking is a newer form of mechanical plant control that can be used to target shallow areas with high plant density. Plants, roots and sediments are dislodged using a mechanical rake through the water column and benthic habitat. Entire plants may be removed, but turbidity and fragmentation will occur which can impact lake fauna. Fragmentation occurs when cut plants are not removed from the waterbody. Plant fragments are transported by wind or wave action spreading to vacant habitat. These habitats can be easily invaded by both native and exotic aquatic plants (NYSFOLA 2009). Many times non-target organisms are affected as fish and invertebrates can become trapped in the rakes or removed with plant disposal. Costs can range from $1,500 to 2,000 a day, plus additional costs for disposal and permitting. Hydro-raking

may need to be performed several times a year depending on density and growth of macrophytes. Few hydro-raking permits have been approved in New York State. The APA and NYSDEC require an Article 24 permit, Freshwater Wetlands permit and labor permit.
Action Timeline: Next annual meeting to discuss permitting and funding.

Action Item 2: Stock triploid grass carp to control nuisance aquatic plant growth.

Grass carp (*Ctenopharyngodon idella*) are used widely for aquatic macrophyte control as this fish is herbivorous. Grass carp introductions can both positively and negatively impact a system as grass carp will typically eradicate all aquatic macrophytes if not properly managed or can have no effect (Pípalová 2006) depending on local conditions. Fish prefer leafy macrophytes, such as waterweed, bigleaf pondweed and musk grass (Pine and Anderson 1991, NYSFOLA 2009), which are all found in Lakes Forest and Allure (SOL Chapter 3). Stocking of fish can reduce overall plant biomass, as well as individual, targeted plant biomass. Triploid grass carp are used in aquatic plant control as sterile fish will not naturally reproduce in a waterbody (Pípalová 2006). Non-target impacts of stocking grass carp can include changes in water quality or sediment chemistry due to nutrient rich excretions from fish (Pípalová 2006) and decreased dissolved oxygen concentrations due to eradication of aquatic macrophytes (Michewicz et al. 1972, Lembi et al. 1978, Fowler and Robson 1978, Pípalová 2006). Because grass carp continuously graze, stocking rates can negatively impact nutrient and chlorophyll *a* concentrations (Gasaway and Drda 1978, Small et al.1985, Maceina et al. 1992, Pípalová 2006). Turbidity may increase, depending on local conditions from disturbed sediments or increased phytoplankton production (Buck et al. 1975, Small et al. 1985, Pípalová 2006). Low density stocking would be suggested due to the sizes of Lakes Forest and Allure to prevent undesired changes in water quality and nutrient concentration (Chilton and Magnelia 2008). NYSDEC regulates grass carp stocking through Environmental Conservation Law Article 11-0507 liberation of fish, shellfish and wildlife (2015). Lake associations are required to obtain an APA Freshwater Wetland permit and complete a State Environmental Quality Review (SEQR). Information regarding the triploid grass carp stocking permit application can be found at: https://www.dec.ny.gov/permits/25024.html and https://www.dec.ny.gov/docs/wildlife_pdf/grasscarpstockap.pdf.
Action Timeline: Next annual meeting to discuss permitting and funding.

3.0 Fisheries Management

3.1 Overview

Historically, Lakes Forest and Allure were enjoyed by anglers, and supported angling opportunities for desired species and for large individual fish (R. O’Boyle, Northwoods Lake Association, personal communication). In recent years, angling has become difficult due to extensive macrophyte cover and low catch rates of quality sized fish. Survey results determined that Lake Forest is a productive panfish and pickerel fishery, while Lake Allure appears to support a panfish fishery only. Pumpkinseed make up a majority of the individuals in both impoundments and serve as important prey items for predatory species.

The stakeholder survey helped determine individual concerns of residents regarding the fish communities of Lakes Forest and Allure. A wide range of comments were made addressing community changes, catchability and the quality of the fishery in both lakes. Low proportional size distributions (PSD) for most species indicate that fish populations are skewed toward smaller individuals, which could indicate problems with either growth or survival to larger sizes. Whereas dense vegetation has the potential to reduce access to prey for large fish, bi-annual drawdowns could interfere with fish growth and survival. With the lack of historical data, it is difficult to determine whether the fish communities have changed drastically over time or these simply reflect changing perceptions and catch rates. It is important to continuously monitor the communities in the future to determine if implemented management practices are impacting these systems with respect to community structure, recruitment and individual size.

3.2 Management concern: Fish community changes over time and future management.
3.2.1 Objective 1: Monitor the communities of Lakes Forest and Allure to understand size structure, community composition and long-term changes.
Action Item 1: Prepare angler logs and surveys to record important fisheries data.

Typically, conservationists and anglers are some of the best data collectors as they are extremely vested in the condition of the resource. Citizen scientists can collect important data about fish communities in lakes to help inform regulations, stocking programs or long-term monitoring and management. Angler records require very little information to obtain a reasonable community assessment of the fishery if they are designed properly. Surveys should ask for vital information such as species and total length of fish caught, and whether they were harvested. Additional data such as date, time, mapped location, estimated water depth and macrophyte cover can help make a more complete survey and may provide valuable long-term information even if coarse.

Anglers could volunteer for the program and fish for a given species a number of times throughout the year. Surveys could occur during the ice covered or ice-free season. Logs should stay in a generalized location that is easily accessible to anglers. Reference appendix 1 for example angler logs and program details.
Action Timeline: Surveys should begin immediately and should be announced in the biannual newsletter, Facebook, website, etc.

Action Item 2: Conduct biannual fishing derbies for NWLA residents, family and friends.

Fishing derbies are a longtime favorite among lake residents and community members as they provide angling opportunities in addition to social experiences such as friendly competition among stakeholders. Biannual ice fishing and open water derbies can provide the opportunity for families and friends to catch fish and help gather vital community data. Derbies can also have cash or trophy awards to encourage participation. If derbies are successful and received well by stakeholders then rods, reels and tackle could be purchased by the association for future use to encourage inexperienced anglers to participate and get involved (possibly supported by entry fees, raffles, or other fundraising as part of the event if desired).

Action Timeline: Derbies should be scheduled for February 2021 and August 2021. Derbies should occur biannually, preferably (every six months) if there is sufficient support from residents.

3.2.2 Objective 2: Grow larger fish and reduce abundant prey species.

Action Item 1: Change the NWLA catch and release policy and follow NYS fishing regulations.

To combat the excessive prey abundance, changing the catch and release policy can help balance the different fish populations in Lakes Forest and Allure. Anglers would have to abide to NYS guidelines and regulations, while holding a valid NYS freshwater license (age 16+). Small individuals can be easily targeted with hook and line. When natural predation from predatory species is low, supplemental management from angling can help balance the predator/prey relationships in a waterbody. Large predatory species such as pickerel and largemouth bass should not be targeted during the spring spawning season and a catch and release policy could be implemented during this time. Statewide angling regulations can be found at: https://www.dec.ny.gov/outdoor/31421.html. The harvest of medium-sized predators and abundant sunfishes will likely reduce competition within and between species and result in larger individual fish size, although this will reduce the overall number. As a general rule of thumb, stakeholders should seek to harvest about 5 lbs. of prey fish (sunfishes) for every 1 lb. of predatory fish (e.g. largemouth bass and pickerel) to achieve balanced size-structures in small waterbodies (Zale et al. 2012).

Action Timeline: Bylaw changes should be discussed with NWLA members at the annual meeting and implemented as soon as possible.

Action Item 2: Supplemental stocking of tiger musky in Lakes Forest and Allure.

Stocking fingerling sized Tiger muskie (*Esox masquinongy x Esox lucius*) would supplement the natural reproducing chain pickerel populations in the lake and exert additional pressure on abundant prey species. Pressure from stocked tiger musky can help reduce panfish abundance, making food items more readily available for the remaining prey species. Stocking should be coordinated along with macrophyte management to insure natural in-lake fish dynamics are preserved. Stocking requires a free permit from the NYSDEC. Permit information and the application can be found at the following link: https://www.dec.ny.gov/permits/25026.html.

Action Timeline: Fish should be stocked in spring when hatchery stock reaches 4 – 6 or 8 – 12 inches in size.

<u>3.2.3 Objective 3:</u> Manage and control native aquatic macrophyte growth to benefit fish habitat, recruitment and predator-prey dynamics.
<u>Action Item 1:</u> Please refer to section 1.0 for macrophyte habitat management.

4.0 Depth and Sediment Management

4.1 Overview

Natural succession occurs over long periods of time causing lakes and ponds to slowly fill in, age and "die". This process occurs over many decades but can be accelerated human actions. Observations by stakeholders can help to identify changes in lake characteristics. Lake succession is primarily driven by the input of organic matter and sediment into a system and the decreased depths of Lakes Forest and Allure are part of the natural aging process. Shallow depths and increased organic matter from the abundant macrophyte community allow for excessive plant growth to occur throughout the year. While succession is natural, it can impact recreation and the use of the waterbody by residents. Many association members commented on the decreased depths and increased flocculant materials within Lake Forest and Lake Allure.

Dredging is one way to remove unwanted sediments from a waterbody as other management alternatives for increasing lake depth may not exist. Dredging can be used to remove nutrient rich sediment from the lake bottom and requires significant permitting and funding on the part of stakeholders. There are two basic types of dredging; drawdown excavation and in-lake dredging.

1. Drawdown excavation: the water is drained, dried and sediment is removed from a specific area.
2. In-lake dredging: used when the dewatering is not feasible, cutterhead hydraulic pumps are used for "suction" dredging whereby sediment is syphoned from the lake bottom.

Under either of these options, sediment is generally transported and disposed of at selected off-site locations, which can be the most significant cost associated with these efforts.

Advantages and Disadvantages

Dredging is a multi-purpose management strategy that can increase lake depth, remove hazardous or accumulated nuisance sediments, and reduce the standing crop of aquatic macrophytes in a specific area. The benefits of dredging may last decades, but it is important to note that there may be negative effects on the lake ecosystem in the short term. As what is commonly viewed as a "drastic" or "disruptive" control technique, dredging requires multiple permits through the NYSDEC and APA, and may require additional permitting through the U.S. Army Corps of Engineers (USACE). Cost is dependent on volume removed, dredging depth, transportation and disposal of sediment, monitoring requirements and more. Average cost per acre of surface area, cut to 3 ft in depth, can range from $1,000 to $40,000. It is important to note that dredged areas should be at a depth that inhibits plant growth. If not deep enough, macrophytes will grow back almost immediately.

4.2 Management concern: Decreased depths and increased flocculant materials on the lakes bottom.

4.2.1 Objective 1: Remove bottom sediments to increase water depth and decrease aquatic plant growth in Lake Forest.

Action Item 1: Determine if permits are attainable and if funding is available to perform drawdown excavation dredging. Areas in drastic need should be prioritized.

The first step should be to determine whether the APA would approve a dredging permit for Lakes Forest and Allure. If approved, an association meeting should be scheduled to discuss funding availability and required permitting to dredge heavily impacted areas in Lake Forest and Allure (Figure 4.1). Dredging requires at least an Environmental Conservation Law Article 15 - Protection of Waters permit from NYSDEC and a freshwater wetlands permit from the APA. Additional permits may be required through NYSDEC, APA or US Army Corps of Engineers. An association-wide decision should be made to determine if dredging is desired by most and planning should begin a year before the start of the proposed project. The advantages and disadvantages associated with dredging should be discussed with stakeholders. Although effective, dredging can be difficult to fund and permit, and it can be among the most difficult lake restoration techniques to successfully complete (NYSFOLA 2009). Information regarding permitting applications and the approval process can be found at: https://www.dec.ny.gov/permits/6230.html.

Action Timeline: The APA should be contacted prior to any consideration of this option to determine if dredging the lakes would be approved. If so, then association-wide discussions should begin immediately and funding allocations and permitting should be discussed and determined. *It is important to note than most dredging permits are denied by the NYSDEC and APA.

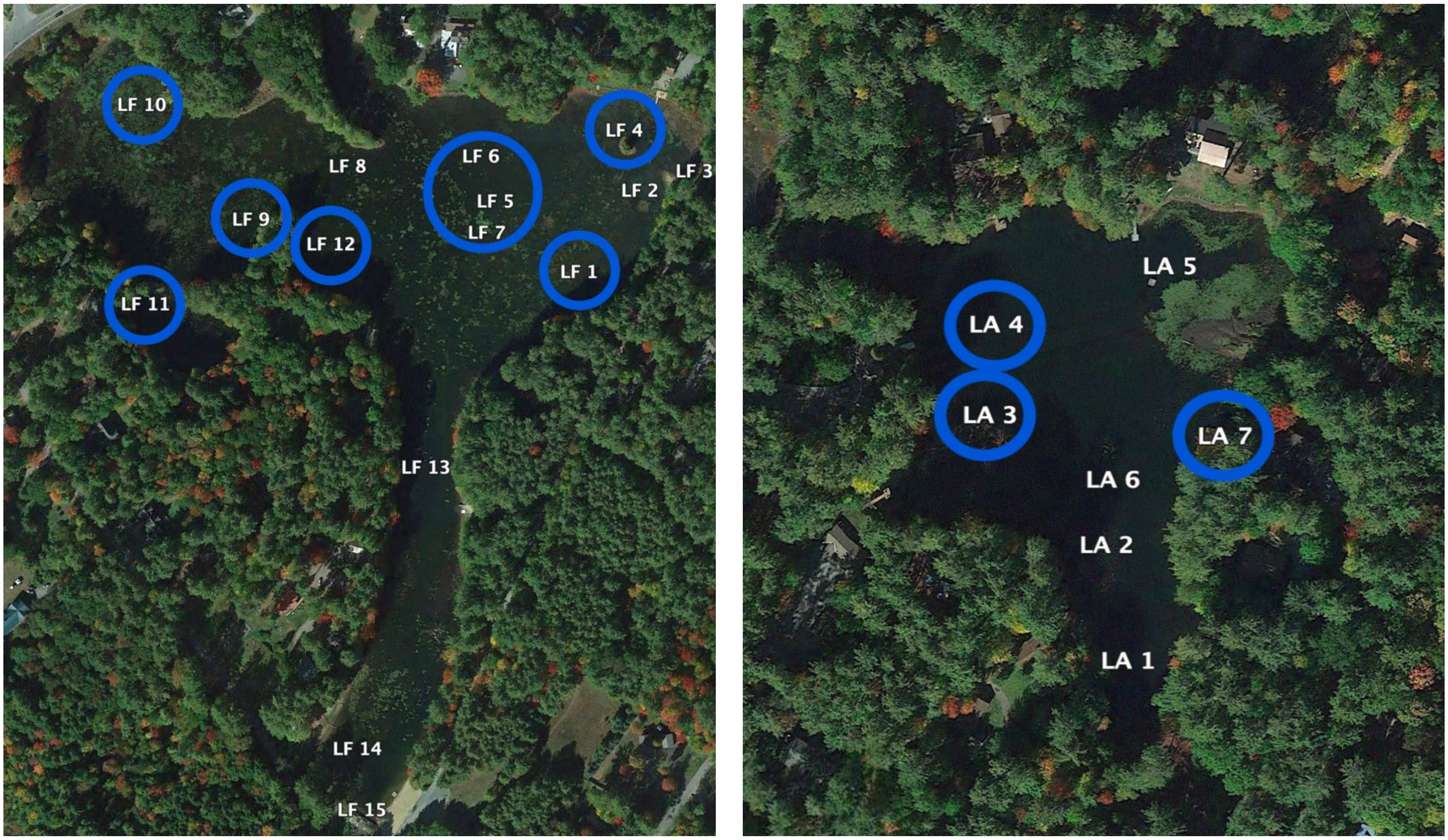

Figure 4.1: Blue circles indicate areas of Lake Forest and Lake Allure that should be prioritized due to increased unconsolidated sediment depths (SOL Chapter 5).

Action Item 2: Leave water depths and allow lakes to naturally age (do nothing), and rely on other options for plant control.

Although lake depths will continue to decrease, the impoundments can still be used by residents with some degree of aquatic macrophyte control. As lakes age, they will progress to a wetland, which will provide many ecosystem functions and services for stakeholders. Allowing the lakes to naturally age and fill in will save association funds for aquatic plant management and other needed management strategies.

Action Timeline: N/A – nothing to be done in this case.

5.0 Nuisance Wildlife Management

5.1 Overview

Aquatic systems are not only home to fully aquatic species, but also other wildlife such as mammals, waterfowl and songbirds. Many species use these areas as breeding and refuge habitat, in addition to food and water sources. North America is home to a wide variety of mammals of which 23 are considered "wetland species". Beaver, muskrat and river otter are attracted to impoundments when conditions are favorable (e.g. water depth, food availability, non-rocky shoreline). Many of these mammals create burrows or dens which can damage dams or levees and impact the lake shoreline. Beavers, in particular, can destroy valuable forests and river otters can exert aggressive predation on fish, crustacean and amphibian populations.

Lake Forest and Allure are home to wildlife such as geese, ducks, otters, and muskrats. While these animals are native to the area, many can alter habitat and can be considered a nuisance to residents. Waterfowl, such as Canada geese, can be a common nuisance species in aquatic systems if they take up residency at lakes they did not historically inhabit.

Stakeholder survey results helped identify nuisance wildlife concerns among residents at Lake Forest and Lake Allure. Many concerns were related to waterfowl, muskrats, and river otters altering habitat and potentially affecting fish abundance. It is important to remember that while these animals can be considered a nuisance, wildlife are a natural part of our aquatic ecosystems and they will continue to utilize these resources if available.

5.2 Management concern: Control of nuisance wildlife such as waterfowl and mammals and their impact on the ecosystems.

5.2.1 Objective 1: Control Canada geese populations from utilizing residential properties.

Action Item 1: Educate stakeholders and create an association-wide understanding of not feeding waterfowl.

The single most effective waterfowl management strategy for small waterbodies is to discourage the feeding of waterfowl. Feeding geese and ducks can encourage these animals to establish residency and cause human-wildlife conflicts. Feeding is strongly discouraged as animals can become extremely comfortable around humans and alter water quality from excessive feces. Waste accumulation on lakeshore properties is another common complaint. The NWLA may choose to pass a collective social value bylaw which is a basic understanding among association residents to not feed waterfowl and other wildlife species. A “Do Not Feed Waterfowl” sign with a list of negative outcomes can educate stakeholders on the repercussions of feeding waterfowl and other wildlife species (e.g. https://www.dec.ny.gov/docs/regions_pdf/feedduck.pdf).

Action Timeline: As soon as possible.

Action Item 2: Let residents decide if they want to participate in one of many potential waterfowl control strategies.

Multiple waterfowl control strategies have been used to discourage geese and ducks from occupying residential properties. It is important to eliminate all pathways that easily allow goslings and adults to move easily between water and land (NYSFOLA 2009). Physical barriers can be installed at the edge of the water to create impediments to traveling geese. Simple string fences with aluminum foil or shiny materials can discourage geese from coming to shore.

Planting dense, native shrubs near the shoreline can also deter geese from coming onto lawns, while providing riparian buffers which can reduce shoreline erosion. Noisemakers and trained dogs can be used without a federal permit only to harass waterfowl to keep them from coming ashore.

Action Timeline: Implementation of nuisance waterfowl control should be discussed at the next annual association meeting.

5.2.2 Objective 2: Control of nuisance furbearers (e.g. muskrat, beaver and otter) on residential properties.

Action Item 1: Find a local trapper to trap and dispatch furbearers following NYS trapping guidelines and regulations.

New York State is home to 10,000 trappers who take pride in their hobby or livelihood. Trappers can control nuisance animal populations and humanely dispatch animals if necessary. Trappers need to be licensed in New York and should follow NYS guidelines and regulations. Lakes Forest and Allure are located in wildlife management unit (WMU) 5J. Local regulations should be followed to ensure legal take of furbearers; especially where lethal traps are required. It is important to discuss trapping objectives with the trapper as well as the lake association members before attempting to implement this action. Many furbearers do not have designated bag limits, so it is important to determine how many of each species should be taken on a yearly basis. New York State regulations can be accessed from the following link: https://www.dec.ny.gov/outdoor/355.html.

Action Timeline: Trapping seasons very, but typically begin at the end of October and continue through mid-April. It is important to identify a volunteer trapper as soon as possible.

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Appendix 1: Angler Survey Data Log

Date: ______________________

Angler Name: ______________________

Which lake are you fishing on? ______________________

What are you fishing from? Boat Shore Kayak/Canoe

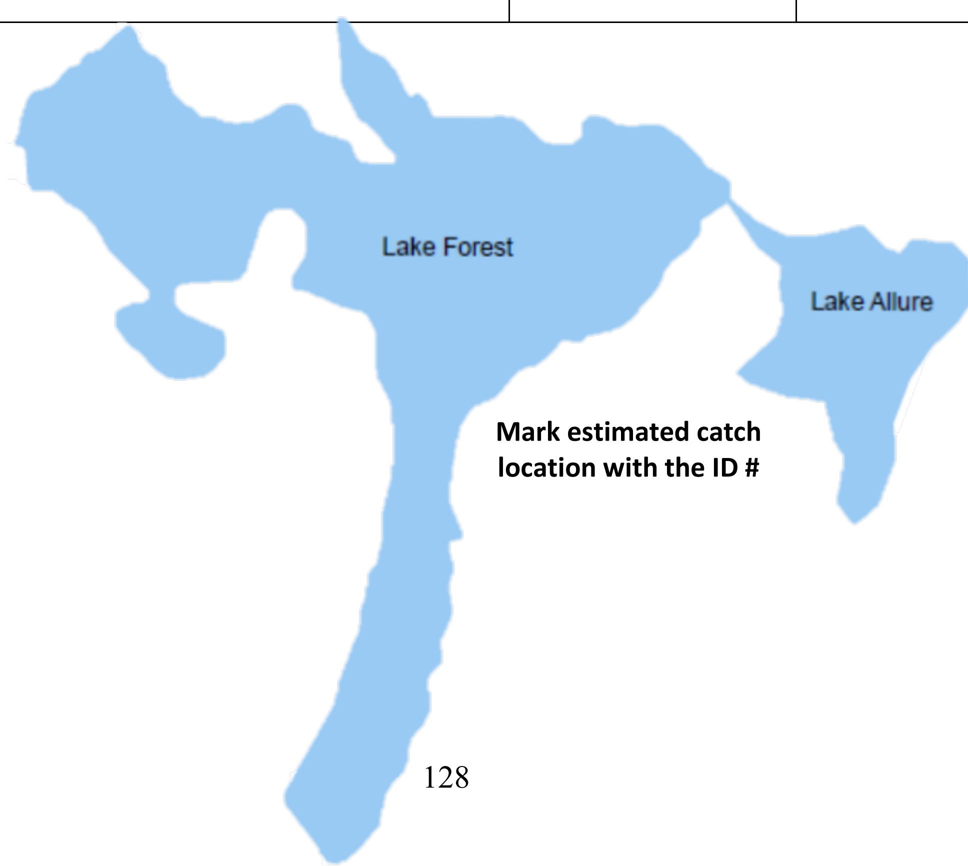
What species are you targeting (if any)? ______________________

Time (start and end): ______________________

Type of Gear (rod and reel/tip-up): ______________________

Please try to keep a camera handy for any fish you are unable to ID!

ID #	Species	Total length (mm)	Harvested or Released
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			



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