Lake Champlain Long-Term Water Quality and Biological Monitoring Program

Summary of Program Activities During 2021

March 30, 2022

Prepared by:

Vermont Department of Environmental Conservation
Watershed Management Division
1 National Life Drive, Davis 3
Montpelier, VT 05620-3522

New York State Department of Environmental Conservation
Region 5
P.O. Box 296
Ray Brook, NY 12977-0296

Lake Champlain Research Institute
SUNY Plattsburgh-Hudson 136D
101 Broad Street
Plattsburgh, NY 12901

Submitted to:

Lake Champlain Basin Program
P.O. Box 204
54 West Shore Rd.
Grand Isle, VT 05458

Purpose of Report

The workplan for the Lake Champlain Long-Term Water Quality and Biological Monitoring Program approved by the Lake Champlain Basin Program specifies the following annual reporting requirements:

An annual report will consist of a summary of the history and purpose of the (program), description of the sampling network, summary of field sampling and analytical methods, parameter listings, and data tables. The purposes of this annual report will be achieved by maintaining an up-to-date Program Description document, graphical presentations of the data, and an interactive database, including statistical summaries, on the project website…… In addition, the quarterly report produced in April each year will provide a summary of program accomplishments for the calendar year just ended, including the number of samples obtained and analyzed at each site by parameter.

The Program Description document, interactive access to the project data, and graphical and statistical summaries of the data are available on the program webpage. The purpose of this report is to provide a summary of sampling activities and other accomplishments during 2021.

Sampling Activities During 2021

The project QAPP outlines sampling frequency and methodology for all target parameters. In 2019, the QAPP was approved as a five-year document. Sampling and analytical methods are summarized annually; events impacting data quality are also noted. Table 1 lists the number of 2021 sampling visits to each lake and tributary station in relation to the target frequencies specified in the project work plan. Table 2 lists the number of samples collected and analyzed for each monitoring parameter. The New York lake and tributary field sampling was conducted by the Lake Champlain Research Institute at SUNY Plattsburgh under an MOU between NYSDEC and SUNY.

The frequency of lake sampling exceeded workplan targets at all stations during 2021. The frequency of tributary sampling was below the workplan targets for all stations. The number of tributary samples obtained each year depends to some extent on the number and timing of high flow events, since sampling is geared toward capturing the highest flow conditions when loading of phosphorus and other materials is greatest. 2021 was a dry year. The Pike River sampling site is in Canada, so no samples were collected in 2021 due to the border closure from COVID-19. Figure 1 shows that sampling at each tributary captured most peak flow events during 2021.

Table 1. Number of sampling visits during 2021 at each lake and tributary station in comparison with workplan targets.

Number of Lake Sampling Visits					Number of Tributary Sampling Visits				
Lake Station	**NY**	**VT**	**Total**	**Workplan Target[1]**	**Tributary Station**	**Crew**	**All Parameters** TP, DP, TSS, Cl, TN	**Total Phosphorus**	**Workplan Target[2]**
2	10	9	19	12	AUSA01	NY	12	12	14/17
4	10	9	19	12	BOUQ01	NY	15	15	14/17
7	10	10	20	12	GCHA01	NY	12	12	14/17
9	10	10	20	12	LAMO01	VT	9	10	14/17
16	10	9	19	12	LAPL01	VT	12	15	14/17
19	10	9	19	12	LAUS01	NY	14	14	14/17
21	10	9	19	12	LCHA01[3]	NY	11	11	14/17
25	10	10	20	12	LEWI01	VT	12	15	14/17
33	10	10	20	12	LOTT01[7]	VT	0	0	14/17
34	10	10	20	12	LOTT03[7]	VT	12	15	14/17
36	10	10	20	12	METT01	VT	9	9	14/17
40	10	10	20	12	MISS01	VT	9	11	14/17
46	10	10	20	12	OTTE01	VT	9	12	14/17
50	10	10	20	12	PIKE01	VT	0	0	14/17
51[6]	0	0	0	12	POUL01	VT	9	9	14/17
53	10	8	18	12	PUTN01[4]	VT	0	0	14/17
					ROCK02	VT	9	11	14/17
					SALM01	NY	14	15	14/17
					SARA01	NY	14	14	14/17
					WINO01	VT	8	8	14/17
					JEWE02	VT	8	10	14/17
					STEV01[5]	VT	9	11	14/17
					MILL01	VT	9	11	14/17

[1] Workplan target for lake sampling (12) applies to most chemical parameters and to phytoplankton, zooplankton, and zebra mussel veligers. Sampling for zebra mussel juveniles in Lake Champlain and for veligers in tributaries and inland lakes is done once annually.

[2] The project workplan calls for 14 samples per year for most chemical parameters, including 10 samples at high flow and four samples at low flow. Additional sampling for total phosphorus only should occur on 3 other dates under high flow conditions, for a target of 17 samples per year for total phosphorus.

[3] Little Chazy flow gage was discontinued in 2014 but was re-established on 9-25-2015.

[4] Putnam Creek sampling was discontinued in 2015 due to lack of funding for the flow gage.

[5] The USGS gage at Stevens Brook was discontinued at the end of June 2017. A new gage was constructed by Stone Environmental and is available at http://vt-ms4-flow.stone-env.com/FlowDev/index.html .

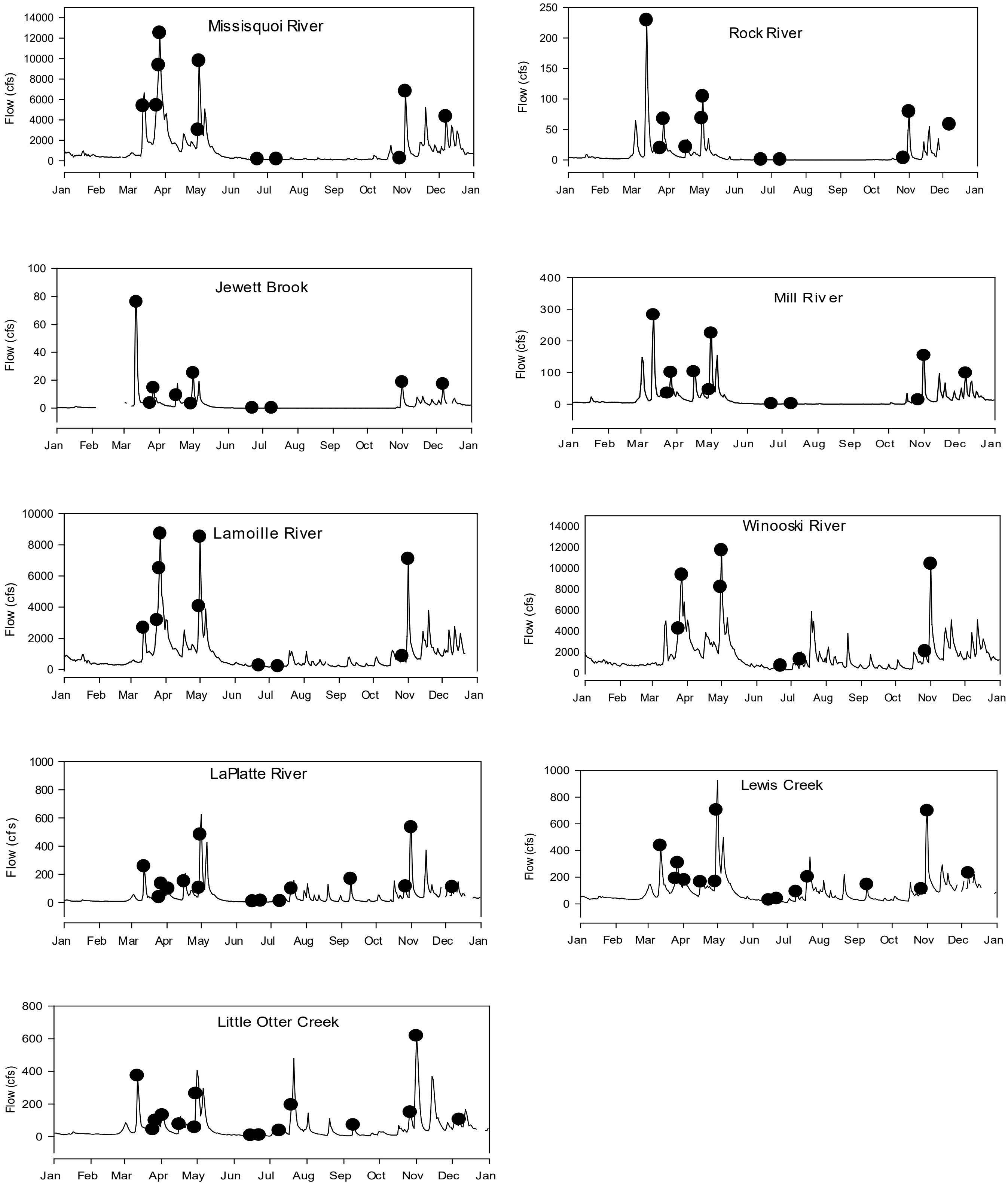
[6] In 2019, field crews were found to have different coordinates for LTM 51. All data have been re-assigned to the correct station and all both crews will sample at LTM 53 in the future.

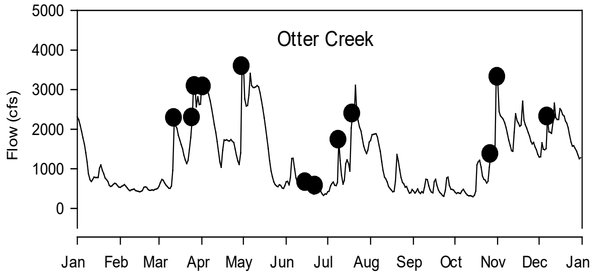
[7] Beginning in 2019, field crews now sample at LOTT03 on Satterly Road, Ferrisburg due to safety concerns after the original location (LOTT01) became overgrown. Concurrent sampling indicated water quality was very similar at the two locations.

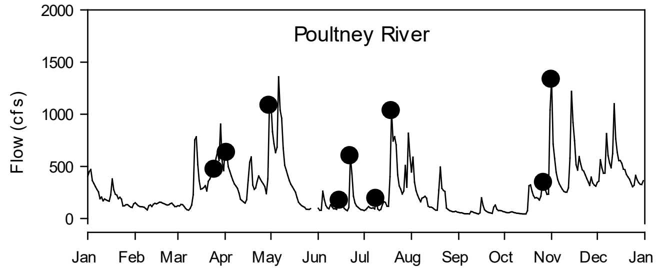
Table 2. Number of samples collected and analyzed for each monitoring parameter during 2021.

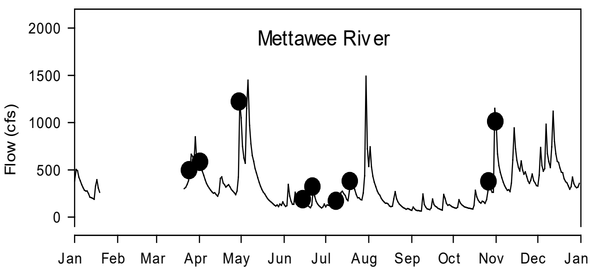
Parameter	Lake	Tributaries	Total
TP	481	284	765
DP	480	256	736
Cl	480	279	759
TN	481	284	765
Ca	69	72	141
Alkalinity	69	72	141
SiO2	479	-	479
K	69	72	141
Na	69	72	141
Mg	69	72	141
Al	69	72	141
Mn	69	72	141
Fe	69	72	141
Total Calculated Hardness	69	72	141
NPOC	153	254	407
DO (Winkler)	0	-	0
Chl-a	364	-	364
TSS	-	256	256
Temperature	-	160	160
Conductivity	-	160	160
pH	-	157	157
Secchi depth	293	-	293
Multiprobe depth profiles	293	-	293
Zebra mussel veligers	111	-	111
Zebra mussel settled juveniles	5	-	5
Mysids	96	-	
Zooplankton	150	-	
Phytoplankton	150	-	
Spiny/Fishhook waterflea	150	-	

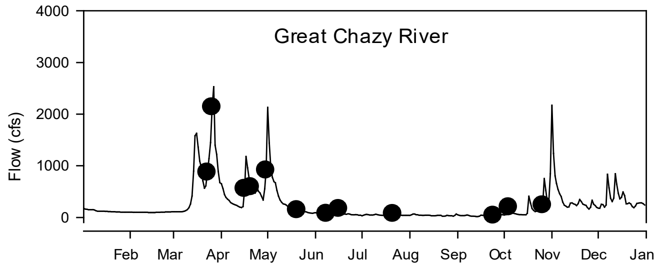
Figure 1. Sampling dates during 2021 in relation to daily flows at each tributary station. Daily flows are shown by lines, and sampling dates are shown by dots.

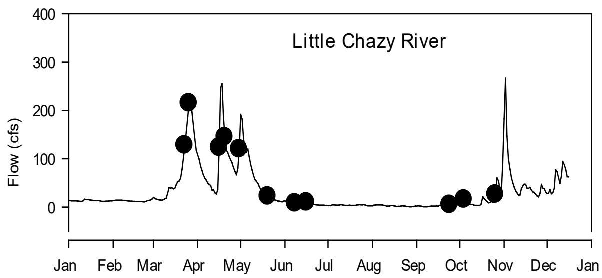


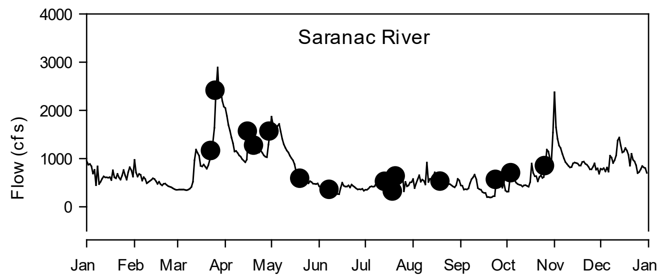

Otter Creek
Flow (cfs)
5000 4000 3000 2000 1000 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

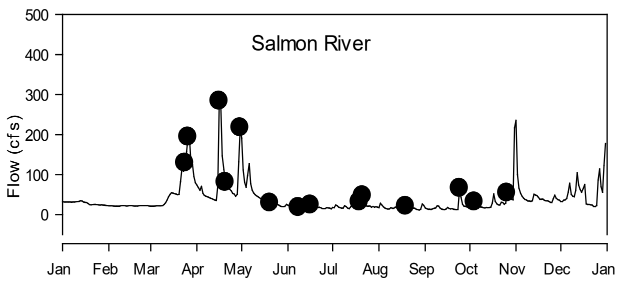

Poultney River
Flow (cfs)
2000 1500 1000 500 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

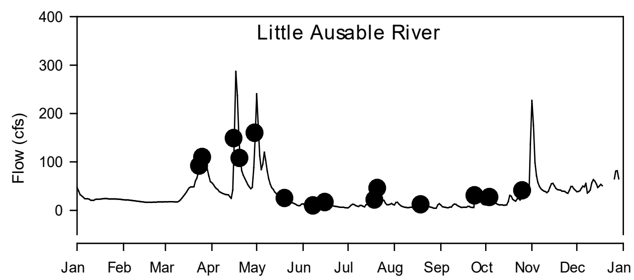

Mettawee River
Flow (cfs)
2000 1500 1000 500 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

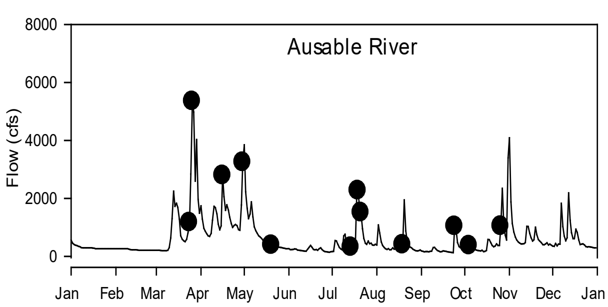

Great Chazy River
Flow (cfs)
4000 3000 2000 1000 0
Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

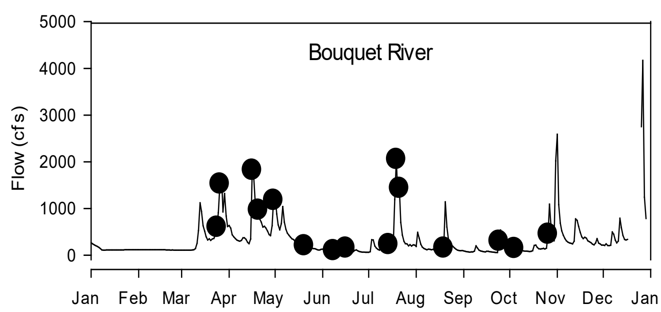

Little Chazy River
Flow (cfs)
400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Saranac River
Flow (cfs)
4000 3000 2000 1000 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Salmon River
Flow (cfs)
500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Little Ausable River
Flow (cfs)
400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Ausable River
Flow (cfs)
8000 6000 4000 2000 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Bouquet River
Flow (cfs)
5000 4000 3000 2000 1000 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

Data Quality Assurance Results

As described in the program's Quality Assurance Project Plan, field equipment blanks and field duplicate samples are obtained on each sampling run. The results for the blank samples are summarized in Table 3. Twenty of the 430 blank samples analyzed during 2021 (4.6%) had concentrations above the analytical detection limits. Results for field duplicate samples are summarized in Table 4 for the chemical analyses.

Table 3. Field equipment blank results during 2021 for lake and tributary samples.

Test	**Detection Limit**	**Units**	**Number of Blanks Obtained**	**Number of Blanks Above Limit**	**High Blank Values**
Alk	1.0	mg/l	11	1	1.1
Cl	2.0	mg/l	53		
TN	0.1	mg/l	55	2	.12, .39
TP	5.0	µg/l	55	4	5.3, 5.3, 5.4, 5.8
DP	5.0	µg/l	53	2	5.3, 7.3
Chl-a	0.5	µg/l	34	5	.56, .68, .98, 1.02, 1.77
TSS	2.5	mg/l	19		
SiO2	0.2	mg/l	34	1	1.62
Al	20	µg/l	11		
Fe	50	µg/l	11		
Ca	0.5	mg/l	11		
Na	0.5	mg/l	11		
K	0.1	mg/l	11		
Mg	0.02	mg/l	11	3	.021, .033, .038
Mn	5	µg/l	11	1	11
NPOC	1	mg/l	28	1	6.2
Total			430	20	

Table 4. Field duplicate results for chemical tests during 2021 showing the number of duplicates obtained (N) and the mean relative percent difference (RPD) between duplicate pairs.

Test	**N**	**Mean RPD**
Chl-a	36	10.7
Cl	59	3.7
NPOC	33	2.0
DP	57	8.7
Alk	11	10.7
TN	59	5.1
TP	59	6.6
TSS	21	15.6
SiO2	15	1.3
Al	10	5.7
Ca	10	2.0
Fe	10	3.7
K	10	1.9
Na	10	1.7
Mg	10	1.8
Mn	10	5.4

Phytoplankton and Zooplankton Database

All phytoplankton data from 2006-2015 have been incorporated into the main Lake Champlain Monitoring Program database. Phytoplankton samples from 2016 were compromised by an initially undetected field error and were not analyzed. Zooplankton data are currently available for the project period of 1993-2013. The data available for download from the web interface include phytoplankton cell densities and biovolumes, and zooplankton densities grouped by major taxonomic category. Counts by individual taxa are available by request. Zooplankton data from 2014-2020 and phytoplankton data from 2017-2020 are available by request but have not been added to the project database. We are currently in the process of converting data from 2016-2020 to be incorporated in the monitoring program database housed at the LCBP.

Wastewater Phosphorus Discharge Data

The project workplan requires an annual compilation of wastewater phosphorus discharge data for all treatment facilities in the Vermont and New York portions of the Lake Champlain Basin. Data on annual mean flow, total phosphorus concentration, and phosphorus load at each facility have been compiled for 2021 along with data from previous years and are available electronically in spreadsheet form on request. The total loads and flows from Vermont and New York wastewater treatment facilities during 2007-2021 are summarized in Table 5.

Table 5. Annual wastewater facility phosphorus loading and flows for Vermont and New York.

State	Number of Facilities	Year	Phosphorus Load (mt/yr)*	Mean Flow Rate (mgd)**	Phosphorus Divided by Mean Flow Rate (mg/L)***
Vermont	60	2007	20.7	51.3	0.29
	60	2008	20.8	49.2	0.31
	60	2009	20.2	42.5	0.34
	60	2010	18.2	39.7	0.33
	59	2011	18.6	41.5	0.32
	59	2012	16.8	42.5	0.29
	59	2013	17	39.9	0.31
	59	2014	17.5	42.2	0.30
	59	2015	13.4	37.2	0.26
	59	2016	11.6	33.9	0.25
	59	2017	13.8	32.3	0.31
	59	2018	13.2	39.8	0.24
	59	2019	11.9	43.1	0.20
	59	2020	9.7	34.7	0.20
	59	2021	10.1	35.5	0.21
New York	29	2007	28.5	33.2	0.62
	29	2008	26.5	34.3	0.56
	29	2009	20.9	31.5	0.48
	29	2010	22	32.8	0.49
	29	2011	23	34.4	0.48
	29	2012	22.6	30.4	0.54
	29	2013	22.9	30.3	0.55
	29	2014	24.7	30.3	0.59
	29	2015	23.7	29.6	0.58
	29	2016	22.2	30.2	0.53
	29	2017	18.7	31.1	0.43
	29	2018	21.3	31.8	0.48
	29	2019	21.7	31.9	0.50
	29	2020	17.2	29.9	0.42
	29	2021	17.8	32.4	0.40

* The annual phosphorus load represents the total of average monthly loads from all facilities in each state. Represented in metric tons (mt) per year.

** The annual mean flow rate represents the total of average monthly flow rates from all facilities in each state. Represented in millions of gallons per day (mgd).

*** Calculated by dividing the annual phosphorus load (in mt/yr) by the annual mean flow rate (in mgd), and multiplying by a conversion factor of 0.723264 to produce a concentration in milligrams per liter (mg/L).

Rock River Monitoring Project

A Rock River Watershed Targeted Best Management Practice (BMP) Implementation Project was initiated in 2010 with funding provided by the Lake Champlain Basin Program (LCBP). It operates under oversight provided by a coordinating committee including the U.S. Natural Resource Conservation Service (NRCS), the Vermont Agency of Agriculture, Food, and Markets (AAFM) and the Vermont Department of Environmental Conservation (DEC). The initial purpose of the project is to demonstrate water quality improvements from focused agricultural BMP implementation in a small watershed where very high rates of phosphorus loading to Lake Champlain have been documented. Ag BMP implementation got underway in 2010 and new installations continue to be added each year.

In order to document water quality improvements resulting from the targeted Ag BMP implementation in the Rock River watershed, the Vermont DEC established monitoring stations immediately upstream and downstream of the BMP implementation area in late 2010 and funded the construction and operation of a U.S. Geological Survey (USGS) stream flow gage at the downstream site. The DEC issues grants to the Friends of Northern Lake Champlain (FNLC) to support sample collection activities by trained local residents, and the DEC Laboratory conducts the sample analyses. The LCBP financially supports the laboratory analytical efforts and supported the stream gaging through September 2014. The State of Vermont now supports the Rock River stream gage through a cooperative agreement with the USGS.

In 2018, project oversight committee members recognized that the original paired watershed study design was no longer valid – NWQI projects as well as Vermont's Required Agriculture Practices (RAPs) and forestry Accepted Management Practices (AMPs) had been implemented in both watersheds for several years. Vermont's new Municipal Roads General Permit requirements will also affect the watershed in the near future. Members felt strongly, however, that monitoring should continue because information on water quality changes in response to BMP implementation at this watershed level are critical to understanding the success of management efforts. While improvements in water quality will not be attributable to a particular suite of BMPs, changes will be indicative of response to management changes at the sector level, primarily agriculture, forestry, and stormwater.

The new study design will be focused on the detection of change over time in load and concentration of TP, DP, TSS and particulate phosphorus (PP) following the approach used to evaluate change over time in the major tributaries monitored by the Long-Term Monitoring Project. Partners will track BMP implementation and provide periodic summaries to document cumulative improvement in the targeted watershed.

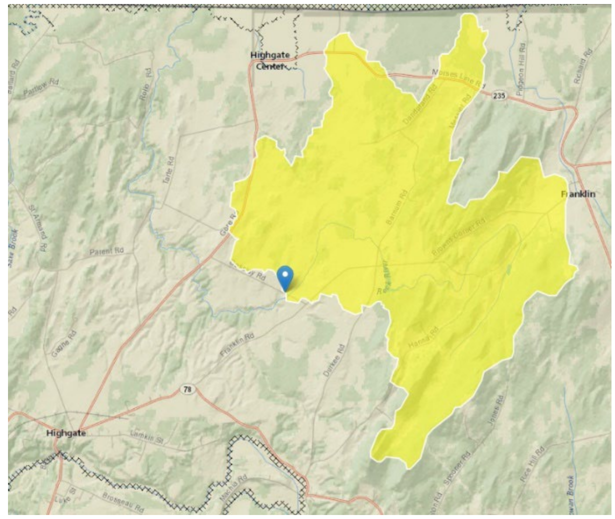
A map of the revised study area and sampling station is shown in Figure 2. The area is approximately 29.3 km^2 in size on the upper Rock River in the towns of Highgate and Franklin, VT. A USGS continuous stream flow gage is co-located with the sampling station (RR14). Sampling was discontinued at RR 20 in 2018.

There have been 364 upstream/downstream paired samples collected and analyzed for TP, DP, and TSS through 2018. This total includes some samples obtained during 2008-2009 by Vermont DEC as part of a previous study. The numbers of paired samples obtained each year are shown in Table 6. The project site map is shown in Figure 2.

Table 6. Numbers of samples obtained.

Year	Number of sample pairs	Number of samples (RR14 only)
2008	10	
2009	2	
2010	18	
2011	66	
2012	55	
2013	55	
2014	51	
2015	27	
2016	33	
2017	42	
2018	5	23
2019		17
2020		18
2021		19
Total	364	77

Figure 2– Map of the project area showing targeted watershed draining to sampling station RR 14 (blue teardrop). Drainage areas were delineated using the USGS StreamStats tool. (https://streamstats.usgs.gov/ss/



Lake Champlain Phytoplankton Report:

Phytoplankton are primary producers that are vital part of the food web and the production of a large percent of the Earth's oxygen (Kruk et al., 2011). Lake Champlain's phytoplankton community composition can vary based on depth, along with other factors such as water temperature and nutrient availability (Bockwoldt et al., 2017). Recently, there have been concerns about the phytoplankton community composition, with regards to blue-green algal blooms in parts of Lake Champlain (Bouyea, 2008). Cyanobacteria blooms can be toxic to aquatic ecosystems and human health (Havens, 2008). As a result, phytoplankton community composition (raw abundance) were analyzed from three time periods 1970, 2000-2005 and 2017-2021 for this report. This is a continuation of work at SUNY Plattsburgh, which examined phytoplankton in Lake Champlain from 1970 to 2005 (Bouyea 2008). Three stations on the main lake were chosen based on the original 1970 data collection performed by Dr. Gerhard Gruendling, along with information from "Limnology of Lake Champlain, Lake Champlain Basin Study" (Myer and Gruendling, 1979).

Percent abundance for each time period for the twenty most common taxa were compared in Lake Champlain (Table 1). Phytoplankton were examined in June, July, August, and September within each time period. The average percent abundance of phytoplankton from stations 19, 7, and 36 were compared between the years. Each site was located in the main lake of Lake Champlain with station 36 located in the northern section, station 19 in the mid-region, and station 7 located in the southern section of the lake. Each sample collected was analyzed under an inverted microscope and counted based upon 10 of the most common phytoplankton taxa or 100 of the most abundant phytoplankton. Phytoplankton taxa were identified to the lowest feasible level.

Table 1. Twenty of the most common phytoplankton taxa in Lake Champlain from 1970 to 2021.

Green algae
Eudorina
Pediastrum
Tetraspora
Desmids
Staurastrum
Diatoms
Asterionella
Aulacoseira
Cyclotella
Fragilaria
Synedra
Stephanodiscus
Tabellaria
Blue-green algae/cyanobacteria
Anabaena
Aphanizomenon
Coelosphaerium
Microcystis
Snowella
Protozoans
Chroomonas/cryptomonas
Ceratium
Dinobryon
Synura

Station 19- Deep lake

Station 19 is the deepest station for Lake Champlain LTM sampling, with a depth of 100 meters. At this site, we observed a shift in phytoplankton community composition from 1970 to 2021 (Figure 3.1). In June 1970, the diatoms *Fragilaria* and *Aulacoseira* were the most common phytoplankton taxa in the samples. In June 2000-2005, there was a shift to *Asterionella*, while *Fragilaria* increased in raw abundance in 2017-2021. Diatoms are known to be more prevalent in spring during the build-up of stratification (Spilling et al., 2018). In the month of July, the most common taxon was *Fragilaria* in all years while the diatoms *Asterionella* and *Tabellaria*, increased in 2000-2005.

We observed long-term shifts among blue green algae (cyanobacteria) across the time periods (Figure 3.1). Throughout 1970, particularly in August and September, *Anabaena* was the most common cyanobacteria in Lake Champlain with 64 percent of the total raw community abundance in August 1970. In 2000-2005 and 2017-2021 we observed a shift in phytoplankton community from the 1970 dominant (*Anabaena*) to

Microcystis spp. In September of 1970, *Anabaena* and *Fragilaria* were the most prevalent phytoplankton at site 19. Although *Fragilaria* has remained at this site throughout the years, *Microcystis spp*. has increased while *Anabaena* has decreased from 2000-2005 and 2017-2021. This represents a major long-term shift in phytoplankton community composition.

Station 7- Port Henry

Port Henry is considered station 7, which has a depth of 50 meters. We also observed a shift in phytoplankton community composition over the years at this site (Figure 3.2). In June of 1970, the most common phytoplankton communities were *Aulacoseira* and *Fragilaria*. While in June 2000 to 2005 *Asterionella* was dominant with around 74 percent raw abundance. However, there were some changes in phytoplankton community composition in July 2017-2021. *Microcystis spp.*, *Tabellaria*, and *Dinobryan* increased in percent abundance compared to past years. *Dinobryan spp.* are a type of Protozoan. In July of 1970, there was a considerable rise in *Snowella spp*., which is a blue-green algae (cyanobacteria). In July of 2000 to 2005, *Asterionella*, *Fragilaria*, and *Tabellaria* were the most common phytoplankton taxa. During July of 2017-2021 *Fragilaria* and *Microcystis spp*. were the most abundant. In August of 1970, *Anabaena* and *Snowella* were the most abundant. Comparatively, *Snowella*, *Fragilaria*, and *Asterionella* increased in abundance for 2000 to 2005. In August of 2017 to 2021, *Microcystis spp.* increased from 0 percent in 1970 samples to about 45 percent in 2000-2005. Noteworthy, in September 1970, Anabaena had an abundance of about 87 percent. In September 2000 to 2005, the phytoplankton community switched to more *Fragilaria*, *Aulacoseria*, *Chroomonas/crytomonas*, and *Microcystis spp*. In September 2017-2021, *Fragilaria* and *Microcystis spp*. were the most abundant phytoplankton.

Station 36- Isle La Motte

Isle La Motte is considered station 36, which has a depth of 50 meters (Figure 3.3). In June of 1970, *Fragilaria* was the dominant taxon, at around 88 percent. There was a change in phytoplankton community composition in 2000-2005, with *Asterionella* and *Tabellaria* increasing in abundance. In June of 2017-2021, *Fragilaria*, *Asterionella*, and *Microcystis spp*. were the main phytoplankton taxa. In 1970, *Anabaena* was more present in July samples but decreased in raw abundance in July of 2000-2005. *Fragilaria* and *Asterionella* were the main phytoplankton taxa during July of 2000-2005 time period which continued for 2017-2021, with the addition of *Microcystis spp*. In August 1970, *Anabaena*, *Chroomonas/ cryptomonas*, *Fragilaria*, and *Synedra* were the main taxa found in samples. Comparatively, in August 2017-2021, *Microcystis spp*., *Fragilaria*, *Aulacoseira* were the most abundant phytoplankton. In September 1970, *Fragilaria*, *Anabaena*, and *Chroomonas/cryptomonas* had the highest raw abundance of phytoplankton. In September 2000-2005, more taxa were noted in the samples such as *Microcystis spp*., *Cyclotella*, *Aulacoseira*, and *Dinobryan*. During 2017-2021. *Microcystis spp*. and *Fragilaria* overall increased in abundance.

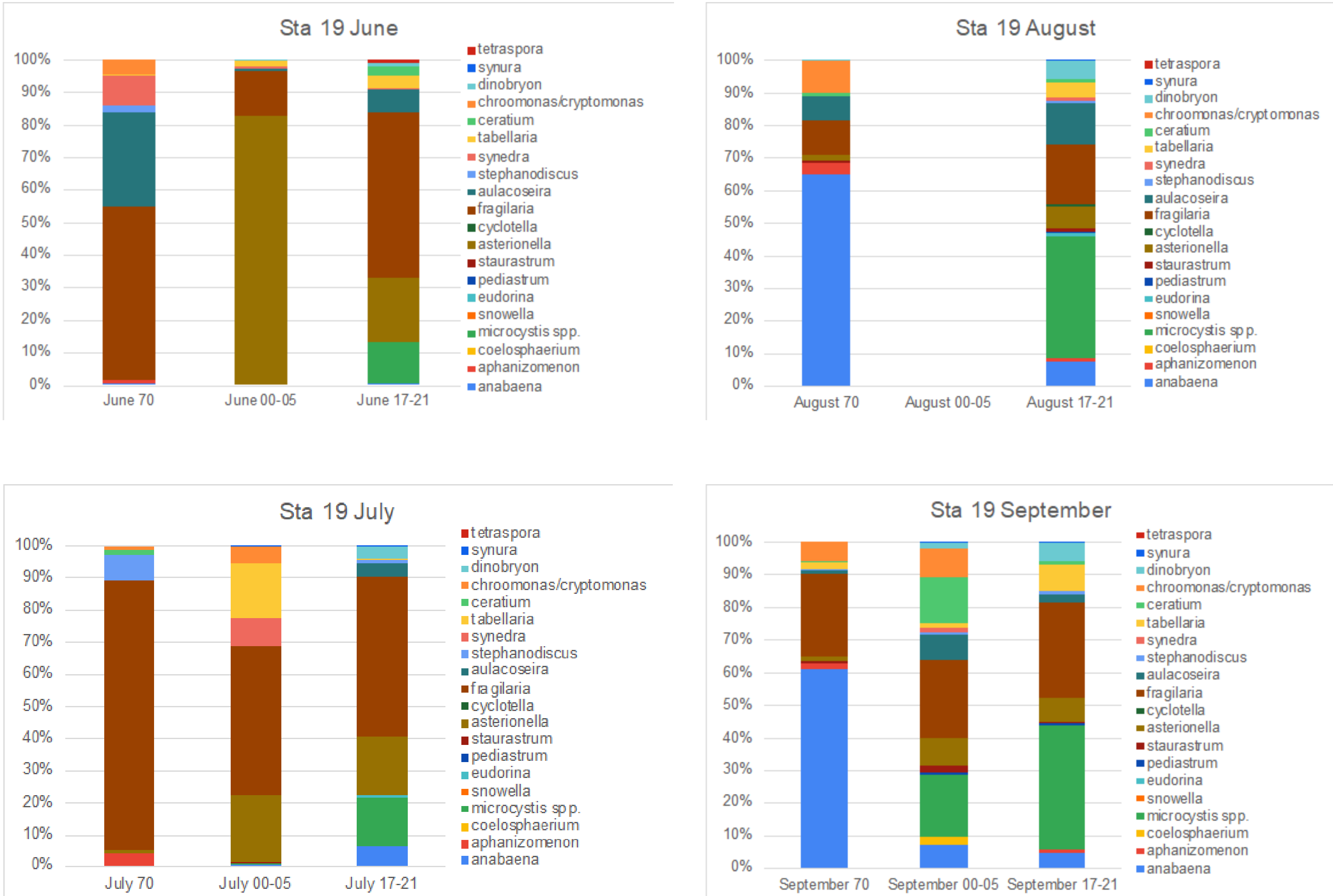


Figure 3.1. Comparison of phytoplankton community composition raw abundace at Station 19 in 1970, 2000 to 2005, and 2017 to 2021, during the months of June, July, August, and September.

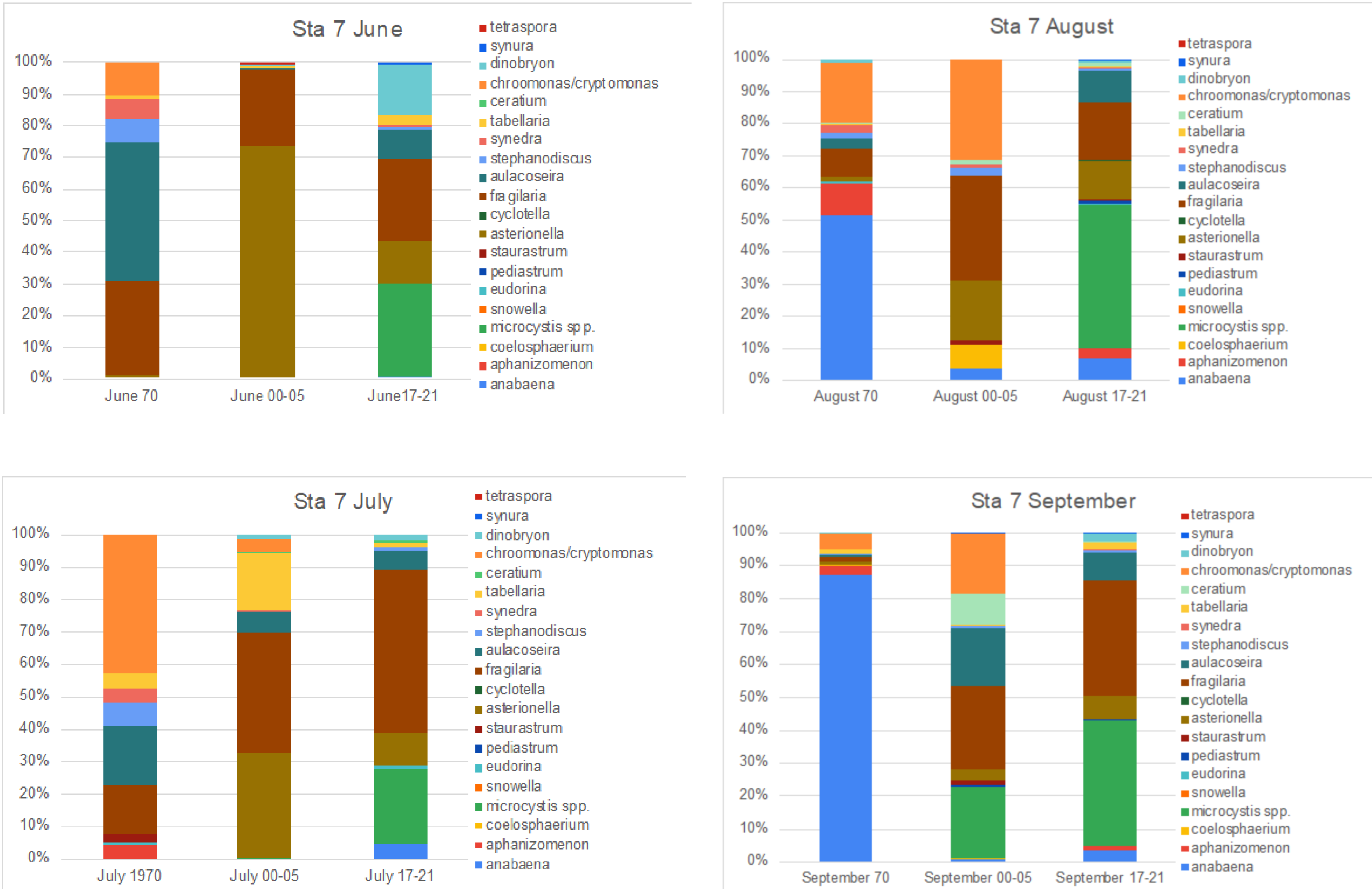


Figure 3.2. Comparison of phytoplankton community composition raw abundance at Station 7 in 1970, 2000 to 2005, and 2017 to 2021, during the months of June, July, August, and September.

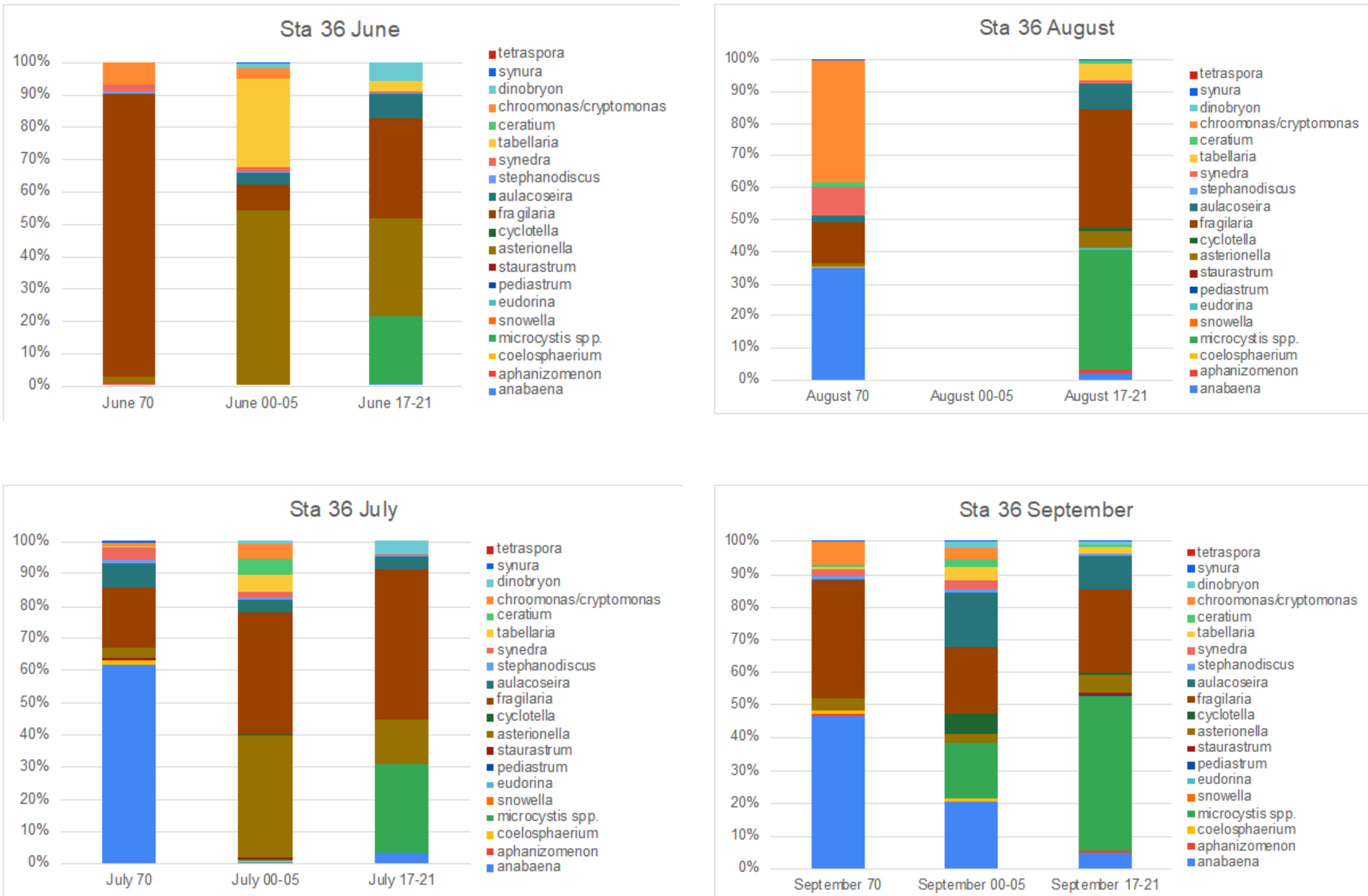


Figure 3.3 Comparison of phytoplankton community composition raw abundance at Station 36 in 1970, 2000 to 2005, and 2017 to 2021, during the months of June, July, August, and September.

Conclusions:

This preliminary data analysis on LTM phytoplankton community composition shows an overall shift from 1970 to 2021. Based on the raw abundance from 1970, 2000-2005, and 2017-2021, we observed a noticeable shift from *Anabaena* dominated phytoplankton communities in 1970 to recent *Microcystis spp*. dominance in Lake Champlain. This phytoplankton community data analysis will be continued in a Master's thesis, which will examine community trends in phytoplankton composition at these stations, along with other sites on the lake.

References:

Bockwoldt, K. A., Nodine, E. R., Mihuc, T. B., Shambaugh, A. D., & Stockwell, J. D. (2017). Reduced phytoplankton and zooplankton diversity associated with increased cyanobacteria in Lake Champlain, USA. *Journal of Contemporary Water Research & Education*, *160*(1), 100-118.

Bouyea, S. (2008). Changes in Lake Champlain Phytoplankton Community Composition and Distribution from 1970 to 2005. *SUNY Plattsburgh Master's Thesis*.

Havens, K. E. (2008). Cyanobacteria blooms: effects on aquatic ecosystems. *Cyanobacterial harmful algal blooms: state of the science and research needs*, 733-747.

Myer, G. E. and Gruendling, G. K. (1979). Lake Champlain Basin Study, New England River Basins Commission. *Limnology of Lake Champlain*. Vol 30.

Kruk, C., Peeters, E. T., Van Nes, E. H., Huszar, V. D. M., Costa, L. S., and Scheffer, M. (2011). Phytoplankton community composition can be predicted best in terms of morphological groups. *Limnology and Oceanography*, 56(1), 110-118.

Spilling, K., Olli, K., Lehtoranta, J., Kremp, A., Tedesco, L., and Tamelander, T. (2018). Shifting diatom—dinoflagellate dominance during spring bloom in the Baltic Sea and its potential effects on biogeochemical cycling. *Frontiers in Marine Science*, 5, 327.

Invasive Species Monitoring
Lake Champlain

Cercopagis pengoi (fish hook waterflea), an invasive predatory cladoceran in the same family as *Bythotrephes longimanus* (spiny waterflea), was first detected in Lake Champlain in August 2018. A total of 150 zooplankton samples were scanned for *Cercopagis* and *Bythotrephes* from monitoring stations on Lake Champlain in 2020 (Table 7, Figures 4 & 5). *Cercopagis* was first detected in early June, with densities greatly increasing into July and August before decreasing in the fall (Figures 5.1 - 5.3). *Bythotrephes* densities remained lower than *Cercopagis* densities throughout the season (Figures 4.1 – 4.3). Whole water vertical tows were taken at each monitoring station using a 250 µm mesh 50 cm plankton net. Samples were then taken to the laboratory where they were visually scanned under a dissecting microscope to determine population densities. All samples were also scanned for other potential invasive invertebrates, including *Hemimysis anomala* (bloody-red shrimp).

Table 7. Invasive plankton monitoring stations in the Lake Champlain. Basin.

Station	Lat	Long	# of sample events	# samples
51	45.0410	73.1290	10	10
50	45.0130	73.1740	10	10
46	44.9480	73.3400	10	10
40	44.7850	73.1620	10	10
36	44.7560	73.3350	10	10
34	44.7080	73.2270	10	10
33	44.7010	73.4180	10	10
25	44.5820	73.2810	10	10
21	44.4740	73.2320	10	10
19	44.4710	73.2990	10	10
16	44.4250	73.2220	10	10
9	44.2420	73.3340	10	10
7	44.1260	73.4120	10	10
4	43.9540	73.4050	10	10
2	43.7140	73.3830	10	10
			Total # of Samples	150

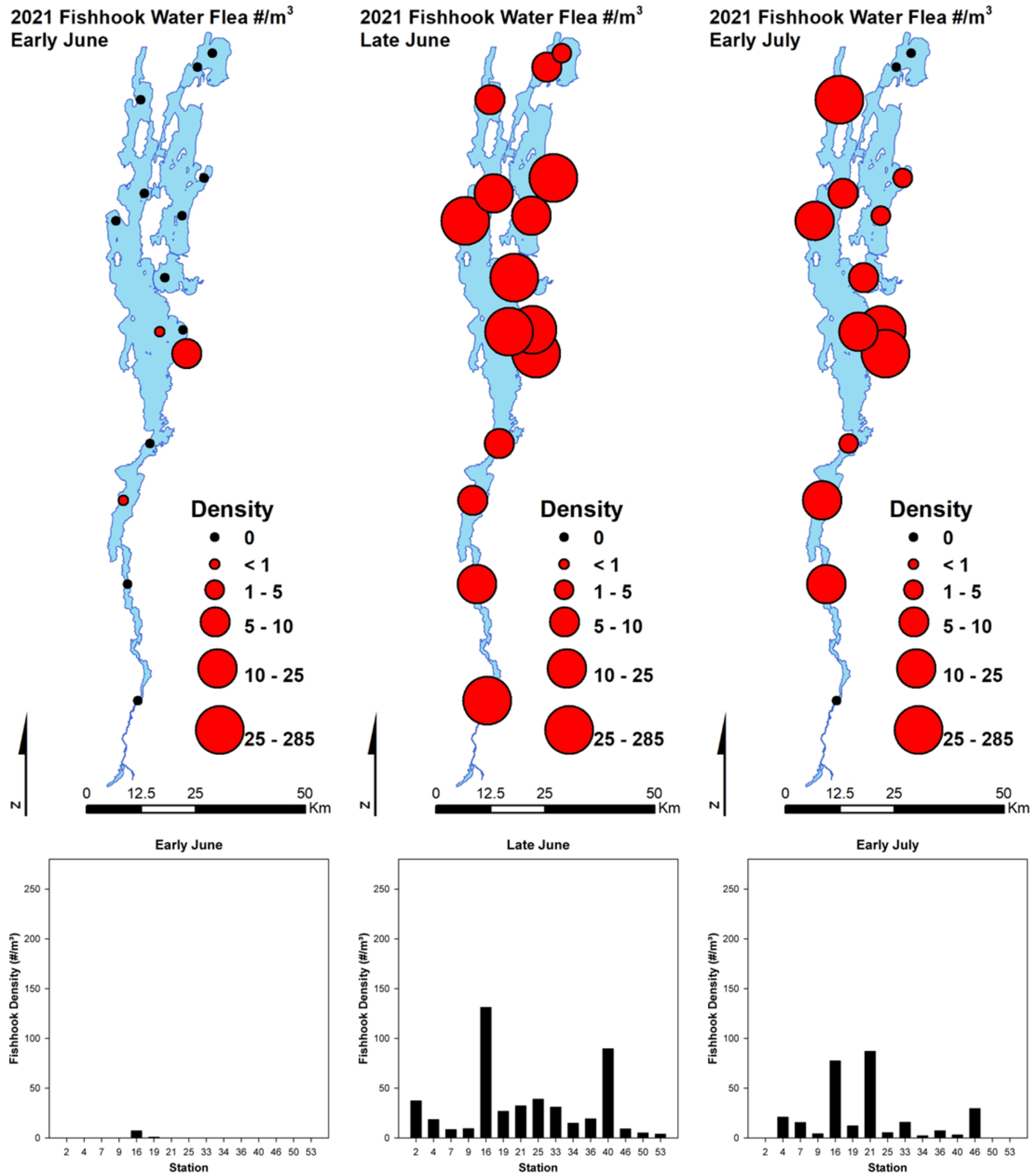


Figure 4.1: Fishhook water flea density from vertical whole water tows from June to July 2021

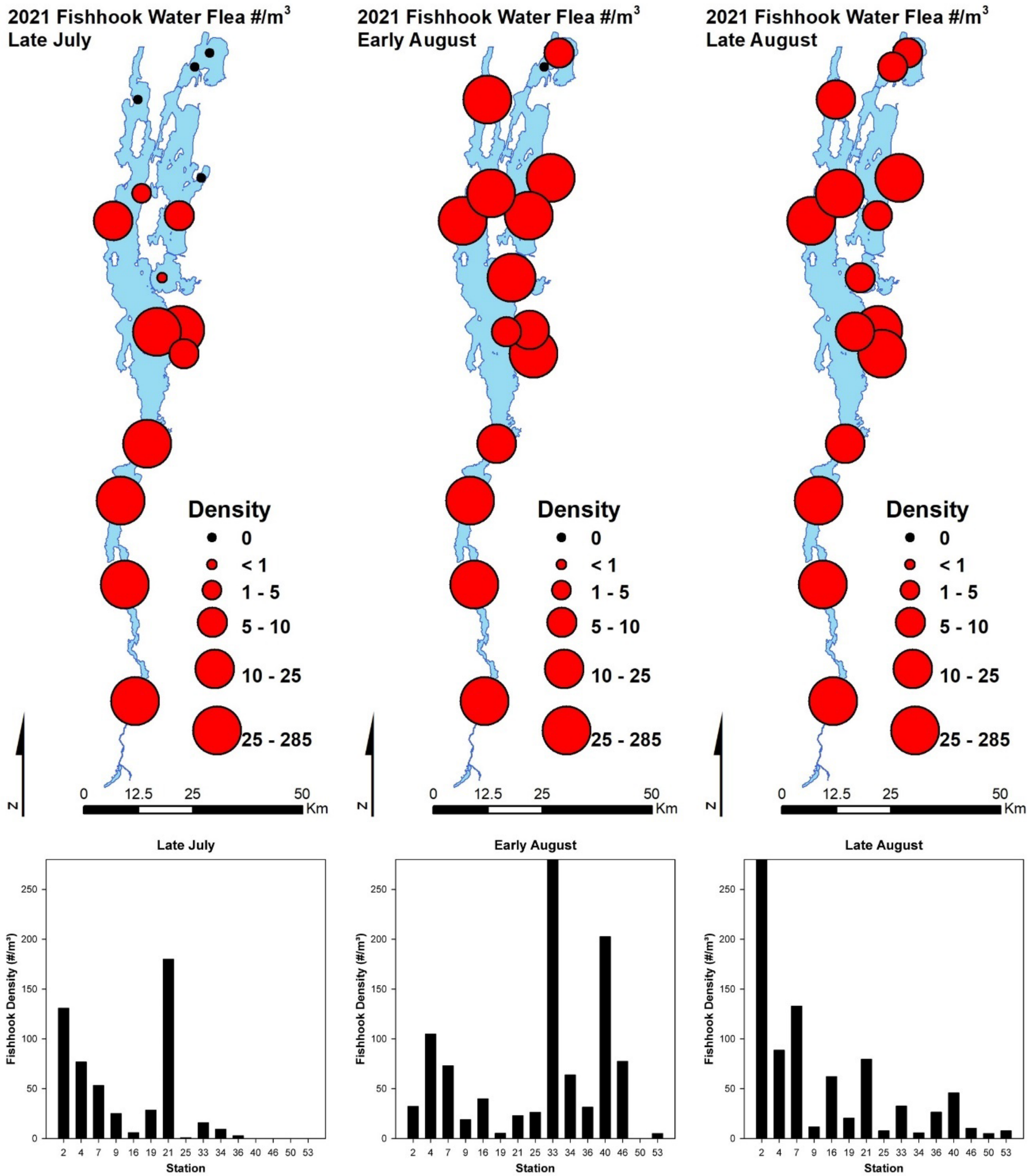


Figure 4.2: Fishhook water flea density from vertical whole water tows from July to August 2021

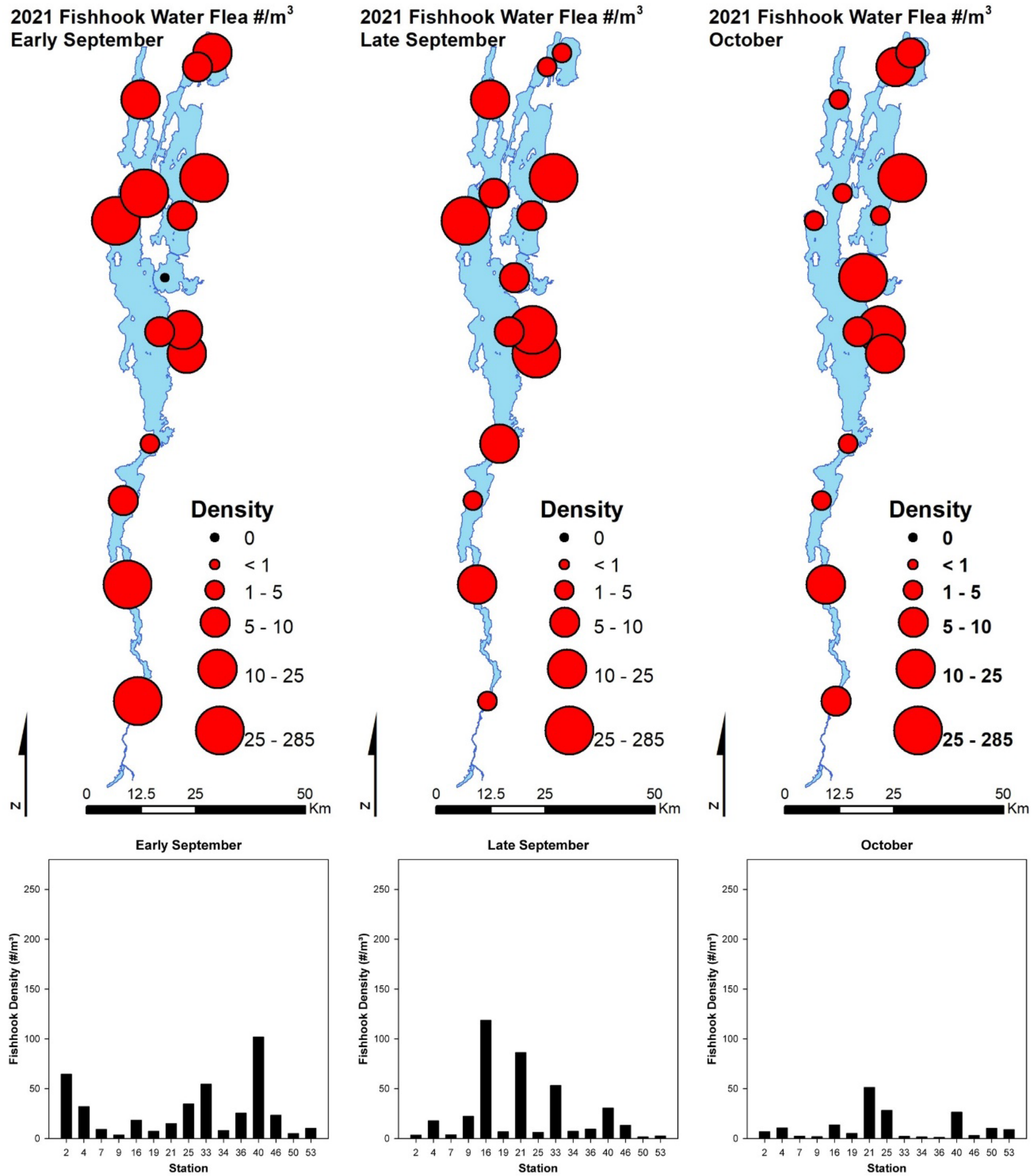


Figure 4.3: Fishhook water flea density from vertical whole water tows from September to October 2021

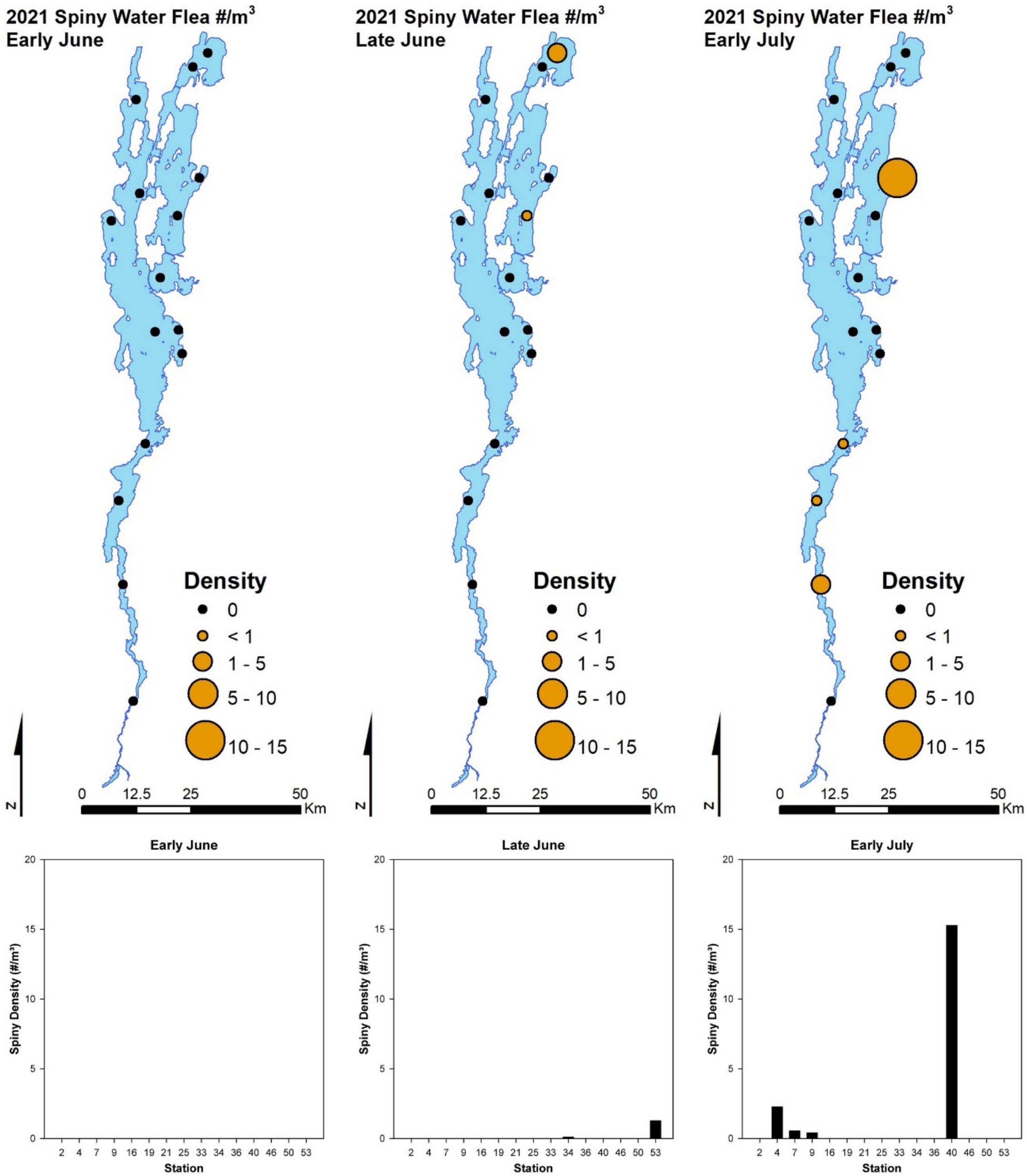


Figure 5.1: Spiny water flea density from vertical whole water tows from June to July 2021

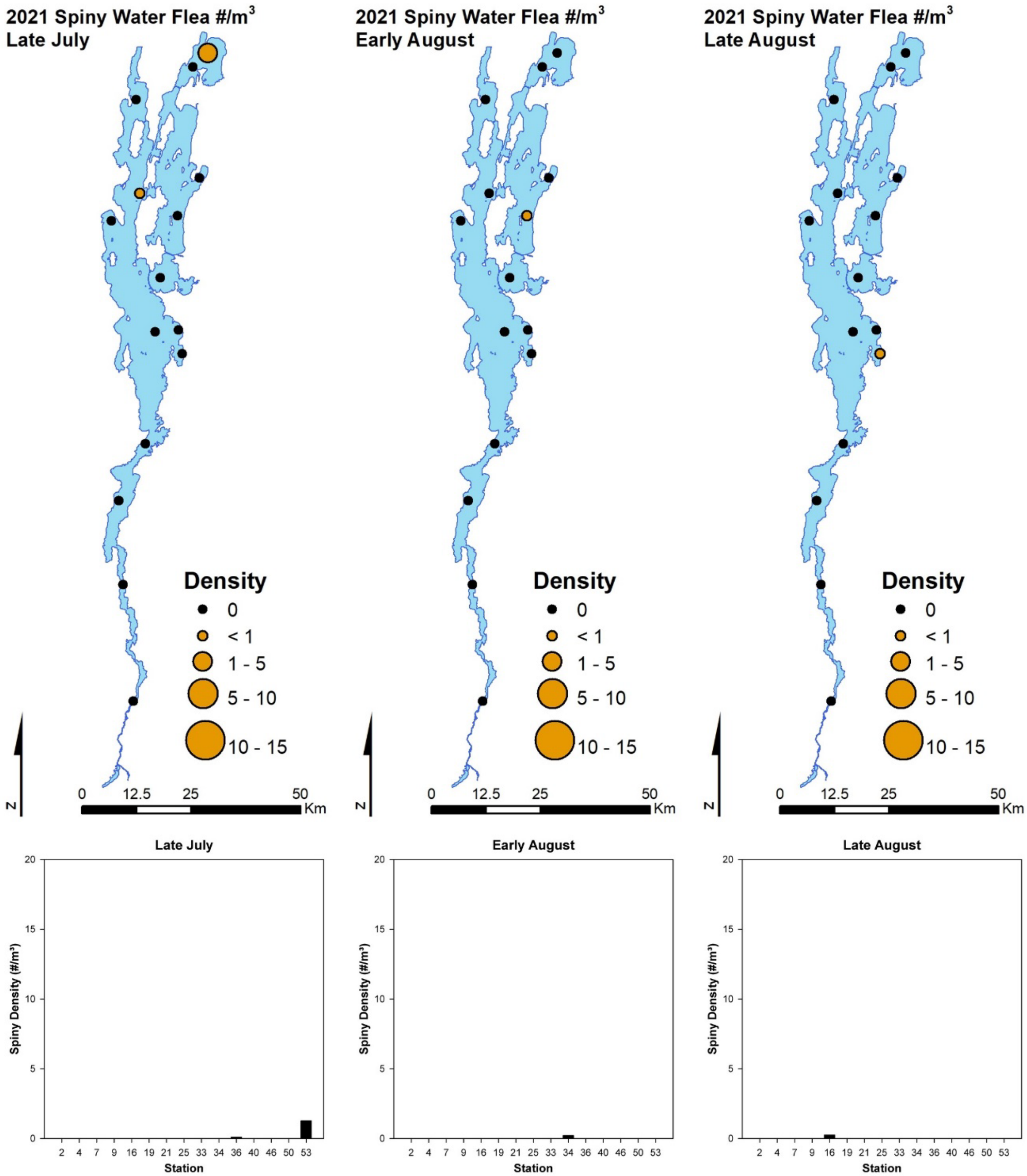


Figure 5.2: Spiny water flea density from vertical whole water tows from July to August 2021

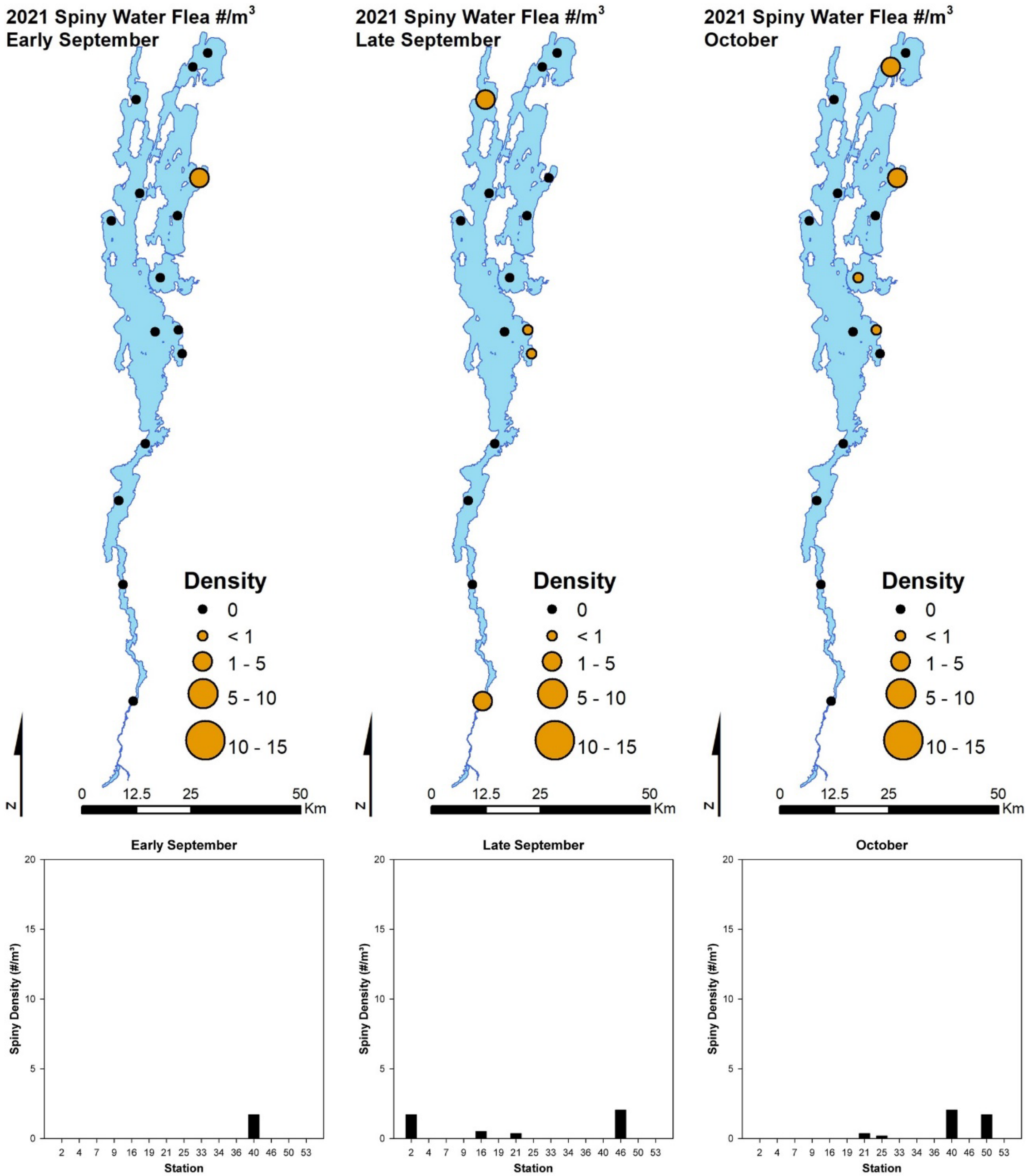


Figure 5.3: Spiny water flea density from vertical whole water tows from September to October 2021

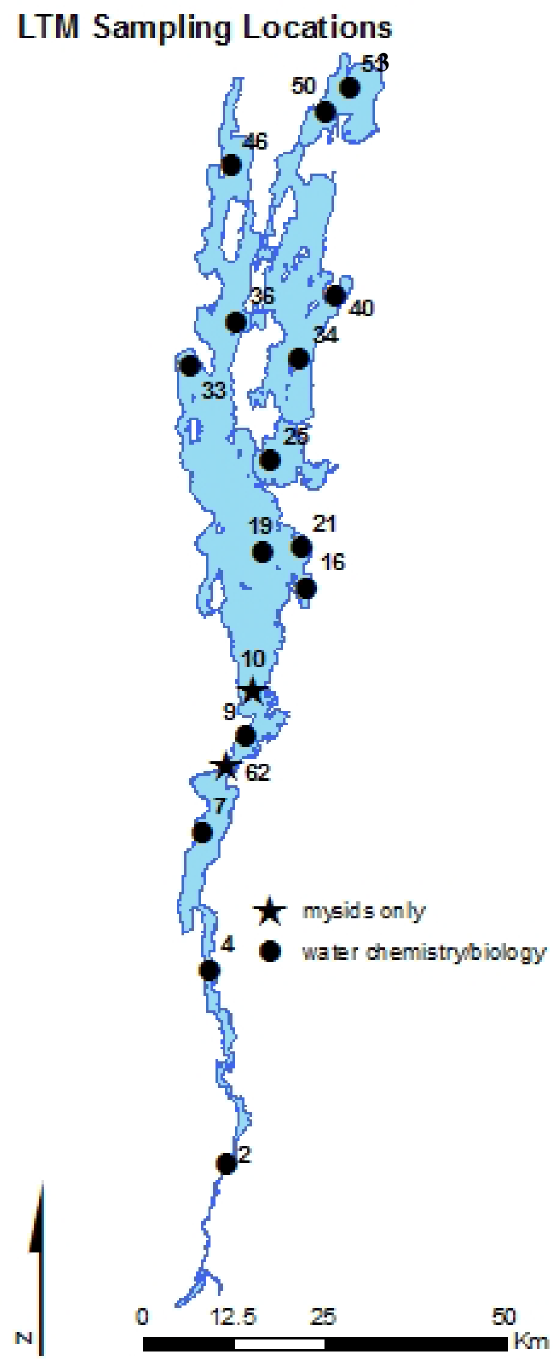


Figure 5. Lake Champlain LTM Sampling Locations