Lake Champlain Long-Term Water Quality and Biological Monitoring Program

Summary of Program Activities During 2022

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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, and in appendices to this report. The purpose of this report is to provide a summary of sampling activities and other accomplishments during 2022.

Highlights of the 2022 Season

The sampling season in 2022 was characterized by continued dry conditions in the Champlain basin, particularly in the eastern portion of the basin during July-August, when tributary flows and lake-levels approached historic minimums in mid-August. The monitoring data reveal a range of trends, which can be explored on the program webpage and the figures in Appendix A-C. Several notable trends will be highlighted here.

Several sites appear show continued trends in epilimnion total phosphorus (TP). In Missisquoi Bay (station 50 and 53) the Lowess smoothing analysis trend shows a continued gradual decline from 2015 through 2022. By contrast, there was a slight continued increase in TP concentrations in the Inland Sea (station 34) and St. Albans Bay (station 40).

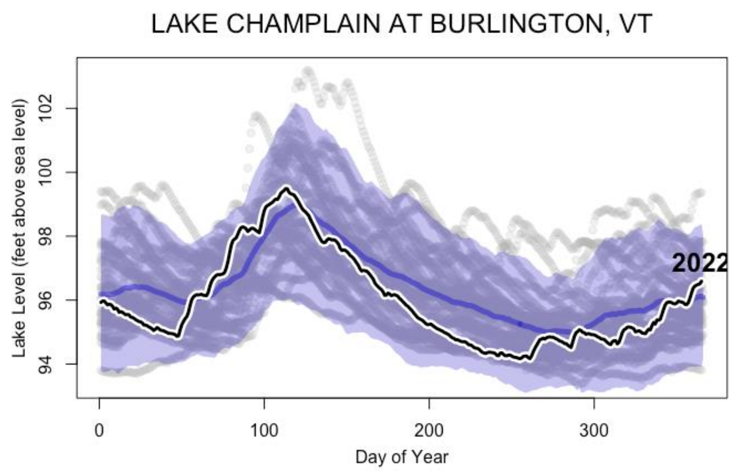


Figure 1: Lake level at Burlington, VT measured at USGS gage 04294500. Blue line represents mean discharge for each day, shaded area represents ± 2 standard deviations around the mean. Black line is 2022.

The Inland Sea and Mallett's Bay continue to show signs of deep-water hypoxia in late summer (fig 2). In the Northeast Arm, this hypoxia appears to be associated with increasing hypolimnetic TP and DP concentrations, indicative of significant internal loading (Fig. 3). Mallett's Bay did not exhibit increasing hypolimnetic TP with concurrent oxygen depletion, suggesting there may be less available phosphorus in Mallett's Bay sediments.

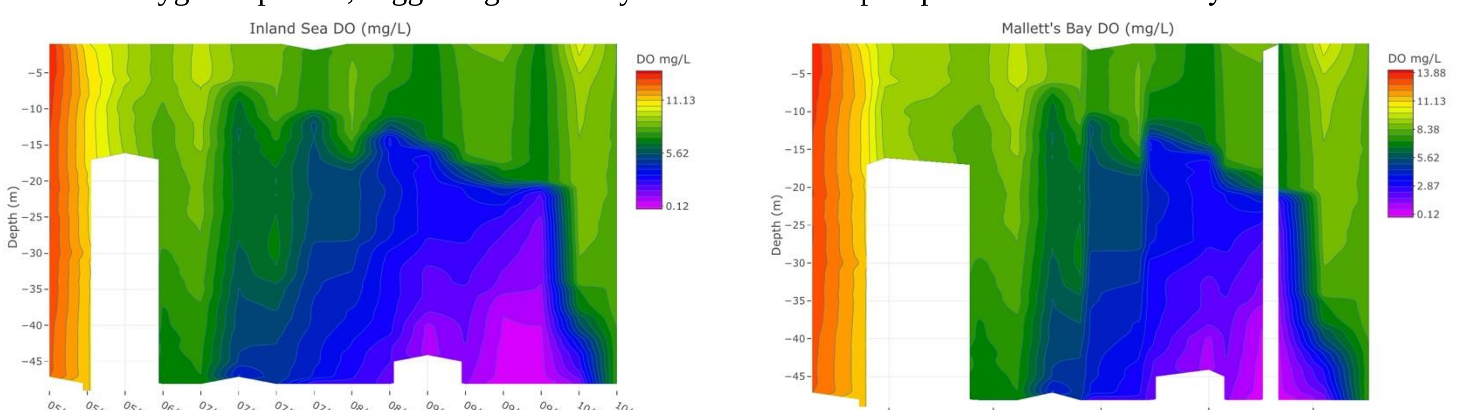


Figure 2. Dissolved Oxygen profiles in the Inland Sea (Sta 34) and Mallett's Bay (Sta 25) showing the development of deepwater hypoxia in late summer and early fall. Low DO concentrations can be associated with internal phosphorus loading and benthic habitat degradation.

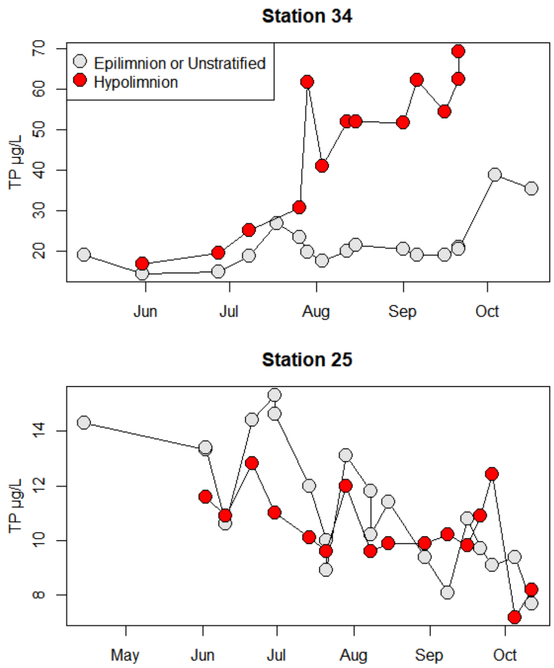


Figure 3. Total phosphorus in epilimnion and hypolimnion in the Inland Sea (Sta. 34) and Mallett's Bay (Sta 25).

Chloride concentrations across all segments of Lake Champlain have had synchronous trends over the last 30 years. Chloride concentrations have been increasing sharply at every monitoring station, particularly from 2010 to 2022, and at nearly all of the 15 lake stations, the concentrations were the highest they have been to date in 2022. Chloride concentrations were highest and most variable in the South Lake sites, followed by the Main Lake, with relatively lower concentrations in Missisquoi Bay, the Inland Sea, and Mallett's Bay. Chloride concentrations are also rising in most monitored tributaries (Appendix C).

The South Lake continued to have declining secchi depth at both stations (particularly South Lake A). South lake sites also had increasing chlorophyll (particularly South Lake B), but no obvious trends in nitrogen or phosphorus concentrations.

Finally, 2022 was the final field season for Pete Stangel, who led the VT field team for more than 20 years. Pete's efforts contributed enormously to current understanding of limnology and water quality in the Lake Champlain basin, and we take this opportunity to again thank Pete for his many years of invaluable service.

Sampling Activities During 2022

The project QAPP outlines sampling frequency and methodology for all target parameters. In 2023, 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 2022 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 2022. 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. 2022 was a dry year. The Pike River sampling site is in Canada, so a limited number of samples were collected in 2022 due to the border closure from COVID-19. Figure 1 shows that sampling at each tributary captured most peak flow events during 2021.

The lake sampling for the 2022 season ran from April 14th to October 21st for VT DEC and from May 24th to October 25th for LCRI at SUNY Plattsburg. Tributary sampling ran from March 8th to December 8th for VT DEC and March 7th to November 8th for LCRI at SUNY Plattsburg.

Table 1. Number of sampling visits during 2022 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	9	9	18	12	AUSA01	NY	14	14	14/17
4	9	9	18	12	BOUQ01	NY	14	14	14/17
7	9	7	16	12	GCHA01	NY	13	13	14/17
9	9	6	15	12	LAMO01	VT	15	17	14/17
16	9	7	16	12	LAPL01	VT	13	15	14/17
19	9	6	15	12	LAUS01	NY	14	15	14/17
21	9	7	16	12	LCHA01[3]	NY	14	14	14/17
25	9	8	17	12	LEWI01	VT	13	14	14/17
33	11	6	17	12	LOTT01[7]	VT			0
34	9	9	18	12	LOTT03[7]	VT	12	14	14/17
36	10	6	16	12	METT01	VT	12	12	14/17
40	10	9	19	12	MISS01	VT	14	16	14/17
46	9	8	17	12	OTTE01	VT	13	15	14/17
50	9	8	17	12	PIKE01	VT	2	2	14/17
51[6]	0	0	0	0	POUL01	VT	12	12	14/17
53	9	8	17	12	PUTN01[4]	VT	0	0	14/17
					ROCK02	VT	14	16	14/17
					SALM01	NY	14	14	14/17
					SARA01	NY	14	14	14/17
					WINO01	VT	15	15	14/17
					JEWE02	VT	14	16	14/17
					STEV01[5]	VT	14	16	14/17
					MILL01	VT	14	16	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 operated by by Stone Environmental between 2017 and 2021 (http://vt-ms4-flow.stone-env.com/FlowDev/index.html) but is now discontinued.

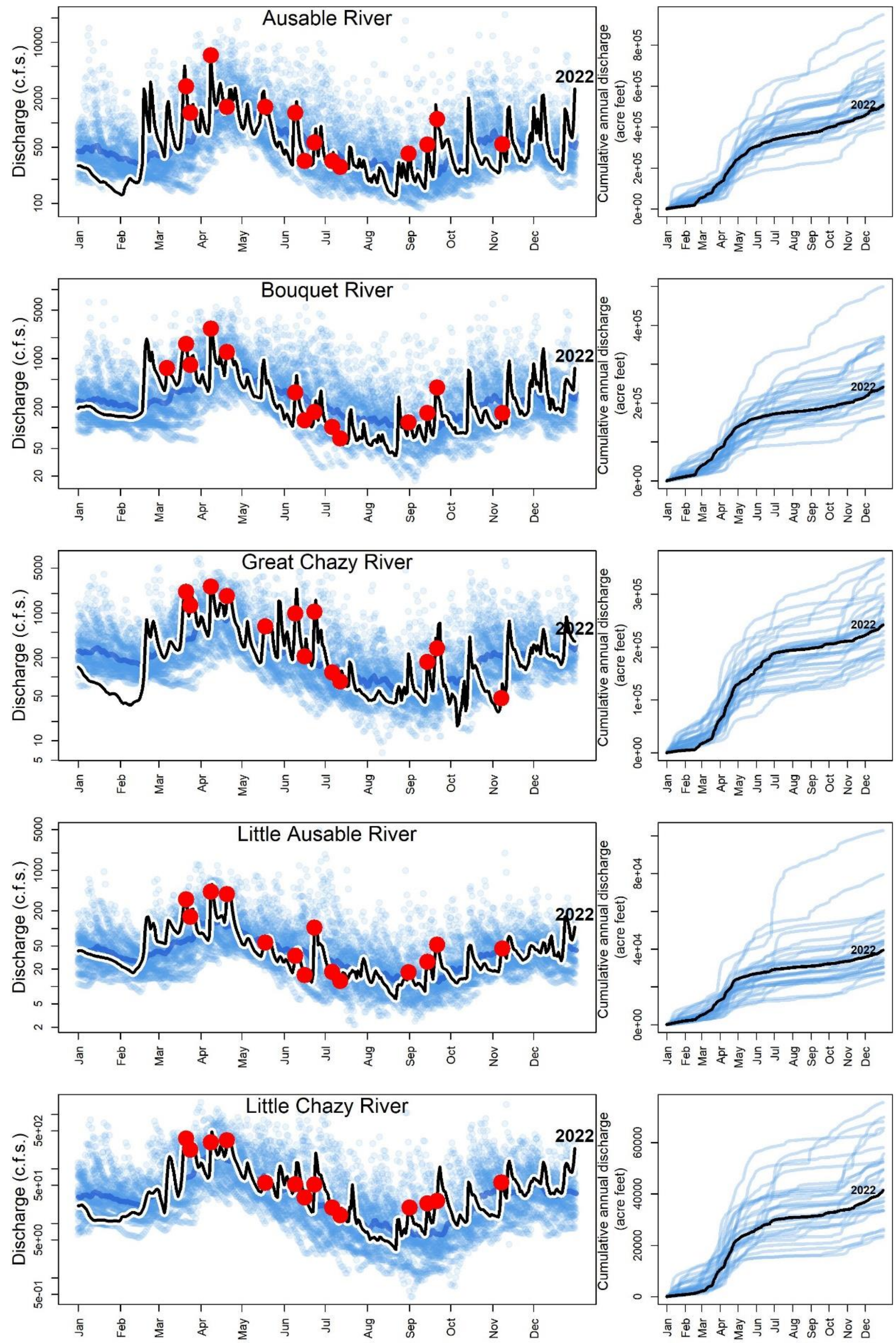
[6] In 2019, field crews were found to have different coordinates for LTM 51. All data have been re-assigned to the correct station and all both crews will sample at LTM 53 in the future.

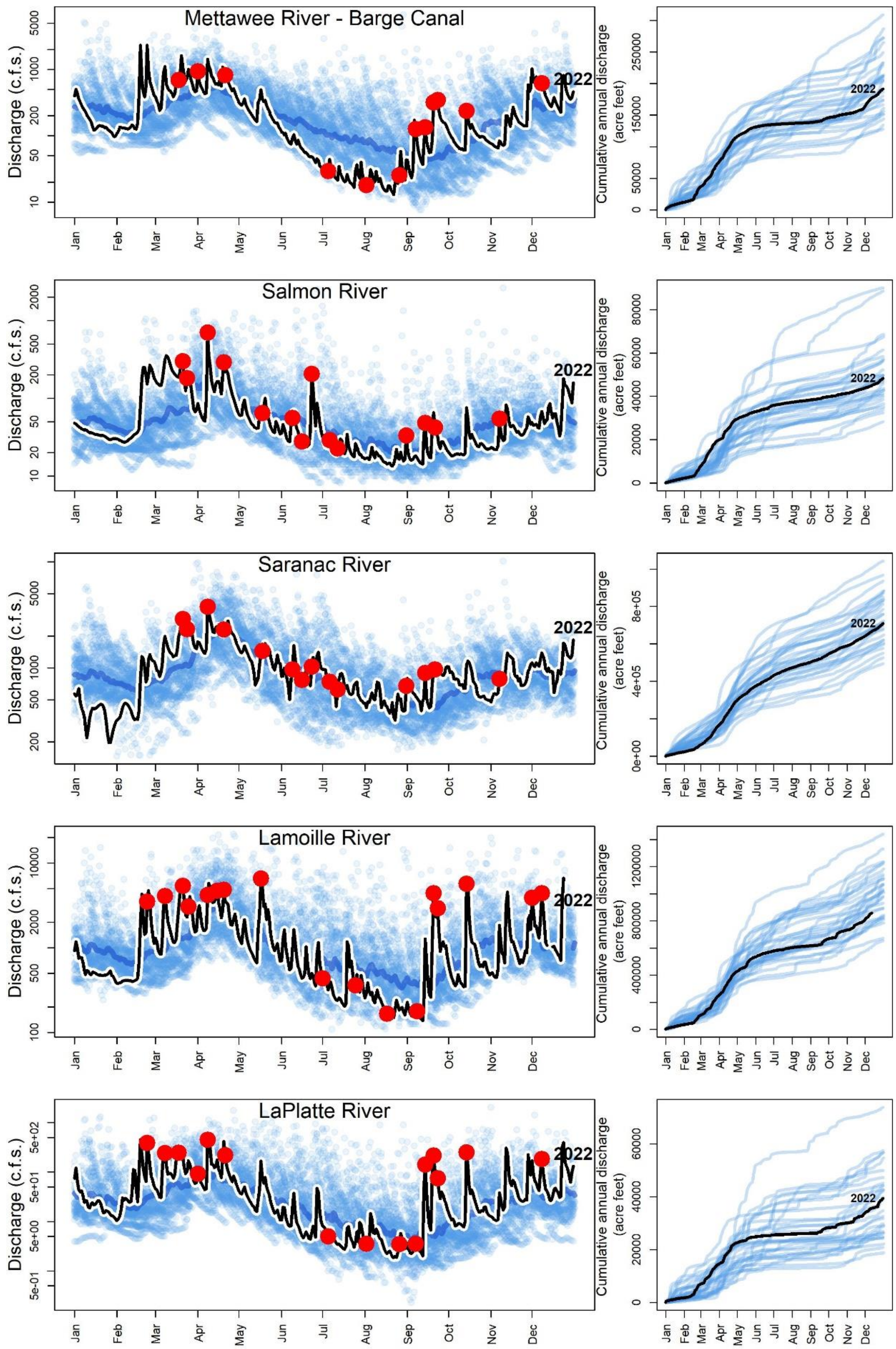
[7] Beginning in 2019, field crews now sample at LOTT03 on Satterly Road, Ferrisburg due to safety concerns after the original location (LOTT01) became overgrown. Concurrent sampling indicated water quality was very similar at the two locations.

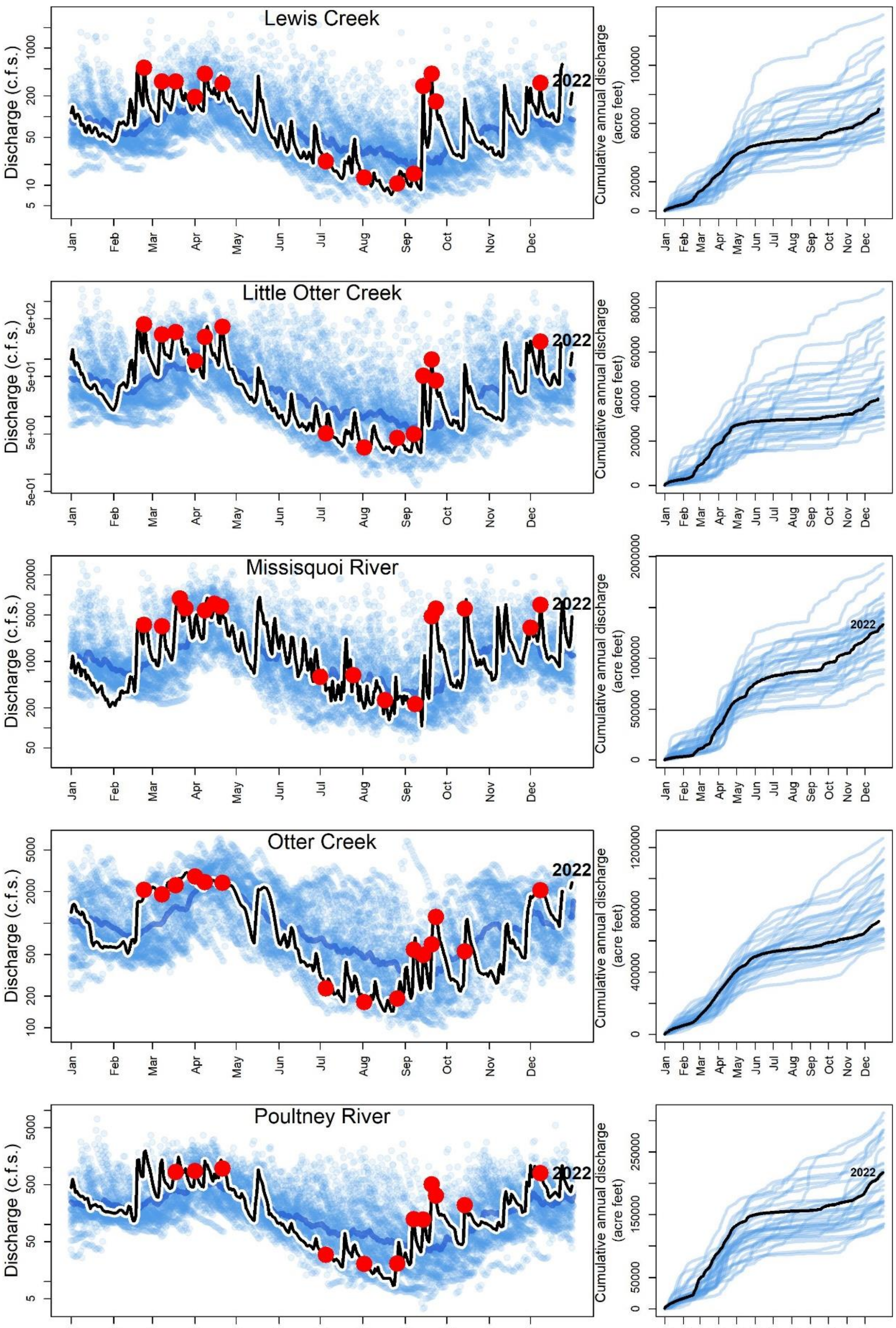
Table 2. Number of samples collected and analyzed for each monitoring parameter during 2022.

Parameter	**Lake**	**Tributaries**	**Total**
TP	252	346	598
DP	250	324	574
Cl	252	346	598
TN	252	345	597
Ca	42	74	116
Alkalinity	42	74	116
SiO2	251	-	251
K	42	74	116
Na	42	74	116
Mg	42	74	116
Al	42	74	116
Mn	42	74	116
Fe	42	74	116
Total Calculated Hardness	42	74	116
NPOC/DOC	79	324	403
			0
Chl-a	249	-	249
TSS	-	324	324
Temperature	-	160	160
Conductivity	-	153	153
pH	-	107	107
Secchi depth	245	-	245
Multiprobe depth profiles	245	-	245
Zebra mussel veligers	87	-	87
Zebra mussel settled juveniles	3	-	3
Mysids	64	-	64
Zooplankton	135	-	135
Phytoplankton	135	-	135
Spiny/Fishhook waterflea	135	-	135

Figure 4. Left: Sampling dates during 2022 in relation to daily flows at each tributary station. Daily discharge (note log-scaled axis) in 2022 are shown as the black line lines, and sampling dates are shown by red circles. Blue points in background represent all daily flow observations during the period of record, with the thick blue line representing median daily flow for each date. Right: Cumulative annual discharge, with the current year shown in black and all previous years shown in blue lines.




Mettawee River - Barge Canal
Salmon River
Saranac River
Lamoille River
LaPlatte River
Discharge (c.f.s.)
Cumulative annual discharge (acre feet)
2022
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Lewis Creek
Little Otter Creek
Missisquoi River
Otter Creek
Poultney River
Discharge (c.f.s.)
Cumulative annual discharge (acre feet)
2022
Jan
Feb
Mar
Apr
May
Jun
Jul
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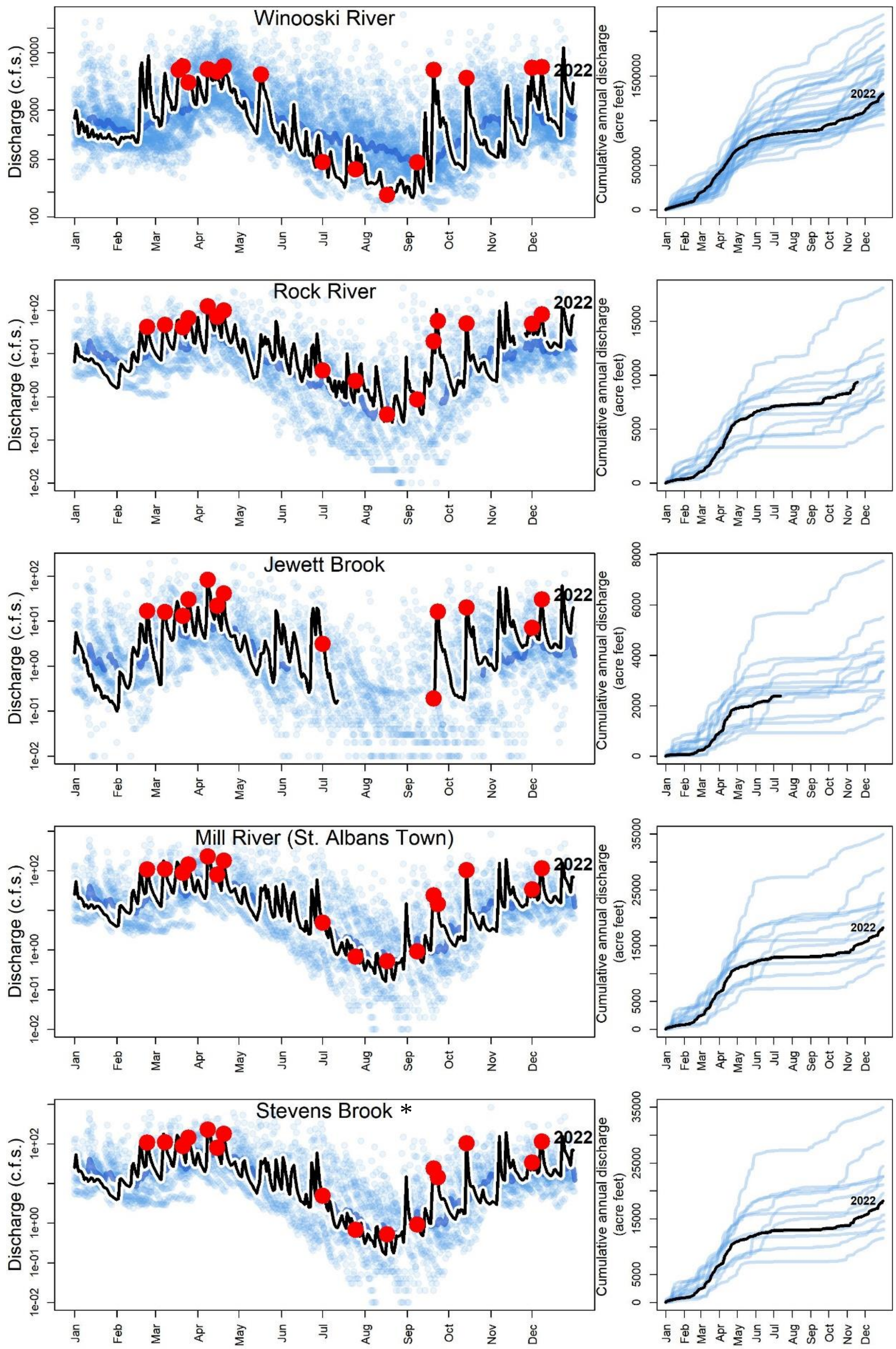
Nov
Dec



***** The Stevens Brook USGS Gage is not in operation, therefore Mill River USGS gage data was used alternatively.

** The dates for Pike River sampling were 10/14/2022 and 12/01/2022.

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 four of the 403 blank samples analyzed during 2022 (5.9%) 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 2022 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	13	1	2.3
Cl	2.0	mg/l	50		
TN	0.1	mg/l	56	3	.56, .54, .54
TP	5.0	µg/l	51	5	5.7, 6.2, 9.8, 6.9, 44.1
DP	5.0	µg/l	49	10	6.4, 5.4, 5.3, 7.0, 9.1, 50.1, 10.7, 8.7, 7.4, 5.8
Chl-a	0.5	µg/l	33	0	
TSS	2.5	mg/l	22		
SiO2	0.2	mg/l	27	0	
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		
Mn	5	µg/l	6		
NPOC	1	mg/l	30	7	1.8, 1.3, 7.9, 1.6, 5.5, 1.2, 1.2
Total			403	24	

Table 4. Field duplicate results for chemical tests during 2022 showing the number of duplicates obtained (N) and the mean relative percent difference (RPD) between duplicate pairs.

Test	N	Mean RPD
Chl-a	27	20.85
Cl	53	2.54
NPOC	33	1.84
DP	52	11.35
Alk	11	1.11
TN	52	6.47
TP	53	7.44
TSS	23	14.88
SiO2	28	6.64
Al	11	7.98
Ca	11	3.94
Fe	10	6.91
K	11	3.27
Na	11	2.99
Mg	10	2.95
Mn	11	6.25

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 2014-2022 and phytoplankton data from 2017-2022 are available by request but have not been added to the project database. We are currently in the process of converting data from 2016-2022 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 2022 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 2007-2022 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
	59	2022	11.5	34.8	0.24
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
	29	2022	20.0	33.5	.43

***** 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. In 2022, a limited number of paired samples were again, because ongoing monitoring data from the downstream site revealed no clear change in nutrient concentrations, despite significant implementation of BMPs in the catchment.

The new study design is 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 or samples from RR14 only obtained each year are shown in Table 6. The project site map is shown in Figure 3.

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
2022	14	24
Total	378	101

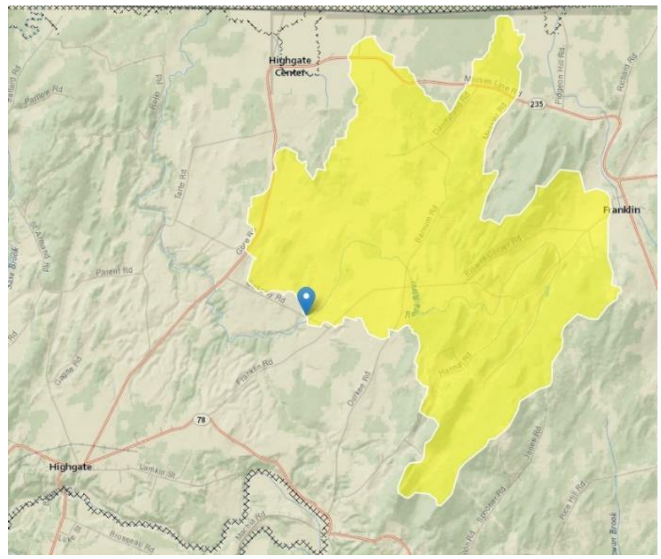


Figure 5. Map of the project area showing targeted watershed draining to sampling station RR 14 (blue teardrop). Drainage areas were delineated using the USGS StreamStats tool. (https://streamstats.usgs.gov/ss/)

Appendix A. Invasive Species Monitoring in 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 135 zooplankton samples were scanned for *Cercopagis* and *Bythotrephes* from monitoring stations on Lake Champlain in 2022 (Table 7, Figures 6 & 7). *Cercopagis* was first detected in early June, with densities greatly increasing into July and August before decreasing in the fall (Figures 6.1 – 6.4). *Bythotrephes* densities remained lower than *Cercopagis* densities throughout the season (Figures 7.1 – 7.4). 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)

Station	Lat	Long	# of sample events	# samples
53	45.0410	73.1290	9	9
50	45.0130	73.1740	9	9
46	44.9480	73.3400	9	9
40	44.7850	73.1620	9	9
36	44.7560	73.3350	9	9
34	44.7080	73.2270	9	9
33	44.7010	73.4180	9	9
25	44.5820	73.2810	9	9
21	44.4740	73.2320	9	9
19	44.4710	73.2990	9	9
16	44.4250	73.2220	9	9
9	44.2420	73.3340	9	9
7	44.1260	73.4120	9	9
4	43.9540	73.4050	9	9
2	43.7140	73.3830	9	9
			Total # of Samples	135

Table 7. Invasive plankton monitoring stations in Lake Champlain.

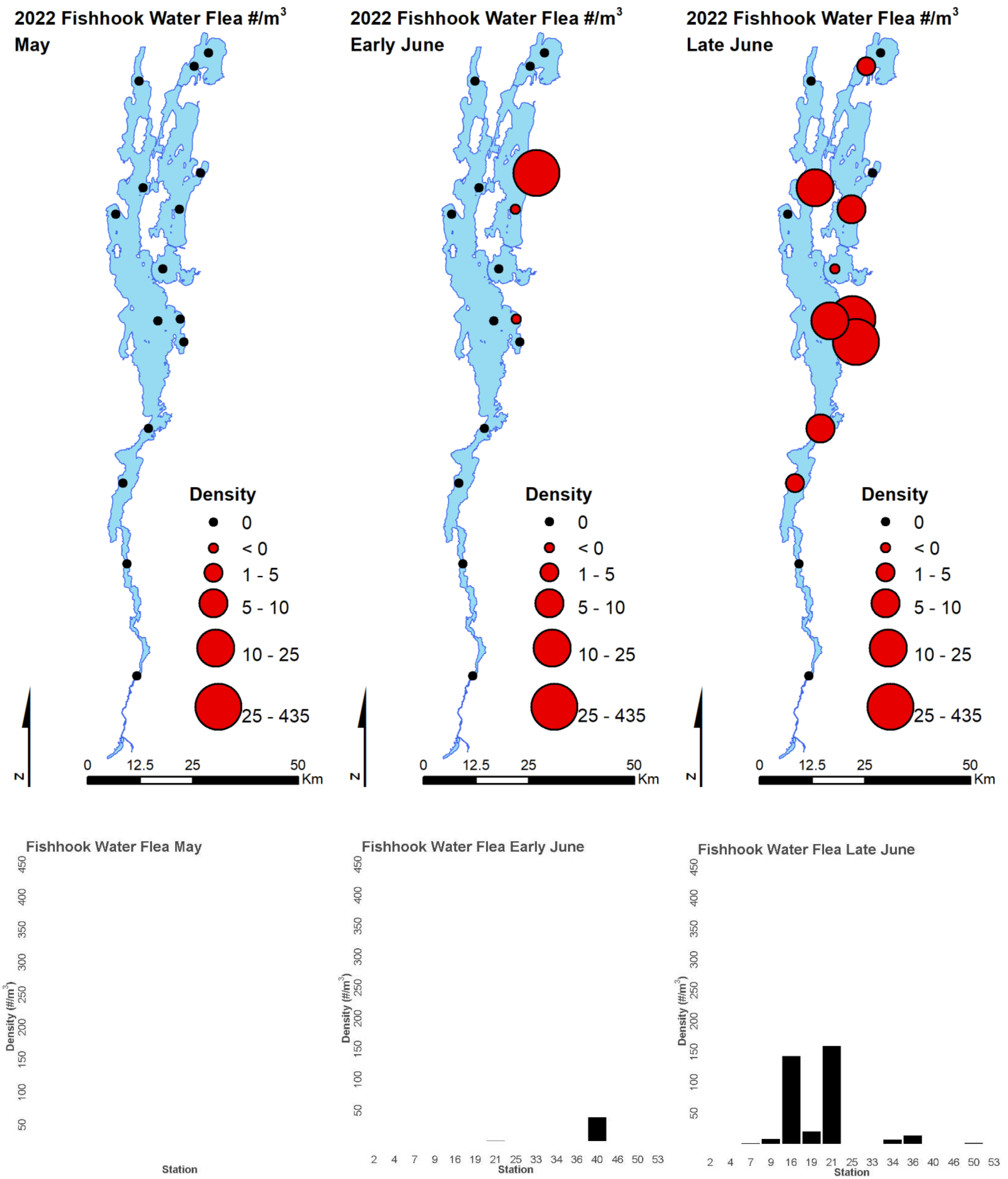


Figure 6.1: Fishhook water flea density from whole water column vertical tows May through June, 2022

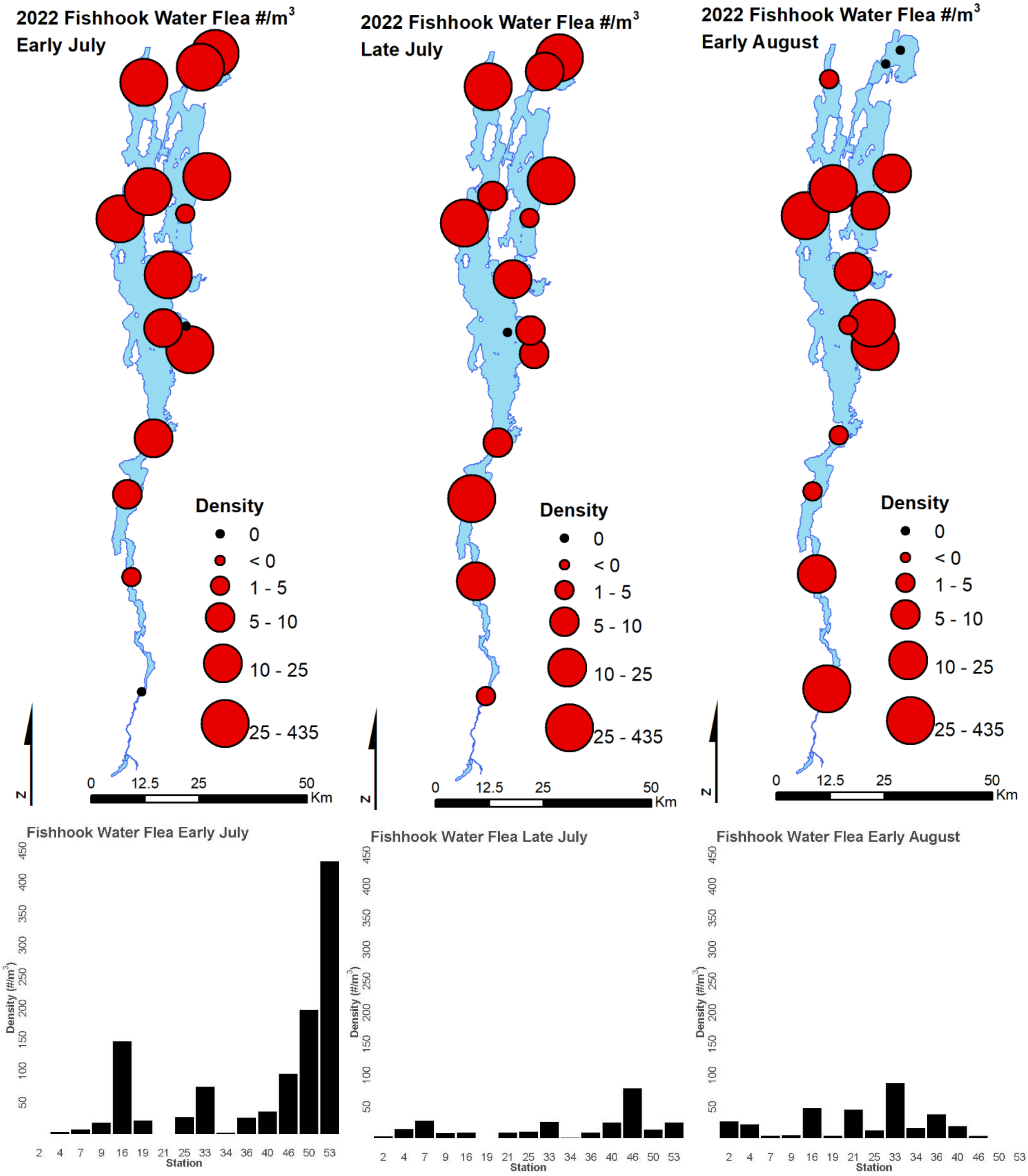


Figure 6.2: Fishhook water flea density from whole water column vertical tows early July through early August, 2022

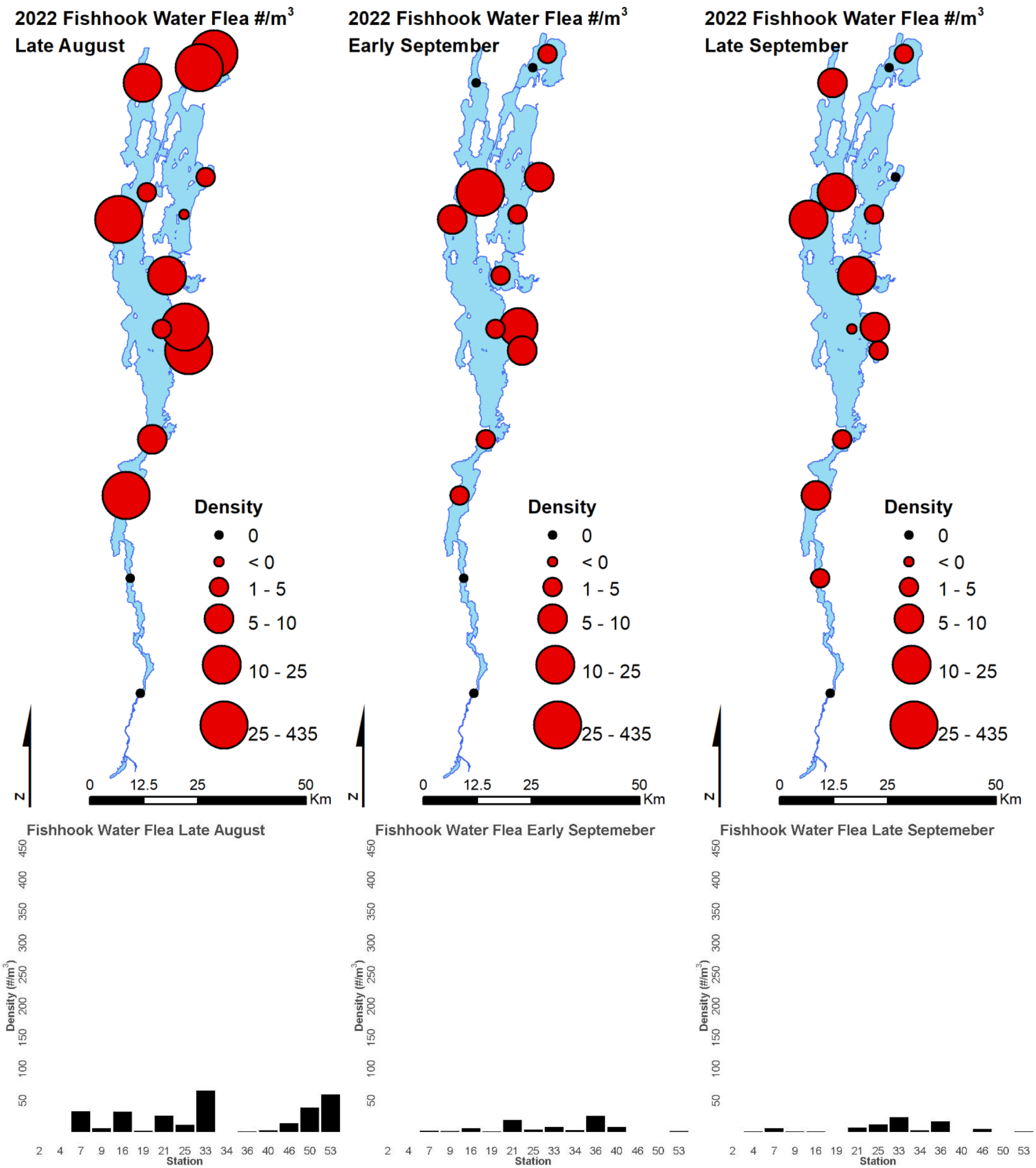


Figure 6.3: Fishhook water flea density from whole water column vertical tows late August through late September, 2022

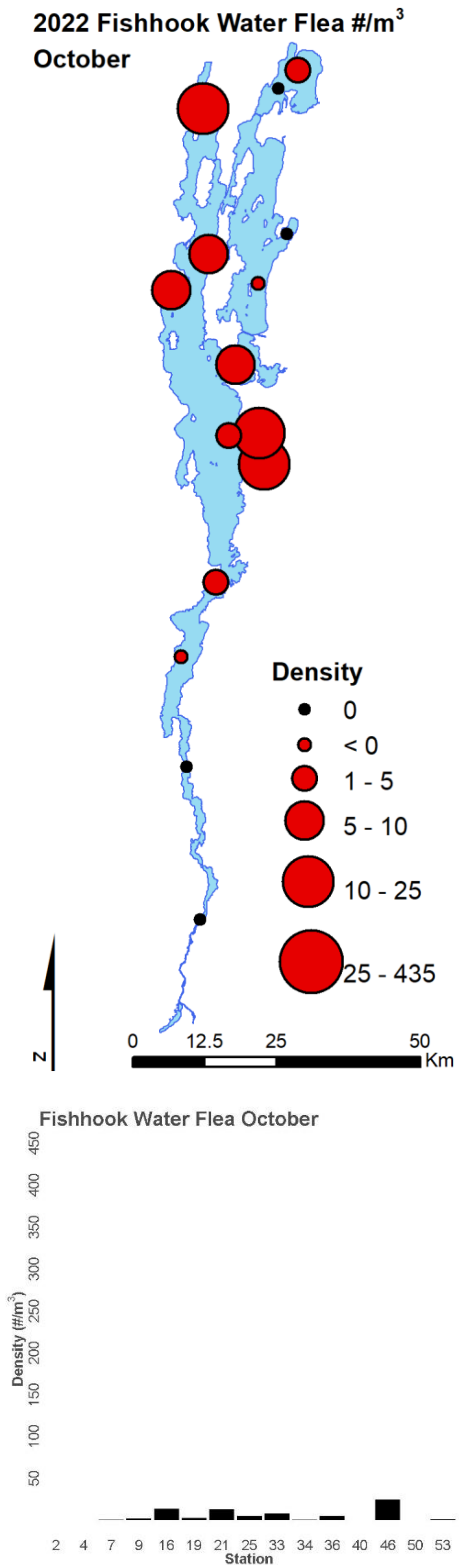


Figure 6.4: Fishhook water flea density from whole water column vertical tows from October 2022

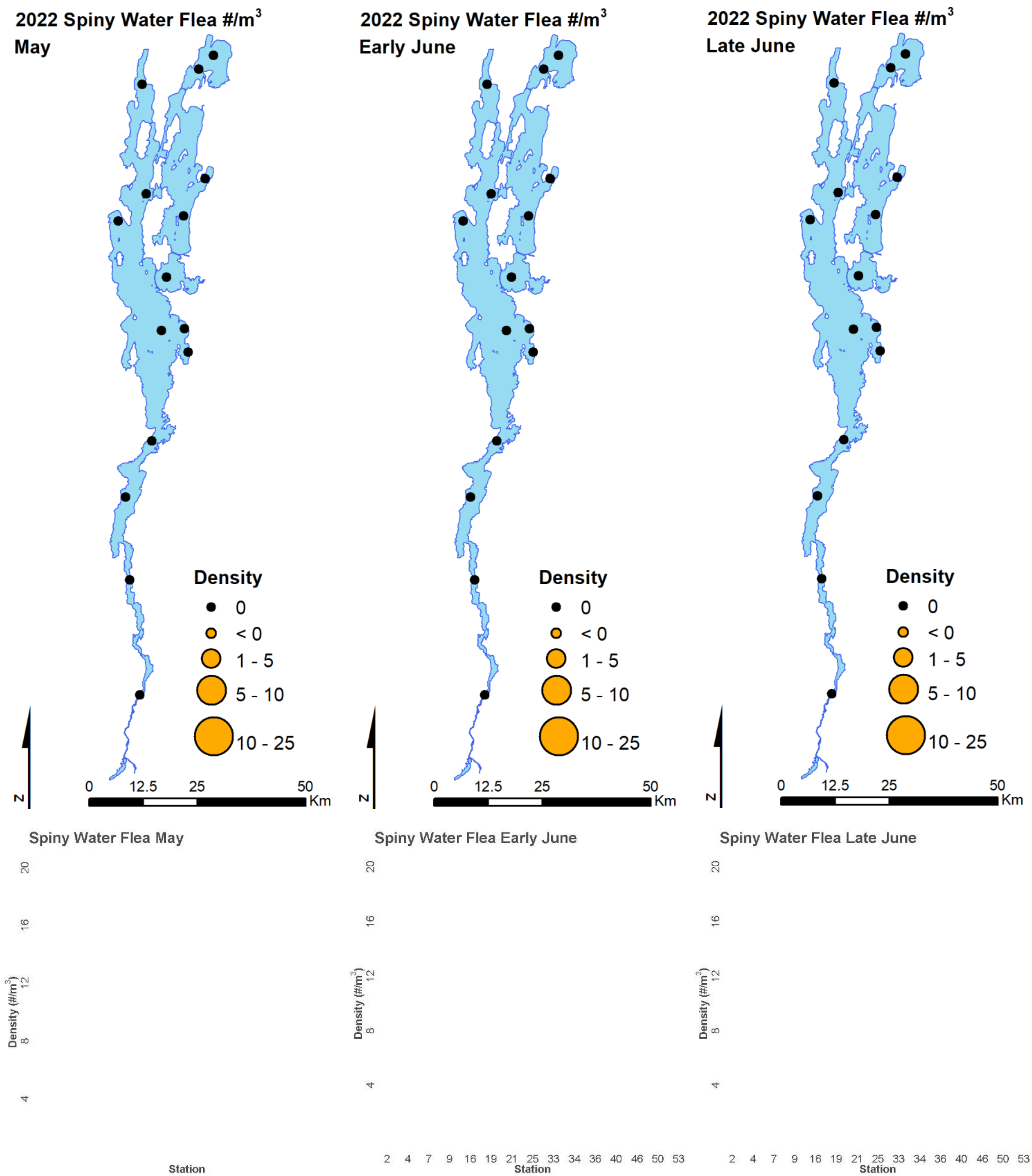


Figure 7.1: Spiny water flea density from whole water column vertical tows May through June, 2022

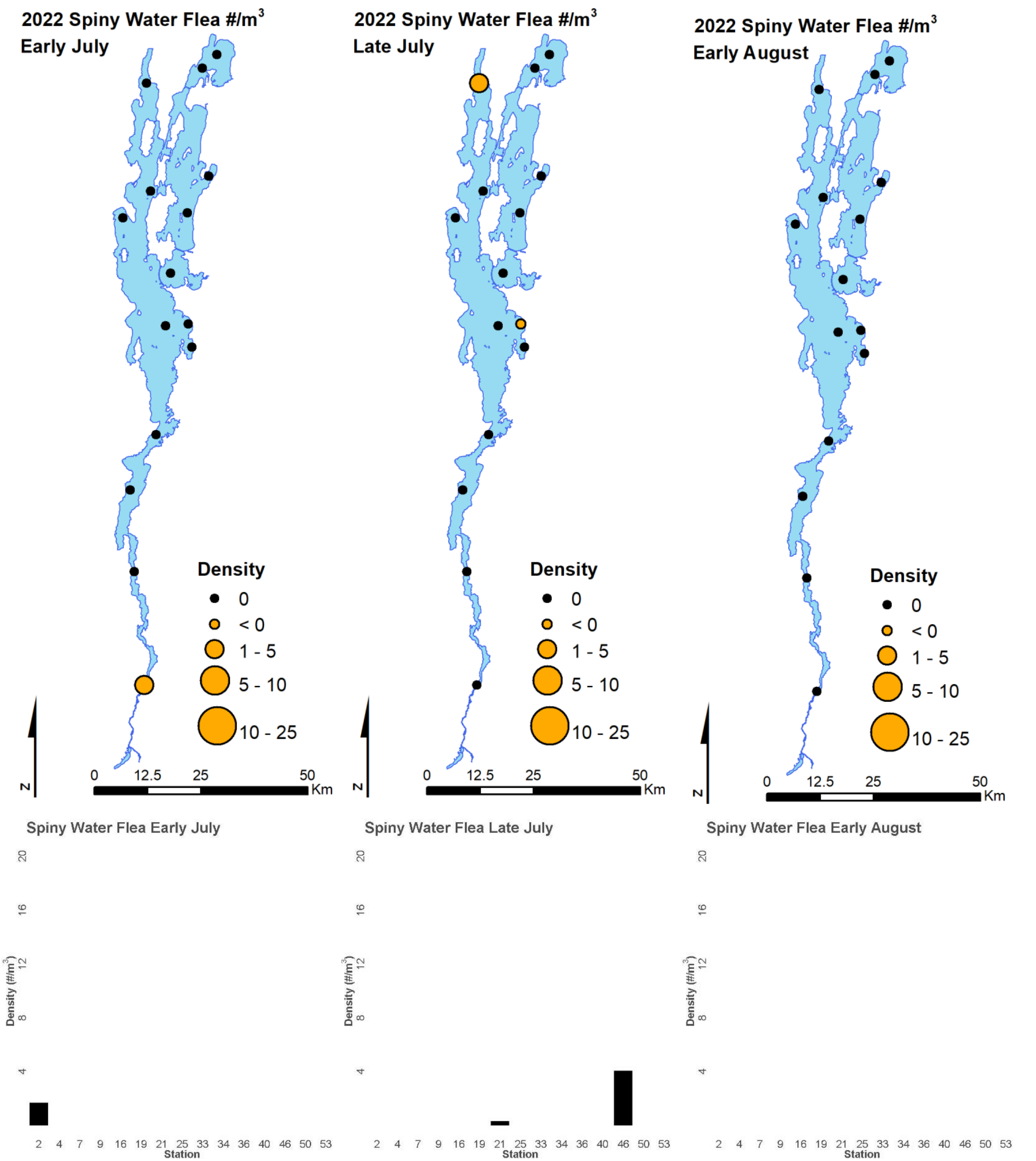


Figure 7.2: Fishhook water flea density from whole water column vertical tows early July through Early August, 2022

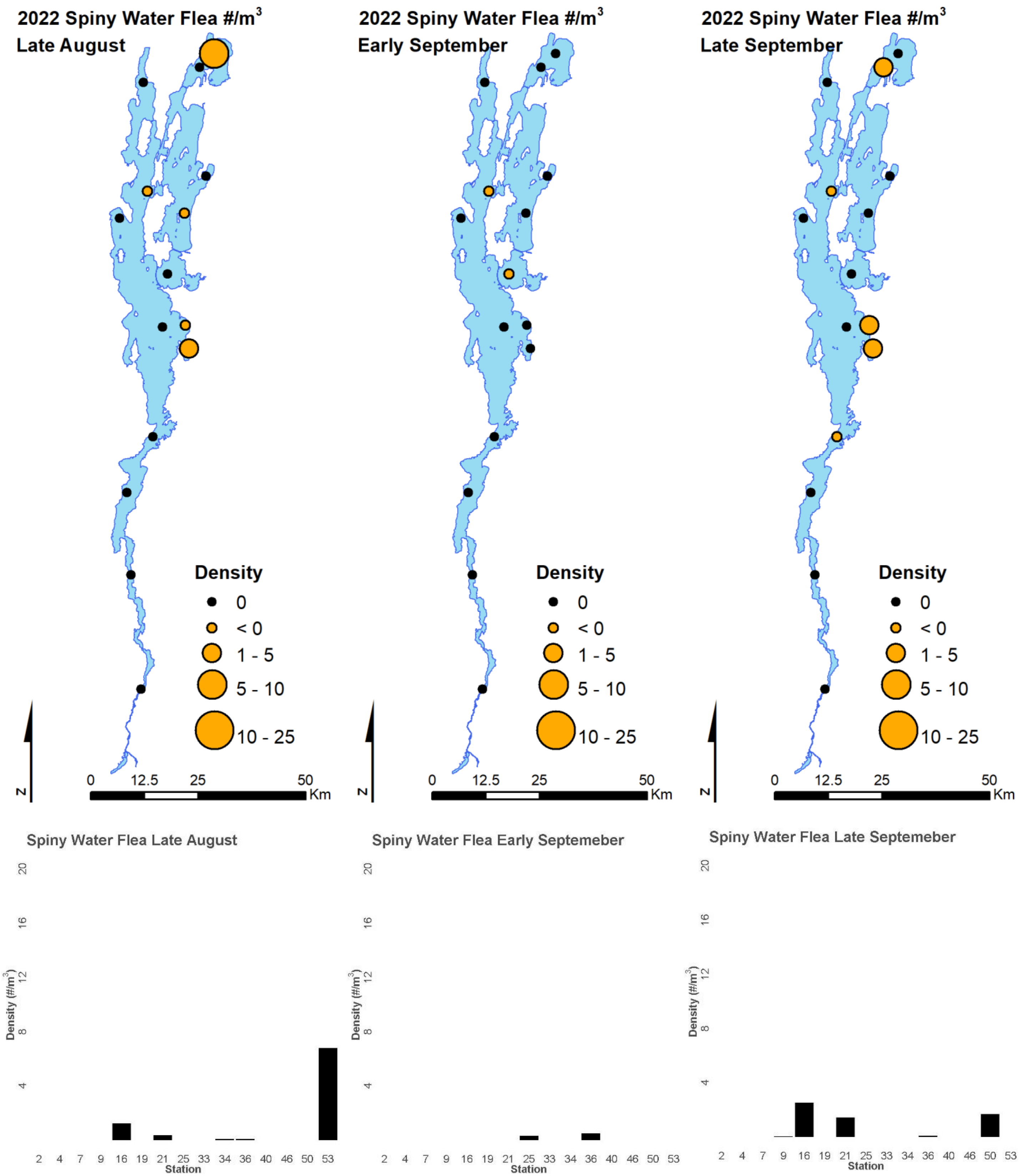
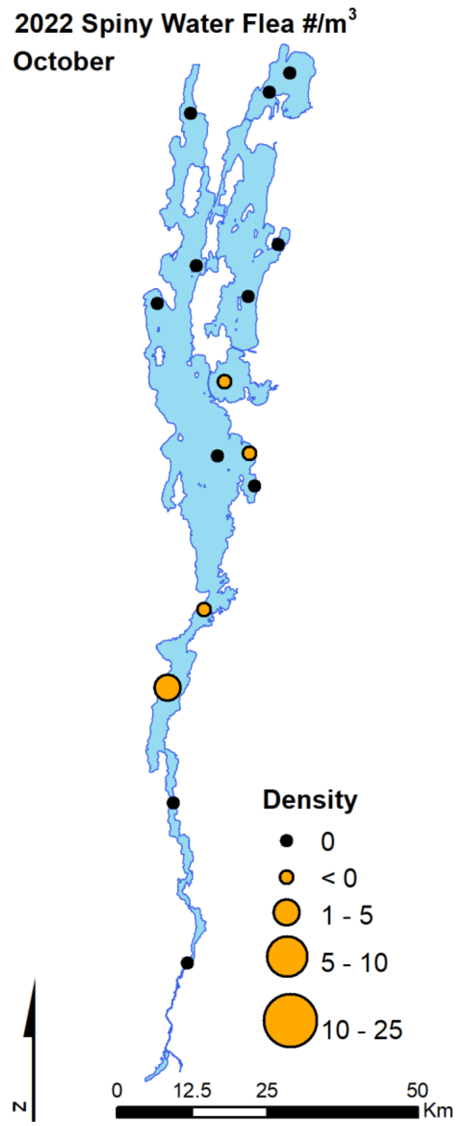


Figure 7.3: Spiny water flea density from whole water column vertical tows Late August through Late September, 2022



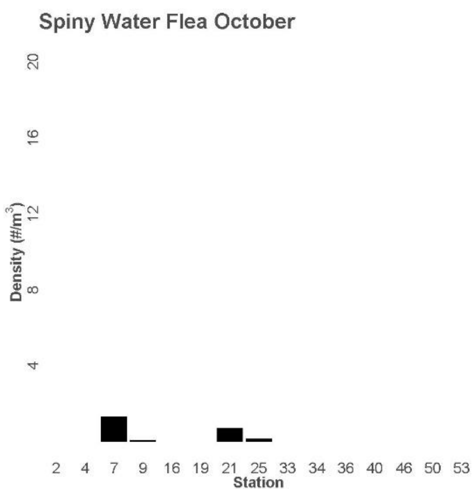


Figure 7.4: Spiny water flea density from whole water column vertical tows from October, 2022

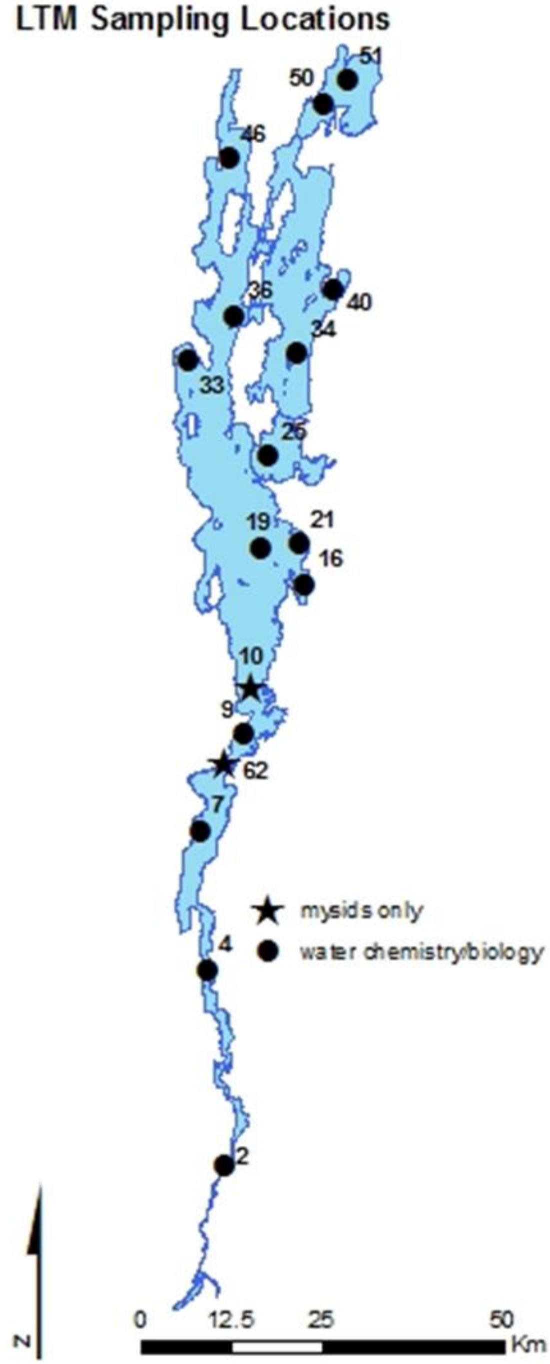
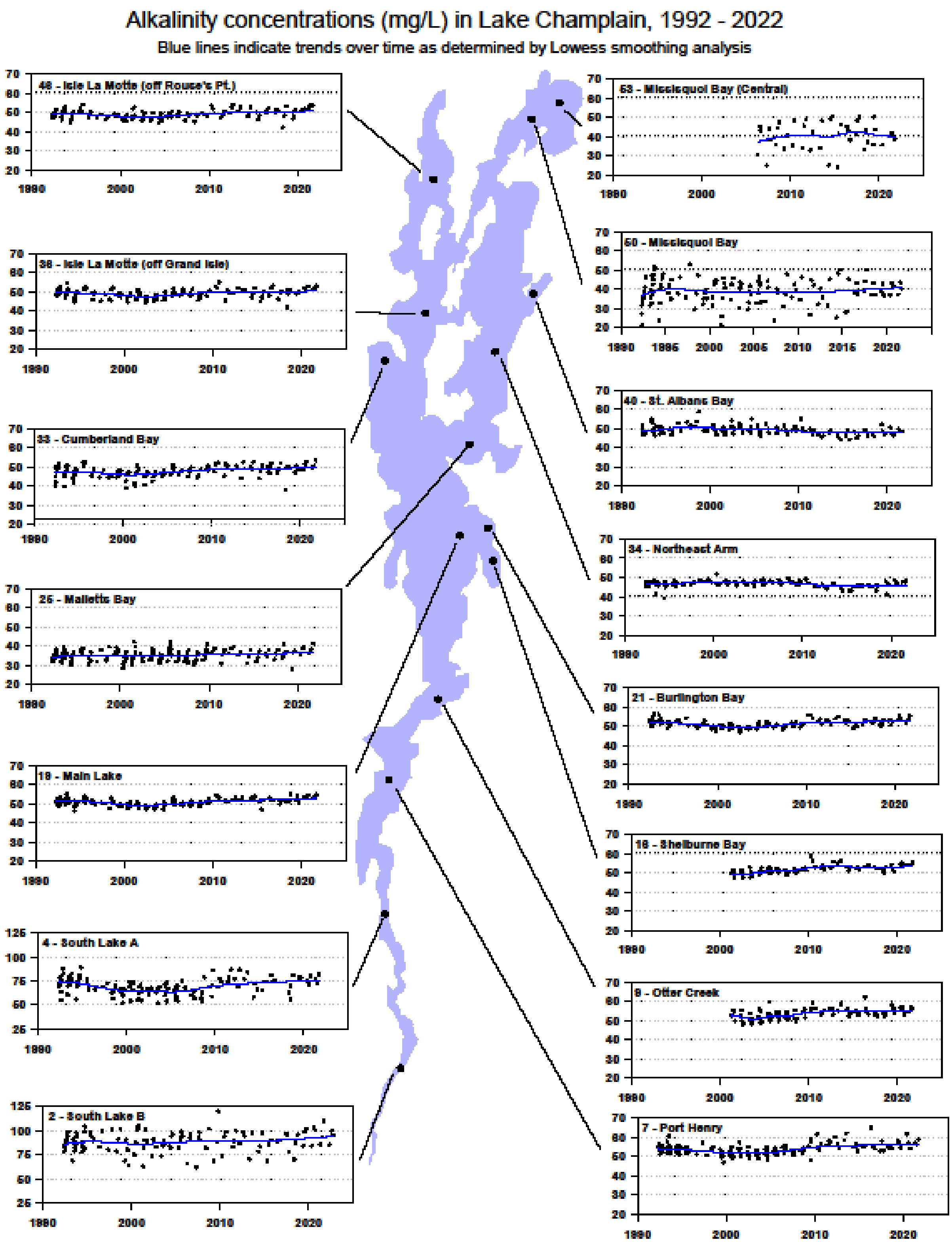


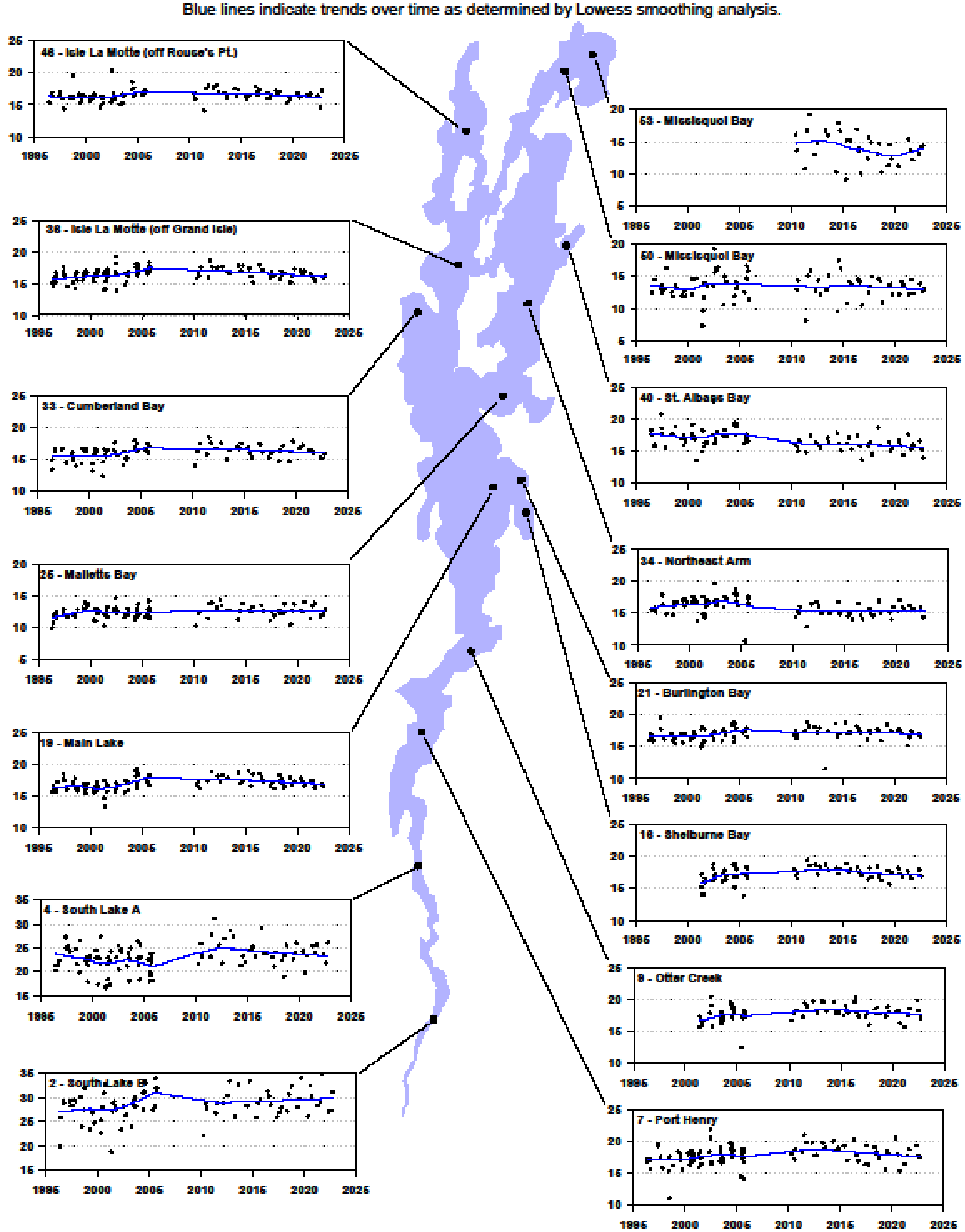
Figure 8. Lake Champlain LTM Sampling Locations

Appendix B. Lake Champlain Biogeochemical Monitoring Data



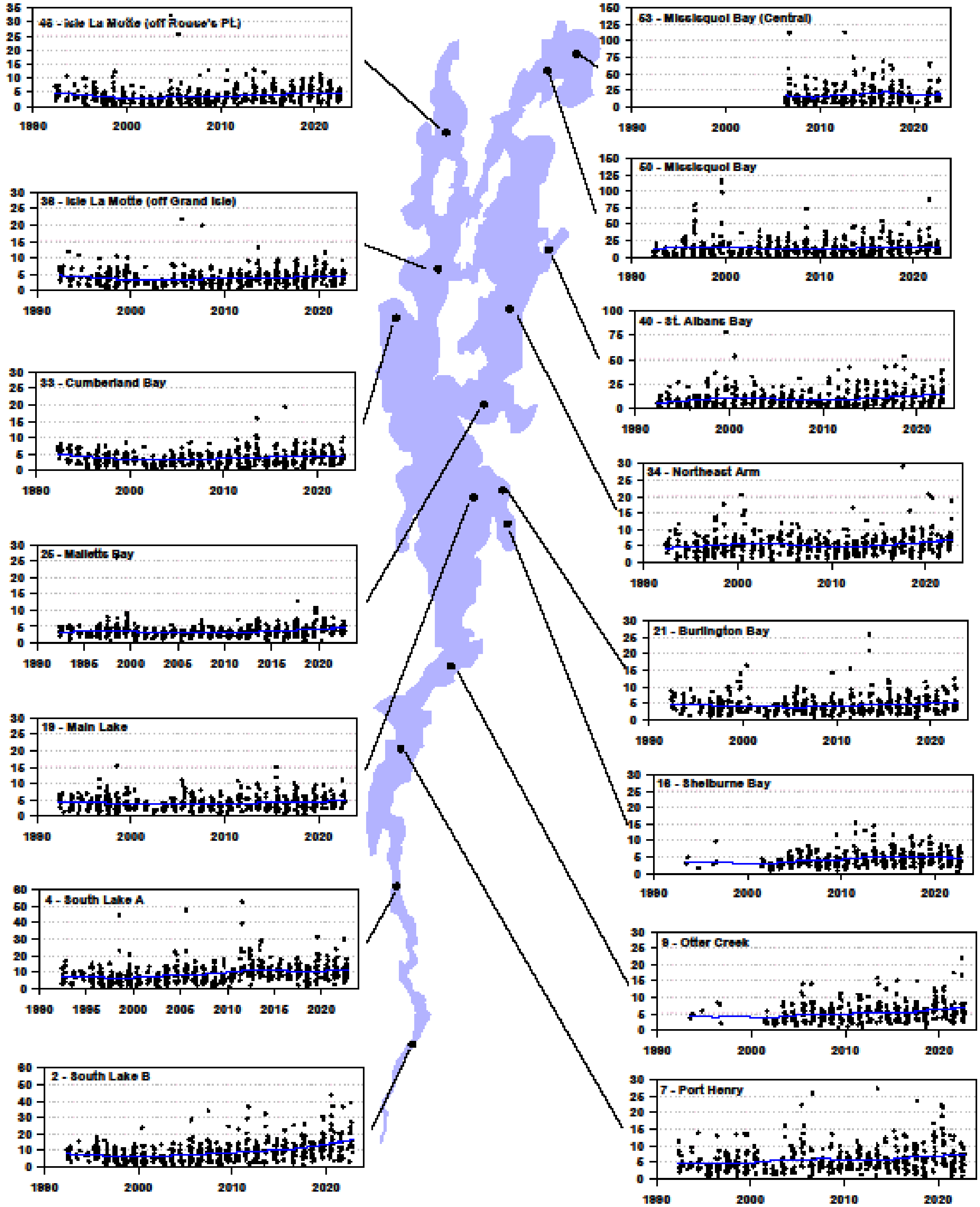
Calcium concentrations (mg/L) in Lake Champlain, 1996 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.

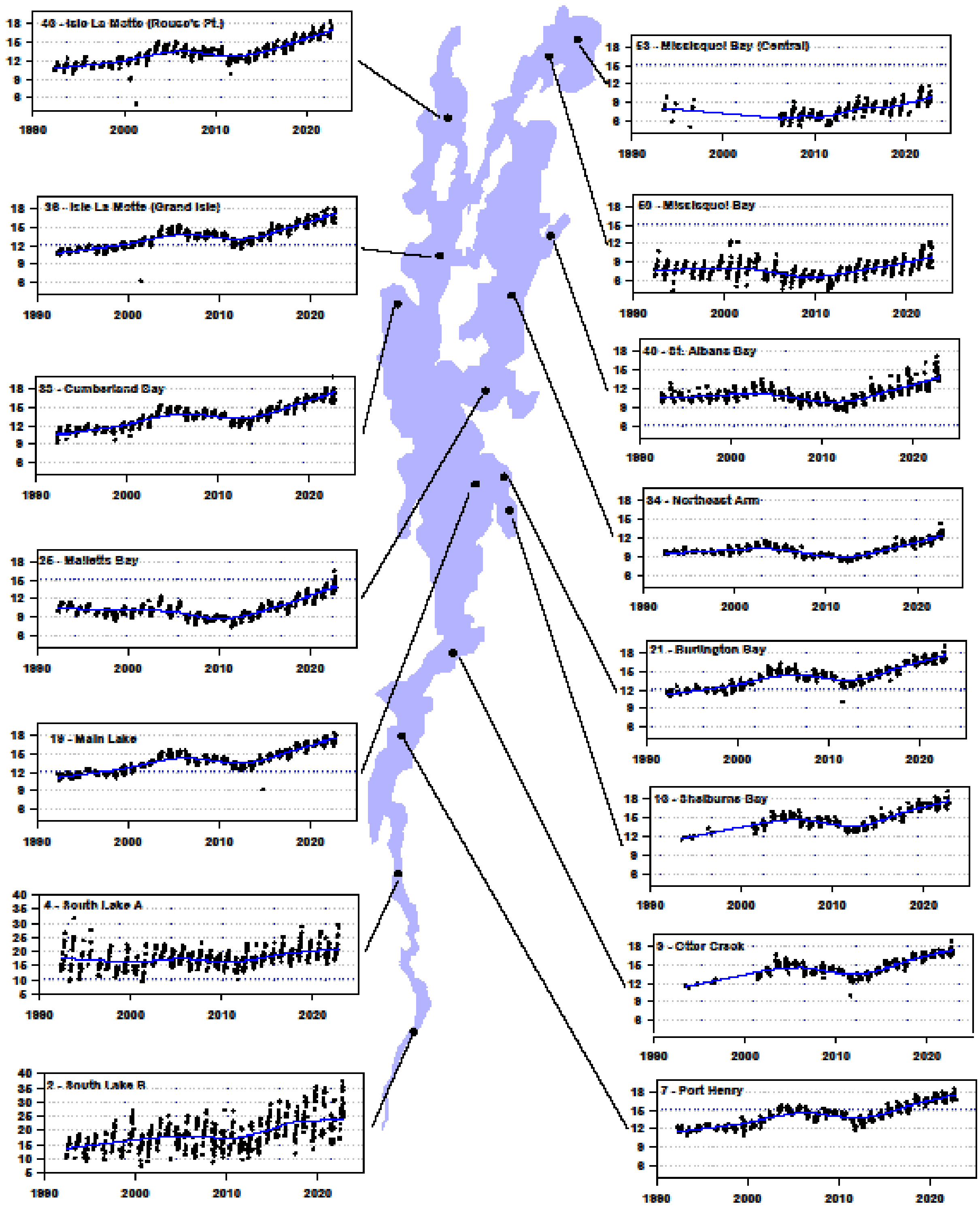


Annual chlorophyll concentrations (mg/L) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as indicated by Lowess smoothing analysis

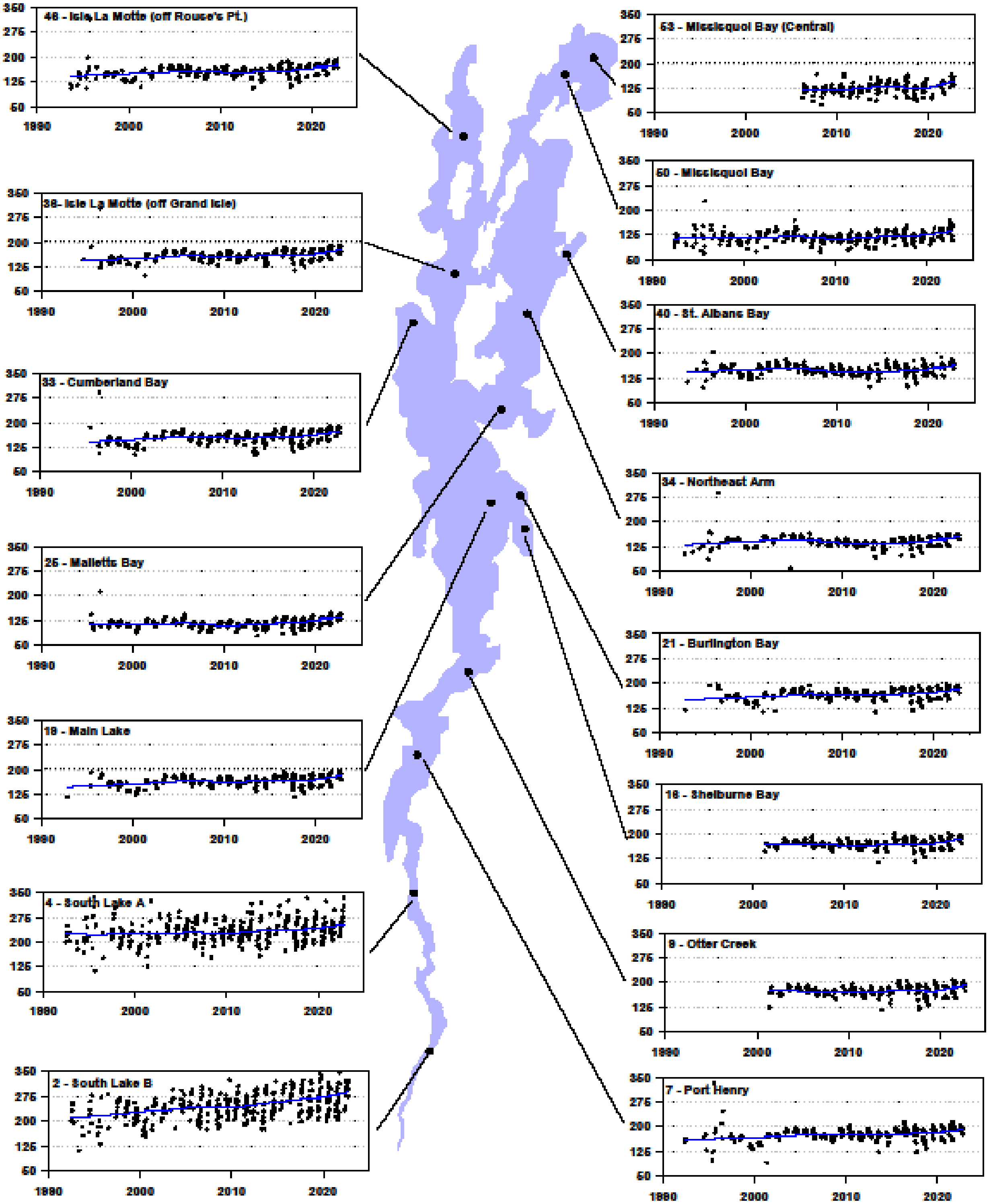


Annual chloride concentrations (mg/L) in Lake Champlain, 1992 - 2022
Blue lines indicate trends over time as determined by Lowess smoothing analysis



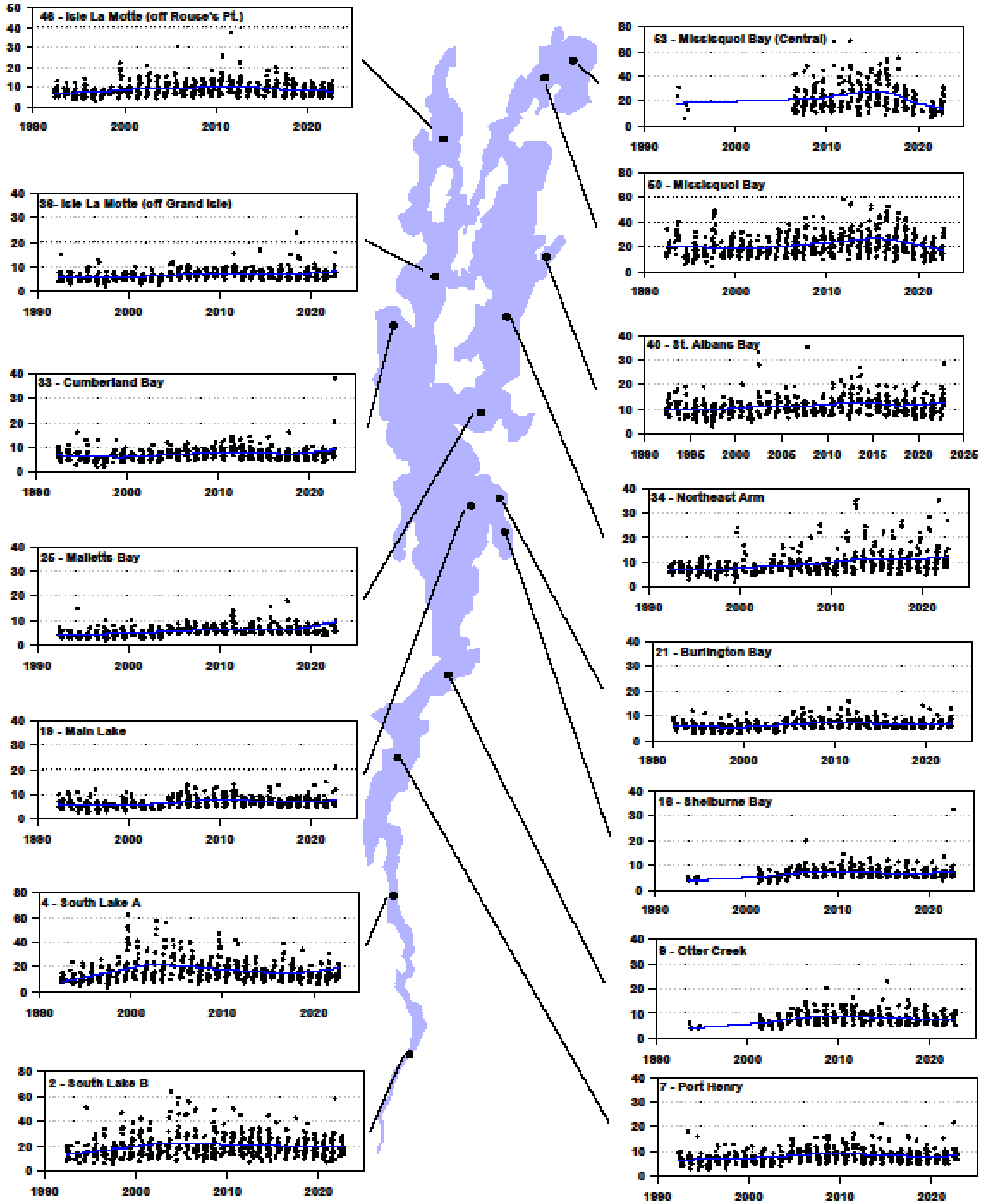
Annual conductivity (mS/cm) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis. Depth = 2m.



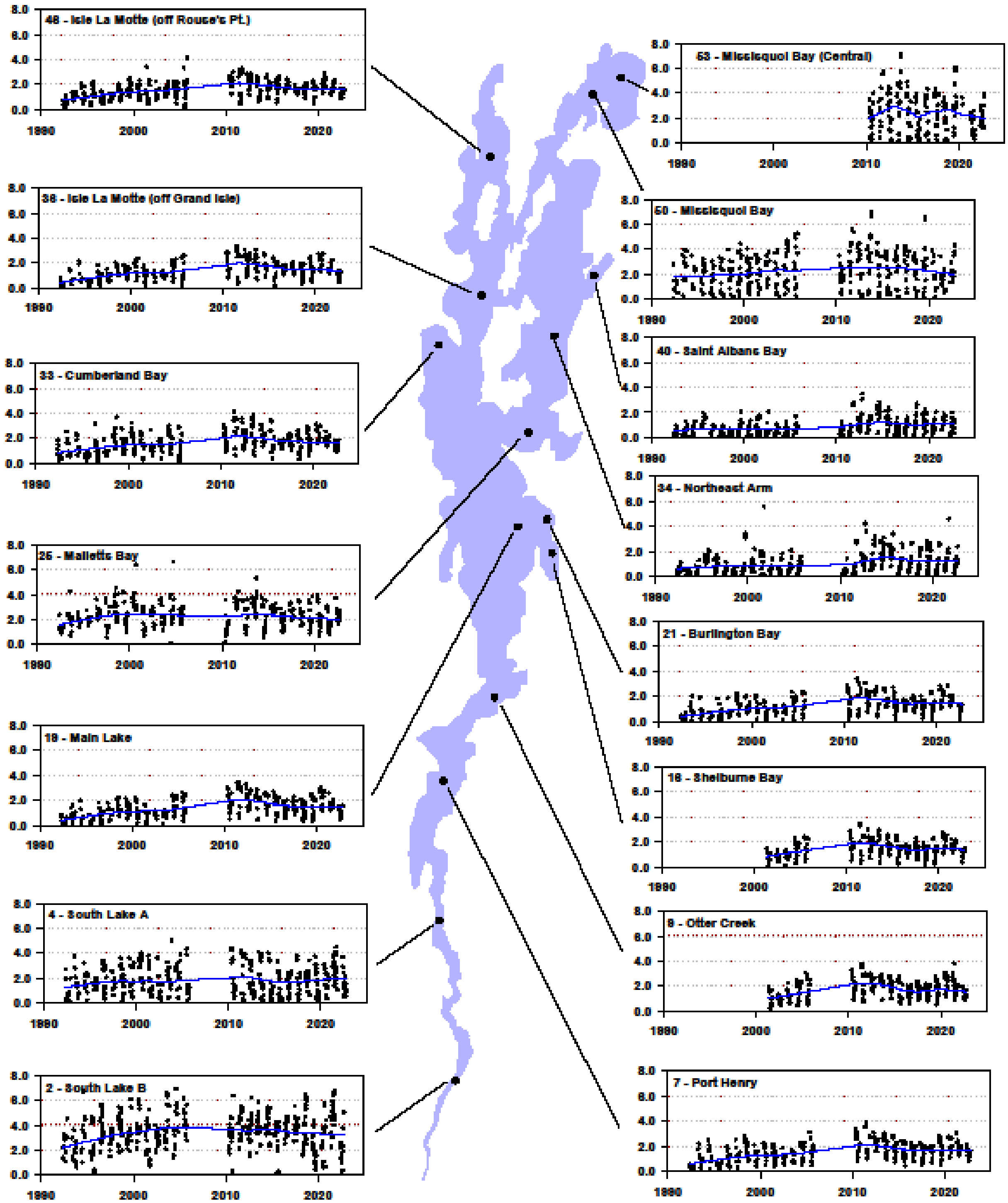
Annual dissolved phosphorus concentrations (µg/L) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



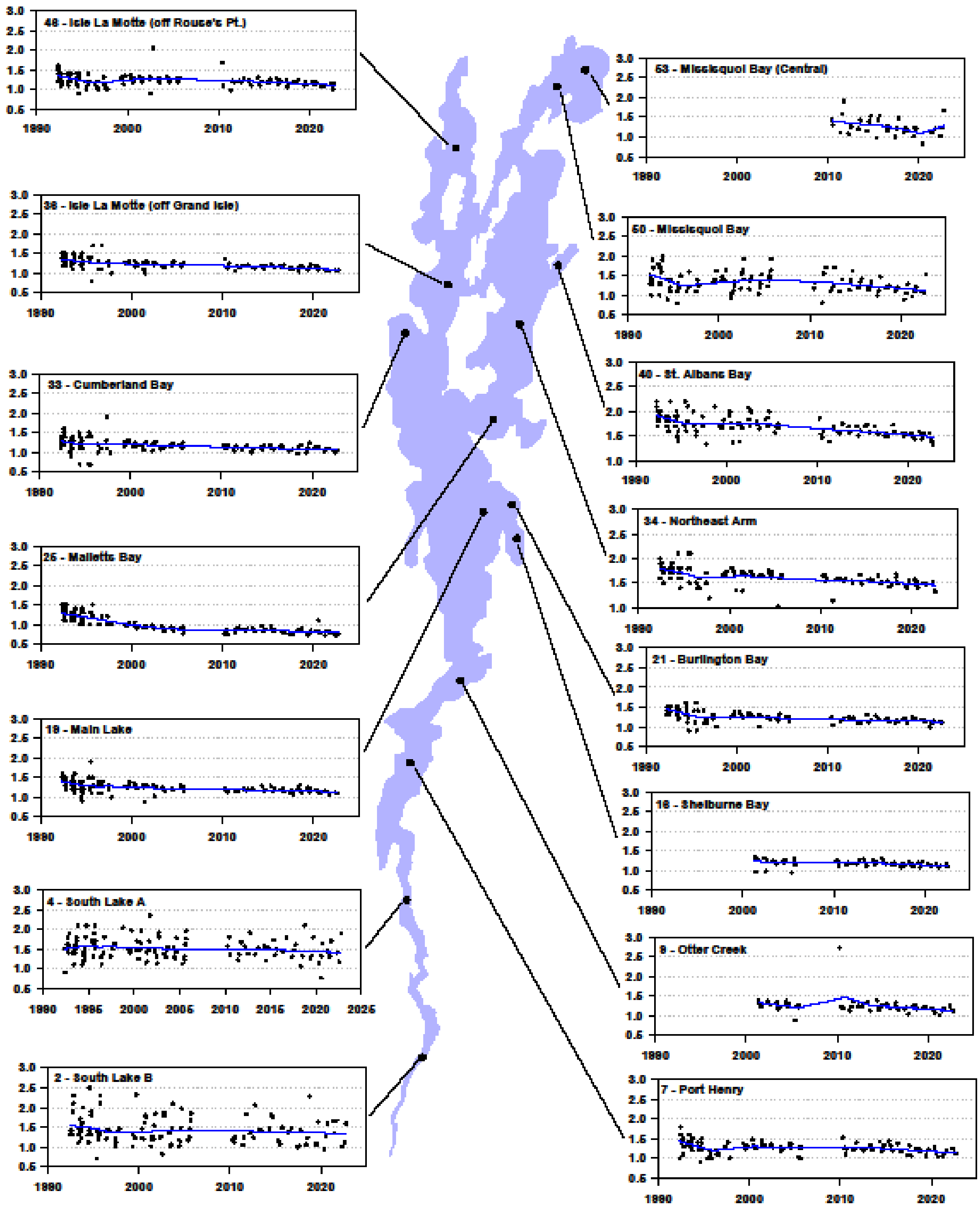
Dissolved silica concentrations (mg/L) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



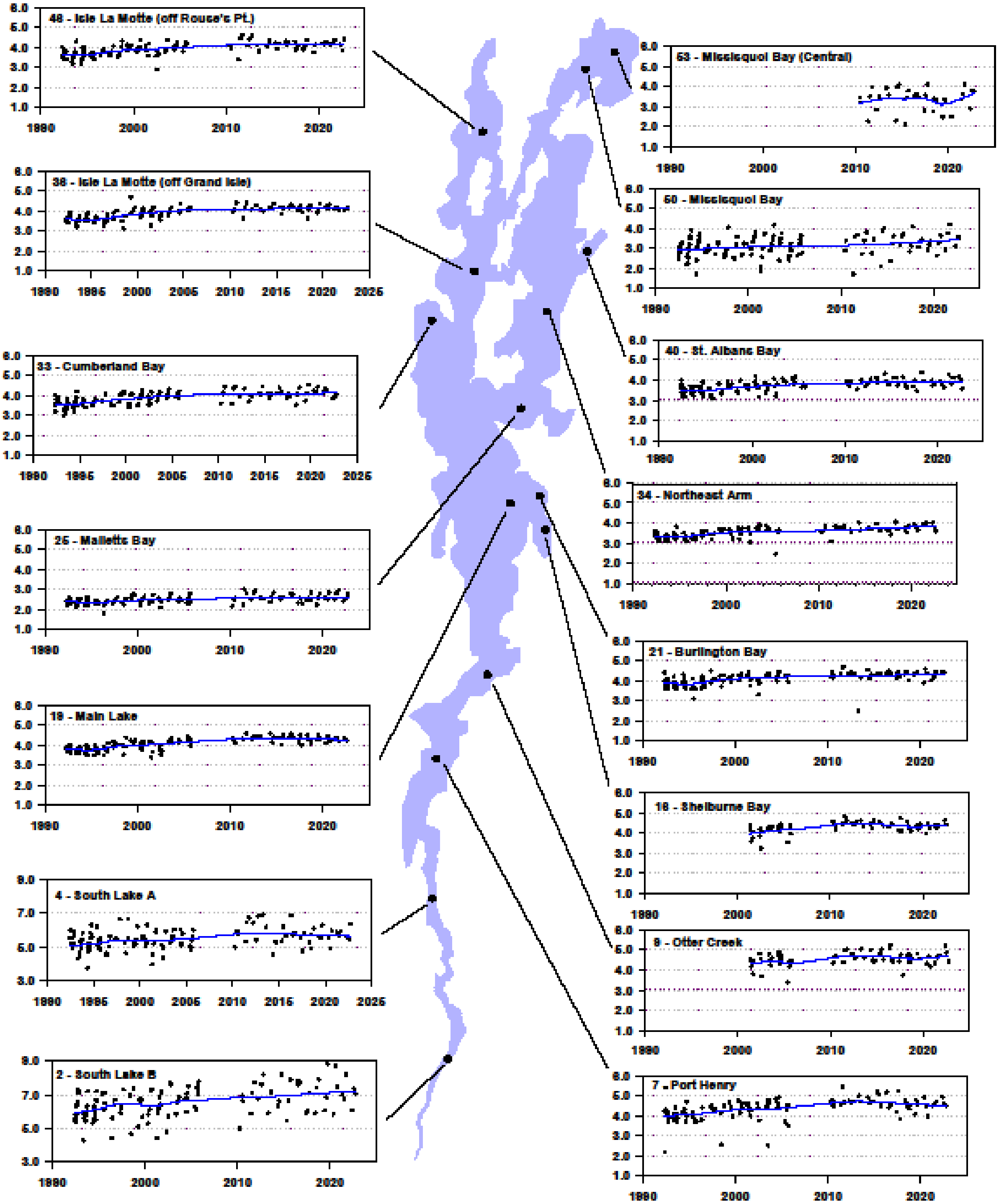
Potassium concentrations (mg/L) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



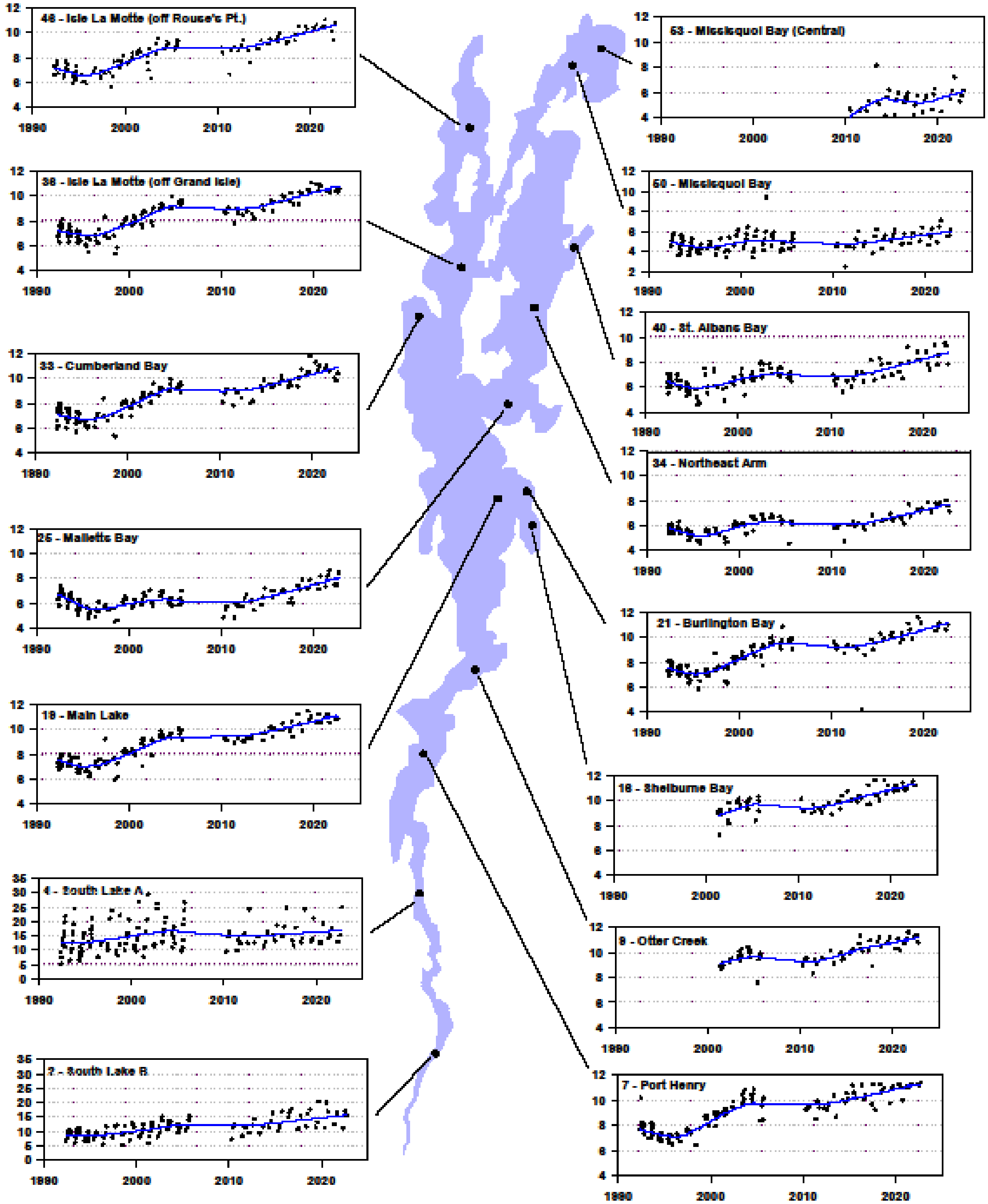
Magnesium concentrations (mg/L) in Lake Champlain
1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



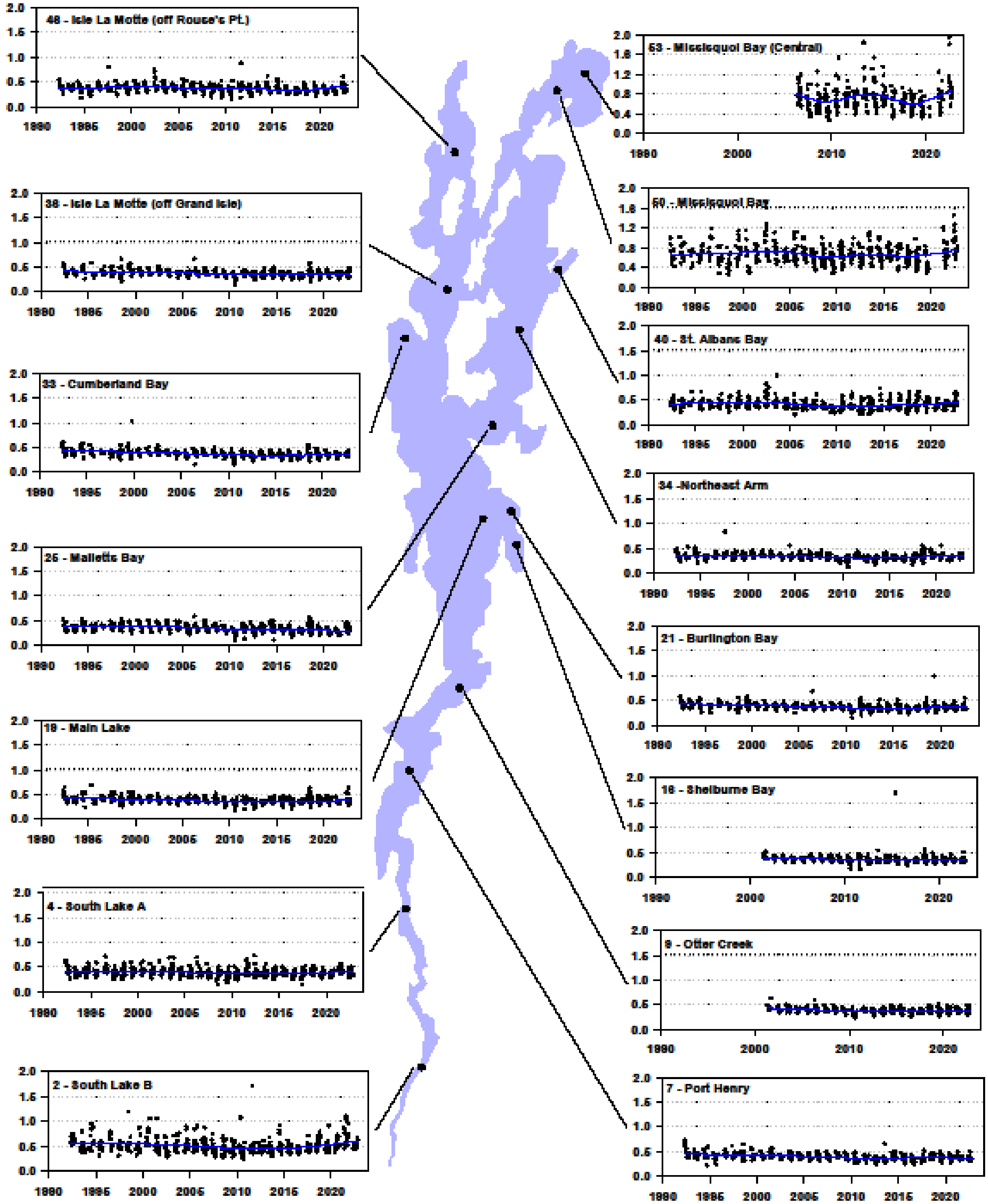
Sodium concentrations (mg/L) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



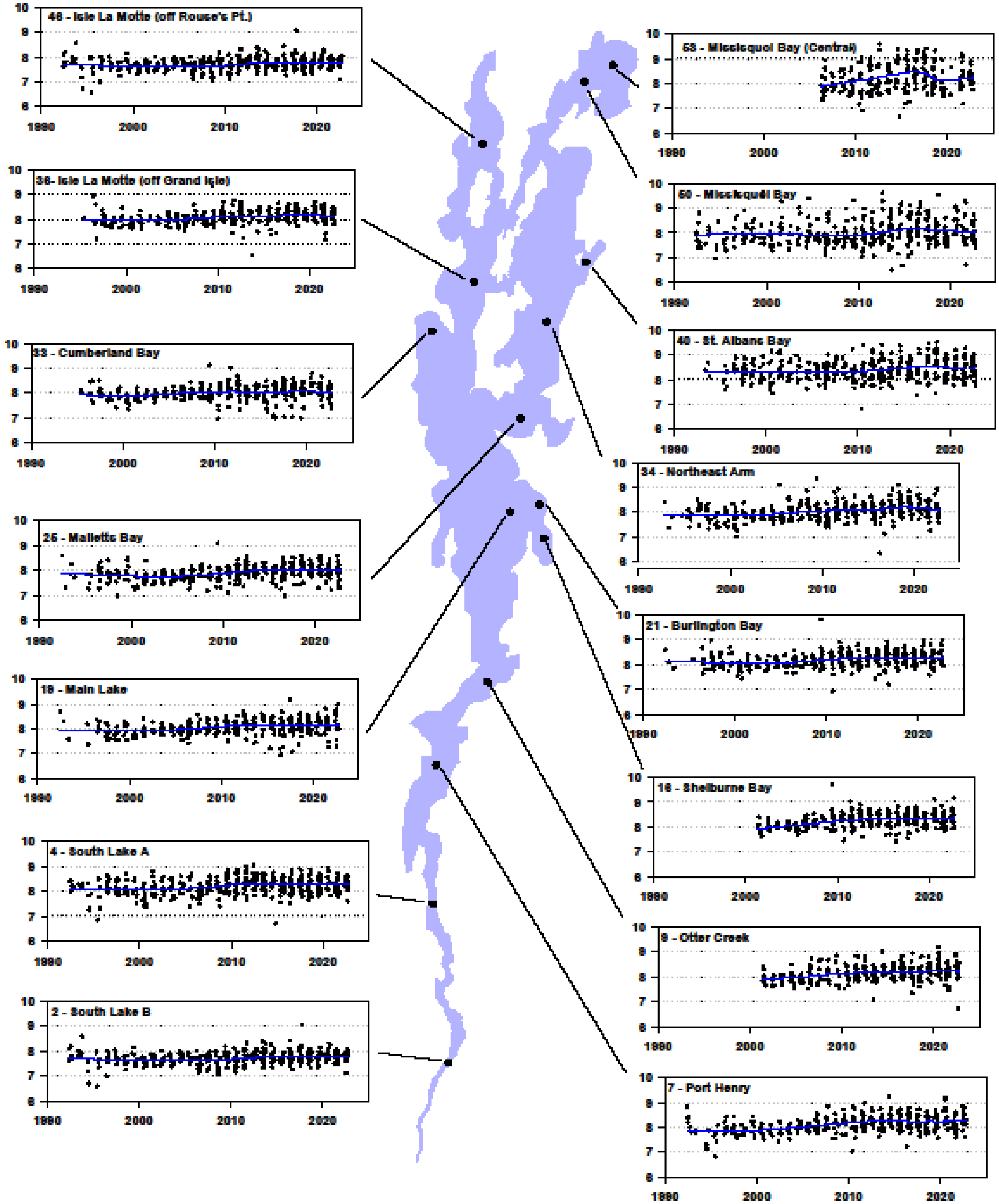
Annual total nitrogen concentrations (mg/L) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



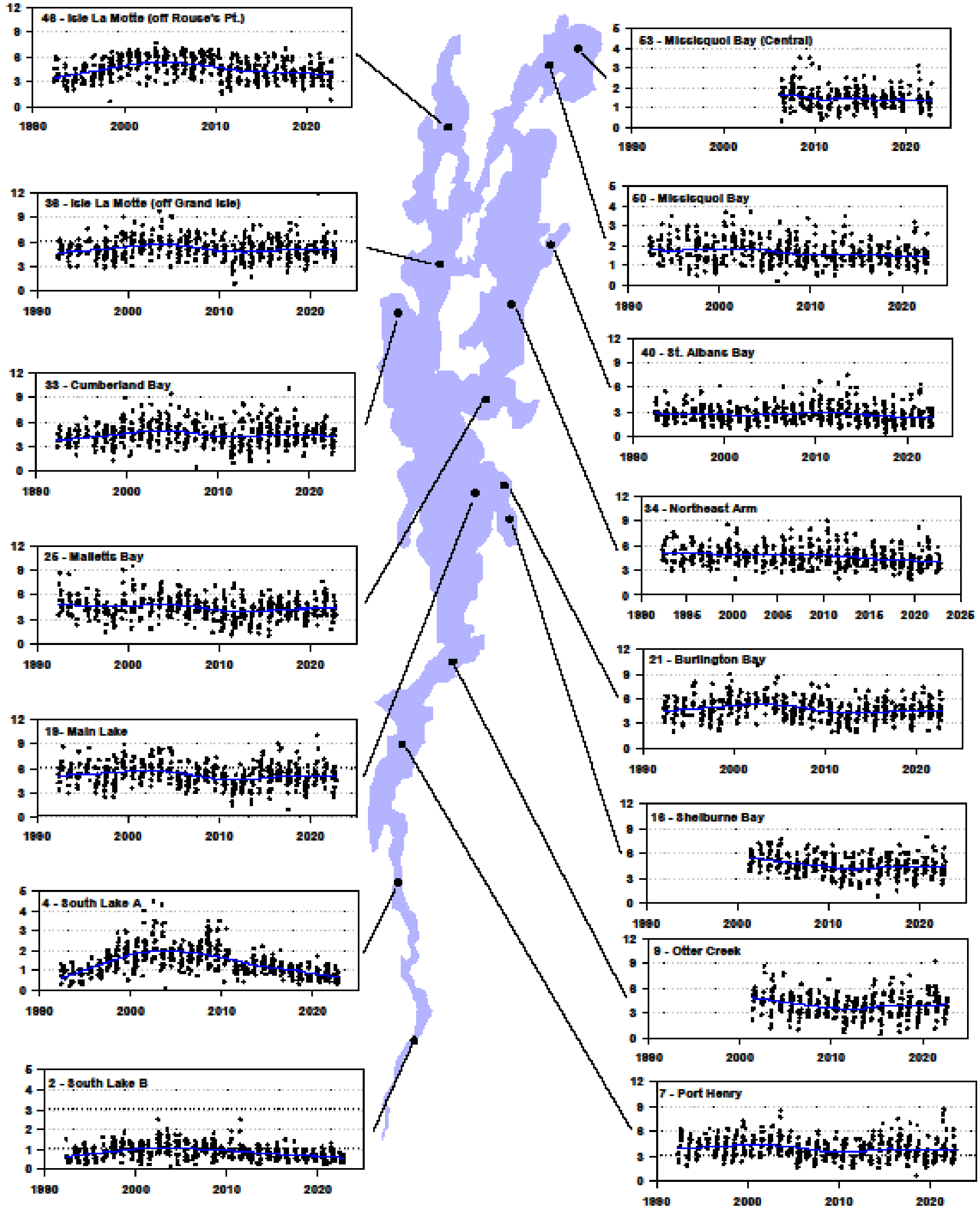
Annual pH at 2m in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing.



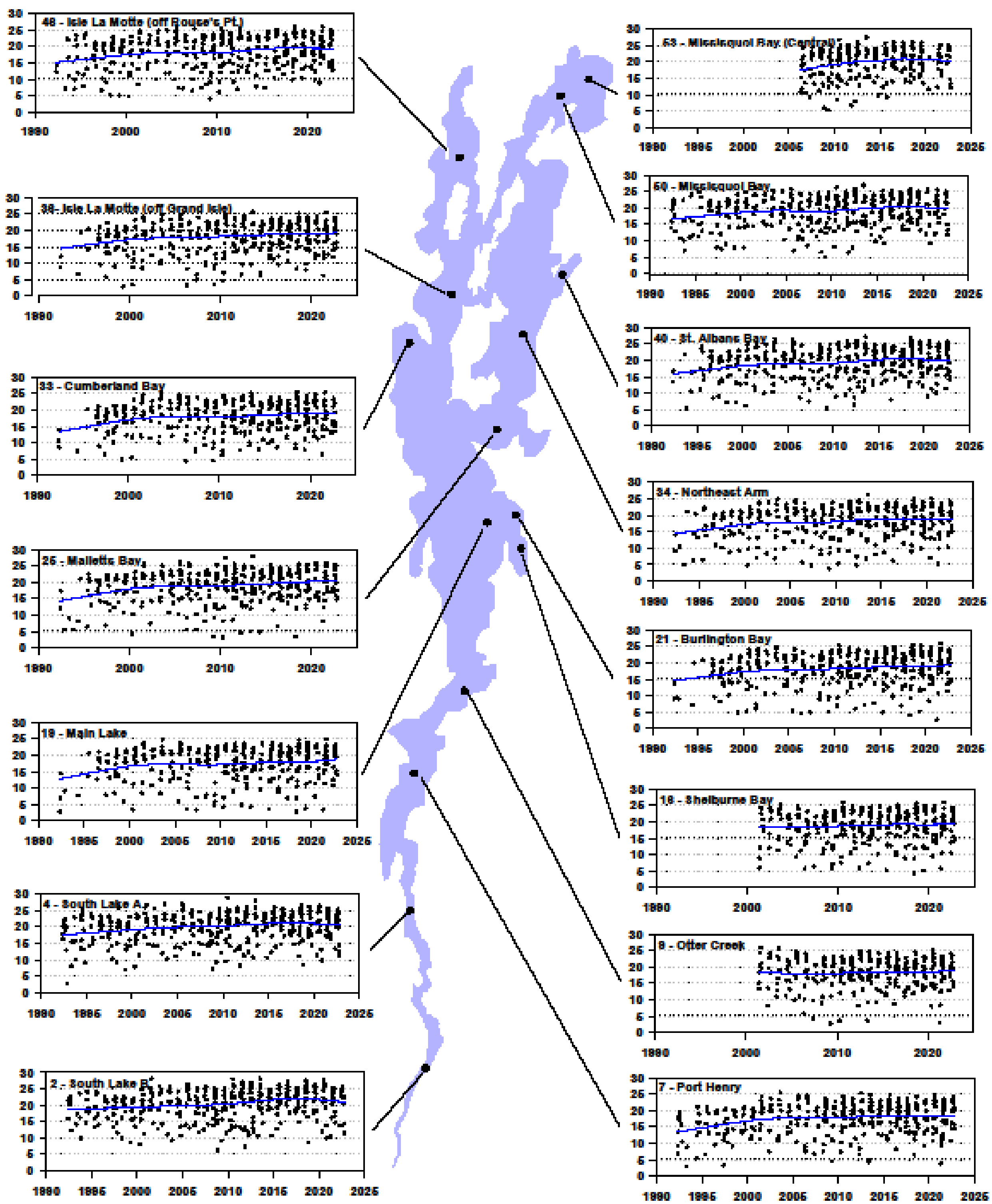
Annual Secchi depth (meters) in Lake Champlain, 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



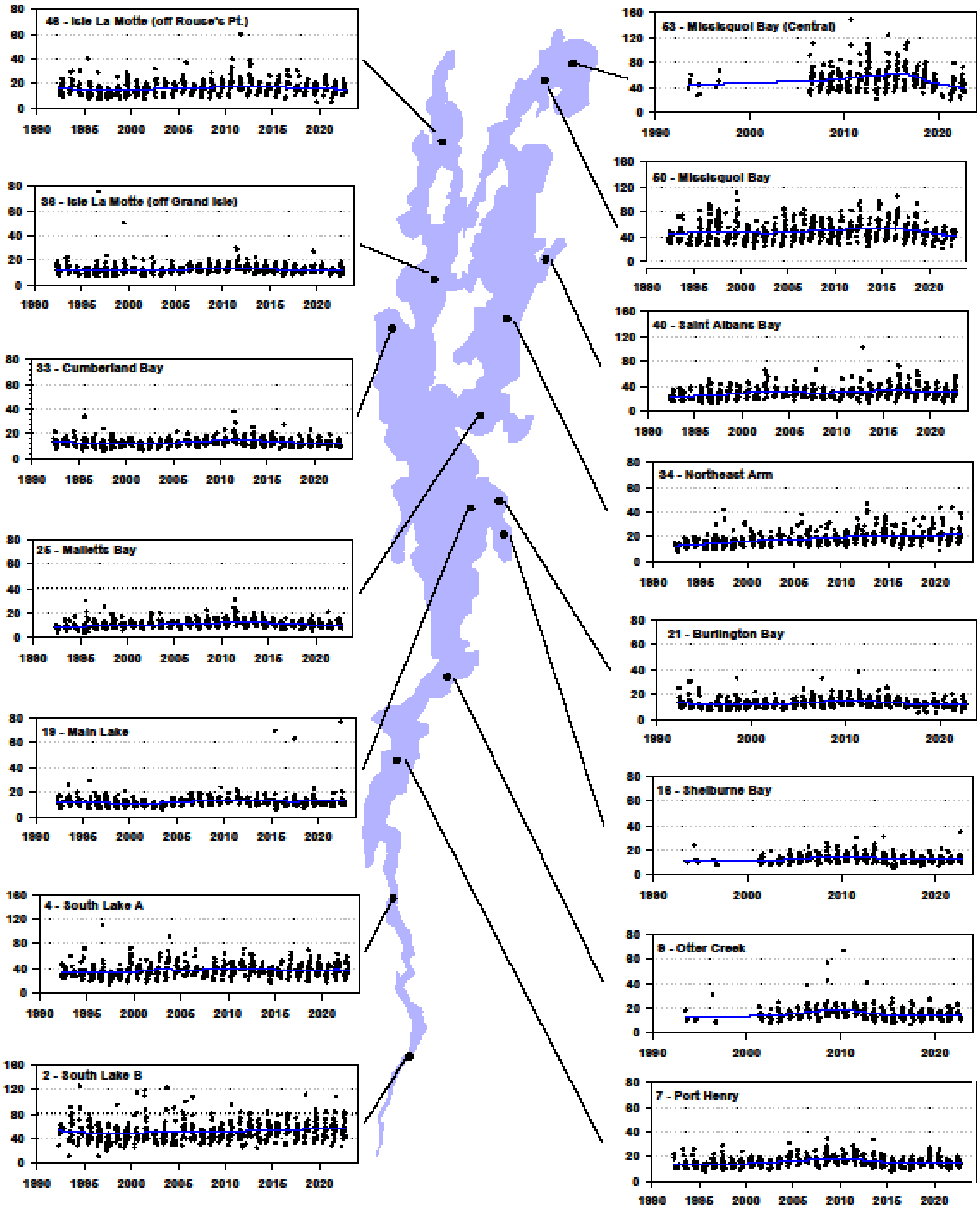
Temperature at 1m in Lake Champlain (degrees C), 1992 - 2022

Blue lines indicate trends over time as determined by Lowess smoothing analysis.



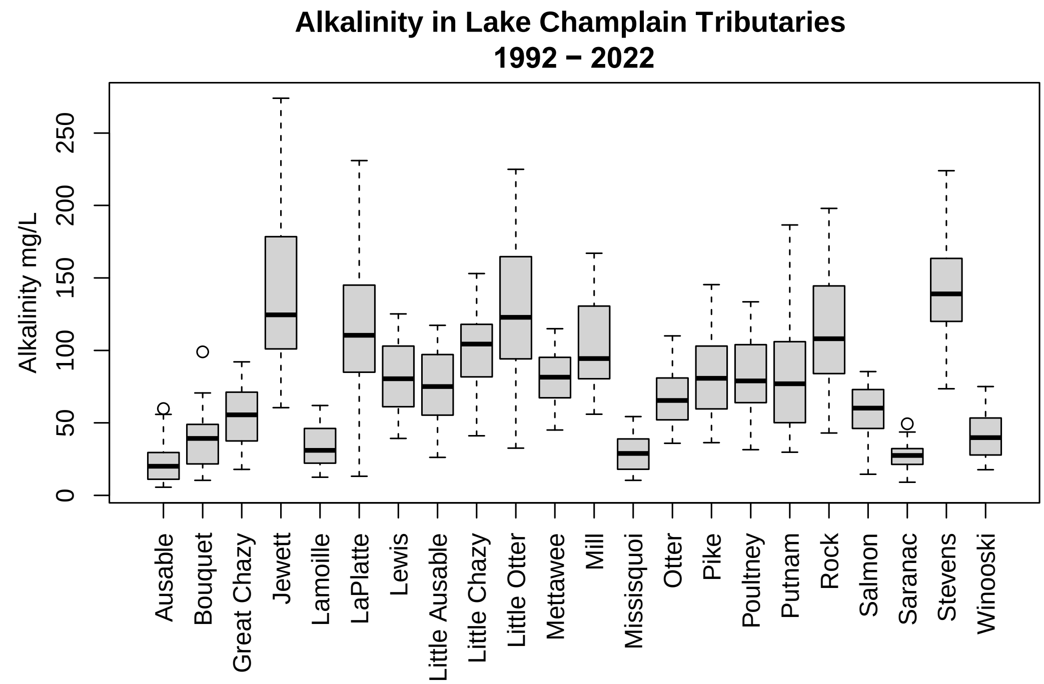
Annual total phosphorus concentrations (µg/L) in Lake Champlain, 1992 - 2022

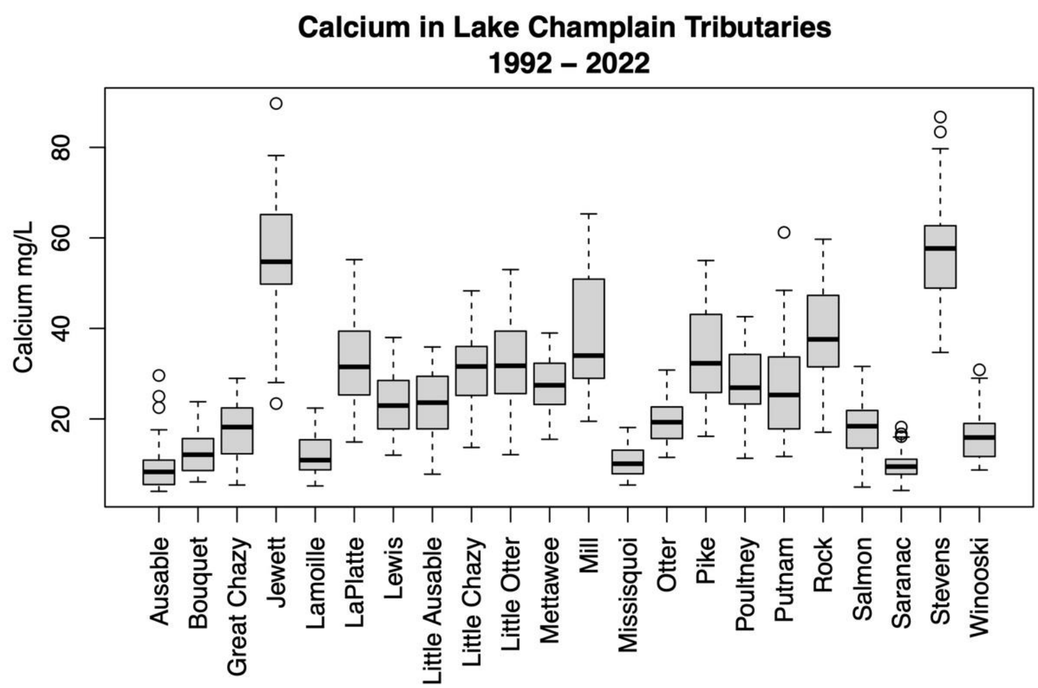
Blue lines indicate trends over time as determined by Lowess smoothing analysis.



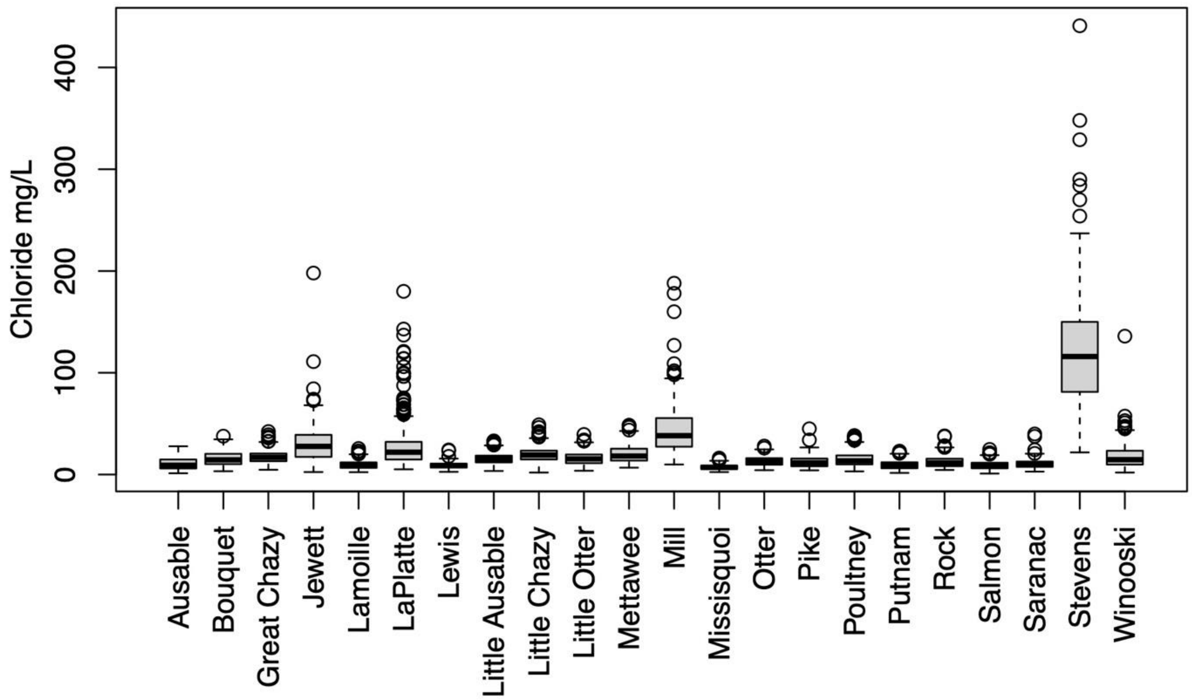
Appendix C. Lake Champlain Tributary Monitoring Data Figures

Fig. C1: Total solute concentrations in Vermont tributaries. Concentrations are not adjusted for flow. The center line of the boxplot represents the median concentration (50th percentile). The bottom and top of the box represent the 25th and 75th quantiles of the data, respectively, and the lower and upper whiskers represent the 10th and 90th percentiles of the data. All available data from each site are used in the boxplots, for most sites from 1992-2022. Sampling began at Steven's Brook and Mill River in 2008, at the Rock River in 2007, and at the Mill River in 2010. Sampling at Putnam Creek was discontinued in 2019.

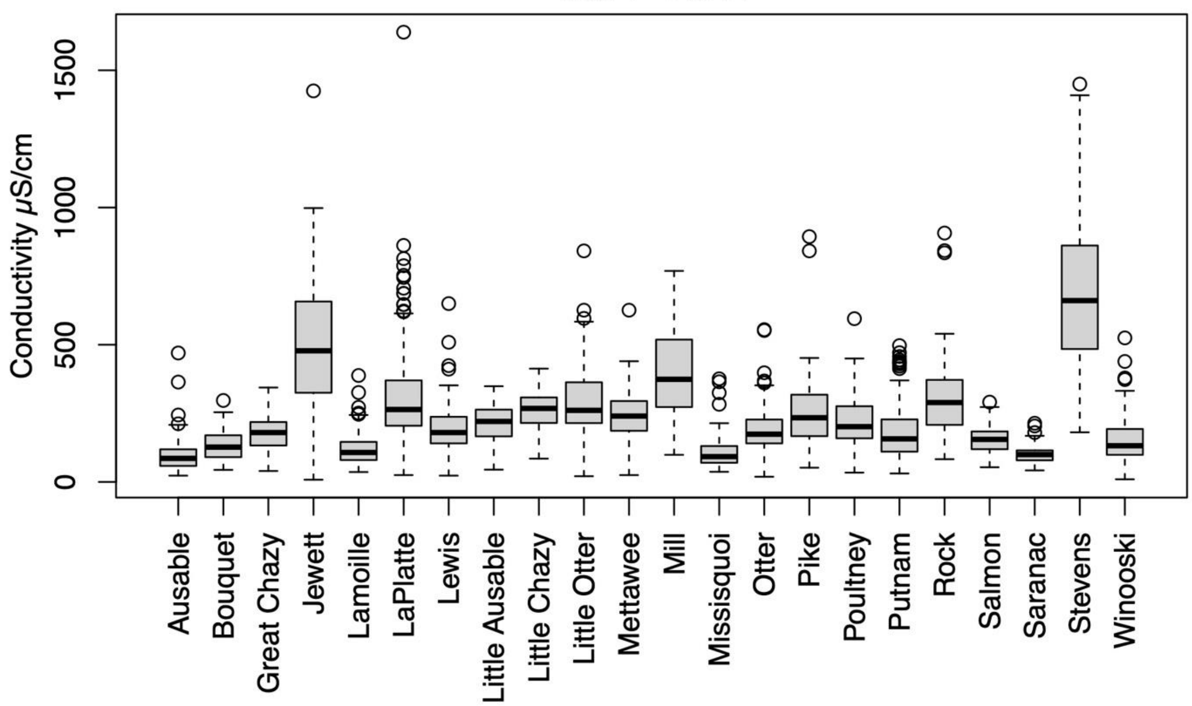


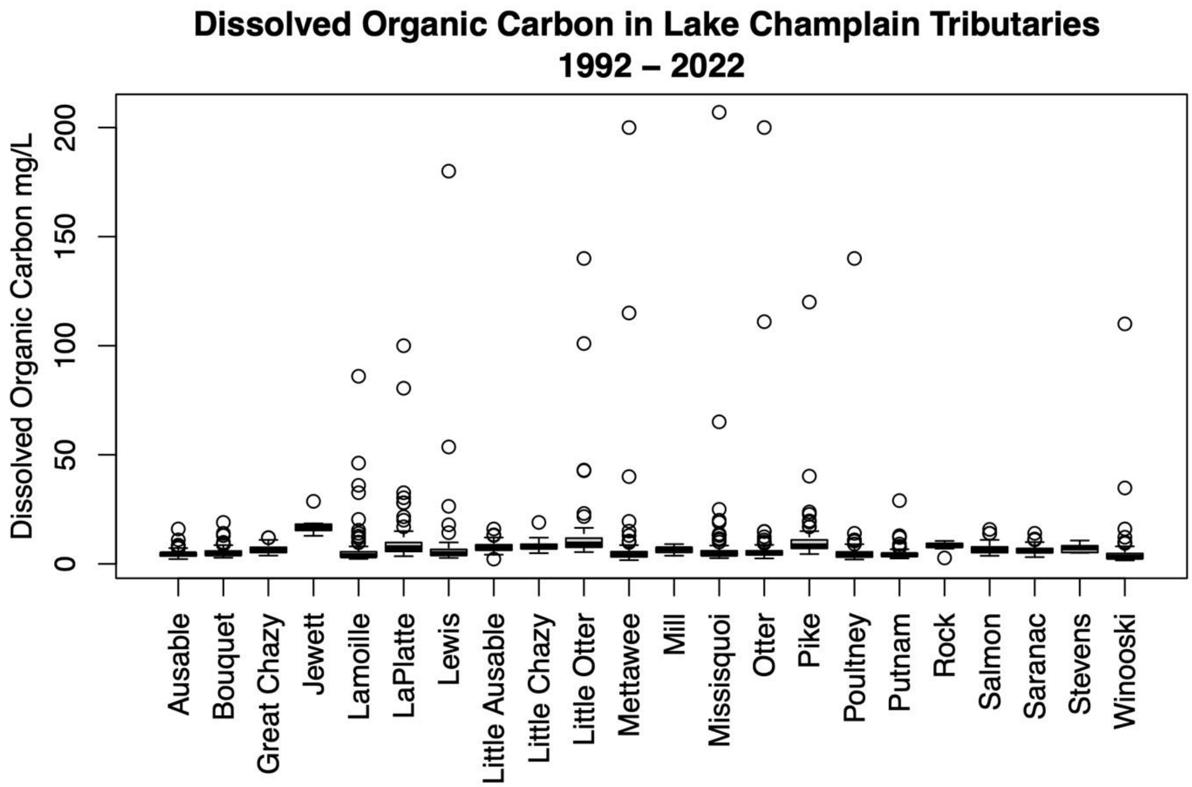


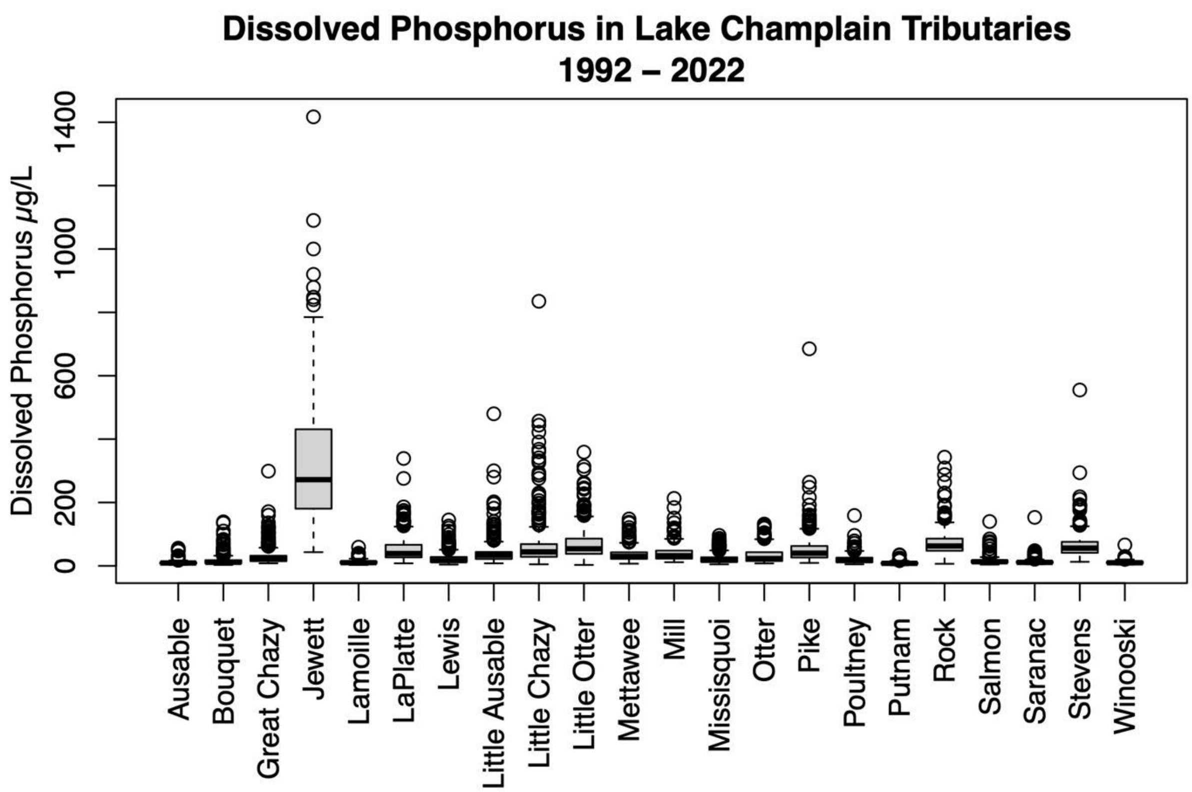
Chloride in Lake Champlain Tributaries
1992 – 2022

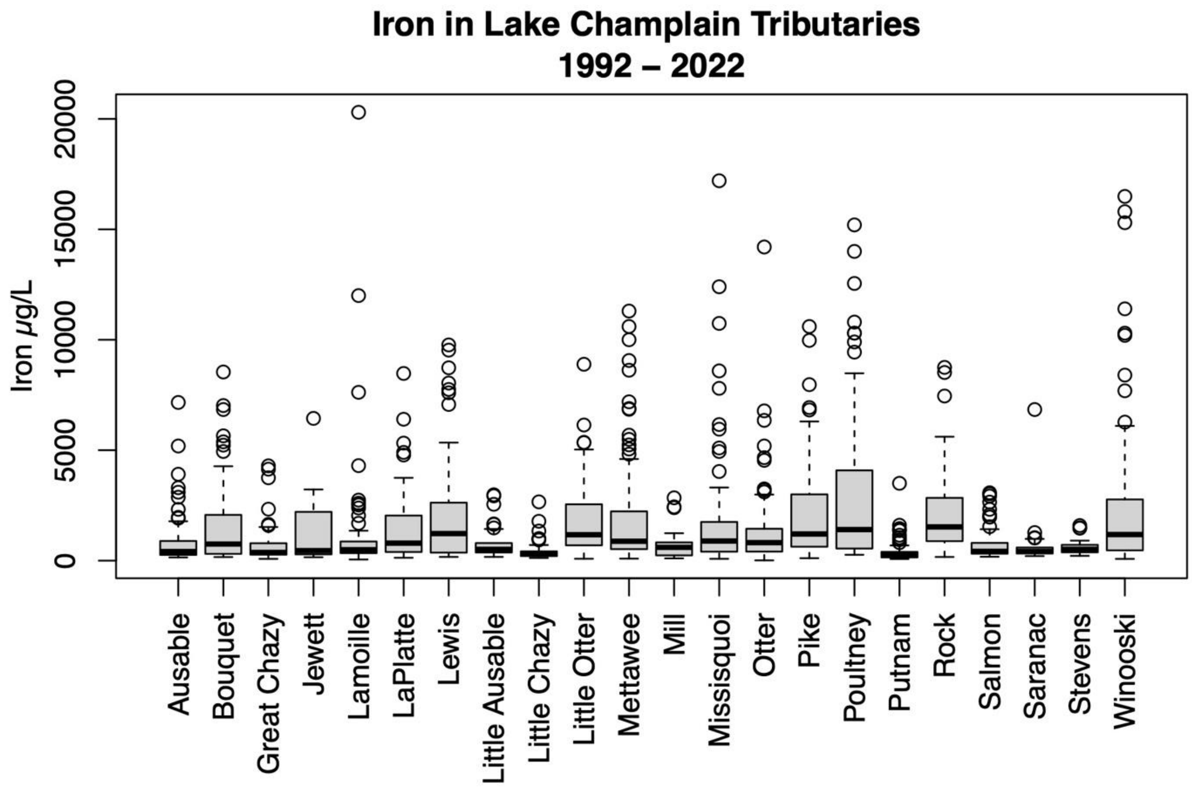


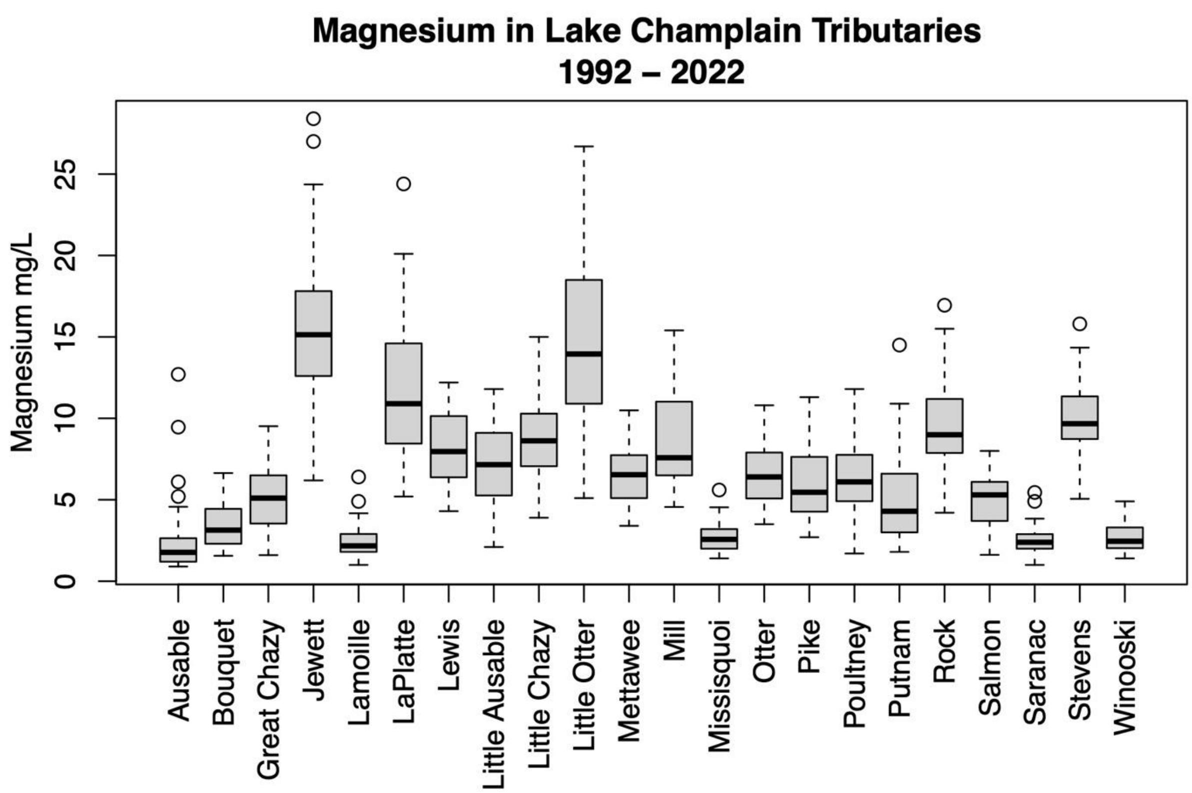
Conductivity in Lake Champlain Tributaries
1992 – 2022

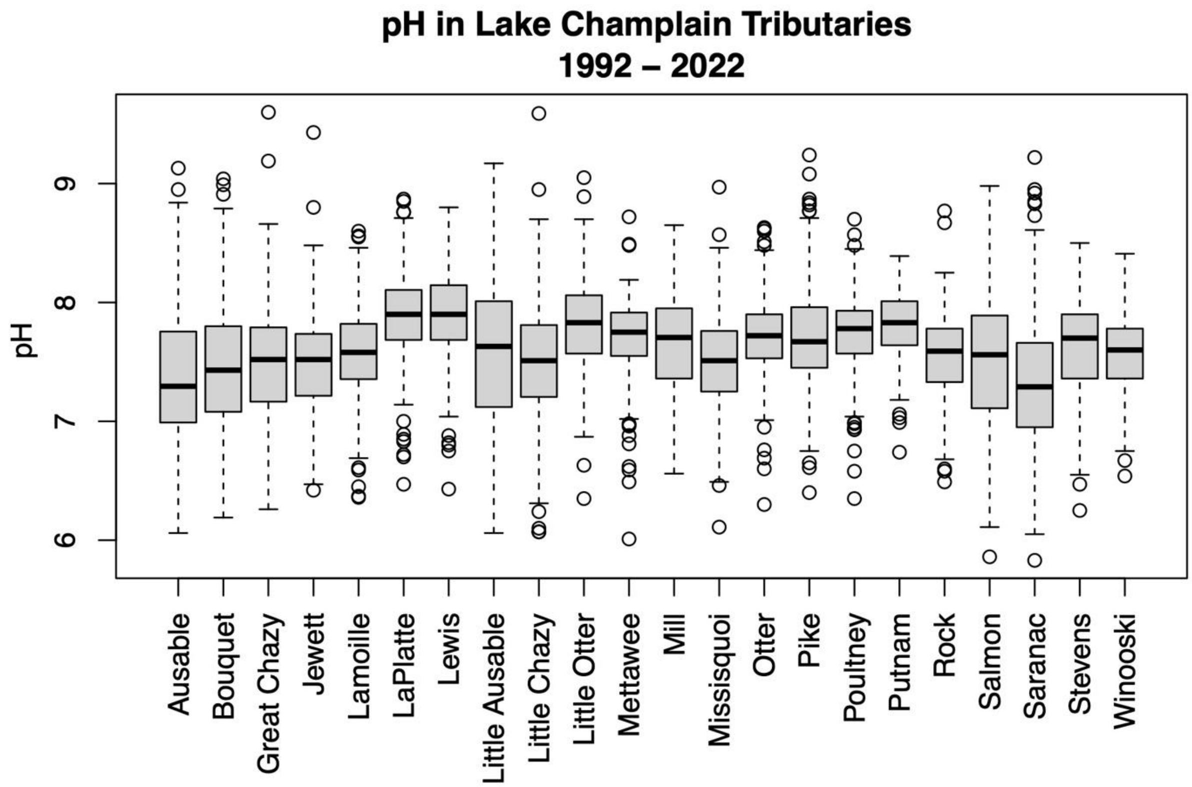


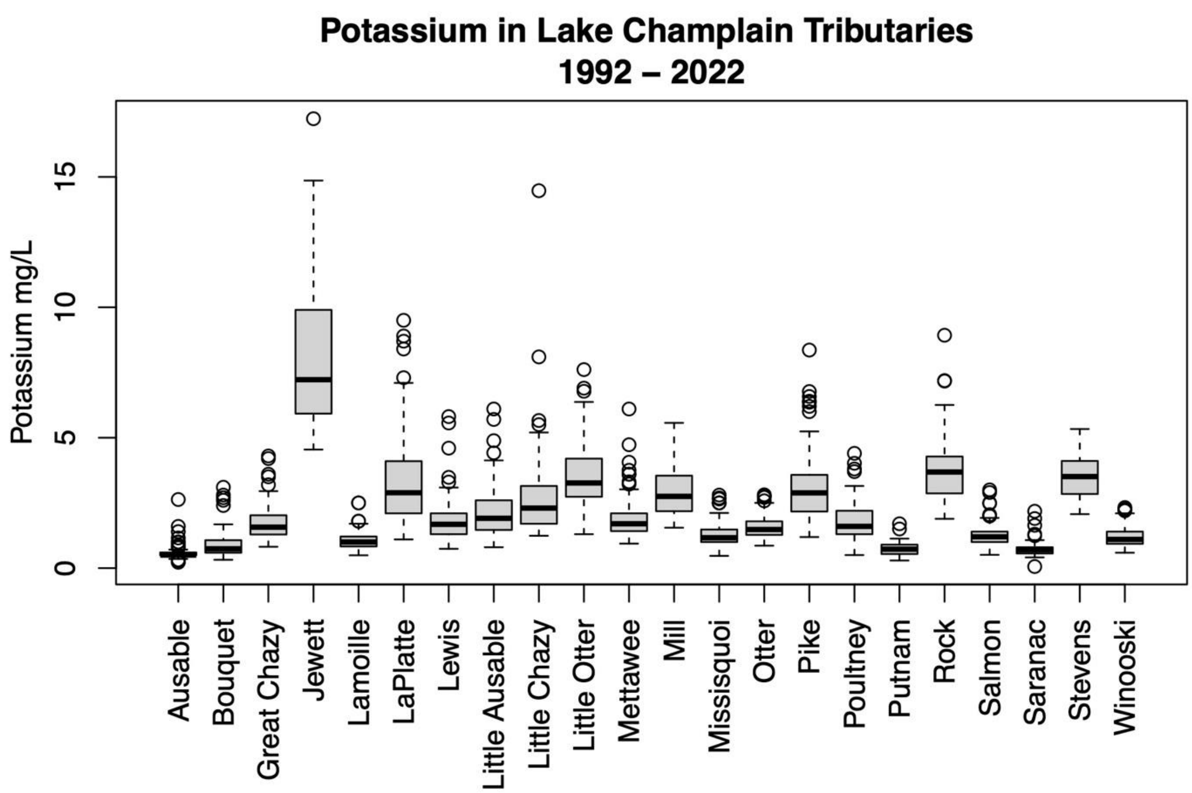

Dissolved Organic Carbon in Lake Champlain Tributaries
1992 – 2022
Dissolved Organic Carbon mg/L
0
50
100
150
200
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski

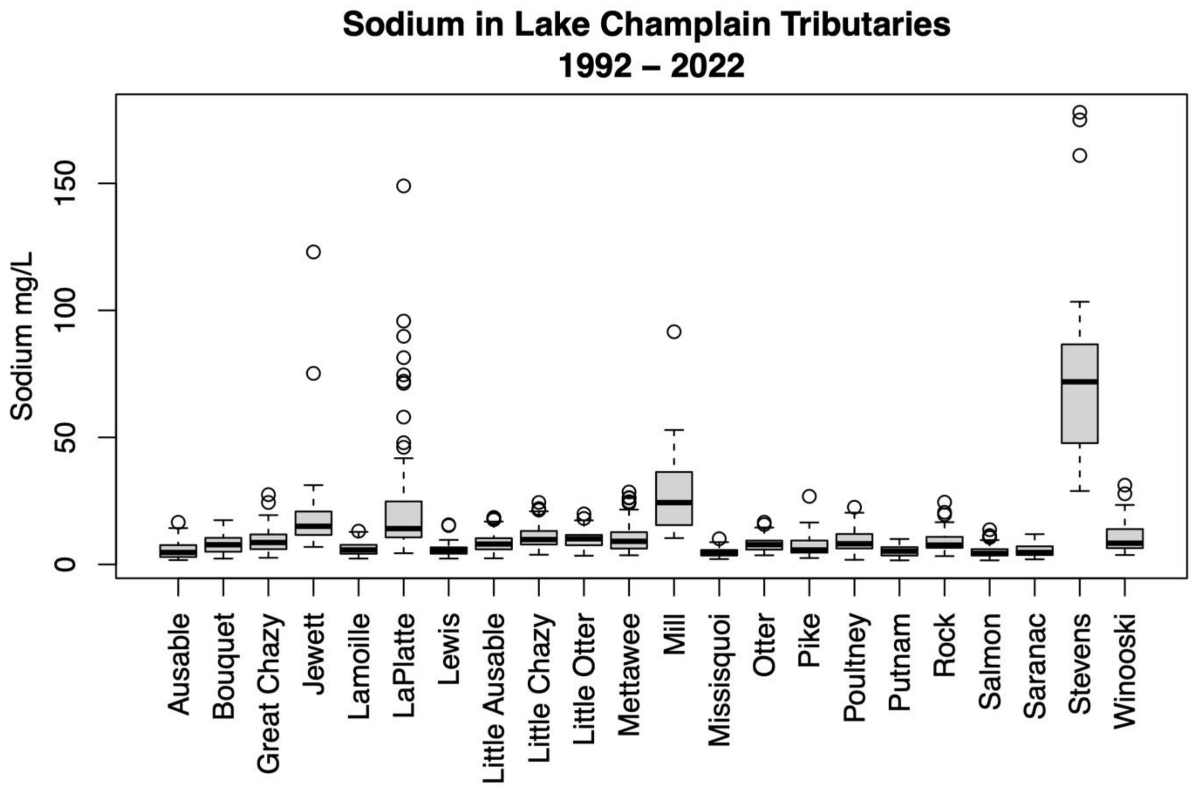

Dissolved Phosphorus in Lake Champlain Tributaries
1992 – 2022
Dissolved Phosphorus μg/L
0
200
600
1000
1400
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski

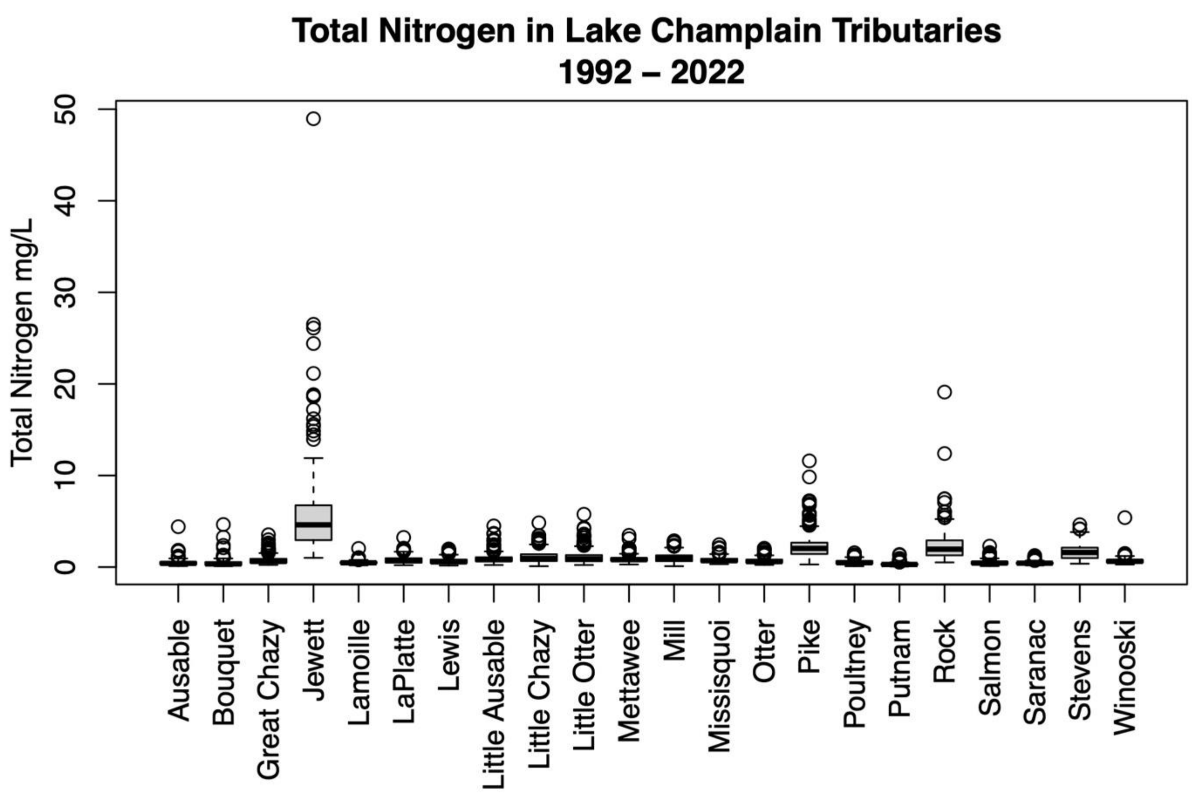

Iron in Lake Champlain Tributaries
1992 – 2022
Iron µg/L
0
5000
10000
15000
20000
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski


Magnesium in Lake Champlain Tributaries
1992 – 2022
Magnesium mg/L
0
5
10
15
20
25
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski

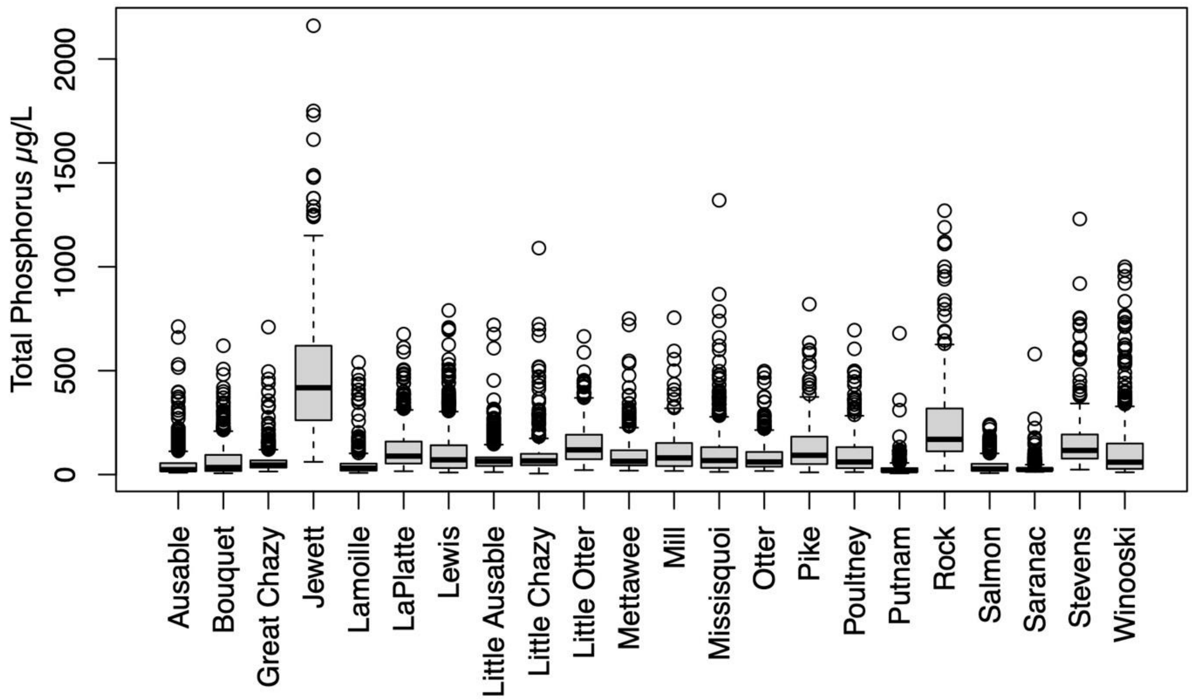

pH in Lake Champlain Tributaries
1992 – 2022
pH
6
7
8
9
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski


Potassium in Lake Champlain Tributaries
1992 – 2022
Potassium mg/L
0
5
10
15
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski


Sodium in Lake Champlain Tributaries
1992 – 2022
Sodium mg/L
0
50
100
150
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski


Total Nitrogen in Lake Champlain Tributaries
1992 – 2022
Total Nitrogen mg/L
0
10
20
30
40
50
Ausable
Bouquet
Great Chazy
Jewett
Lamoille
LaPlatte
Lewis
Little Ausable
Little Chazy
Little Otter
Mettawee
Mill
Missisquoi
Otter
Pike
Poultney
Putnam
Rock
Salmon
Saranac
Stevens
Winooski

Total Phosphorus in Lake Champlain Tributaries 1992 – 2022



Total Suspendid Solids in Lake Champlain Tributaries 1992 – 2022

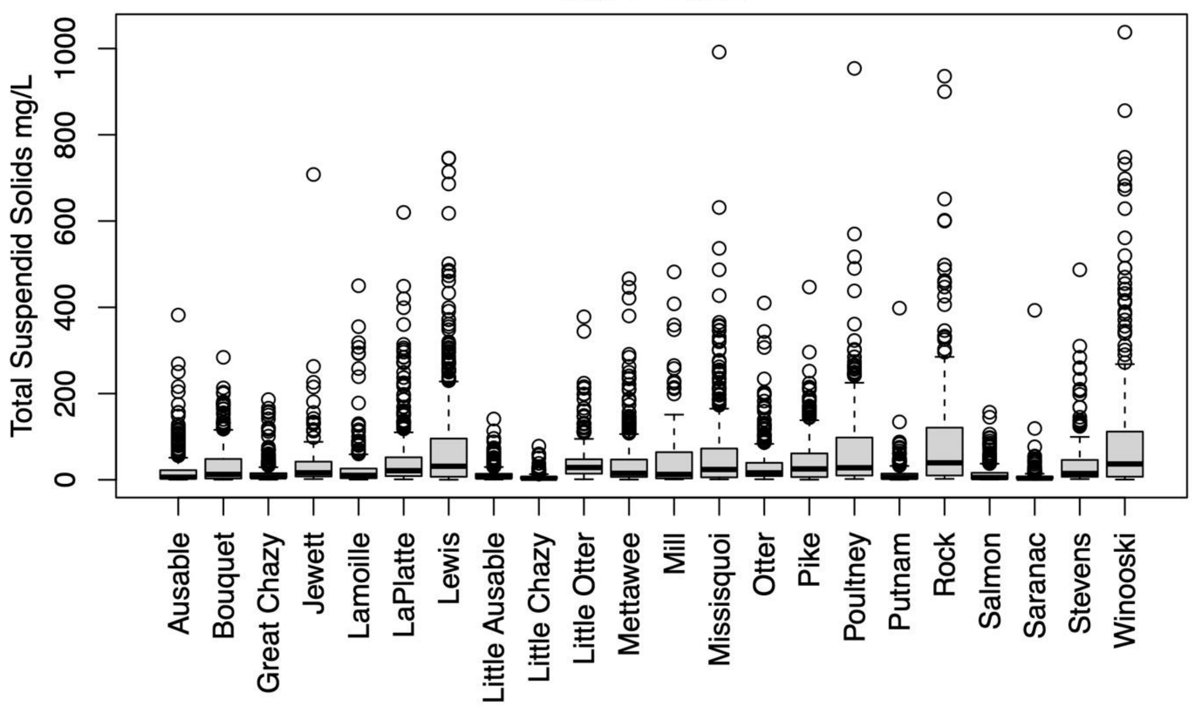
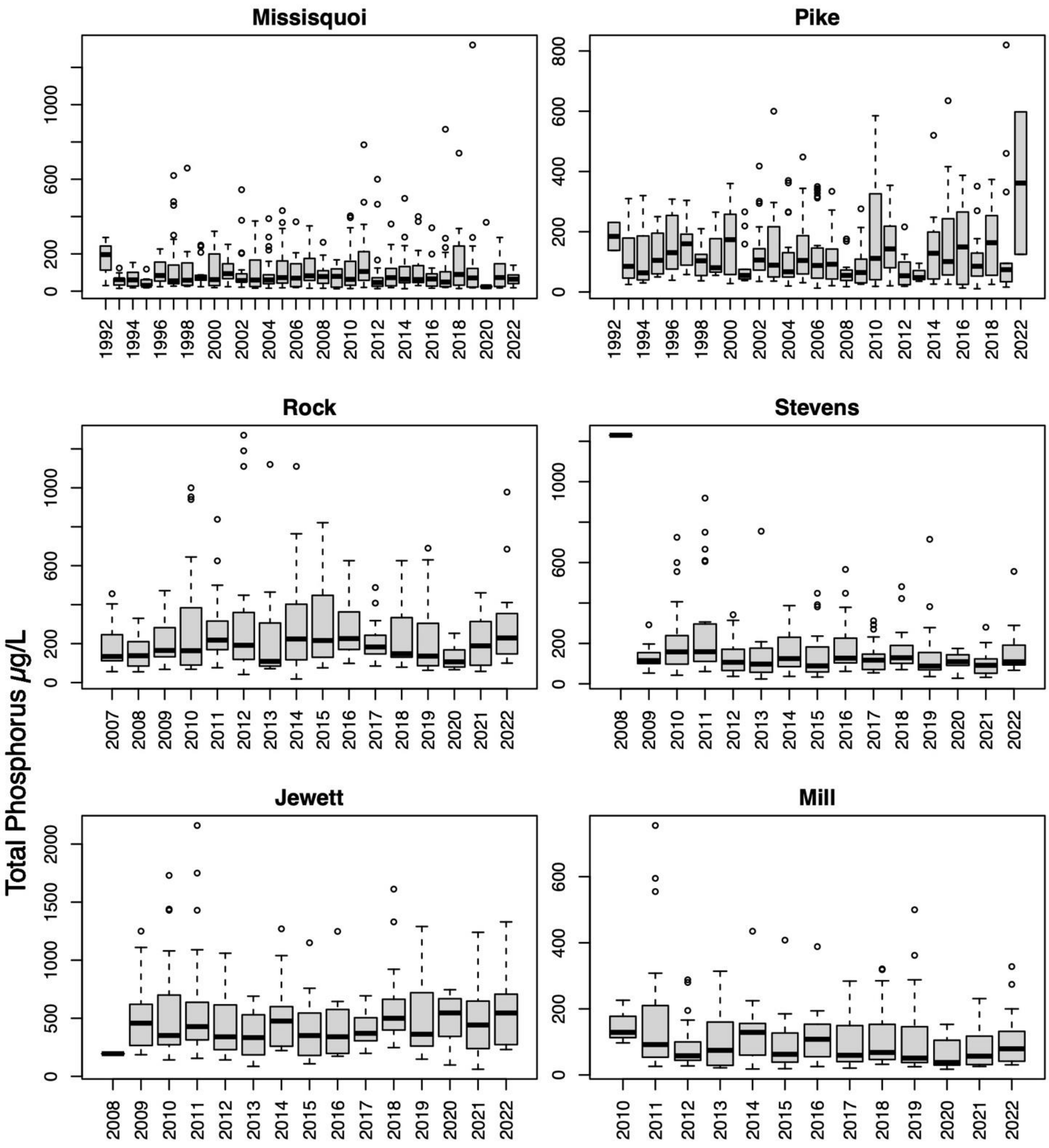
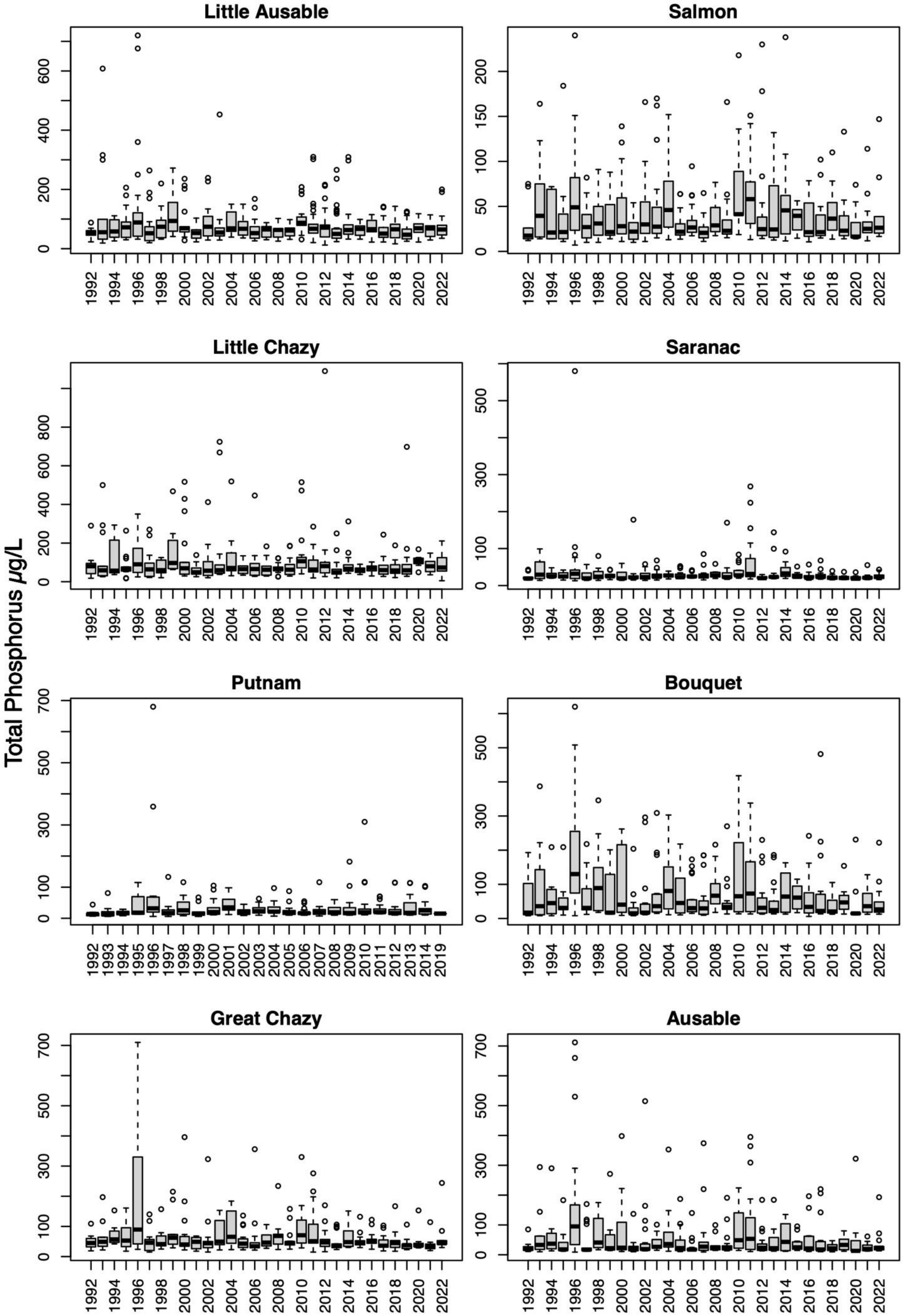
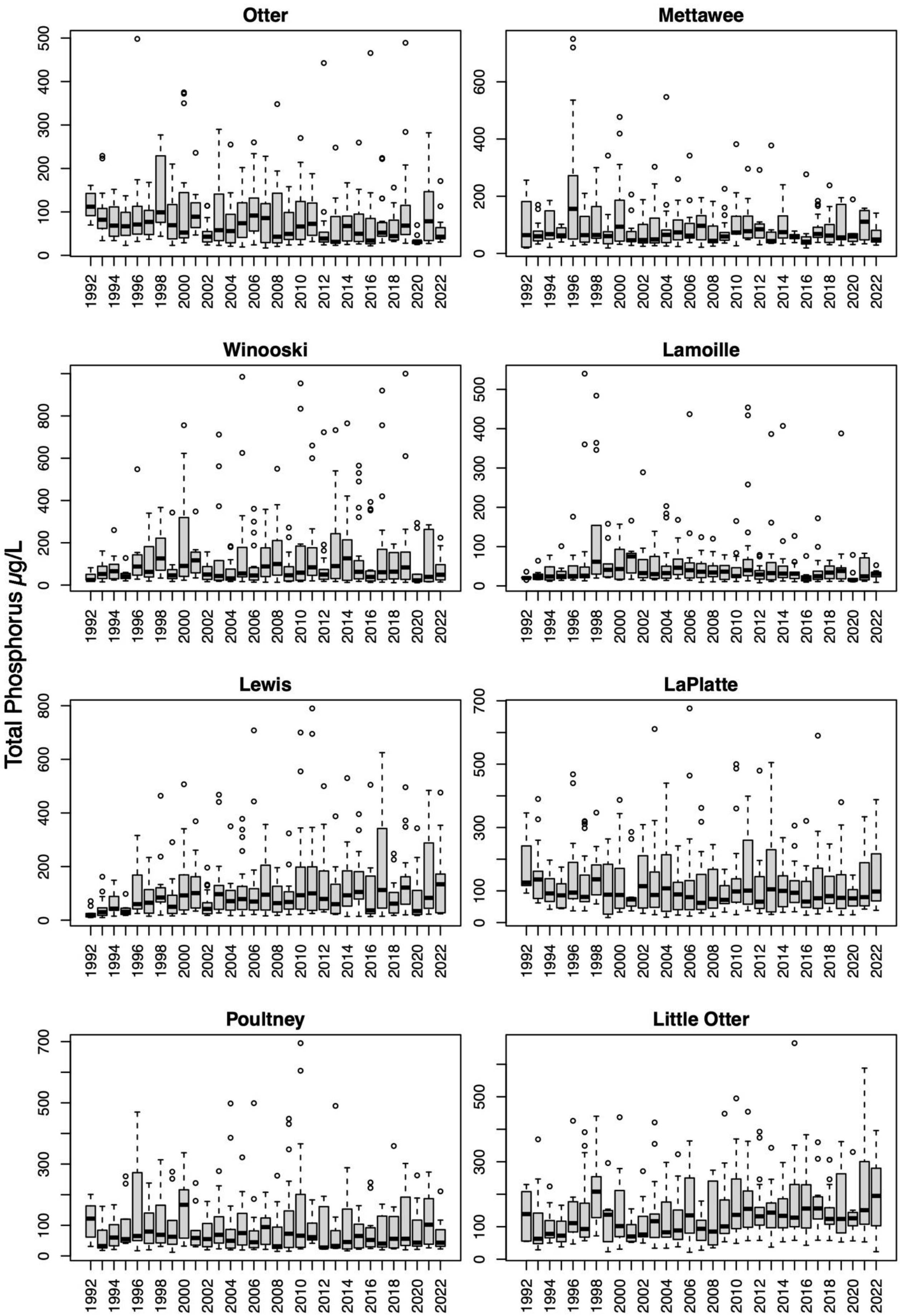


Figure C2: Boxplots of tributary concentrations for individual tributaries by year for selected analytes.

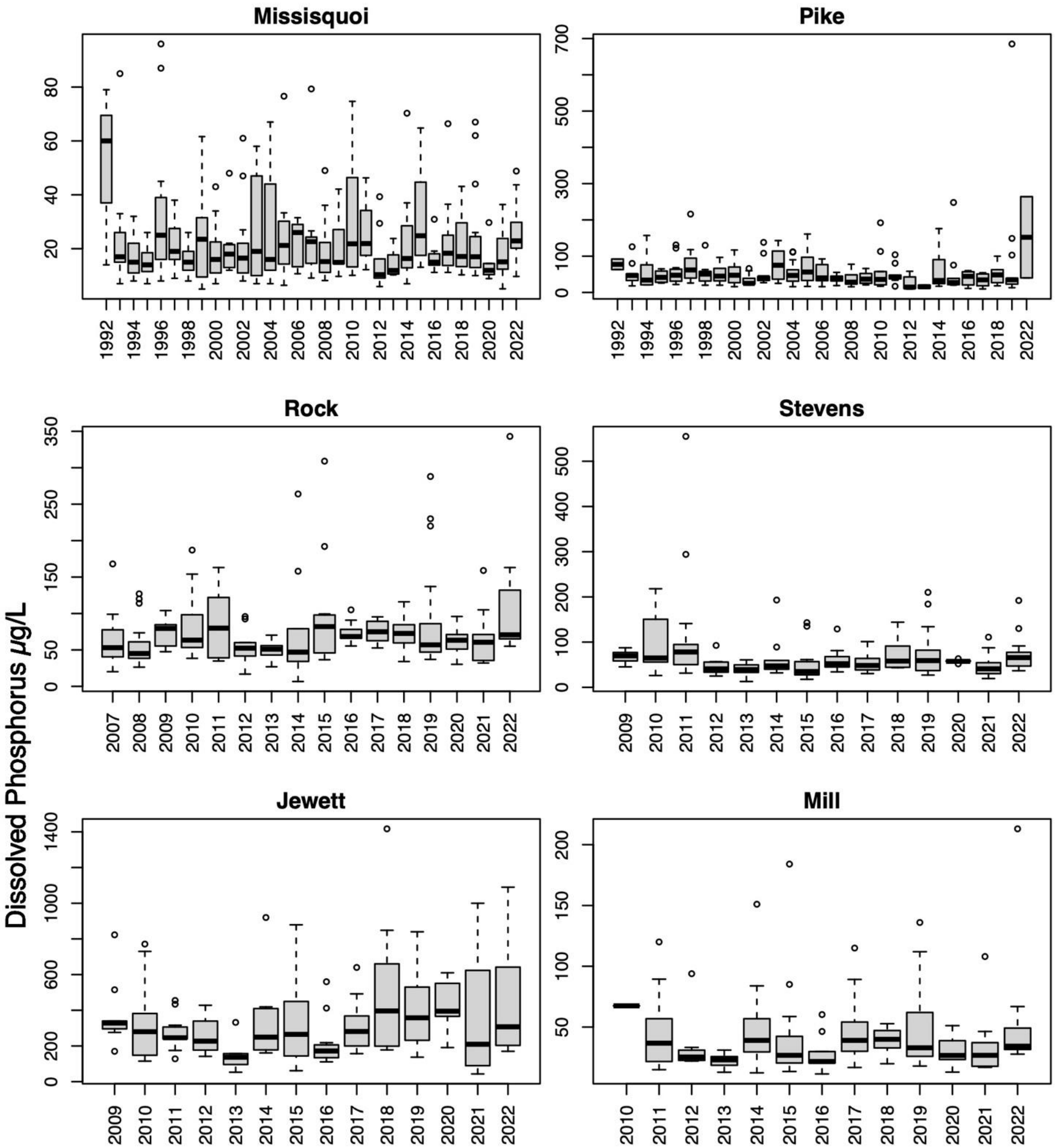
Total Phosphorus

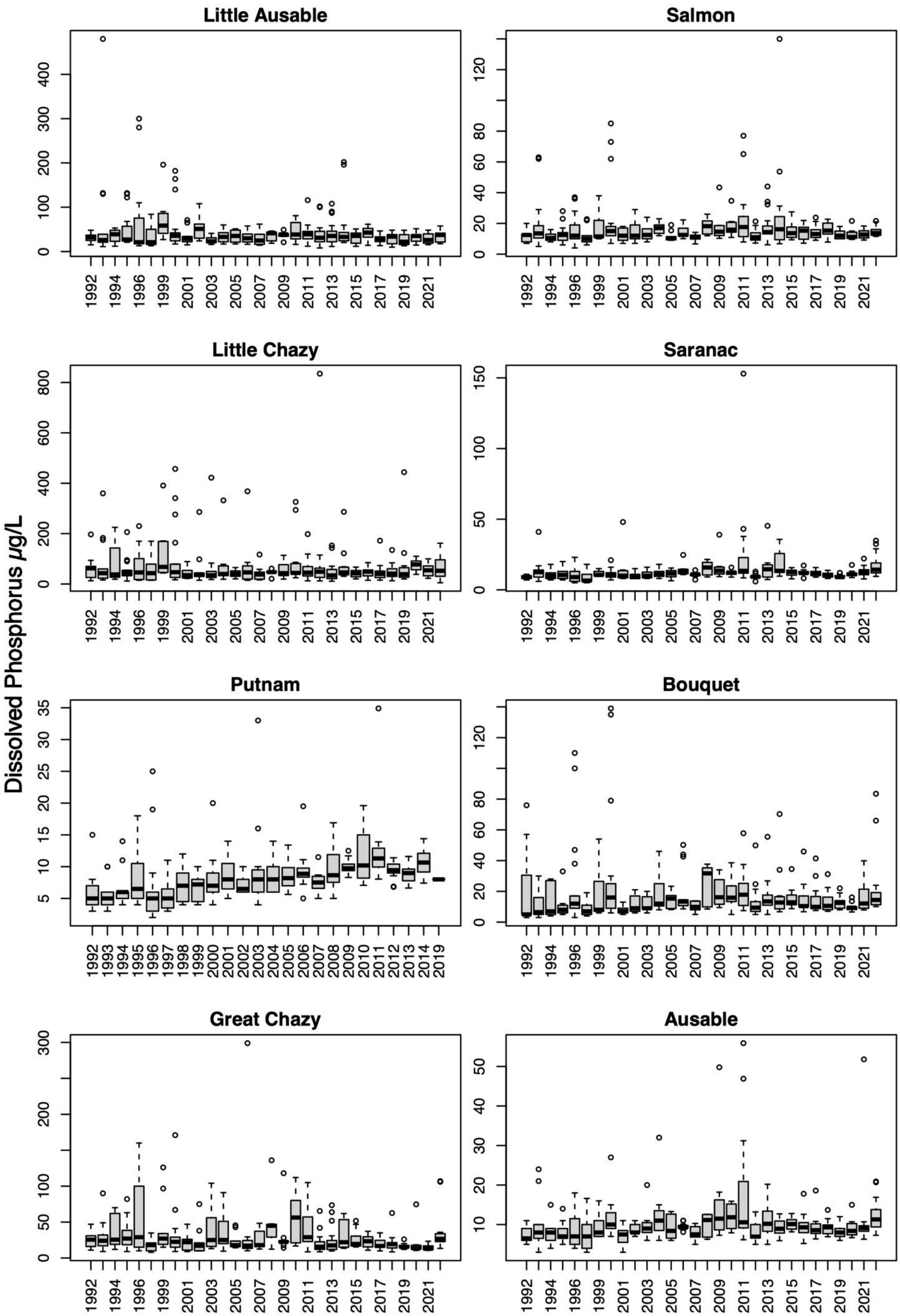


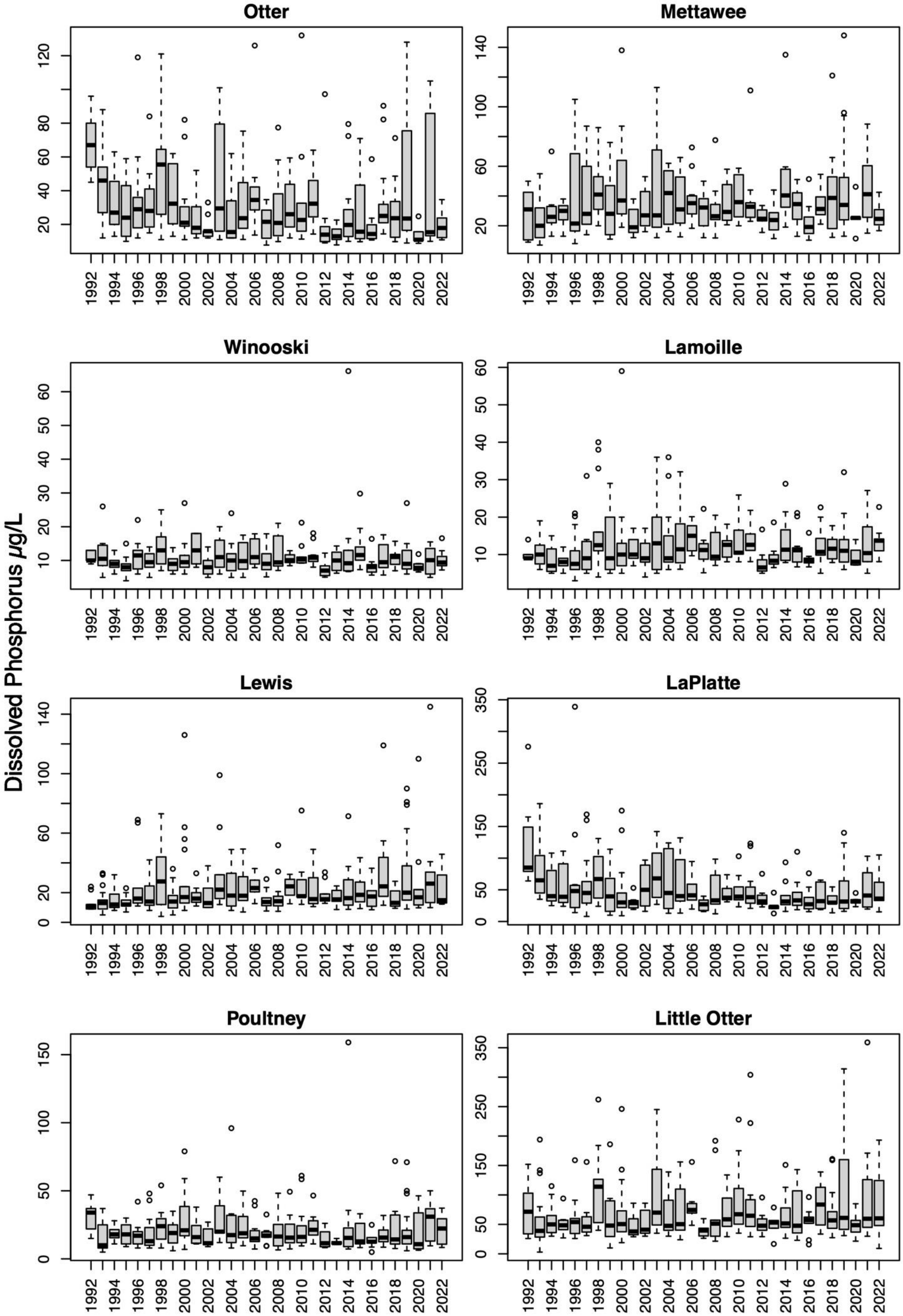

Little Ausable
Salmon
Little Chazy
Saranac
Putnam
Bouquet
Great Chazy
Ausable
Total Phosphorus μg/L


Otter
Mettawee
Winooski
Lamoille
Lewis
LaPlatte
Poultney
Little Otter
Total Phosphorus μg/L

Dissolved Phosphorus

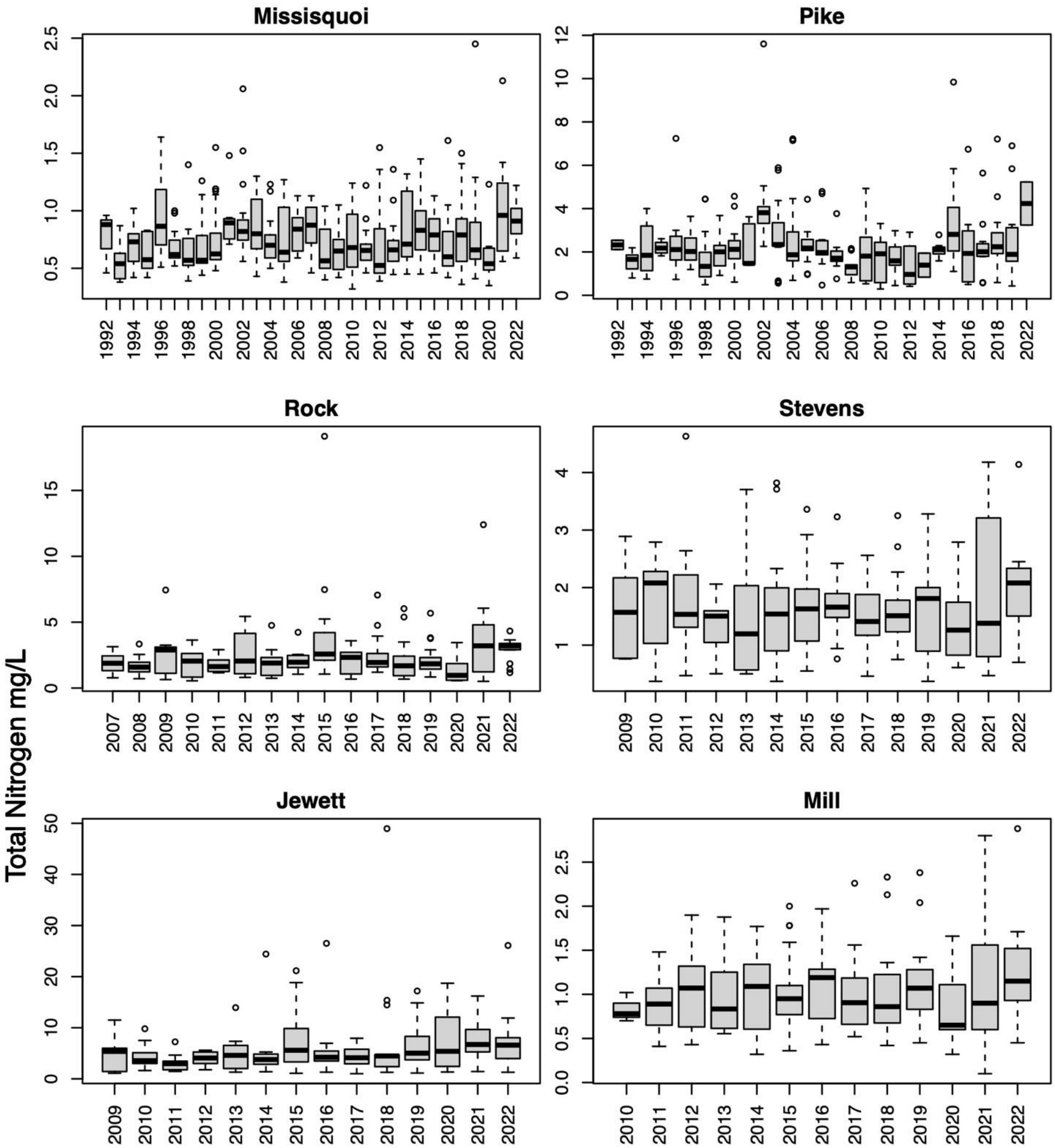


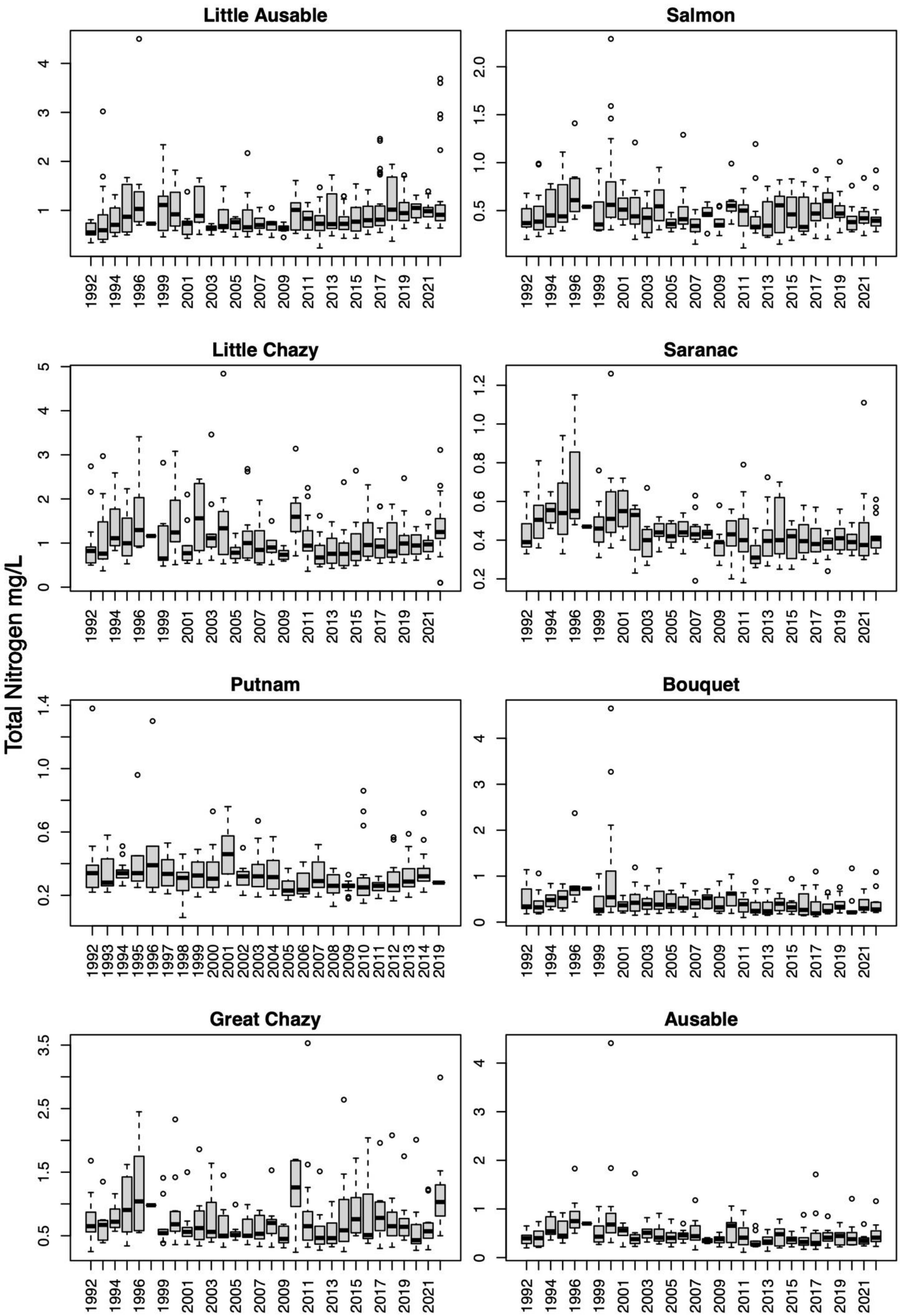

Little Ausable
Salmon
Little Chazy
Saranac
Putnam
Bouquet
Great Chazy
Ausable
Dissolved Phosphorus μg/L

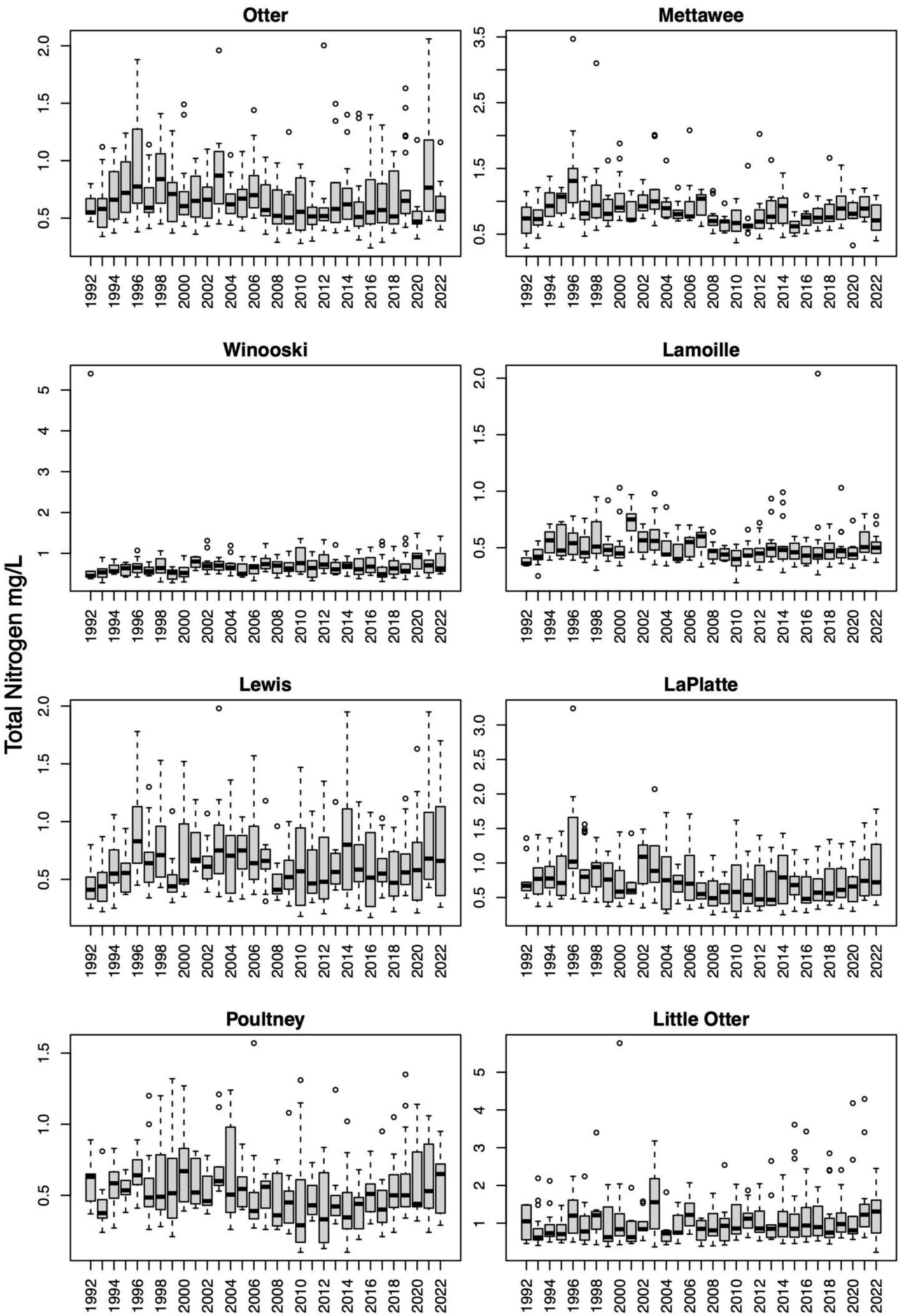


Otter
Mettawee
Winooski
Lamoille
Lewis
LaPlatte
Poultney
Little Otter
Dissolved Phosphorus μg/L

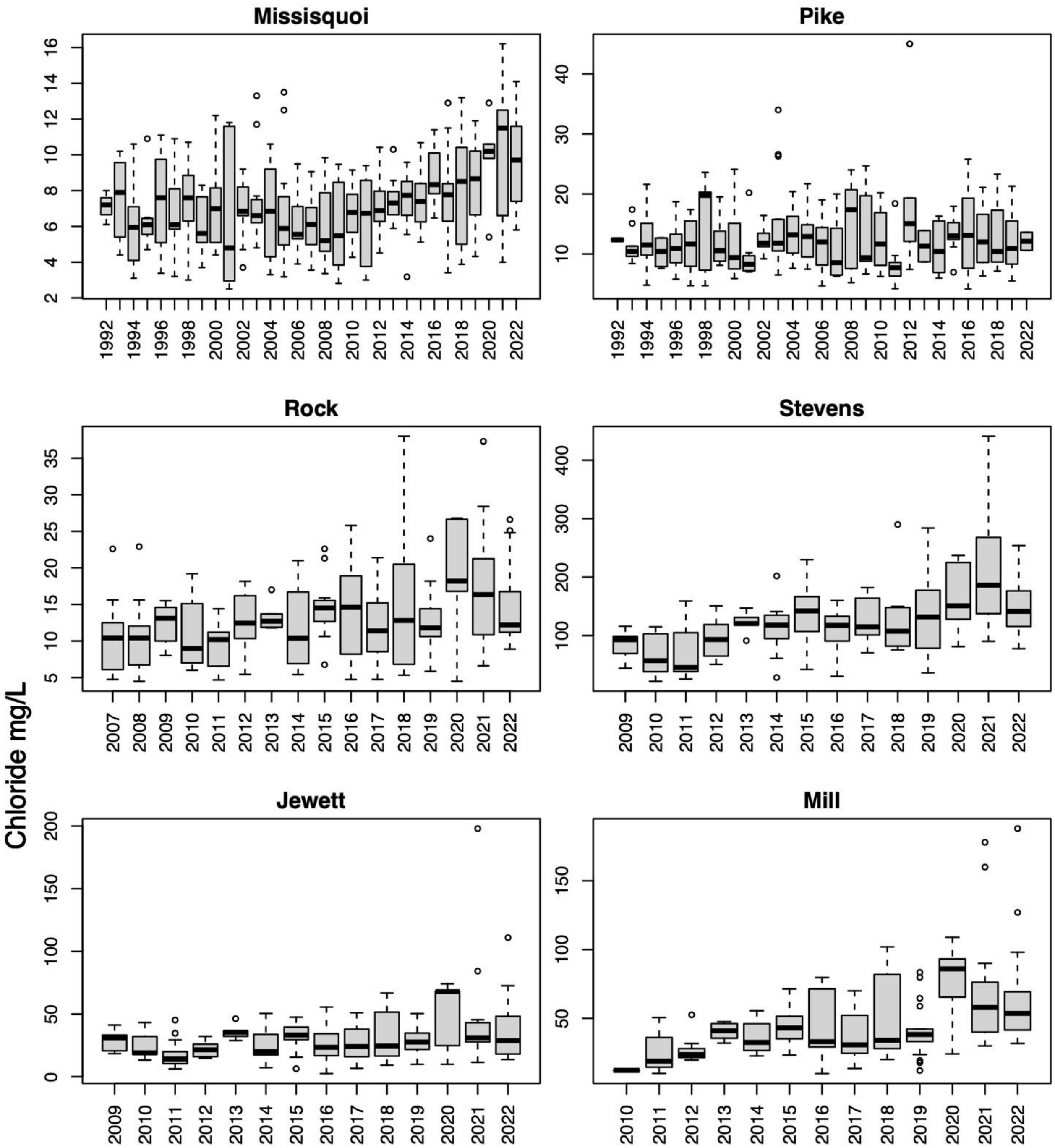
Total Nitrogen

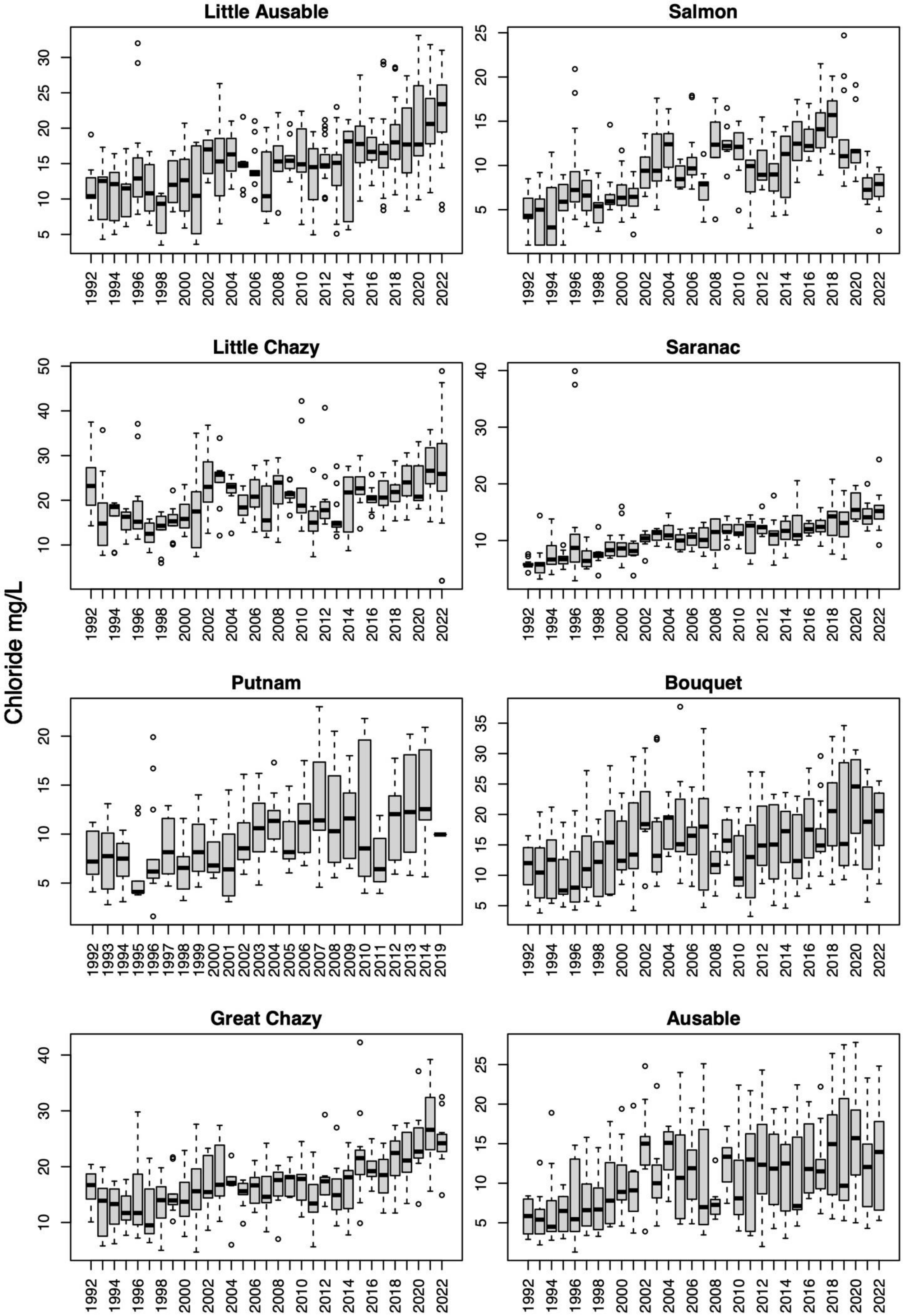


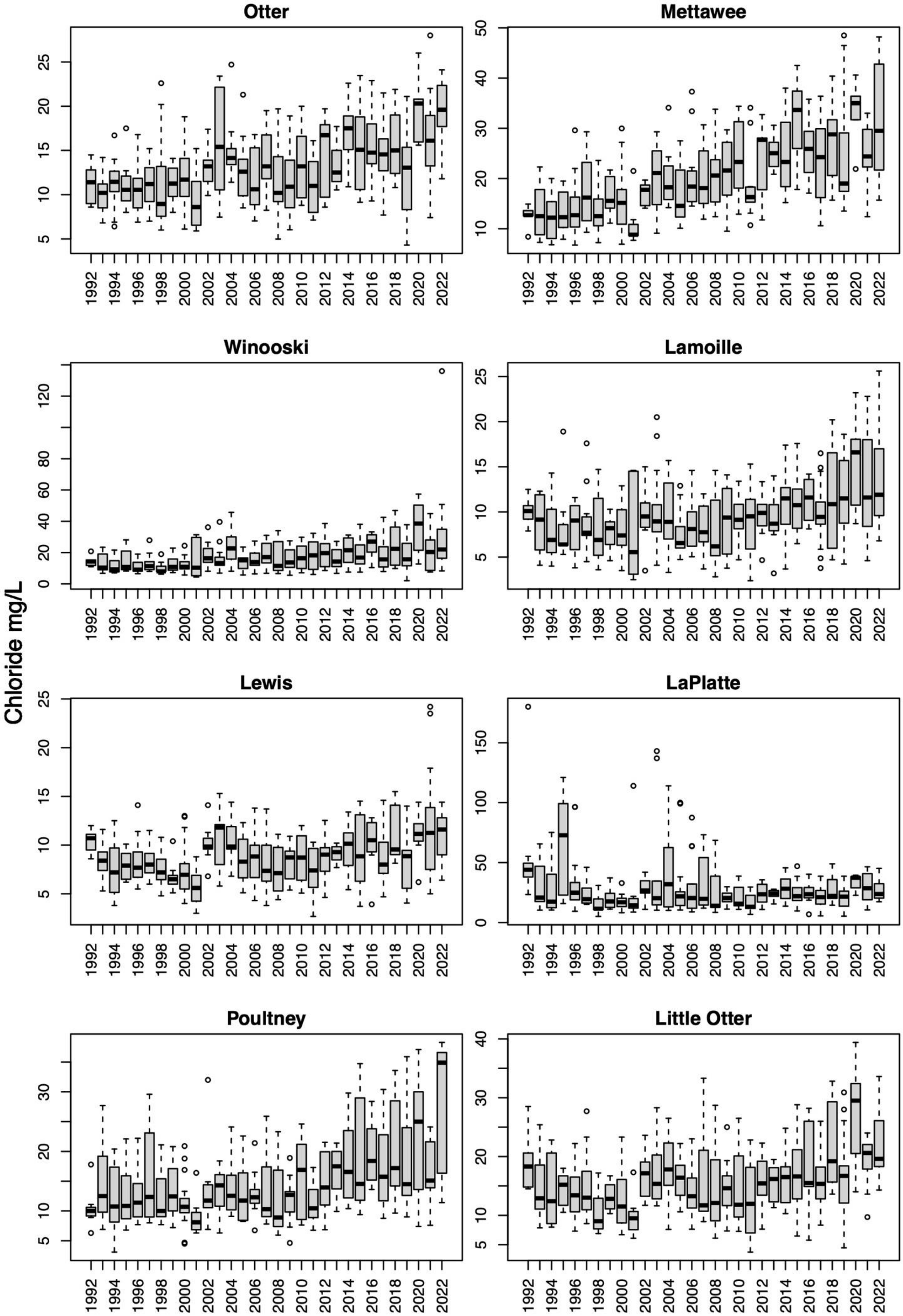

Little Ausable
Salmon
Little Chazy
Saranac
Putnam
Bouquet
Great Chazy
Ausable
Total Nitrogen mg/L


Otter
0.5 1.0 1.5 2.0
Mettawee
0.5 1.5 2.5 3.5
Winooski
1 2 3 4 5
Lamoille
0.5 1.0 1.5 2.0
Lewis
0.5 1.0 1.5 2.0
LaPlatte
0.5 1.0 1.5 2.0 2.5 3.0
Poultney
0.5 1.0 1.5
Little Otter
1 2 3 4 5
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
Total Nitrogen mg/L

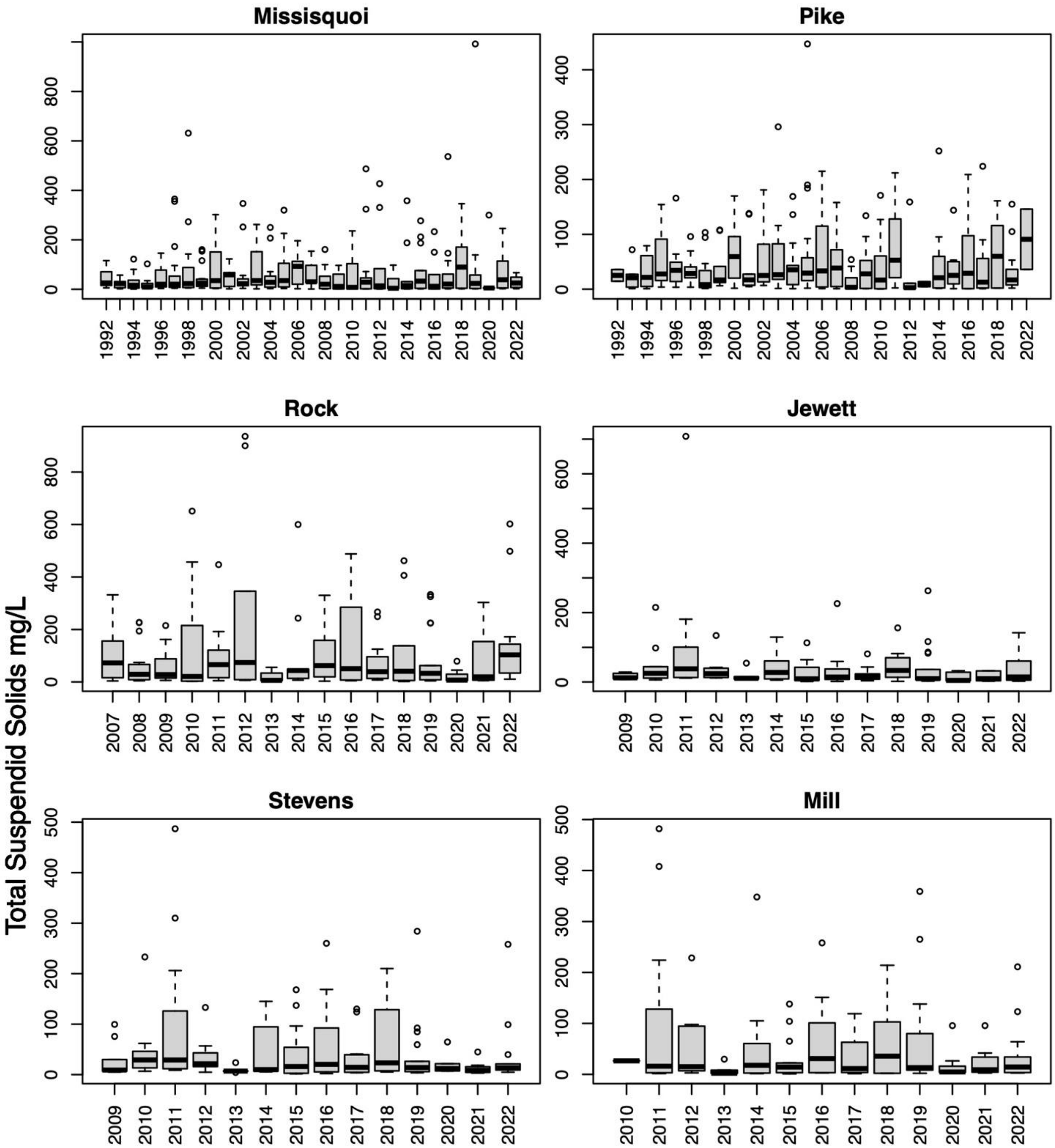
Chloride:

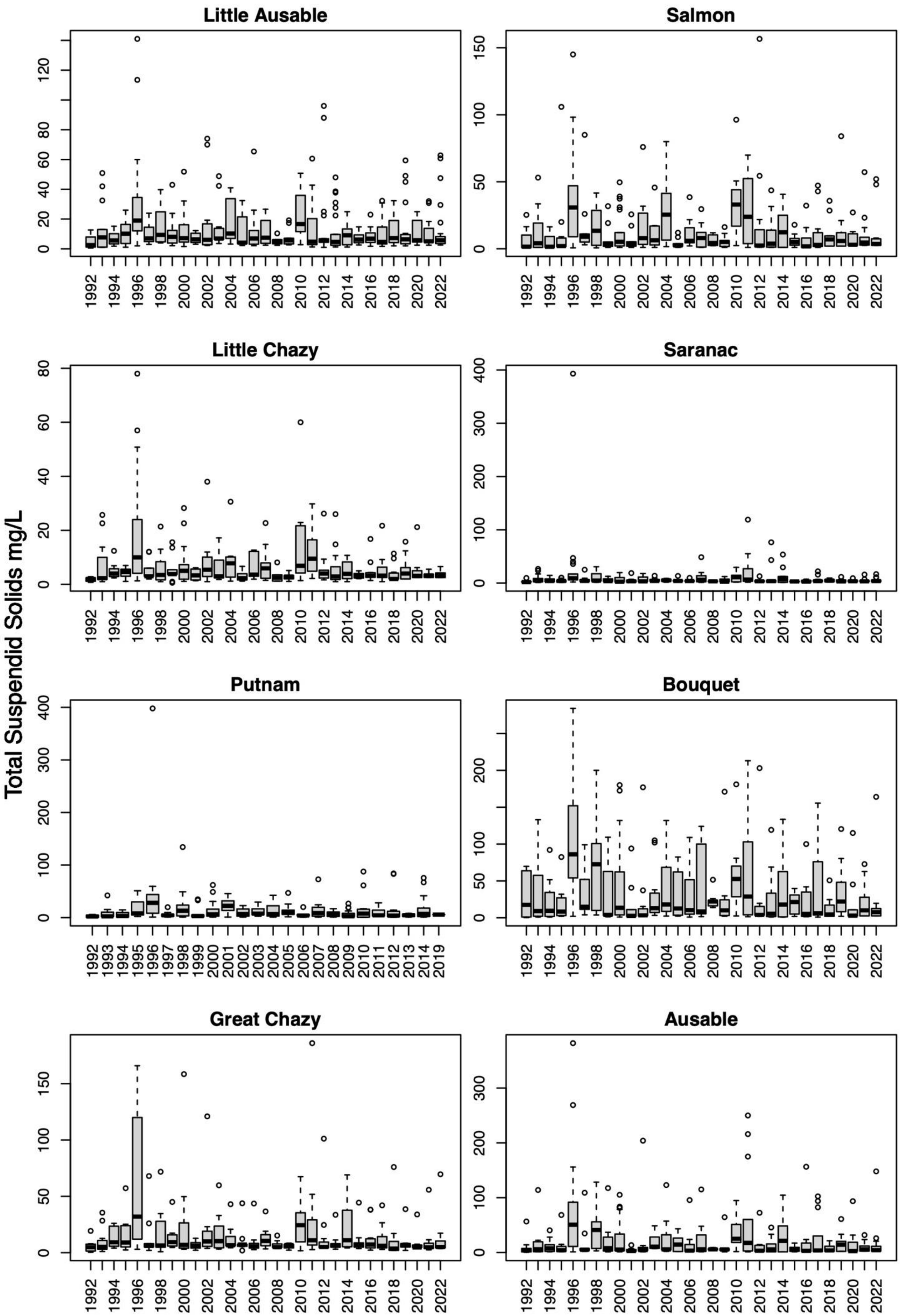


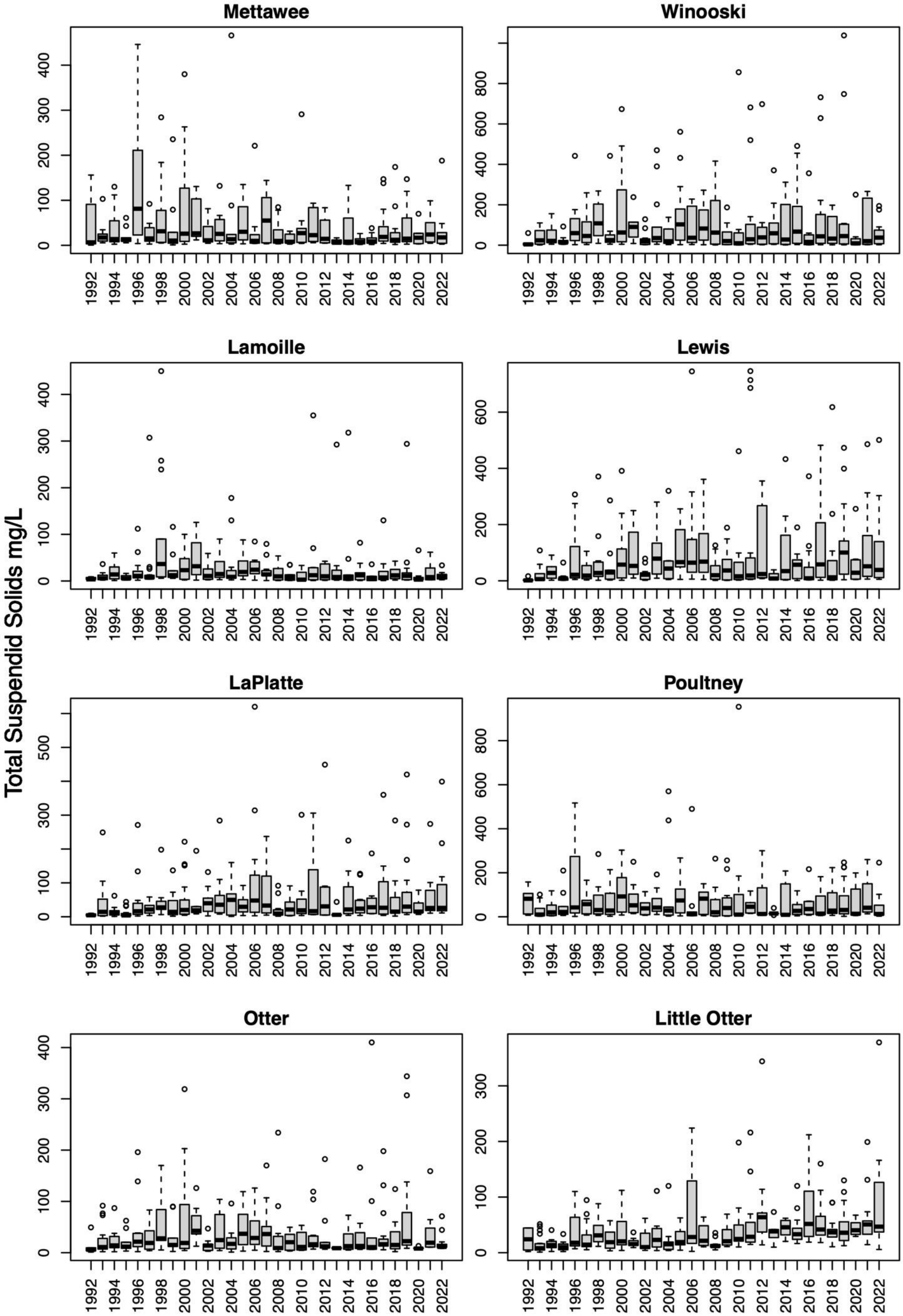

Little Ausable
Salmon
Little Chazy
Saranac
Putnam
Bouquet
Great Chazy
Ausable
Chloride mg/L


Otter
Mettawee
Winooski
Lamoille
Lewis
LaPlatte
Poultney
Little Otter
Chloride mg/L
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022

Total Suspended Solids




Total Suspendid Solids mg/L
Little Ausable
Salmon
Little Chazy
Saranac
Putnam
Bouquet
Great Chazy
Ausable



Total Suspendid Solids mg/L
Mettawee
Winooski
Lamoille
Lewis
LaPlatte
Poultney
Otter
Little Otter
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022