Appendix A: Precipitation Data

Table A1. Summary of 2022 and long-term precipitation data measured at the New Hope, MN station (Station ID: 215838).

Month	2022 Precipitation (inches)	1992-2021 Monthly Average Precipitation (inches)	Departure from Historical Average (inches)
January	0.87	0.95	-0.37
February	0.52	0.98	-0.32
March	2.82	1.88	0.64
April	2.5	3.18	1.53
May	3.28	4.26	-0.68
June	2.06	4.46	-3.34
July	0.86	4.39	-2.85
August	6.88	4.30	0.78
September	1.48	3.17	-2.71
October	1.88	2.92	-2.55
November	0.85	1.66	0.48
December	1.95	1.42	0.86
TOTAL	25.95	33.55	-8.53

Appendix B: 2022 West Mississippi Stream Data

65th Avenue

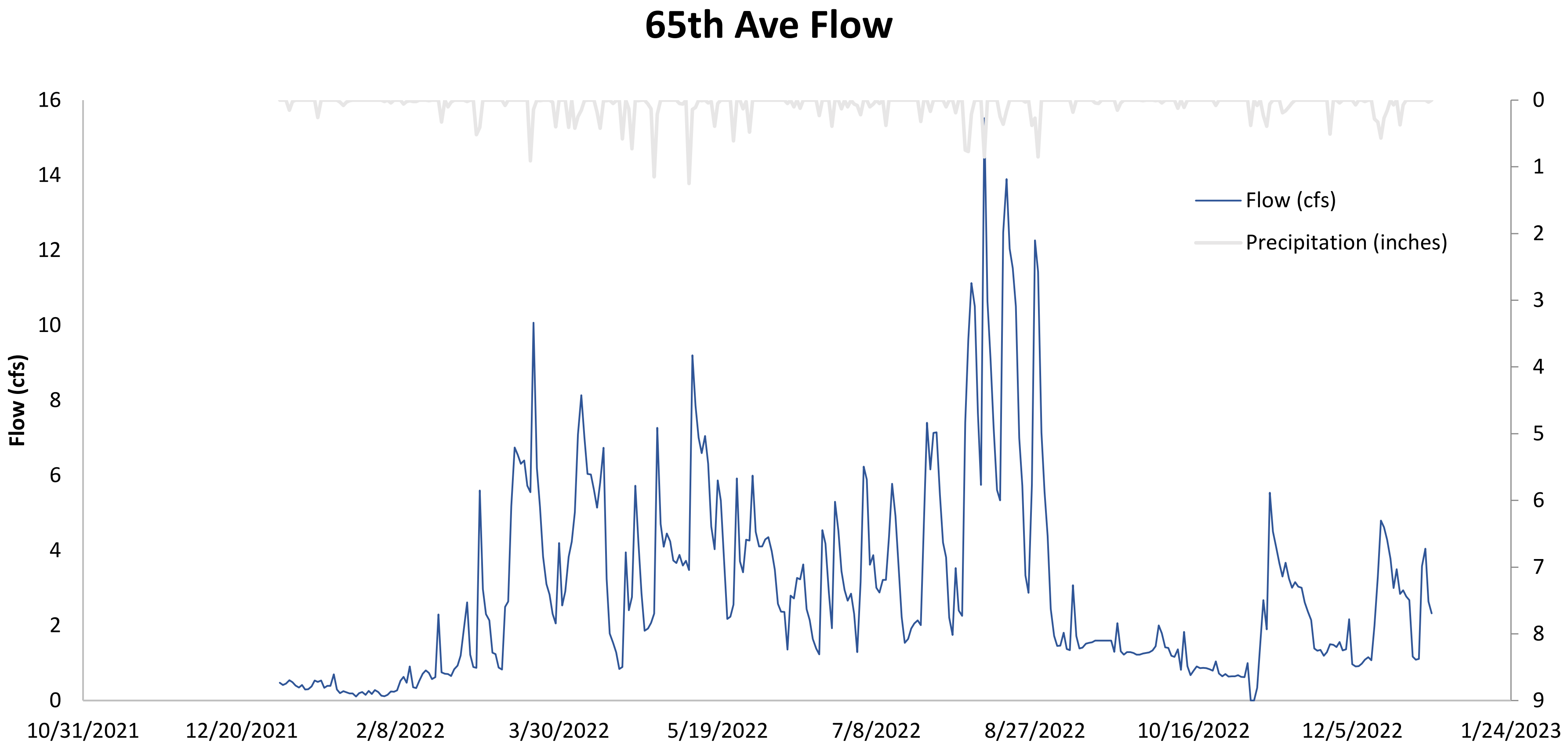


Figure B1. Flow at the 65th Ave sampling station in 2022. The blue line represents flow in cubic feet per second (cfs). Daily precipitation, measured at the New Hope, MN weather station, totals in inches are represented in gray on the secondary axis.

Table B1. Water quality data from the 65th Ave site measured in 2022. Parameters measured include temperature (temp.), dissolved oxygen (DO), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS), chloride, Escherichia coli (E. coli), Volatile Suspended Solids (VSS) and Total Kjeldahl Nitrogen (TKN).

Date	Time	Temp. [°C]	DO [mg/L]	pH	Sp. Cond. [µS/cm]	Salinity [ppt]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]	VSS [mg/L]	TKN [mg/L]
1/4/2022	9:00	36.1	12.39	8.15	1787.4	0.90	0.112	0.03	5	388	93	~2	2.3
2/15/2022	8:55	33.4	13.20	7.93	2739.2	1.39	0.268	0.122	6	716	112	3	1.8
2/28/2022	16:50						0.446	0.189	91	2530		42	4.2
3/1/2022	9:10	41.6	11.36	8.63	2363.7	1.21	0.189	0.058	8	588	299	4	1.5
4/5/2022	8:05						0.083	0.015	4	278	435	<3	1.2
5/3/2022	8:10	48.9	10.75	7.35	1044.0	0.52	0.056	0.013	4	240	43	3	1.1
6/7/2022	7:50	62.1	9.87	8.74	1458.8	0.74	0.07	0.0175	3.00	307.50		<3	1.25
7/5/2022	9:15	70.9	8.34	8.34	1361.3	0.68	0.11	0.051	<3	251.00	326	<3	0.955
8/2/2022	8:50	67.8	8.79	8.79	1530.9	0.77	0.081	0.058	<3	316	140	<3	0.8
8/16/2022	8:45	65.4	8.23	7.35	1136.2	0.57	0.098	0.049	<3	197	126	<3	1
9/6/2022	8:30	71.2	9.65	7.51	411.0	0.20	0.092	0.032	3	264	63	<3	0.94
9/20/2022	8:45	64.1	8.69	7.19	1518.0	0.77	0.04	0.0235	<3	277.00	172	<3	0.665
10/18/2022	8:55	47.8	10.37	7.41	1468.5	0.74	~0.047	0.012	<3	288		<3	0.71
11/1/2022	8:20	55.3	9.56	7.25	1475.0	0.75	0.050	0.019	<4	293		<4	0.79
12/6/2022	13:36	41.2	11.41	7.34	1541.0	0.77			3.00			<3	

Table B2. Other water quality data from the 65th Ave site measured on four different dates in 2022. Parameters measured include Alkalinity, Ammonia, CBOD5-day, Chemical Oxygen Demand, Nitrate/Nitrate, Nitrate/Nitrite, Nitrite+Nitrate, Sulfate, TBOD5-day, Total Dissolved Solids, Total Organic Carbon, and Total Zinc.

Date/Time	**4/6/22 02:10	6/7/22 07:51	7/5/22 09:15	8/2/22 08:50	8/16/22 08:45	9/20/22 08:45	10/18/22 08:55	11/1/22 08:20
Alkalinity, total	61	265	526	291	215	616	303	300
Ammonia Nitrogen	0.32	0.23	0.37	0.21	0.24	0.27	0.19	0.18
CBOD_I-5-day		2.6	3	0.7	2.1	2.2	1.2	1.5
COD	28	22	40	15	25	34	17	15
Copper						4.6	5	
Nitrate N	0.36	0.91	1.85	1.39	0.8	2.43	1.32	1.22
Nitrite N	0.06	0.06	0.12	0.06	0.06	0.18	0.06	0.06
Nitrite Plus Nitrate	0.36	0.91	1.85	1.39	0.8	2.61	1.32	1.22
Sulfate (SO4)	14.6	82.1	182	76.3	55.5	148.2	74.6	74.3
TBOD_I 5-day		2.7	3.2	0.8	2.1	2.8	1.3	1.6
Total Dissolved Solids	298	831	1568	863	641	1736	849	832
Total Organic Carbon	4.2	5.1	9.8	3	7.1	6.1	2.7	2.9
Zinc						19	5	

** Sample taken from a storm capture day

Table B3. Stormwater quality data from the 65th Ave site in 2022. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS), Escherichia coli (E. coli), Volatile Suspended Solids (VSS) and Total Kjeldahl Nitrogen (TKN).

Start Date	Time	End Date	Time	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]	VSS [mg/L]	TKN [mg/L]
3/22/2022	11:55	3/23/2022	20:40	0.177	0.039	56	208	23	1.2
4/6/2022	2:10	4/6/2022	8:17	0.0485	0.013	12		6	0.91
5/11/2022	19:30	5/12/2022	1:40	0.232	0.046	67	6300	27	1.8
8/6/2022	7:55	8/6/2022	17:55	0.2	0.056	53		17	1.2

Table B4. Annual Nutrient and Chemical Loading for the 65th Ave site.

Site	TP load (lbs)	TSS load (lbs)	Chloride load (lbs)
65th Ave	60	732	190,098

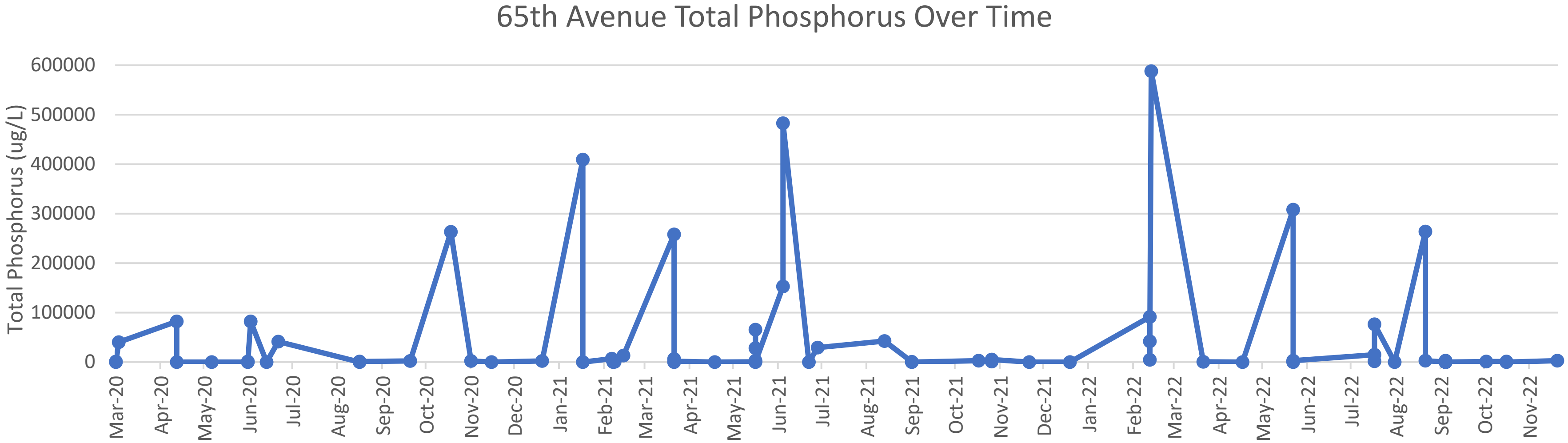


Figure B2. Total Phosphorus trends from 2020 to 2022 for the 65th Ave site.

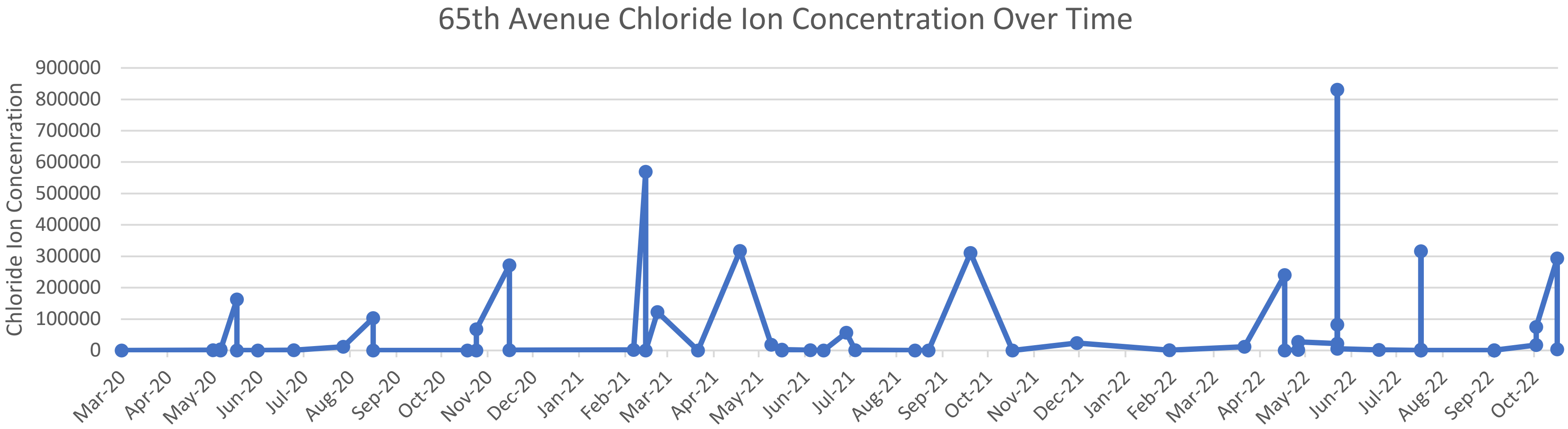


Figure B3. Chloride trends from 2020 to 2022 for the 65th Ave site.

Environmental Preserve

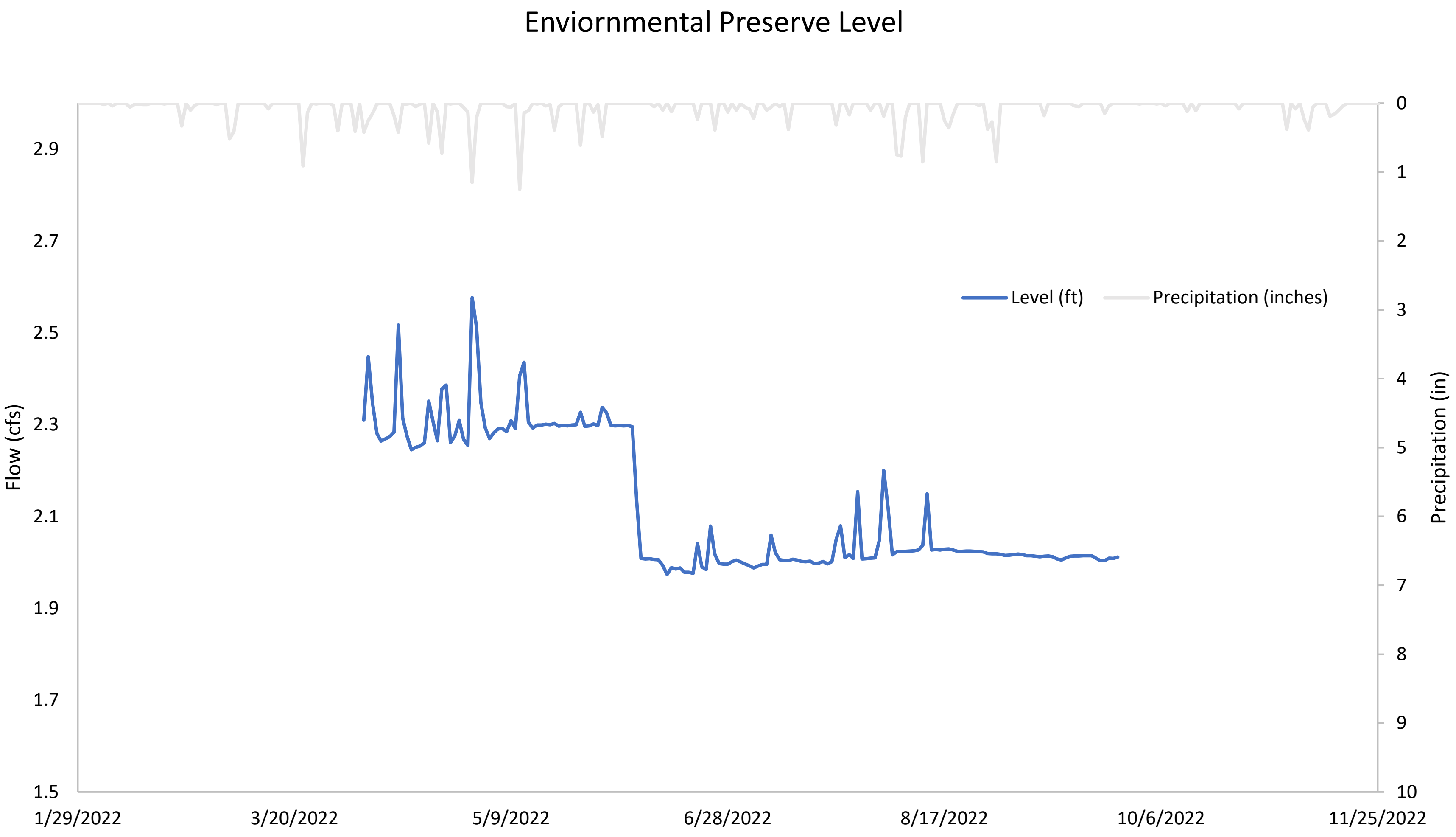


Figure B4. Level at the Environmental Preserve sampling station. The blue line represents level in feet (ft). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table B5. Water quality data from the Environmental Preserve (ENVP) stream site measured in 2022. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. Cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
5/10/2022	13:16	19.84	12.54	141.5	8.19	885.5	379	0.089	0.01	2.3	7.8	
6/7/2022	11:57	17.514	6.9	75	7.54	427.3	171.9	0.132	0.034	1.9	10.4	201.4
7/15/2022	11:55	23.479	6.63	80.2	7.76	544	97.8	0.173	0.082	2.1	18.2	770.1
8/3/2022	11:25	22.162	6.57	78.5	7.73	579	163.1	0.179	0.119	24	10.6	259.5

Table B6. Storm water quality data from the Mattson Brook stream site measured in 2022. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	Time	TP [mg/L]	OrthoP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
5/25/2022	8:15	5/26/2022	6:47	0.182	0.022	30	648.8
8/12/2022	6:34	8/13/2022	12:19	0.19	0.043	28.4	> 2419.6
8/18/2022	17:46	8/19/2022	23:31	0.133	0.028	11.8	1119.9

Appendix C: 2022 Shingle Creek Stream Data

OVERVIEW

Shingle Creek (AUID 07010206-506) is impaired for chloride, aquatic life (macroinvertebrate IBI, fish IBI), and aquatic use (*E. coli*). Bass Creek (AUID 07010206-784), a headwater stream to Shingle Creek, is impaired for chloride and aquatic life (macroinvertebrate IBI, fish IBI). West Mississippi streams have not been assessed. The Shingle Creek and West Mississippi Third Generation Watershed Management Plan includes annual monitoring of four stream locations in the Shingle Creek Watershed, one on Bass Creek (BCP) and three on Shingle Creek (SC-3, SC-0, and USGS), and rotating monitoring of two sites in the West Mississippi Watershed (ENVP, Mattson Brook, Oxbow, and 65th Ave). The primary purpose of the stream monitoring program is to assess progress toward achieving the TMDLs and state water quality standards for the impaired streams and to track water quality of unimpaired streams. Activities included in the stream monitoring program include routine and storm water quality, flow, and conductivity monitoring. Three of the Shingle Creek sites (BCP, SC-3, and SC-0) and two rotating West Mississippi sites are monitored routinely during the growing season (April through October) for multiple water quality parameters. Shingle Creek sites are monitored once a month in the winter (November through March) for chloride concentrations. The USGS site is only monitored in the winter for chloride.

In Section 1.0, we provide an overview of the various stream sampling methodologies (Section 1.0) used to collect routine water quality (Section 1.1), storm water quality (Section 1.2), flow and load calculations (Section 1.3), and conductivity (Section 1.4) data at the stream sites. In Sections 2.0 and beyond we summarize activities and results from 2020 monitoring for each of the four sites monitored.

Results and discussions for each Shingle Creek stream can be found in the following order:

- Section 2.0 – BCP
- Section 3.0 – SC-3
- Section 4.0 – SC-0
- Section 5.0 – USGS
- Section 6.0 – Rainfall

See Appendix B for West Mississippi streams data.

1.0 Sampling Methods

1.1 ROUTINE WATER QUALITY

Shingle Creek and West Mississippi streams are within highly urban areas but serve as important water features to the cities they flow through. The streams flow through various parks and have multiple miles of adjacent walking paths. The streams are home to many animals including muskrats, fish, crayfish, and ducks. The Minnesota Pollution Control Agency (MPCA) monitors and assesses streams around the state to determine if they meet water quality standards. The agency relies on local partners, including soil and water conservation districts, watershed districts, tribal entities, nonprofit groups, and citizens to help monitor the thousands of streams in the state. Shingle Creek Watershed Management Commission (Commission) is an active participant in aiding the MPCA in sampling and collecting information on the state of water quality of its streams. The Commission is focused on sampling total suspended solids, total phosphorus, total dissolved phosphorus, soluble reactive phosphorus, chloride, and *E. coli*. In addition to these parameters for water quality standard comparison, the Commission collects certain chemical and physical parameters on its streams.

Routine stream monitoring samples are typically collected twice per month starting in April and ending in October. For three streams (BCP, SC-3, and SC-0), water samples are collected and assessed for total suspended solids (TSS), total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorus (ortho-P), chloride, and *E. coli*. In addition to these chemical parameters, *in-situ* readings of physical parameters are also taken. A YSI or similar multimeter water quality sonde is used to collect these measurements. Parameters measured include dissolved oxygen (DO) concentration, water temperature, pH, oxidation-reduction potential (ORP), and specific conductivity. During the late fall, winter, and early spring chloride samples and physical parameters are taken at the three previously mentioned stream sites and one additional site (USGS).

Stream stage height at BCP, SC-3, SC-0, and West Mississippi monitoring sites is measured using an automated water sampler (ISCO model 6712) which is deployed in early April until late October. The ISCO water sampler is connected to a pressure transducer deployed in the stream (ISCO 720 Submerged Probe Flow Module). Stage height is periodically adjusted throughout the monitoring season using stream tape-down measurements taken in the field. Tape-down measurement are the distance to water from a known, fixed elevation in or near the stream. Stream stage height is converted to flow (discharge) measurements during data processing. The process is described in Section 1.3. Flow data are collected year-round at the USGS gage site 05288705 on Shingle Creek.

Flow data, lab samples, and *in-situ* data are used to understand the cycling of chemicals and nutrients in the stream system, identify watershed pollutant loads, and indicate areas of excess chemicals and nutrients.

1.2 STORM WATER QUALITY

Storm water quality samples are typically collected from April through October when a storm event of 0.5 inches or greater occurs. Storm samples are taken each year at BCP, SC-3, and SC-0 sites, and at West Mississippi sites chosen for routine monitoring that year. Storm event water samples are collected using the ISCO automated water sampler at 15-minute intervals. Discrete water samples are composited and sent to the lab for analysis of TSS, TP, TDP, OP, and *E. coli.* No physical parameters are measured during storm events.

1.3 FLOW AND LOAD CALCULATIONS

ISCO-measured state height is converted to flow measurements at the end of each field season. Field staff measure streamflow using a FlowTracker Handheld IDV (San Diego, CA) periodically throughout the monitoring season. Field staff developed a relationship between stream stage height and stream flow measured in the field. This relationship is fit with a polynomial equation that relates stage height to flow for the time that the ISCO is deployed (April through October). During winter months when the ISCO is not deployed at field sites, flow at SC-0, SC-3, and BCP is linearly interpolated using data from the USGS gage on Shingle Creek.

Flow and routine water quality samples are used together to generate load calculations for various water quality pollutants. Loads were estimated as the total streamflow volume at each site multiplied by the flow-weighted mean concentration (FWMC) of a given water quality parameter. Flow weighted mean concentrations are calculated as:

$$FWMC = \frac{\sum_{l}^{n} c_i * q_i}{\sum_{l}^{n} q_i}$$

Where c_i is the pollutant concentration of the i^{th} sample and q_i is the streamflow of the i^{th} sample.

1.4 CONTINUOUS SPECIFIC CONDUCTIVITY MONITORING

Specific conductivity and temperature is collected year-round at the USGS monitoring site. Specific conductivity and temperature are measured in 15-minute intervals and uploaded live to the USGS website.

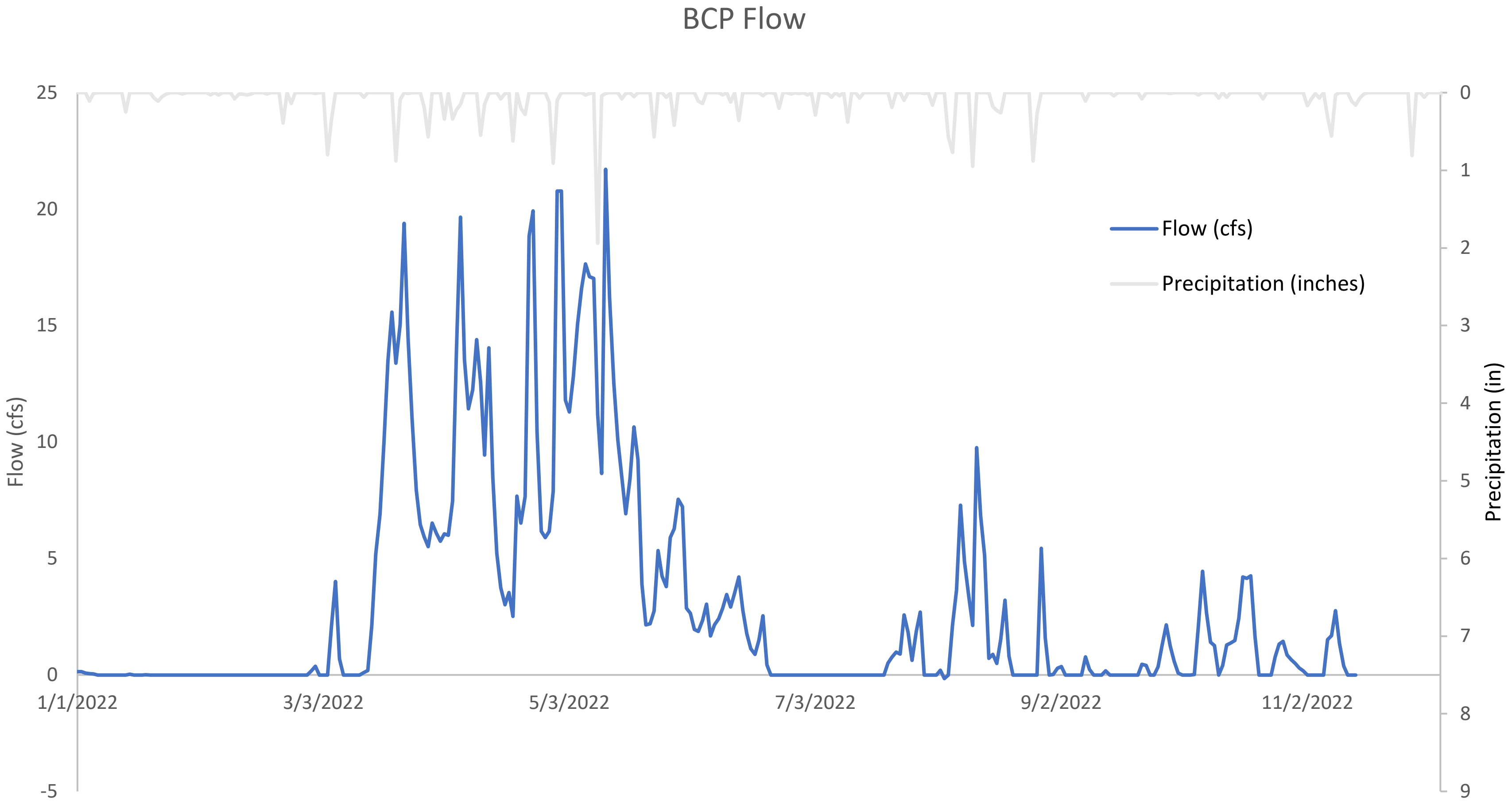


Figure C1. Flow at the BCP sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C1. Water quality data from the Bass Creek Park (BCP) stream site measured in 2022. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO$_{sat}$), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride and Escherichia coli (E. coli). Note that there is no data from February because water was frozen at this site during sampling events.

Date	Time	Temp. [°C]	DO [mg/L]	DO$_{sat}$ [%]	pH	Sp. Cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
3/16/2022	8:43											676	
3/30/2022	11:03											423	
4/11/2022	9:38	5.28	10.28	84.4	7.75	863.5	444	0.075	0.015	0.032	<3.3	201	22.6
5/10/2022	10:02	14.88	10.32	105.3	7.93	888	388	0.052	0.017	0.027	2.6	172	45.7
5/27/2022	10:12	12.594	8.9	86.7	7.59	975	173.1	0.08	0.019	0.048	1.9	223	172.3
6/7/2022	9:44	16.938	2.92	31.4	7.19	1299	190	0.199	0.013	0.06	8.8	278	214.3
6/21/2022	9:29	23.977	1.02	11.9	7.27	1285	158	0.307	0.017	0.057	17.5	288	1299.7
7/15/2022	9:38	23.26	2.84	34.3	7.27	548	131.5	0.268	0.063	0.196	4.4	170	159.4
7/21/2022	12:58	26.42	8.39	105.6	7.84	710	106.6	0.18	0.036	0.076	22.2	221	9.6
8/3/2022	8:59	22.96	2.02	24.5	7.43	645	186.9	0.104	0.032	0.053	8.3		24.3
8/18/2022	10:13	20.335	4.57	50.4	7.78	558	280.4	0.169	0.093	0.132	4	165	> 2419.6
8/30/2022	10:30	18.058	5.79	63	7.05	591	217.2	0.165	0.096	0.121	1.8	139	143.9
9/14/2022	10:26	15.968	70.2	6.73	7.22	959	223.2	0.068	0.017	0.063	2.3	229	60.2
10/5/2022	10:00	16.316	1.66	17.7	7.69	983	376.8						
10/18/2022	13:58	6.471	3.54	29.3	7.34	531	258						

Table C2. Storm water quality data from the Bass Creek Park (BCP) stream site measured in 2022. Parameters measured include total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
5/25/2022	7:28	5/26/2022	8:42	0.157	0.031	0.045	21	1413.6
7/26/2022	15:20	7/27/2022	21:05	0.182	0.028	0.065	52	> 2419.6
8/17/2022	17:06	8/18/2022	17:06	0.124	0.029	0.068	20.8	> 2419.6

Table C3. BCP historic load calculations including TP, TSS and Chloride load calculations for 2022.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2014	6,837	1,881	101	776	42	106,971	6			4,281	0.23	13,736	0.74		
2015	1,493	792	192	531	129	107,640	23.1			1,856	0.148	5,123	1.14		
2016	4,107	1,024	99	854	82	189,576	18.2					1,707	0.16		
2017	5,537	1,670	119												
2018	2,754	9,701	139												
2019	6,753	2,114	124												
2020	2,562	479	90			231,824	13.9							1,009,950	156
2021	1,566	454	107			58,231	13.7							581,796	137
2022	1,897	548	106			74,347	14.4							1,002,046	194

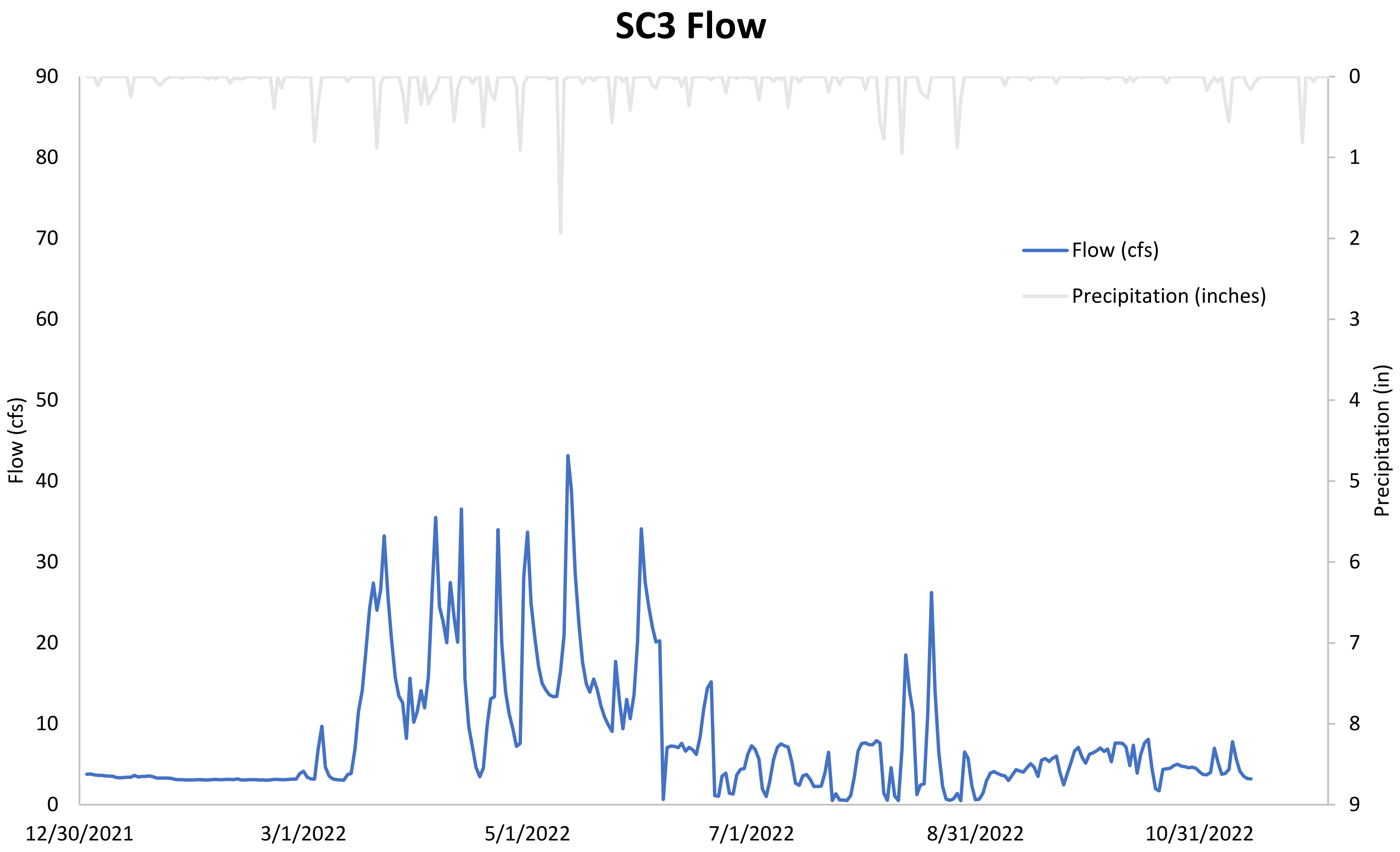


Figure C4. Flow at the SC-3 sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C4. Water quality data from the Shingle Creek SC-3 stream site measured in 2022. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DO_{sat}), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride (mg/L) and Escherichia coli (E. coli). Note that there is no data from January and February because water was frozen at this site during sampling events.

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
3/16/2022	9:04											747	
3/30/2022	11:26											240	
4/27/2022	12:46	6.45	13.35	110.8	7.86	1011.5	418	0.061	0.01	0.024 [1]	7.1	218	410.6
5/10/2022	11:06	15.05	8.62	88.1	7.79	969.3	373	0.065	0.028	0.043	1.7	186	62.4
5/27/2022	11:06	13.039	7.94	78.2	7.48	909	174	0.083	0.018	0.043	2.6	192	201.4
6/7/2022	10:16	17.344	2.81	30.5	7.23	1050	58.8	0.194	0.058	0.106	3.9	214	30.9
6/21/2022	10:24	23.67	0.93	11.2	7.13	350.1	94.4	0.463	0.153	0.199	13.4	45	> 2419.6
7/15/2022	10:27	18.976	4.68	50.6	7.34	631	117.2	0.303	0.074	0.244	19.8	152	344.8
7/21/2022	12:16	16.266	6.14	62.9	7.5	898	149.9	0.125	0.025	0.027	9.5	156	65
8/3/2022	9:46	17.949	5.86	64.5	7.56	735	172.8	0.24	0.05	0.108	7	NA	> 2419.6
8/18/2022	11:22	21.9	6.5	76.6	8.08	355.6	264.7	0.14	0.006	0.026	12	102	> 2419.6
8/30/2022	11:35	19.499	5.75	64.4	7.04	453.3	209.9	0.168	0.095	0.132	4.4	114	435.2
9/14/2022	11:01	16.89	89.7	8.4	7.4	980	219.2	0.24	0.123	0.229	10.4	136	613.1
10/5/2022	10:31	16.553	9.32	99.3	7.9	988	344.9						
10/18/2022	14:22	6.31	7.59	61.6	7.27	1081	270.6						

Table C5. Storm water quality data at the Shingle Creek SC-3 stream site measured in 2022. Parameters include TP (total phosphorus), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Start Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
5/25/2022	9:10	5/26/2022	8:06	0.19	0.037	0.061	32.8	2419.6
6/15/2022	13:15	6/16/2022	1:22	0.567	0.013	0.071	61.2	> 2419.6
7/26/2022	14:50	7/27/2022	20:35	0.406	0.025	0.053	166	> 2419.6
8/17/2022	17:31	8/18/2022	17:31	0.24	0.035	0.049	57	> 2419.6
8/18/2022	18:16	8/19/2022	0:01	0.152	0.006	0.023	18.2	2419.6

Table C6. SC-3 historic load calculations including estimated TP, TSS and chloride loads in 2022.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	7,355	4,189	209	1,543	77	599,657	30	255,736	13	6,173	0.31				
2005	10,616	5,500	191	2,640	92	464,200	16	215,600	7	8,800	0.30	35,200	1.22		
2006	3,843	2,200	211	880	84	451,000	43	138,600	13			20,240	1.94		
2007	6,270	2,200	129	880	52	391,600	23	105,600	6	3,960	0.23	24,200	1.42		
2008	2,962	880	109	220	27	85,800	11	92,400	11	1,540	0.19	8,580	1.07		
2009	961	220	84			33,000	13	15,400	6	440	0.17	1,320	0.51		
2010	4,799	1,980	152	660	51	391,600	30	147,400	11	4,180	0.32	17,820	1.37		
2011	10,099	3,192	116	719	26	591,218	22	211,470	8	3,326	0.12	25,419	0.93		
2012	5,147	2,024	145	615	44	287,380	21	108,114	8			12,572	0.90		
2013	7,033	4,110	215	1,012	53	633,717	33	395,899	21			43,336	2.27		
2014	11,736	5,042	158	1,594	54	983,344	31			8,865	0.28	34,023	1.07		
2015	5,159	2,334	166	1,289	75	293,355	20.9			2,101	0.15	15,950	1.14		
2016	17,247	4,301	149	3,588	108	796,091	54.7					7169	0.201		
2017	13,130	2,928	88												
2018	7,010	2,620	148												
2019	19,593	5,563	112												
2020	6,620	1,501	89			231,824	13.8							2,952,334	177
2021	3,613	1,739	176			373,214	37.9							1,018,485	104
2022	5,101	1,812	131			181,604	13.1							1,135,428	154

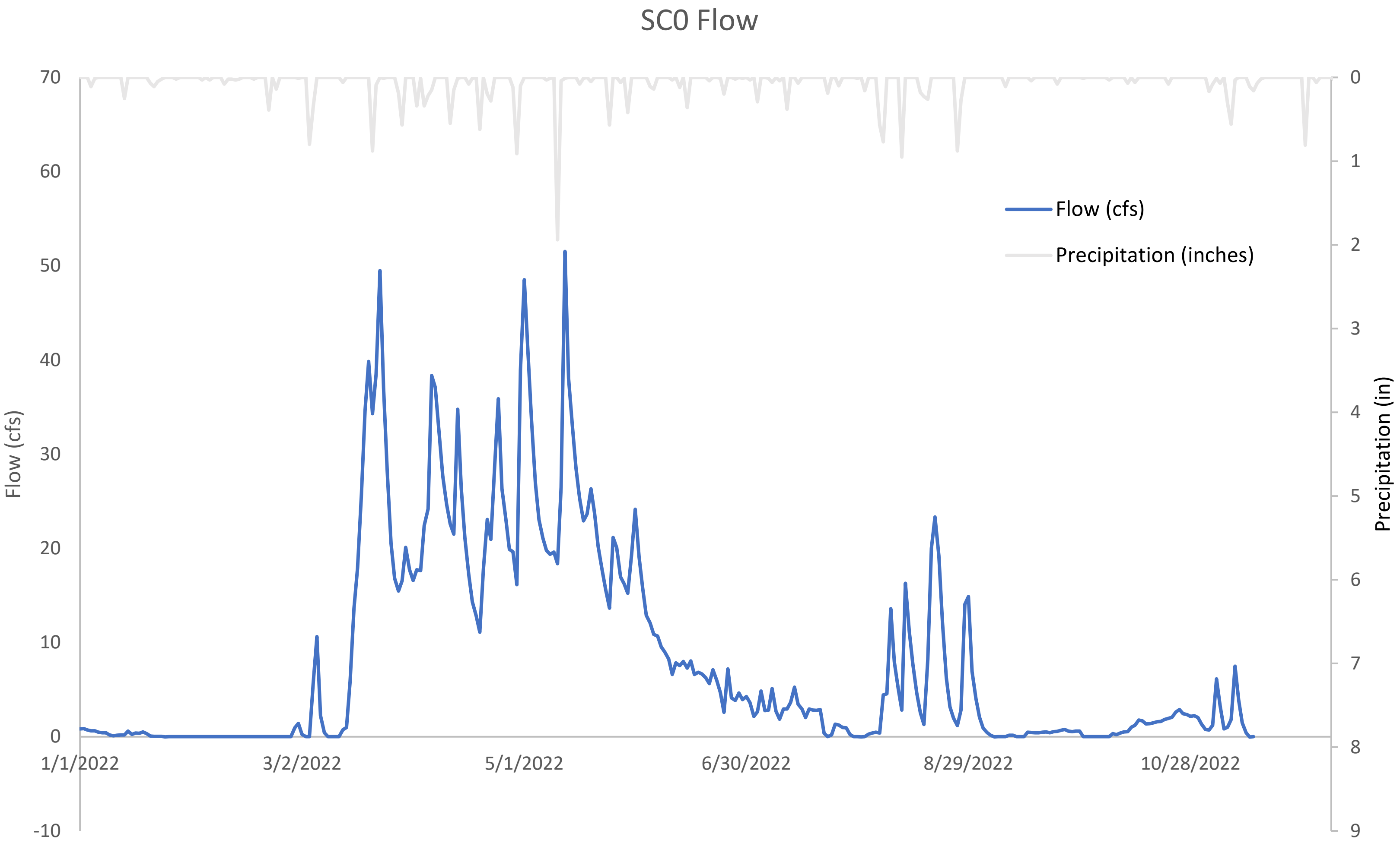


Figure C1. Flow at the SC-0 sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C7. Water quality data from the Shingle Creek SC-0 stream site measured in 2022. Parameters measured include temperature (temp.), dissolved oxygen (DO), percent saturated dissolved oxygen (DOsat), pH, specific conductivity (sp. cond.), oxidation reduction potential (ORP), total phosphorus (TP), orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS), chloride and Escherichia coli (E. coli).

Date	Time	Temp. [°C]	DO [mg/L]	DO_{sat} [%]	pH	Sp. cond. [µS/cm]	ORP [mV]	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	Chloride [mg/L]	E. coli [MPN/100mL]
4/27/2022	14:03	9.14	14.49	128.6	8.06	1038.5	398	0.074	0.007	0.027	6.6	202	27.9
5/10/2022	12:00	16.91	12.34	131.2	8.23	1073	375	0.087	0.008	0.026	8.8	183	49.5
5/27/2022	12:04	14.53	9.15	93	7.75	904	164.7	0.097	0.016	0.042	4.2	165	111.9
6/7/2022	11:09	17.48	5.9	64.1	7.44	1135	173.8	0.081	0.017	0.045	3.4	197	146.7
6/21/2022	11:02	23.116	3.37	39.3	7.63	1198	114	0.112	0.035	0.043	7	191	1454
7/15/2022	11:12	21.515	5.39	63	7.59	783	115.2	0.062	0.037	0.072	1.8	186	190.4
7/21/2022	10:58	21.242	4.78	53.9	7.44	827	159.8	0.077	0.037	0.074	1.9	187	228.2
8/3/2022	12:29	23.424	4.44	54.5	7.46	547	161.9	0.094	0.028	0.035	4.5		1553.1
8/18/2022	13:54	22.251	4.19	49.8	7.31	638	230.4	0.108	0.045	0.058	2.6	138	261.3
8/30/2022	12:22	20.965	4.78	55	7.11	411.6	207	0.1	0.056	0.078		76.2	122.3
9/14/2022	11:50	16.771	6.57	67.9	7.41	927	209.1	0.06	0.026	0.053	2.2	173	290.9
10/5/2022	11:05	16.066	5.7	59.7	7.6	994	361.8						
10/18/2022	14:52	4.365	6.58	51.9	7.32	908	265.9						

Table C8. Storm water quality data from the Shingle Creek SC-0 stream site measured in 2022. Parameters include TP (total phosphorus, orthophosphate (orthoP), total dissolved phosphorus (TDP), total suspended solids (TSS) and Escherichia coli (E. coli).

Start Date	Start Time	End Date	End Time	TP [mg/L]	OrthoP [mg/L]	TDP [mg/L]	TSS [mg/L]	E. coli [MPN/100mL]
6/15/2022	13:13	6/16/2022	17:24	0.184	0.007	0.038	8	> 2419.6
7/26/2022	16:18	7/27/2022	22:03	0.268	0.035	0.065	95.8	1986.3
8/12/2022	5:24	8/13/2022	11:09	0.332	0.026	0.039	66.8	> 2419.6
8/18/2022	18:31	8/19/2022	0:01	0.228	0.019	0.038	55.6	> 2419.6

Table C9. SC-0 historic load calculations including TP, TSS and Chloride load calculations for 2022.

Year	Flow	TP		Ortho-P		TSS		VSS		Nitrate		TKN		Chloride	
	Acre-ft	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (µg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)	Load (lbs)	Conc (mg/L)
2004	8,612	3,748	160	882	38	749,572	32	308,647	13	4,409	0.19	--	--		
2005	15,367	6,820	163	1,320	32	1,577,400	38	1,031,800	25	13,420	0.32	52,800	1.26		
2006	13,255	5,060	140	1,540	43	1,095,600	30	459,800	13	--	--	39,600	1.10		
2007	11,239	3,960	130	880	29	811,800	27	431,200	14	9,240	0.30	38,720	1.27		
2008	7,950	3,080	142	660	31	367,400	17	248,600	12	6,380	0.30	25,080	1.16		
2009	3,917	880	83	220	21	231,000	22	92,400	9	1,320	0.12	5,720	0.54		
2010	7,634	3,300	159	660	32	561,000	27	233,200	11	3,740	0.18	22,000	1.06		
2011	18,023	5,814	119	1,255	26	1,098,478	22	465,297	9	14,807	0.30	54,294	1.11		
2012	7,943	3,384	157	579	27	648,520	30	286,019	13			21,219	0.98		
2013	9,916	4,382	163	511	19	660,628	24	583,448	22			36,177	1.34		
2014	17,483	5,945	125	1,131	24	1,239,189	26					55,102	1.16		
2015	8,630	2,187	113	1,679	71	683,057	29.1			4,680	0.073	23,688	1.01		
2016	17,007	4,241	148	3,538	72	785,013	58					7,069	0.309		
2017	16,149	3,601	88												
2018	9,886	2,850	114												
2019	24,763	7,001	112												
2020	14,340	3,047	84			438,045	12.1							4,726,436	131
2021	8,482	2,552	111			509,224	22.1							2,570,757	111
2022	5,060	1,872	136			237,535	17.3							1,720,104	125

Note: Annual flows presented in acre-feet/year, pollutant loads in pounds/year, and pollutant flow weighted mean concentrations in mg/L

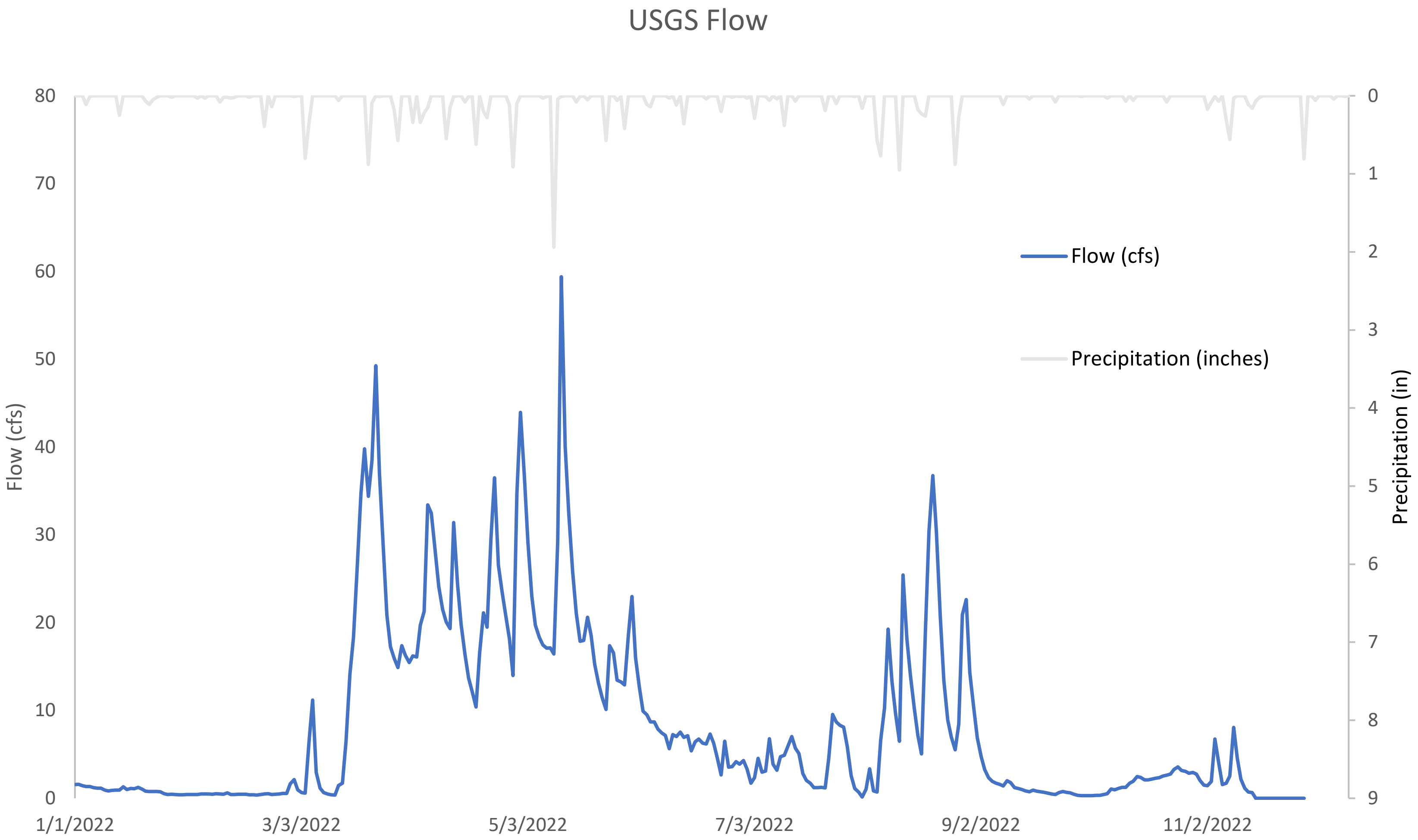
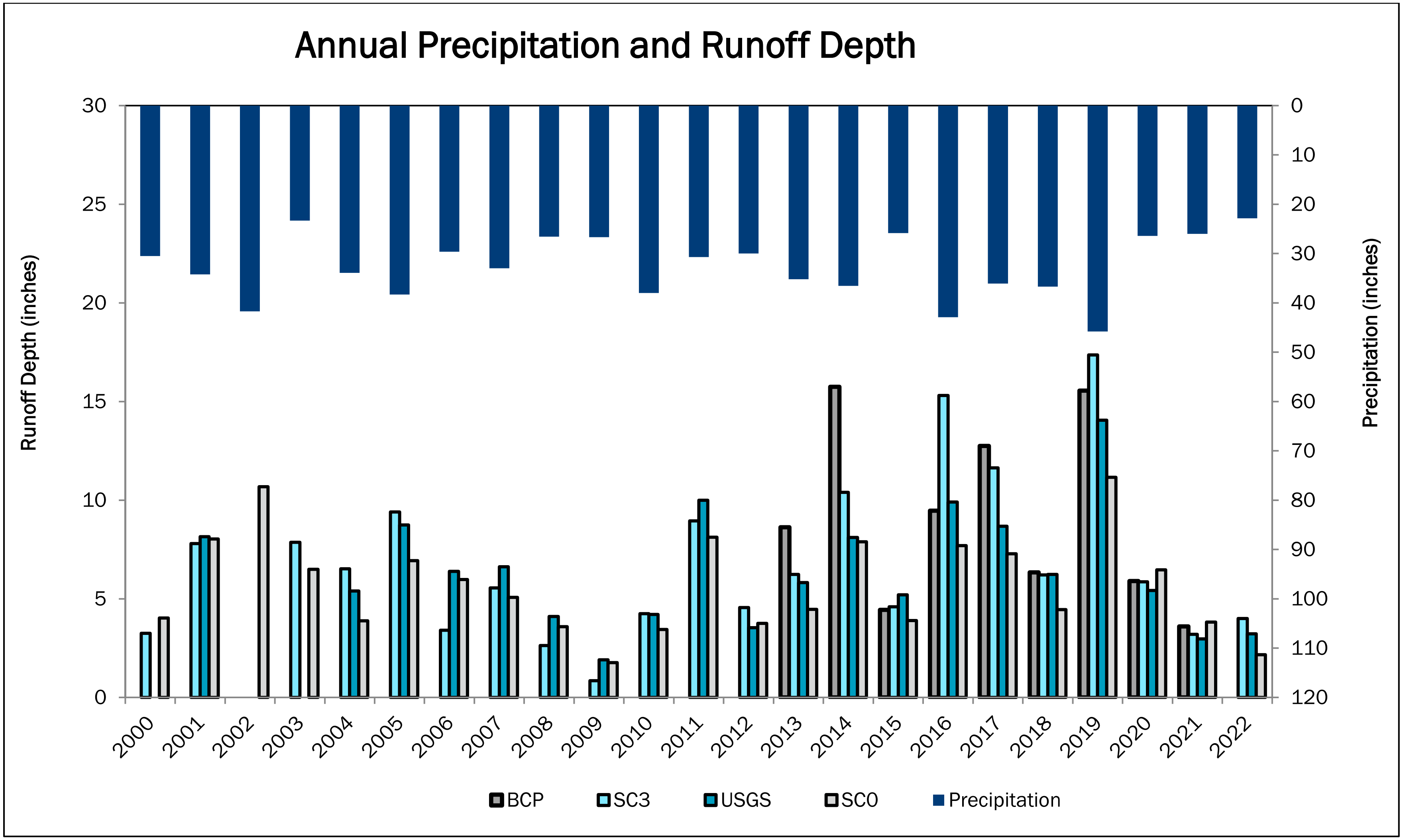


Figure C10. Flow at the USGS sampling station. The blue line represents flow in cubic feet per second (cfs). Daily precipitation totals in inches are represented in gray on the secondary axis.

Table C10. Water quality data from the United States Geological Survey (USGS) stream site measured in 2022.

Date	Time	Chloride [mg/L]
1/4/2022	14:00	190
1/31/2022	12:54	269
2/28/2022	12:40	681
3/16/2022	9:25	395
3/30/2022	11:47	240

Figure C10. Historic Annual Runoff Depth and Precipitation over the subwatershed area for each stream site including: BCP, SC3, USGS and SC0 (2000 – 2021).



Appendix D: 2022 Lake Monitoring

OVERVIEW

The Shingle Creek Third Generation Watershed Management Plan includes a rotating schedule of intensive monitoring on all lakes in the Shingle Creek Watershed. The primary purpose of the intensive lake monitoring program is to evaluate protection efforts for lakes that are not impaired, and to assess progress toward achieving the TMDLs and state water quality standards for all impaired lakes throughout the watershed. Activities included in the intensive lake monitoring program include water quality monitoring, aquatic vegetation surveys, and fish sampling coordinated with the Minnesota Department of Natural Resources (DNR).

In Section 1.0, we provide an overview of the various sampling methodologies (Section 1.0) used to collect water quality (Section 1.1), phytoplankton and zooplankton sampling (Section 1.2), submersed aquatic vegetation (Section 1.3), and fisheries (Section 1.4) data on the lakes within Shingle Creek watershed. In Sections 2.0 and beyond we summarize activities and results from 2023 monitoring for each of the four lakes monitored.

Results and discussions for each lake can be found in the following order:

- Section 2.0 – Schmidt Lake
- Section 3.0 – Lake Magda
- Section 4.0 – Meadow Lake
- Section 5.0 – Crystal Lake

1.0 Sampling Methods

1.1 WATER QUALITY

Lakes are central to Minnesota's economy and our way of life, making it imperative that we protect our high-quality lakes and work to restore those with poor water quality. The Minnesota Pollution Control Agency (MPCA) monitors and assesses lakes around the state to determine if they meet water quality standards. The agency relies on local partners, including soil and water conservation districts, watershed districts, tribal entities, nonprofit groups, and citizens to help monitor the more than 10,000 lakes in the state. Shingle Creek Watershed Management Commission (Commission) is an active participant in aiding the MPCA in sampling and collecting information on the state of water quality of its lakes. The Commission is focused on sampling total phosphorus (nutrient), chlorophyll-*a* (a pigment in algae), and Secchi depth (a measure of water clarity). In addition to these parameters for water quality standard comparison, the Commission collects certain chemical and physical parameters on its lakes.

Routine lake sampling occurs on a rotating basis. For a lake that is selected for sampling in a given year, water samples are typically collected twice per month starting in May or June and ending in September. For all lakes, surface water samples are collected and assessed for total phosphorus (TP), soluble reactive phosphorus (ortho-P), total suspended solids (TSS), and chlorophyll-*a* (chlorophyll-a). In some of the deeper lakes, a hypolimnetic (deep) water sample is collected and tested for TP and ortho-P. In addition to these chemical parameters, a physical profile of the lake is assessed in the deepest part of the lake. A profile typically consists of measurements at the water's surface and at each meter below the surface throughout the entire water column. A YSI or similar multimeter probe is used to collect these measurements. Parameters measured include dissolved oxygen (DO), dissolved oxygen percent saturation, temperature, pH, oxidation reduction potential (ORP) and specific conductivity. Additionally, a Secchi depth reading is taken during every assessment to record the relative level of water transparency.

Lake profiles are used to better understand the chemical and nutrient cycling processes occurring within the lake, in addition to the stressors that may be contributing to biological impairments. The surface water chemical information is used for multiple reasons, one of which is to compare to the North Central Hardwood Forest (NCHF) ecoregions water quality standards established by the MPCA (Table 1.1).

Table 1.1. MPCA water quality standards for the NCHF ecoregion by lake type.

	Depth Class	**TP (ug/L)**	**Chl-*a* (ug/L)**	**Secchi depth (m)**
North Central Hardwood Forest	Deep	40	14	1.4
	Shallow	60	20	1.0

*Shallow lakes are defined as those with maximum depths of 4.5 meters (15 feet) or less or where 80 percent or more of the lake is littoral (≤ 4.5 meters).

1.2 PHYTOPLANKTON AND ZOOPLANKTON SAMPLING

The phytoplankton and zooplankton communities are a key part of the lake ecosystem. They represent the base of the food chain and are often indicators of nutrient regimes and water quality. We began routine sampling for phytoplankton and zooplankton communities in 2020 by sampling each lake in early and late summer.

Both phytoplankton and zooplankton samples are taken by towing a plankton net with a known mesh size and net diameter vertically through the water column. The sample is transferred to a bottle and a known volume is subsampled for identification. Plankton were identified to the genera classification.

Five different phytoplankton families were identified in Shingle Creek lakes in 2021: Cyanobacteria, Chlorophyta, Dinoflagellate, Diatom, and Golden Algae. Cyanobacteria are commonly known as blue green algae and have the potential to form toxic blooms which are detrimental to human and ecosystem health. Cyanobacteria are indicative of nutrient rich, calm water. Cyanobacteria are not a preferred food source for zooplankton and they out compete other phytoplankton which are more important to the food chain. Chlorophyta are commonly known as green algae; they are prolific in mid-summer when harmful algae blooms (HABs) are not present. Green algae are a good sink for dissolved nutrients and are an important food source for zooplankton. Dinoflagellates are ubiquitous in freshwater lakes; they are an important part of the food chain and are indicative of low nutrients. Diatoms are most prevalent in the early growing season and they are a very important part of the food chain. Golden algae are similar to diatoms but are more uncommon in freshwater systems and can be found in the benthos (lake bottom).

Changes in phytoplankton composition are important for understanding:

- Pre and post management; indications of management impacts on water quality and all trophic cascades.
- Seasonal changes in nutrients and mixing regimes
- Food chain health throughout the growing season
- Risk of HAB formation

The most common composition change in a healthy lake ecosystem will shift from diatoms in the early spring to green algae in mid-summer to cyanobacteria in late summer. However, it is important to note that in healthy system that no one genera should be the only one represented. One hundred percent of one genera indicates an imbalance in the ecosystem in which one genera was able to completely out-compete the others.

1.3 SUBMERSED AQUATIC VEGETATION

In healthy lake ecosystems aquatic vegetation will grow throughout the littoral area (< or = 15 feet depth) and consist of a diverse native community (Figure 1.1). A well vegetated littoral area promotes and facilitates the health of a lake’s ecosystem by providing critical spawning, foraging and nursery habitat for aquatic insects, amphibians, birds, and fishes. The littoral area is also important for human recreation and aesthetic enjoyment.

Figure 1.1. Biotic community health continuum portrayed using submersed aquatic vegetation.

1.3.1 Point Intercept Methods

To assess the presence, abundance, and health of the lake's aquatic vegetation community, two point-intercept surveys are typically conducted: an early season (May/June) and a late season survey (August). During each point-intercept survey, all submerged, floating leaf, and emergent species were identified at each survey point. Early season surveys are primarily conducted to understand the presence and distribution of Potamogeton crispus (curly-leaf pondweed, CLP), an aquatic invasive species (AIS) with high spring growth and early senescence. Late season surveys target the greatest assessment of SAV (submerged aquatic vegetation) community, abundance, and spatial distribution because the community is ideally at peak diversity.

Point-intercept survey point locations were replicated from previous surveys performed by Stantec and served as predetermined sampling locations for each lake. These points were originally developed by overlaying a grid across the entire lake according to the point-intercept methods presented in (Madsen 1999). To limit sampling of vegetation where it is not expected to grow, all deep lakes within Shingle Creek are capped to a maximum sampling depth of 20 feet or more (lake specific), therefore, all sampling points in depths beyond the designated cap are removed from the sampling grid. Thus, the sampling protocol and reporting of each lake is similar and allows comparisons to be made across systems and between years.

At each survey location a double-sided, weighted 14-tine rake was thrown from the boat, allowed to sink, and pulled across the lake bottom to represent approximately 1 square meter of lake area. We refer to this process as a rake toss. For each rake toss, vegetation is removed from the rake, identified to the species level, placed in a perforated bucket, weighed, and assigned a proportion of the total biomass based on visual approximation (i.e., 80% of total weight was CLP and 20% of total weight was coontail). All biomass values are reported in wet weights (kg). Emergent plant species, lily species, duckweed species, and filamentous algae are not included in any biomass measurements due to difficulty in collecting a representative sample with the sample rake, however, their presence (P) and location are still recorded.

Continuous sonar readings were also collected during each survey trip using a Lowrance Elite 7 Sonar/GPS unit. This data was processed using CiBioBase (BioBase) software (https://www.cibiobase.com/) that allows for mapping water depth, bottom hardness, and plant biovolume. Biovolume differs from biomass in that it provides context to vegetation water column saturation. The higher the biovolume the more saturated the water column is with vegetation. Sonar readings in depths <2 feet are subject to extreme 'sonar noise' and therefore are not always accurate. Sonar readings do not detect surface floating vegetation (i.e., pad of Lily species, duckweed). BioBase interpolates sonar readings between boat tracks to estimate biovolume.

Variation in boat tracks during surveys sometimes results in areas where biovolume cannot be estimated because boat tracks were not dense enough. There are a few cases of missing biovolume estimates in this report described in the results.

Point-intercept survey data can be used to calculate various survey metrics and indices to assess the health of the SAV community and easily compare across survey years and lakes. The metrics total point sampled during the survey, total littoral (<15 feet deep) points sampled, percent of littoral points with vegetation, maximum depth of plant growth, and species richness (i.e., the number of species observed) were calculated for each lake. In addition, the key indices used to assess the SAV survey results in this study and previous studies were Floristic Quality Index (FQI), biomass estimates, Simpson's Diversity Index (Simpson's D), and Aquatic Macrophyte Community Index (AMCI). Typha sp. (cattail), emergent wetland plants that often grow in shoreline and littoral areas in lakes and wetlands, are not included in SAV survey metrics in this report.

1.3.2 SAV Community Metrics

Floristic Quality Index (FQI). The FQI is an assessment tool used to determine the biological health of the SAV community. The FQI uses species richness and the habitat specificity (C-score) of each species identified to score community health (**Equation 1**). C-score is an index of how desirable a particular species is and how tolerant it is to stressors. Minnesota Department of Natural Resources (DNR) standard C-scores range from 1 to 10 with 1 being the least desirable and most tolerant to stressors, and 10 being the most desirable and least tolerant to stressors.

Equation 1. Definition of the DNR's Floristic Quality Index (FQI).

$$FQI = \overline{C_{Score}} * \sqrt{No.of\ Species}$$

Lakes with higher FQI scores and taxa richness are typically comprised of diverse, native communities with abundant plant growth across the entire littoral area. As stressors to the SAV community increase, we typically see reduced species diversity, introduction of invasive species, more monodominant stands of vegetation, and decreased late-season SAV abundance and density within the littoral area. Extremely degraded lakes become void of plant growth and become dominated by algae, which can sometimes be harmful during blooms.

The DNR developed thresholds for FQI and species richness to assess the health of lake vegetation communities and compare communities across lakes (Radomski and Perleberg 2012). Thresholds for deep and shallow lakes in the Central Hardwood Forest and Western Corn Belt Plains ecoregions are presented in Table 1-1. All surveyed lakes are in the Central Hardwood Forest ecoregion.

Table 1-1. FQI and species richness thresholds for deep and shallow lakes in the Central Hardwood Forest ecoregion.

	Depth Class	FQI threshold	Species Richness Threshold
North Central Hardwood Forest	Deep	18.6	12
	Shallow	17.8	11

Vegetation Biomass. We developed a model to estimate the total SAV biomass within each lake. Depth was stratified into four intervals (0-5, 5-10, 10-15, >15 feet) to more accurately account for spatial variation in vegetation growth and improve model accuracy. For each species we calculate a depth interval specific FQI, an average rake toss biomass, and a depth interval lake area. Multiplying these three parameters results in a species-specific total biomass/depth interval. All species-specific depth interval biomasses are then summed within each depth interval to calculate depth-specific biomasses and all depth intervals are summed to calculate a total lake biomass (**Equation 2**). The total lake biomass estimation uses the individual surveyed data point information to extrapolate coverage estimates across the entire basin. This is not meant to serve as an exact biomass calculation, rather, this estimate is useful to 1) make relative comparisons to other observed species, 2) be used to compare to future sampling efforts, and 3) provide general information to assist aquatic vegetation management planning.

Equation 2. Definition of total in-lake submersed aquatic vegetation biomass.

$$Total\ Lake\ Biomass = \sum ([Depth\ Interval]\ (Species\ Biomass * Species\ \%\ Occurence * Basin\ Area))$$

Biomass data were collected for this study; however, the data are not presented in this report. Biomass data will be kept for use with future management efforts.

Simpson's Diversity Index. Data collected during the point-intercept surveys was used to calculate the Simpson's Diversity Index (Simpson's D) (Simpson 1949). Simpson's D is a measure of community diversity that accounts for the relative abundance of each species rather than just the community composition. This index is useful in assessing communities that have a high abundance of only a few species and low abundance of other species, giving more weight to more abundant species. The index ranges from 0–100 with 100 representing high diversity and even abundance across species and 0 representing low diversity and disproportionate abundance.

Equation 3. Simpson's Diversity index.

$$D = 1 - \left(\frac{\sum n\ (n-1)}{N\ (N-1)}\right) * 100$$

n = the total number of organisms of a particular species

N = the total number of organisms of all species

Aquatic Macrophyte Community Index (AMCI). The Aquatic Macrophyte Community Index (AMCI) is a metric used to assess the biological quality of lake aquatic plant communities (Nichols et al. 2000). The AMCI combines maximum depth of plant growth, percent of littoral zone vegetated, Simpson's D, the relative frequencies of submersed, sensitive, and exotic species, and taxa number. AMCI ranges from 0-70, with higher values representing higher quality plant communities. The AMCI was calculated for each point-intercept survey using the methods described by Nichols et al. (2000).

1.4 FISHERIES ASSESSMENT

Fish communities are sampled using various techniques and equipment to target specific aspects of the fish community or due to the type of system being sampled. Three survey techniques and assessment methods were used to assess the fisheries communities.

1.4.1 Trap and Gill Net Surveys

DNR survey game fish populations using standardized trap and gill net survey methods to assess gamefish populations within lakes. DNR standard trap and gill net surveys consist of setting trap and gill nets at predetermined locations based on lake size (Schlagenhaft 1993). The trap and gill nets are meant to tangle or entrap fish over a 12 to 24-hour period. Trap nets contain a lead net perpendicular to shore with a series of hoops and funnels at the end of the net that direct and entrap fish. The gill nets catch fish via gill entanglement and consist of multi-sized mesh panels. The gill nets are typically set in deeper (~8-12 feet), open water habitats. Fish captured from trap and gill net assessments are identified, total length measured and weighed. Furthermore, a quantification of fish captured is calculated using catch per unit effort (CPUE). A CPUE is calculated by adding the total number of each fish species captured in each respective gear type (i.e., trap net and gill net) and dividing the number of captured fish by the number of each gear type placed in the lake.

The CPUE can be used to compare and assess fish communities by using the DNR developed Schupp lake class (Schupp 1992). The Schupp system creates a standard fisheries-based lake class system that allows fish community health to be evaluated to lakes with similar size, structure, and regionality.

1.4.2 Common Carp Population Evaluation

The common carp (*Cyprinus carpio*) is a widespread AIS that can have deleterious effects on lake ecosystems. Common carp uproot aquatic vegetation, resuspend lake bottom sediments, and increase available nutrients that can fuel algal growth. The presence of common carp can lead to ecosystem degradation. Significant water quality degradation has been shown to begin at common carp densities of 100 kg/hectare (89 lbs/ acre) (Bajer 2012). Efforts aimed at restoring water quality that do not reduce the presence of common carp have limited success in long term restoration, therefore, survey efforts are used to determine common carp densities and whether there is a need for carp management. Common carp population assessments implement boat electrofishing techniques that target the carp population within a lake. Carp are targeted along shoreline habitats with captured carp total length measured, weighed, and tallied. A regression model is then used to extrapolate the abundance and density of common carp with the lake. Inputs into the regression model include the amount of time fished (shocking time), the total number of fish captured, and total biomass captured.

2.0 Schmidt Lake

2.1 INTRODUCTION & SAMPLING OVERVIEW

Schmidt Lake (Public Water No. 27010200) is in the city of Maple Grove within Hennepin County, MN. Schmidt Lake has an approximate surface area of 44.66 acres, 34 of which are in the littoral area (i.e., area less than 15 feet deep), 1.74 miles of shoreline, and a maximum depth of 25 feet. Schmidt lake is classified as a shallow lake. The list below summarizes the year in which each type of sampling was most recently performed on Schmidt Lake:

- Water Quality - 2022
- SAV – 2022
- Phytoplankton/Zooplankton – 2022
- Fisheries – 2019
- Carp – Not assessed

2.2 WATER QUALITY

Water was collected biweekly from late May through late September 2022 (Figure 2.2.1). Total phosphorus met the standard of 60 ug/L. Chlorophyll-a peaked in mid-summer but met the standard of 20 ug/L throughout the whole summer. The increase in chlorophyll-a occurred simultaneously with decreased water clarity. However, the water clarity also remained above the standard of 1 meter Secchi depth reading.

Historic monitoring data shows improvements in both total phosphorus and chlorophyll-a concentrations and Secchi readings (Figure 2.2.2). All parameters are meeting the shallow lake standard. Water quality met the shallow lake standard for the entire monitoring period.

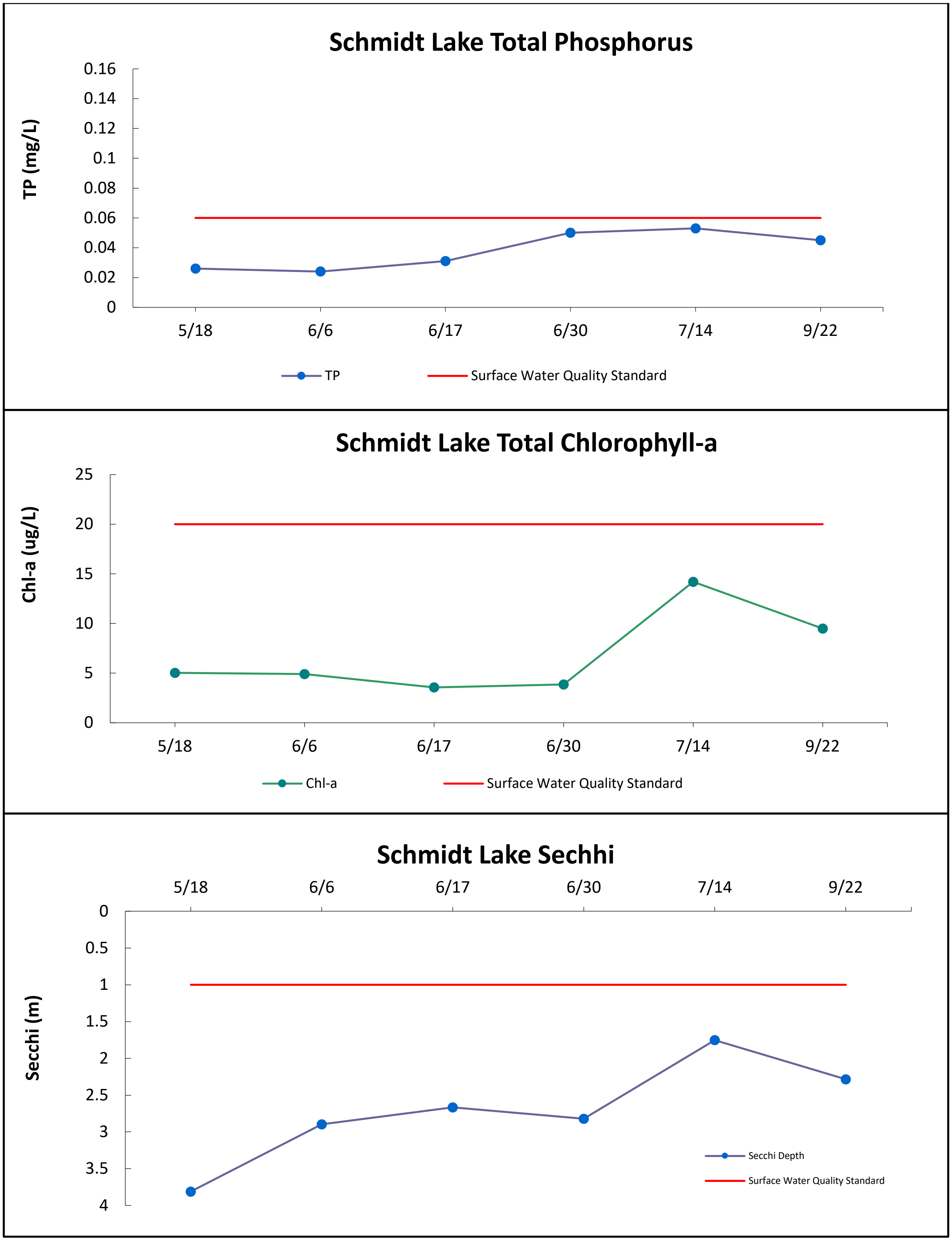


Figure 2.2.1. Seasonal TP, chlorophyll-a, and Secchi measurements and standards.

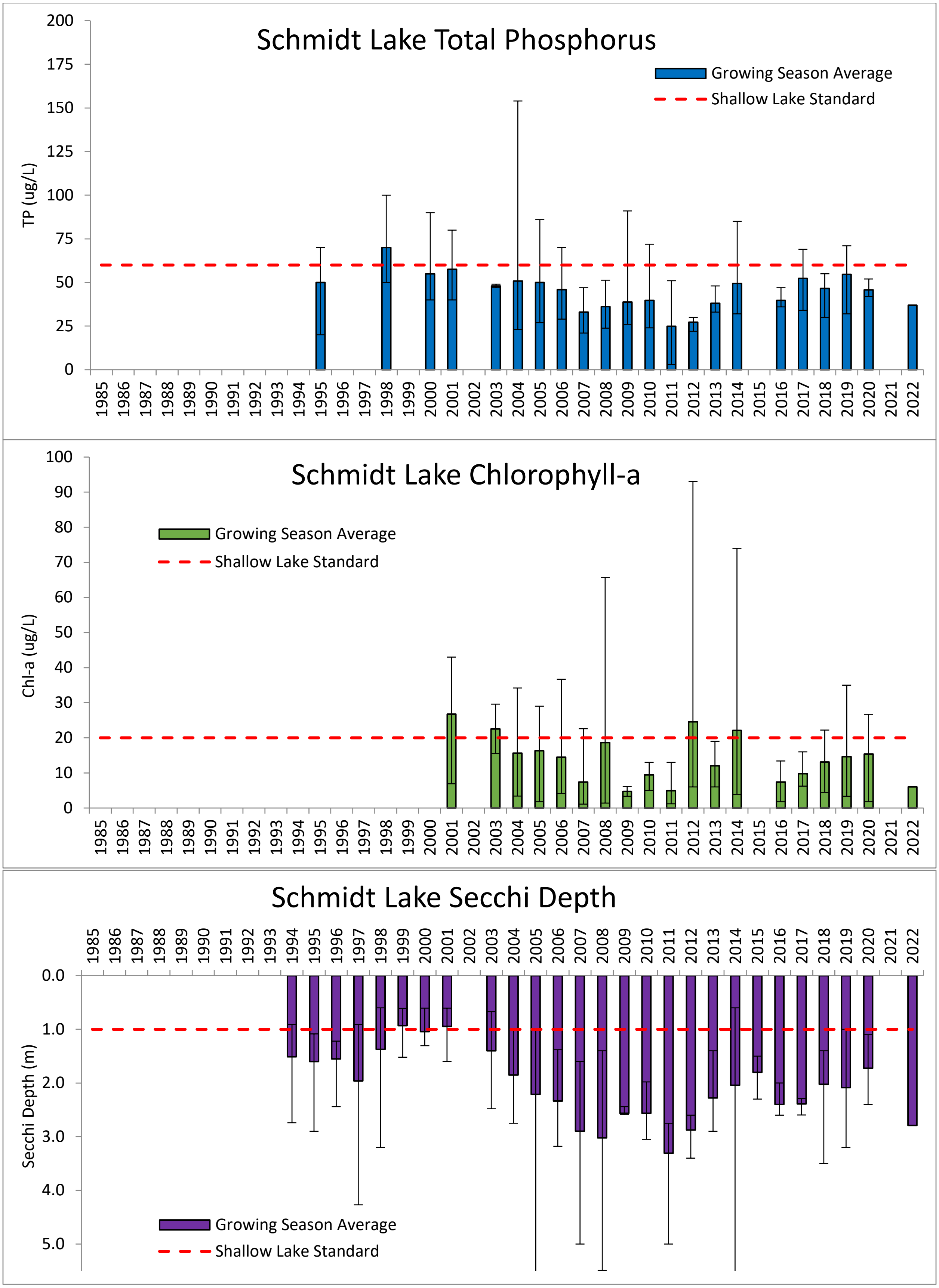


Figure 2.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

2.3 PHYTOPLANKTON AND ZOOPLANKTON

Analyses of the phytoplankton and zooplankton community represents a healthy ecosystem. The phytoplankton community was dominated by cyanobacteria with some green algae present (Figure 2.3.1). The cyanobacteria present were a diverse assemblage and in low concentrations which is a typical phytoplankton community for Minnesota lakes in August.

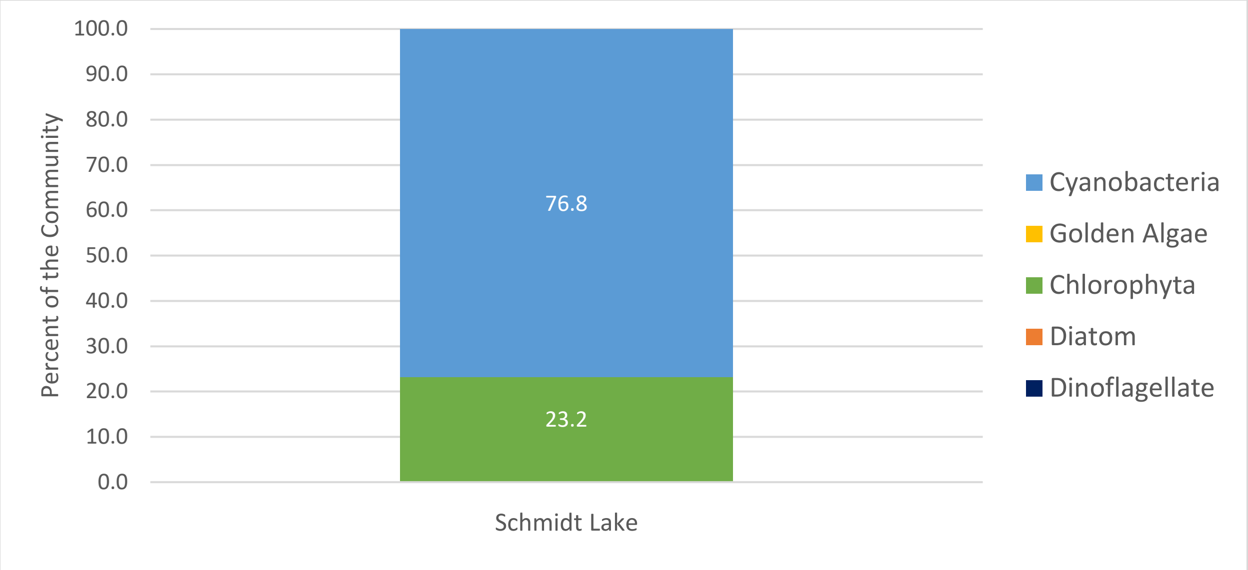


Figure 2.3.1: Phytoplankton relative percentage in Schmidt Lake.

The zooplankton community is dominated by *bosmina* (Figure 2.3.2), which are a group of zooplankton that can feed on low quality food sources like cyanobacteria and have an advantage in late summer. Although the sample was dominated by *bosmina* at 54%, there is a healthy mix of other zooplankton which reflects a healthy zooplankton community and a strong base of the food web.

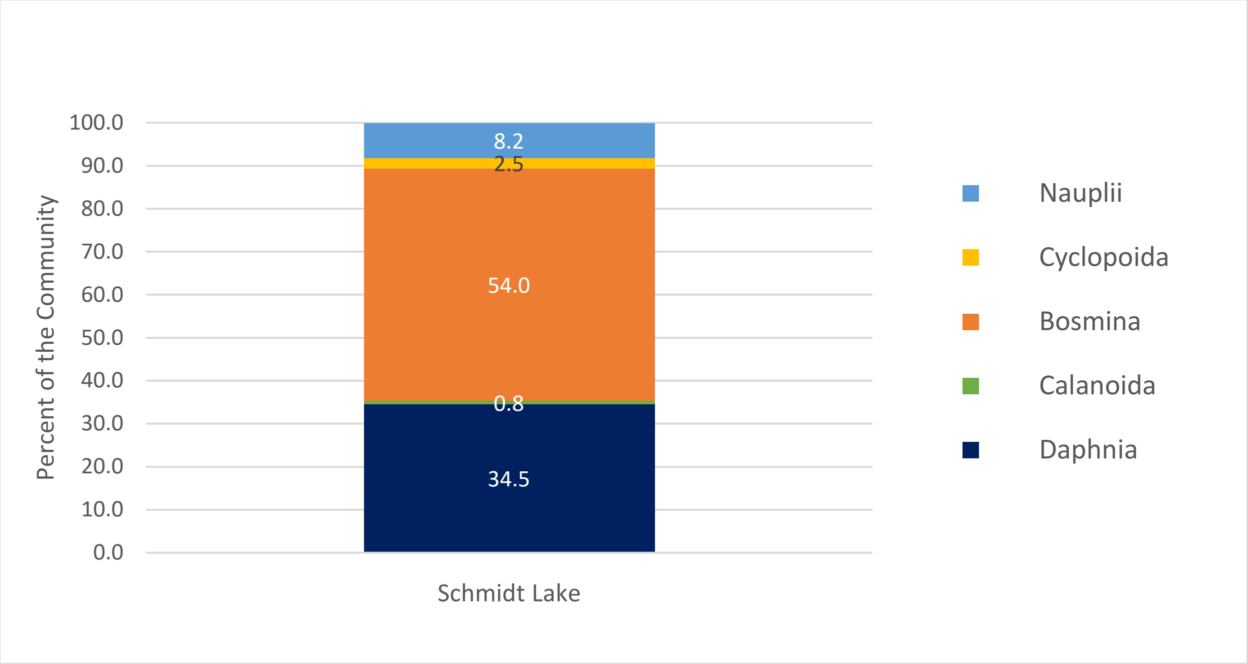


Figure 2.3.2: Zooplankton relative percentage in Schmidt Lake.

2.4 SUBMERSED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on May 31, 2022 and August 22, 2022 to document the spring and summer submersed aquatic vegetation in Schmidt Lake (These surveys will be referred to as the spring and summer surveys.). Below are two tables outlining survey results and associated metrics and indices (**Table 2.4.1** and **Table 2.4.2**). Maps include early and late-season BioBase maps of vegetation biovolume (**Figure 2.4.1**), number of taxa at each sample point (**Figure 2.4.2**), CLP location and density (**Figure 2.4.3**), and Eurasian Water Milfoil location and density (**Figure 2.4.4**).

Table 2.4.1. Schmidt Lake SAV metrics and indices.

	May 31, 2022	**August 22, 2022**
LAKEWIDE METRICS		
Total Points Sampled	72	72
Total Littoral Points Sampled	66	65
% Littoral with Vegetation	95	88
Max depth of plant growth (ft)	12.4	12.1
Shallow Lake Species Richness Threshold	*11*	
Species Richness	10	10
COMMUNITY INDICES		
Shallow Lake FQI Threshold	*17.8*	
Floristic Quality Index (FQI)	15.8	16.4
Simpson's Diversity Index	85.6	85.0
Aquatic Macrophyte Community Index (AMCI)	41	52

*Typha (cattail) is not included in Taxa or Community Indices calculations as it does not have a C value.

Table 2.4.2. Schmidt Lake plant taxa and littoral frequency of occurrence from 2022 surveys.

Taxa	Common Name	May 31, 2022	August 22, 2022
SUBMERSED TAXA			
Chara sp.	musk grass	29	28
Ceratophyllum demersum	coontail	39	29
Elodea canadensis	waterweed (Canadaian)	29	13
Heteranthera dubia	water stargrass	3	13
Myriophyllum spicatum	water milfoil (Eurasian)	35	--
Potamogeton crispus	curly-leaf pondweed	50	3
Potamogeton zosteriformis	flat-stemmed pondweed	22	51
Ranunculus aquatilis	white water buttercup - limp	14	--
Vallisneria americana	water celery	4	24
FLOATING TAXA			
Lemna trisulca	duckweed (star)	1	7

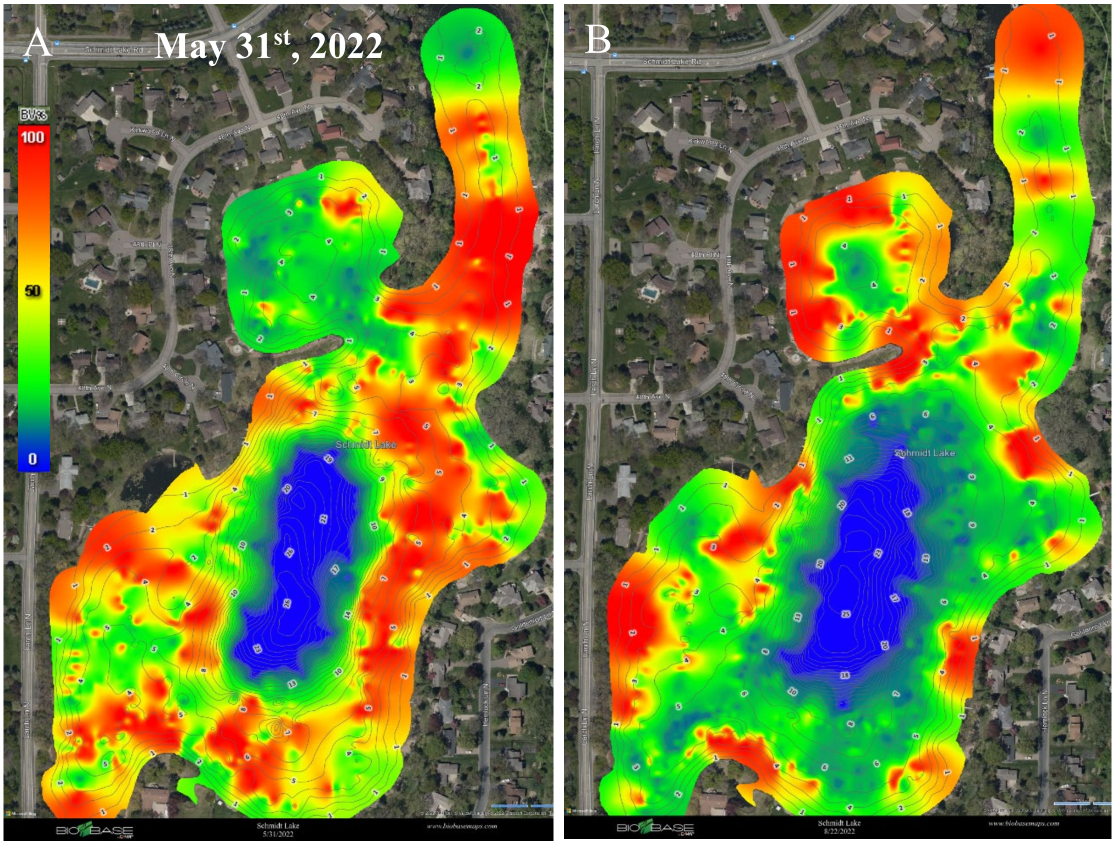


Figure 2.4.1. Biovolume heat maps for Schmidt Lake during the May 31st (A) and August 22nd (B) 2022 surveys. In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

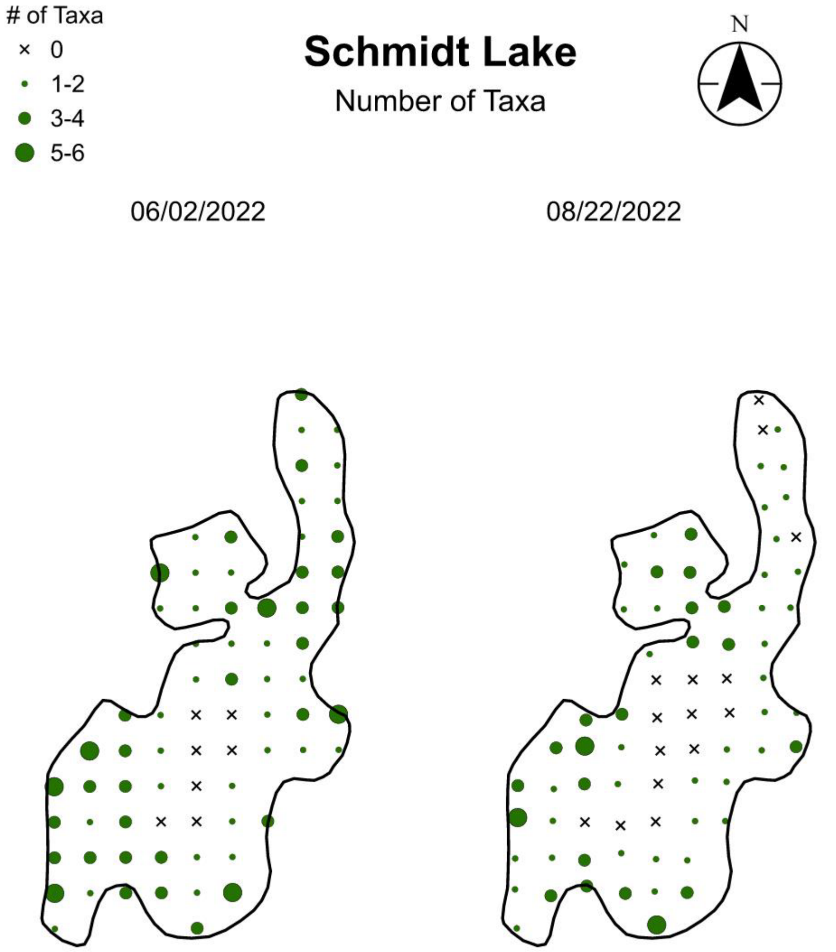


Figure 2.4.2. Map of the Number of taxa found at each point in Schmidt Lake.

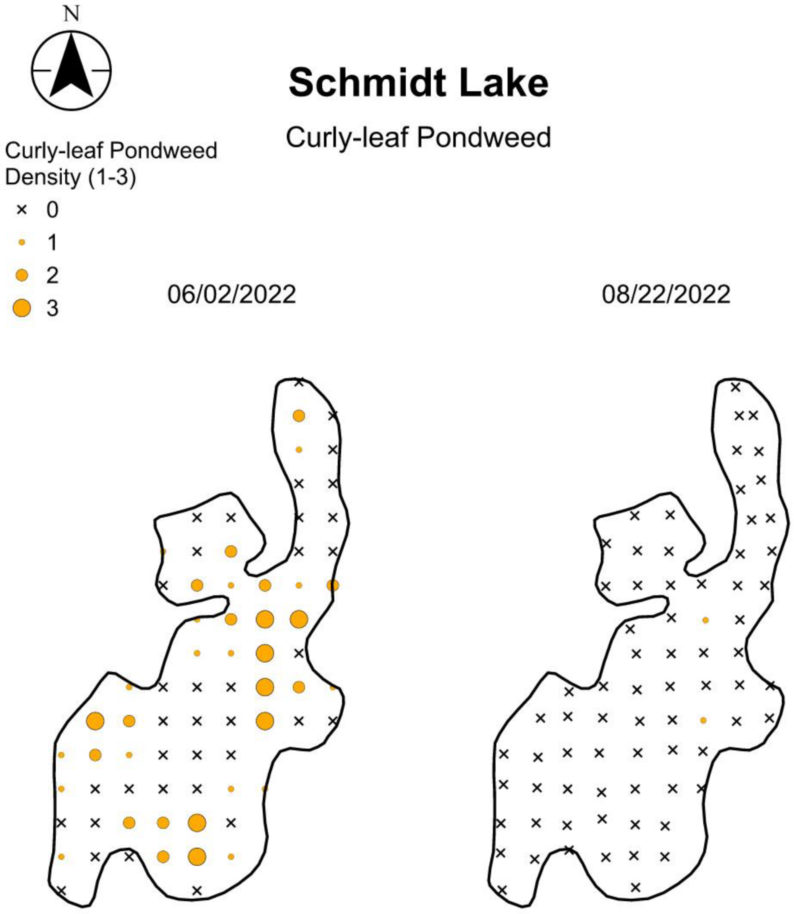


Figure 2.4.3. Map of the location and density of Curly-leaf Pondweed in Schmidt Lake.

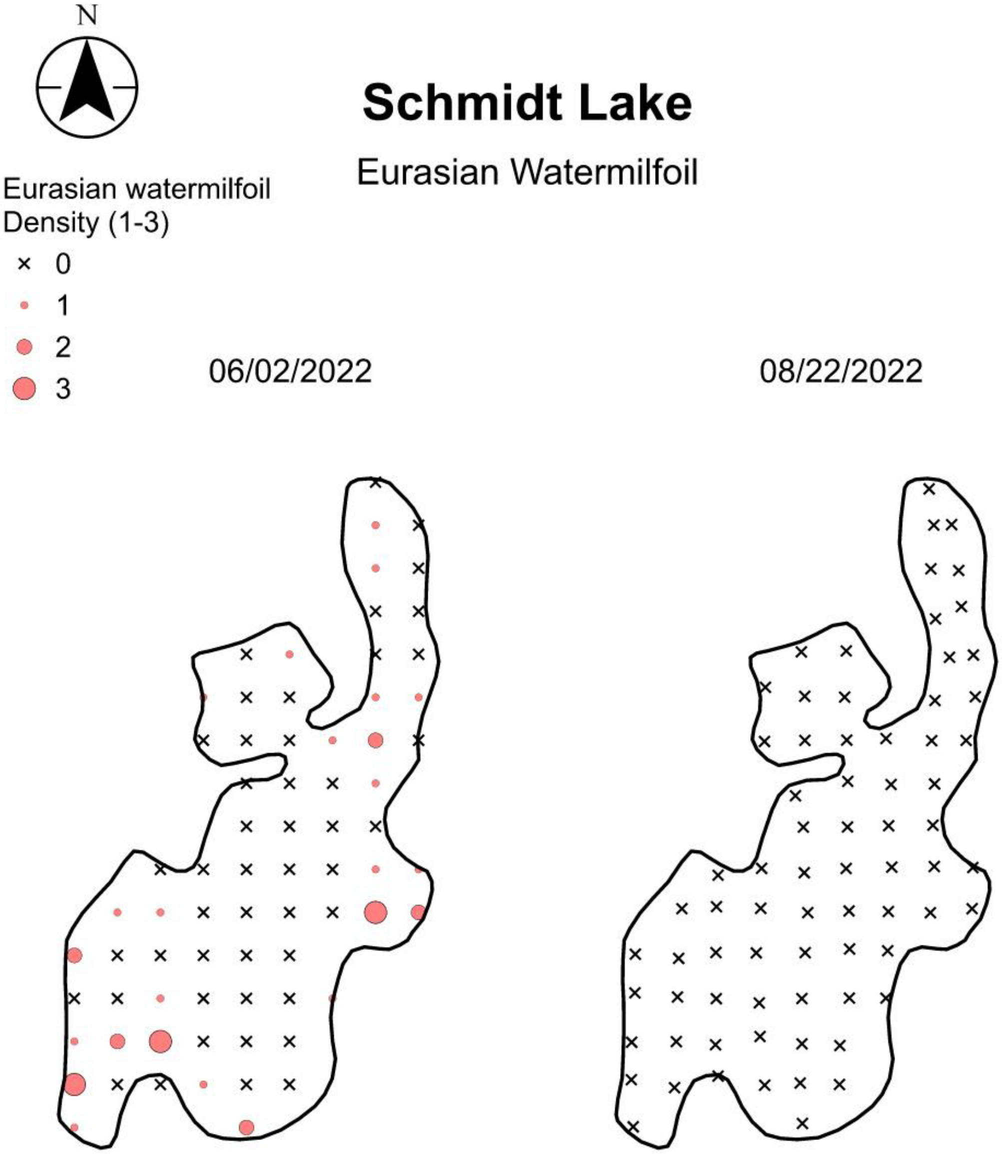


Figure 2.4.4. Map of the location and density of Eurasian Watermilfoil in Schmidt Lake.

3.0 Lake Magda

3.1 INTRODUCTION & SAMPLING OVERVIEW

Lake Magda (Public Water No. 27006500) is located in New Hope within Hennepin County, MN. Lake Magda is classified as a shallow lake and has an approximate surface area of 10 acres. Lake Magda is classified as a Shallow Lake due to 100% of the lake being classified in the littoral zone (i.e., <15 feet deep). The list below summarizes the year in which each type of sampling was most recently performed on Lake Success:

- Water Quality - 2022
- SAV – 2022
- Phytoplankton/Zooplankton - 2022
- Fisheries – 2022
- Carp – Not assessed

3.2 WATER QUALITY

Figure 3.2.1 shows TP, secchi, and chlorophyll-a concentrations from May through September 2022. TP generally met the standard of 60 ug/L for most of the monitoring period except the late spring and early fall. Chlorophyll-a, a measure of algal abundance in lake water, remained below the standard of 20ug/L for most of the monitoring period except the late spring and early fall. Water clarity, measured as Secchi depth, declined over the monitoring period, falling below the standard from the middle of summer threw early fall.

Figure 3.2.2 shows historic average concentrations collected during the growing season. Magda has increased in overall water quality, with all three water quality parameter meeting the shallow lake standard for the first time in the lakes history.

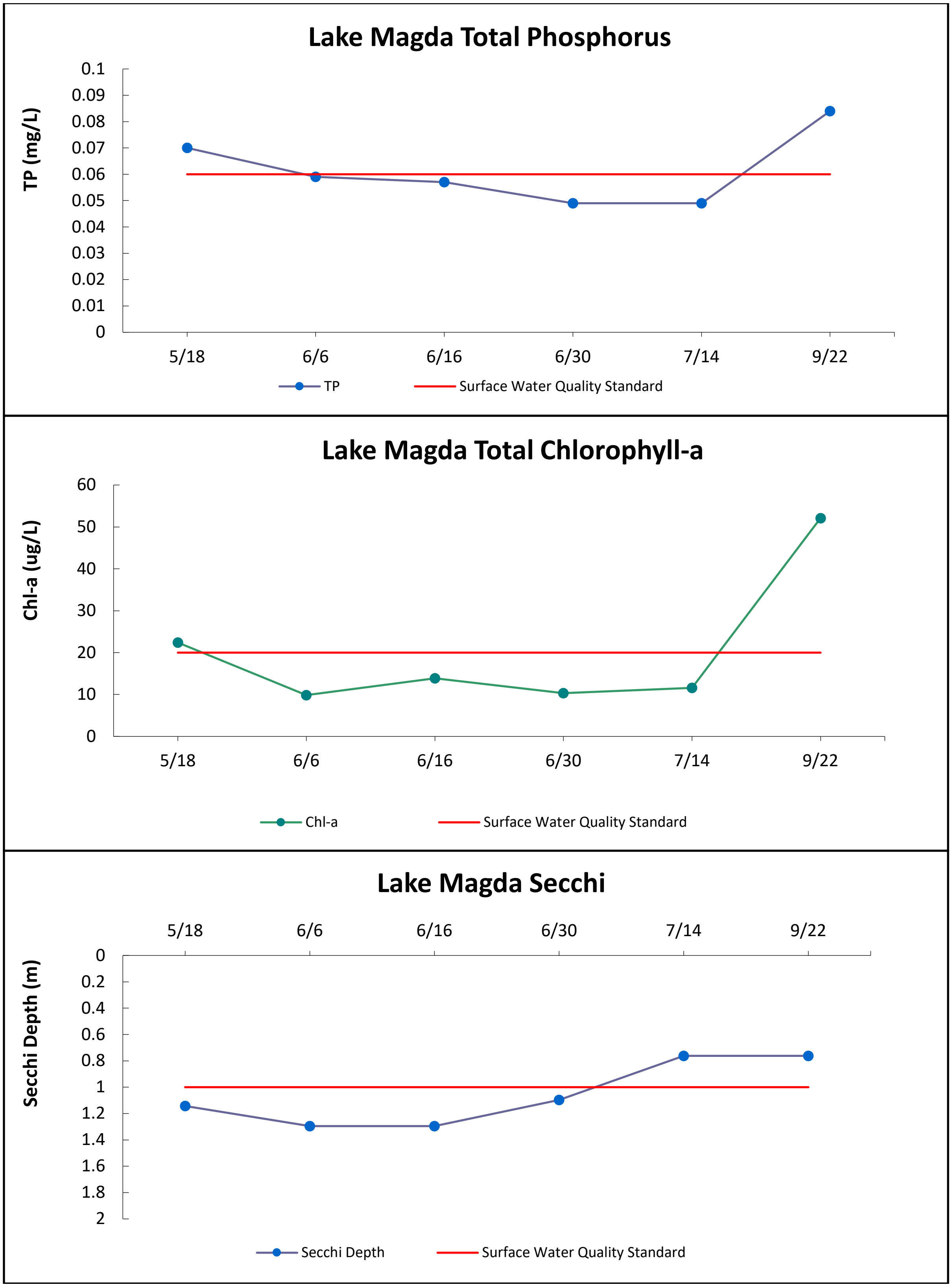


Figure 3.2.1. Seasonal TP, chlorophyll-a, and Secchi measurements and standards.

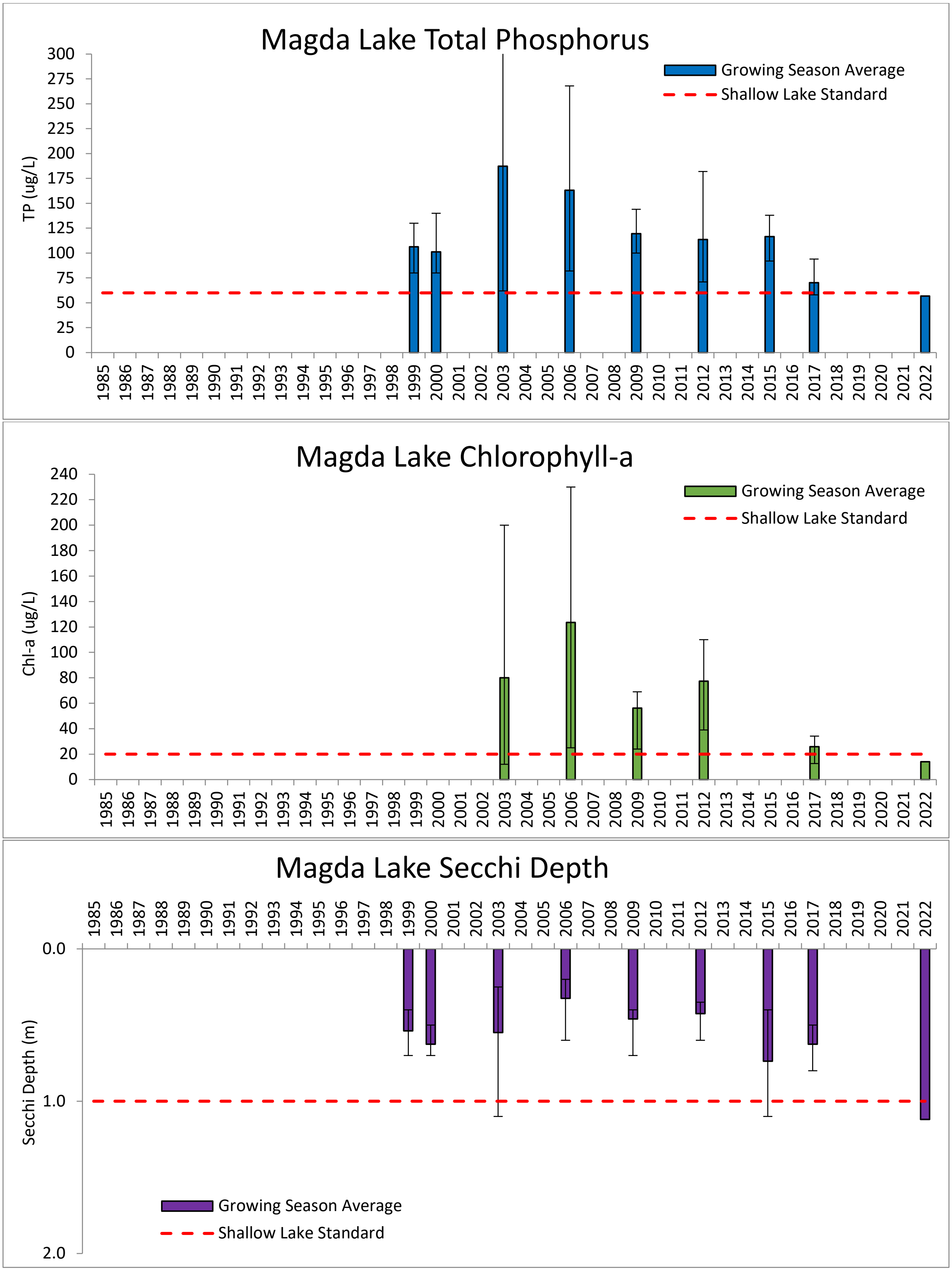


Figure 3.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth in Lake Success, with shallow lake standards in red for reference.

3.3 PHYTOPLANKTON AND ZOOPLANKTON

Lake Magda was highly dominated by a diverse assemblage of cyanobacteria phytoplankton (Figure 3.3.1) at a low concentration. Cyanobacteria domination is typical for Minnesota lakes in August and the diversity of genera and low concentration are not a sign of a harmful algae bloom.

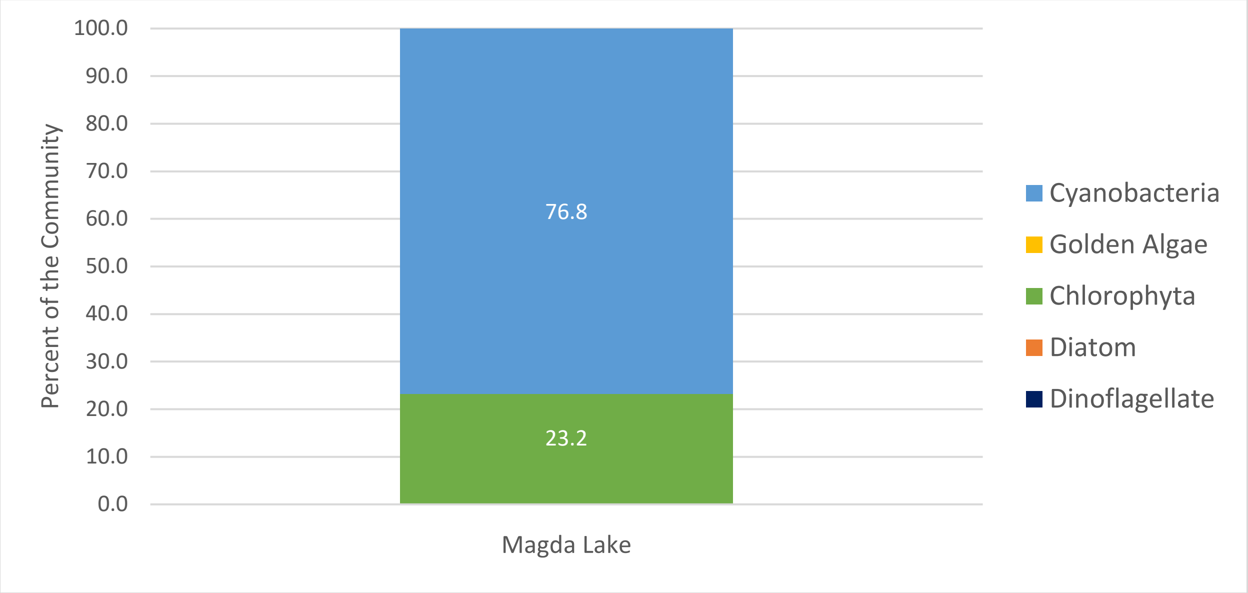


Figure 3.3.1: Phytoplankton relative percentage in Magda Lake.

The lake contained 100% Nauplii in 2022 (Figure 3.3.2). Nauplii are the early stage of many zooplankton species. Their abundance in summer indicates a healthy zooplankton community with a plentiful food source.

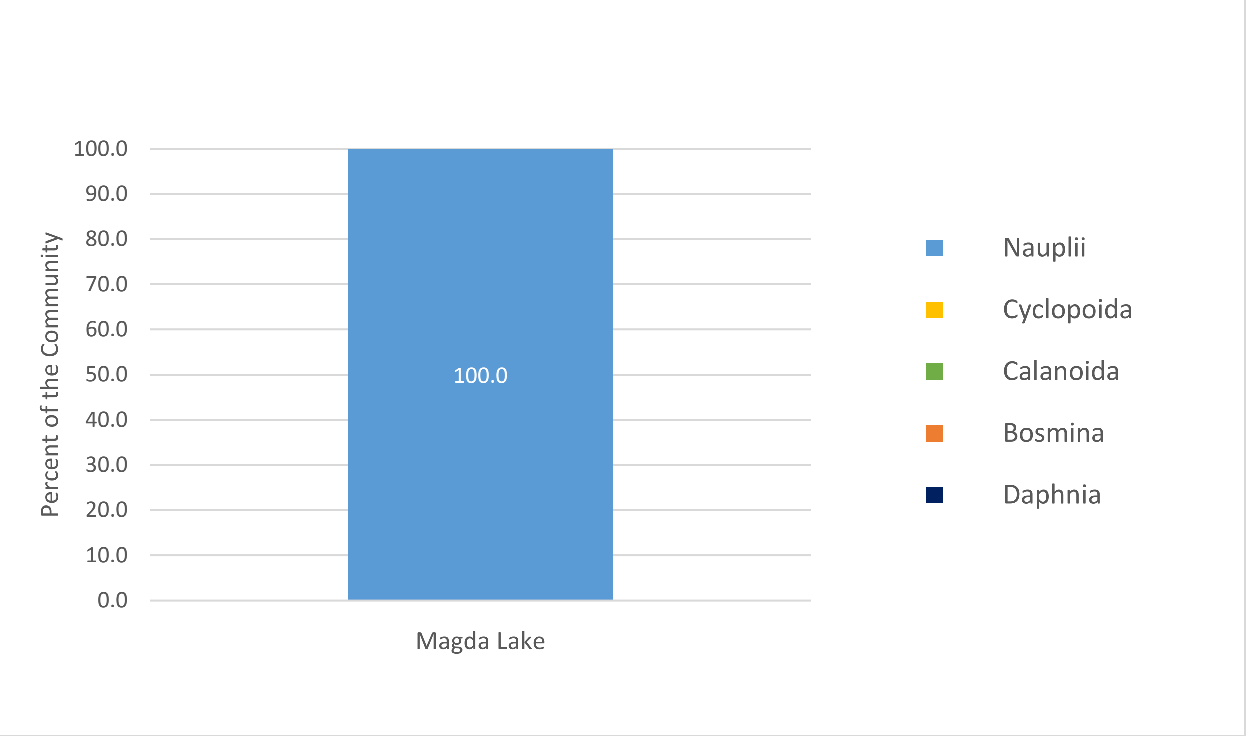


Figure 3.3.2: Zooplankton relative percentage in Magda Lake.

3.4 SUBMERSED AQUATIC VEGETATION

One point intercept aquatic vegetation survey was conducted on June 16, 2022 to document the submersed aquatic vegetation in Lake Magda. Below are two tables outlining survey results and associated metrics and indices (**Table 3.4.1** and **Table 3.4.2**). Maps include a BioBase maps of vegetation biovolume (**Figure 3.4.1**), number of taxa at each sample point (**Figure 3.4.2**), and CLP location and density (**Figure 3.4.3**), no Eurasian Watermilfoil was found in the survey.

Table 3.4.1. Lake Magda SAV metrics and indices.

	July 16, 2022
LAKEWIDE METRICS	
Total Points Sampled	51
Total Littoral Points Sampled	51
% Littoral with Veg	98
Max depth of plant growth (ft)	6.0
Shallow Lake Species Richness Threshold	11
Species Richness	9
COMMUNITY INDICES	
Shallow Lake FQI Threshold	17.8
Floristic Quality Index (FQI)	16.7
Simpson's Diversity Index	74.7
Aquatic Macrophyte Community Index (AMCI)	43

Table 3.4.2. Meadow Lake plant taxa and littoral frequency of occurrence from 2022 surveys.

Taxa	**Common Name**	**July 16, 2022**
SUBMERSED TAXA		
coontail	Ceratophyllum demersum	61
hornwort	Ceratophyllum echinatum	4
waterweed (Canadaian)	Elodea canadensis	67
water milfoil (northern)	Myriophyllum sibiricum	2
yellow waterlily (common)	Nuphar variegata	4

Taxa	Common Name	July 16, 2022
curly-leaf pondweed	Potamogeton crispus	2
straight-leaved pondweed	Potamogeton strictifolius	41
FLOATING TAXA		
Lemna minor	duckweed (lesser)	8
Spirodela polyrhiza	greater duckweed	8

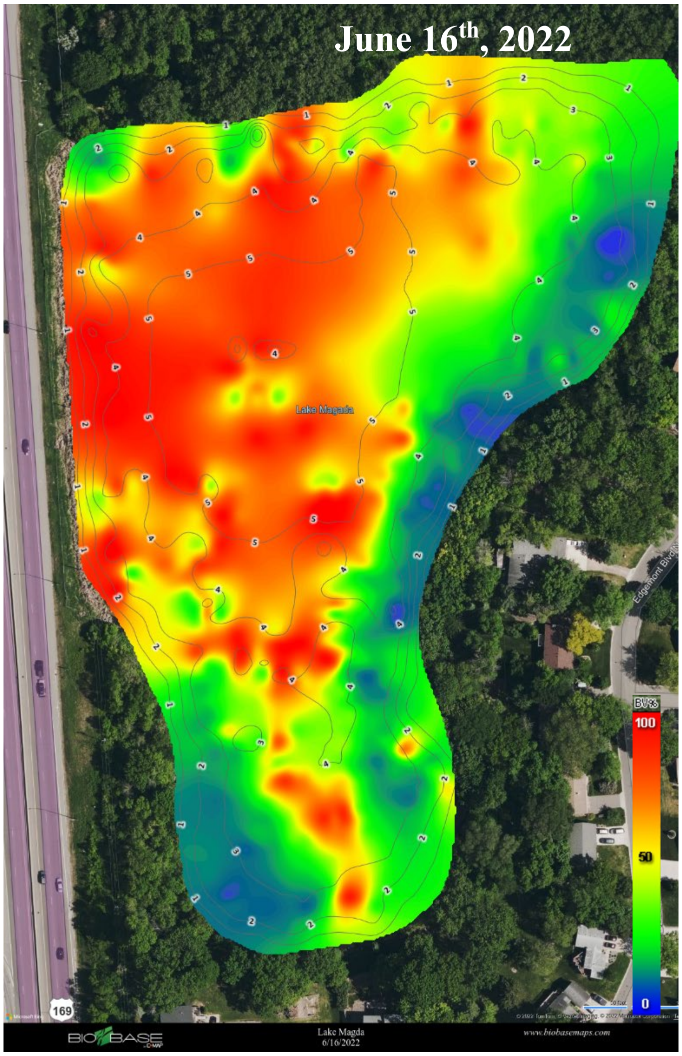


Figure 3.4.1. Biovolume heat maps for Lake Magda during the June 16th 2022 survey. In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

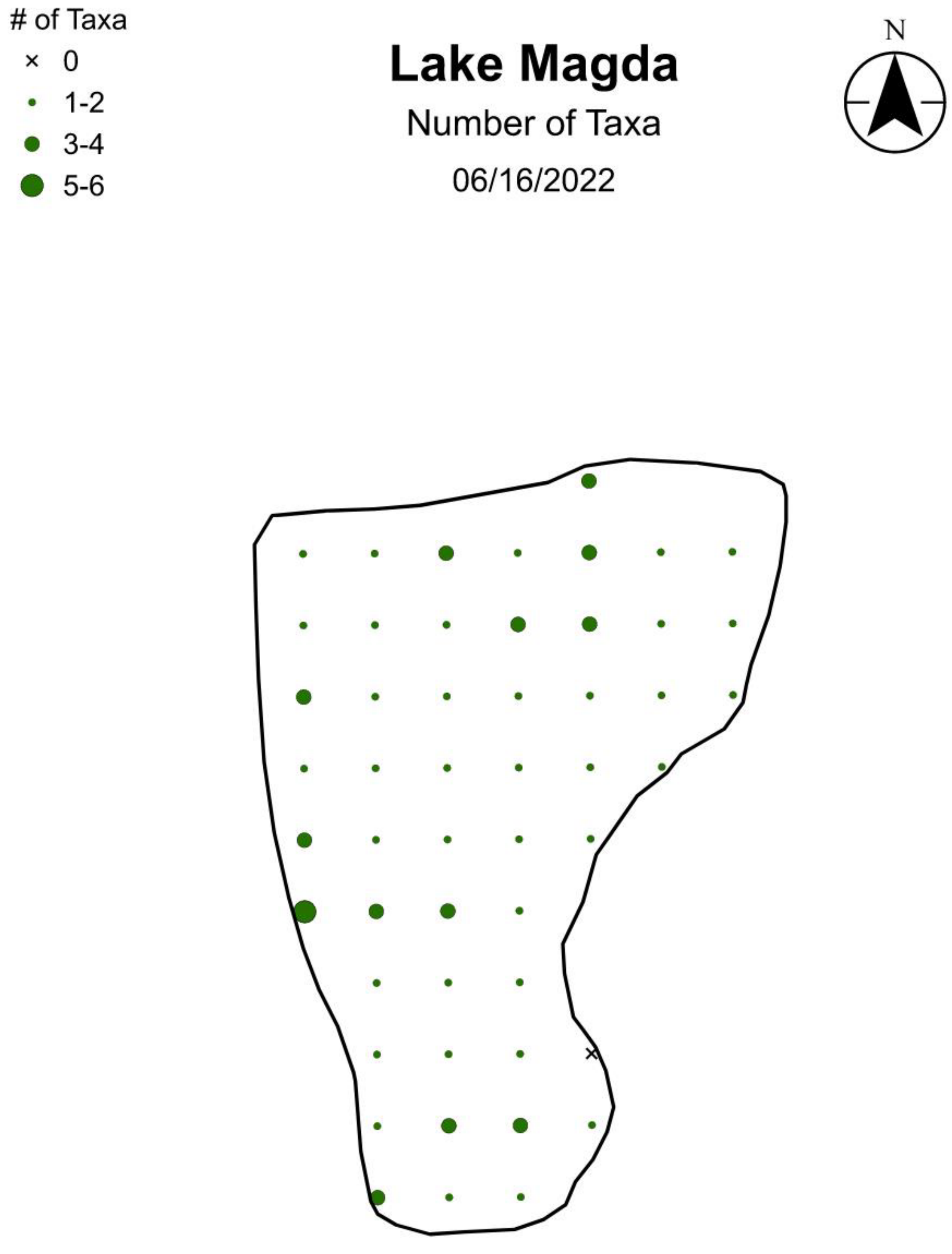


Figure 3.4.2. Map of the number of taxa found at each point in Lake Magda.

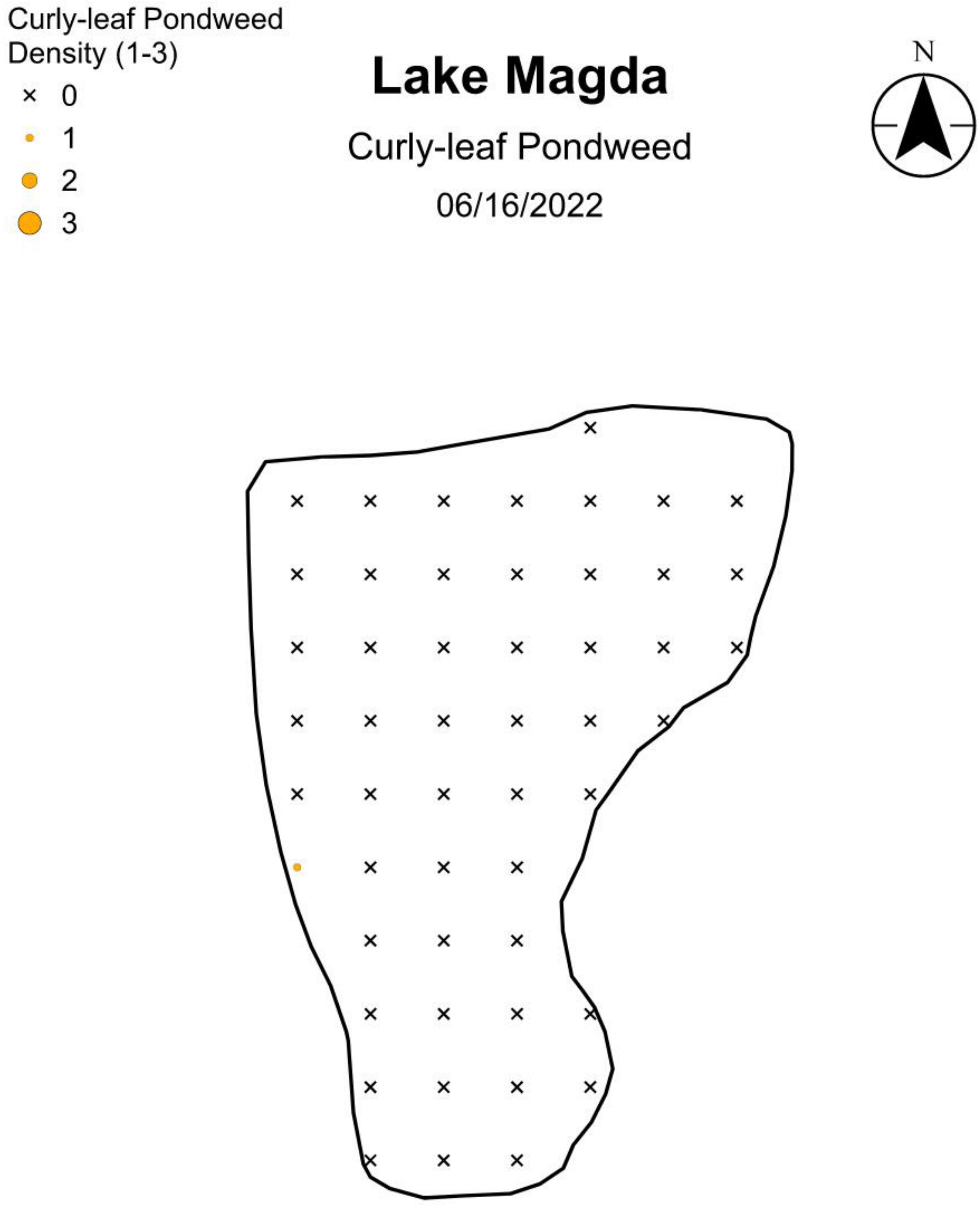


Figure 3.4.3. Map of the location and density of curly-leaf Pondweed in Lake Magda.

3.5 FISHERIES

Three trap nets were deployed in Lake Magda on July 20th, 2023 to survey the fisheries community in Lake Magda. Only black bullhead and fathead minnows were captured, indicating a highly disturbed lake environment with tolerant species. Both bullheads and fathead minnows can contribute to internal loading of phosphorus through sediment resuspension, as their feeding habits include grazing in lake sediments.

4.0 Meadow Lake

4.1 INTRODUCTION & SAMPLING OVERVIEW

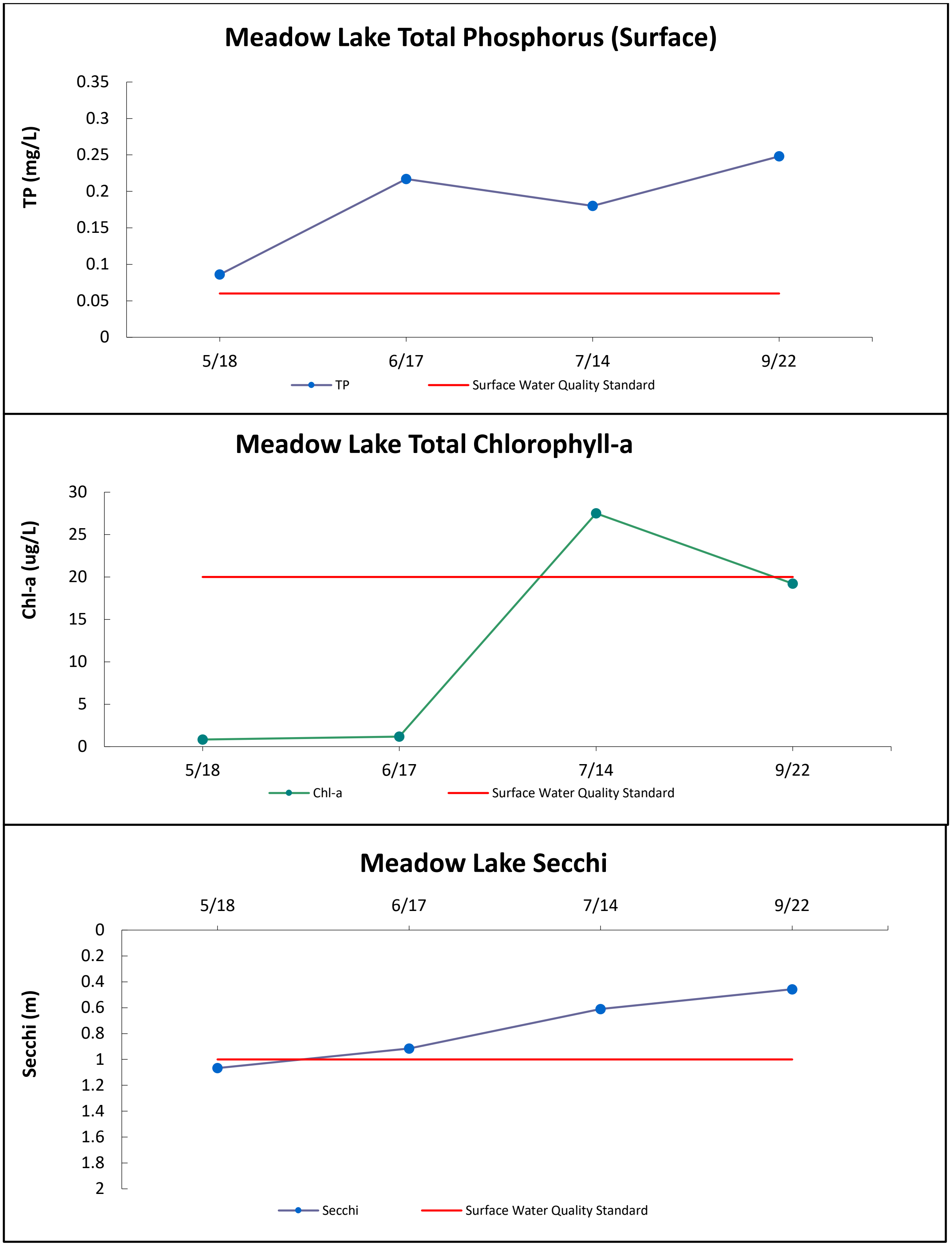
Meadow Lake (Public Water No. 27005700) is located in the city of New Hope within Hennepin County, MN. Meadow Lake is classified as a shallow lake and has an approximate surface area of 10 acres. Meadow is classified as a Shallow Lake due to 100% of the lake being classified in the littoral zone (i.e., <15 feet deep). The list below summarizes the year in which each type of sampling was most recently performed:

- Water Quality – 2022
- Phytoplankton/Zooplankton - 2022
- SAV – 2022
- Fisheries - 2022
- Carp – NA

4.2 WATER QUALITY

Figure 4.2.1 shows TP, chlorophyll-a, and Secchi depth transparency from samples collected during the monitoring season in 2022. Phosphorus concentrations exceeded the standard for the full sampling season increasing as the summer progressed. Chlorophyll-a concentrations increased in mid-summer, exceeding eutrophication standards and indicating an algae bloom, then decreased to below standards in late September. Secchi depth decreased over the course of the summer and did not meet the water quality standard.

Figure 4.2.2 shows historic averages. Water quality in Meadow Lake has been improving since monitoring started in 1996. Chlorophyll-a had an average monitoring season concentrations below the shallow lake standard. TP and Secchi depth exceeded the shallow lake standard but have improved in recent years.



4.2.1. Seasonal TP, *chlorophyll-a*, and Secchi measurements and standards.

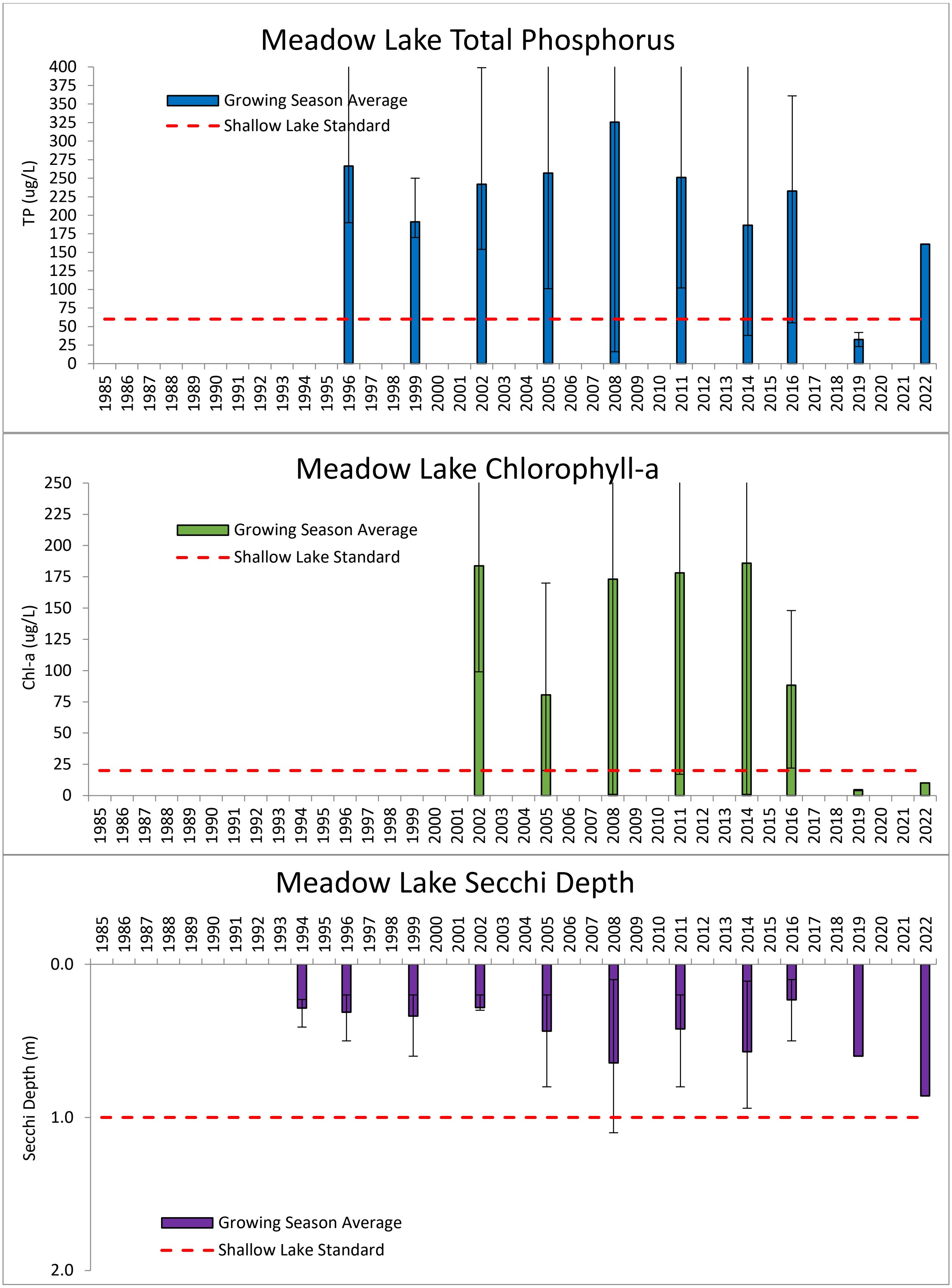


Figure 4.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

Phytoplankton and Zooplankton

The phytoplankton community had some diversity with diatoms, chlorophyta, and cyanobacteria (Figure 4.3.1). Cyanobacteria dominated the sample which is typical for Minnesota lakes in August. The concentrations were low and there were multiple cyanobacteria species observed, which indicates a balanced phytoplankton community.

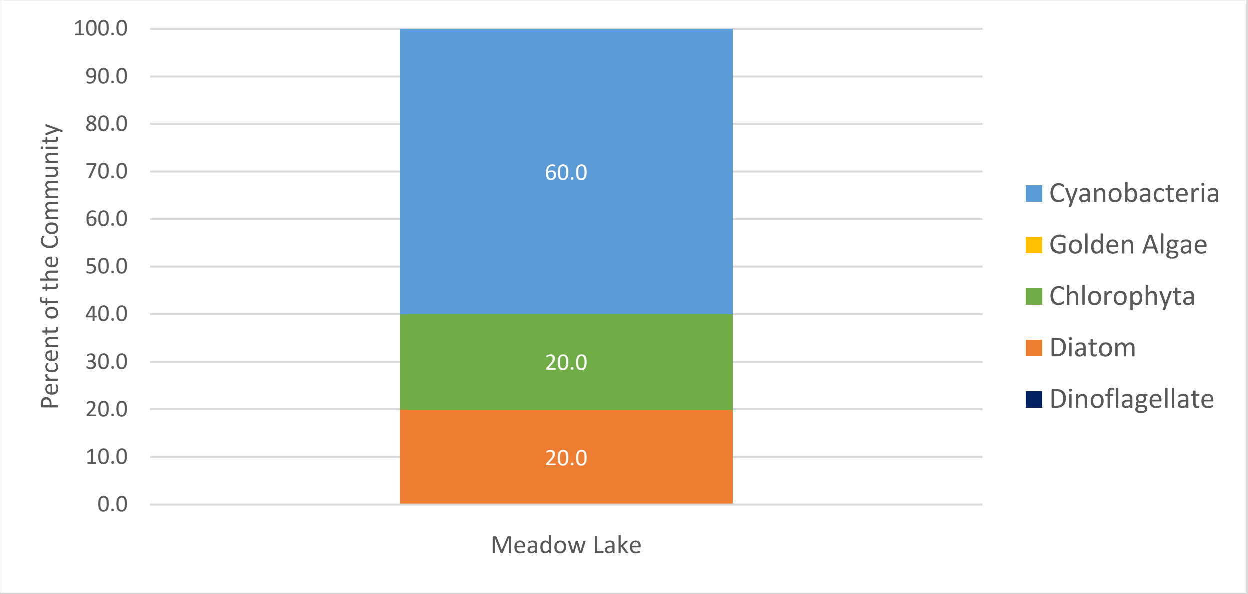


Figure 4.3.1: Phytoplankton relative percentage in Meadow Lake.

The zooplankton community is nauplii-dominated with a healthy mix of other mature zooplankton (Figure 4.3.2). Nauplii are the early stage of many zooplankton species. Their abundance in summer indicates a healthy zooplankton community with a plentiful food source.

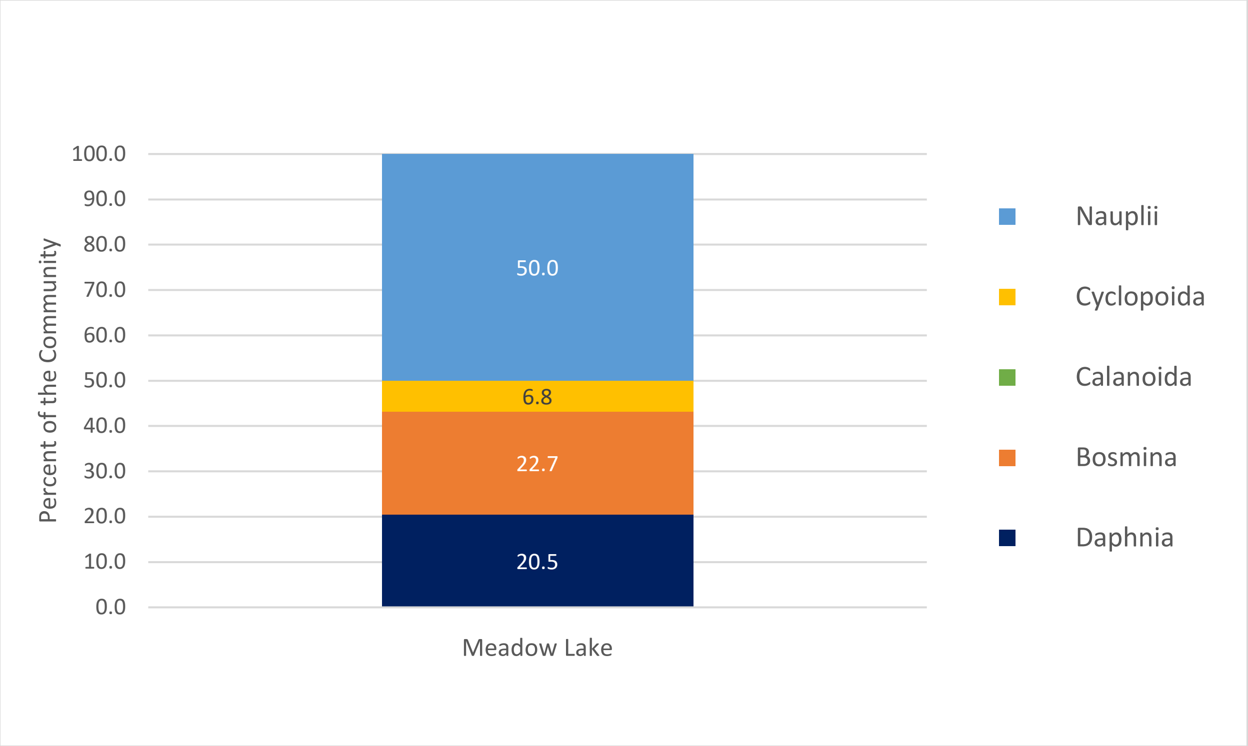


Figure 4.3.1: Zooplankton relative percentage in Meadow Lake.

4.3 SUBMERSED AQUATIC VEGETATION

One point intercept aquatic vegetation survey was conducted on July 26, 2022 to document the submersed aquatic vegetation in Meadow Lake. Below are two tables outlining survey results and associated metrics and indices (**Table 4.4.1** and **Table 4.4.2**). Maps include the number of taxa at each sample point (**Figure 4.4.1**) and the CLP location and density (**Figure 4.4.2**). A BioBase map was not created due to insufficient data, and no Eurasian Watermilfoil was found in the survey.

Table 4.4.1. Meadow Lake SAV metrics and indices.

	July 26, 2022
LAKEWIDE METRICS	
Total Points Sampled	56
Total Littoral Points Sampled	56
% Littoral with Veg	100
Max depth of plant growth (ft)	4.0
Shallow Lake Species Richness Threshold	11
Species Richness	9
COMMUNITY INDICES	
Shallow Lake FQI Threshold	17.8
Floristic Quality Index (FQI)	15.7
Simpson's Diversity Index	83
Aquatic Macrophyte Community Index (AMCI)	38

Table 4.4.2. Meadow Lake plant taxa and littoral frequency of occurrence from 2022 surveys.

Taxa	Common Name	July 26, 2022
SUBMERSED TAXA		
Chara sp.	muskgrass	11
Ceratophyllum demersum	coontail	16
Najas flexilis	bushy pondweed	88
Potamogeton crispus	curly-leaf pondweed	57
Potamogeton foliosus	leafy pondweed	75
Potamogeton zosteriformis	flat-stemmed pondweed	2
Stuckenia sp.	pondweed	4
FLOATING TAXA		
Lemna minor	duckweed (lesser)	82
Spirodela polyrhiza	greater duckweed	82

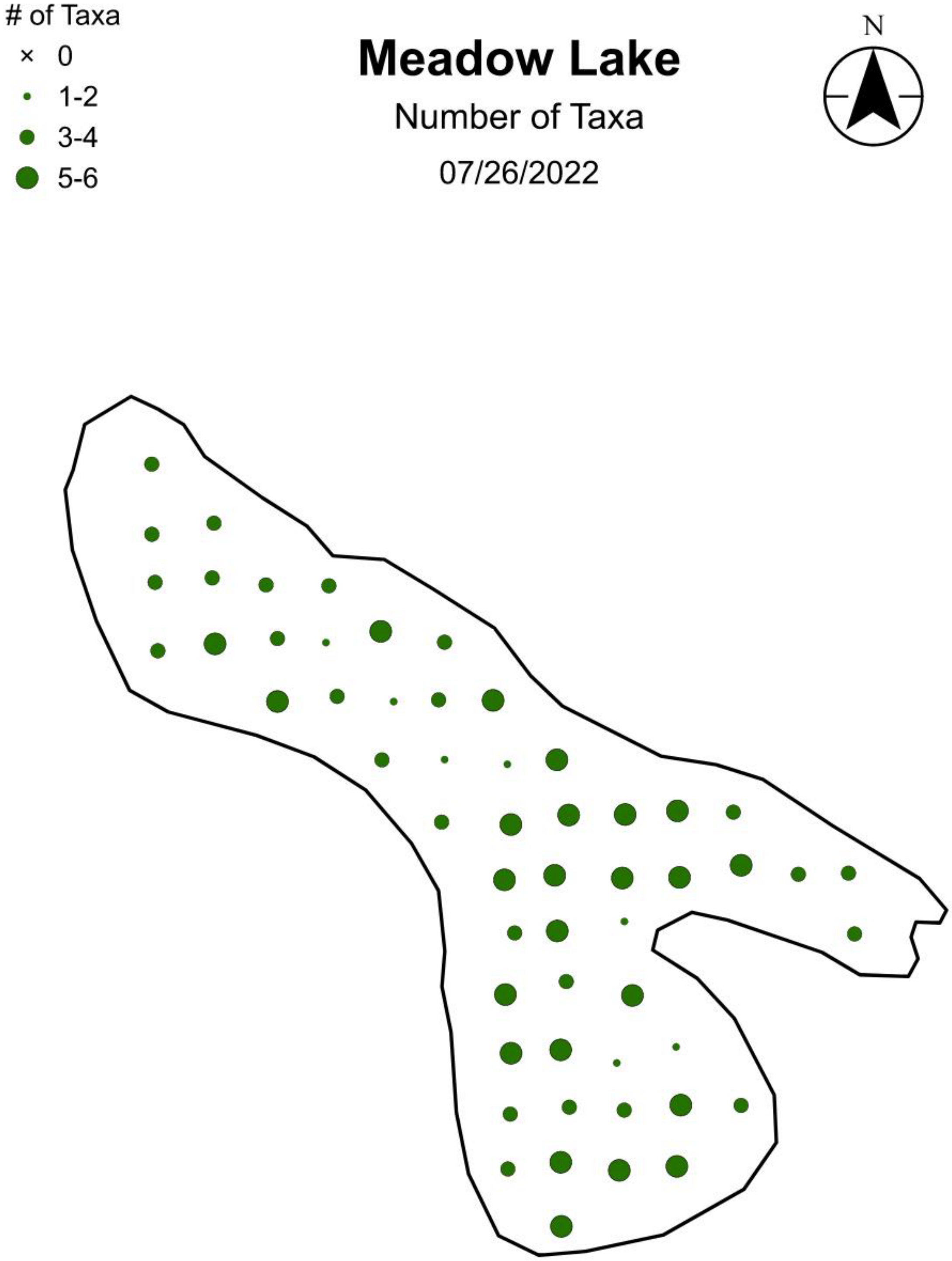


Figure 4.4.1: Map of the number of taxa found at each point-intercept survey location on Meadow Lake.

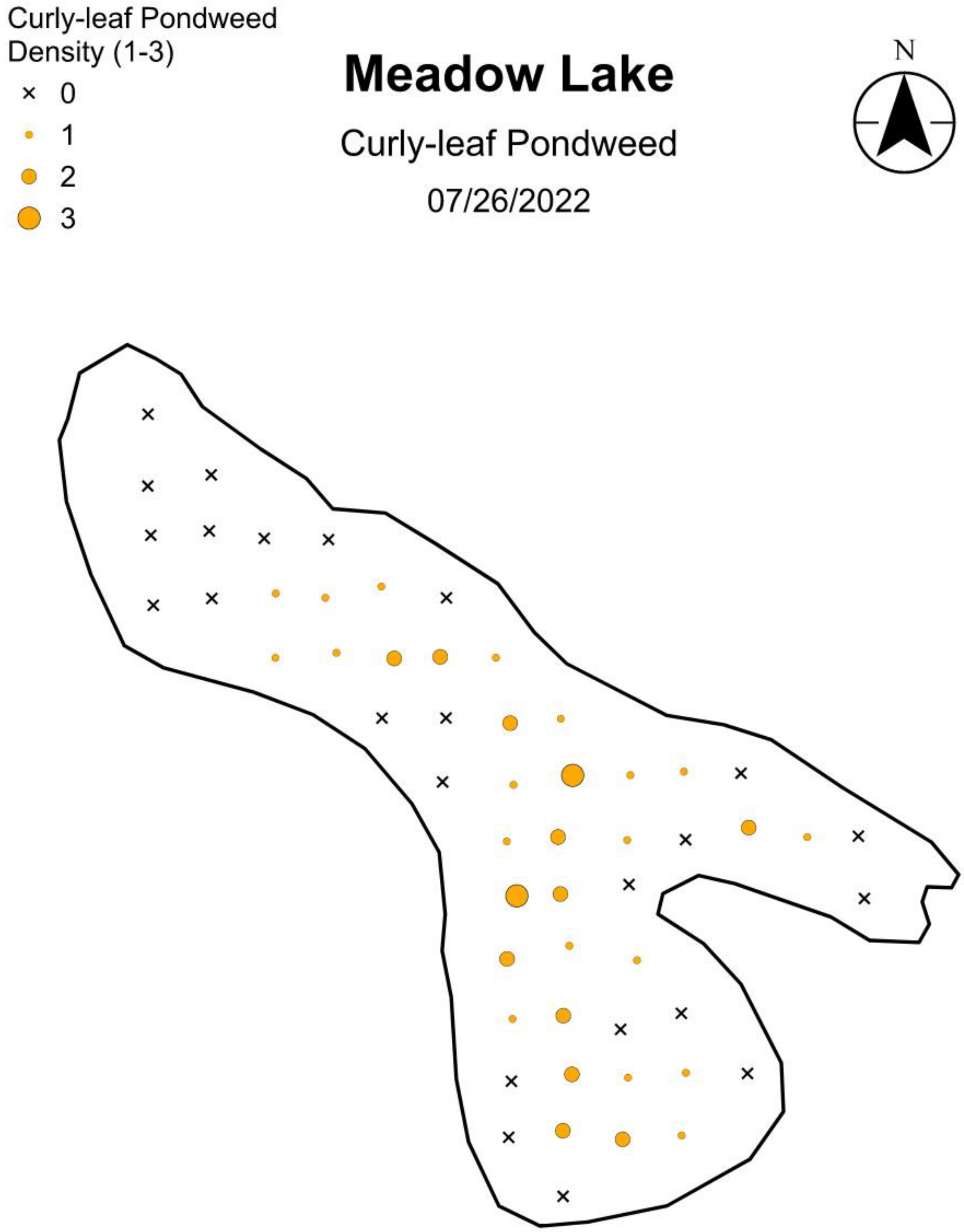


Figure 4.4.2. Map of the location and density of curly-leaf pondweed in Meadow Lake during point-intercept surveys.

4.4 FISHERIES

A trap and gill net fisheries survey was conducted on Meadow Lake in 2022 to assess the success of the drawdown in controlling the fathead minnow population. No fish were captured during the survey.

5.0 Crystal Lake

5.1 INTRODUCTION & SAMPLING OVERVIEW

Crystal Lake (Public Water No. 27003400) is in Robbinsdale, MN within Hennepin County. Middle Twin Lake is classified as a deep lake and has an approximate surface area of 79 acres, 53 acres of littoral area (i.e., area less than 15 feet deep), an average depth of 9.8 feet, and a maximum depth of 39 feet. Crystal Lake is classified as a Deep Lake due to less than 80% of the lake being classified in the littoral zone. The list below summarizes the year in which each type of sampling was most recently performed on Crystal Lake:

- Water Quality - 2022
- SAV – 2022
- Phytoplankton/Zooplankton - 2022
- Fisheries – 2022
- Carp – 2022

5.2 WATER QUALITY

Figure 6.2.1 show TP, Secchi depth, and chlorophyll-a from 2021 over the course of the monitoring season. Surface TP exceeded the deep lake eutrophication standard in mid-June and remained above the standard for the remainder of the summer. Chlorophyll-a concentrations similarly exceeded the standard during all monitoring events except the first sampling date in May. Secchi declined over the summer and did not meet the eutrophication standards except for the first sampling event in May. TP samples taken from the hypolimnion show a peak in mid-summer with concentrations declining in August and September.

Historic water quality data from Crystal Lake show the lake generally does not meet the deep lake standards (Figure 6.2.2). Average monitoring season TP concentrations have previously been below the impairment threshold; however, it has exceeded the eutrophication standard for the last three monitoring seasons. Both chlorophyll-a and Secchi depth, currently and historically, fail to meet the deep lake eutrophication standards. In 2022, deep water TP concentrations failed to meet eutrophication standards; however, deep water TP in recent years has been lower than historically.

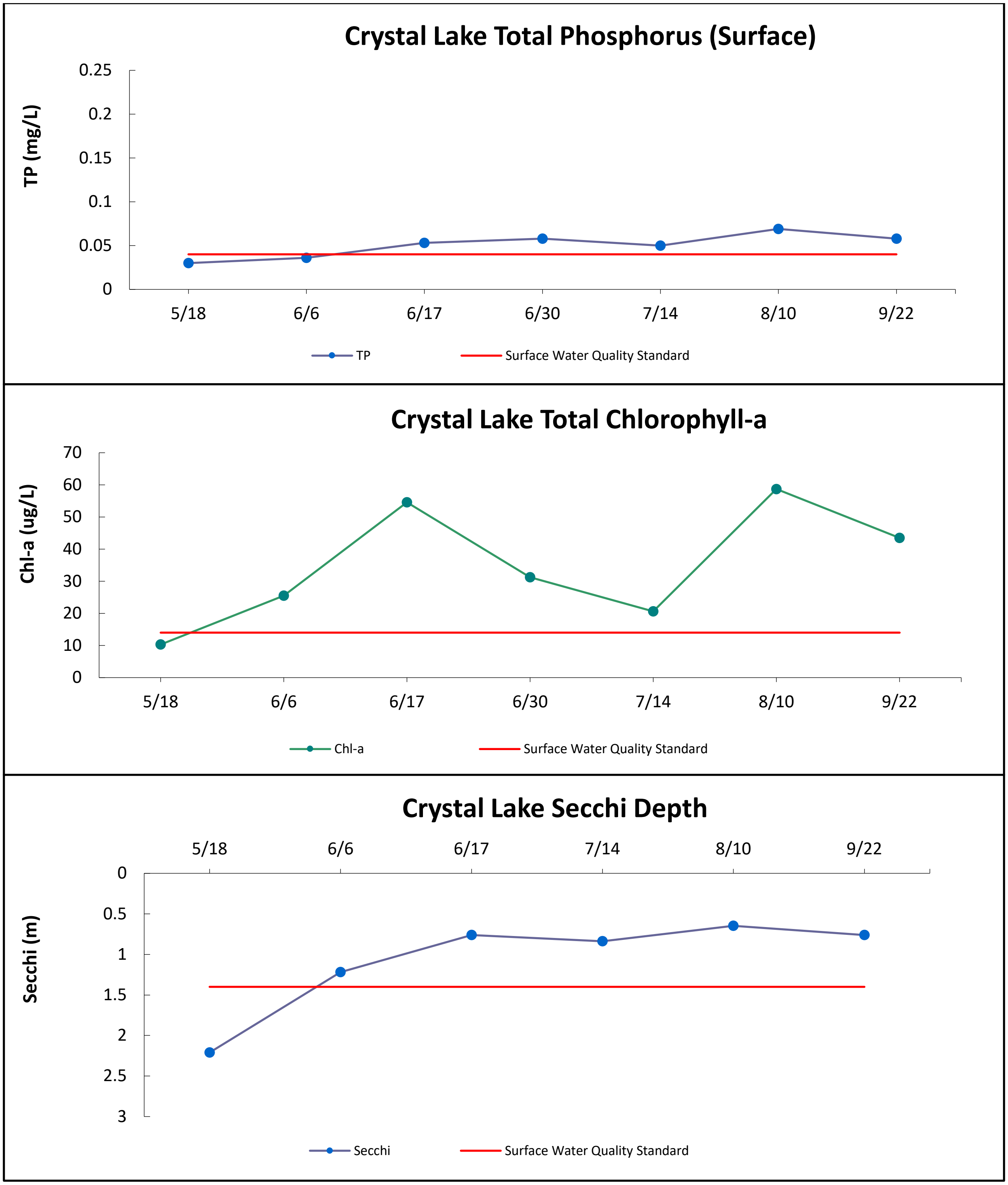


Figure 6.2.1. Seasonal TP, chlorophyll-*a*, and Secchi measurements and standards.

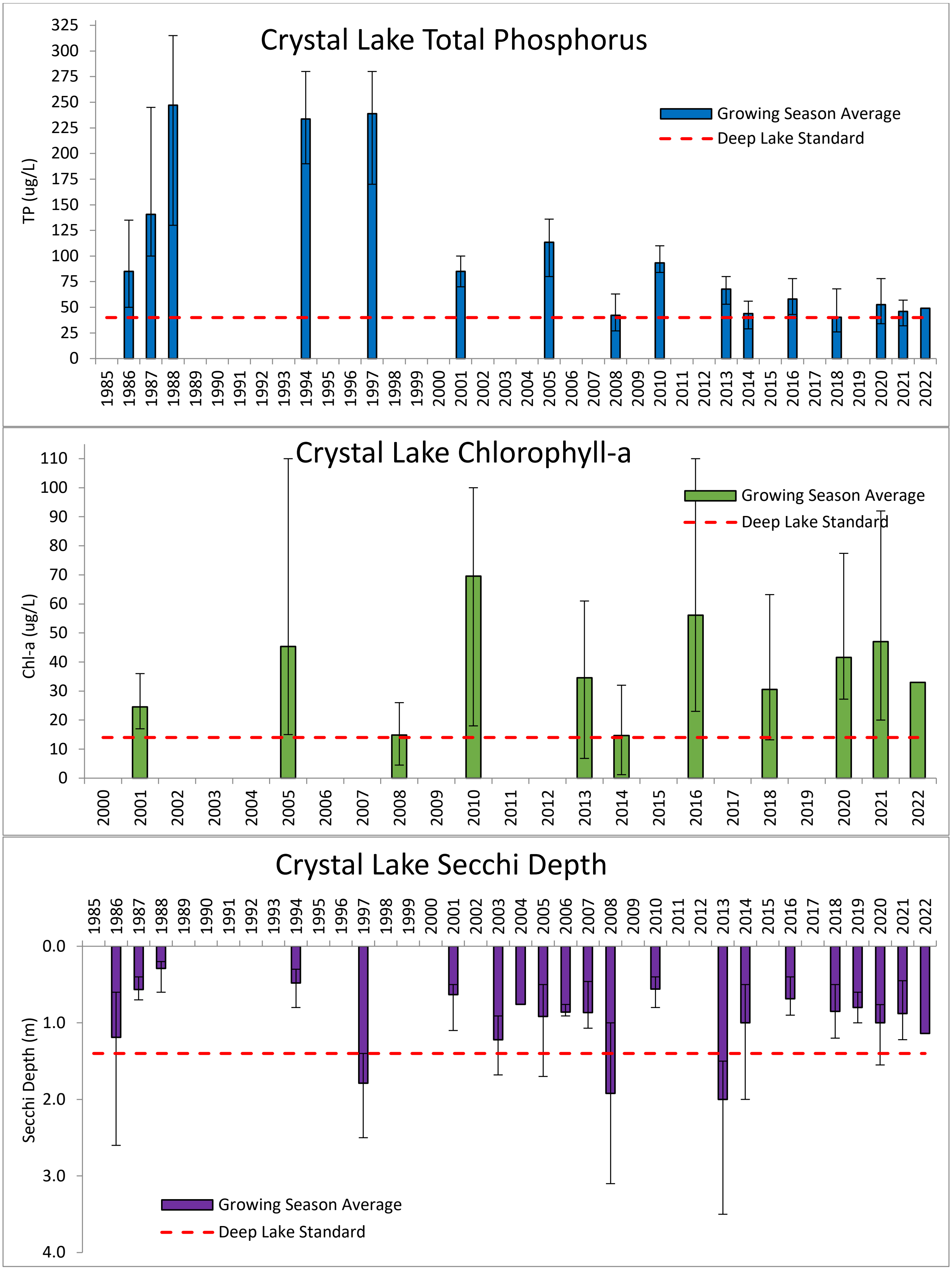


Figure 6.2.2. Annual growing season averages for total phosphorus, chlorophyll-*a*, and Secchi depth, with shallow lake standards in red for reference.

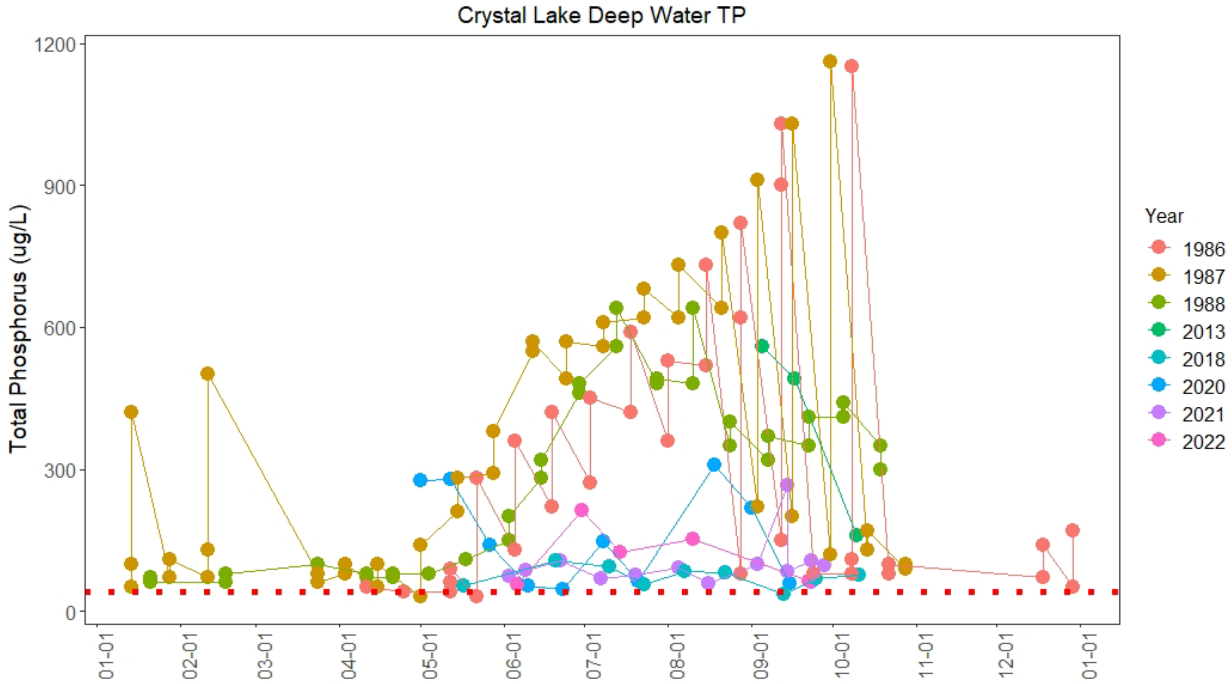


Figure 6.2.3. Hypolimnetic (deep) total phosphorus (TP) throughout the summers in Crystal Lake for available years.

5.3 PHYTOPLANKTON AND ZOOPLANKTON

An analysis of the phytoplankton in Crystal Lake was made up completely of cyanobacteria, with only a negligible fraction of chlorophyta. Concentrations of cyanobacteria were very high and only one genus (Figure 5.3.1). The sole genus was *microcystis*, which is an aggressive, bloom-forming cyanobacteria that has the potential for toxin production. The presence of only *microcystis* and such high concentrations indicate the likelihood of a HAB.

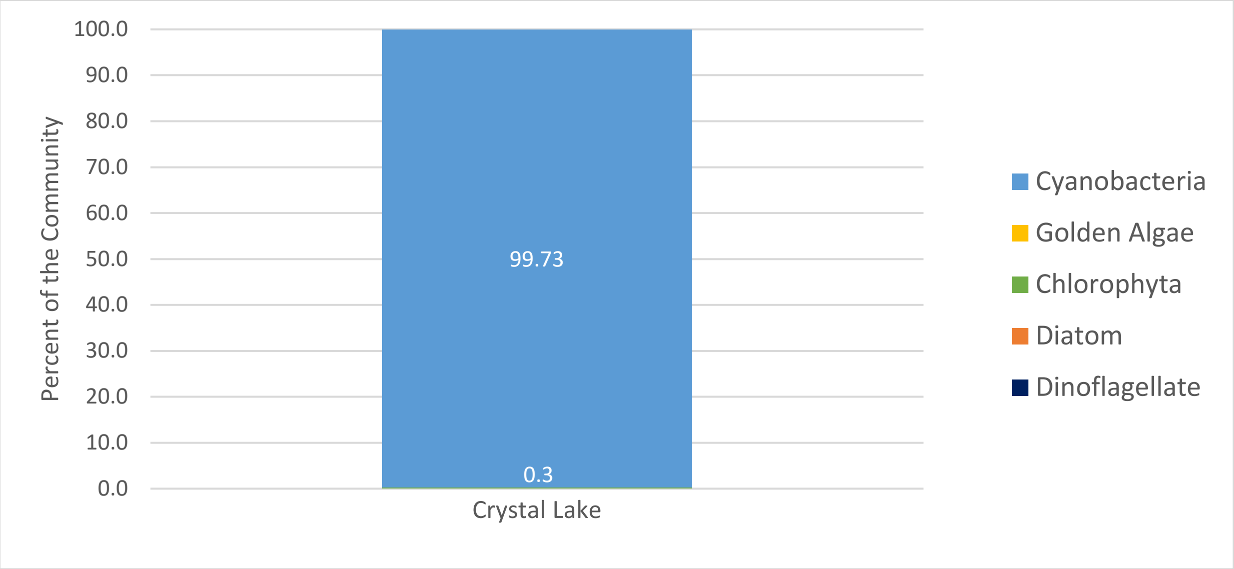


Figure 5.3.1. Phytoplankton relative percentage in Crystal Lake.

The zooplankton community was diverse at the time of sampling with no dominate species (Figure 5.3.2). The diversity indicates a healthy zooplankton community and a strong food web base.

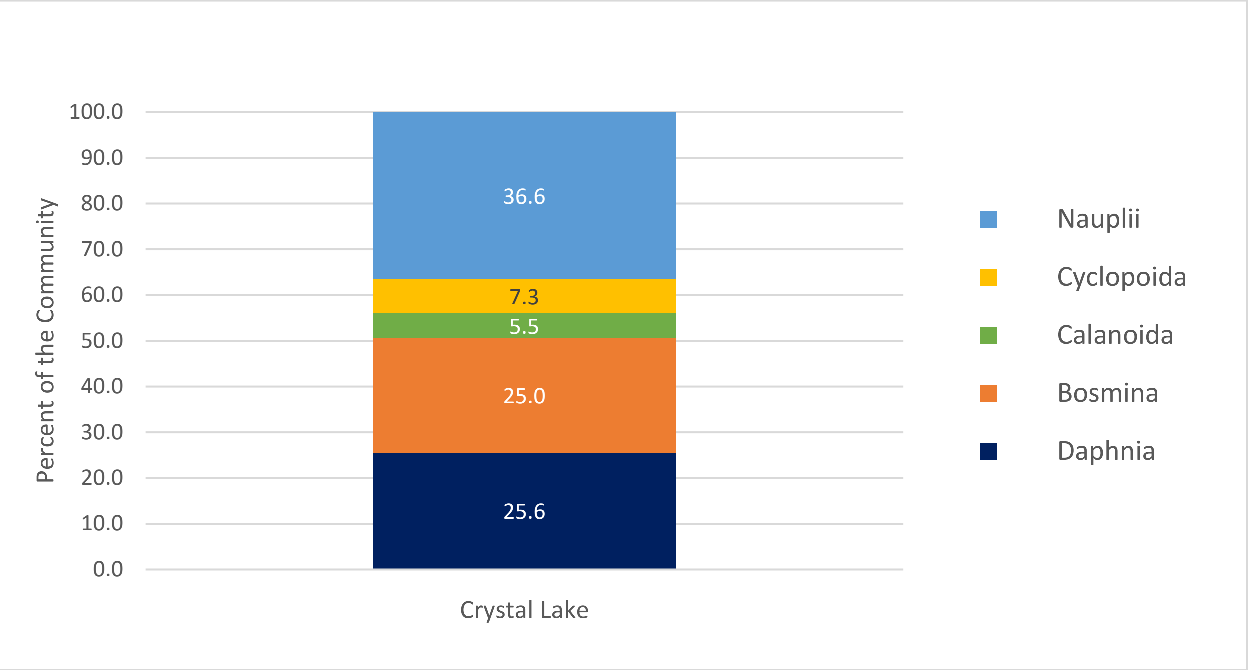


Figure 5.3.2: Zooplankton relative percentage in Crystal Lake.

5.4 SUBMERSED AQUATIC VEGETATION

Point intercept aquatic vegetation surveys were conducted on July 24, 2022 and August 22, 2022 to document the spring and summer submersed aquatic vegetation in Crystal Lake (These surveys will be referred to as the spring and summer surveys.). Below are two tables outlining survey results and associated metrics and indices (**Table 5.4.1** and **Table 5.4.2**). Maps include early and late-season BioBase maps of vegetation biovolume (**Figure 5.4.1**), number of taxa at each sample point (**Figure 5.4.2**), and location and density of curly-leaf pondweed (**Figure 5.4.3.**). No Eurasian Watermilfoil was found in the surveys.

Table 5.4.1. Crystal Lake SAV metrics and indices.

	July 24, 2022	**August 22, 2022**
LAKEWIDE METRICS		
Total Points Sampled	78	82
Total Littoral Points Sampled	49	55
% Littoral with Veg	6	3
Max depth of plant growth (ft)	5.6	5.3
Deep Lake Species Richness Threshold	*12*	
Species Richness	2	2
COMMUNITY INDICES		
Deep Lake FQI Threshold	*18.6*	
Floristic Quality Index (FQI)	7.5	6.4
Simpson's Diversity Index	40.0	50
Aquatic Macrophyte Community Index (AMCI)	12	11

Table 5.4.2. Crystal Lake plant taxa and littoral frequency of occurrence from 2022 surveys.

Taxa	**Common Name**	**July 24, 2022**	**August 22, 2022**
SUBMERSED TAXA			
Potamogeton crispus	Curly-leaf pondweed	1	1
FLOATING TAXA			
Nymphaea odorata	White waterlily	5	4

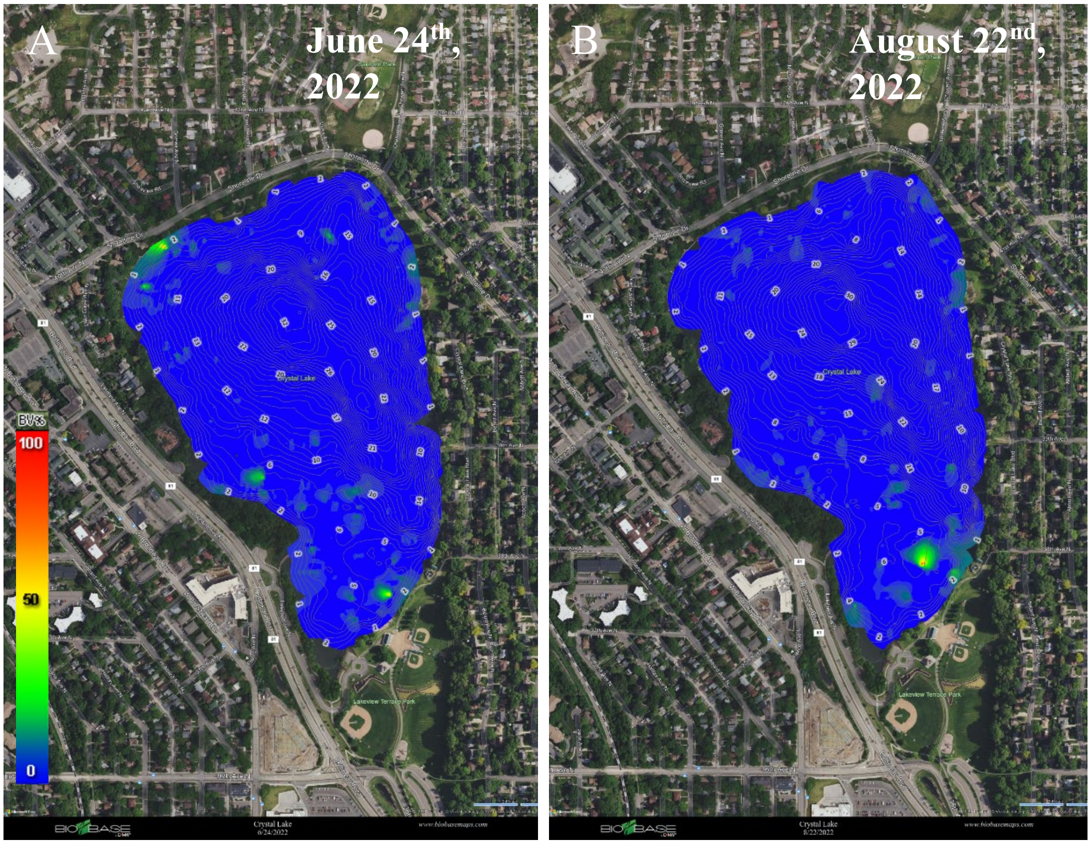


Figure 5.4.1. Biovolume heat maps for Schmidt Lake during the June 24th (A) and August 22nd (B) 2022 surveys. In the heatmaps, red indicates 100% biovolume and blue indicates 0% biovolume. Biovolume refers to the percentage of the water column taken up by vegetation.

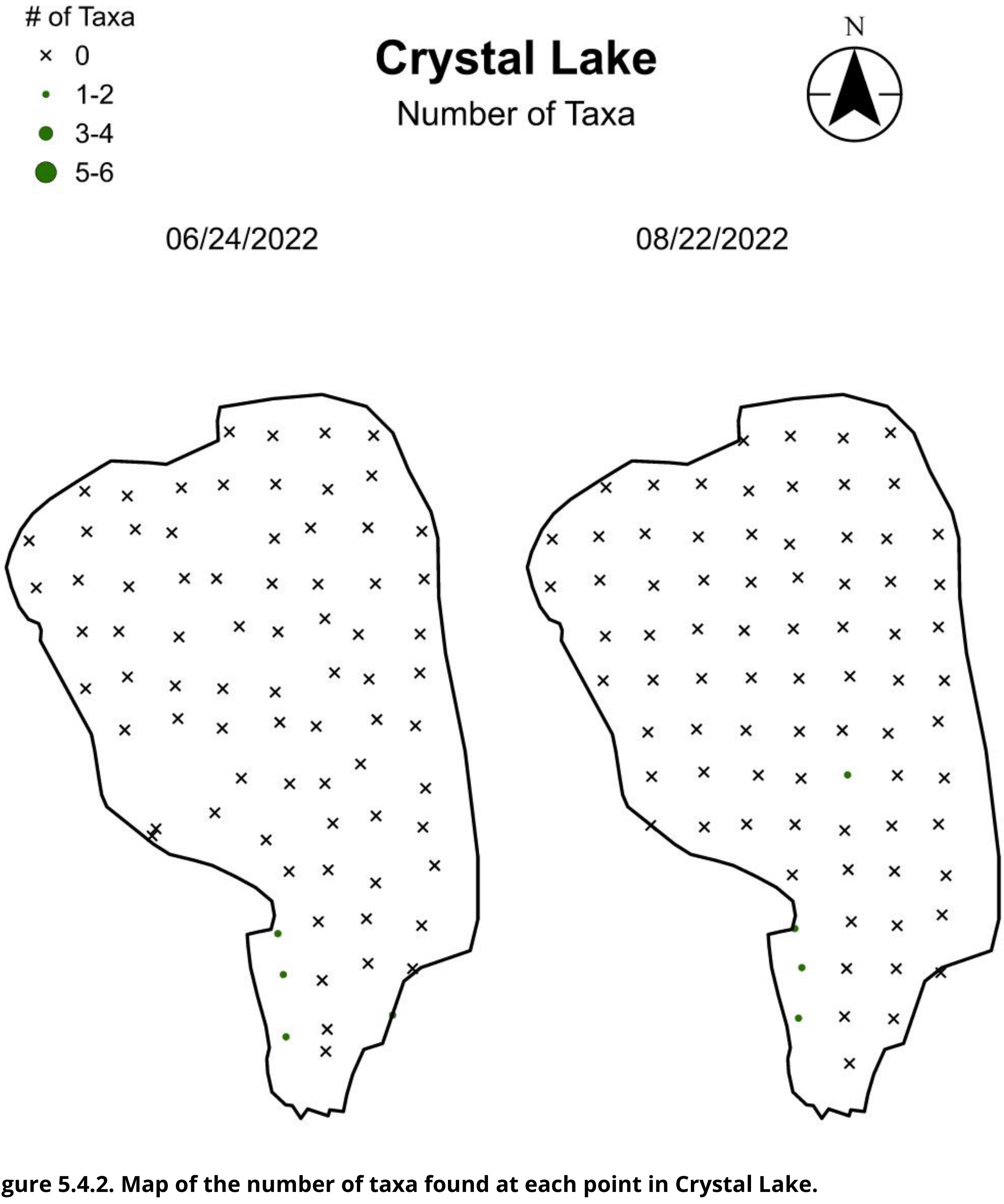


Figure 5.4.2. Map of the number of taxa found at each point in Crystal Lake.

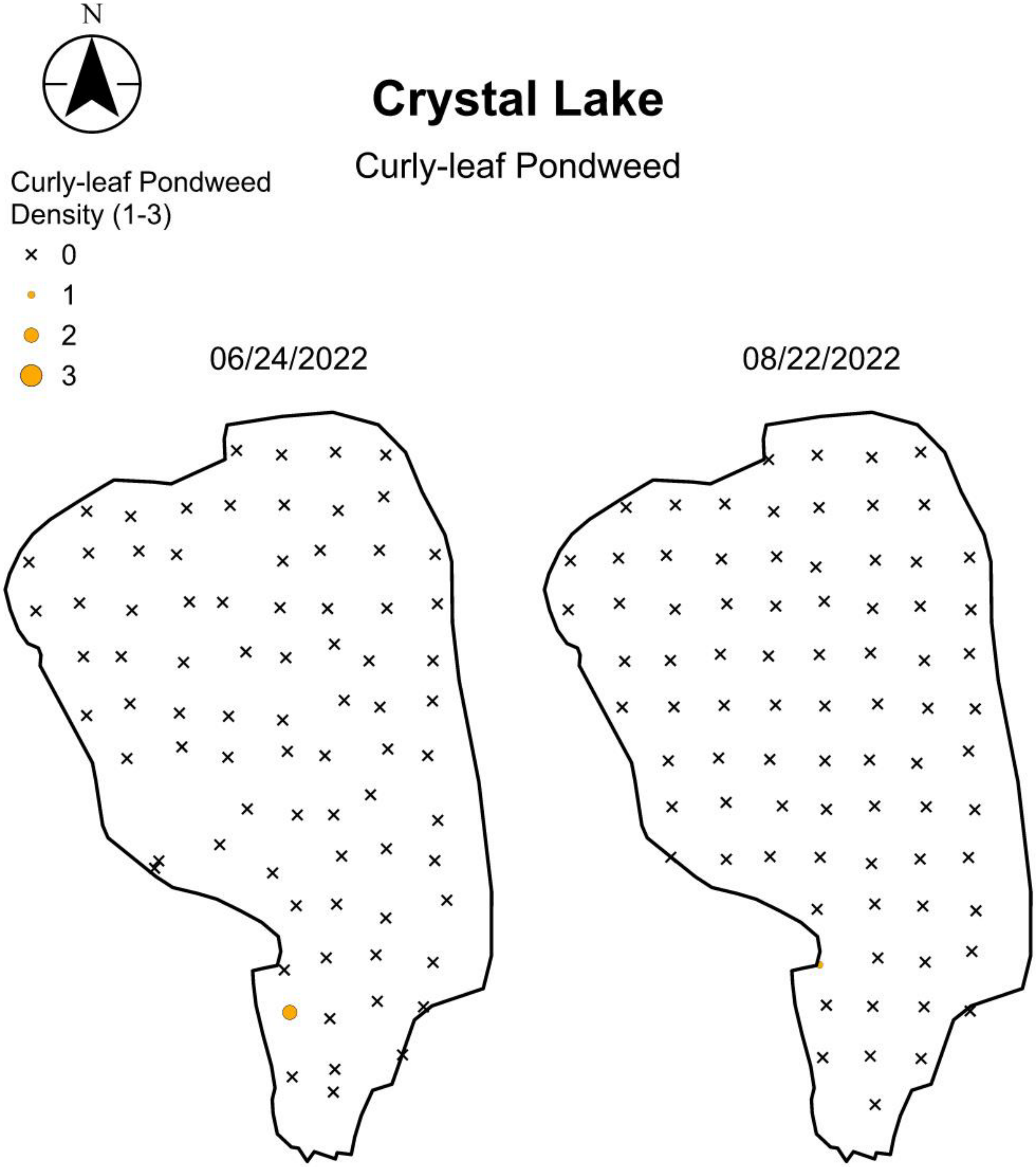


Figure 5.4.3. Map of the location and density of curly-leaf pondweed in Crystal Lake during point-intercept surveys.

5.5 FISHERIES & CARP ASSESSMENTS

5.5.1 Fisheries Survey

In 2022, the MnDNR conducted a general fisheries survey on Crystal Lake using standard gill and trap netting methods. The most recent general fisheries survey was conducted in 2004. Table 5.5.1 shows gill and trap net summaries from the survey and compares them to quartiles for lakes of Lake Class 30. In personal communication with the MnDNR, the lake has a suitable population of crappie, bluegill, perch, and pumpkinseed for carp control. These species are known to feed on carp eggs and keep the carp population in check.

Table 5.5.1. MnDNR gill and trap net survey summaries in Crystal Lake.

Species	Total Fish	Number Per Set	Quartiles for Lake Class 30[1]		
			25%	50%	75%
Gill net summary					
Black bullhead	1	0.25	5.19	18.42	56.19
Black crappie	82	20.5	1.88	6.25	18.00
Bluegill	2	0.50	NA	NA	NA
Common carp	27	6.75	0.5	1.75	4.00
Golden shiner	13	3.25	0.67	1.25	3.88
Green sunfish	1	0.25	0.33	0.75	1.56
Hybrid sunfish	1	0.25	NA	NA	NA
Pumpkinseed	4	1.00	NA	NA	NA
Tiger Muskellunge	3	0.75	NA	NA	NA
White sucker	6	1.50	0.50	1.00	2.00
Yellow bullhead	1	0.25	1.00	2.50	6.88
Yellow perch	80	20.00	1.50	4.00	12.75
Trap net summary					
Black crappie	48	6.00	1.75	5.00	18.08
Bluegill	127	15.88	6.54	24.60	59.60
Bowfin (Dogfish)	1	0.13	0.31	0.63	1.00
Common carp	3	0.38	0.33	0.80	2.55
Golden shiner	6	0.75	0.20	0.40	1.37
Green sunfish	2	0.25	0.25	0.50	2.00
Hybrid sunfish	1	0.13	NA	NA	NA
Pumpkinseed	10	1.25	0.80	2.00	5.33
White sucker	1	0.13	0.33	0.60	1.60
Yellow bullhead	1	0.13	0.75	1.61	5.00
Yellow perch	29	3.63	0.29	0.67	1.45

[1] Quartiles for number per set

To supplement the MnDNR trap and gill net surveys, Stantec conducted nearshore seining and electrofishing. The nearshore methods capture smaller fish than the gill and trap nets. The only additional species captured during nearshore methods included largemouth bass.

5.5.2 Carp Assessments and Removals

Stantec conducted a baseline common carp electrofishing CPUE assessment in 2020 to assess the abundance and biomass density of common carp present in Crystal Lake. See the 2020 Annual Report for results of the assessment.

In 2021 and 2022, the Commission took on carp removal efforts in Crystal Lake. Three nets and two distinct methods were deployed during removal efforts in 2021 and 2022. The makeup of the nets consisted of two baited box nets and one experimental baited float net, all located on the south shoreline of Crystal Lake where high carp catch rates were previously observed, and the water depth, bottom consistency, and lack of aquatic vegetation allowed for the greatest success in capture rates.

Four removal events occurred between June 18 and July 16, 2021 and 6 removal events occurred between June 17, 2022 and July 21, 2022. In total, 3,923 carp were captured and removed from the lake in 2021 (**Table 5.5.2**). and 3,737 were removed in 2022. (**Table 5.5.3**). Due to higher averages for the Box nets, in 2022 all Box nets were used.

Table 5.5.2. Crystal Lake common carp captures by removal event in 2021.

Date	Trap	Carp Caught	Total
18-Jun	Box net 1	845	2,361
	Box net 2	771	
	Float net	745	
30-Jun	Box net 1	48	233
	Box net 2	74	
	Float net	111	
9-Jul	Box net 1	337	1,001
	Box net 2	608	
	Float net	56	
16-Jul	Box net 1	163	328
	Box net 2	161	
	Float net	4	
			3,923

Table 5.5.3. Crystal Lake common carp captures by removal event in 2022.

Date	Trap	Carp Caught	Total
17-Jun	Box net 1	132	381
	Box net 2	75	
	Box net 3	174	
24-Jun	Box net 1	205	620
	Box net 2	75	
	Box net 3	340	
29-Jun	Box net 1	150	590
	Box net 2	206	
	Box net 3	234	
8-Jul	Box net 1	404	1029
	Box net 2	281	
	Box net 3	344	
15-Jul	Box net 1	102	793
	Box net 2	363	
	Box net 3	328	
21-Jul	Box net 1	12	344
	Box net 2	126	
	Box net 3	206	
			3,757

Approximately 65% of the estimated common carp population was removed during netting efforts in 2021and 2022 combined that resulted in a decrease in biomass of 270.6 lbs/acre (**Table 5.5.4 and Table 5.5.5**). The removal target was exceeded and the current estimated biomass in the lake is 158lbs/acre.

Table 5.5.4. Crystal Lake common carp removal statistics 2021.

Metric	Result
Average length	459 mm (17.8 inches)
Average weight	1.31 kg (2.87 lbs)
Population Metrics	
2020 CPUE population estimate	12,011 carp
Total carp removed in 2021	3,923 carp
Percent of population removed	33%
Post removal population estimate	8,088 carp
Biomass Metrics	
2020 CPUE biomass estimate	311 lbs/acre
Lbs/acre removed in 2021	142.3 lbs/acre
Post removal effort biomass estimate	168.7 lbs/acre
Future Management Goals	
Water quality impairment threshold	89 lbs/acre
Carp removal goal to reach water quality impairment threshold	3,000-4,000 carp
Biomass removal goal to reach water quality impairment threshold	79.7 lbs/acre

Table 5.5.5. Crystal Lake common carp removal statistics 2022.

Average length	18.6 inches (Up from 17.8 inches in 2021)
Average weight	2.8 lbs (like 2021 at 2.87 lbs)
Total carp caught	3,757 (131 were released with PIT tags)
Total carp removed	3626 removed (down from 3923 carp in 2021)
Original population estimate	12,011 carp
Original biomass estimate	436 lbs/acre
% of population removed in 2021	33%
Lbs/acre removed in 2021	142.3 lbs/acre
% of original population removed in 2022	31%
2021 and 2022 culmulative % population removed	64%
Lbs/acre removed in 2022	128.3 lbs/acre
Current biomass estimate	158 lbs/acre

6.0 References

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