

LAKE LEMON MONITORING PROGRAM

2021 Results Summary



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Lake Lemon 2021 Water Monitoring Overview

The Lake Lemon Conservancy District (LLCD) began contracting Indiana University in 1998 to monitor water quality of the lake and incoming tributaries. Figure 1 shows the sampling locations for Lake Lemon and the tributaries in 2021. IU has provided full sampling methods to the LLCD. Figure 2 displays precipitation during the sampling season with individual sampling events indicated.

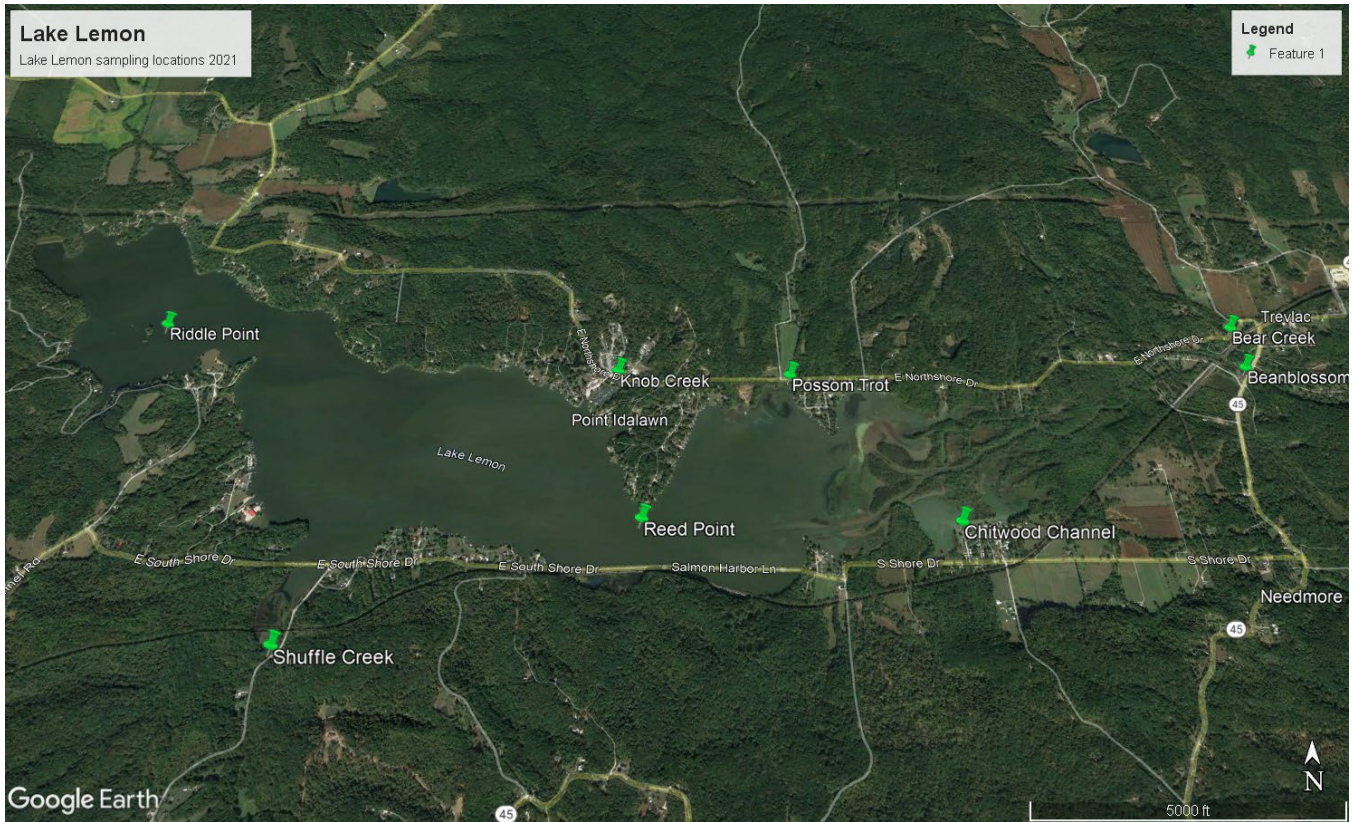


Figure 1 Sampling locations for the Lake Lemon Water Monitoring Program.

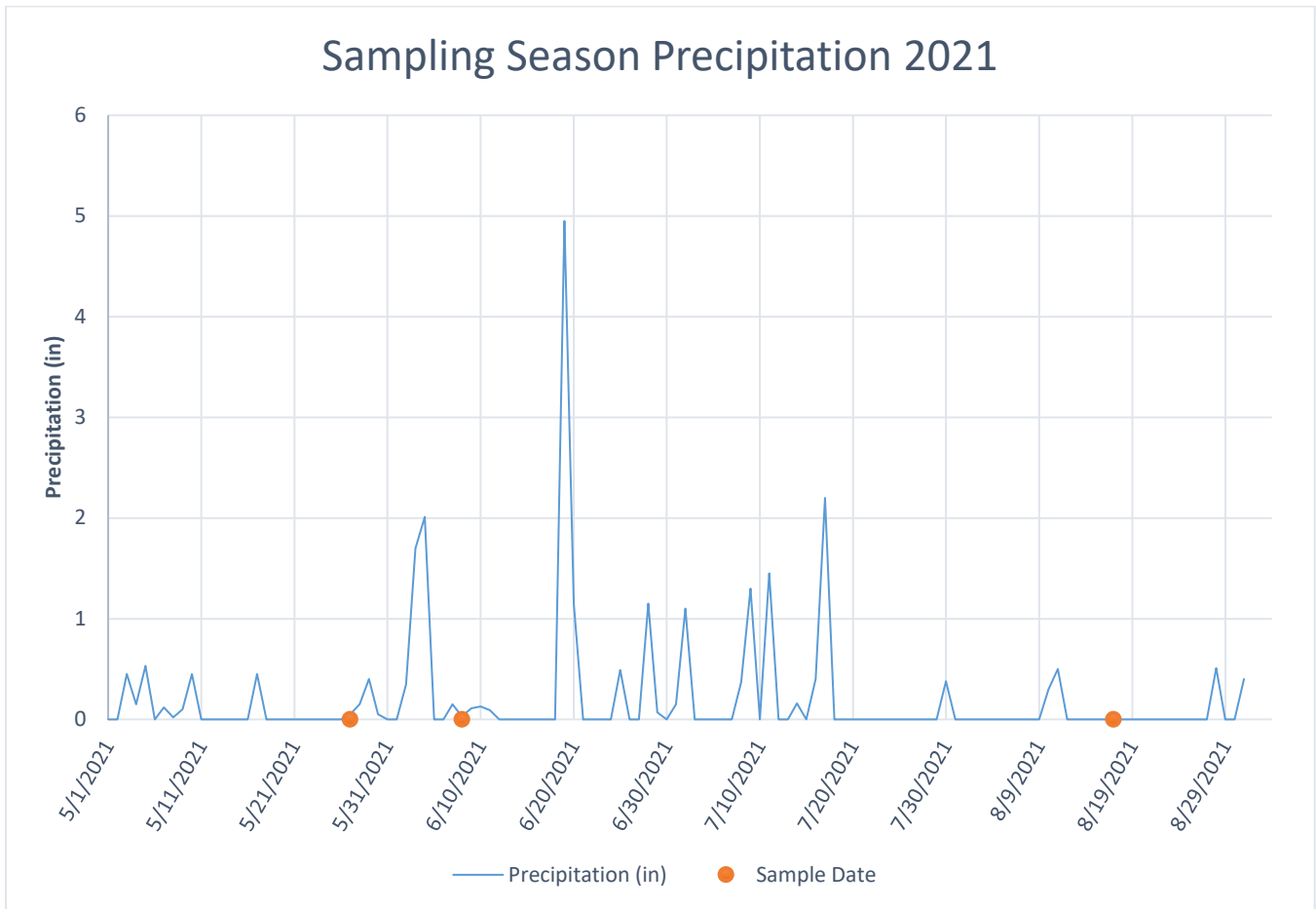


Figure 2 Precipitation amounts during the 2021 sampling season.

Lake Lemon 2021 Summary Results

Temperature and Dissolved Oxygen

IU collected a full profile of temperature and dissolved oxygen from one-meter depth increments through the water column at Riddle and Reed Point in Lake Lemon. The temperature profile illustrates the seasonal variation in water temperature and thermal stratification that occurs as the surface water warms. The upper 2 meters of water remained oxygenated during all three sampling events at Riddle Point (Figure 3). The August dissolved oxygen concentrations averaged 8.6975 mg/L in the epilimnion, a slight decrease of approximately 0.13 mg/L respectively from the sample collected during late July of 2020 at Riddle Point. Anoxic conditions develop below 3 meters depth as organic matter on the lake bottom creates biochemical oxygen demand (BOD) that breaks down the organic matter consuming available oxygen. Stratification of the surface water reduces mixing of oxygen in the deeper water. The shallow depth of Reed Point and lake turbulence usually keep this area of the lake well mixed and oxygenated, however later this season, we saw hypoxic conditions approaching anoxia below 2 meters deep for all sampling events (Figure 4).

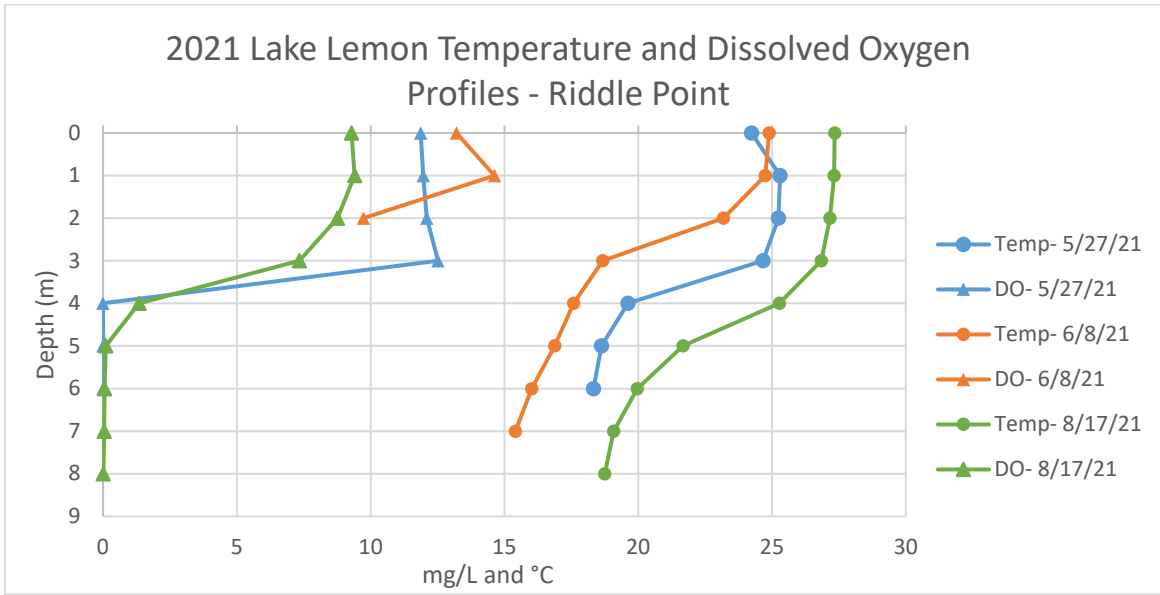


Figure 3 Temperature and dissolved oxygen profiles from all sample dates from Indiana University at Riddle Point in 2021.

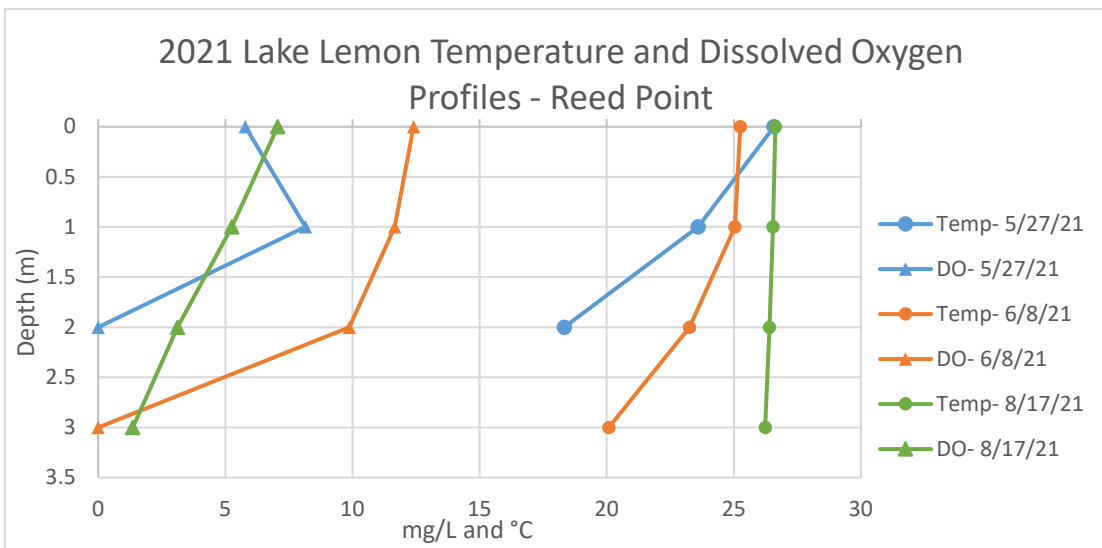


Figure 4 Temperature and dissolved oxygen profiles from all sample dates from Indiana University at Reed Point in 2021.

Water Quality Summary

IU collected epilimnion samples from the top 2 meters of the water column and hypolimnion at 6 meters depth (19.7 ft) at Riddle Point. IU collected samples in the epilimnion only at Reed Point.

Table 1 Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 5/27/2021.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	1.7	--	0.7
Light trans @ 1m (%)	13.9	--	5.9
1% Light Level (ft)	11.2	--	6.2
% Water Column Oxic	0	--	66.7
pH	8.61	7.53	7.71
Conductivity (uS/cm)	--	--	241.38
Alkalinity (mg/L)	66.5	63.0	69.5
Nitrate (mg/L)	0.015	< 0.008	< 0.008
Ammonia (mg/L)	< 0.014	0.176	< 0.014
Total Nitrogen (mg/L)	0.5	0.5175	1.018
Orthophosphate (mg/L)	0.01	0.0105	0.009
Total Phosphorus (mg/L)	0.021	0.0385	0.045
Chlorophyll- <i>a</i> (ug/L)	--	--	--
Plankton (Cells/mL)	14,478	--	32,958
Blue-green (Cells/mL)	11,842	--	29,191
HAB (Cells/mL)	403	--	569
HAB %	3	--	2
<i>E. coli</i> (#/100 mls)	0	--	30

Table 2 Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 6/8/2021.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	1.25	--	0.85
Light trans @ 1m (%)	16.2	--	11.3
1% Light Level (ft)	9.2	--	6.2
% Water Column Oxic	75	--	25
pH	8.59	6.83	8.02
Conductivity (uS/cm)	236.3	259.70	237.12
Alkalinity (mg/L)	57.0	65.0	33.5
Nitrate (mg/L)	< 0.008	0.01	< 0.008
Ammonia (mg/L)	< 0.014	0.1875	0.025
Total Nitrogen (mg/L)	0.511	0.6175	0.646
Orthophosphate (mg/L)	0.017	0.007	0.008
Total Phosphorus (mg/L)	0.033	0.025	0.046
Chlorophyll-a (ug/L)	17.3015	--	22.861
Plankton (Cells/ml)	19,883	--	33,718
Blue-green (Cells/mL)	14,475	--	23,250
HAB (Cells/mL)	52	--	649
HAB %	0	--	2
<i>E. coli</i> (#/100 mls)	10	--	26

Table 3 Water Quality Characteristics of Lake Lemon – Riddle Point and Reed Point, 8/17/2021.

Parameter	Riddle		Reed
	Epilimnion	Hypolimnion	Epilimnion
Secchi (m)	0.65	--	0.55
Light trans @ 1m (%)	5.3	--	3.0
1% Light Level (ft)	6.2	--	4.3
% Water Column Oxic	44.4	--	75
pH	8.76	7.09	8.07
Conductivity (uS/cm)	171.64	236.33	177.18
Alkalinity (mg/L)	64.5	74.0	59.0
Nitrate (mg/L)	0.008	< 0.008	0.008
Ammonia (mg/L)	0.015	0.7705	0.095
Total Nitrogen (mg/L)	0.939	1.5905	0.956
Orthophosphate (mg/L)	0.003	0.054	0.01
Total Phosphorus (mg/L)	0.052	0.104	0.065
Chlorophyll-a (ug/L)	57.8965	--	40.082
Plankton (Cells/ml)	458,045	--	396,568
Blue-green (Cells/mL)	448,051	--	385,343
HAB (Cells/mL)	160,038	--	99,146
HAB %	35	--	25
<i>E. coli</i> (#/100 mls)	0	--	8

Primary Productivity

Chlorophyll-a, which is a measure of the primary pigment in algae, is a direct measure of algal productivity. In the integrated epilimnion samples from the surface to the 2-meter depth, the chlorophyll-*a* concentrations ranged from 17.3 $\mu\text{g/L}$ in June to 57.9 $\mu\text{g/L}$ in August. Chlorophyll-*a* concentrations $>7 \mu\text{g/L}$ are indicative of eutrophic lake conditions. Overall, we see a seasonal pattern of nutrient increase by late summer as total phosphorous concentrations increase, which is characteristic of Lake Lemon. This pattern is mirrored by increases in chlorophyll-*a* concentrations. This suggests that conditions exist for increasing growth of algae during the growing season (Figures 5 and 6).

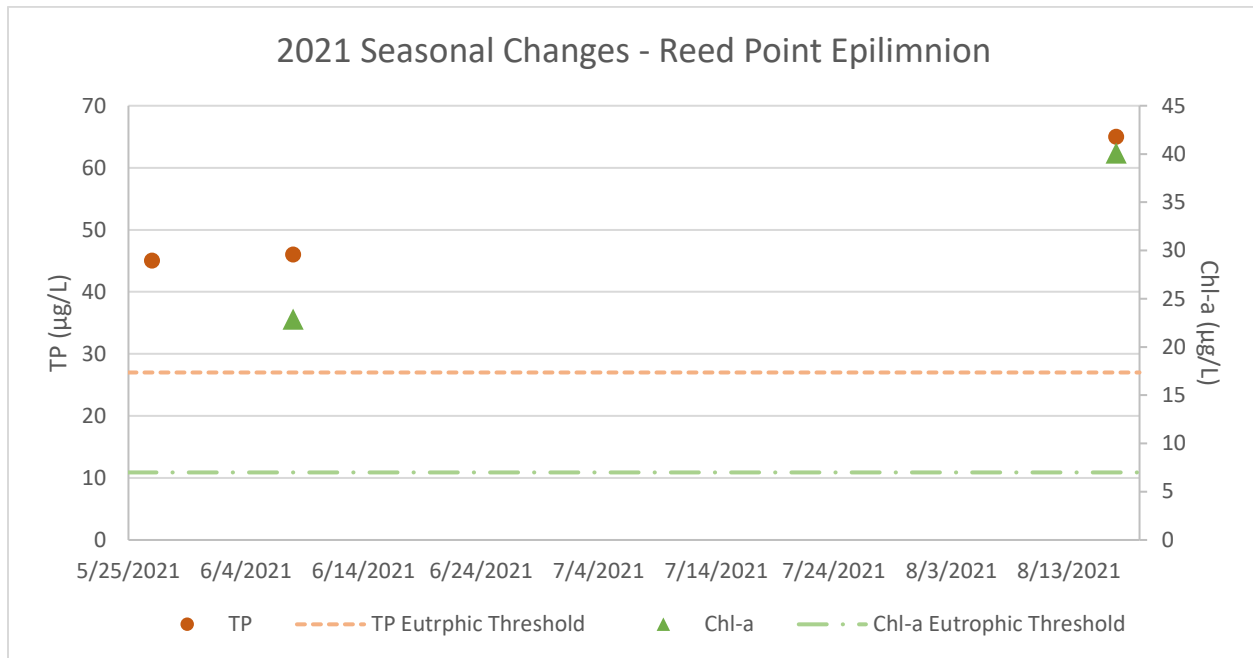


Figure 5 Seasonal changes in total phosphorus and chlorophyll-a in the surface waters (epilimnion) at Reed Point in Lake Lemon in 2021.

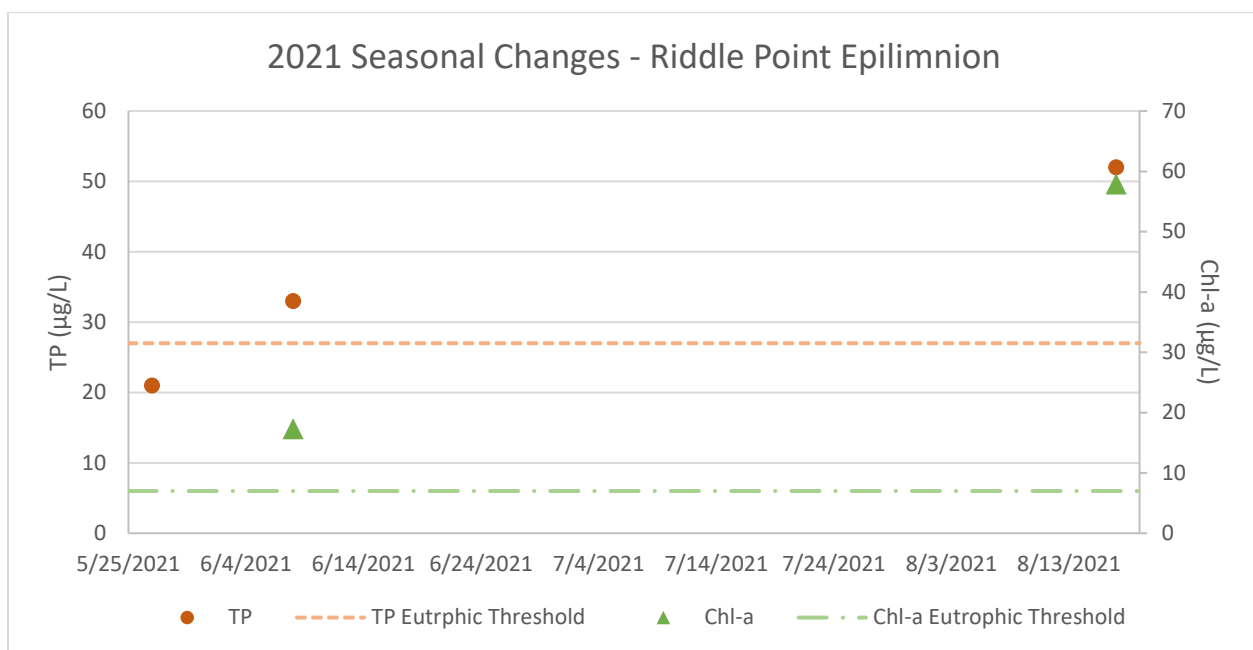


Figure 6 Seasonal changes in total phosphorus and chlorophyll-a in the surface waters (epilimnion) at Riddle Point in Lake Lemon in 2021.

Bacteria at Beach and Tributaries

IU collected *E. coli* samples around the Lake Lemon watershed in 2021 (Tables 4 and 5). The state standard for full body contact and recreation is 200 colonies per 100mLs. While 2021 did not see some of the higher numbers of *E. coli* in years past, significant amounts of colonies were still recorded throughout the watershed and at the beach. Weekly monitoring of the beach and its lower level of *E. coli* compared to the watershed does bring down the historical count of EPA *E. coli* standard exceedances for recreation at Lake Lemon and its tributaries from about 53% to 43% (Figure 7). See Appendix A for historical sampling at another watershed site, Chitwood, that was not contracted for this year.

Table 4 Tributary *E. coli* for 2021.

	<i>E. coli</i> (#/100 mls)	<i>E. coli</i> (#/100 mls)
	5/27/21	8/17/21
Chitwood Channel	37	4
Beanblossom Creek	56	48
Bear Creek	176	48
Knobb Creek	620	>760
Possom Trot	136	4
Shuffle Creek	110	40

Table 5 Beach *E. coli* for 2021.

Lake Lemon Beach	<i>E. coli</i> (#/100 mls)	Lake Lemon Beach	<i>E. coli</i> (#/100 mls)
5/7/21	6	7/12/21	208
5/13/21	4	7/19/21	200
5/21/21	30	7/22/21	40
5/27/21	10	7/26/21	20
6/2/21	2	8/2/21	12
6/8/21	40	8/9/21	6
6/15/21	22	8/17/21	0
6/22/21	130	8/26/21	8
6/28/21	30	9/1/21	8
7/7/21	60	9/8/21	8

Lake Lemon Historic E. coli Counts

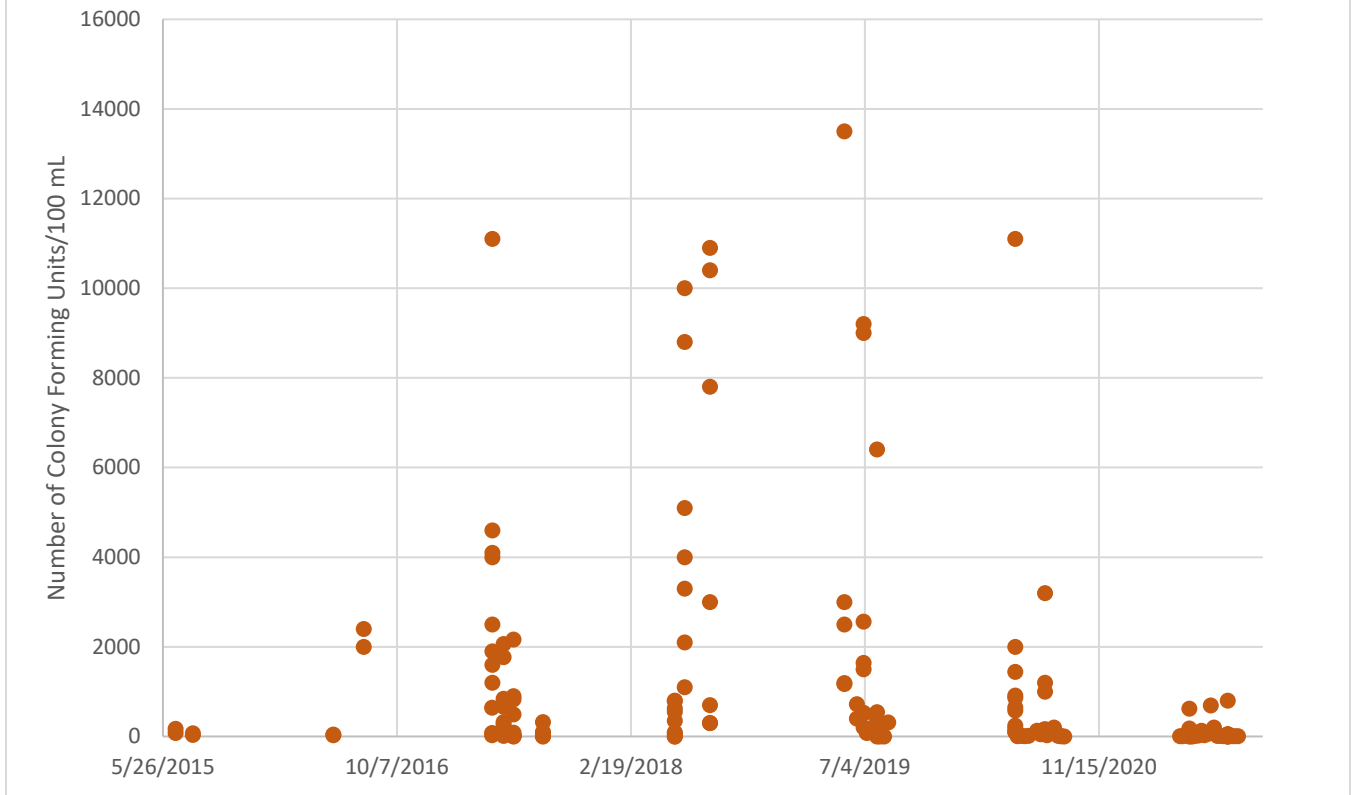


Figure 7 Changes in *E. coli* concentrations at Lake Lemon beach and tributaries during sample events from 2015 to 2021. Note that 75 of the 175 events exceeded 200 CFU/100 mLs.

Phytoplankton at Beach and Overflow Pond

As part of the expanded HAB monitoring, 5 phytoplankton samples were taken at the Overflow Pond and 6 samples from the beach over the course of the summer (Table 6). The beach and pond had 3 overlapping sampling events: 7/7/2021, 7/26/2021, and 8/17/2021. Plankton numbers increased over the course of the summer for both the beach and overflow pond, reaching a peak in late August for the beach but earlier in the summer in late July for the overflow pond. HAB blooms occurred with warming temperatures throughout July and August at both locations.

Table 6 Phytoplankton counts at Lake Lemon Beach and the Overflow Pond during the 2021 summer season.

Site	Date	Plankton (Cells/mL)	HAB (Cells/mL)	HAB %
Beach	6/15/2021	8,050	522	6
	7/7/2021	26,356	16,934	64
	7/26/2021	65,163	35,444	54
	8/9/2021	131,635	98,372	75
	8/17/2021	287,641	169,199	59
	9/1/2021	121,283	58,397	48
Overflow Pond	5/27/2021	12,732	905	7
	6/22/2021	10,673	855	8
	7/7/2021	178,639	142,023	80
	7/26/2021	848,909	818,678	96
	8/17/2021	198,080	159,731	81

Trophic State

The trophic state of a lake helps characterize the level of productivity and the expected life that may exist in a lake. The overall classifications of lakes can help with comparison across lakes as well as from year to year. We use Carlson's Trophic State as it was developed based on lakes similar to those in Indiana.

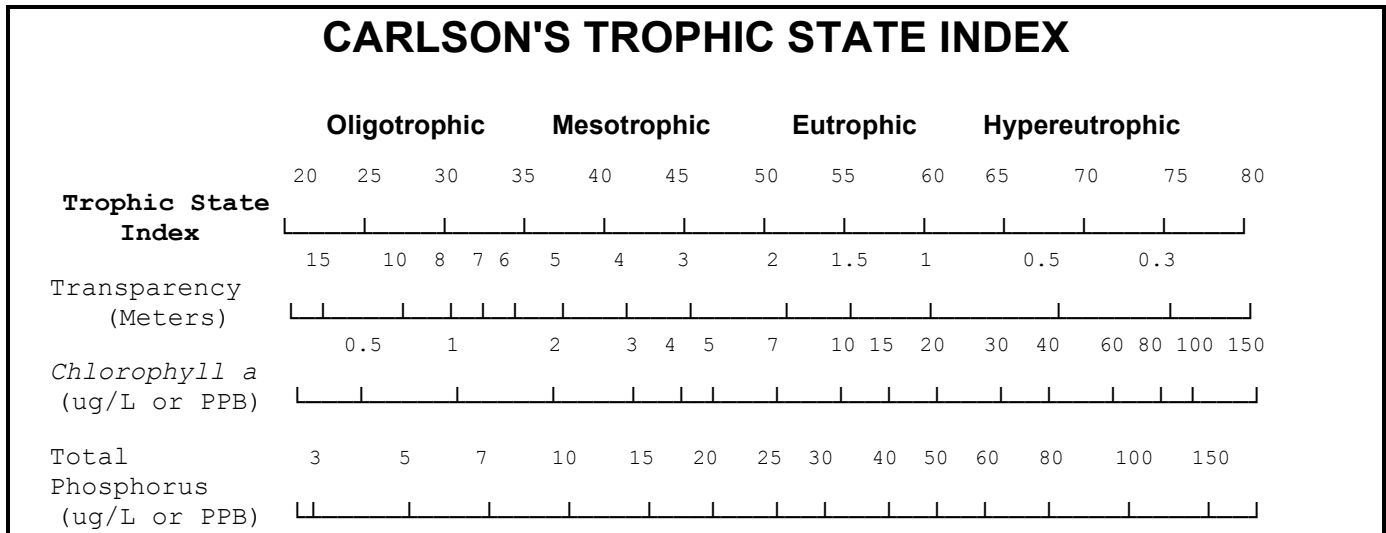


Figure 8 Carlson's trophic state index.

Table 7 Characteristics of trophic state categories.

Classification	Transparency	Nutrients	Algae	D.O.	Fish
Oligotrophic	clear	Low TP < 6 µg/L	few algae	Hypo has D.O.	can support salmonids (trout and salmon)
Mesotrophic	Less clear	Moderate TP 10-30 µg/L	healthy populations of algae	Less D.O. in hypo	lack of salmonids
Eutrophic	transparency <2 meters	High TP > 35 µg/L	abundant algae and weeds	No D.O. in the hypo during the summer	Warmwater fisheries only. Bass may dominate.
Hypereutrophic	transparency <1 meter	extremely high TP > 80 µg/L	thick algal scum Dense weeds	No D.O. in the hypo during the summer	Rough dominate. Summer fish kills possible.

We use Riddle Point Carlson TSI scores to look at the historic trend for Lake Lemon demonstrating that the lake is generally characterized as eutrophic. Figures 11-13 illustrate the Carlson TSI historic trends for Secchi disk, total phosphorus, and chlorophyll-*a*. Blue diamonds represent May and June samples while the orange diamonds represent the last summer samples, usually late July or August. The eutrophic status for Carlson TSI across the three parameters is 50 and represented in each figure by a purple dotted line. The 24-year mean for each reading: Secchi disk, chlorophyll-*a*, and total phosphorus is above this Carlson TSI eutrophic status score. Overall, a pattern of seasonal variation of lower scores (less eutrophic) in the spring and increasing trophic state to eutrophic/hypereutrophic status by late summer exists during the monitoring of Lake Lemon. As evident by the graphs, rarely do any of the late summer samples fall below the eutrophic categorization. This only happened once in 2006 for chlorophyll-*a* and once in 2018 for total phosphorus. All Secchi disk TSI values in late summer are above eutrophic status.

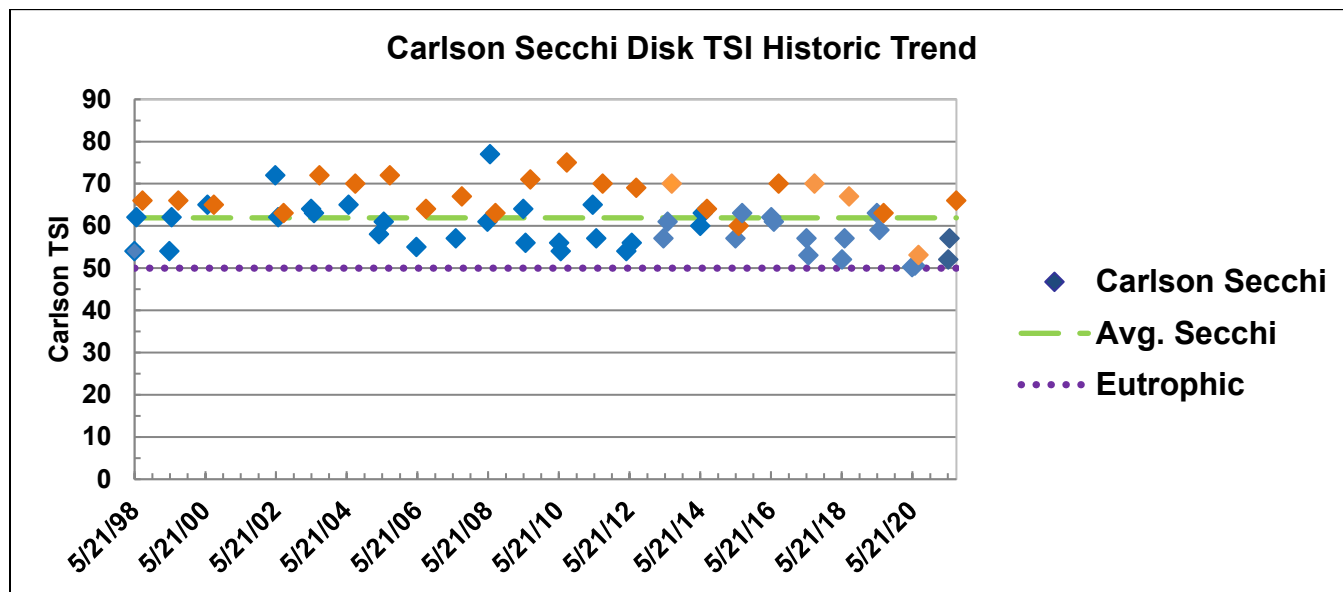


Figure 9 The 24-year historic trend for Carlson Secchi disk TSI scores in blue and orange with the average Secchi across this timeframe as the green dashed line.

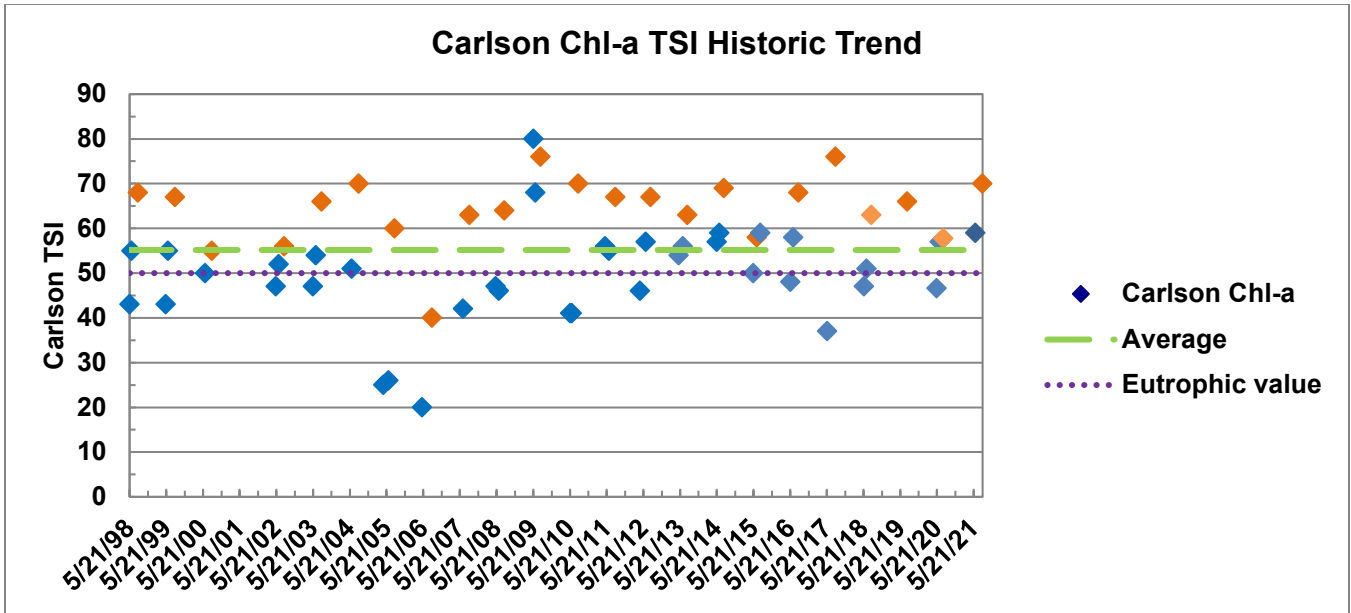


Figure 10 The 24-year historic trend for Carlson chlorophyll-a TSI scores in blue and orange with the average chlorophyll-a across this timeframe as the green dashed line.

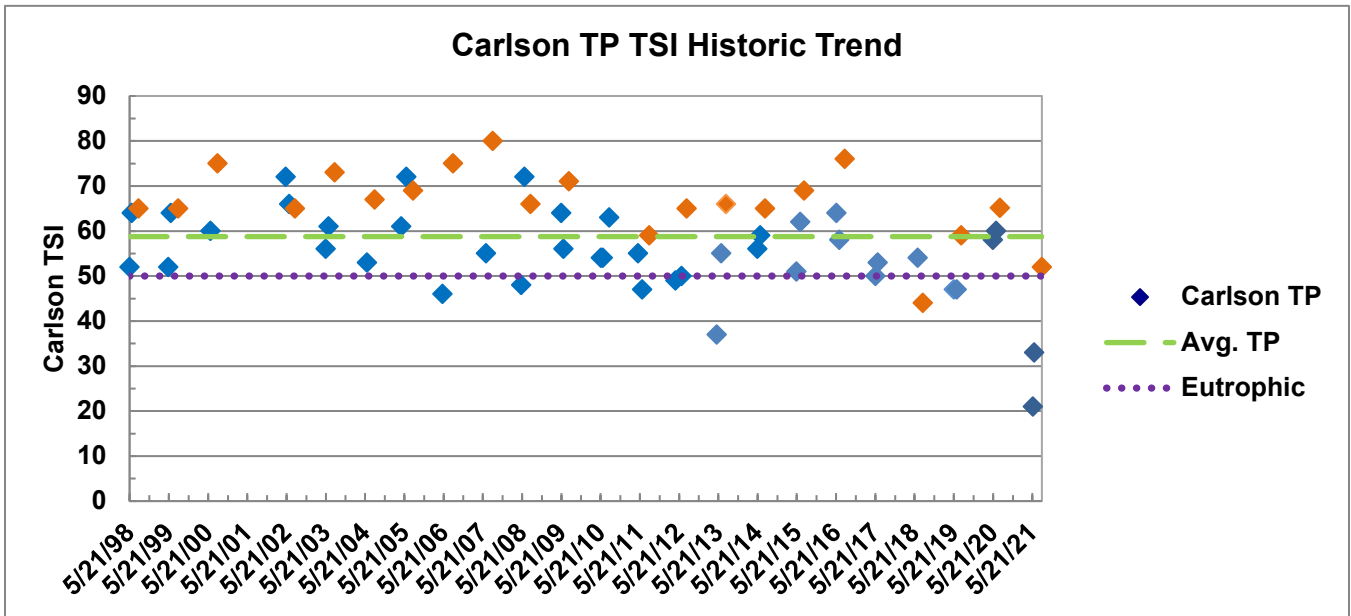


Figure 11 The 24-year historic trend for Carlson total phosphorus TSI scores in blue and orange with the average TP across this timeframe as the green dashed line.

Lake Lemon Water Monitoring Conclusions and Recommendations

Harmful algal blooms (HABs), algae groups that are known toxin producers, continue to be an area of concern for the lake. May and June samples at Riddle and Reed Point remained below the 100,000 cells/mL threshold for recreation advisories. Only in August do we see the Beach, Reed and Riddle Point begin to exceed the recreational advisory levels. In previous recommendations we have discussed development of a HAB response plan. We have been working with the Lake Manager to develop the best strategy for monitoring HABs. As part of the plan, we recommend continuing to monitor algal blooms in 2022 and using the contract lab Phycotech for speed and consistency of results. We recommend bi-weekly beach monitoring for HABs and will continue to monitor the Overflow Pond, Reed, and Riddle Point during normal sampling events in May and July/August.

Bacteria issues still are a challenge in the incoming tributaries to the lake. We will continue to monitor the stream inlets. Bacteria source tracking analysis was completed but did not yield any useful data.

In the summer of 2022 we intend to explore the use of in situ measurements with a phycocyanin and chlorophyll-a sensors to see if we can develop a relationship between lab analyzed data to reduce cost of HAB monitoring to the Conservancy.

Appendix A

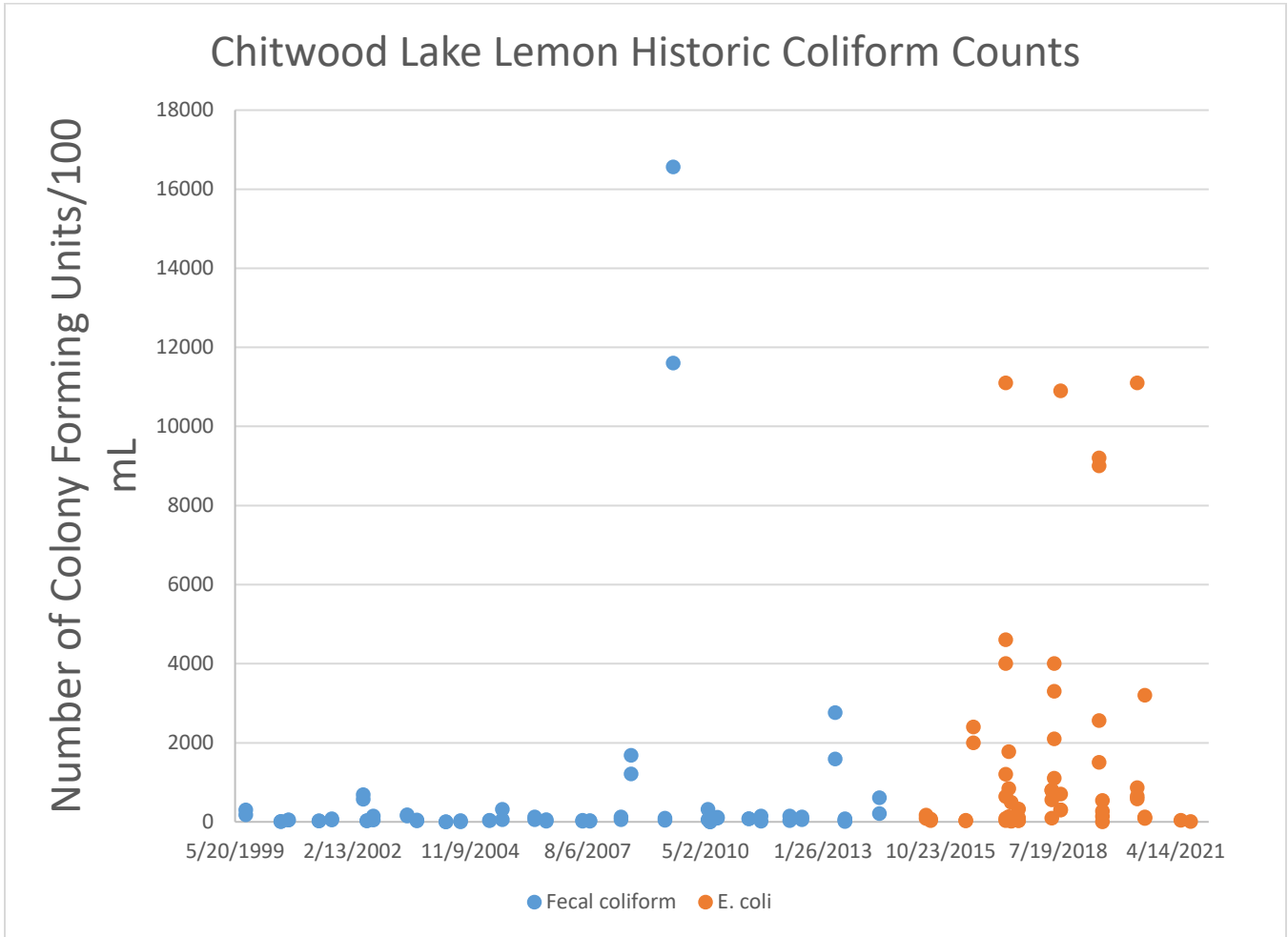


Figure 9. Changes in Fecal Coliform and *E. coli* concentrations in Chitwood area as part of the Lake Lemon watershed during sample events from 1999 to 2021. Note that 34 of the 57 events from 2015 to 2021 exceeded 200 CFU of *E. coli* per 100 mLs.