To the Lake Wynonah Property Owners Association

Report of 2024 PLEON Analysis and Historical Data

From the Pocono Lakes Ecological Observatory Network

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I. Summary of Wynonah and Fawn Lake Data Collection at a Glance

PLEON partnered with the Lake Wynonah Property Owners Association (LWPOA) and Dr. Sarah Princiotta (Penn State Schuykill) to monitor Lake Wynonah (Wynonah) and Fawn Lake (Fawn) in 2023 and 2024. LWPOA collected profile data using their own probe and collected water samples. Samples were processed by Dr. Princiotta and were analyzed by PLEON. This report also includes data from 2021 and 2022 as provided by the Lake Wynonah POA (Table 1).

Table 1: Sampling of Wynonah and Fawn Lake since 2021.

	Variables Monitored	Crew
2021	• Profiles of temperature, dissolved oxygen, conductivity, salinity, and pH taken at least once a month from May-September. • Secchi Depth • Chlorophyll a (composite sample by AEC in July and August) • Nitrate and Total P (composite sample by AEC collected in July and August).	Aquatic Environmental Consultants, Inc. Wynonah Lake Association
2022	• Profiles of temperature, dissolved oxygen, conductivity, salinity, and pH taken at least once a month from May-October, except for September. • Secchi Depth • Chlorophyll a (composite sample by AEC once in July and August) • Nitrate and Total P (composite sample by AEC collected in July and August).	Aquatic Environmental Consultants, Inc. Wynonah Lake Association
2023	• Profiles of temperature, dissolved oxygen, conductivity, salinity, and pH taken once in May (Wynonah only), July, and September. • Secchi depth • Chlorophyll a (2 depths – surface and bottom waters, September only) • Total N, Total P (2 depths – surface and bottom waters, September only)	Wynonah Lake Association Sarah Princiotta (Sample processing) PLEON (data workup and sample analysis)
2024	• Profiles of temperature, dissolved oxygen, conductivity, salinity, and pH taken once in June, July, August, and September. • Secchi depth • Chlorophyll a (3 depths June, July, September; 2 depths in August) • Total P (3 depths June, July, September; 2 depths in August)	Wynonah Lake Association Sarah Princiotta (Sample processing) PLEON (data workup and sample analysis)

Table 2: Summary of Lake Wynonah in 2024 at the deepest location sampled.

	25 June	18 July	21 Aug	24 Sept	8 Oct
Location	#2	#1	#1	#1	#1
Thermally stratified?	YES	YES	YES	PARTIAL	YES
Epilimnion depth (m)	5	6	6	9	11
Metalimnion depth (m)	14	14	17	NA	15
Secchi depth (m)	5.2	5.2	4.0	NC	4.9
Mean hypolimnetic DO (mg/L)	6.54	7.06	3.01	NA	1.35
Epilimnetic chlorophyll (µg/L)	0.90	2.46	2.54	0.90	NC
Epilimnetic TP (µg/L)*	BD	BD	8.8	BD	NC
TSI_{Secchi}	36.2	36.2	40.0	NC	37.1
$TSI_{chlorophyll}$	26.6	39.4	39.7	29.6	NC
TSI_{TP}	NA	NA	35.5	NA	NC
Trophic Classification	OLIGO**	OLIGO**	OLIGO-MESO**	OLIGO**	OLIGO***

** BD = below detection, NC= not collected* ***Calculated based on TSI_{chla}.* ****Calculated based on Secchi depth.*

Table 3: Summary of Fawn Lake in 2024 at the deepest point (Site #12).

	25 June	18 July	21 Aug	24 Sept	8 Oct
Thermally stratified?	PARTIAL	PARTIAL	NC***	PARTIAL	NONE
Epilimnion depth (m)	3	3	NA	5	NA
Metalimnion depth (m)	NA	NA	NA	NA	NA
Secchi depth (m)	3.0	1.8	2.4	NC	3.0
DO at sediments (mg/L)	4.38	2.43	6.36	0.43	4.88
Epilimnetic chlorophyll (µg/L)	2.81	4.31	2.49	1.84	NC
Epilimnetic TP (µg/L)	11.6	15.2	19.1	13.4	NC
TSI_{Secchi}	44.2	51.5	47.4	NC	44.2
$TSI_{chlorophyll}$	40.7	44.9	39.5	36.6	NC
TSI_{TP}	39.5	43.3	46.7	41.6	NC
Trophic classification	MESO*	MESO*	OLIGO-MESO*	OLIGO*	MESO**

**Calculated based on TSI_{chla}.* ***Calculated based on Secchi depth.* ****insufficient data collected to determine.*

Oligo = oligotrophic Meso = mesotrophic oligo-meso = oligo-mesotrophic

II. Chemical Profiles

A. Temperature

Wynonah appeared to be thermally stratified during the June, July, August, and October 2024 samplings (Figure 1). A metalimnion, or middle layer of rapid temperature change, began at roughly 5 m, 6 m, 6 m, and 11 m during the June, July, August, and October samplings while the hypolimnion, or deep, cooler layer began at approximately 14 m, 14 m, 17 m, and 15 m, respectively. The September profile is incomplete but appears to follow a similar pattern for epilimnion and metalimnion formation, though the epilimnion ends at a lower depth of 9 m. Data was insufficient to detect the development of a hypolimnion.

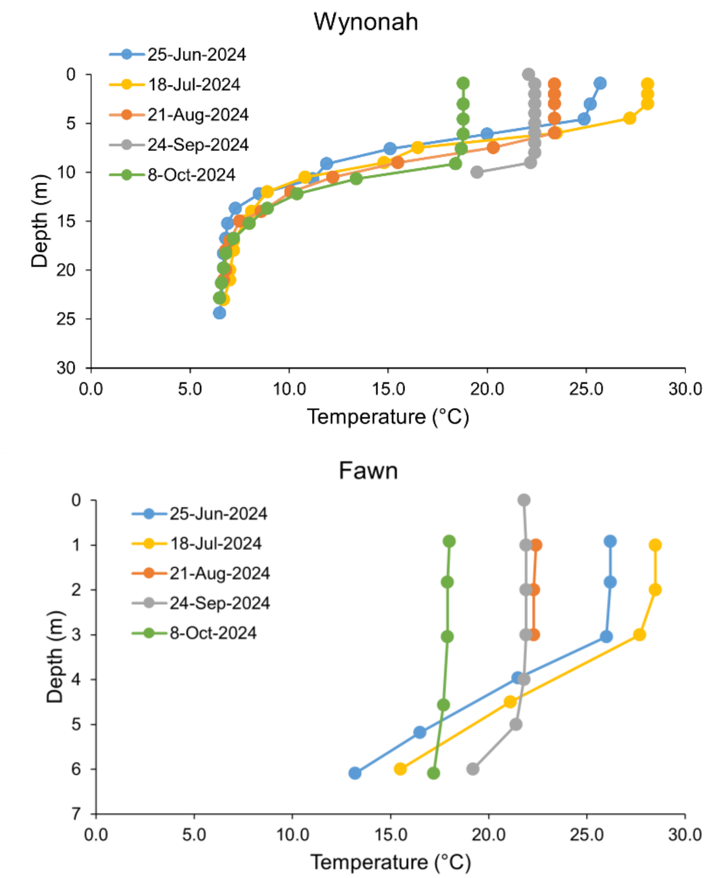

Figure 1: Temperature profiles of Wynonah and Fawn in 2024. Data provided by LWPOA. Note difference in scales of Y-axes.

Partial stratification occured in Fawn Lake in June, July, and September with the development of an epilimnion and a layer of rapid temperature change approaching the sediments. (Figure 1). A hypolimnion was not detected on any of the sampling dates. The epilimnion extended to depths of 3 m on the June and July sampling dates, and 5 m in September. On the Augst sampling date, temperature was only collected to a depth of 3 m and a metalimnion was not detected. The October 8th sampling date indicated a steady temperature throughout the water column to a total depth of 6 m.

Thermal stratification of deep lakes is expected in the Pocono region as the surface water is heated by the sun and the deeper water remains cool. Thermal stratification breaks down in the fall as surface waters cool and lakes “turnover”, or the layers mix. Partial stratification can occur in more shallow lakes that mix more frequently, as perhaps seen in Fawn Lake.

B. Dissolved oxygen

Wynonah was well oxygenated throughout the epilimnion in each of the 2024 samplings (Figure 2). Dissolved oxygen concentration (DO) peaked in the metalimnion during the June, July, and August samplings. DO decreased in the deeper waters reaching a low of 4.4 mg/L, 4.6 mg/L, and 2.0 mg/L at the lowest sampled depth in June, July, and August, respectively. September DO was fairly consistent through the epilimnion and into the metalimnion, decreasing only below 8 m to a low of 5.4mg/L at 10 m. During the October sampling, DO concentration was below the 2 mg/L threshold for oxygen depletion from 17 m down to the sediments.

Fawn was consistently well-oxygenated in the epilimnion, decreasing at lower depths. Minimum oxygen levels were detected at the lowest sampled depths, at 4.4 mg/L, 2.4 mg/L, 6.4 mg/L, and 4.9 mg/L in June, July, August, and October, respectively. DO concentration was below the 2 mg/L threshold for oxygen depletion at the sediments on the September sampling date (0.43 mg/L).

Oxygen depletion is common in the hypolimnion or near the sediments where decomposition of organic matter removes oxygen, and the lack of light prohibits photosynthesis. The hypolimnion often remains hypoxic until thermal stratification breaks down and the lake layers mix.

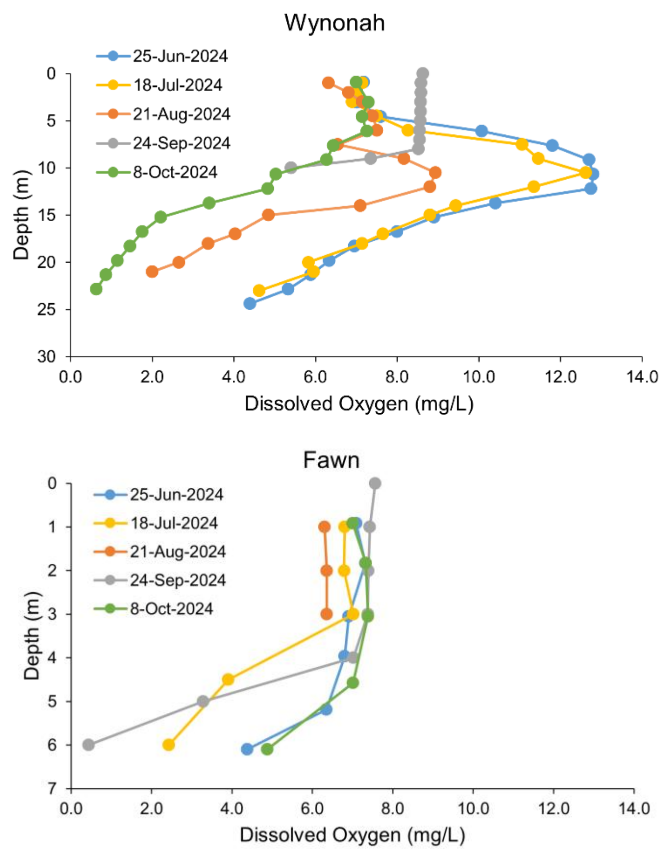

Figure 2: Dissolved oxygen profiles of Wynonah and Fawn in 2024. Data provided by LWPOA. Note difference in scales of Y-axes.

C. Conductivity

Wynonah conductivity in June and July decreased with depth to the metalimnion, then increased to the sediments (Figure 3). August and October conductivity was consistent through the epilimnion, then increased toward the sediments. Conductivity ranged from 136.3-176.9 µS/cm.

Conductivity in Fawn was more variable (Figure 3). June conductivity decreased from 1 m to 3 m, then remained relatively steady to the sediments. On the July and October sampling dates, conductivity was consistent in the epilimnion, increasing slightly at lower depths. August conductivity was only collected in the epilimnion and was steady down the water column to 3 m. Conductivity ranged from 131.2-156.0 µS/cm.

Conductivity is a measure of the amount of ions, or charged particles, in the water which come from dissolved compounds. Lake conductivity responds to several factors including underlying geology, runoff, point-source inputs, precipitation, evaporation, and in-lake productivity.

D. pH

pH in Wynonah ranged from 6.45 to 8.32 (Figure 4). pH generally decreased through the water column, with maximum values obtained in the epilimnion in July, August, and October. June pH increased with depth to a maximum of 8.32 at 11 m. Below this depth, pH decreased to the sediments. pH generally decreases throughout the summer and fall, with the highest average pH in June and the lowest average in October.

pH in Fawn ranged from 6.65-8.64, decreasing towards sediments in June, July, and October (Figure 4). August data indicates a steady pH, lower in value than June and July, though only the first 3 m of depth were measured.

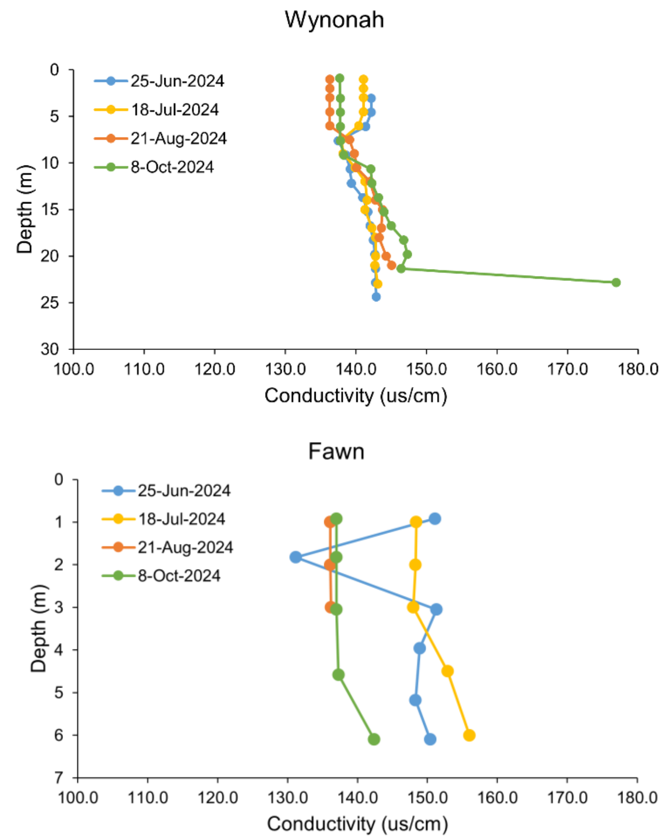

Figure 3: Conductivity profiles of Wynonah and Fawn in 2024. Data provided by LWPOA. Note difference in scales of Y-axes.

pH is a measure of the acidity of water with a logarithmic scale ranging from 0 (very acidic) to 14 (very basic). Freshwater ecosystems are usually pH neutral, typically ranging from 6-9[1]. pH in Wynonah and Fawn was within this range. Several factors affect water pH, including geology, precipitation, runoff, point-source inputs, and carbon dioxide. Carbon dioxide, a byproduct of decomposition, forms carbonic acid in water. Decomposition in the hypolimnion can contribute to the declining pH through depth in stratified lakes[2].

III. Water Transparency

A. Secchi depth

Secchi depth is a measure of water transparency and is defined as the depth at which an 8-inch diameter black and white disk lowered straight down into the water disappears from view. Lakes with clear water have deeper Secchi depths than those with more murky or dark water. Several factors influence water transparency such as the concentration of suspended particles (including algae) and the amount and color of dissolved compounds.

At deepest point

At the deepest part of the lake (Site #1), Secchi depth was 5.2 m, 4.0 m, and 4.9 m during the 2024 June, August and October samplings in Wynonah. Secchi depth was not recorded for Site #1 in June.

Fawn Secchi depths at site #12 were 3.0 m, 1.8 m, 2.4 m, and 3.0 m during the June, July, August, and October samplings, respectively.

Secchi depth can be used to calculate Carlson's Trophic State Index (TSI) and to assign trophic status[3]:

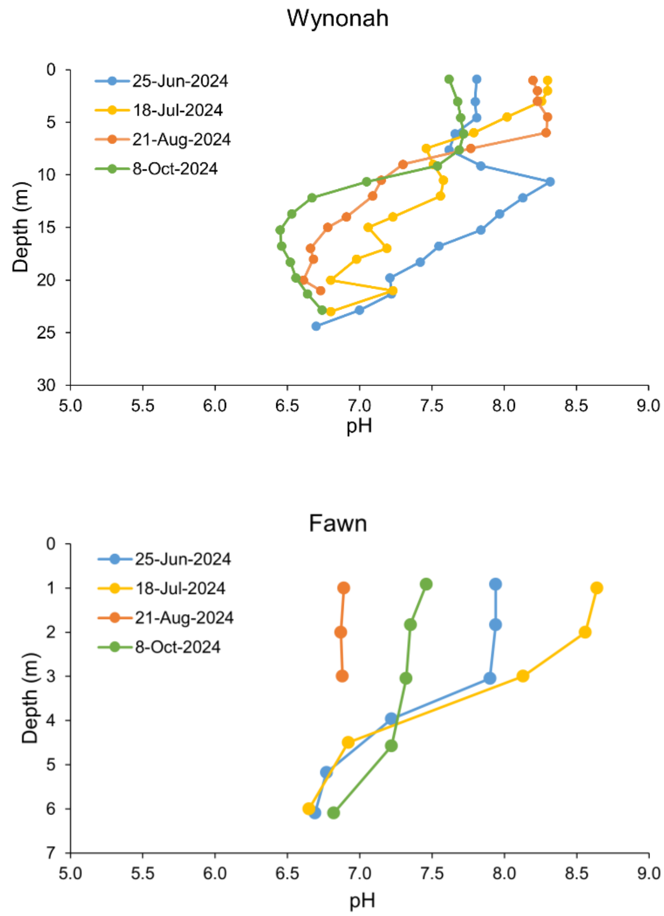

Figure 4: pH profiles of Wynonah and Fawn in 2024. Data provided by LWPOA. Note difference in scales of Y-axes.

$$TSI_{secchi} = 60 - 14.41 \times \ln(Secchi\ depth)$$

TSI_{Secchi} of Wynonah at the deepest site (#1) was 36.2 in July, 40.0 in August, 37.1 in October, classifying Wynonah as oligotrophic in June, July, and October and oligo-mesotrophic in August (Table 4). TSI_{Secchi} of Fawn at site #12 was 44.2, 51.5, 47.4, and 44.2 in June, July, August, October, respectively classifying Fawn as mesotrophic during the June, August and October samplings and eutrophic during the July sampling.

Table 4: Trophic status description.

TSI	Secchi depth (m)	TP (µg/L)	Chla (µg/L)	Classification	Description
<40	>4	0-12	0-2.6	Oligotrophic	Low primary production, clear, low nutrient concentration
40-50	2-4	12-24	2.6-7.3	Mesotrophic	Intermediate production, aquatic plants
50-70	0.5-2	24-96	7.3-56	Eutrophic	High productivity, low transparency, excess nutrients
70-100	<0.5	96+	>56	Hypereutrophic	Very high productivity, frequent blooms, excess nutrients

Spatial variation

Secchi depth was measured at 7-8 locations within Wynonah (designated by LWPOA) in 2024 (Figure 5). Secchi depth across these locations ranged from 0.9 m to 6.4 m in June, 0.9 m to 5.2 m in July, from 0.9 m to 4.0 m in August, and from 0.9 m to 5.2m. Sites #4, #8, and #9 were generally the least clear. Sites #1, # 2, #5, #6, and #7 were more clear, but variable over the sampled months.

Secchi depth was measured at 3 locations within Fawn (designated by LWPOA) in 2024 (Figure 5). Secchi depth across these locations ranged from 0.9 m to 3.0 m in June, from 1.2 m to 2.4 m in July, from 0.91 m to 2.4 m in August, from 0.9 m to 3.0 m. Site #15 was consistently the least clear site.

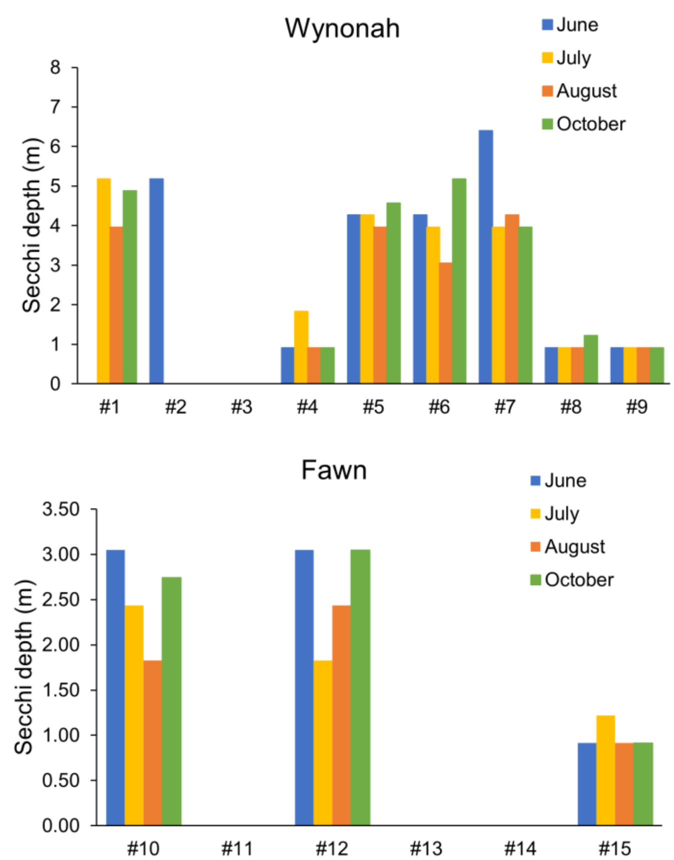

Figure 5: Secchi depth at various locations sampled in Wynonah and Fawn in 2024. Missing bars indicate no collection. Note differences in Y axes between panels.

Generally, the sites with shallow Secchi depths (i.e., the least clear water) seemed to be the shallower locations in both Wynonah and Fawn. They were also generally located in an inlet and/or near one of the community docks. The relatively lower water clarity in these areas may be due to turbulence disturbing the sediments, increased surface runoff from these areas, and/or increased algal growth facilitated by shallow water depth.

IV. Chlorophyll Results

Chlorophyll *a* (chla) is a pigment found in algal cells and is used as a proxy for algal abundance and lake productivity. In 2024, chla concentrations were measured in duplicate samples collected from the epilimnion, metalimnion, and hypolimnion in June and July. Samples were analyzed in the epilimnion and hypolimnion in August. One sample was analyzed at each of three depths in September.

Epilimnetic chla concentrations in Lake Wynonah ranged from 0.90 (± 0.01) µg/L in both June and September to 2.54 (± 1.48) µg/L in August (Figure 6). Chla concentration peaked in the epilimnion in July and August, the metalimnion in June, and the hypolimnion in September. The hypolimnetic chla concentration in September was the highest measured value in 2024, at 10.91 µg/L.

Epilimnetic chla concentrations in Fawn Lake ranged from 1.84 µg/L in September to 4.31 (± 2.31) µg/L in July. Chla concentration peaked in the metalimnion in June and the hypolimnion in August and September. Epilimnetic and hypolimnetic chla concentrations were similar during the July sampling.

TSI can be calculated from chlorophyll *a* concentration measured at 0.5 m as[3]:

$$TSI_{chlorophyll} = 30.6 + 9.81 \times \ln\left(\text{chlorophyll a}\frac{\mu g}{L}\right)$$

$TSI_{chlorophyll}$ of Wynonah calculated from the surface samples collected during the June, July, August, and September 2024 samplings were 29.6, 39.4, 39.7, and 29.6, respectively. This classifies Wynonah as oligotrophic.

$TSI_{chlorophyll}$ of Fawn calculated from surface samples were 40.7, 44.9, 39.5, and 36.6 during the June, July, August, and September 2024 samplings, respectively. This

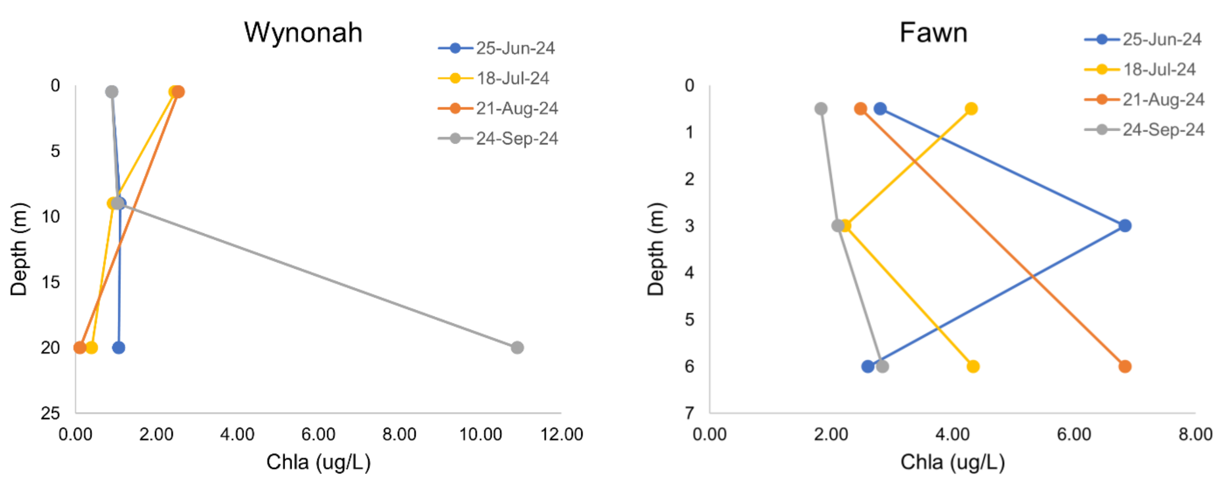

Figure 6: Chlorophyll concentration at 3 depths in Wynonah and Fawn during the 2024 sampling season. Symbols are means of replicate samples.

classifies Fawn as mesotrophic in June and July, oligo-mesotrophic in August, and oligotrophic in September (Table 4).

V. Nutrient Results

A. Total phosphorus

Total phosphorus concentration (TP) in Wynonah samples were below the minimum detection level (MDL = 6.0 µg/L)) at all depths in June, July, and September. August samples were taken at 0.5 m and 20 m and both TP concentrations were detectable, at 8.8 and 8.9 µg/L, respectively (Figure 7).

In Fawn, TP concentrations in the epilimnion ranged from 11.6 µg/L to 19.1 µg/L. Metalimnetic concentrations were similar to epilimnetic concentrations, ranging from 11.3 µg/L to 14.8 µg/L. Hypolimnetic concentrations ranged from 13.4 µg/L to 32.9 µg/L, with a large increase of ~12 µg/L from August to September.

Phosphorus is an essential nutrient for aquatic life and is often considered to be the primary nutrient limiting algal growth in lakes. Elevated concentrations of phosphorus can be a sign of eutrophication and can fuel algal blooms. TP concentrations in Wynonah and Fawn were mostly below the 25 µg/L threshold for nutrient pollution suggested by Penn State Extension[1] at all sampling depths. Only the hypolimnetic September TP concentration in Wynonah was above this threshold.

TSI can be calculated from TP concentration at 0.5 m as[3]:

$$TSI_{TP} = 4.15 + 14.42 \times \ln\left(\mathrm{TP}\frac{\mu g}{L}\right)$$

TSI_{TP} of Wynonah could only be calculated from the August sampling data, as all other months were below the MDL. The August TSI_{TP} of Wynonah was 35.5, classifying Wynonah as oligotrophic (Table 4). The TSI_{TP} of Fawn was 39.5, 43.3, 46.7, and 41.6 in June, July, August, and September, respectively. This

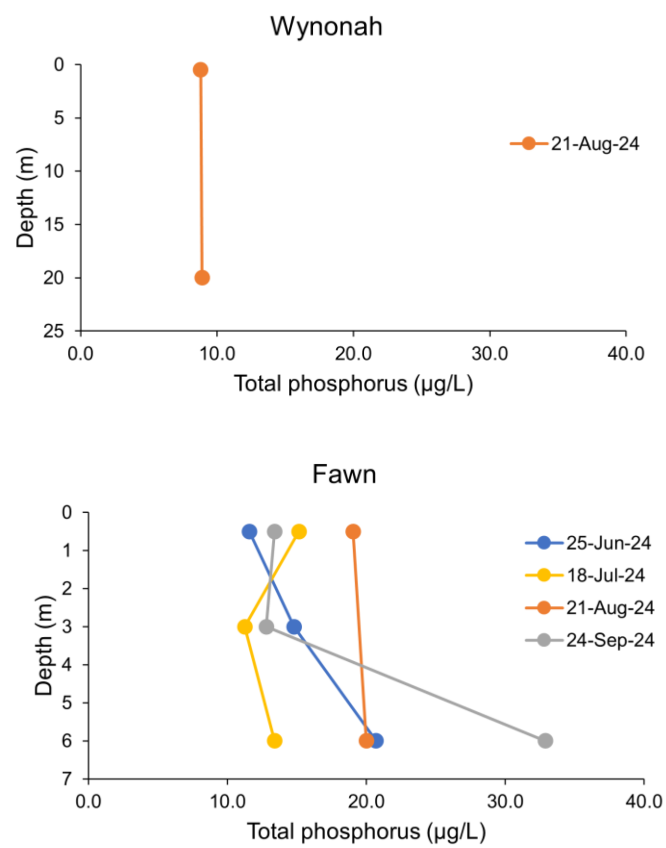

Figure 7: Average total phosphorus concentration at 3 depths in Wynonah and Fawn during the 2024 sampling season (2 depths in August). Symbols are means of replicate samples.

classifies Fawn as oligo-mesotrophic in June, and mesotrophic in July, August, and September.

VI. Historical Context: Wynonah and Fawn Over Time

A. Description of historical dataset

This report includes 4 years of data from Wynonah and Fawn: 2021, 2022, 2023, and 2024. Data from 2021 and 2022 were collected by Aquatic Environmental Consultants (July data) and by the LWPOA. Data from 2023 and 2024 were collected by LWPOA and water samples were analyzed by PLEON in partnership with Dr. Sarah Princiotta at Penn State University Schuylkill. Samples collected in 2021 and 2022 were composite samples while samples from 2023 and 2024 were collected at discrete depths. At least five (preferably more) years of data are needed to identify temporal trends, so the comparisons below are preliminary and should be interpreted with caution.

B. Chemical profiles over time

This section focuses on comparisons among the July profiles from 2021-2024 as these likely represent the lakes during summer stratification.

Wynonah fully stratified in all July samplings and was well oxygenated in the epilimnion and into the metalimnion during July samplings (Figure 8). DO peaked within the metalimnion in all four years (between 9 m and 12 m) and declined into the hypolimnion. DO levels became anoxic after 20 m in 2021, 2022, and 2023. DO at the sediments was above the 2.0 mg/L threshold for anoxia in July 2024. Conductivity in Wynonah was typically greatest at shallower depths and declined rapidly through the metalimnion. In 2024, conductivity was fairly consistent throughout the water column. Conductivity ranged from 94.8-164.3 µS/cm over the 4-year July dataset, which is representative of all conductivity data in this lake (Appendix I). pH for Wynonah was typically stable through depth and ranged from 6.2-8.3 across the July dataset.

Fawn showed inconsistent stratification over the 4-year dataset, although the profile from 2023 not complete (Figure 9). Fawn was well oxygenated in the epilimnion and into the metalimnion during July samplings, with DO maxima occurring in the epilimnion in three of the sampled years. DO peaked in the metalimnion in 2022. DO rapidly declined through deeper waters. Conductivity in Fawn remained relatively stable. Conductivity ranged from 148-203.6 µS/cm across the 4-year July dataset, which was more constrained than the full dataset (Appendix I). pH in Fawn generally decreased with depth and ranged from 6.2-9.0 over the July dataset.

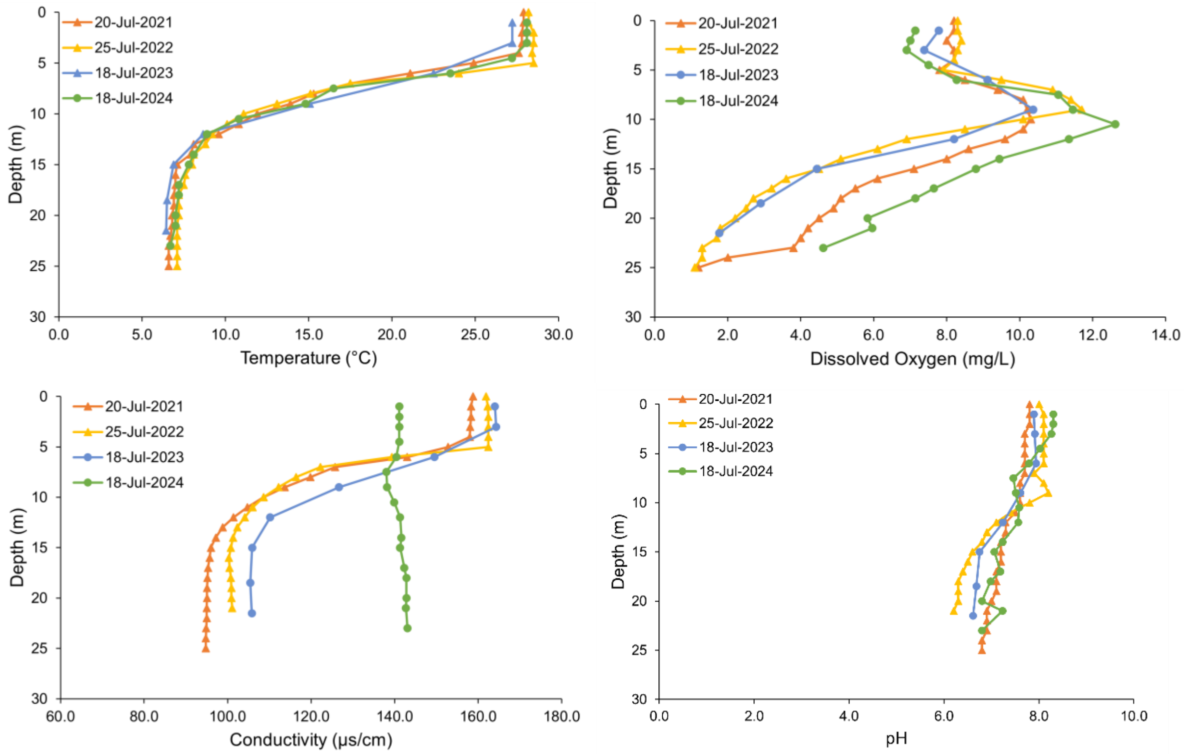

Figure 6: Temperature, DO, conductivity, and pH in Wynonah from 2021-24. AEC and LWPOA data are triangles and circles, respectively.

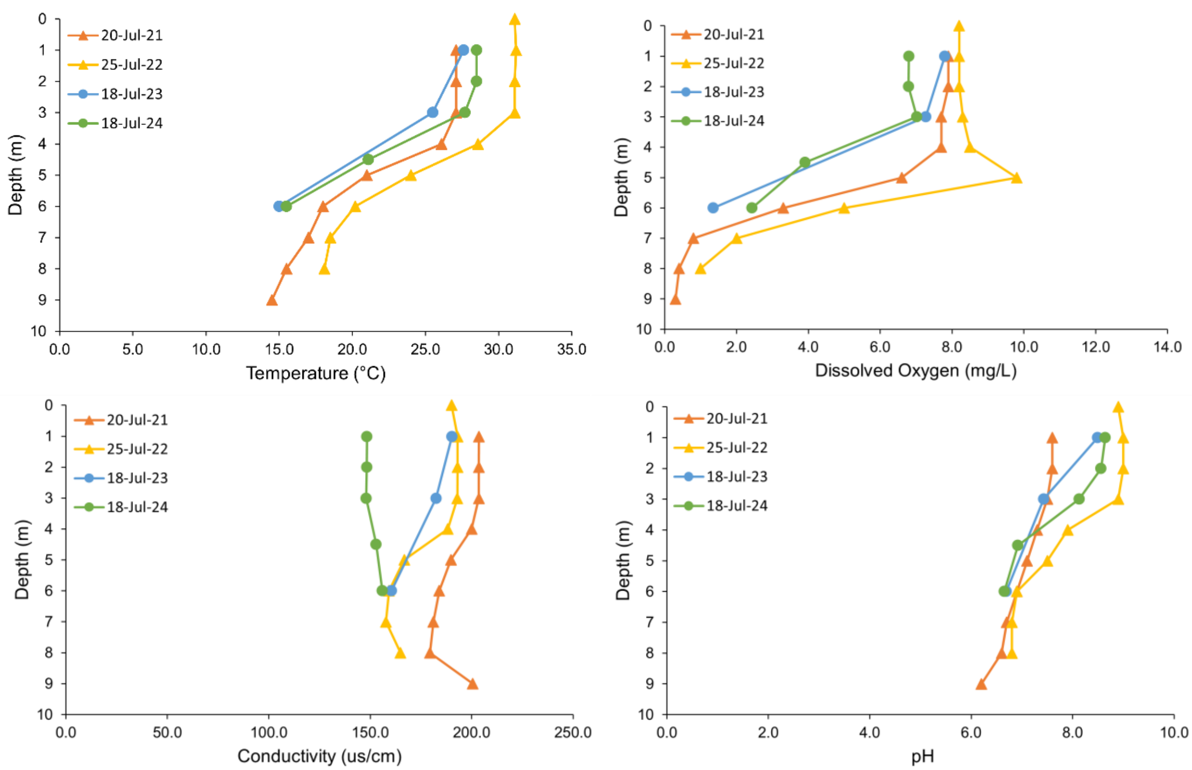

Figure 7: Temperature, DO, conductivity, and pH in Fawn from 2021-24. AEC and LWPOA data are triangles and circles, respectively.

C. Water transparency over time

Secchi depth over the entire dataset ranged from 4.0 m to 6.1 m in Wynonah and from 1.5 m to 7.3 m in Fawn (data not shown). This section describes trends in average summer (June, July, and August) water transparency. All trends discussed should be interpreted with caution due to the limited amount of data.

At deepest point

Wynonah average summer Secchi depth increased by approximately 1.5 m from 2022 to 2023, but decreased in 2024, comparable to past Secchi depths (Figure 10).

Unlike Wynonah, the average summer Secchi depth in Fawn decreased by approximately 3 m from 2022 to 2023 and remained at a similar depth in 2024, indicating declining water clarity over this time. Continued monitoring is needed to determine if this trend persists.

Spatial variation

The differences in water clarity among sites observed in 2024 were generally consistent over the temporal dataset (Appendix II). Site #1 in Wynonah was consistently the most clear while Sites #8, and #9 were consistently the least clear. Site#10 was the most clear in Fawn Lake, while Sites #13 and #15 were consistently the least clear (only sites #10, #12, and #15 were sampled in 2024).

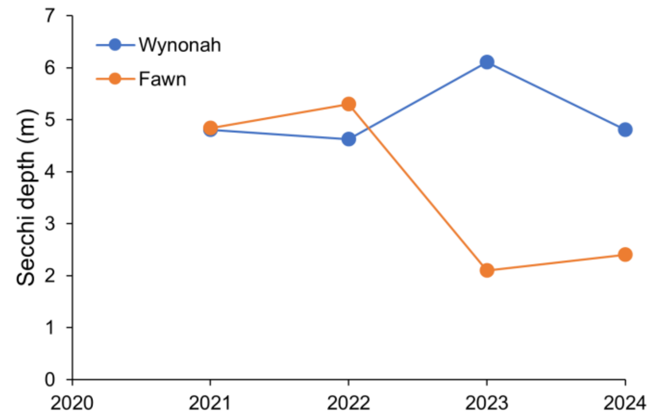

Figure 8: Average summer (June, July, August) Secchi depth in Wynonah and Fawn from 2021-24. Symbols are single readings or averages if lakes were sampled more than once per summer.

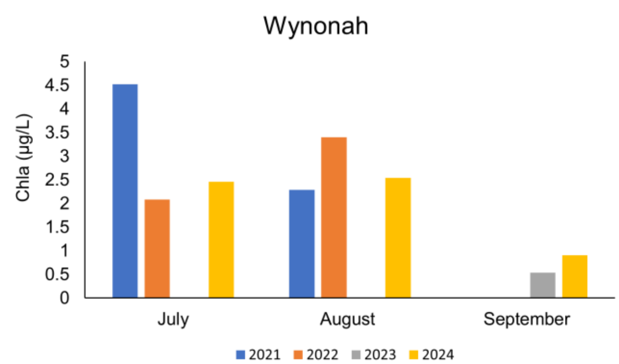

Figure 9: Chlorophyll concentration in Wynonah samples by month. 2021 and 2022 are composite samples, while 2023 and 2024 are surface samples.

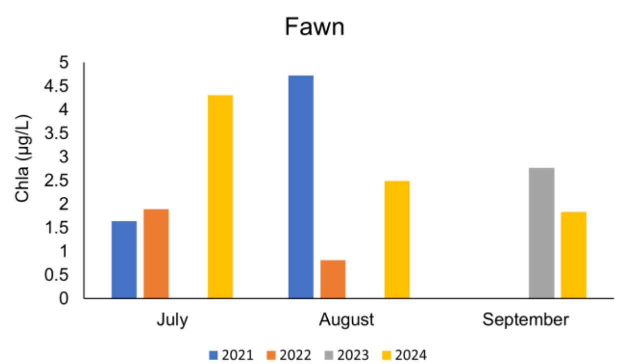

Figure 10: Chlorophyll concentration in Fawn samples by month. 2021 and 2022 are composite samples, while 2023 and 2024 are surface samples.

D. Chlorophyll a over time

Productivity and algal abundance are difficult to compare due to samples prior to 2023 being composites of several depths. Figures 11 and 12 use epilimnion samples for 2023 and 2024 for a comparison of monthly chla concentration from year to year.

The chla concentration in the Wynonah samples peak in July or August each year (Figure 11). Chla concentration was relatively low in September samplings.

Chla concentration in Fawn was generally more variable compared to Lake Wynonah (Figure 12). Peak productivity was observed in August 2021, while the 2022 and 2024 peak occurred in July. Direct comparison is difficult, as described above. Further data collection is recommended to determine any trends in algal productivity.

E. Total Phosphorus over time

TP in Wynonah was less than ≤10 µg/L in Wynonah and ≤18 µg/L in Fawn (Table 5). Across the four years of sampling, TP summer averages in composite, surface, and bottom samples are well below the 25 µg/L threshold the Penn State Extension utilizes to indicate phosphate pollution[1]. Year-to-year trends are difficult to assess because samples were collected from different depths (composite samples in 2021 and 2022 vs. discrete depths in 2023) and during different months. 2024 date in Table 5 includes summer averages (June, July, and August). Late September sampling indicated a TP concentration near the sediments in Fawn to be above the 25 µg/L threshold.

Table 5: Total phosphorus concentration in Wynonah and Fawn from 2021 to 2024.

Wynonah			
Year	**Composite**	**Surface**	**Bottom**
2021	<7.59	NC	NC
2022	<7.09	NC	NC
2023	NC	0.89	2.39
2024	NC	4.93	4.97

Fawn			
Year	**Composite**	**Surface**	**Bottom**
2021	14.0	NC	NC
2022	10.0	NC	NC
2023	NC	2.41	0.96
2024	NC	15.26	18.03

2021 and 2022 data are averages of July and August samplings while 2023 data are from samples collected in September. 2024 samples are averaged of June, July, August at each depth.

F. Trophic status over time

When considering trophic status over time, note that $TSI_{chlorophyll}$ and TSI_{TP} in 2021 and 2022 were estimated from composite samples as opposed to near surface samples as in 2023. Additionally, $TSI_{chlorophyll}$ and TSI_{TP} in 2023 for Wynonah and Fawn are calculated from September data rather than summer (samples taken in June, July, and August) averages. This may explain some of the variation and trends seen in differences in TSI values in 2023 compared to prior years. Values in 2024 are summer averages (June, July, and August) of surface samples. As of now, it is difficult to determine if the trends observed are simply temporal variation, due to differences in sampling and/or analytical techniques, or if they are ecologically significant. More years of routine sampling are needed to determine if the suggestions below are meaningful.

In Wynonah, TSI_{TP} and $TSI_{chlorophyll}$ decreased dramatically from 2022 to 2023 (but see caveat above, Figure 13), followed by an increase in 2024. $TSI_{chlorophyll}$ is the most direct measurement of algal abundance or productivity. In Wynonah, $TSI_{chlorophyll}$ ranged from 24.5 to 42.5, classifying Wynonah as generally meso-oligotrophic. TSI_{Secchi} decreased slightly over the 4-year dataset, suggesting water clarity may be impacted by factors other than algae. However, this is difficult to determine given the limited data and the different chlorophyll sampling methods as described above.

Fawn was also generally meso-oligotrophic from 2021-24. Fawn experienced an increase of $TSI_{chlorophyll}$ which is mirrored by a similar increase in TSI_{Secchi}, suggesting water clarity may be closely impacted by algal production (Figure 13). $TSI_{chlorophyll}$ and TSI_{Secchi} trended together in Fawn, suggesting algae may impact water clarity.

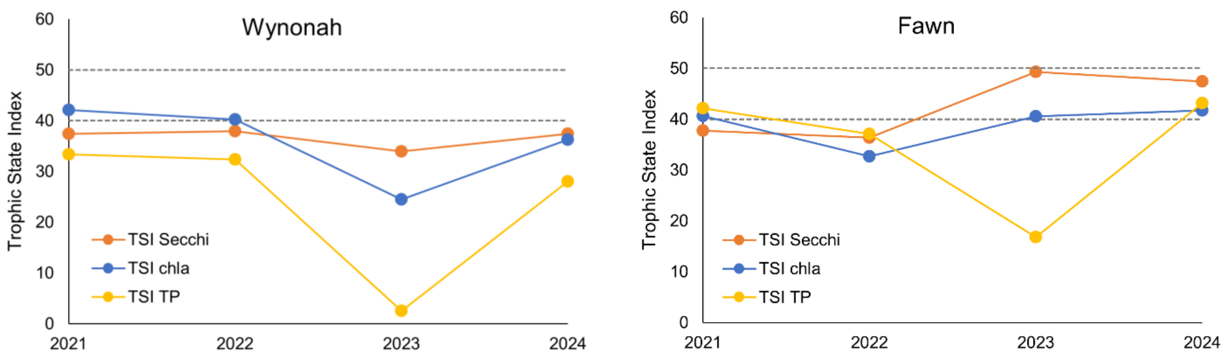

Figure 11: TSI of Wynonah and Fawn from 2021 to 2024. Dotted lines denote thresholds of oligotrophy (<40), mesotrophy (40-50), and eutrophy (>50). Chla and TP samples in 2021 and 2022 were composite samples, while 2023 and 2024 samples were taken at 0.5 m depth.

VII. Wynonah and Fawn in the Context of the Poconos

A. Description of PLEON Lakes

The PLEON dataset consists of 33 lakes in Pike, Wayne, Monroe, Lackawanna, and Schuylkill Counties. Lakes range in surface area, shoreline, and depth (Figure 14). The 33 lakes sampled by PLEON have an average depth of 7.6 m. Fawn's depth is close to this average, while Wynonah is much deeper.

B. Water transparency

PLEON recorded Secchi depth at least once during the summer months (June, July, August) in 19 of the 33 lakes during 2024. The average summer Secchi depth in these lakes ranged from 0.95 m to 4.80 m with an average of 2.37 m (Figure 14). Wynonah's average summer Secchi depth was the highest measured of the 2024 PLEON lakes. Fawn lake had an average summer Secchi depth of 2.4, very near the PLEON average for 2024.

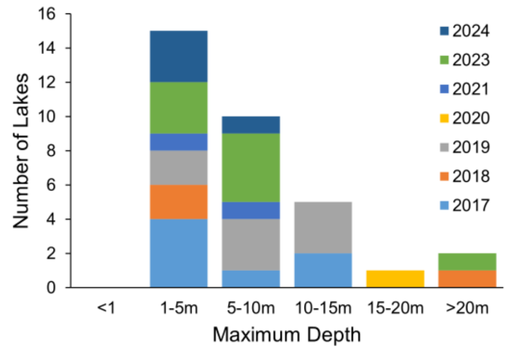

Figure 12: Maximum depth of PLEON lakes. Years refer to the first PLEON sampling year. Not all lakes are sampled every year.

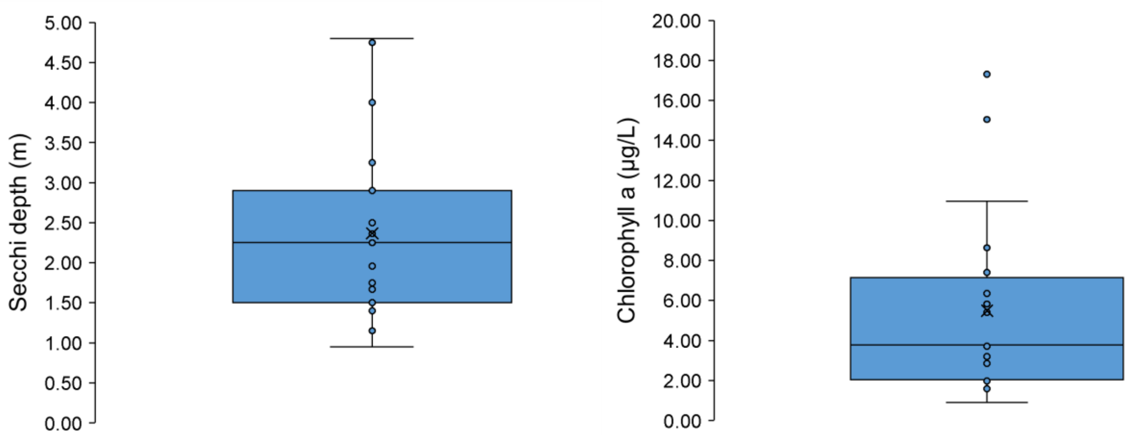

Figure 15: Average summer (June, July, August) Secchi depth (left) and chlorophyll a concentration at 0.5 m (right) across 19 PLEON lakes monitored in 2024. Lines within boxes are medians and X symbols are means. Upper and lower box boundaries denote the 75th and 25th percentile, respectively while upper and lower whiskers are the maximum and minimum values, respectively. Circles represent a single measurement from a lake or an average if the lake was sampled more than once during the summer.

C. Lake productivity

Lake productivity, as measured by chla concentration at 0.5 m depth, was assessed in 19 PLEON lakes during the summer months (June, July, August) in 2024. Average summer Chla concentration in these lakes ranged from 0.90 µg/L to 19.99 µg/L with an average of 5.72 µg/L (Figure 15). Both Wynonah and Fawn had average summer chla concentrations well below the PLEON average, with Wynonah's average at 1.97 µg/L and Fawn's average at 3.20 µg/L.

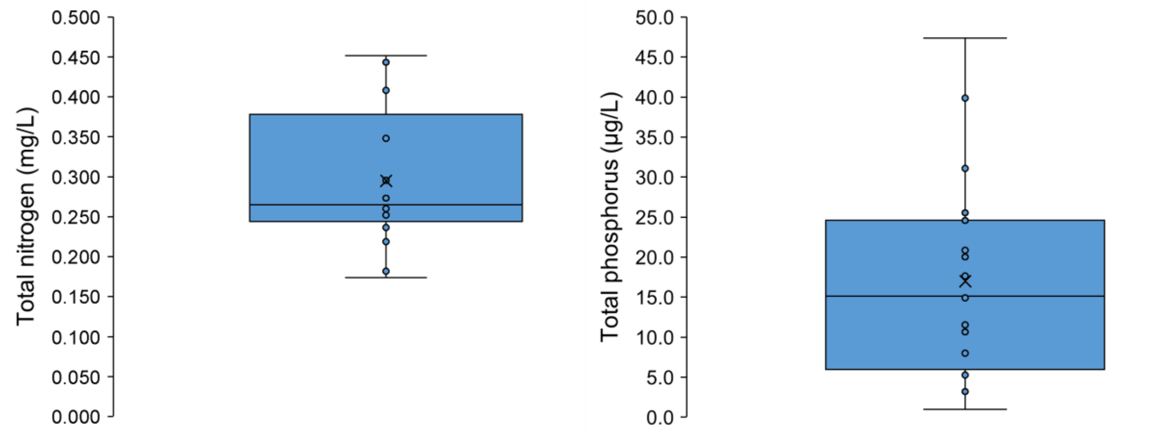

Figure 16: Average summer (J, J, A) TN and TP of PLEON lakes monitored in 2024. Lines are medians and X symbols are means. Upper and lower boundaries are the 75th and 25th percentile, respectively. Whiskers show maximum and minimum values. Circles are single measurements or an average if the lake was sampled more than once during the summer. Nutrient concentrations were quantified from 0.5 m depth.

D. Nutrient concentration

Total phosphorus (TP) concentration was quantified at 0.5 m depth in 19 PLEON lakes during the summer months (June, July, August) of 2024. Average summer TP concentration ranged from values below detection to 47.4 µg/L, with an average of 17.0 µg/L (Figure 16). The summer average epilimnetic TP concentration in Wynonah (4.93 µg/L) was much lower than the PLEON average, while Fawn was slightly below the PLEON average, at 15.26 µg/L.

E. PTOX Cyanobacteria

Cyanobacteria (sometimes called blue-green algae) are a common group of photosynthetic bacteria often classified as algae. Some cyanobacteria are capable of producing toxins that can be harmful to wildlife, pets, and humans. Cyanobacteria are the algae most commonly responsible for harmful algal blooms, or HABs, in freshwater ecosystems. Potentially toxigenic (PTOX) cyanobacteria genera can be identified using a microscope.

PLEON did not screen samples from Wynonah or Fawn for potentially toxigenic (PTOX) cyanobacteria or for cyanotoxins. This section is included to provide LWPOA a regional context for assessing the risk of toxic cyanobacteria blooms in Wynonah and Fawn.

Since 2017, PLEON has collected 295 samples for PTOX screening as a part of its formal monitoring program. These samples were collected from 24 lakes during months ranging from May through September. This count includes samples collected from different locations within the same lake on the same day. Samples include collections from 0.5 m, surface grabs, and composite samples and include pelagic, shore and near-shore environments. All samples were screened by Greenwater Laboratories.

Eleven (possibly 12, some specimens are difficult to identify) PTOX cyanobacteria genera have been found in PLEON samples to date (Figure 17). The most commonly found genera are *Dolichospermum*, followed by *Aphanizomenon* (or *Aphanizomenon*-like). *Chrysosporum*, *Woronichinia*, and *Microcystis* were also common. Eighty-one of the samples (or 27%) did not have PTOX taxa present. Three lakes within the dataset have been consistently free of PTOX taxa but these lakes were among the lakes sampled the least frequently.

Based on the results of the PTOX screens, Greenwater Laboratories has recommended quantifying microcystin/nodularin concentration in 29% of the PLEON samples and quantifying cylindrospermopsin, anatoxin-a, and/or saxitoxin concentration in 22% of the samples. Cyanotoxin quantification is an opt-in service; to date, between 64% and 78% of the recommended analyses have been conducted, depending on the toxin.

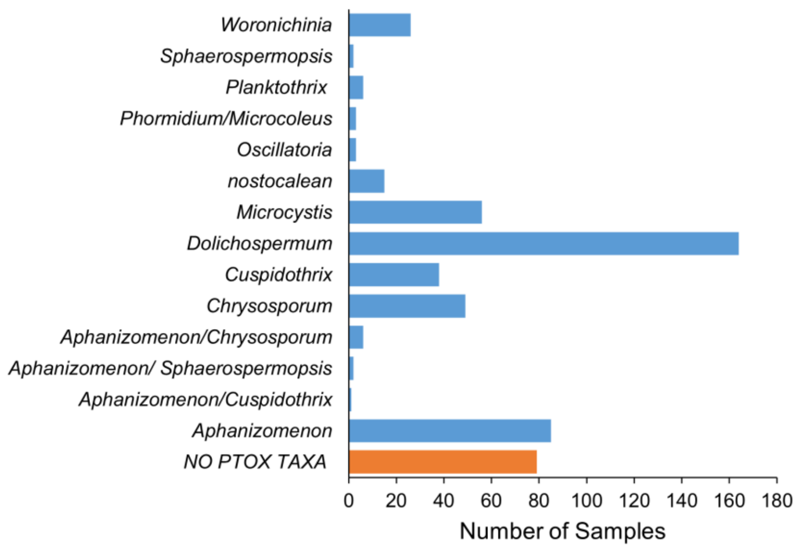

Figure 13: Potentially toxic (PTOX) cyanobacteria genera found in samples collected from PLEON lakes since 2017. PTOX screens were conducted by Greenwater Laboratories.

Microcystin/nodularins, cylindrospermopsin, and saxitoxin have been detected in PLEON lakes (Table 6). Microcystin/nodularins are hepatotoxins, cylindrospermopsin is a hepatotoxin and a nephrotoxin, and saxitoxin is a potent neurotoxin[4]. The US Environmental Protection Agency recommends microcystin and cylindrospermopsin magnitude thresholds of 8 µg/L (or ng/mL) and 15 µg/L in recreational waters[5]. The Lake Erie Harmful Algal Bloom Monitoring and Response Strategy recommends a Recreational Use Advisory when saxitoxin concentration is 0.8 µg/L or above[6]. Commonwealth of Pennsylvania does not have recommended thresholds at this time.

Table 5: Samples tested for cyanotoxins from PLEON lakes since 2017. Cyanotoxin analyses were conducted by Greenwater Laboratories.

Toxin	# samples recommended for testing	# tested	# ≥ MDL*	Mean concentration (ng/mL)	Range (ng/mL)
microcystins/nodularins	86	66	20	9.44	0.16-129
cylindrospermopsin	64	41	1	0.07	-
anatoxin-a	64	44	0	-	-
saxitoxin	64	45	5	0.40	0.15-0.73
homoanatoxin-a	1	1	0	-	-

**MDL = minimum detection limit*

VIII. What it all Means: Emerging Concerns for Wynonah and Fawn.

Identifying ecological trends requires at least five time points, preferably many more. To date, PLEON has 4 years of data from Wynonah and Fawn but samples were collected at different times of the year and from different depths. Therefore, the points below simply highlight findings that warrant further monitoring rather than statistically or even ecologically significant trends.

1. Oxygen depletion at depth may result in nutrient regeneration from sediments.

Profiles of both lakes show consistent oxygen depletion in the hypolimnion during times we would expect the strongest stratification (e.g., mid-summer). This is common in many lakes in the region, particularly deep lakes with strong thermal stratification, like Wynonah. This is a result of several factors. First, oxygen in the hypolimnion is consumed by bacteria and other microorganisms as they decompose organic matter that settles to the bottom of the lake. Second, the algae that produce oxygen through photosynthesis are typically not present in the dark, cool hypolimnion. Finally, thermal stratification prevents the warm, oxygen-rich surface waters from mixing with the cool deep waters.

When oxygen levels near the sediments are low, nutrients that were bound up in the sediments may be released; a process called nutrient regeneration. Both phosphorus and nitrogen can build up in the hypolimnion under anoxic conditions and can fuel algal growth. There was some evidence of nutrient regeneration in Fawn in 2024, as TP near the sediments increased from August to September to a concentration above the 25 µg/L threshold for nutrient pollution suggested by Penn State Extension[1]. There was no corresponding increase in chla concentration in September.

There are currently insufficient data to determine if algal abundance in Wynonah and Fawn is changing over time. Continued sampling of chla as well as nutrients from June to September at discrete depths (at least the surface and deep waters) will help identify trends. Determining what nutrient sources are important to Wynonah and Fawn will require targeted sampling and is important if nutrient concentrations are increasing over time or if algae growth becomes problematic.

2. Water clarity decreased in Fawn.

Water clarity as determined by Secchi depth decreased from 2022 to 2023 in Fawn, decreasing from 5.3 m to 2.1 m in depth. This decrease in water clarity continued in 2024, when the summer average Secchi depth was 2.4 m. Wynonah Secchi depth was variable with no trends apparent over the 4-year data set.

Water clarity is influenced by many factors including the concentration of suspended particles and the amount and color of dissolved compounds, all of which can be impacted by precipitation patterns, surface runoff, and disturbance to the sediments from recreational use of the lake. Water clarity may also be impacted by algal growth. There are not yet enough data to determine a relationship between water clarity and algal growth.

Further monitoring can determine if clarity is continuing to decrease in Fawn or if these conditions are typical for this lake. More monitoring may also reveal important drivers of water clarity in both Fawn and Wynonah.

3. It is important to continually evaluate the risk of harmful algae blooms.

Cyanobacteria (or blue-green algae) are photosynthetic bacteria, are very common and are found in almost all lakes. Some cyanobacteria produce toxins that are harmful to humans and animals.

PLEON sampling of Wynonah and Fawn did not include screening for cyanobacteria. However, cyanobacteria blooms are common in Pocono lakes and it is important to be aware of the potential of future blooms.

Often, although not always, potential cyanobacteria blooms can be identified visually. Educating lake community members on how to identify algae blooms can facilitate rapid response. LWPOA may also want to consider developing a cyanobacteria monitoring and response strategy. More information about harmful algae blooms (HABs), tips for identification, and other resources can be found on the PLEON HABs webpage.

APPENDIX I: Chemical Depth Profiles for Wynonah and Fawn 2021-2024.

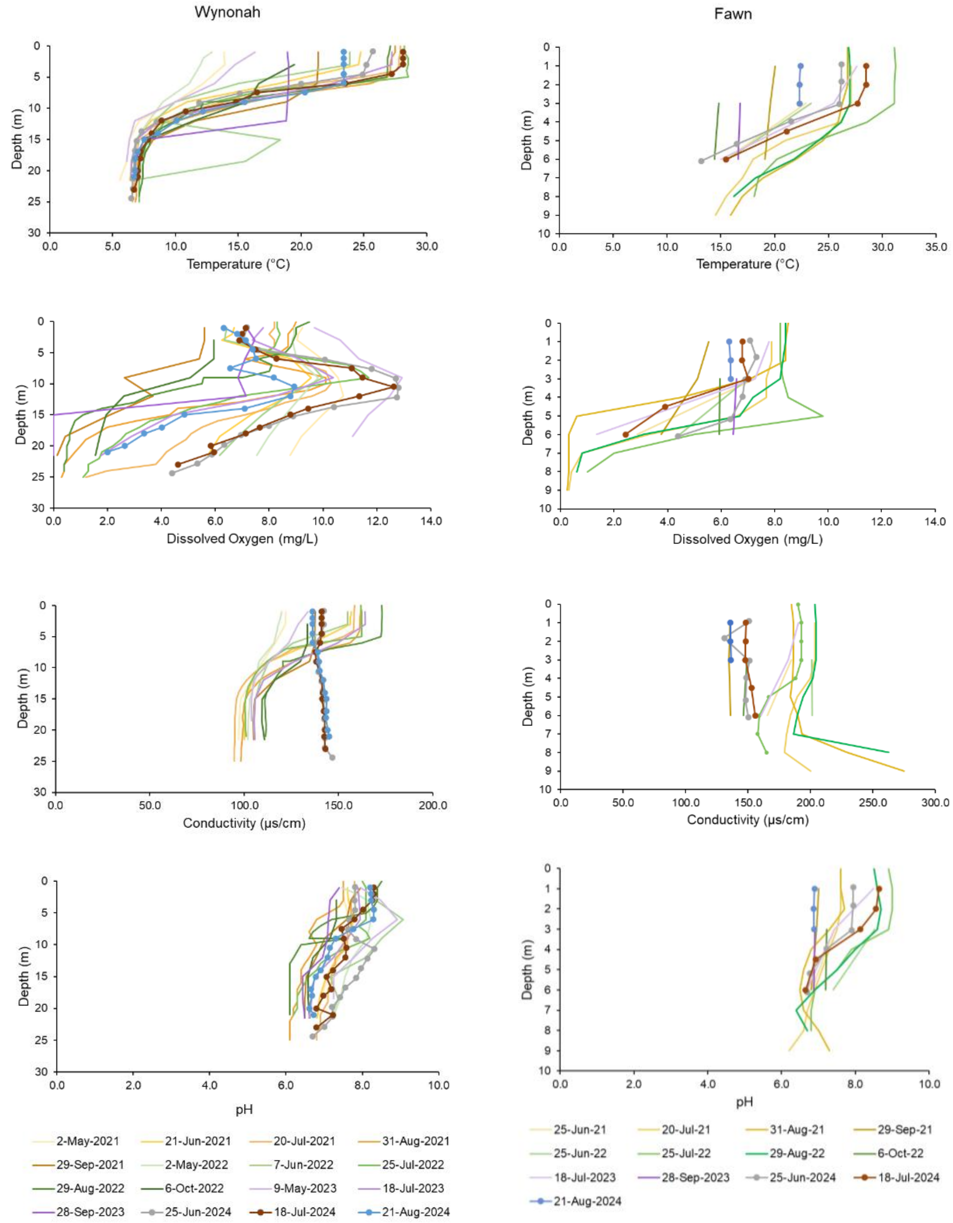

Figure 14: Chemical profiles from all samplings on Wynonah (left) and Fawn (right). From top to bottom, all depth profiles of temperature, dissolved oxygen, conductivity, and pH are graphed for both lakes. 2024 samplings are marked with circular points. Note differences in X- and Y-axes scales

APPENDIX II: Spatial Variation in Secchi Depth over time

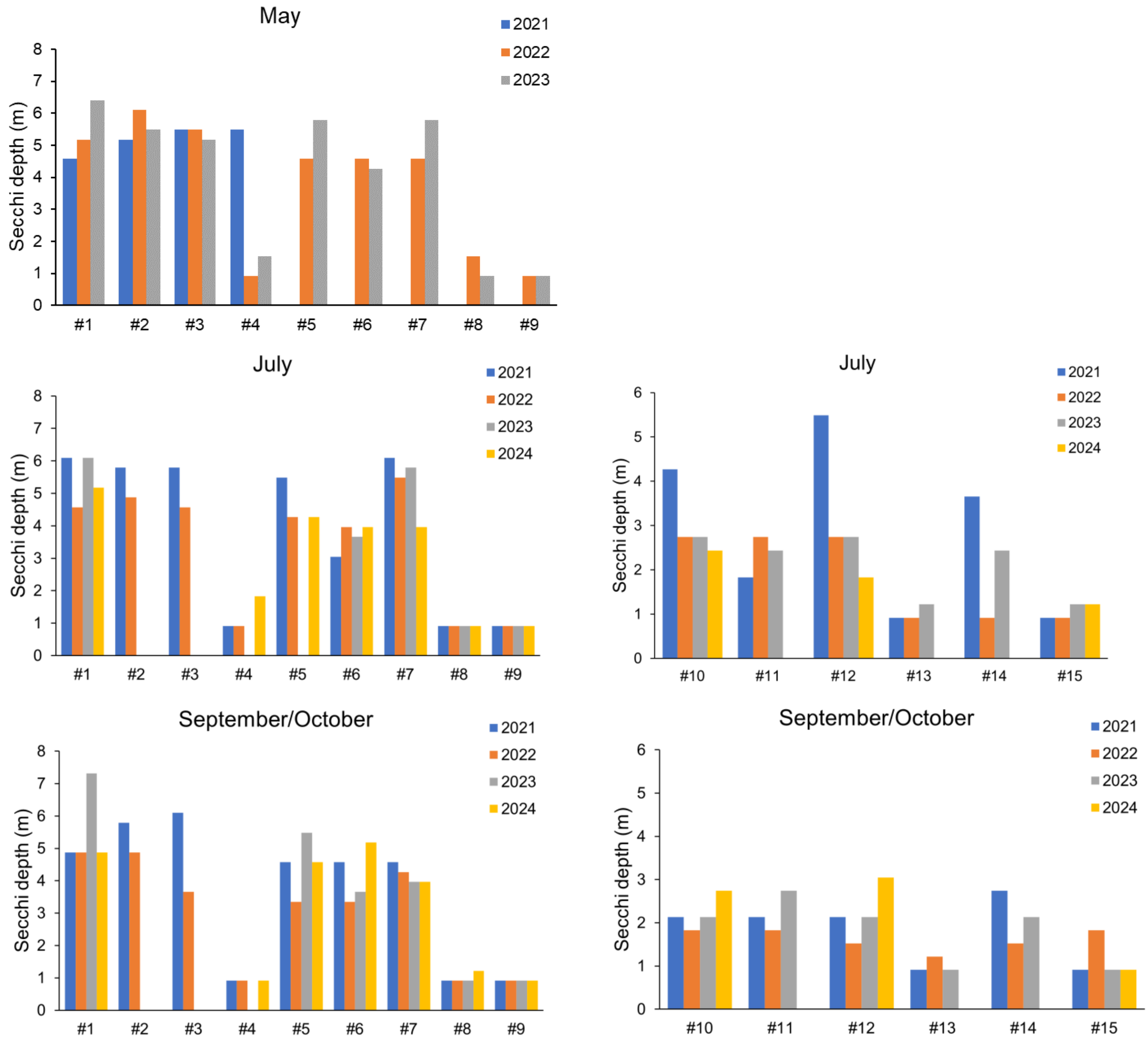

Figure 15: Secchi depth in Wynonah (left panels, sites #1-9) and Fawn (right panels, sites #10-15) in spring, summer, and fall. Wynonah samples were collected on 2 May, 19 July, 29 Sep 2021; 2 May, 26 July, 6 Oct 2022; 9 May, 18 July, 28 Sep 2023; and 25 June, 18 July, 21 August, 8 Oct 2024. Fawn samples were collected on 29 July, 29 Sep 2021; 26 July, 6 Oct 2022; and 18 July, 28 Sep 2023; and 25 June, 18 July, 21 August, 8 Oct 2024.

APPENDIX III: Description of Field Sampling Methods

A. Physical Profiles

Temperature, dissolved oxygen, conductivity, and pH were not measured by PLEON directly. These data were provided either by LWPOA (using their own equipment) or another vendor.

B. Chlorophyll

Water samples were collected from the epilimnion, metalimnion (when appropriate), and hypolimnion (determined by temperature profile collected on the same day) using a Van Dorn bottle. Two replicate samples were collected from each depth. Samples were kept cold until filtered. For each replicate, a known volume was filtered onto a glass fiber filter with nominal pore size of 0.7 µm using a vacuum pump. Filters were frozen until extraction. Pigments were extracted from filters with 10 ml of a 9:1 acetone:water solution. The extraction took place over 18 hours at -20°C. Chlorophyll concentration of the extractant was determined via fluorometry (Turner Designs 10AU fluorometer) and corrected for phaeophytin according to EPA method 445.0.

C. Nutrients

Two replicate water samples were collected using a Van Dorn horizontal water sampler from the epilimnion, metalimnion (if applicable), and hypolimnion. Water samples were collected in acid washed bottles and kept cold until return to the lab. A 60-ml subsample of each replicate was frozen at -20°C until analysis for total nitrogen (TN) and total phosphorus (TP) concentration (EPA methods 353.2 and 365.1, respectively).

Total nutrient samples were digested using an alkaline persulfate oxidizing reagent and heating at 80°C for 16-24 hours. This process simultaneously converts ammonium, inorganic nitrogen (excluding N_2), and organic nitrogen to nitrate (NO_3^-) and inorganic and organic phosphorus to orthophosphate (PO_4^{-3}).

Samples intended for dissolved nutrient analysis were filtered through ashed GF/F filters (Whatman, 0.7 um pore size) and frozen at -20°C until analysis for nitrate (NO_3-N), ammonium (NH_4-N), and phosphate (PO_4-P).

NO_3-N concentration of the digested samples was quantified via cadmium reduction using a discrete autoanalyzer (AQ300, SEAL Analytical) at Drexel University (EPA method 353.2).

NH_4-N concentration of the digested samples was quantified via the indophenol blue colorimetric method using a discrete autoanalyzer (AQ300, SEAL Analytical) at Drexel University (EPA method 350.1)

PO_4-P concentration of the digested samples was quantified via the ascorbic acid colorimetric method using a discrete autoanalyzer (AQ300, SEAL Analytical) at Drexel University (EPA method 365.1).

D. PTOX screening and cyanotoxin analysis

PLEON sends PTOX samples to GreenWater Laboratories for PTOX screening. Samples are kept cold in the field and sent to GreenWater Laboratories within 30 hours. GreenWater Labs provides the following description of the screening process:

“A one mL aliquot of each sample was prepared using a Sedgewick Rafter cell. The samples were scanned at 100X for the presence of potentially toxigenic (PTOX) cyanobacteria using a Nikon Eclipse TE200 inverted microscope equipped with phase contrast optics. Higher magnification was used as necessary for identification and micrographs.”

Cyanotoxins were analyzed by Greenwater Laboratories using Enzyme-Linked Immunosorbent Assay (ELISA; microcystin-nodularins and saxitoxins) or Liquid chromatography mass spectrometry/mass spectrometry (LC-MS/MS; anatoxins and cylindrospermopsin) according to laboratory-specific protocols.

Appendix IV: Literature Cited

1. Swistock, B. 2015. Interpreting Water Tests for Ponds and Lakes. Retrieved on 22 February 2020, https://extension.psu.edu/interpreting-water-tests-for-ponds-and-lakes

2. Fondriest Environmental, Inc. “pH of Water.” Fundamentals of Environmental Measurements. 19 Nov. 2013. Web. https://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/.

3. Carlson, R. E. 1977. A trophic state index for lakes. Limnology and Oceanography 22(2): 361-369.

4. GreenWater Laboratories. “What Are Algal Toxins?” Accessed 31 March 2022. Web. https://www.greenwaterlab.com/what-are-algal-toxins/

5. US EPA. Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin. Retrieved on 10 March 2020, https://www.epa.gov/sites/production/files/2019-05/documents/hh-rec-criteria-habs-factsheet-2019.pdf

6. Lake Erie harmful algal bloom monitoring response strategy. July 2017. https://seagrant.psu.edu/sites/default/files/PA%20Lake%20Erie%20HAB%20Response%20Strategy%207-24-2017_0.pdf

Appendix V: Glossary

Anatoxin-a: A neurotoxin produced by some cyanobacteria, including members of the genera *Microcystis*, *Aphanizomenon*, *Planktothrix*, and *Cylindrospermum*. Considered dangerous for humans and pets.

Carlson's trophic state index: An index designed by R. E. Carlson (1977) ranking lakes on a scale of 0-100 based on algal biomass and calculated using Secchi depth, chlorophyll concentration, or phosphorus concentration.

Conductivity: the ability of a solution to conduct electricity (also called specific conductance). Dissolved materials increase the conductivity of water so this variable can indicate the amount of dissolved solids. Sea water, for example, has a conductivity of 50,000 µS/cm.

Cyanobacteria: a group of photosynthetic bacteria commonly found in freshwater phytoplankton communities. Some taxa are capable of fixing nitrogen from the atmosphere. Some taxa produce toxins harmful to humans.

Cylindrospermopsin: a liver and kidney toxin produced by some cyanobacteria.

Dissolved oxygen: The amount of oxygen gas dissolved in water. This variable is important because oxygen is required for respiration by lake organisms. Dissolved oxygen enters water via diffusion at the water surface and through the process of photosynthesis, of which oxygen is a waste product.

Epilimnion: The surface layer of a thermally stratified lake. The epilimnion is mixed by waves and wind; therefore the temperature is fairly uniform throughout this layer. The lower boundary of the epilimnion is determined by a rapid change in temperature. This layer is typically more oxygenated than the lower layers.

Eutrophic: trophic state describing productive lakes. Eutrophic lakes are typically high in nutrients with low transparency.

Hypereutrophic: trophic state describing highly productive lakes. Hypereutrophic lakes have extreme levels of excess nutrients and have very low transparency.

Hypolimnion: the deep waters of a thermally stratified lake. The hypolimnion consists of cold water that does not mix with the warmer epilimnion. This layer can be depleted in oxygen due to the absence of photosynthesis.

Mesotrophic: trophic state describing lakes with intermediate productivity. Mesotrophic lakes have intermediate levels of nutrients and intermediate transparency.

Metalimnion: the middle layer of rapidly changing temperature in a thermally stratified lake. This is the transition layer between the epilimnion and hypolimnion.

Metalimnetic Oxygen Maximum: elevated dissolved oxygen concentration that can develop in the metalimnion, often due to a concentration of phytoplankton that are producing oxygen through photosynthesis.

Microcystin: a group of toxins produced by some cyanobacteria genera including *Microcystis* and *Planktothrix.* Microcystins are liver toxins that can be harmful to humans and pets.

Oligotrophic: trophic state describing lakes with low productivity. Oligotrophic lakes are nutrient poor and have high transparency.

pH: a measure of hydrogen ions on a logarithmic scale from 0-14. Values above 7 are considered basic and values below 7 are considered acidic. Lake organisms have specific pH tolerances.

Photosynthetically Active Radiation (PAR): wavelengths of light that are used in the process of photosynthesis. Range from 400-700 nm.

Phytoplankton: Planktonic microscopic organisms that use sunlight to convert carbon dioxide to sugar in a process called photosynthesis. The base of lake food webs, phytoplankton provide food for zooplankton and some fish. Phytoplankton also drive nutrient cycling and produce oxygen.

Potentially Toxic (PTOX) Cyanobacteria: cyanobacteria groups that are known to have the capability to produce toxins that are harmful to humans and pets.

Saxitoxin: a neurotoxin produced by some cyanobacteria genera including *Aphanizomenon* and *Planktothrix.* Exposure can be harmful to humans and pets.

Secchi depth: a standardized value of water transparency measured using a flat disk with black and white quadrants called a Secchi disk. Secchi depth is positively correlated with transparency.

Vertical Extinction Coefficient (*k*): The rate at which light attenuates with depth. Different wavelengths of light have different coefficients. Dependent on dissolved and particulate matter in lake water that may reflect or absorb light.

Zooplankton: planktonic animals found in lake water. Zooplankton are critical to lake food webs, feeding on phytoplankton and dead organic matter and providing food for fish and other large lake organisms.