2024 Big Indian Pond Water Quality Assessment

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Executive Summary

Baseline water quality monitoring of Big Indian Pond in St. Albans, Maine was conducted by LWRMA on August 29, 2024. Additional, and very helpful water clarity data for this assessment were provided by certified volunteer lake monitor, Robin Steinwand. This report analyses and summarizes the findings of the data gathered during summer period.

Indicators of lake water quality are affected by numerous influences, including the natural features (morphometry) of individual lakes and their watersheds, development within the watershed, weather and climate, which have a significant bearing on the seasonal and annual variability of water quality, and which is increasingly significant in the era of a warming climate and associated extreme weather. The identification of long-term trends in the overall health of a lake require data over a period of time in order to be able to identify trends with confidence.

The weather during the 2024 monitoring period was in sharp contrast to the unusually wet conditions in 2023, and the significant drought years of 2021 and 2022. Substantial decomposed organic matter from the extended period of drought in 2021 and 2022 was washed into lakes in 2023 by the nearly continuous precipitation that occurred during the spring, summer and early fall period. Humic compounds transported in stormwater runoff to lakes throughout Maine resulted in record high concentrations of color, reduced water clarity, and greater solar radiation absorption during the period. The extensive flushing that continued well beyond the lake monitoring period likely resulted in a purge of the humic compounds, as well as phosphorus and algae (chlorophyll) toward the end of the year, especially in lakes with moderate natural flushing rates.

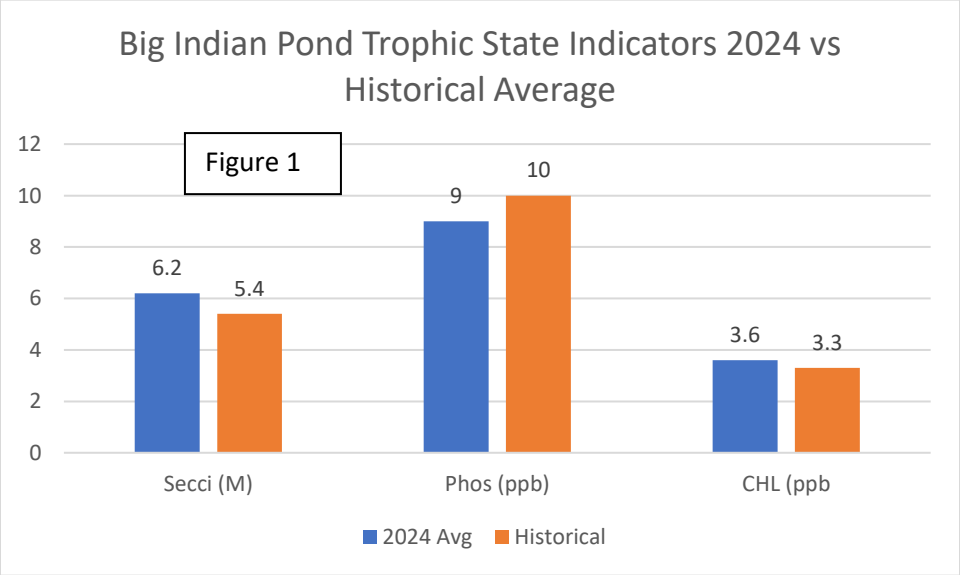
The weather in 2024 was significantly drier throughout the May through September period, and a heat wave in late June through much of July resulted in unusually high lake surface temperatures, which could have resulted in significant planktonic algae growth in many lakes, if not for the fact that August and September were substantially cooler and very dry. Cyanobacteria generally proliferate in warm waters with high concentrations of phosphorus. The lack of precipitation and stormwater runoff, and cooler weather, allowed many sensitive/vulnerable lakes to "dodge the bullet" in 2024.

Big Indian Pond is characterized by the Maine Department of Environmental Protection as a Coastal Shallow Lake, based on three broad geographic areas, within which lakes have similar characteristics. This classification system can be helpful in anticipating and interpreting the conditions of the bodies of water within each region.

Overall, conditions in Big Indian Pond in 2024 were average to above average. This determination is based on three "trophic state" indicators: Secchi Transparency (Water Clarity); Total Phosphorus and Chlorophyll-a). These indicators are used to estimate the overall biological productivity of lake ecosystems. The indicators estimate overall algae density in the water.

Big Indian Pond was clearer in 2024 than its historical average, based on several readings taken from June through August. The concentration of the nutrient phosphorus, which is a limiting nutrient for algae growth, was slightly lower than the historical average for the lake, and chlorophyll-a, a pigment in algae, was very close to the historical average for Big Indian.

Figure 1 illustrates the 2024 averages for the key "trophic state" indicators, compared to the historical average for Big Indian Pond.



The surface temperature of the lake on August 29 was 23.3 degrees C (73.8 F), which was likely several degrees cooler than the peak temperature of the summer in late July, following a significant heat wave. By August 29, the surface temperature was likely cooler due to significantly cooler weather during the late summer. Summer surface temperatures in Maine lakes have risen into the low to mid 80's F in recent years, and have been approximately 10 degrees (C) warmer than three decades ago (Source: MDEP Data Summaries for ME Lakes). Such high temperatures can result in multiple negative effects on lake ecosystems, including fishery impacts and algal community shifts favoring cyanobacteria

The lake was weakly thermally stratified at the "deep hole" monitoring station on August 29, with only a 5 degree temperature drop from the surface to 8 meters depth. The relatively shallow bathymetry and the orientation of the lake basin to prevailing winds is such that the development of thermal layers (stratification) during the summer months is likely brief and recurring (ephemeral). Any period of moderate wind would likely cause the lake to turn over (mix).

Dissolved oxygen (DO) levels were near 100% saturation (relative to water temperature) from the surface to 5 meters depth, below which the water temperature dropped a few degrees, and DO levels also dropped to nearly zero at 8 meters (0.7 meters from the lake bottom). The cooler, "heavier" water presented a barrier to mixing with the overlying water, and was thus not exposed to the atmosphere, (unlike the water in the upper layer) when wind mixing took place. The low oxygen water was likely replenished through mixing of the entire water column within a short period following August 29, as the days shortened, nights were cooler, and wind events occurred. Historical temperature and dissolved oxygen profiles taken during the late summer have been similar to the August 29, 2024 profiles, which are illustrated in Figure 2.

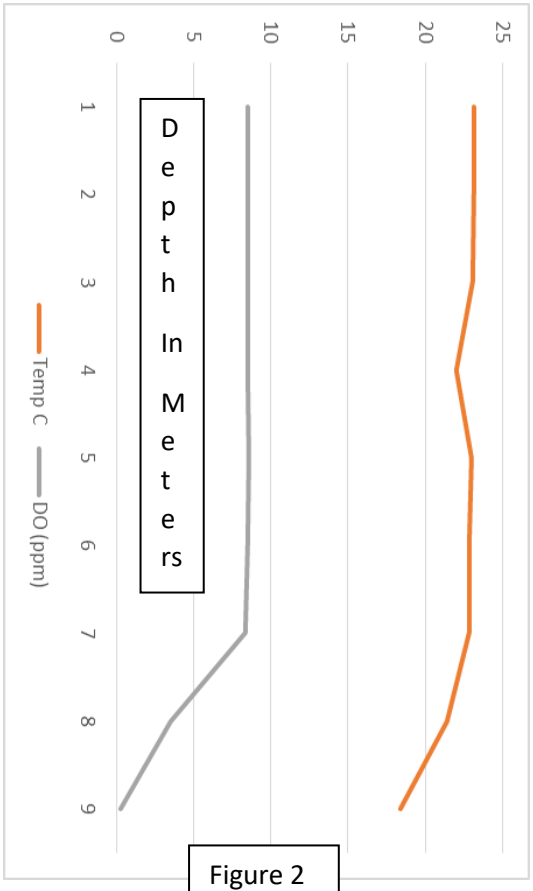
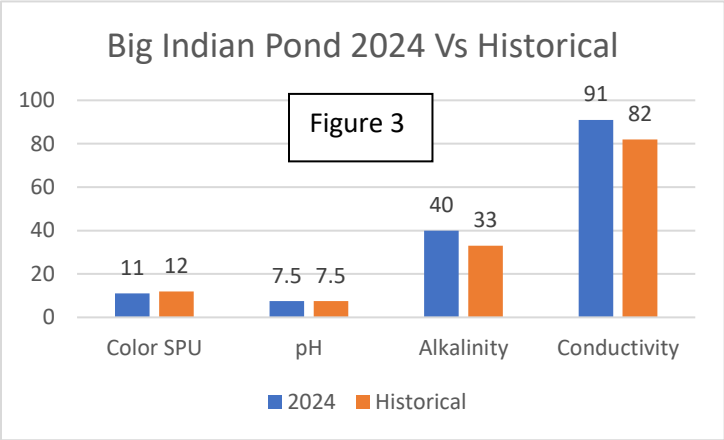


Figure 2

A Phosphorus sample taken at 8.5 meters depth, near the bottom sediments was higher than an integrated core sample taken near the surface. However, it was not sufficiently higher than the surface sample to indicate whether or not the low oxygen near the bottom had triggered a release of phosphorus from the bottom sediments. Low concentrations of dissolved oxygen at the sediment-water interface can, under certain circumstances and conditions (including sediment geochemistry), result in the release of phosphorus that is chemically bonded to iron and aluminum. The ephemeral nature of thermal stratification in Big Indian Pond is such that it would likely be necessary to take multiple samples during the course of the summer months to determine whether or not this phenomenon is taking place. Limited historical bottom phosphorus samples taken on the lake during the late summer are also relatively low.

Additional supporting indicators, including Color, Conductivity and Total Alkalinity were close to the historical averages for the lake, as illustrated in Figure 3.



Conductivity (specific conductance) is a measure of the concentration of ions in the lake. Both the historical average and the 2024 sample are relatively high on the continuum for Maine lakes. Conductivity tends to increase along with watershed development, often related in part to winter road salt application. The shoreline of Big Indian Pond is moderately developed. Protective forested buffers have been cleared to the lake on sloped terrain. The extensive disturbance of the natural shoreline removes critical filter vegetation that stabilizes soils and filters pollutants. Re-establishing shoreline buffer strips could significantly protect the lake from the potentially negative effects of development (shoreline and upland), and could also reduce the impact of climate warming because wooded buffers provide cool zones for tributaries and runoff to the lake.

Spot checks of several shallow zones of shoreline were done on August 29 to assess and document the extensive aquatic plant communities. No invasive species were observed, although “look alike” native plants that resemble non-native aquatic invaders were observed. Overall, the plant communities, while dense in some areas, were balanced and healthy. Native rooted aquatic plants provide numerous benefits to Maine lakes, including nursery areas for fish, forage for beneficial aquatic insects, shoreline protection from the erosive force of wind waves and boat

wakes, and the uptake of nutrients that could otherwise be available to algae, resulting in less clear water.

The most dominant species of rooted aquatic plant observed was *Vallisneria* , commonly known as "Eel Grass". A common Milfoil look-alike, "Water Marigold", was observed in multiple areas. Both of these plants are common in lakes throughout Maine, as were virtually all of the macrophytes (rooted aquatic plants) observed.

Several areas of dense "metaphyton" growth were observed. This filamentous form of several species of algae is sometimes characterized as having the appearance of "green cotton candy". Observational data from Maine lakes during the past two decades suggests that this form of algae may be on the increase, although its abundance in individual lakes can vary significantly from one year to the next. Metaphyton has been in Maine's lakes for as long as data have been gathered on lake algae in Maine. It provides numerous benefits to aquatic ecosystems. However, a substantial increase in metaphyton growth may be an indication of ecosystem changes. Warmer lake water may be a factor if, in fact, metaphyton is increasing overall in Maine's lakes.

Overall, we found Big Indian Pond to be healthy and balanced on August 20, 2024. It is important to bear in mind that lakes are highly complex and dynamic systems that are strongly influenced by the forces of nature. Storm events that involve precipitation, and wind can result in reduced water clarity due to nutrient enrichment and turbidity from mixing. Shorter periods of ice cover, record high summer water temperatures a longer growing season for algae and other lake plants, and an increase in severe weather, ranging from soil-eroding storm events to extended periods of drought may adversely affect lake ecosystems in a number of ways. Climate warming has the potential to significantly amplify the threats of watershed development on lake water quality. *Ongoing efforts to protect the lake through* ***aggressive watershed conservation*** *initiatives will continue to be essential to the continued long term health of the lake.*

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Background Factors that Influence Maine's Lakes

Lake Water Quality in the Era of a Warming Climate:

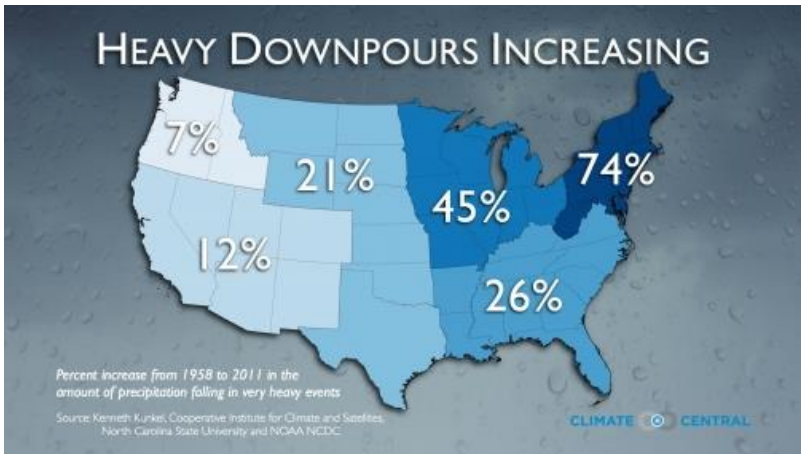
Lake water quality may be influenced at any point in time by a wide range of both natural and anthropogenic factors. The sum effect of these is responsible for the extent to which monthly, seasonal and annual "natural variability" occurs in many of the indicators that are used to assess lake ecosystems.

Annual weather fluctuations and trends in temperature, wind, and precipitation typically have a strong bearing on short and long-term conditions that occur in individual lakes. The extent to which each of these powerful weather and climate influences affects each lake is dependent on both the natural characteristics of the lake, and the degree to which the lake and watershed have been disturbed through development. Natural characteristics include, but are not limited to the bathymetry (depth profile) and shape of the lake basin, and its orientation to prevailing winds,

and the geographic area, soil chemistry, and hydrologic characteristics of the watershed. The presence of natural features such as wetlands within the watershed may also be an influence. The combined effect of these natural characteristics plays a role in the sensitivity and response of individual lakes to external influences, including watershed development.

Foremost among the influences of weather on Maine's lakes are precipitation and temperature, both of which are now becoming intensified through the process of climate warming. In recent years, unusually warm ambient temperatures throughout the year have resulted in historic high summer lake water surface temperatures (mid 80's F in southern and central Maine), later formation of ice cover in the fall/winter, and earlier "ice out" in the spring. The overall reduced period of ice cover on lakes will likely have, and undoubtedly is already having, a profound influence on Maine's lakes, relative to historical conditions.

Precipitation patterns are becoming more extreme. Multiple years of moderate to severe drought have occurred throughout much of Maine during the past two decades. Among other impacts, drought reduces the inflow of water to lake basins from their watersheds, resulting in low water levels, which can cause the desiccation of sensitive, beneficial aquatic plants and other habitat in littoral areas. Drought may also increase shoreline erosion, and through evaporation, the concentration of various substances in the lake.



Periods of drought have increasingly been punctuated by localized extreme precipitation events, during at which time high-velocity, erosive stormwater runoff from the watershed can reach lakes, carrying with it elevated concentrations of soil particles and nutrients. In recent years, unusual algal blooms that have been observed and documented in a number of Maine lakes have been determined to have been triggered by the combined effects of extreme weather.

Historically, it has generally been accepted that clearer lake water is an indication of a healthy lake ecosystem. This may not always be the case in the era of climate change. Many Maine lakes tend to be clearer during drier years, ostensibly due to reduced stormwater runoff from their watersheds during such periods, resulting in less algal growth.

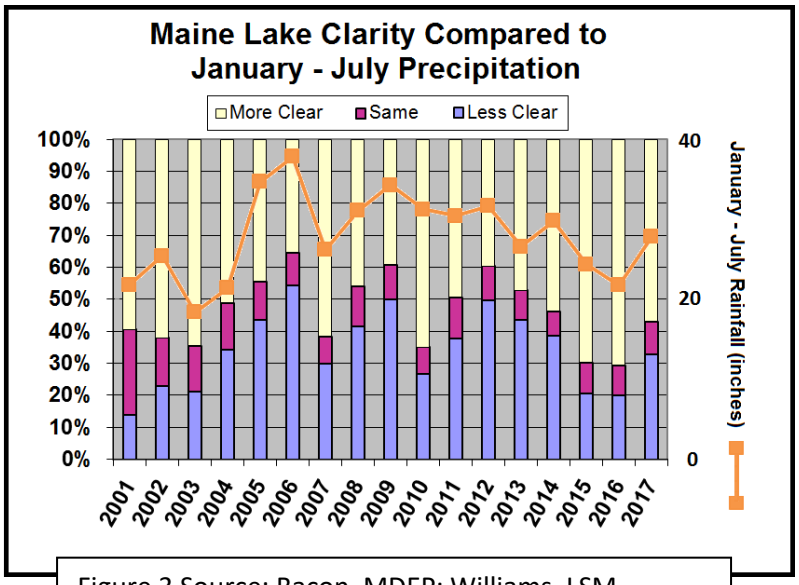
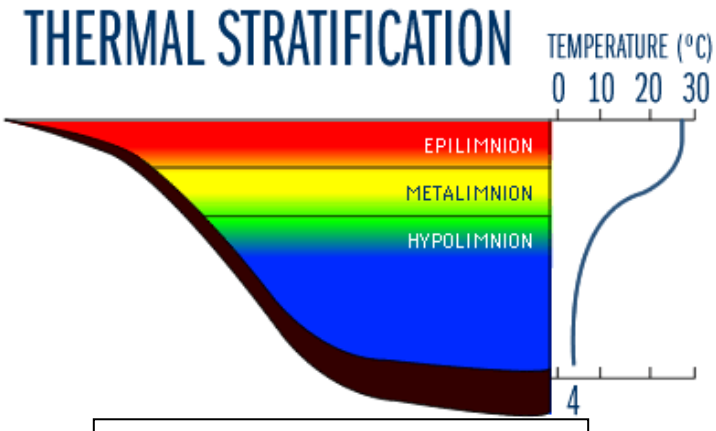


Figure 3 Source: Bacon, MDEP; Williams, LSM

An observational analysis of the Secchi transparency (water clarity) of Maine lakes from 2001 through 2017 (Linda Bacon/MEP; and Scott Williams/LSM) showed that a significant number of Maine lakes tend to be clearer during drier years (Figure 3). Stormwater runoff is the vehicle by which phosphorus and other pollutants are transported from watersheds to lakes. A significant number of Maine lakes have been less clear during years when there is more precipitation during the period from January through mid- summer. Thus, periods of drought may be deceptively causing apparent improving trends in water quality for some lakes in Maine, based on deeper Secchi disk readings, and lower concentrations of phosphorus and planktonic algae. It will therefore likely become increasingly important to take the influence of weather extremes associated with a warming climate into account when assessing lake water quality in the future.

While a majority of Maine's lakes appear to be clearer during drier years, smaller groups of lakes are either unchanged, or in some cases, are less clear than their historical average. This may be due, in part, to the fact that warming lake water temperatures may result in longer periods of thermal stratification, and some relatively shallow lakes that have undergone little or no stratification in the past are now experiencing this phenomenon.

Extended duration of thermal stratification typically results in a greater loss of dissolved oxygen in the lake water column during the period. If the oxygen loss drops to a critical level, phosphorus in the lake sediments may be released to the overlying water. The "pulse" of phosphorus associated with this internal release process may result in an increase in planktonic algal growth, and reduced water clarity, especially during the warm summer and early fall period.



Typical Summer Temperature Profile in a Thermally Stratified Lake

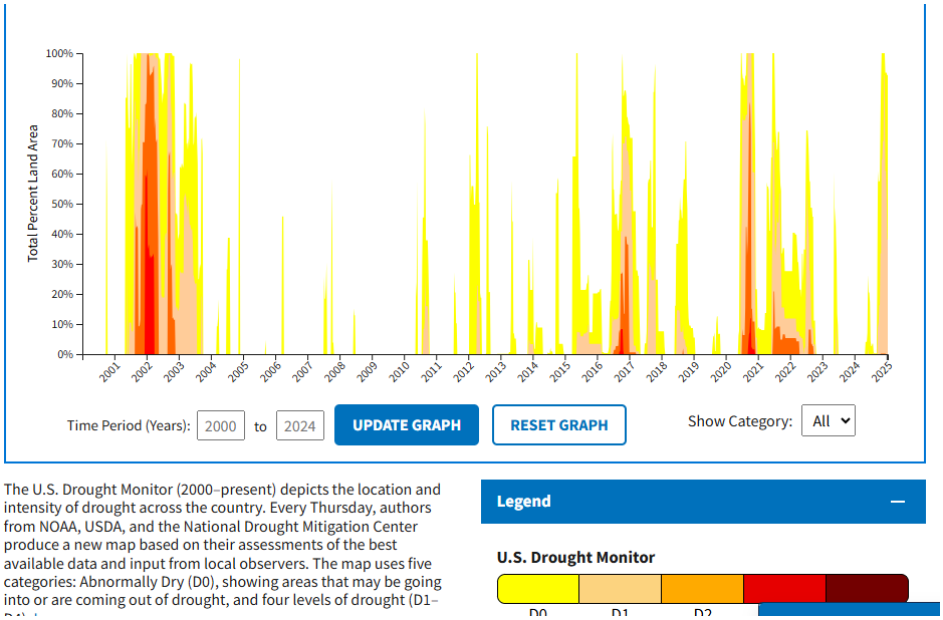
A group of lakes that may actually be clearer during wet years are those that are highly productive, and which experience regular severe algae blooms. These lakes may actually benefit from the diluting effects of precipitation, because phosphorus concentrations in the body of water are already higher than incoming levels in stormwater runoff.

Climate warming, and the associated extreme weather events may compound (and confound) the complexity of tracking, predicting and characterizing lake water quality. In recent years, an increasing number of lakes that have historically experienced relatively "good" water quality, and which have otherwise been considered to be stable, have experienced a significant decline, very likely due to the de-stabilizing influence of a warming climate. Although in some cases it may be possible to predict the manner in which individual lakes will respond to climate change, the process through which warming effects complex lake ecosystems may not always be evident in advance of the changes.

Potential Weather Influences in 2024:

In stark contrast to the very dry weather conditions in 2021 and 2022, the spring and summer of 2023 was one of the wettest on record for much of the State of Maine. This was followed by a relatively dry early spring and mid summer period in 2024, and very dry conditions in the late summer and early fall. The effects of drought on lakes may be cumulative, depending on the amount of time that it takes (on average) for the volume of water in a lake to be replaced, or "flushed" (not to be confused with "turning over", or mixing). Because this natural process is relatively slow, a dry year may continue to influence water quality and ecological effects for a year or more following the period of drought. Drought-related effects may be cumulative, depending on the duration and severity of drought conditions.

The image below (Source: Drought.gov) illustrates the extent of drought in 2021 and 2022, as well as the abrupt change conditions in 2023, followed by a return to relatively dry conditions in 2024. The color box in the lower left begins with "abnormally dry" in yellow, to more extreme conditions in the far right boxes. Note that many years since the severe drought period of 2001-2003, show significant drought conditions.



Summary of 2024 Findings for Big Indian Pond:

The following summary information is the result of "baseline" sampling and assessment that was conducted on August 29 by LWRMA staff. Additional (and very helpful) Secchi disk transparency (water clarity) readings submitted by Certified Lake Monitor Robin Steinwand are included in this analysis and report.

Water quality monitoring/sampling was conducted at the "deep hole" station, which is the location of the deepest point in Big Indian Pond (approximately 30 feet) - the area in the lake where the greatest volume of historical data has been obtained.

For most Maine lakes, August and early September sampling is generally considered to be the most critical period of the year because potentially stressful conditions in the lake associated with several months of warm weather are typically most evident. However, in order to confidently detect both short-term changes (such as an impending algal bloom), as well as long-term trends, greater sampling frequency is required over a period of several months (May through September or October). Historical data sources referenced are from the Maine Department of Environmental Protection, Lake Stewards of Maine (www.lakesofmaine.org), and LWRMA field records and reports.

Secchi transparency –*The distance one can see down into the water from the surface) varied throughout the monitoring period from low (least clear) reading of 5.8 meters in late June to the (deepest) reading of 6.9 meters on August 29, which was one of the deepest/clearest readings on*

record for Big Indian. The Average for the monitoring period was 6.2 meters, compared to the historical average of 5.4 meters for Indian Pond. Figure 4 below illustrates the variability of Secchi transparency/water clarity readings during the monitoring period. Note that higher (deeper) numbers indicate clearer water.

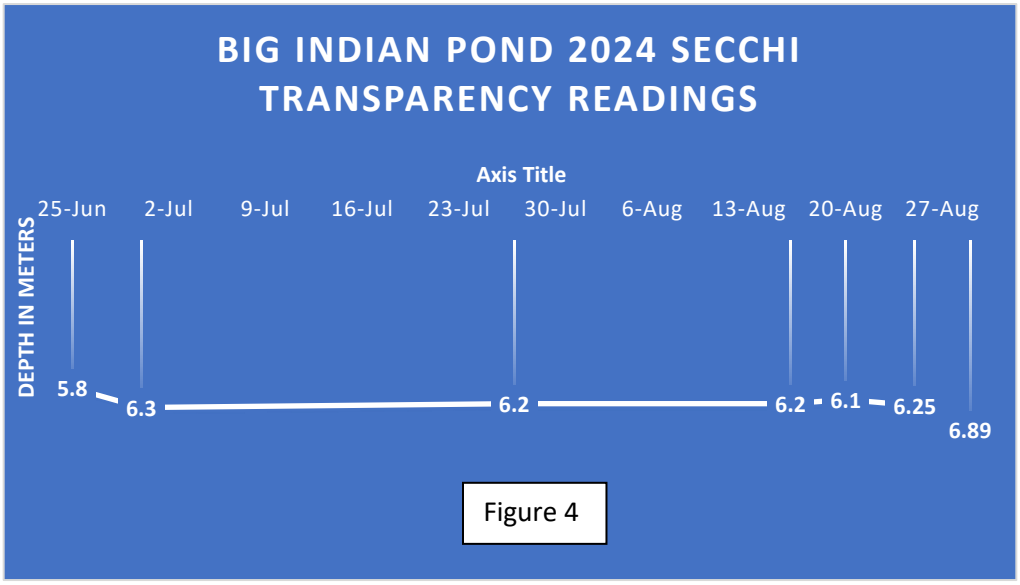


Figure 4

Total Phosphorus (combined organic and inorganic): A total Phosphorus (organic and inorganic) integrated water column (epilimnetic core) sample taken on August 29 measured 9 parts per billion (ppb), which is slightly lower than the historical average of 10 ppb for Big Indian.

The concentration of **Chlorophyll-a** (CHL) on August 29 from the integrated water column sample measured 3.6 ppb – very close to the historical average of 3.3 ppb for the lake..

Natural Lake Color: A sample to measure natural color was collected from the integrated core sample. Color is measured to determine the relative concentration of humic compounds in lake water. Such compounds typically leach from wetland vegetation, and from decaying leaves from hardwood trees and other organic matter along the shoreline. High concentrations of natural color in lakes (generally greater than 25 CPU) can significantly influence water clarity, and disrupt the normal relationships between water clarity, phosphorus, and chlorophyll.

Historical color levels in Big Indian have averaged 12 Standard Platinum Cobalt Units (SPU) compared to the August 29, 2024 sample, which measured 11 SPU.

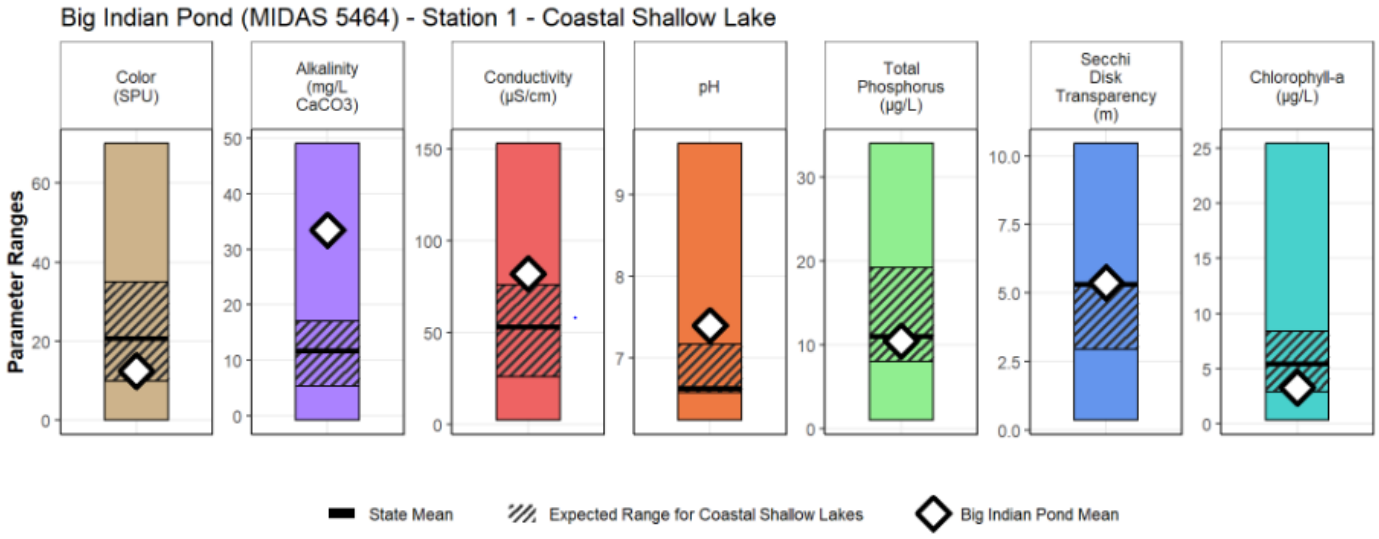
Hypoplimnetic Phosphorus Concentration measured close to the bottom of the deep monitoring station was higher than the surface core sample concentration, but not high enough to suggest that phosphorus was being released from the bottom sediments at that time. Internal phosphorus release is a phenomenon that can occur when dissolved oxygen levels at the

sediment/water interface drop below a critical point. Due to the ephemeral nature of thermal stratification in Big Indian Pond, multiple phosphorus samples and temperature/dissolved oxygen profiles, taken over the course of a season, could be helpful in determining the extent to which (if at all) P is being released from the sediments during periods of anoxia.

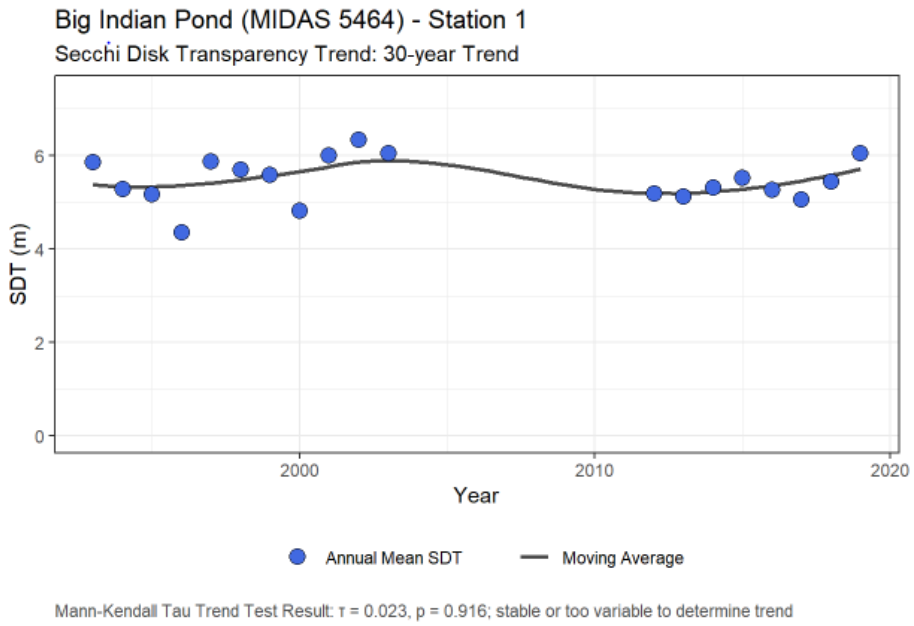
Total Alkalinity – A measure of the capacity of the water in Big Indian Pond to buffer acidified precipitation, measured 40 mg/l – within the range of historical values from previous sampling of the lake. The historical average is 33 mg/l.

Conductivity is an indicator that may be used to correlate with watershed development over time. The 2024 sample measured 91 microsiemens/centimeter (Ms/cm), a relatively high level, and somewhat higher than the historical average of 82.

Big Indian Pond in Comparison to Other Coastal Shallow Lakes: The colored bar charts below were created by the Maine DEP to provide additional perspective for each of the lake water quality parameters indicated. The colored section of each bar shows the parameter ranges for most Maine lakes. The dark horizontal black line indicates the mean (average) value for all Maine lakes. The striped pattern shows the "expected range" for Coastal Shallow Lakes – one of three categories of lakes determined by the Maine DEP. Big Indian is classified as a Coastal Shallow Lake. *The white diamond indicates the mean (average) value for Big Indian Pond for each indicator. Note that Big Indian is near the lower end of the range for coastal shallow lakes for total phosphorus and chlorophyll-a, and is above the average for Secchi transparency – all good!*



In 2023, a 30 year statistical trend analysis (Mann Kendall-Tau T test) was done for Secchi Transparency for Big Indian Pond. The following graphic illustrates the 30 year smoothed data plots on which the analysis was based. Based on the available data, the analysis concluded that conditions were stable, or too variable to determine a statistically valid trend.



The following narrative regarding trend analysis is from the Maine DEP Lakes Program:

"Long-term Secchi Disk Transparency (SDT), total phosphorus (TP), and Chlorophyll-a data are used to determine if the trophic state of a lake may be changing. Long-term trends may be calculated if there are at least 10 years of data collected within the last 30 years (1993-2022). If there are at least eight years of data within the most recent 10 years, a recent trend test may be calculated as well. The results of trend tests are presented here if there have been enough data collected from Big Indian Pond for any of the three parameters.

The Maine Department of Environmental Protection uses Mann-Kendall Tau (τ) trend tests on these data to test for significantly changing conditions. The tau value is a measure of trend direction and magnitude. Positive tau values indicate positive (upward) trends, negative tau values indicate negative (downward) trends. Values further from zero (closer to -1 or 1) indicate a stronger trend. Tau values less than -0.5 or more than 0.5 here suggest the trophic state of a lake may be changing. Trends with p-values less than 0.05 indicate statistically significant trends."

Temperature and dissolved Oxygen Profiles:

2024: August 29 Temperature and Dissolved Oxygen Profiles

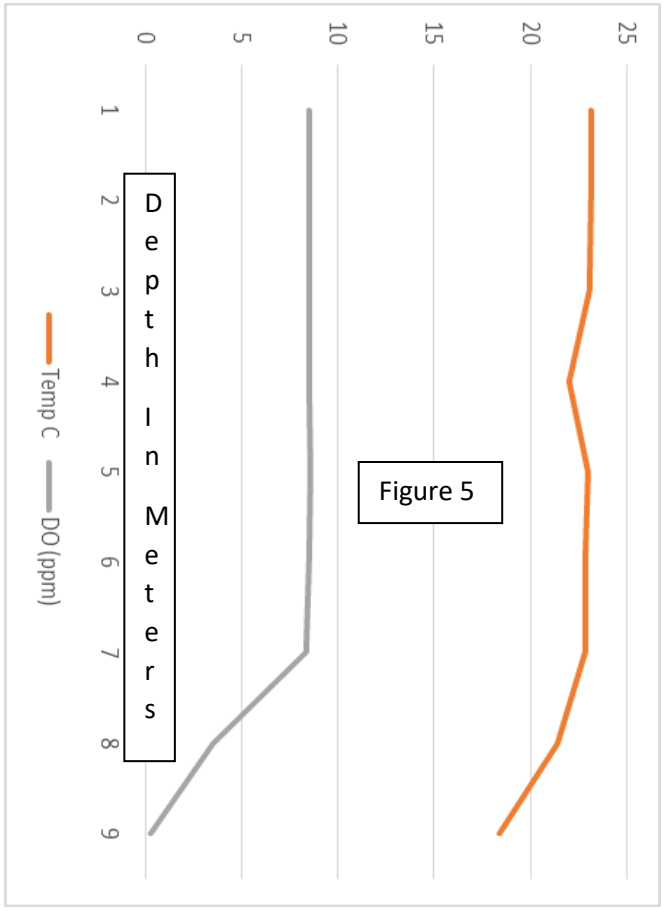


Figure 5

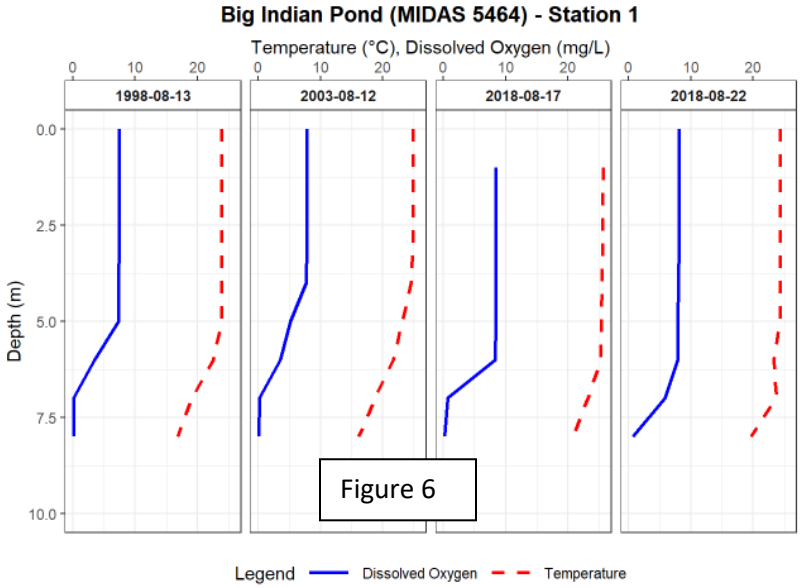


Figure 6

Historical Late Summer Temperature and Dissolved Oxygen Profiles for Big Indian Pond

The late summer temperature and dissolved oxygen (DO) profiles taken on August 29 in Figure 5 illustrate the relatively weak thermal stratification at that time, and the DO loss that was documented at the time. Late summer DO loss is common in most lakes that experience thermal stratification. The shallow bathymetry of Big Indian is such that thermal stratification is relatively weak, very likely due to the destratifying effects of prevailing wind. Wind causes mixing of the water column, resulting in the re-oxygenation of the portion of the water column that is mixed. Sufficiently strong wind, combined with the cooling effects of late summer weather very likely causes the entire water column to mix, resulting in complete re-oxygenation over a period of hours or days, depending on the strength and duration of the wind.

Figure 6 (Source MDEP) illustrates several late summer historical temperature and DO profiles for Big Indian Pond – all of which are similar to the profiles documented in August, 2024.

While late summer DO loss does not appear to be significant in Big Indian Pond at the present time, warming of the lake due to the effects of climate warming could increase the strength and duration of thermal stratification in the future. Such a scenario could result in greater oxygen loss, with multiple negative consequences for the lake. Combined with nutrient enrichment from shoreline and watershed development, the negative effects on the lake could be even more serious. The identification of land use issues in the watershed, such as soil erosion and stormwater runoff to the lake, and the resolution of such problems using lake conservation protective measures, such as vegetated buffers, should be an ongoing process. Raising public awareness through information and education programs throughout the lake community should be a high priority.

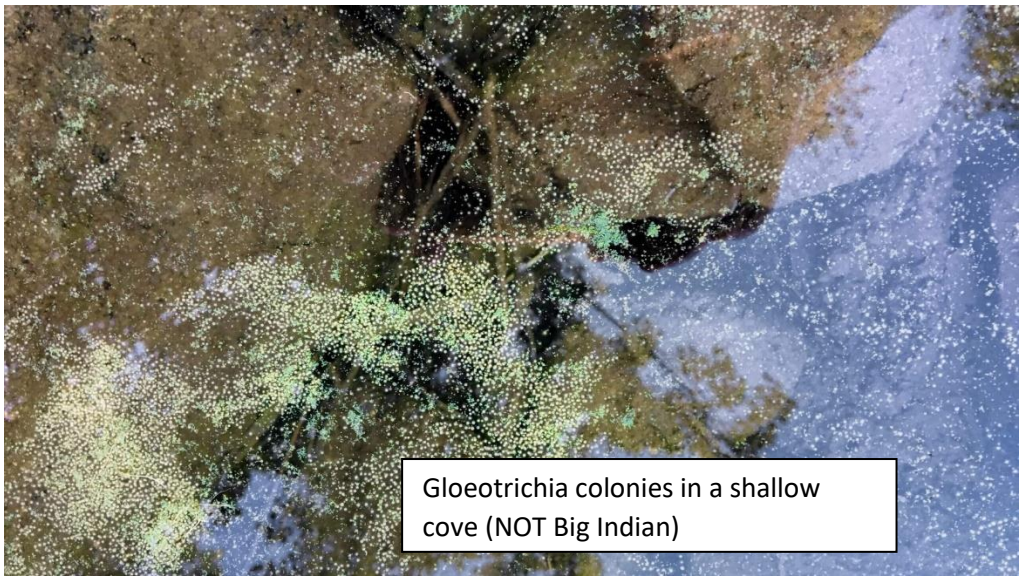
Metaphyton: Many of the shallow, protected coves along the shoreline of Big Indian Pond provide optimum habitat for metaphyton masss. Multiple metaphyton masses were observed in shallow areas of Big Indian. While the ecological benefits of metaphyton are known, the reason(s) for what appear to be significant increases in metaphyton in some lakes in recent years have not been well researched. There has been speculation among some lake scientists that possible increasing metaphyton in lakes is related to climate warming.


Metaphtyon masses in a shallow lake cove (not from Indian Pond)

Gloeotrichia echinulata is a species of cyanobacteria (aka: bluegreen algae) that has been known to be present in a number of relatively clear Maine lakes for several decades, typically

during the late summer at very low densities. “Gloeo” has been documented in other clear lakes like throughout New England. The relatively large colonies of this alga are visible to the naked eye.

During the past two decades, there has been a significant increase in the density of this organism in a number of Maine lakes. The presence of Gloeo in lake water does not appear to be tied to lake productivity, or to anthropogenic influences in lake watersheds. High density Gloeo has been documented in a number of lakes throughout the country where there is virtually no human activity in the watersheds of the lakes. The increase in the presence and abundance of this organism in lakes is the subject of ongoing research. There has been speculation that some aspect of climate change may be involved in the phenomenon. *No Gloeo masses were observed at the deep monitoring station, or during the screening of multiple shoreline areas.*



Gloeotrichia colonies in a shallow cove (NOT Big Indian)

Limited Area Rooted Aquatic Plant and Invasive Aquatic Species Survey:

As discussed previously in this report, several shallow coves were surveyed to evaluate native rooted aquatic plant communities and screen for invasive aquatic species. The native plant communities, although very dense in some areas, were balanced, healthy and growing in shallow, fertile substrate that provides optimum habitat for their growth.

We did observe one native species (Water Marigold) that can be mistaken for one of the invasive Milfoils. NO species of either native or invasive milfoils were observed in the limited survey.

Given Big Indian Ponds ability to support large rooted aquatic plant communities, the introduction of an invasive species could be catastrophic. Every effort should be taken to inform users of the lake of the risk of introducing an aquatic invader, and the relatively simple means of screening boats to prevent their introduction. Signage placed at all boat launch sites, and training volunteers from the community through the Lake Stewards of Maine program could significantly reduce the risk of introduction.

Big Indian Pond appeared to be stable and healthy on August 29, 2024. But a single snapshot of the lake, while valuable, does not fully capture the dynamic nature of a lake ecosystem. Continued frequent monitoring of Secchi transparency (water clarity) by certified volunteer lake monitors like Robin Steinwand will be essential to detecting any changes that take place over time. Periodic baseline assessments of the type that took place in 2024 should also be done as resources allow.

Public resources invested in the protection and health of the lake is essential to the long-term wellbeing of Big Indian Pond, as well as all of Maine's lakes.

Prepared by LWRMA Limnologist, Scott Williams