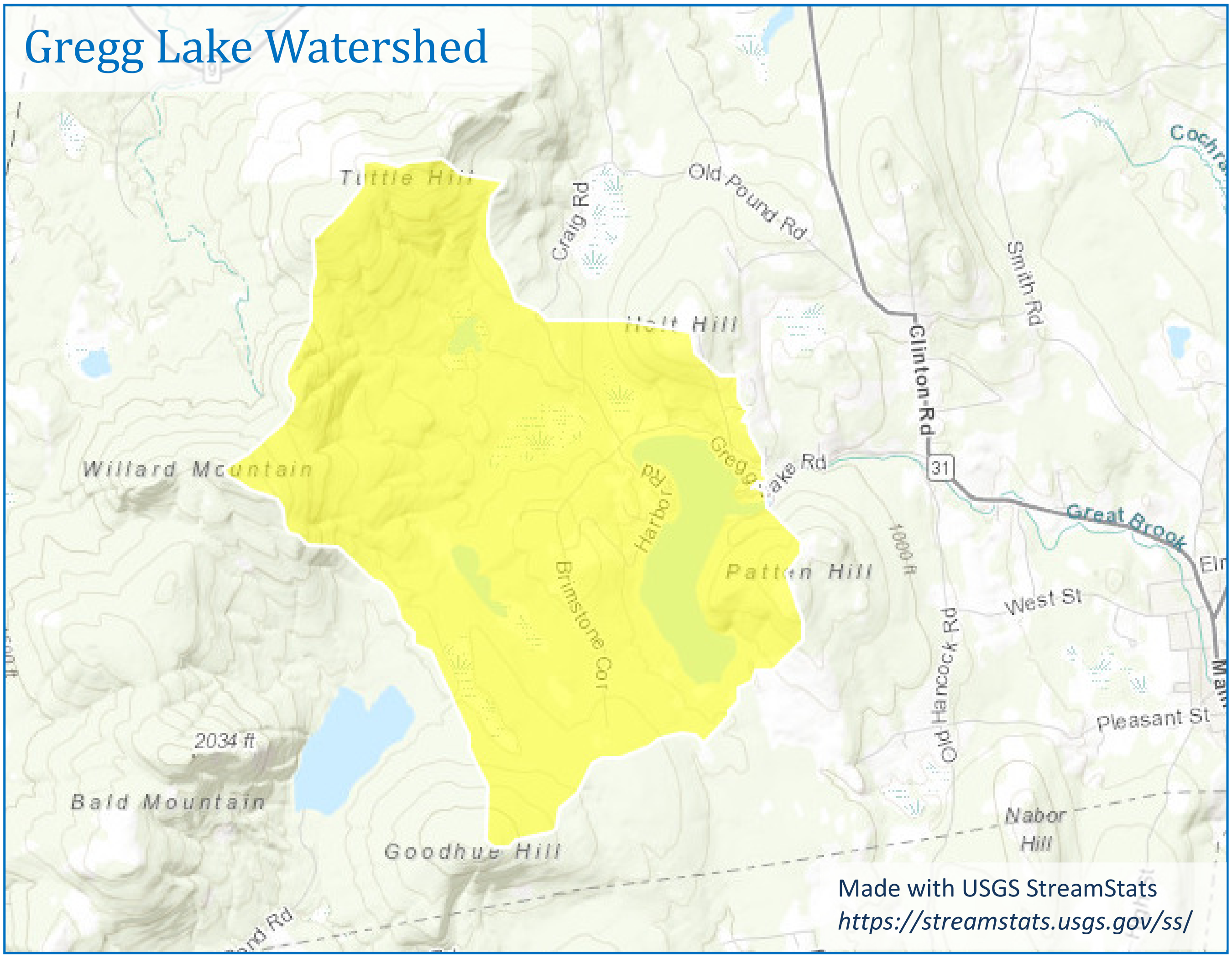
In The Swim
with Gregg Lake

Gregg Lake Water Quality Summary

Prepared by the Gregg Lake Watershed Management Plan Committee
February 2019



Gregg Lake Watershed

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Ben and Joan head up the channel to skirt the remaining ice and reach the Deep Spot for water sampling before ice out on April 18, 2018. *Photo: Frank Gorga*

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Algal bloom in Gregg Lake on July 31, 2017. *Photo: Cathy Spedden*

1. ABSTRACT

Water quality data for Gregg Lake have been gathered with variable frequency since 1978. Phosphorus, a plant nutrient, is elevated at the inlet and in the deepest water levels. Chlorophyll-*a*, an indicator of algae, is frequently above the criterion for an oligotrophic lake, and algal blooms have been observed in recent years. Low dissolved oxygen leaves 20 % of the lake volume impaired for supporting aquatic life during the summer and likely contributes to increased phosphorus loading. Increasing turbidity is a concern for both aquatic life integrity and nutrient loading. The acid neutralizing capacity is low, as expected for a New Hampshire lake, and the pH remains below the desirable range. Bacteria at the public beach, as measured by *E. coli* levels, have rarely been of concern, but Gregg Lake experienced a probable cyanobacteria bloom in 2018. Conductivity does not appear to be increasing.

The purpose of this document is to review the available water quality data and help guide the Gregg Lake Water Quality Advisory Committee in setting a water quality goal for Gregg Lake. The water quality goal will be used to measure the success of future watershed management actions, which will be a major component of the Gregg Lake Watershed Management Plan.

Funding for this project was provided in part by a Watershed Assistance Grant from the New Hampshire Department of Environmental Services (NHDES) with Clean Water Act Section 319 funds from the U.S. Environmental Protection Agency.

2. INTRODUCTION

Gregg Lake (NHLAK700030108-02-1) is a 195 acre lake in the Town of Antrim, in Hillsborough County, New Hampshire. Gregg Lake's watershed, at 2977 acres, is large relative to the lake's surface area, with a watershed-to-lake area ratio of 15.3. The lake stratifies in summer and has a maximum depth of 11 meters (36.7 feet), a mean depth of 5.3 meters (17 feet) and a relatively low flushing rate of 1.6 times per year, based on NHDES trophic survey reports. The watershed includes several large wetland areas, which feed the primary inflow, Hattie Brown Brook. The outflow is through Great Brook, which flows east to the Contoocook River. Although it is a natural lake, Gregg Lake's water level has been raised by more than 3 meters (10 feet) by a dam at its outlet.

Gregg Lake

Town:	Antrim, NH
Watershed Area:	2977 Acres
Lake Area:	195 Acres
Shore Length:	6400 m
Volume:	4,199,000 m^3
Mean Depth:	5.3 m
Max Depth:	11 m
Mean Transparency:	4.1 m
Flushing Rate:	1.6/year
Drains to:	Great Brook
Classification:	Oligotrophic
Watershed Groups:	GLA, WBPA

New Hampshire sets water quality standards designed to protect the state's surface waters for a number of designated uses. Those that apply to Gregg Lake are **Aquatic Life Integrity**, which includes survival and reproduction of fish and other aquatic organisms; **Fish Consumption**; **Primary Contact Recreation**, which includes swimming and other activities that involve full body contact or accidental ingestion of water; **Secondary Contact Recreation**, which includes boating; **Potential Drinking Water Supply**, after adequate treatment; and **Wildlife**.

Indicators used to assess **Aquatic Life Integrity** status especially relevant to Gregg Lake are dissolved oxygen levels; acidity (pH); biological indicators, including fish and macroinvertebrate (such as insect larvae) populations; habitat condition; the related parameters of levels of phosphorus (usually the limiting plant nutrient in New Hampshire lakes) and algae, which can thrive when phosphorus levels increase; acid neutralizing or buffering capacity; turbidity; and exotic macrophytes (vascular plants). High phosphorus levels, low pH, low oxygen content, and high algae levels are all indicators of a threat to a lake's ability to support aquatic life.

Indicators used to assess **Fish Consumption** use include pathogens that could cause a risk to humans and toxic substances, such as mercury or lead.

Indicators used to determine **Primary Contact Recreation** status are bacteria (pathogen) levels; discharges of untreated sewage; algae levels; color, foam, debris, scum or odors that pose a risk; and cyanobacteria, blooms of which can produce a severe human health risk. Bacteria can cause illness or infection in humans, and algae can be a nuisance, irritating or toxic, depending on the species and level of growth.

Trophic State describes the nutrient content of a lake, as assessed by transparency, chlorophyll-*a* levels, phosphorus concentrations, number of large vascular plants and the quantity of dissolved oxygen near the bottom.

Oligotrophic - Scant nutrients

Mesotrophic - Intermediate

Eutrophic - Rich in nutrients

Indicators used to assess **Secondary Contact Recreation** status are bacteria, untreated sewage and boating navigational hazards.

Indicators used to determine **Wildlife** use status are under development.

The quality of a lake's water is influenced by the lake's shape and size, by the soils in its surroundings and by its climate. Conditions in the lake's watershed—that is, the surrounding area that drains into the lake—can also greatly affect water quality. Water entering the lake from the watershed can carry both dissolved nutrients and sediments that support plant growth but may limit aquatic animal life. Desirable conditions for human recreational use and aquatic wildlife include adequate acid neutralizing (buffering) capacity, neutral pH, low levels of plant nutrients such as phosphorus, low levels of algae and bacteria, and sufficient amounts of dissolved oxygen in the water.

A clear lake with a low level of nutrients and high oxygen content is called "oligotrophic," meaning "scant nutrients." At the other end of the spectrum is a "eutrophic" lake, rich in nutrients and supporting an abundance of plant life, but often low in dissolved oxygen because it is used up during plant decay. "Mesotrophic" lakes lie in between in clarity, nutrient levels and plant abundance. Gregg Lake was classified as oligotrophic in surveys performed by NHDES in 1978 and again in 1994-5.

Since 1997, volunteers from the Gregg Lake Association have collected lake water samples for analysis at the NHDES labs, working through the NHDES-sponsored Volunteer Lake Assessment Program (VLAP). Based on VLAP data, in 2004 Gregg Lake was listed as impaired for Aquatic Life Use on the NHDES 303(d) List of Impaired Waters due to high levels of chlorophyll-*a* (used as an indicator of algae levels) and total phosphorus,

Chlorophyll-*a* (Chl-*a*) is the green pigment found in nearly all plants, including microscopic algae. It is measured in µg/L and is used as an estimate of algal biomass—the higher the Chl-*a* value, the higher the amount of algae in the lake.

Total Phosphorus (TP) is one of the major nutrients needed for plant growth. It is generally present in small amounts (measured in µg/L) and limits plant growth in NH lakes. In general, as the amount of TP increases, the amount of algae also increases.

because the median concentrations exceed the thresholds set for oligotrophic lakes. Gregg Lake is also listed as impaired for Aquatic Life Use due to low pH (high acidity). Gregg Lake has remained on the 303(d) List since then, but it is also ranked high in recovery potential. Listed lakes require an in-depth study of water quality parameters and watershed conditions to identify changes that can be made to improve and stabilize water quality for the long term.

In 2017, the Town of Antrim applied for and received a NHDES Watershed Assistance grant to develop a watershed-based management plan for Gregg Lake. The purpose of the plan is to identify potential sources of nonpoint source pollution in the watershed and to develop recommendations that will address these sources, and ultimately reduce the amount of phosphorus and overall productivity in the lake, so the lake will not continue to experience algae blooms.

A major component of developing a watershed plan is reviewing current and historical water quality data to determine what trends, if any, are causing the impairment, and setting goals to improve the water quality. Analyzing trends of measured parameters over a long-term sampling period provides critical insight into the function and health of a waterbody. By identifying the processes affecting Gregg Lake, local officials, residents, lake associations and watershed groups can work together to develop manageable goals for improving water quality.

3. METHODS

3.1. Sources of Water Quality Data

The water quality of Gregg Lake was first monitored in a trophic survey by NHDES in 1978 at the deepest spot on the lake. A full trophic survey was performed again in 1994-5. From 1997–2001, 2005–2014, and 2016–2018 data was collected through the VLAP program by trained volunteer monitors (Table 3.1).

Table 3.1. *Sources of water quality data for Gregg Lake.*

Data Source	Agency/Organization	Years Sampled	# of Years Sampled
NH Trophic Survey	NHDES	1978, 1994/1995	2
NH VLAP	NHDES	1997-2001, 2005-2014, 2016-2018	18

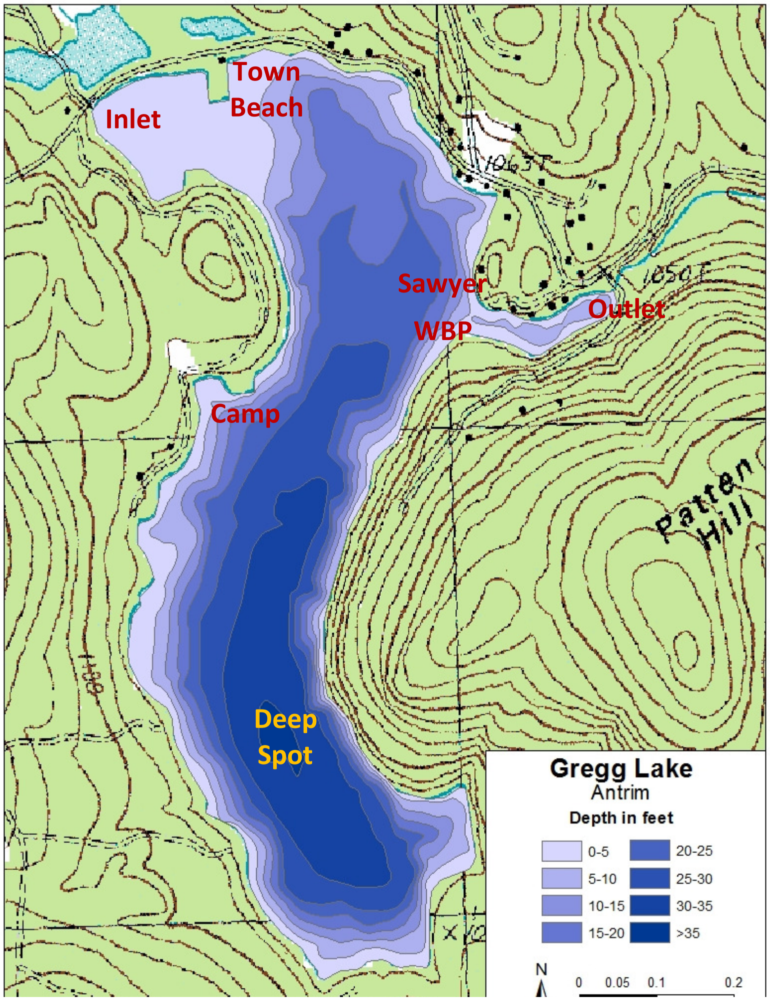


Figure 3.1. *Long-time Gregg Lake sampling stations. WBP indicates the private White Birch Point beach. Camp indicates the private summer camp beach. Bathymetry data collected by VLAP volunteers in 2017 and plotted by NHDES.*

Basic chemical information, including pH and conductivity measurements, total phosphorus, chlorophyll-*a*, dissolved oxygen concentrations, and water transparency readings, was collected on most monitoring dates. Additional water quality parameters, including chloride ion concentration, turbidity, color, phytoplankton composition and acid neutralizing (buffering) capacity were measured with varying frequency.

Sampling Times. From 1997-2014, VLAP sampling was performed once, or occasionally twice, each summer, with a gap from 2002-2004. In 2016, samples were collected in June, July and August; in 2017 and 2018, samples were collected monthly from ice-out in April until October. Late winter sampling was performed by NHDES for the trophic surveys in 1978 and 1994-5.

Sampling Locations. Samples were collected at designated lake locations (Fig. 3.1, Table 3.2). Basic water quality parameters were measured at the Deep Spot in all sampling years. Samples were also collected in most years at Inlet and Outlet locations. NHDES monitored *E. coli* levels (used as an indicator of fecal bacteria) at Antrim's public Town Beach from 1985–2018 and the summer camp (formerly Camp Chenoa) beach from 1997–2012. VLAP monitors collected *E. coli* samples at the private White Birch Point beach frequently from 2005–2018 and in front of the Sawyer cabin once in 2011. Four upstream sampling stations were added in 2018 to try to investigate upstream phosphorus sources (Fig. 3.2).

Table 3.2. *Current and historic monitoring stations at Gregg Lake.*

Sampling Stations	Site Name	Site ID	Description/Notes
Current	Castor Lane	GREANTCL	Downstream side of culvert on Castor Lane
	Craig Road Bridge	GREANTCRB	Upstream side of Craig Road bridge
	Deep Spot	GREANTD	South of mid-lake
	Hattie Brown Brook	GREANTHBB	Upstream side of Gregg Lake Road bridge
	Hattie Brown Road	GREANTHBR	Upstream side of Hattie Brown Brook culvert on Hattie Brown Road
	Inlet	GREANTI	Lake side of Gregg Lake Road bridge
	Outlet	GREANTO	At dam
	White Birch Point	GREANTWBP	At WBP beach
	Public Beach	BCHTWBANT	Left, center and right of beach
Historic	Chenoa Beach	BCHCHEANT	Summer camp beach, left or right
	Sawyer	GREANTS	At Sawyer cabin beach

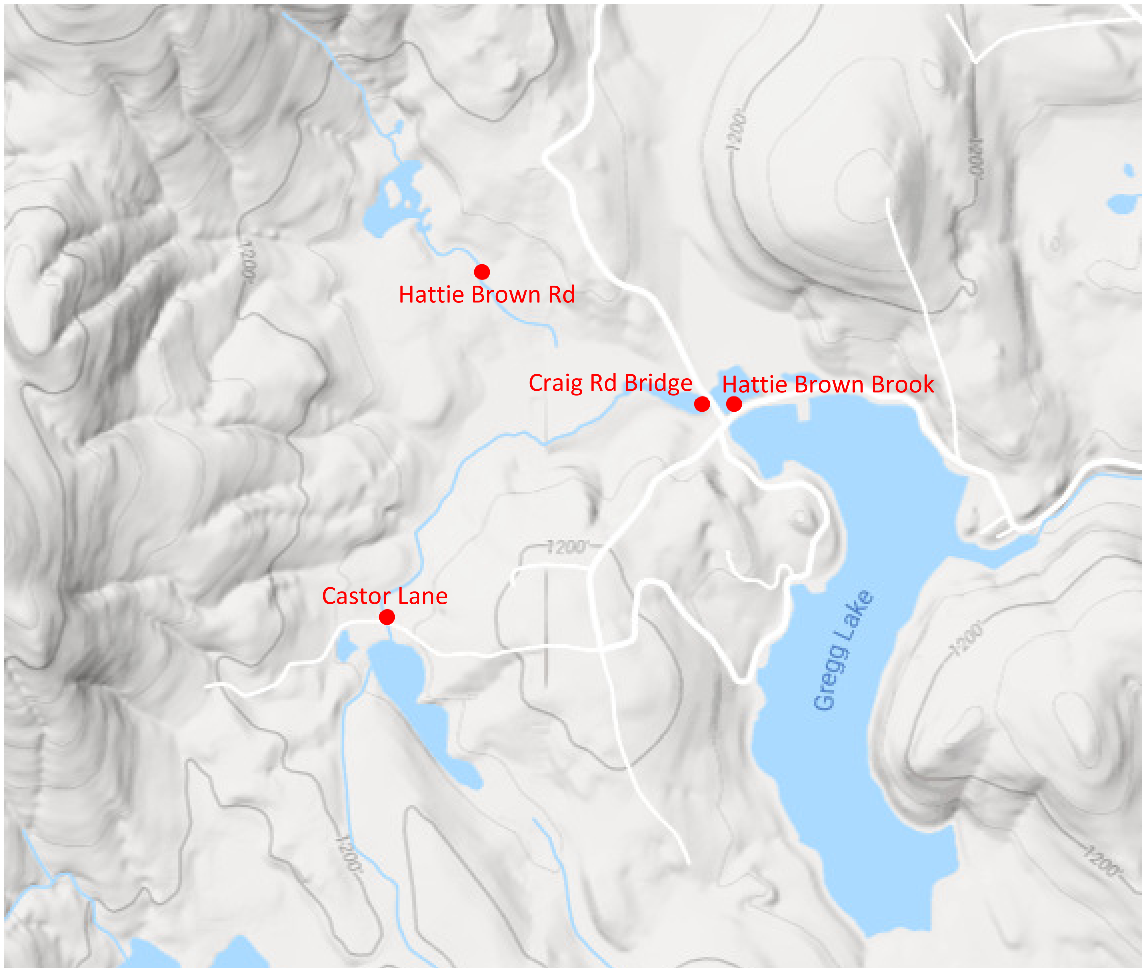


Figure 3.2. *Gregg Lake upstream sampling locations added in 2018.*

Sampling Depths. At most sampling stations samples were collected at one depth, just below the surface. At the Deep Spot, samples and measurements were collected from different layers in the water column. The sampling depths were established by taking temperature readings from the surface to the bottom to map the three thermal layers (epilimnion, metalimnion and hypolimnion).

Gregg Lake stratifies over the course of the summer (Fig. 3.3). At ice-out, the lake water "turns over" as the ice melts and the coldest water near the surface warms slightly to its densest point at 4°C (39°F) and sinks to the lake bottom. At this time, the temperature is nearly uniform from the surface to the bottom (red trace in Fig. 3.3). As the surface warms further, three layers are formed. The epilimnion (upper layer) is generally uniformly warm and oxygen-rich due to mixing within the layer. The temperature changes rapidly through the metalimnion (middle layer, which contains the thermocline). The uniformly cold, unstirred hypolimnion is found on the bottom. As the surface cools late in the season, the water again turns over, with the cold surface water becoming denser and sinking to the bottom.

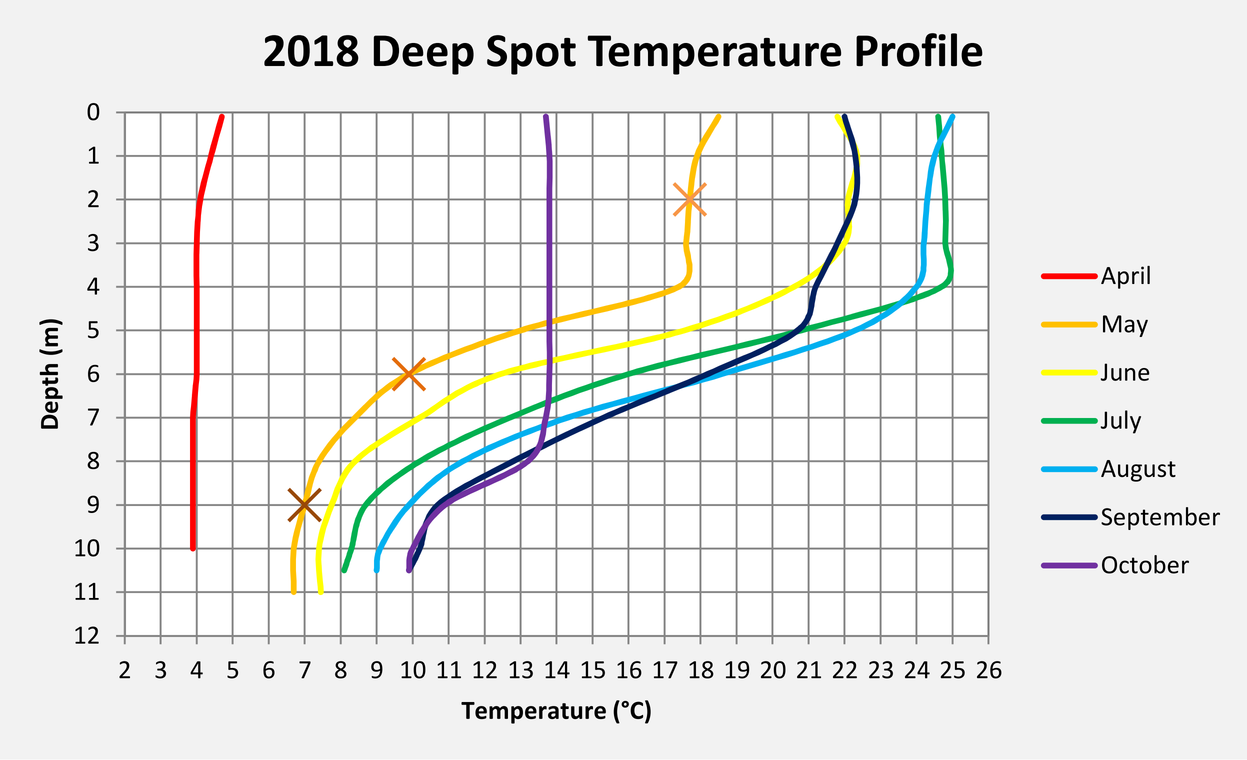


Figure 3.3. *Gregg Lake temperature profiles measured at the Deep Spot at monthly intervals from April to October in 2018. Temperature readings were taken just below the surface and then every meter from the top to ½ meter above the bottom between the 15th and the 23rd days of the indicated months. In each case, the uniformly warm upper layer identified the epilimnion; the vertical center ranged from 1 to 3.5 meters deep as the water warmed over the season. The area where the temperature changed rapidly with increasing depth identified the metalimnion; the center ranged from 3.5 to 8.5 meters deep. The uniformly cold lower layer identified the hypolimnion; the center ranged from 8 to 10 meters deep. In the May temperature profile, X's mark the centers of the epilimnion (light orange), the metalimnion (medium orange) and the hypolimnion (dark orange).*

Samples were collected from the middle of each thermal layer at the Deep Spot. Since algae typically grow where there is ample sunlight and nutrients, chlorophyll-*a* samples were collected to represent the column of water reaching from the surface to the middle of the metalimnion, either by feeding a hollow tube to the desired depth or by combining equal volumes of samples taken every meter down to the desired depth. A Deep Spot temperature profile was performed at most sampling visits; occasionally the previous year's values were used to determine the middle of each layer.

3.2. Data Acquisition and Analysis

Data acquisition and analysis followed protocols set forth in the Site Specific Project Plan (SSPP). Water quality monitoring data was accessed through the NHDES OneStop Environmental Monitoring Database (EMD). Melanie Cofrin of NHDES provided all physical/chemical data from two NHDES trophic studies and eighteen years of VLAP sampling from the EMD in a single Excel spreadsheet, as well as available biological data from the EMD. Sara Steiner of NHDES provided phytoplankton data. Jason Carrier of the NH Fish & Game Department (NHFGD) provided fish survey data.

Water quality data were sorted by date and station for Quality Assurance/Quality Control in order to avoid duplicate data sets. All duplicates were removed, and the arithmetic mean was determined for multiple samples collected on the same day. Any data not marked as "valid" were excluded and data below the detection limit were replaced with half the detection limit. "Full Season" data were collected between mid-April and mid-October. For comparisons of historic (1978–2008) and recent (2009–2018) data and for long-term trend analyses, only "Summer Season" data, collected between May 24 and September 15, were used. For Deep Spot data collected in different depth zones, data were sorted by sampling depth (epilimnion, metalimnion and hypolimnion).

Median total phosphorus and chlorophyll-*a* for recent (2009–2018) summer epilimnetic samples were used as the "Existing Median Water Quality" values applied to the Assimilative Capacity Analysis, which NHDES uses for determining if a waterbody is Impaired, Tier 1 or Tier 2. Similar methodology was used to calculate summary statistics for dissolved oxygen, Secchi-disk transparency, turbidity, apparent color, pH, acid neutralizing capacity, and conductivity. Secchi-disk transparency records were separated into those collected with or without a viewscope, since the use of a viewscope can increase Secchi-disk transparency.

If more than 10 years of data existed, trends in water quality parameters over time were analyzed by the Mann-Kendall test using the *rkt* package (Marchetto, 2017) in the R computing environment (R Core Team, 2018). The Mann-Kendall test determines whether the water quality parameter of interest tends to increase or decrease over time. Trend test statistics were reported (Table 3.3). For a more detailed description of the Mann-Kendall test see Helsel and Hirsch, 2002.

Table 3.3. *Descriptions of Mann-Kendall statistical analysis parameters.*

Mann-Kendall Statistic	Description
Kendall's Tau	A non-parametric correlation coefficient
Kendall's S Score	Measures the monotonic dependence of the water quality parameter (y) on time (x)
Variance of S Score	Variance of Score
2 sided p-value	For Kendall's S score, if less than 0.05 then statistically significant trend
Theil-Sen slope	Indicates slope of trend; (-) is decreasing, (+) is increasing

Analyses were compared to the most recent VLAP report (NHDES, 2018), and no significant discrepancies between the analyses were found.

For examination of “Full Season” (April–October) trends, data from 2016 sampling in June, July and August and data from 2017 and 2018 monthly sampling from April through October were used. For most of these analyses, only 2–3 data points were available; in some cases only a single data point was available. Arithmetic means for these data were determined by month, as all sampling was performed in mid-month, between the 15th and 23rd days.

3.3. Water Quality Standards and Criteria

New Hampshire’s water quality standards are designed to protect the state’s surface waters. The standards provide a baseline measure of water quality that surface waters must meet to support designated uses. Water quality thresholds are set to identify water quality exceedances and determine the effectiveness of state regulatory pollution control and prevention programs. To determine whether a waterbody is supporting its designated uses, thresholds for various water quality parameters (*e.g.*, chlorophyll-*a*, phosphorus, dissolved oxygen, pH and toxins) are applied to the water quality data for that waterbody. If the waterbody meets or is better than the established water quality criteria, the designated use is supported; if not, the waterbody is considered impaired for the designated use.

Water quality criteria for each classification and designated use in New Hampshire can be found in RSA 485 A:8, IV and in the State’s surface water quality regulations Env-Wq 1700 (NHDES, 2008). New Hampshire has developed water quality thresholds for lakes based on trophic state. These thresholds, based on summer median total phosphorus and chlorophyll-*a*, were incorporated into the *Consolidated Assessment and Listing Methodology (CALM)* for determining impairment status for biannual water quality reports to Congress. The most recent report is the Draft 2018 Section 303(d) Surface Water Quality List (NHDES, 2018). This draft substitutes geometric means for medians for some criteria.

Waterbody Classification Systems

Trophic State refers to the “maturity” of a lake, based on nutrient content, as assessed by transparency, chlorophyll-*a* levels, phosphorus concentrations, number of large vascular plants and the quantity of dissolved oxygen near the bottom.

Oligotrophic – Scant nutrients

Mesotrophic – Intermediate

Eutrophic – Rich in nutrients

Class is a NH legislative determination, based on designated uses:

Class A – generally of the highest quality and considered potentially usable for water supply after adequate treatment. Discharge of sewage or wastes is prohibited to these waters.

Class B (the majority of surface waters) – of the second highest quality, and considered acceptable for fishing, swimming and other recreational purposes, and, after adequate treatment, for use as water supplies.

Water quality antidegradation tiers are a federal Clean Water Act designation:

Tier 3 – Outstanding Resource Water

Tier 2 – High Quality Water – water quality better than 10 % of the standard

Tier 1 – Marginal Quality Water – water quality within 10 % of the standard

Impaired – water quality below the standard

New Hampshire incorporates criteria in its water quality regulations to help determine whether nutrients are affecting lake water quality. For aquatic life uses, the State has a narrative nutrient criterion with a numeric translator or threshold, consisting of a “nutrient indicator” (for example, phosphorus) and a “response indicator” (in this case, chlorophyll-*a*). The water quality threshold for Aquatic Life Integrity was set by analyzing 233 New Hampshire lakes (about one-fourth of all NH lakes) for phosphorus, chlorophyll-*a* and trophic state. The results of that analysis indicated that statistically significant values for phosphorus could be determined for each trophic state (Table 3.4).

Table 3.4. *New Hampshire Aquatic Life Integrity nutrient (total phosphorus, TP) and response (chlorophyll-a, Chl-a) indicator criteria by trophic class.*

Trophic State	TP (µg/L)	Chl-*a* (µg/L)
Oligotrophic	<8.0	<3.3
Mesotrophic	>8.0–12.0	>3.3–5.0
Eutrophic	>12.0–28.0	>5.0–11.0

Sampling results from both the nutrient indicator and the response indicator are used to assess Aquatic Life Integrity in New Hampshire lakes. The data indicate that a lake will exhibit characteristics of a lower trophic class when chlorophyll-*a* levels exceed the identified thresholds. Nutrient and response indicators are intricately linked, since increased phosphorus loading frequently results in increased phytoplankton levels, which can be assessed by measuring chlorophyll-*a* levels. Greater amounts of phytoplankton may lead to decreased dissolved oxygen, decreased water clarity and possibly changes in aquatic species composition.

For Aquatic Life Integrity assessment, chlorophyll-*a* and total phosphorus results are combined according to a decision matrix (Table 3.5). The chlorophyll-*a* concentration dictates the assessment if both chlorophyll-*a* and total phosphorus data are available and the assessments differ.

Table 3.5. *Decision matrix for Aquatic Life Integrity assessment determinations in New Hampshire.*

Nutrient Assessments	TP Threshold Exceeded	TP Threshold NOT Exceeded	Insufficient Info for TP
Chl-*a* Threshold Exceeded	Impaired	Impaired	Impaired
Chl-*a* Threshold NOT Exceeded	Potential Non-support	Fully Supporting	Fully Supporting
Insufficient Info for Chl-a	Insufficient Info	Insufficient Info	Insufficient Info

Dissolved oxygen thresholds are based on waterbody class. Gregg Lake is considered a Class B water, for which the water quality criterion is 5 mg/L dissolved oxygen.

3.4. Antidegradation

The antidegradation provision (Env-Wq 1708) in New Hampshire’s water quality regulations serves to protect or improve the quality of the State’s waters by limiting or reducing future pollutant loading. The provision is often invoked for projects adjacent to waters that may be negatively impacted. Antidegradation provisions require a 10% reserve, or assimilative capacity, to protect our surface waters from degrading. Lakes that are on the 303(d) list for not supporting designated uses, such as Gregg Lake, require a Total Maximum Daily Load (TMDL) study, essentially a clean-up plan, to prevent further degradation of the water quality.

4. RESULTS

4.1. Weather/Water Temperature

Weather. Weather is one of the major factors influencing variability in lake water quality. Abnormally dry summer conditions reduce the amount of runoff (containing sediment and nutrients) to surface waters, generally resulting in improved water quality, whereas wetter years transport more material from the landscape to surface waters, resulting in degraded water quality. Mean summer temperatures have remained relatively constant since water data collection began in 1978. However, a statistically significant increasing trend has been found for summer precipitation in southwestern New Hampshire from 1978 to 2018 (Fig. 4.1.1). Along with this trend there have been dramatic extremes in precipitation totals as well as large storm events that carry greater amounts of nutrients and sediments into the lake. These large storm events are forecast to increase.

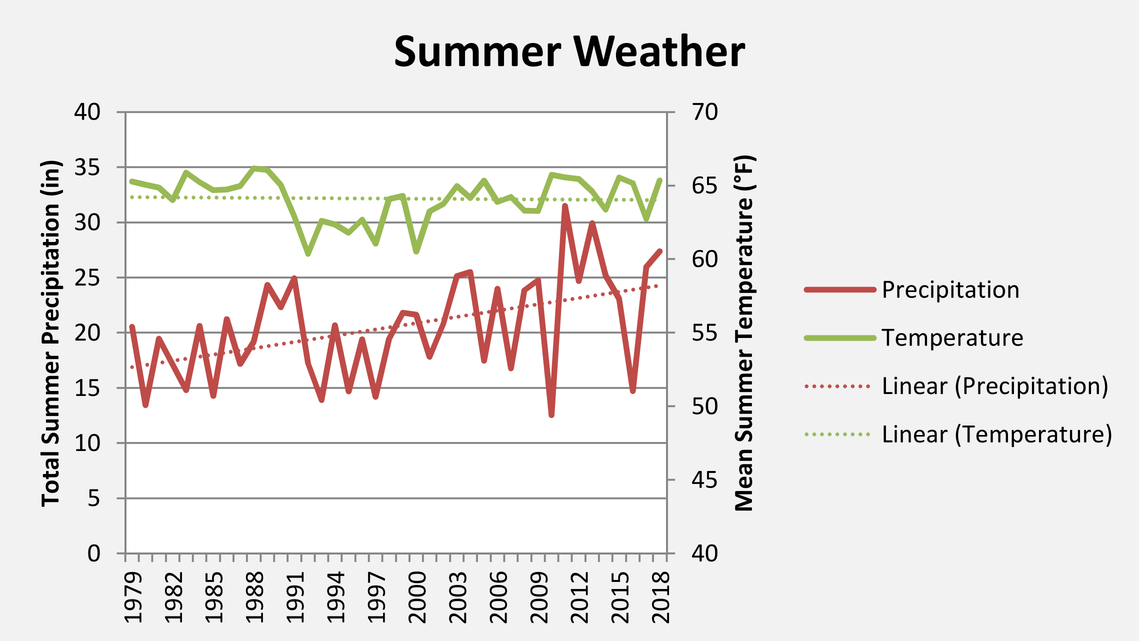


Figure 4.1.1. *Total annual summer precipitation (May–September) and summer mean temperatures recorded for Keene, NH (Station ID: USC00274399), with data gaps covered by the weather station at the Jaffrey Municipal Airport (Station ID: USW00054770), obtained from NOAA NCEI.*

Water Temperature. Consistent with the fact that local summer air temperatures have shown no significant change, recorded Gregg Lake water temperatures do not show a difference between historical and recent mean temperatures at the Deep Spot (Table 4.1.1), and measurements made at the Town Beach since 2009 have shown no change (Fig. 4.1.2). It should be noted that most recent temperature measurements at the Deep Spot were taken in June, whereas all historic measurements were made in July and August.

Table 4.1.1. *Mean temperatures measured at the Deep Spot in Gregg Lake at depths of 0.1 to 2 m in June, July and August from 1997–2008 (Historic) and 2009–2018 (Recent).*

	Temperature (°C)	
	Historic	Recent
Mean	23.3	22.8
SD	2.0	2.0

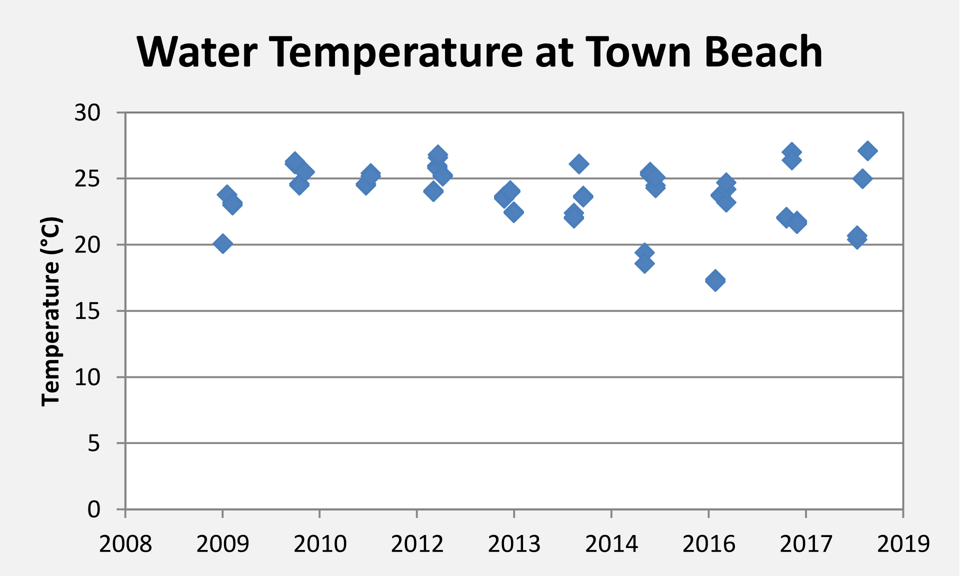


Figure 4.1.2. *Water temperature measured at the Antrim Town Beach on Gregg Lake by NHDES during regular E. coli sampling.*

Summary. Precipitation from a relatively large watershed area (15 times the area of the lake) drains into Gregg Lake, which leads to the potential for large amounts of sediment and nutrients to be deposited into the lake, especially during large storm events. At the same time, Gregg Lake flushes only 1.6 volumes/year, leading to a relatively low rate of removal of soluble pollutants. Summer rainfall has increased significantly since 1978, whereas water temperatures have not shown a significant change.

4.2. Total Phosphorus (TP)

Total phosphorus (TP) refers to the total concentration of phosphorus found in the water, including organic and inorganic forms. Phosphorus is one of the major nutrients needed for plant growth, and is generally the limiting nutrient for both vascular plants and algae in freshwater ecosystems. Low levels of dissolved oxygen (anoxia) can release phosphorus bound to sediments in the water, thus increasing the available phosphorus for phytoplankton and plant growth. Humans can also contribute phosphorus to lakes through stormwater runoff, lawn or garden fertilizers and leaky or poorly maintained septic systems. Heavy motorboat activity has been shown to increase the potential for phytoplankton growth in shallow lakes due to stirring up bottom sediments and causing release of phosphorus. As TP increases within a system, the amount of algae also increases, and may lead to nuisance algal blooms, low water clarity and low dissolved oxygen.

TP Variation across the Full Season. For many of the years in which data were collected at Gregg Lake, especially in more recent years, samples were collected only once between mid-June and early September. In order to get a better picture of changes in lake water quality across the full open-water season, samples were collected in June, July and August in 2016, and monthly from April through October in 2017 and 2018.

At the Deep Spot, TP values in the epilimnion and metalimnion were relatively stable across the full season, whereas TP rose late in the summer in the hypolimnion (Fig. 4.2.1)

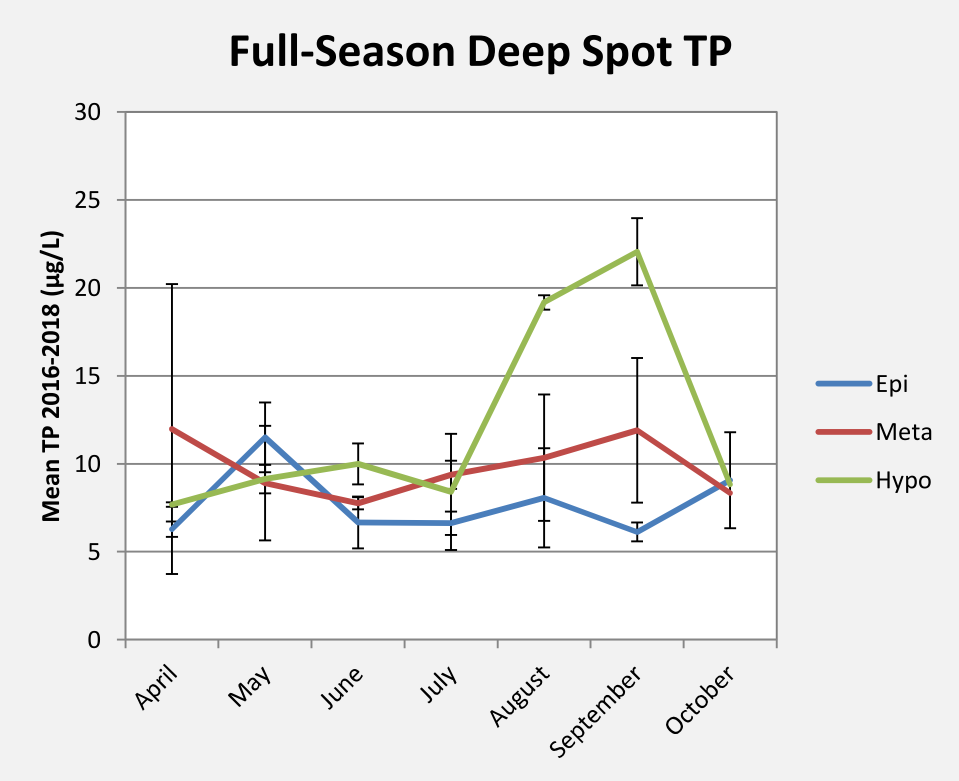


Figure 4.2.1. *Mean TP measured at the Gregg Lake Deep Spot in the epilimnion, metalimnion and hypolimnion in 2016–2018. Standard deviations were calculated for monthly data sets containing 2 or 3 values; metalimnion and hypolimnion values for October each represent a single point.*

Total Phosphorus (TP)

Phosphorus is the most important water quality parameter measured in our lakes. It is one of the major nutrients needed for plant growth. It is generally present in small amounts and is the nutrient that limits algae's ability to grow and reproduce. In general, as the amount of TP increases, the amount of algae also increases. Phosphorus sources around a lake typically include septic systems, animal waste, lawn fertilizer, erosion from roads and construction sites and natural wetlands.

TP ranges for NH lakes and ponds:

TP (µg/L)	Category
1-10	Low (good)
11-20	Average
21-40	High
>40	Excessive

The late-season rise in TP in the hypolimnion suggests the release of phosphorus from bottom sediments due to anoxic conditions, a condition referred to as internal loading. The difference in TP between the epilimnion and hypolimnion was used to estimate the contribution of internal loading to the total lake phosphorus load (Table 4.2.1).

Table 4.2.1. *Calculation of phosphorus internal loading in Gregg Lake, using mean late-summer (August and September) TP values measured in 2016–2018, with the assumption that the hypolimnion occupies the volume of water from a depth of 7.5 meters (25 ft) to the bottom and that the anoxic zone lies below a depth of 9 meters (30 ft).*

Aug-Sep Mean TP (µg/L)		TP Attributable to Internal Loading (µg/L)	Approximate Hypolimnion Vol (m^3)	TP Internal Load (kg/yr)	Approximate Surface Area of Anoxic Zone (Ha)	Internal TP Coefficient (kg/ha/yr)
Epilimnion	**Hypolimnion**	**Hypo – Epi**				
7.1	20.6	13.5	373,000	5.0	3.3	1.6

Inlet, Outlet and Upstream TP. In 2018, in response to consistently elevated TP levels at the Gregg Lake Inlet, compared to the epilimnion, samples were collected at several locations upstream of the Inlet sampling station (see map, Fig. 3.2). Inlet samples have always been collected on the lake side of the Gregg Lake Road bridge, under which beavers have persistently built dams in recent years. The Hattie Brown Brook station was added on the upstream side of the Gregg Lake Road bridge (and beaver dam) in July, and the high TP value obtained there led to the addition of stations farther upstream—on the upstream side of the Craig Road bridge (and associated beaver dam), up Hattie Brown Brook where it crosses Hattie Brown Road, and up the unnamed brook that drains the wetlands west of Gregg Lake at the point where it exits a beaver pond and crosses Castor Lane.

Whereas Outlet TP levels remained relatively constant across the full season and were similar to TP in the epilimnion (Fig. 4.2.2), Inlet TP was higher through the peak of the summer (June through September). The upstream stations showed TP values consistent with, and in some cases higher than, the elevated Inlet TP values. Rainfall was low from April to August in 2018; heavy September rains may have led to the increase in TP seen at nearly all upstream stations. All upstream TP values, as well as the Inlet TP, dropped to Outlet levels by October.

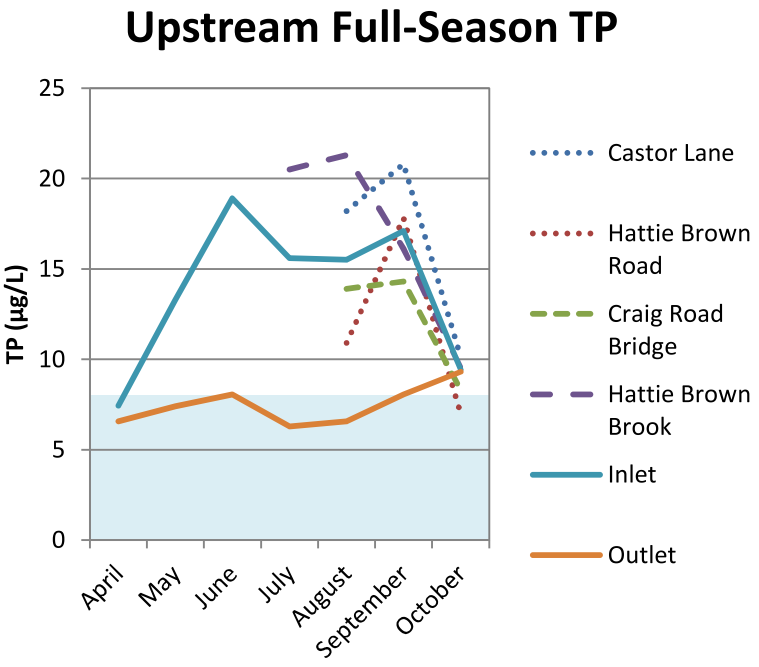


Figure 4.2.2. *Inlet, Outlet and Upstream TP. All data represent single points collected in mid-month from April–October in 2018. The shaded area represents values below the water quality threshold for TP for an oligotrophic lake.*

Summer Season TP. For comparison of TP data with samples collected in years before 2016, only "summer season" data, that is, data collected between May 24 and

September 15 were used. Mean and median summer season TP values for the epilimnion, metalimnion and hypolimnion layers at the Deep Spot and for the Inlet and Outlet (Table 4.2.2) showed Inlet and hypolimnion TP to be consistently higher than that in the epilimnion and metalimnion and at the Outlet (Fig 4.2.3). Median TP at the Inlet and Outlet and in the hypolimnion was above the TP threshold for an oligotrophic lake.

Table 4.2.2. *Gregg Lake summer season TP in the epilimnion (Epi), metalimnion (Meta) and hypolimnion (Hypo) layers at the Deep Spot and at the Inlet and Outlet. Values are given for the number of samples (n) and the minimum (Min), mean, maximum (Max), standard deviation (SD) and median values for each data set. The recent median epilimnion TP value (highlighted) was used as the Existing Median Water Quality in assimilative capacity calculations.*

Summer Season TP (µg/L)										
	Historical					Recent				
Value	Inlet	Epi	Meta	Hypo	Outlet	Inlet	Epi	Meta	Hypo	Outlet
n	11	14	13	14	12	15	15	15	15	15
Min	7.0	1.0	2.0	6.0	1.0	12.0	2.5	5.5	6.2	5.3
Mean	16.7	6.5	7.5	14.2	7.0	16.5	6.7	8.3	13.2	7.0
Max	27.0	16.0	18.0	32.0	20.0	28.2	11.3	12.9	19.6	9.8
SD	6.2	4.3	4.3	7.4	5.7	4.0	2.5	2.1	4.3	1.3
Median	18.0	5.9	6.0	11.5	5.0	16.0	6.8	7.8	13.0	6.8

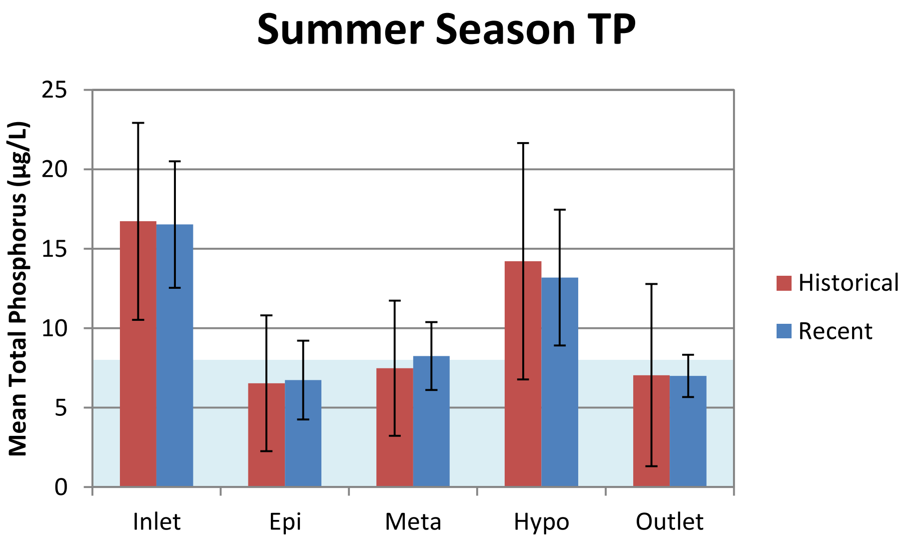


Figure 4.2.3. *Gregg Lake mean summer season TP, using data from Table 4.2.2. Error bars show the standard deviation for each sample set. The shaded area represents values below the TP water quality threshold for an oligotrophic lake.*

Due to sample variability, there were no apparent differences between historical and recent mean or median TP values at each site. The recent median epilimnion TP value (highlighted in Table 4.2.2) was used as the Existing Median Water Quality in assimilative capacity calculations.

Using dissolved oxygen profiles and bathymetry data collected by VLAP volunteers, estimates were made of the mean volumes of the epilimnion, metalimnion and hypolimnion during the summer months; these values, along with the median recent summer TP value at each depth at the Deep Spot, were used to calculate the total amount of phosphorus in the lake in the summer (Table 4.2.3). Gregg Lake was estimated to contain a total of approximately 32 kg of phosphorus during the summer months.

Table 4.2.3. *Estimation of the total amount of phosphorus in Gregg Lake, using bathymetry data to calculate the volume of each thermal layer and recent summer median TP values to calculate the amount of phosphorus in each layer. For ease of calculation, the bottoms of the layers were approximated to be 15 ft (4.5 m) for the epilimnion, 25 ft (7.5 m) for the metalimnion and the lake bottom (36 ft, 11 m) for the hypolimnion.*

	Summer Median TP (µg/L)	Approx Summer Bottom Depth (m)	Approx % of Lake Volume	Total Volume (m^3)	Total P (kg)	Total P (lb)
Epilimnion	6.8	4.5	66.1	2775599	19	42
Metalimnion	7.8	7.5	25.0	1050767	8	18
Hypolimnion	13.0	11.0	8.9	372634	5	11
Total			**100**	**4199000**	**32**	**70**

Long-term Trends in TP. Long-term trends in phosphorus levels in the epilimnion, metalimnion and hypolimnion at the Deep Spot (Fig. 4.2.4) and at the Inlet and Outlet (Fig. 4.2.5) were assessed using summer TP data obtained since Gregg Lake sampling began in 1978. Trend analysis using the statistical program *rkt* in R showed a significant slight increasing TP trend only for the metalimnion (Table 4.2.4); trends were not significant at other locations.

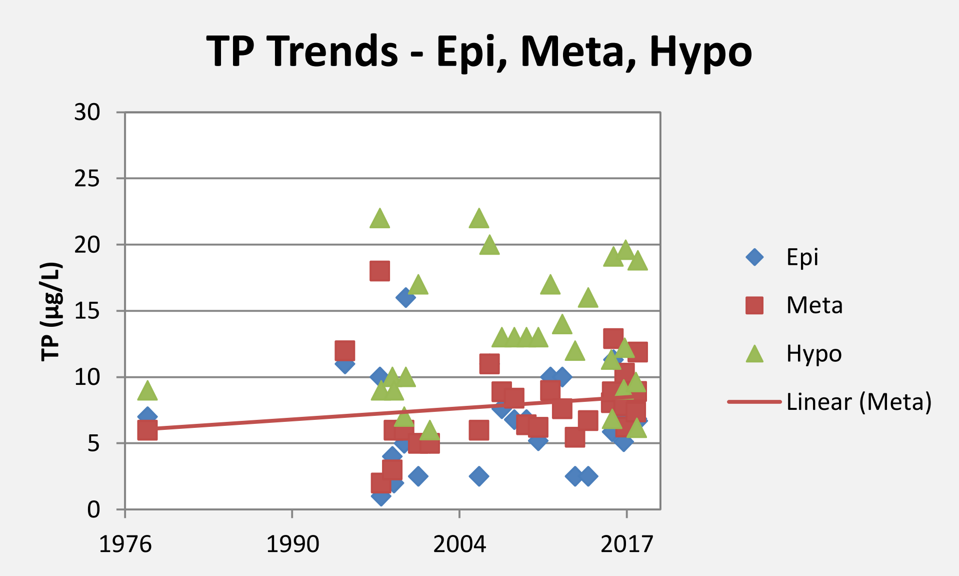


Figure 4.2.4. *Gregg Lake Deep Spot summer TP epilimnion, metalimnion and hypolimnion data for all sampling years, with a linear trendline applied to the metalimnion data.*

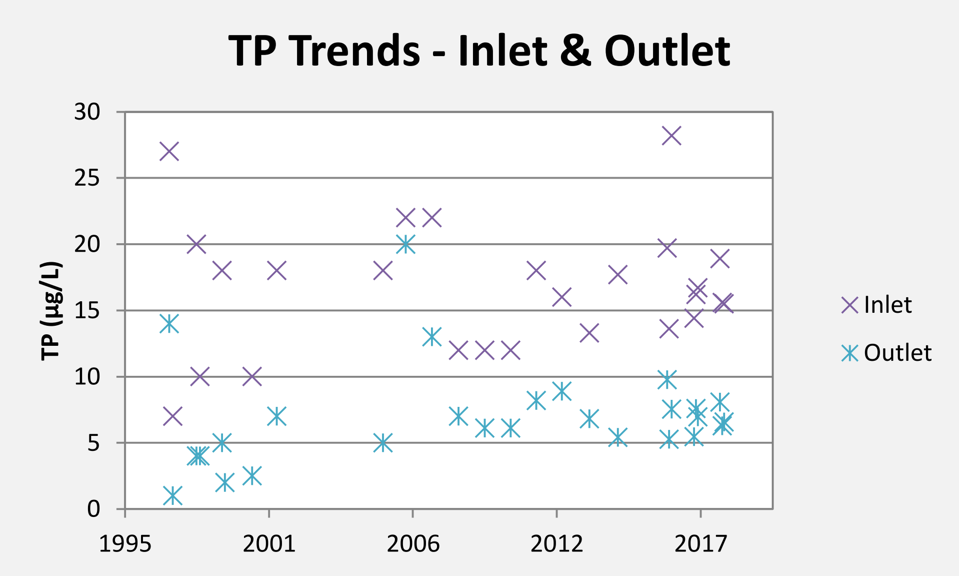


Figure 4.2.5. *Gregg Lake Inlet and Outlet summer TP data for all sampling years.*

Table 4.2.4. *Long-term trend statistics calculated for summer season TP data for the Inlet, Outlet and three depths at the Gregg Lake Deep Spot analyzed using the rkt package in the R computing environment.*

Mann-Kendall trend statistics	Sampling Location				
	Inlet	Epilimnion	Metalimnion	Hypolimnion	Outlet
Kendall's Tau	0.04	0.08	0.29	-0.01	0.23
Kendall's Score	12	32	110	-6	79
Variance in Score	2044	2827	2551	2827	2297
2-sided p-value	0.81	0.56	*0.03	0.93	0.10
Thiel-Sen's slope	3.92e-05	2.15e-05	12.2e-05	0	12.7e-05

TP Summary. Inlet and upstream sampling showed phosphorus entering Gregg Lake from the extensive upstream wetlands. The rise in TP in the hypolimnion late in the season suggested internal loading—the release of phosphorus from bottom sediments under anoxic conditions. The difference between the late-season epilimnion and hypolimnion TP values was used to estimate a lake phosphorus load of 5 kg/yr due to internal loading. Median epilimnion and metalimnion values fell below the TP threshold for an oligotrophic lake; TP in other locations was above the threshold. The only significant long-term trend was a slight increasing trend in TP in the metalimnion.

4.3. Chlorophyll-*a* (Chl-*a*)

Chlorophyll-*a* (Chl-*a*) is a green pigment used in photosynthesis, and is found in nearly all plants, including microscopic plants such as algae and cyanobacteria. Measurement of Chl-*a* is used as an estimate of algal abundance or lake productivity—higher Chl-*a* equates to a greater amount of algae in a lake. Chl-*a* concentrations are believed to be related to phosphorus concentrations; increased concentrations of phosphorus result in increased algal growth. That is, chlorophyll-*a* is used as a "response indicator" to the "nutrient indicator" phosphorus in water quality determinations.

Chl-*a* was measured at the Deep Spot in nearly all Gregg Lake surveys between 1978 and 2018. Since algae typically grow where there is ample sunlight and nutrients, samples were collected to represent the column of water reaching from the surface down to the middle of the metalimnion, either by feeding a hollow tube to the desired depth or by combining equal volumes of samples taken every meter down to the desired depth.

Chlorophyll-*a* (Chl-*a*), a green pigment found in nearly all plants, including microscopic algae, is used as an indicator of algal abundance. The concentration of chlorophyll-*a* found in the water provides an estimation of the concentration of algae.

NHDES criteria:

Chl-*a*	Category
0-5 µg/L	Good
5.1-15 µg/L	More than Desirable
>15 µg/L	Nuisance Amounts

Chl-*a* Variation across the Full Season. Chl-*a* data collected in 2016–2018 suggested an early summer peak in algal growth, followed by a more variable second proliferation of algae into the fall (Fig. 4.3.1). These results are consistent with the general pattern of seasonal succession of algae observed in lakes, in which an early wave of diatoms and golden-brown algae is followed by successive waves of green algae, cyanobacteria and diatoms and golden browns, as nutrient and temperature conditions allow (described more fully in Phytoplankton Results).

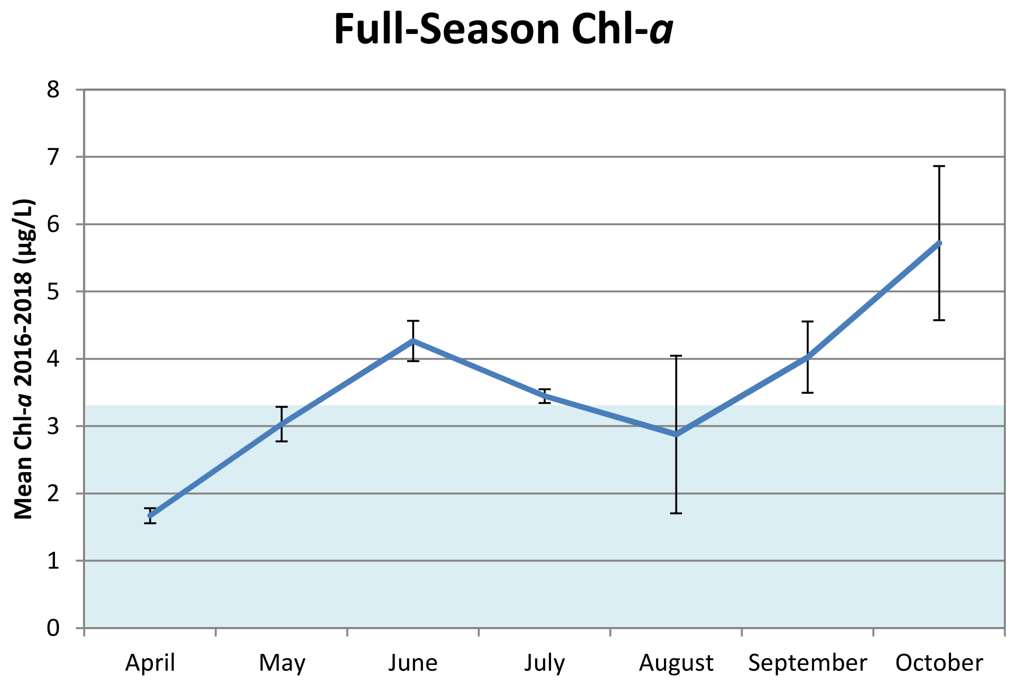


Figure 4.3.1. *Gregg Lake Deep Spot Chl-a values measured mid-month from June-August in 2016 and April-October in 2017 and 2018. Means and standard deviations for 2-3 data points were plotted. The shaded region indicates values below the Chl-a water quality threshold for an oligotrophic lake.*

Summer Season Chl-*a*. Historical (1978–2008) and recent (2009-2018) summer Chl-*a* values were compared (Table 4.3.1). Although recent mean and median values were higher than historical values, due to variability, the difference was not significant (Fig. 4.3.2). All mean and median values were higher than the threshold value of 3.3 µg/L Chl-*a* for an oligotrophic lake. The recent median Chl-*a* value (highlighted in Table 4.3.1) was used as the Existing Median Water Quality in assimilative capacity calculations.

Table 4.3.1. *Analysis of historical and recent summer season Chl-a measured at the Gregg Lake Deep Spot. The recent median Chl-a value (highlighted) was used as the Existing Median Water Quality in assimilative capacity calculations.*

	Chl-*a* (µg/L)	
Value	Historical	Recent
n	13	15
Min	2.13	1.53
Mean	3.70	4.34
Max	6.05	7.47
SD	1.27	1.78
Median	3.46	3.93

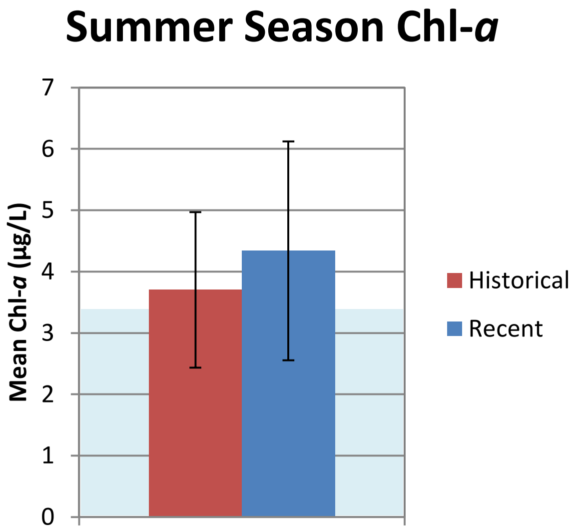


Figure 4.3.2. *Gregg Lake summer season Chl-a, using data from Table 4.3.1. Mean Chl-a values are plotted with error bars showing the standard deviation for each sample set. The shaded area represents values below the Chl-a threshold for an oligotrophic lake.*

Long-term Trends in Chl-*a*. Summer Chl-*a* data (1978–2018) were analyzed for long-term trends (Fig. 4.3.3) using the statistical program *rkt* in R (Table 4.3.2). No significant trend was found for Chl-*a*.

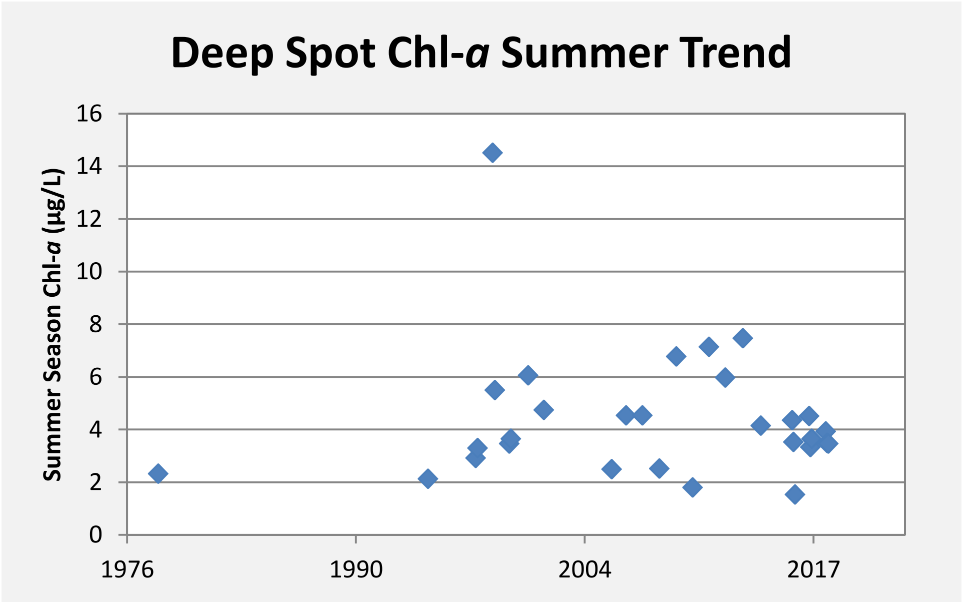


Figure 4.3.3. *Gregg Lake Deep Spot summer Chl-a data collected since 1978.*

Table 4.3.2. *Summer Chl-a data for the Gregg Lake Deep Spot analyzed for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall trend statistics	Chl-*a*
Kendall's Tau	0.002
Kendall's Score	1
Variance in Score	2841
2-sided p-value	1
Thiel-Sen's slope	7.9e-04

Chl-*a* Summary. Chl-*a* peaks in June and again in October were consistent with successive cycles of algae growth. Historic and recent mean and median summer Chl-*a* values were above the threshold for an oligotrophic lake. There was no apparent difference between historic and recent Chl-*a* values, and there was no significant increasing or decreasing long-term trend.

4.4. Dissolved Oxygen

Dissolved Oxygen (DO) refers to the amount of oxygen contained within the water. Much of the DO in lakes comes from the atmosphere, inflowing streams and photosynthesis. Fish and other aquatic life depend on DO to survive. Seasonal changes can affect DO concentrations throughout the year. Warmer temperatures during the summer speed up the rates of photosynthesis and decomposition. When plants and algae die and decompose, oxygen is consumed. This decreases the amount of oxygen, especially in the uncirculated hypolimnion (lower) water layer. In the winter, under ice cover, the DO content can also deplete due to the lack of circulation from the atmosphere.

DO levels above 5.0 mg/L are considered sufficient for most aquatic life, although some cold water fish species require higher DO levels.

Oxygen gas dissolved in lake water is critical for aquatic organisms that breathe with gills, including fish. Since oxygen dissolves more readily in cold water than in warm water, warm water that is 100% saturated with oxygen contains less oxygen than the same amount of cold water that is saturated. DO concentrations below 5 mg/L (and water temperatures above 24°C) can cause stress and reduce habitat for fish and other aquatic organisms; some fish, such as trout, require higher oxygen levels and are generally found only in cold-water lakes. Although plants produce oxygen during photosynthesis, decaying plants consume oxygen and can deplete the water of dissolved oxygen. The minimum water quality criterion for Class B waters is 5 mg/L DO.

Depletion of dissolved oxygen in bottom waters is common in New Hampshire lakes. Thermal stratification prevents warmer, oxygenated waters at the surface from mixing with cooler, oxygen-depleted water at the bottom. Oxygen is absorbed from the atmosphere at the surface and is also produced in the upper water layers, where sunlight drives photosynthesis. Oxygen is depleted near the bottom, where organic matter accumulates and decomposes. Anoxia, or low dissolved oxygen, at the lake bottom can also lead to release of sediment-bound phosphorus (known as internal phosphorus loading), which becomes a food source for algae. While thermal stratification and oxygen depletion in bottom waters are natural phenomena, human activities can exacerbate these conditions.

Dissolved oxygen levels were measured along with water temperature recordings by gradually lowering a sensor from just below the surface to just above the bottom at the Deep Spot, with readings taken every meter. Oxygen content was recorded in two ways—by measuring the absolute amount of dissolved oxygen (DO) in units of milligrams of oxygen gas per liter of water (mg/L) and by measuring the amount of dissolved oxygen as a fraction of the total possible oxygen content, expressed as percent saturation (DO %). The total possible oxygen content depends on water temperature, salt content and elevation. The impairment threshold set by NHDES for Class B waters (waters of the second-highest quality, considered acceptable for fishing, swimming, and other recreational purposes; generally not intended for use as a water supply, but acceptable with adequate treatment), such as Gregg Lake, is 5 mg/L DO and 75 % saturation.

DO Profile across the Full Open-Water Season. DO profiles in the early years of VLAP testing were generally performed during state biologist visits; from 2016–2018, DO profiles were performed by VLAP volunteer monitors at each sampling. Full-season results from 2018 are shown in Fig. 4.4.1. DO levels were above the threshold to support aquatic life at all depths in April, but had begun to drop at depths below the middle of the metalimnion by May. By mid-June, water below a depth of about 7.5 meters (25 feet) would not support aquatic life. By September the lowest level with a DO concentration that met the threshold to support aquatic life had climbed to just over 5 meters (16 feet). By this time, insect larvae and nymphs normally found in the organic layer at the lake bottom either moved or died off, and fish that fed on them were forced into a zone higher in the water. By October, DO levels in the upper layers had improved and met the threshold down to nearly 8 meters (26 feet).

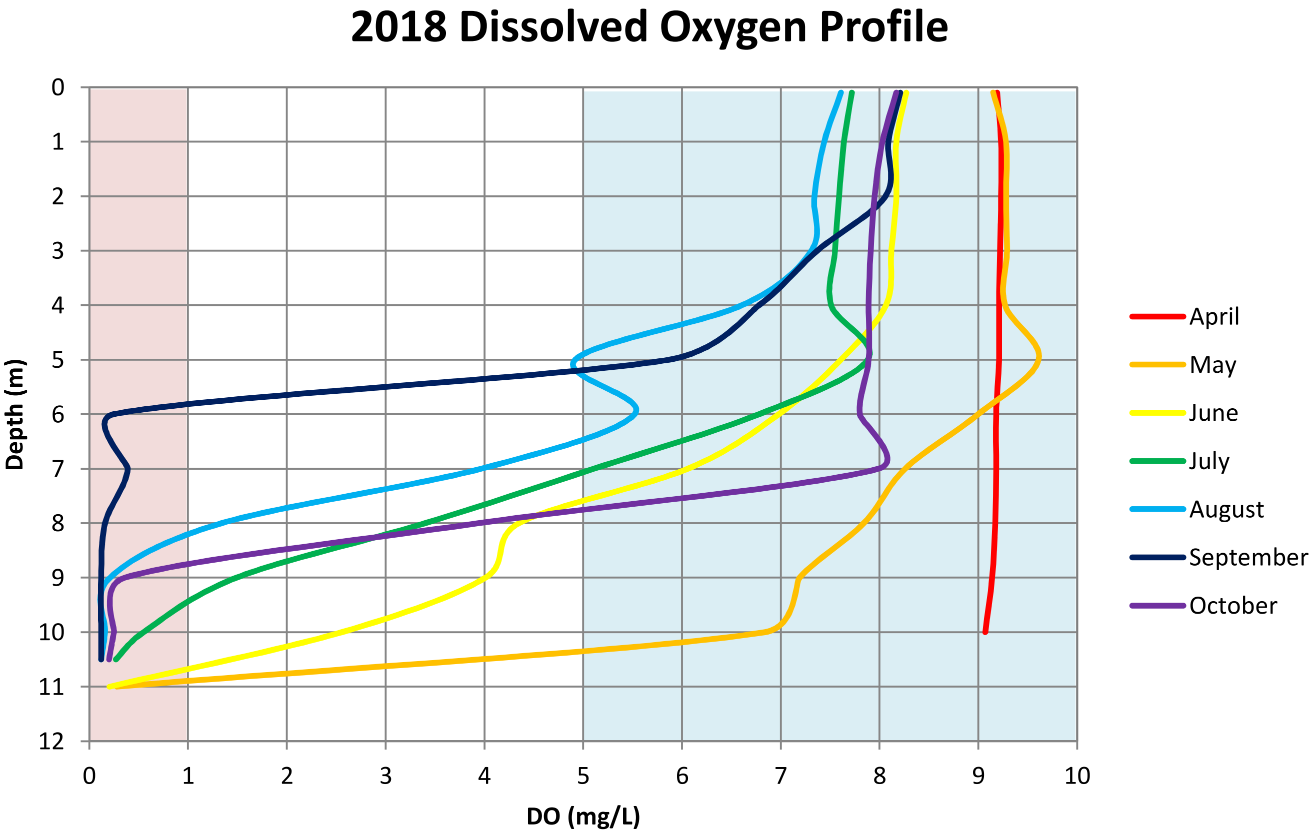


Figure 4.4.1. *Gregg Lake dissolved oxygen profiles measured at the Deep Spot at monthly intervals from April to October in 2018. DO readings were taken just below the surface and then every meter from the top to ½ meter above the bottom between the 15th and the 23rd days of the indicated months. Blue shading indicates DO levels that met the DO criterion for supporting aquatic life. Red shading indicates the DO range in which internal phosphorus loading is likely.*

Changes in DO levels across the full open-water season are perhaps more easily visualized by looking at how DO levels at a single depth changed over the course of the season (Fig. 4.4.2). DO at the surface dropped as the water warmed in mid-summer and rose again as the surface cooled. Oxygen is replenished at the surface through wave action and epilimnion mixing. DO at a depth of 9 meters (1–2 meters above the bottom) dropped sharply after spring turnover, was below the threshold for supporting aquatic life by early June and stayed low for the remainder of the season, presumably until fall turnover. By August, DO at 9 meters fell into the anoxic range (below 1 mg/L), where bound phosphorus is likely to be released from sediments.

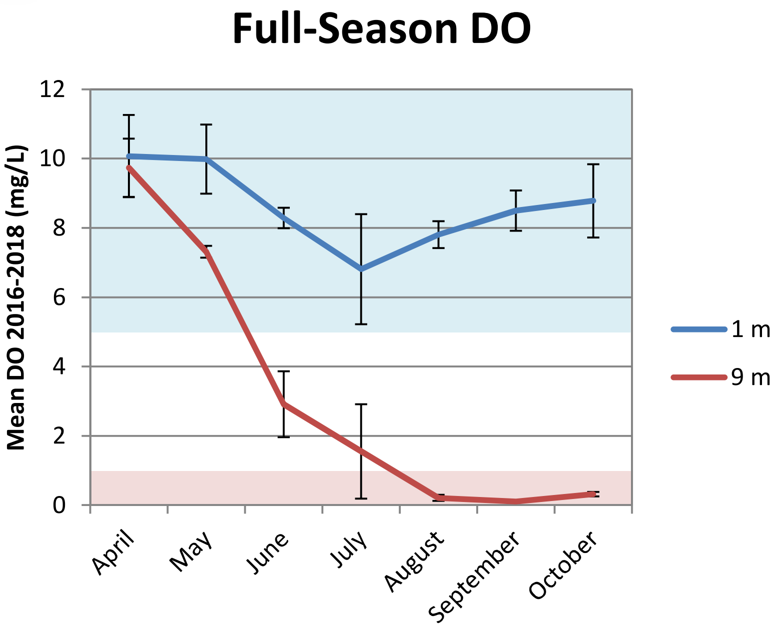


Figure 4.4.2. *Mean Gregg Lake DO measured near the surface (at a depth of 1 meter) and near the bottom (at a depth of 9 meters) from mid-June through mid-August in 2016 and mid-April through mid-October in 2017 & 2018. Bars show standard deviations of 2-3 measurements. Blue shading shows DO levels above the threshold for supporting aquatic life. Red shading shows DO levels considered to be anoxic.*

Table 4.4.1. *Summary of summer season DO data obtained at the Gregg Lake Deep Spot.*

DO (mg/L)				
	Historical		Recent	
Depth	Top	Bottom	Top	Bottom
n	10	10	15	15
Min	7.18	0.20	4.98	0.12
Mean	7.97	0.96	7.93	1.42
Max	8.50	1.98	8.78	4.01
SD	0.52	0.53	0.92	1.20
Median	8.20	0.85	8.17	1.49

Summer Season DO. Historic (1994–2008) and recent (2009–2018) DO data obtained between May 24 and September 15 were analyzed for minimum, mean, maximum and median DO values (Table 4.4.1). Samples taken at a depth of 1 meter were used to represent surface DO levels and samples taken at a depth of 9 meters were used to represent DO levels near the bottom. Recent and historical median DO values were similar at each location (Fig. 4.4.3). DO values at the top were well above the minimum 5 mg/L DO threshold for an oligotrophic lake, whereas bottom values were well below that value. DO concentration at the lake bottom is considered for establishing lake trophic status.

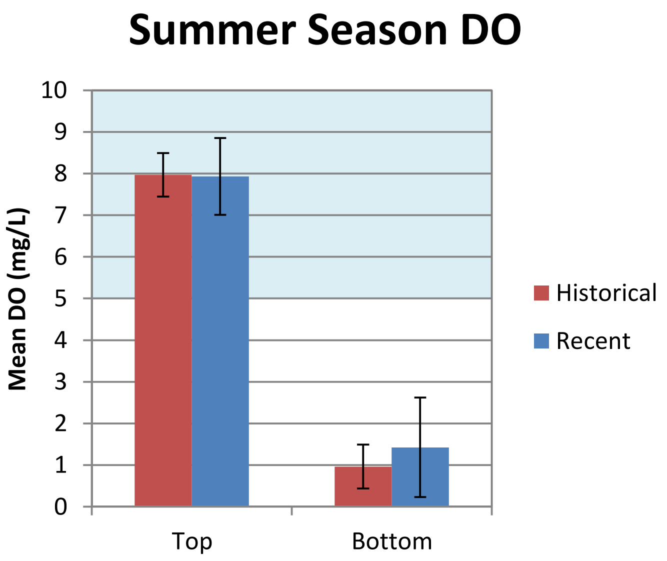


Figure 4.4.3. *Historical and recent Gregg Lake mean summer season DO, using data from Table 4.4.1. Mean DO values are plotted with error bars showing the standard deviation for each sample set. The shaded area represents values above the DO threshold for an oligotrophic lake.*

Long-term Trends in DO. Summer DO data were analyzed for long-term trends; DO values obtained between May 24 and September 15 from 1994–2018 at depths of 1 and 9 meters at the Deep Spot were analyzed for significant trends using the statistical program *rkt* in R (Fig. 4.4.4); neither trend was found to be statistically significant (Table 4.4.2)

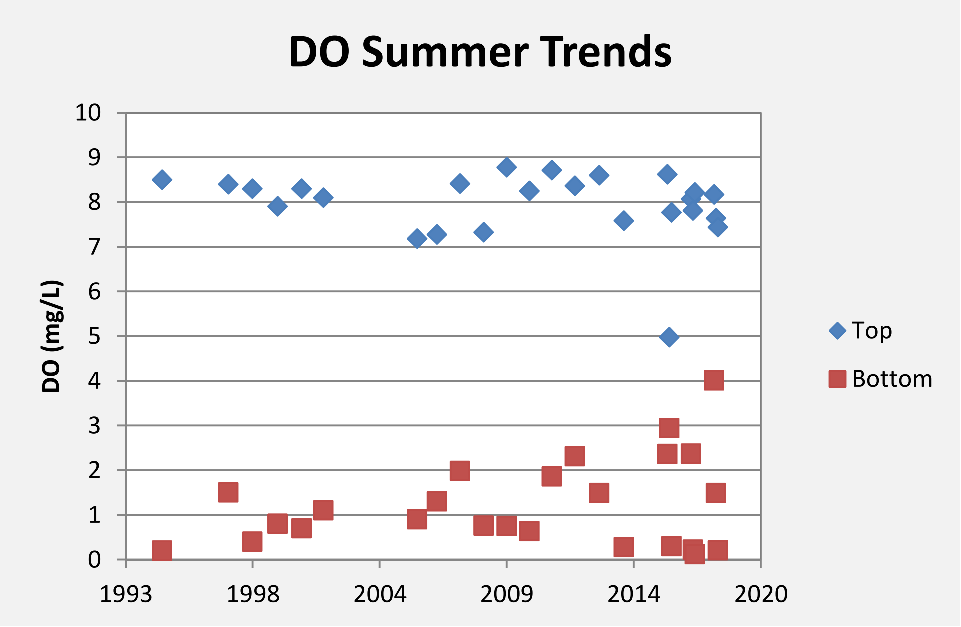


Figure 4.4.4. *Gregg Lake Deep Spot summer DO trends for all years in which data were collected.*

Table 4.4.2. *Summer DO data for the Gregg Lake Deep Spot analyzed for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall trend statistics	DO, 1 m	DO, 9 m
Kendall's Tau	-0.18	0.09
Kendall's Score	-55	27
Variance in Score	1832	1832
2-sided p-value	0.21	0.54
Thiel-Sen's slope	-0.018	0.022

DO % Saturation Profile across the Full Open-Water Season. As was the case for DO, DO % profiles in the early years of VLAP testing were performed during state biologist visits; from 2016–2018, DO % profiles were performed by VLAP volunteer monitors at each sampling. Results from 2018 are shown in Fig. 4.4.5. DO % levels were close to the 75 % threshold to support aquatic life at all depths in April. As this sampling was performed just before ice-out was complete, it is likely that the water had not yet become fully saturated with oxygen. By mid-May the surface waters were fully saturated with oxygen, but oxygen saturation had already dropped below the threshold at a depth of 7 meters (23 feet), and was near zero at the bottom. The maximum depth supporting aquatic life had risen to 4.3 meters (14 feet) in August.

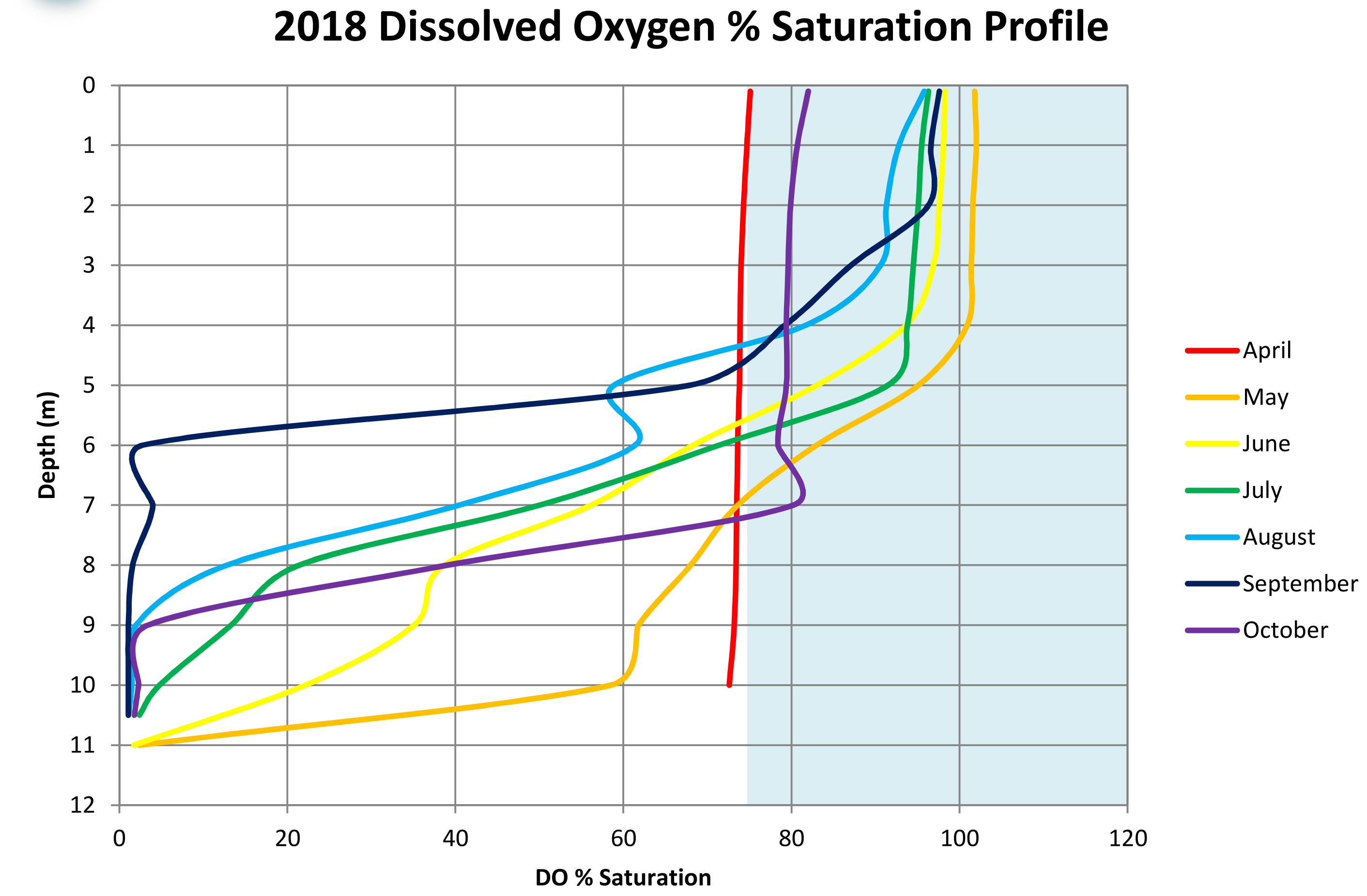


Figure 4.4.5. *Gregg Lake DO % Saturation profiles measured at the Deep Spot at monthly intervals from April to October in 2018. The shaded area indicates DO % levels that meet the criterion for supporting aquatic life.*

As seen for DO, DO % levels dropped rapidly near the bottom over the course of the season (Fig. 4.4.6) and did not recover, presumably until fall turnover.

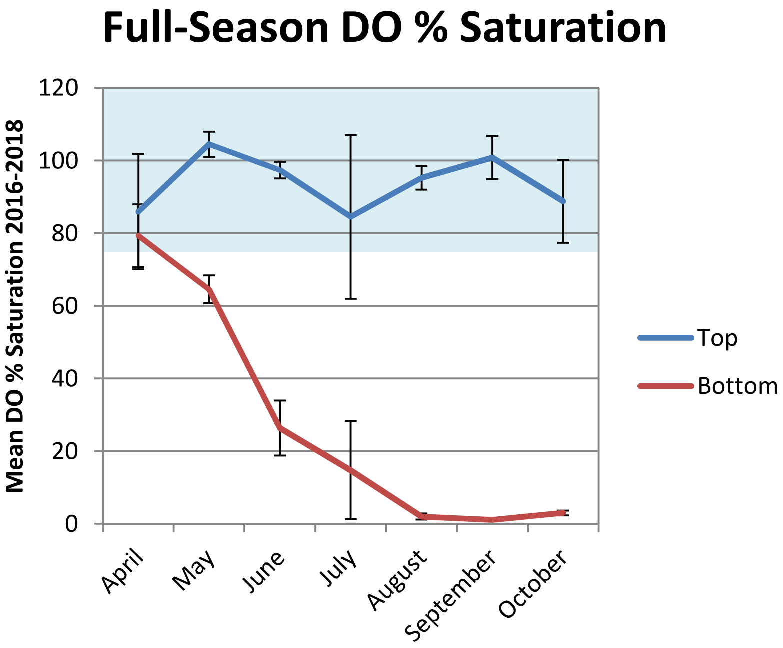


Figure 4.4.6. *Mean Gregg Lake DO % measured near the surface (at a depth of 1 meter) and near the bottom (at a depth of 9 meters) from mid-June through mid-August in 2016 and mid-April through mid-October in 2017 & 2018. Bars show standard deviations for 2-3 samples. The shaded area shows DO % levels above the threshold for supporting aquatic life.*

Summer Season DO % Saturation. Historic (1994–2008) and recent (2009–2018) DO % data obtained between May 24 and September 15 were analyzed for minimum, mean, maximum and median DO % values. Samples taken at a depth of 1 meter were used to represent surface DO % saturation and samples taken at a depth of 9 meters were used to represent DO % saturation near the bottom (Table 4.4.3). Recent and historical median DO % values were similar for both the top and the bottom (Fig. 4.4.7). DO % values at the top were well above the minimum threshold DO % saturation value of 75 % for an oligotrophic lake, whereas bottom values were well below the value required to support aquatic life. DO % saturation near the lake bottom is considered for establishing lake trophic status.

Table 4.4.3. *Summary of summer season DO % Saturation data obtained at the Gregg Lake Deep Spot.*

DO % Saturation				
	Historical		Recent	
Value	Top	Bottom	Top	Bottom
n	10	10	15	15
Min	83.0	1.0	58.5	1.1
Mean	92.8	8.6	94.8	13.1
Max	101.1	17.6	102.8	35.1
SD	6.0	4.9	10.5	10.9
Median	93.7	7.6	98.1	13.0

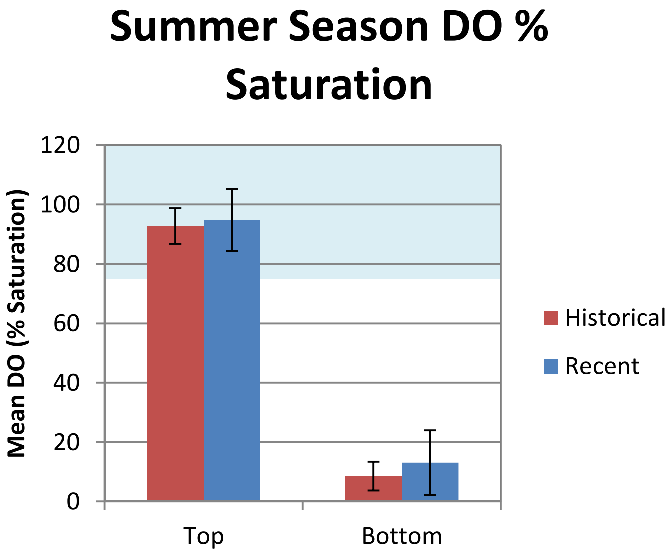


Figure 4.4.7. *Historical and recent Gregg Lake mean summer season DO %, using data from Table 4.4.3 . Mean DO % values were plotted with error bars showing the standard deviation for each sample set. The shaded area represents values above the DO % Saturation threshold for an oligotrophic lake.*

Long-term Trends in DO % Saturation. As performed for DO analysis, summer DO % data gathered at depths of 1 and 9 meters at the Deep Spot since 1994 (Fig. 4.4.8) were analyzed for long-term trends using the statistical program *rkt* in R. No significant trends were found (Table 4.4.4).

Table 4.4.4. *Summer DO % Saturation data for the Gregg Lake Deep Spot analyzed for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall Statistics	DO, 1 m	DO, 9 m
Kendall's Tau	0.05	0.11
Kendall's Score	16	34
Variance in Score	1833	1831
2-sided p-value	0.73	0.44
Thiel-Sen's slope	0.057	0.23

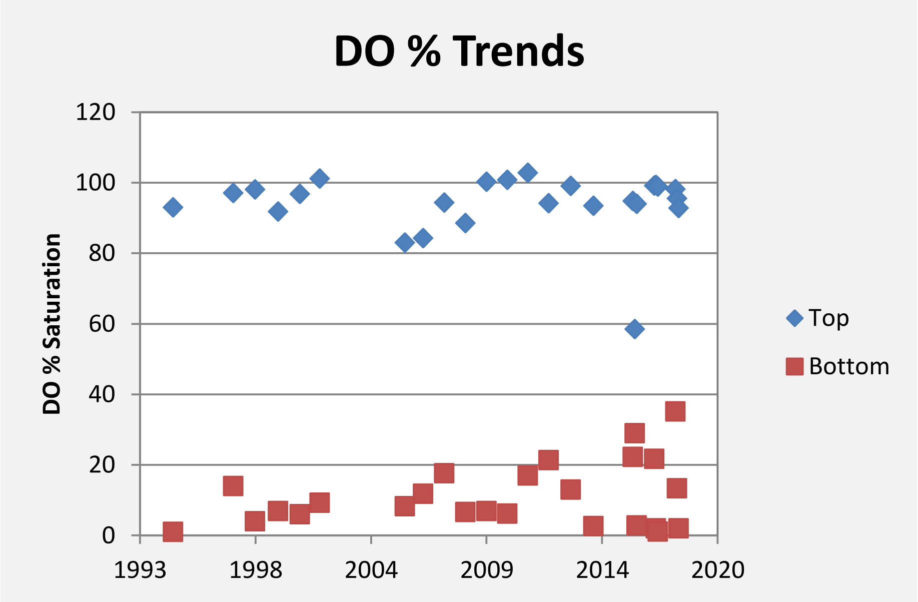


Figure 4.4.8. *Gregg Lake Deep Spot summer DO % Saturation trends for values near the top (1 m) and bottom (9 m) of the water column for each year in which data were collected..*

Lake Volume Not Supporting Aquatic Life due to DO or DO % Saturation Exceedance. The shallowest depth for which there was a DO or DO % Saturation violation was determined for all recent years (Table 4.4.5), and the mean was used to approximate the percent of the lake volume that was affected by low dissolved oxygen.

Table 4.4.5. *Mean depths of shallowest DO and DO % violations in summer samples in recent years (2009–2018), minimum DO and DO % values, and calculation of the percent of the lake volume affected by low oxygen levels.*

Date	Shallowest DO Violation (m)	Minimum DO (mg/L)	Shallowest DO % Violation (m)	Minimum DO %
7/9/2009	6	0.2	5	1.9
6/30/2010	7	0.29	6	2.8
6/21/2011	6	1.41	5	13.3
6/14/2012	8	0.22	4	2.1
7/2/2013	6	1.49	5	13
7/29/2014	6	0.28	5	2.6
6/14/2016	8	2.36	7	22.2
7/13/2016	0.1	2.13	0.1	29
8/17/2016	7	0.29	6	2.7
6/21/2017	7	2.37	5	21.7
7/19/2017	5	0.11	4	1
8/17/2017	5	0.11	4	1
6/20/2018	8	0.2	6	1.75
7/18/2018	8	0.27	6	2.4
8/15/2018	5	0.12	5	1.1
Mean	**6.1**	**0.8**	**4.9**	**7.9**
% of Lake Volume Affected	**20**		**30**	

Dissolved Oxygen Summary. DO and DO % values near the bottom of Gregg Lake fall below those supporting aquatic life early in the summer and remain low through October. There were no significant differences between historical and recent DO or DO % mean or median values, and there were no significant trends in either DO or DO % from 1994–2018. Summer mean values for the minimum depth supporting aquatic life gave an estimated 20 % of the lake volume not supporting aquatic life based on DO criteria and 30 % of the lake volume not supporting aquatic life based on DO % criteria during the summer months. Extremely low oxygen (below 1 mg/L) at depths below 9 m (30 feet) likely contributes to internal phosphorus loading by promoting release of bound phosphorus.

4.5. Transparency (SDT)

Transparency is a measure of the ability of light to penetrate water, and is another factor used in lake trophic status determination. Increased algae, water color and suspended sediment can all affect transparency, and are frequently a result of human disturbance.

Gregg Lake water transparency was measured by lowering a disk with black and white markings (called a Secchi-disk) into the water with a marked chain until it was just visible. Secchi-disk transparency (SDT) was measured only with the naked eye from 1978-2005. From 2006-2018, two measurements were made—through a viewscope on the sunny side of the boat and with the naked eye on the shady side. At least two people took measurements both ways, and the mean value was reported for each method.

SDT Variation across the Full Season. Gregg Lake SDT varied moderately over the course of the season in 2016–2018 (Fig. 4.5.1). Transparency measured with a viewscope was generally slightly greater than transparency measured without a viewscope. Mean SDT decreased from April to June, increased in July and August and declined again through September and October, with the overall trend being a decline in transparency across the full season.

Secchi-Disk Transparency

The Secchi-disk is a 20-cm disk with alternating black and white quadrants used to measure water clarity (how far a person can see into the water).

Transparency, a measure of water clarity, is affected by the amount of algae, color and particulate matter within a lake.

Water Clarity	Category
<2 m	Poor
2-4.5 m	Good
>4.5 m	Exceptional

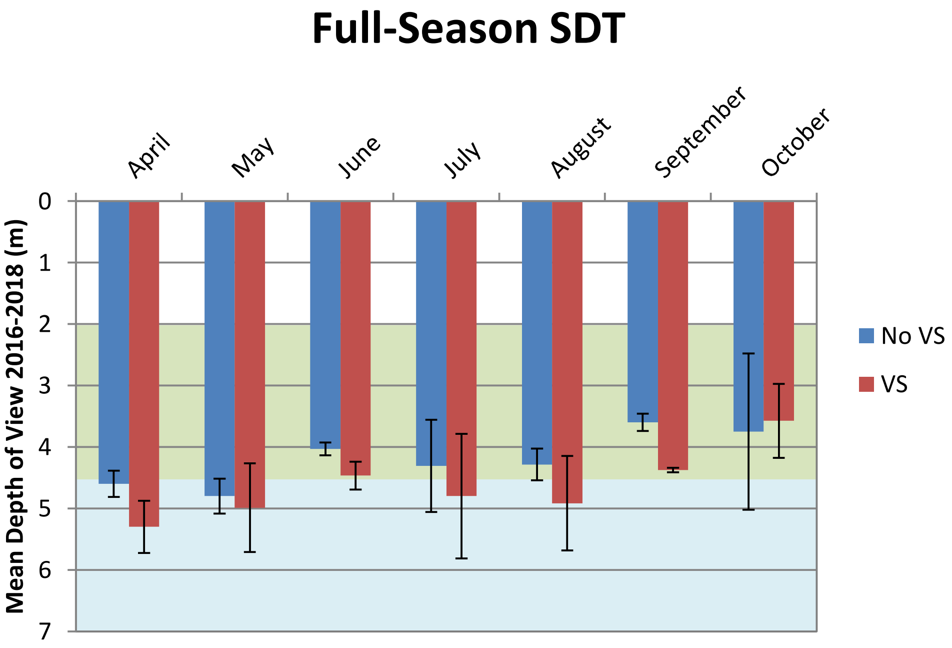


Figure 4.5.1. *Mean Secchi-disk transparency measured with (VS) or without (No VS) a viewscope in mid-month from June through August in 2016 and April through October in 2017 & 2018. The blue shaded area indicates SDT depths considered "Exceptional" and the green shaded area is considered "Good." Error bars represent standard deviations for each set of 2-3 samples.*

Summer Season SDT. Comparison of historical (1978–2008) and recent (2009-2018) SDT values measured at the Deep Spot in the summer months (Table 4.5.1) showed no significant difference between historical and recent values due to variability in the readings (Fig. 4.5.2). However, recent readings were consistently lower than historical readings.

Table 4.5.1. *Historical and recent Gregg Lake Secchi-disk transparency measured in meters with a viewscope (VS) or without (No VS).*

	Historical SDT (m)		Recent SDT (m)	
Value	No VS	VS	No VS	VS
n	14	3	14	14
Min	3.5	4.5	3.0	3.7
Mean	4.9	5.3	4.1	4.7
Max	8.3	6.5	5.1	5.8
SD	1.3	1.0	0.5	0.7
Median	4.6	5.0	4.1	4.5

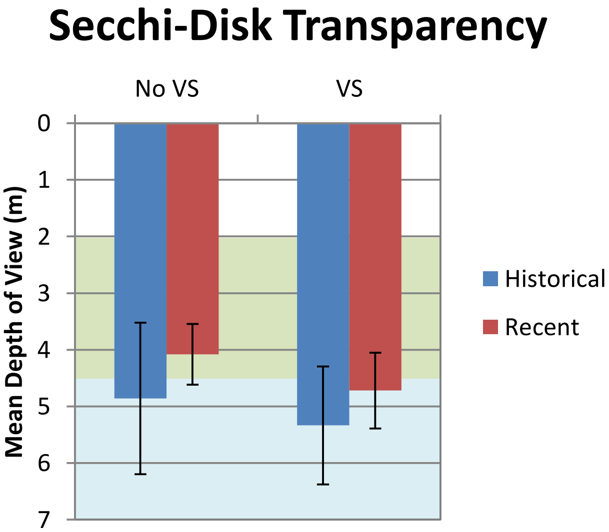


Figure 4.5.2. *Mean historical and recent SDT measured with (VS) or without (No VS) a viewscope as shown in Table 4.5.1. The blue shaded area indicates SDT depths considered "Exceptional" and the green shaded area is considered "Good." Error bars represent standard deviations for each set of samples.*

Long-term Trends in SDT. Summer SDT data were analyzed for long-term trends (Fig. 4.5.3), and the significance of the trends were examined using the statistical program *rkt* in R (Table 4.5.2). No significant trend was found for SDT.

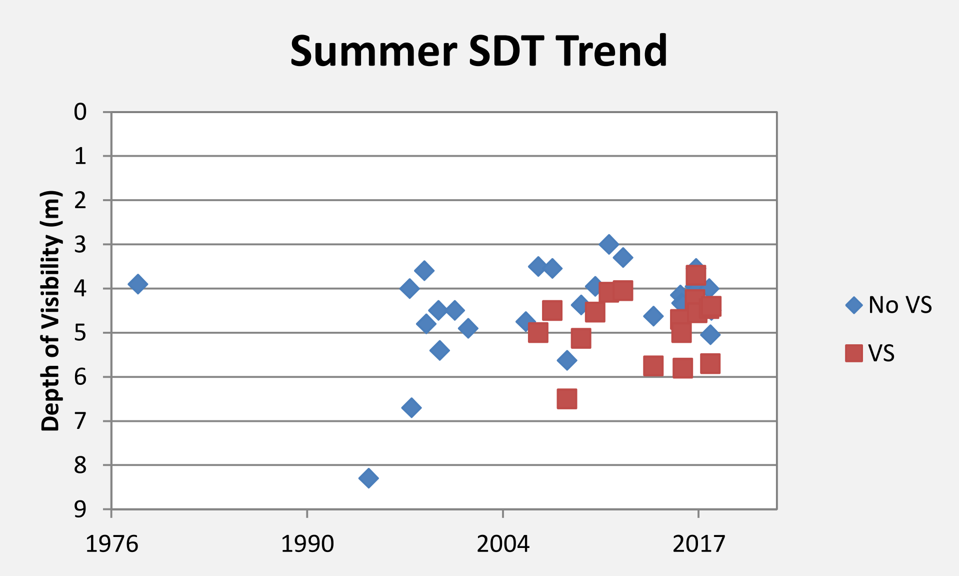


Figure 4.5.3. *Summer season SDT measured with (VS) from 1978–2018 or without (No VS) a viewscope from 2006–2018 at the Gregg Lake Deep Spot.*

Table 4.5.2. *Summer season SDT data for the Gregg Lake Deep Spot analyzed for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall Trend Statistics	No Viewscope	Viewscope
Kendall's Tau	-0.16	-0.15
Kendall's Score	-62	-21
Variance in Score	2553	588
2-sided p-value	0.23	0.41
Thiel-Sen's slope	-0.022	-0.040

SDT Summary. Secchi-disk transparency fluctuated through the full season in approximate correlation with changes in chlorophyll-*a* and turbidity levels, with a clear overall loss of transparency through the season. Readings taken with a viewscope were consistently higher than those taken without a viewscope. Mean and median historical readings were also consistently higher than recent readings, but the differences were not statistically significant. The apparent decreasing trends in summer SDT also were not statistically significant.

4.6. Turbidity

Turbidity, caused by particles such as algae or sediment suspended in the water, can be a major contributor to both loss of transparency and phosphorus release into the water. Suspended particles clog gills of aquatic organisms and prevent light from reaching plants, impairing aquatic life and leading to further phosphorus release as plants die off.

Turbidity Variation across the Full Season. Turbidity levels in Gregg Lake were measured in samples collected in June, July and August in 2016 and monthly from April through October in 2017 and 2018 (Fig. 4.6.1). Overall, turbidity levels were quite low. Turbidity was high in the metalimnion in April, spiked in the hypolimnion in August and September and rose in the Inlet, epilimnion and Outlet in September.

Upstream Turbidity. Late-summer sampling upstream from the Inlet showed turbidity levels to be equal to or lower than those in the lake proper and suggested that the upstream sources do not contribute substantially to lake turbidity (Fig. 4.6.2). Multiple layers of beaver dams work to trap much sediment before it can enter the lake. However, periodic breaching of the beaver dam under the Gregg Lake Road bridge releases accumulated sediment, branches and other debris directly into the lake.

Turbidity in water is caused by suspended matter (such as clay, silt and algae) that cause light to be scattered and absorbed, not transmitted in straight lines. High turbidity readings are often found in water adjacent to construction sites. Improper sampling techniques (such as hitting the bottom sediments or sampling streams with little flow) may also cause high turbidity readings. The Class B standard for a water quality violation is 10 NTUs over the lake background level.

Statistical summary of Turbidity values for NH lakes and ponds:

Turbidity (NTUs)	Category
<0.1	Minimum
22.0	Maximum
1.0	Median

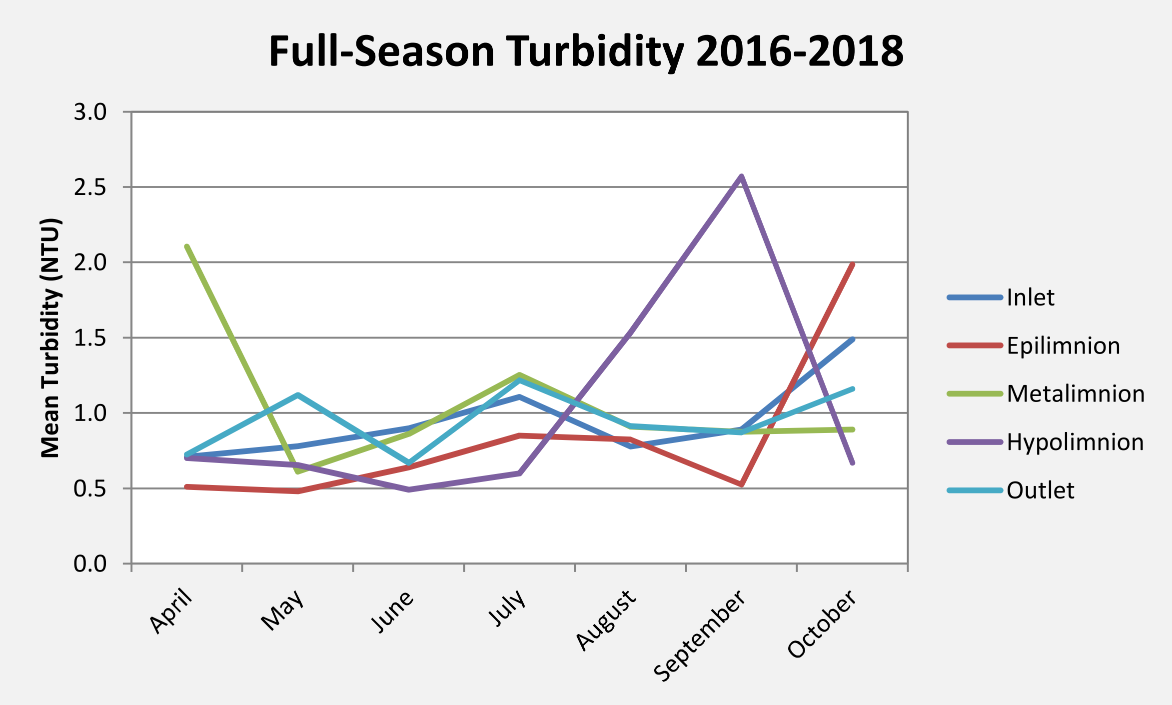


Figure 4.6.1. *Full-season turbidity measured in 2016–2018. Data represent single points or means of 2–3 samples.*

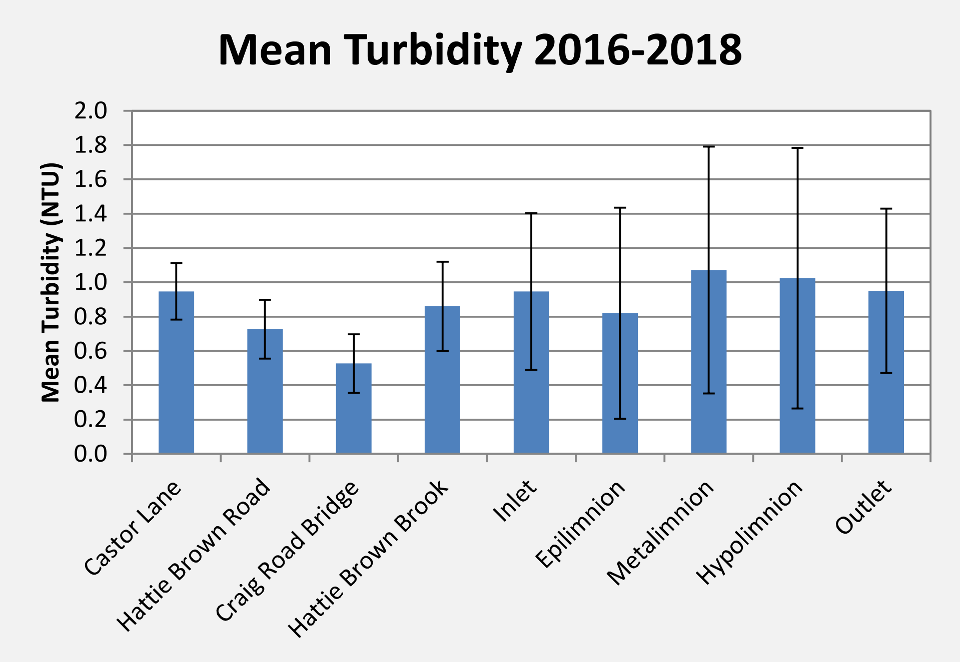


Figure 4.6.2. *Comparison of turbidity at upstream sites with turbidity at the Inlet, Outlet and three depths at the Deep Spot in Gregg Lake. Columns represent means of 3–17 turbidity readings taken at each site from 2016–2018, with bars representing standard deviations.*

Summer Season Turbidity. Historical (1978–2008) and recent (2009-2018) summer turbidity values were compared (Table 4.6.1). Most recent mean and median values were higher than historical values (Fig. 4.6.3).

Table 4.6.1. *Analysis of historical and recent summer season turbidity measured at the Inlet, Outlet and Deep Spot.*

Turbidity (NTU)										
	Inlet		Epilimnion		Metalimnion		Hypolimnion		Outlet	
Value	Historic	Recent	Historic	Recent	Historic	Recent	Historic	Recent	Historic	Recent
n	10	15	12	15	11	15	12	15	11	15
Min	0.35	0.42	0.21	0.41	0.31	0.45	0.28	0.33	0.20	0.52
Mean	0.61	0.91	0.49	0.73	0.53	0.81	0.87	0.79	0.44	0.83
Max	0.86	1.49	1.00	1.12	1.10	2.25	2.20	2.11	0.89	2.29
SD	0.18	0.32	0.23	0.23	0.21	0.46	0.51	0.52	0.20	0.43
Median	0.61	0.91	0.52	0.76	0.50	0.63	0.75	0.51	0.38	0.72

Long-term Trends in Turbidity. As performed for TP analysis, summer turbidity data were analyzed for long-term trends (Fig. 4.6.4) using the statistical program *rkt* in R (Table 4.6.2). Significant increasing turbidity trends were found for the Inlet, Outlet, epilimnion and metalimnion.

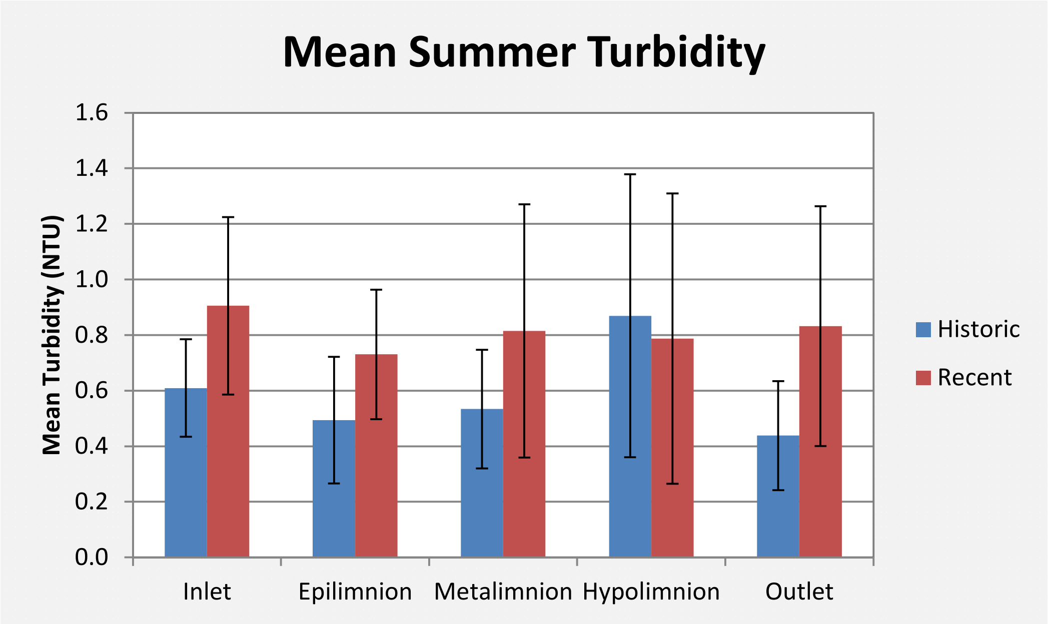
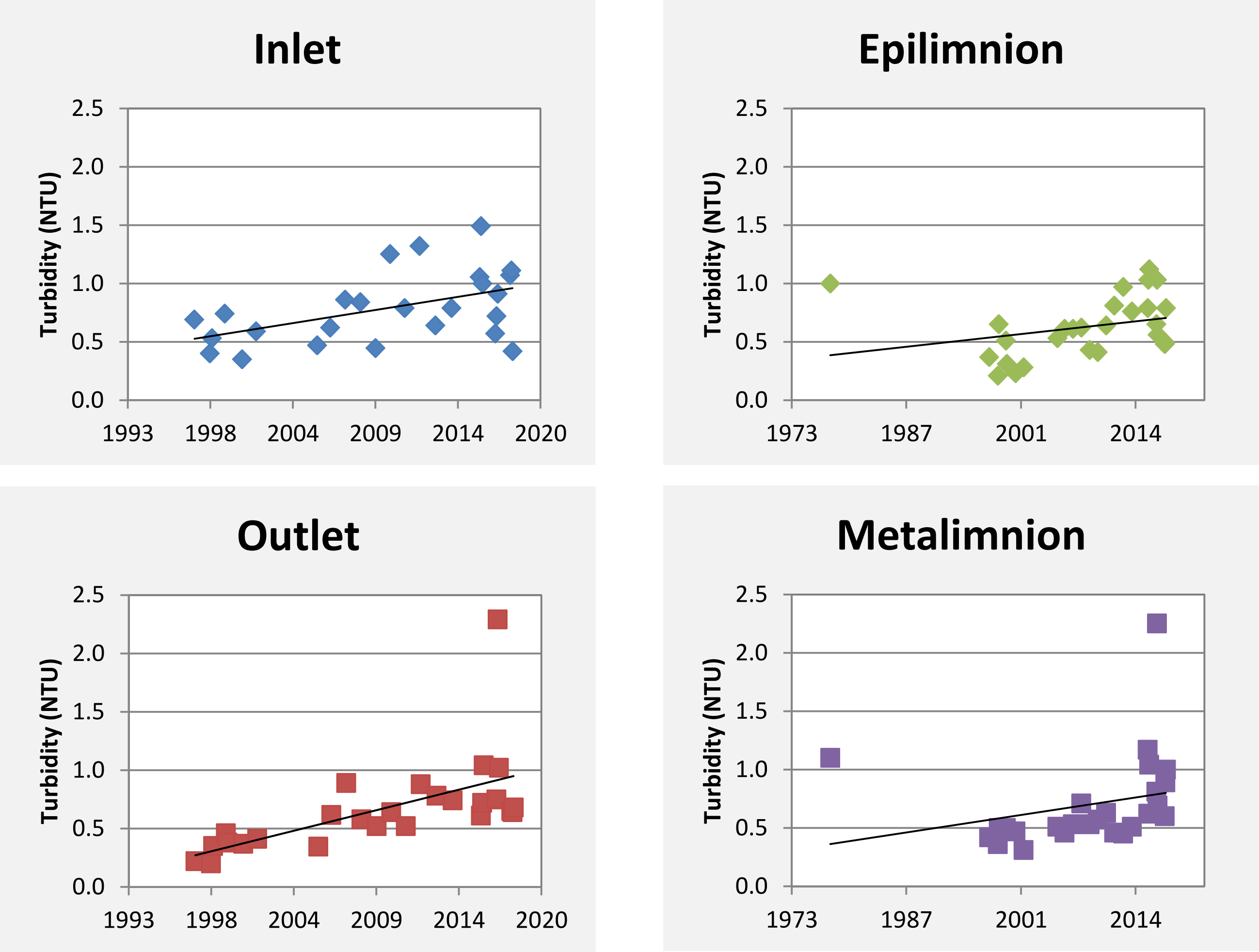


Figure 4.6.3. *Gregg Lake summer season turbidity, using data from Table 4.6.1. Mean turbidity values were plotted with error bars showing the standard deviation for each sample set.*

Table 4.6.2. *Summer turbidity data for the three depths at the Gregg Lake Deep Spot and the Inlet and Outlet analyzed separately for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall Test Statistics	Sampling Location				
	Inlet	Epilimnion	Metalimnion	Hypolimnion	Outlet
Kendall's Tau	0.33	0.33	0.45	-0.03	0.56
Kendall's Score	99	117	145	-12	183
Variance in Score	1832	2297	2054	2297	2056
2-sided p-value	*0.02	*0.02	*0.001	0.82	*5.98e-05
Thiel-Sen's slope	0.020	0.017	0.016	-0.002	0.023

Turbidity Summary. Turbidity varied across the full season, with a steep rise in the hypolimnion in August and September. Similar or lower turbidity levels in upstream samples ruled out excessive turbidity routinely entering the lake from upstream sources. Significant increasing turbidity trends were found for the Inlet, Outlet, epilimnion and metalimnion.



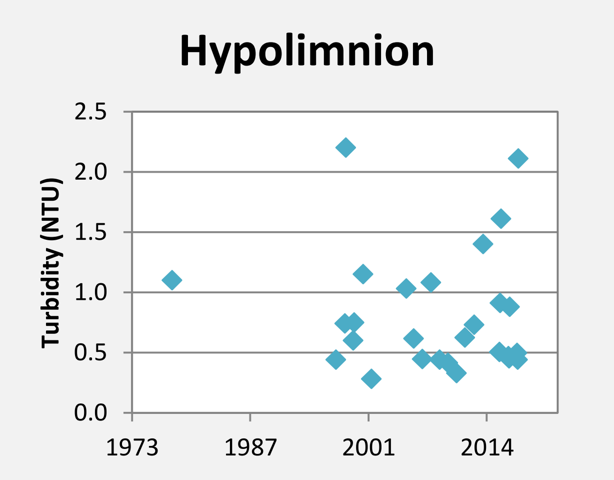


Figure 4.6.4. *Long-term trends in turbidity in Gregg Lake at the Inlet, Outlet and the epilimnion, metalimnion and hypolimnion at the Deep Spot. All data collected between May 24 and September 15 were used for trend analysis. Significant trends in increasing turbidity were found for the Inlet, Outlet, epilimnion and metalimnion, but not for the hypolimnion. Linear trendlines were applied for illustration.*

4.7. Apparent Color

Color can be contributed by both suspended and dissolved matter, which may be derived from rocks and soils, vegetation and land use. An increase in color affects light penetration and transparency, and may result in increased levels of phosphorus and favor cyanobacteria growth.

Increased color can also affect water temperature. Lakes with high color can warm up more quickly in the spring, which can also affect the seasonal succession of phytoplankton in terms of both types of phytoplankton found and timing of phytoplankton cycles. If nutrients such as phosphorus remain constant, warmer lake temperature, driven by increased color, can lead to greater growth of cyanobacteria. Climate change will also likely be a factor, as large storm events result in irregular pulses of color and nutrients from Gregg Lake's extensive upstream wetlands.

Little color data, reported as apparent color, is available for Gregg Lake. The lake water apparent color was measured in 1978, 1994, 1995 and 1997 at the Deep Spot. In 1997, water color was also assessed at the Inlet and Outlet, with the Inlet apparent color much higher than that at the Outlet (32 vs. 8 PCU). This correlates with current visual observations that the Inlet water is more highly colored than the Outlet water.

Apparent Color is a visual measure of the color of water. This color is generally caused by decaying organic matter or by naturally occurring metals in the soils, such as iron and manganese. A highly colored lake generally has extensive wetlands along the shore or within the watershed, and often a mucky bottom, conditions often associated with eutrophic waters. NHDES criteria:

Color (PCU*)	Category
0-25	Clear
25-40	Light Tea Color
40-80	Tea Color
>80	Highly Colored

*PCU=Platinum cobalt unit

Apparent Color Variation across the Full Season. Apparent color was assessed in the epilimnion at the Deep Spot in 2017 and 2018 (Fig. 4.7.1). The shortage of data points limits the significance of any conclusions, but it seems likely that water color increases over the course of the full season. It is also apparent that Gregg Lake epilimnion water now consistently falls into the "Tea Color" category.

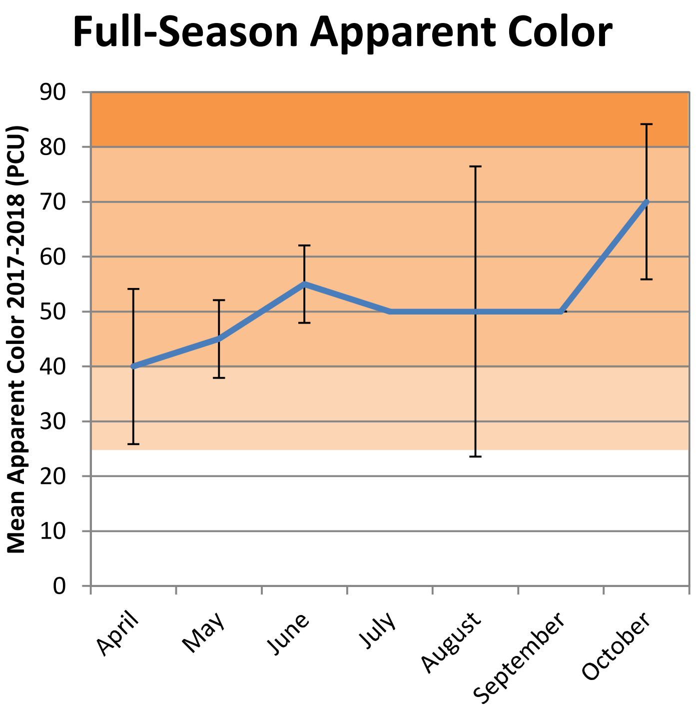


Figure 4.7.1. *Apparent color in Deep Spot epilimnion samples taken mid-month from April through October in 2107 and 2018. Data show the mean and standard deviation of two samples. Shading shows "Light Tea," "Tea" and "Highly Colored" ranges.*

Summer Season Apparent Color. Historical (1978–1997) and recent (2017-2018) summer apparent color values were compared (Table 4.7.1). Recent mean and median values were higher than historical values (Fig. 4.7.2), although the limited number of data points makes statistical analysis difficult.

Table 4.7.1. *Apparent color in Gregg Lake epilimnion summer samples.*

	Apparent Color (PCU)	
Value	Historical	Recent
n	3	6
Min	8.0	40.0
Mean	16.7	55.0
Max	30.0	80.0
SD	11.7	13.8
Median	12.0	50.0

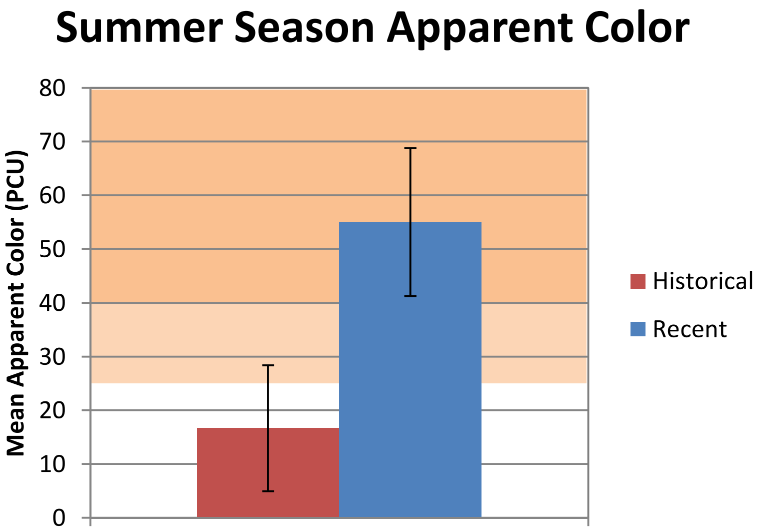


Figure 4.7.2. *Mean historical and recent summer apparent color values for the Gregg Lake epilimnion at the Deep Spot. Error bars show standard deviations. Shading shows "Light Tea" and "Tea" color ranges.*

Long-term Trends in Apparent Color. Gregg Lake apparent color has increased since the initial color measurements were made 40 years ago (Fig. 4.7.3), but trend analysis was not valid due to the shortage of data points.

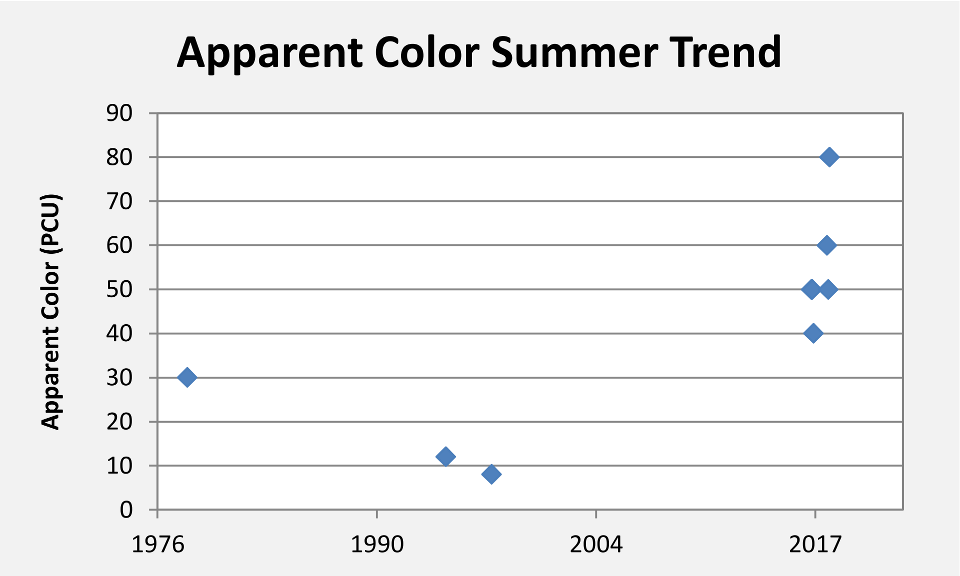


Figure 4.7.3. *Historical and recent epilimnion apparent color data for Gregg Lake.*

Apparent Color Summary. Gregg Lake apparent color increases across the full season. Apparent color in recent samples is substantially higher than that in historical samples. Trend analysis could not be done because there were too few data points.

4.8. Acidity (pH)

Lake acidification in New England occurs primarily as a result of atmospheric deposition (acid rain). Our granitic bedrock, unlike limestone, provides little buffering capacity for acidic materials that enter a lake.

The desirable pH range for survival of aquatic life is from pH 6.5 to 8.0. Gregg Lake pH levels regularly fluctuate below this level. Data is available for the three levels at the Deep Spot since 1978 and for the Inlet and Outlet stations since 1997.

pH Variation across the Full Season. Gregg Lake pH was measured in Deep Spot samples collected in June, July and August in 2016 and monthly from April through October in 2017 and 2018 (Fig. 4.8.1). In May and June, and again in August and September, the mean epilimnion pH rose above 6.5, into the “Satisfactory” range. In the epilimnion in April, July and October and in all metalimnion and hypolimnion samples, the pH fell into the “Endangered” range.

pH is a measure of acidity. It is measured on a logarithmic scale of 0 to 14, with 0 being the most acidic. Lake pH is important to the survival and reproduction of fish and other aquatic life. A pH below 5.5 severely limits the growth and reproduction of fish.

pH (units)	Category
<5	Acidified
5.0-5.4	Critical
5.5-6.4	Endangered
6.5-8.0	Satisfactory

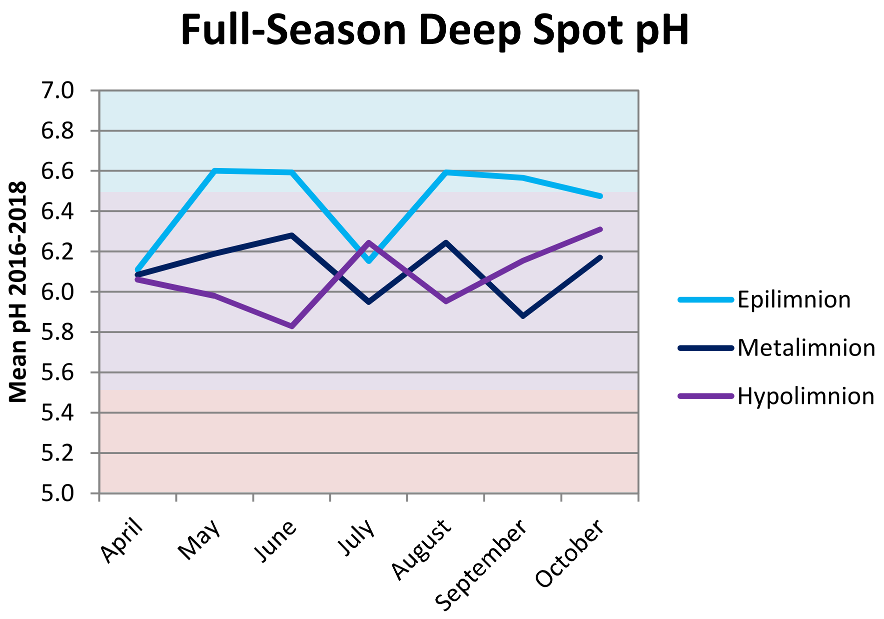


Figure 4.8.1. *Mean pH of 1-3 Deep Spot samples collected mid-month in 2016–2018. The satisfactory range is shaded in blue; endangered, in purple; and critical, in red.*

The pH at the Outlet also rose slightly in the early summer months before dropping in July, rising again in August and dropping late in the season (Fig. 4.8.2). The Inlet pH was consistently lower than the Outlet pH, and late-summer sampling upstream from the Inlet showed all areas to be quite acidic, as expected for extensive wetlands that include floating peat bogs. The upstream acidity likely contributes substantially to the low pH of the main body of Gregg Lake (Fig. 4.8.3).

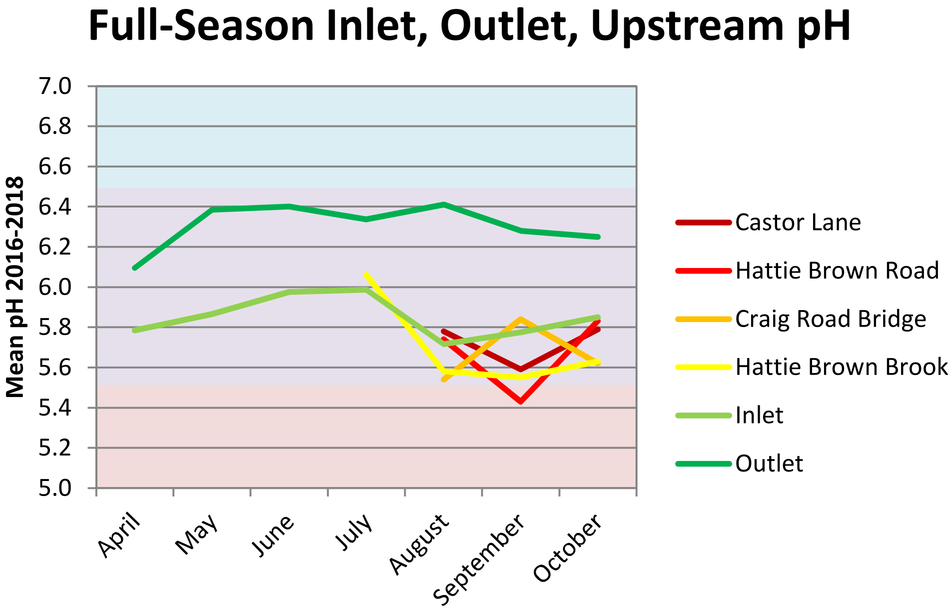


Figure 4.8.2. *Mean pH of Inlet, Outlet and Upstream samples collected mid-month in 2016–2018. The satisfactory range is shaded in blue; endangered, in purple; and critical, in red. Data represent single measurements for upstream stations or means of 2-3 samples at the Inlet and Outlet.*

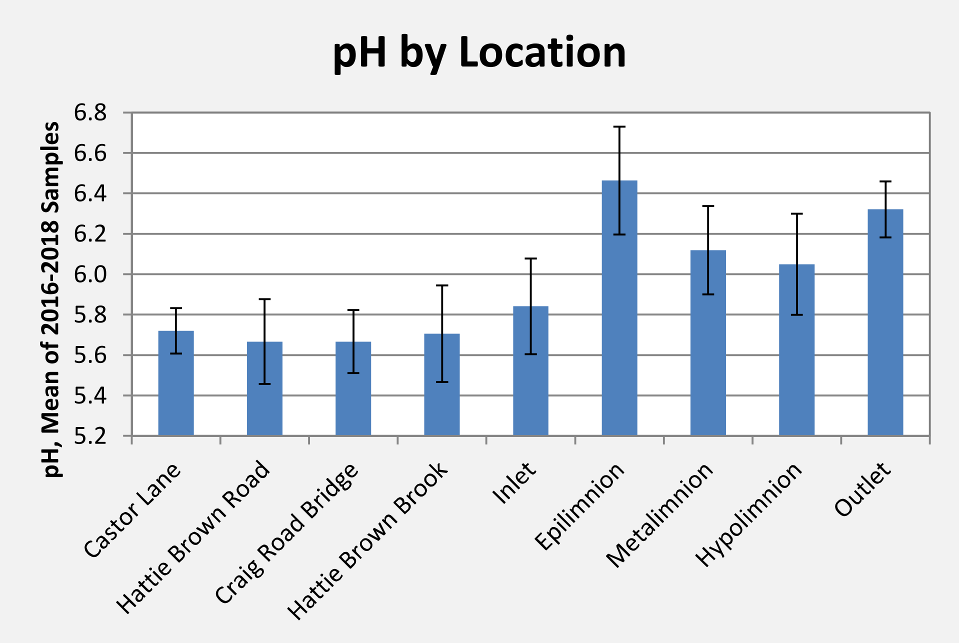


Figure 4.8.3. *Mean pH of all samples taken across the full season in 2016–2018. Error bars show the standard deviations for 3-17 samples.*

Summer Season pH. Historical (1978–2008) and recent (2009-2018) summer pH values were compared (Table 4.8.1). There was no significant difference between recent and historical values (Fig. 4.8.4).

Table 4.8.1. *Analysis of historical and recent summer season pH measured at the Inlet, Outlet and Deep Spot.*

pH										
	Inlet		Epilimnion		Metalimnion		Hypolimnion		Outlet	
Value	**Historical**	**Recent**	**Historical**	**Recent**	**Historical**	**Recent**	**Historical**	**Recent**	**Historical**	**Recent**
n	10	15	13	15	12	15	13	15	11	15
Min	5.55	4.87	5.58	5.48	5.55	5.52	5.41	5.31	6.13	6.07
Mean	5.82	5.77	6.35	6.38	5.96	6.03	5.78	5.85	6.30	6.36
Max	5.99	6.27	6.91	6.76	6.39	6.57	6.42	6.59	6.44	6.54
SD	0.14	0.34	0.32	0.37	0.28	0.28	0.28	0.32	0.10	0.13
Median	5.85	5.72	6.38	6.52	6.03	6.01	5.76	5.81	6.30	6.37

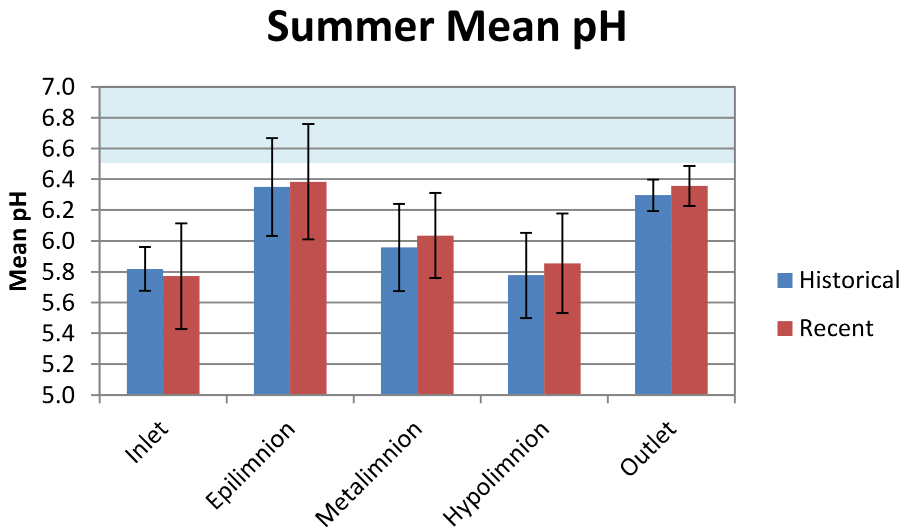
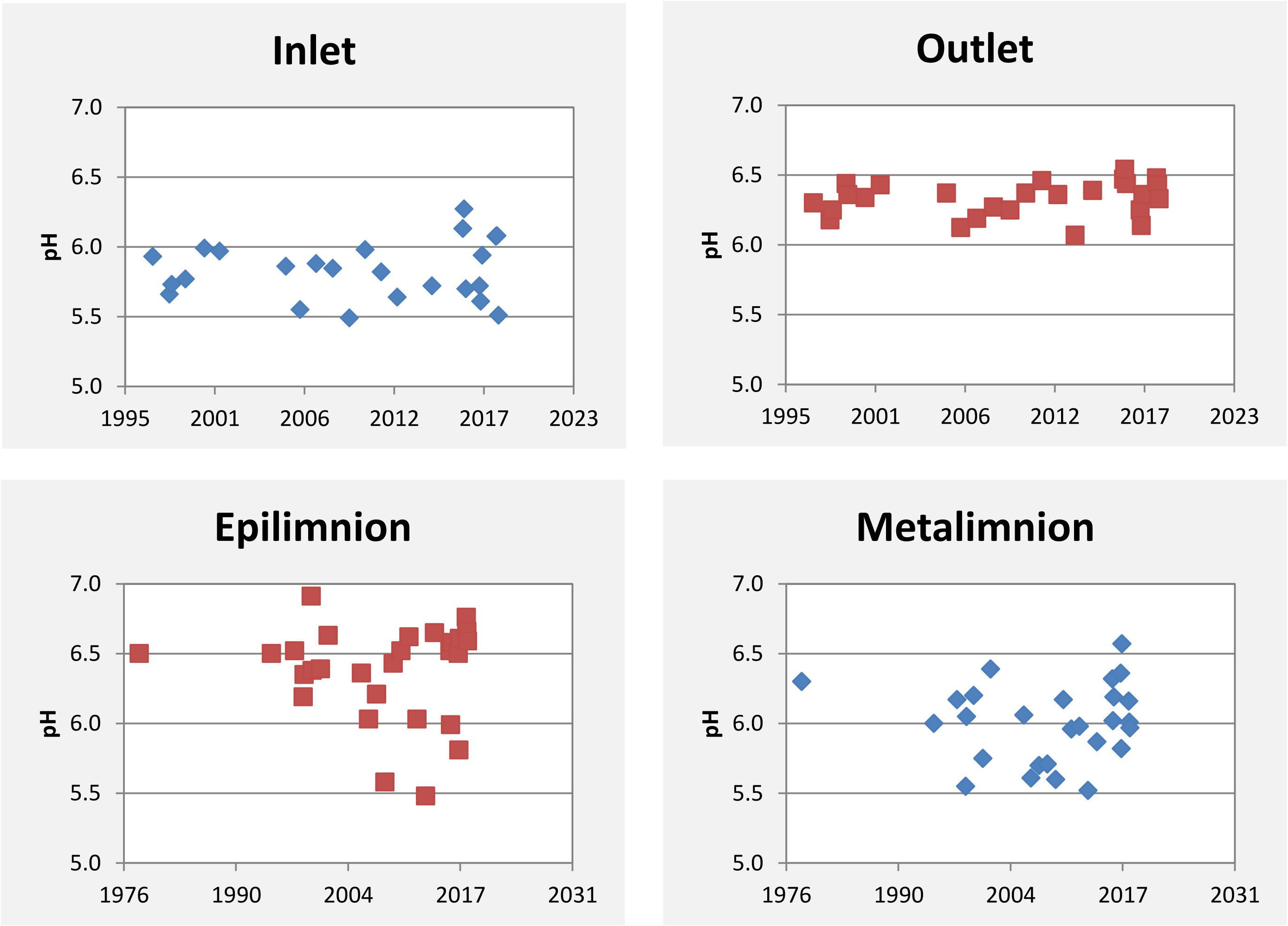


Figure 4.8.4. *Gregg Lake summer season pH, using data from Table 4.8.1. Mean turbidity values were plotted with error bars showing the standard deviation for each sample set.*

Long-term Trends in pH. Summer season pH data were analyzed for long-term trends (Fig. 4.8.5) using the statistical program *rkt* in R (Table 4.8.2). No trends were statistically significant.

Table 4.8.2. *Summer pH data for the three depths at the Gregg Lake Deep Spot and the Inlet and Outlet analyzed separately for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall Statistics	Sampling Location				
	Inlet	Epilimnion	Metalimnion	Hypolimnion	Outlet
Kendall's Tau	0.01	0.12	0.06	0.16	0.19
Kendall's Score	3	45	22	62	62
Variance in Score	1832	2554	2300	2555	2048
2-sided p-value	0.96	0.38	0.66	0.23	0.18
Thiel-Sen's slope	8.11e-04	4.08e-03	4.55e-03	3.81e-03	4.65e-03



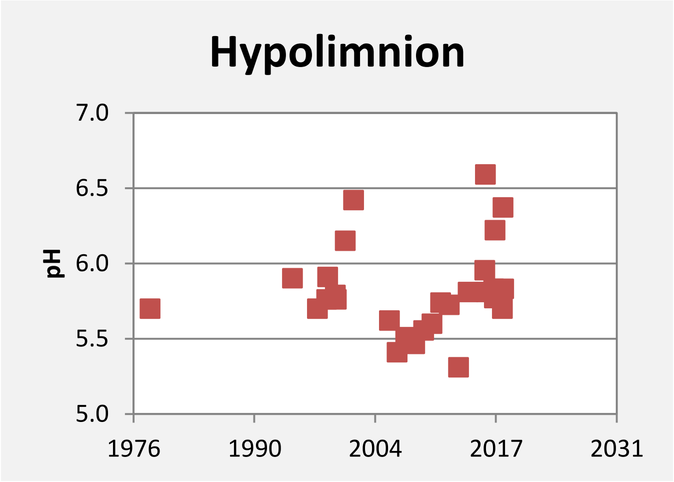


Figure 4.8.5. *Long-term trends in pH in Gregg Lake at the Inlet, Outlet and the epilimnion, metalimnion and hypolimnion at the Deep Spot. All data collected between May 24 and September 15 were used for trend analysis.*

pH Summary. pH varied somewhat across the full season, with nearly all values being below the satisfactory range. The pH at the Inlet and in the metalimnion and hypolimnion was routinely lower than the pH in the epilimnion and at the Outlet. Upstream wetlands are more acidic than the lake itself and likely contribute to low lake pH. There was no significant difference between historical and recent pH, and no significant long-term trends in pH.

4.9. Acid Neutralizing Capacity (ANC)

The ability of a lake to absorb acid without a drop in pH is called the acid neutralizing, or buffering, capacity (ANC). New Hampshire lakes tend to have low ANC because of the underlying geology, and Gregg Lake is no exception.

ANC Variation across the Full Season. ANC in Gregg Lake was measured in samples collected in June, July and August in 2016 and monthly from April through October in 2017 and 2018 (Fig. 4.9.1). Because the single point available for April was high, and one low value in July skewed the July mean, no conclusions can be drawn concerning changes in ANC across the full open-water season.

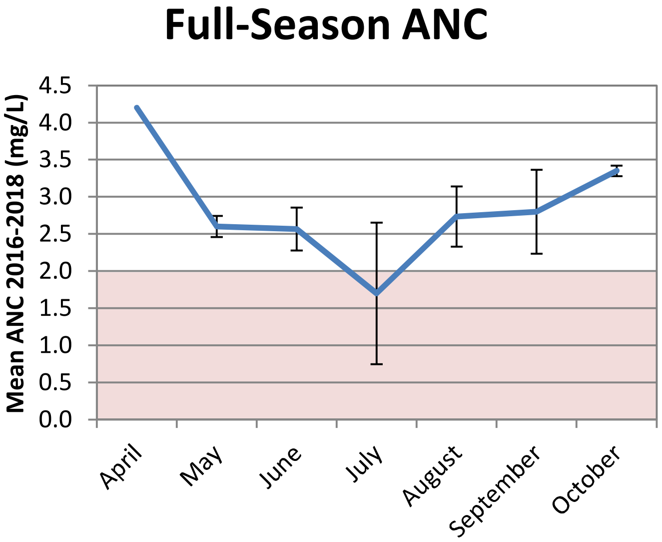


Figure 4.9.1. *Full-season ANC measured in 2016–2018. Points represent single points or means of 2–3 samples. The shaded area represents the Extremely Vulnerable range.*

Acid Neutralizing Capacity or buffering capacity describes the ability of a solution to resist changes in pH by neutralizing acidic input. The presence of calcium carbonate ($CaCO_3$) from bedrock limestone allows some lakes to absorb considerable amounts of acid without a drop in pH. Historically, NH waters have had low ANC because of the prevalence of granite bedrock. Low ANC values mean NH surface waters are vulnerable to the effects of acid rain.

NHDES criteria:

ANC (mg/L as $CaCO_3$)	Category
<0	Acidified
0-2	Extremely Vulnerable
2.1-10	Moderately Vulnerable
10.1-25	Low Vulnerability
>25	Not Vulnerable

Summer Season ANC. Historical (1978–2008) and recent (2009-2018) summer ANC values were compared (Table 4.9.1). Most recent mean and median values were higher than historical values (Fig. 4.9.2), but trends were not significant when analyzed using the statistical program *rkt* in R (Table 4.9.2).

ANC Summary. ANC hovers close to the Extremely Vulnerable range, and appears to dip during the peak of the summer, but limited data make it hard to draw conclusions. No significant differences were found between historic and recent ANC values, and there was no significant long-term trend.

Table 4.9.1. *Analysis of historical and recent Gregg Lake ANC values measured in the epilimnion at the Deep Spot.*

	ANC (mg/L)	
Value	Historical	Recent
n	13	15
Min	1.30	0.70
Mean	1.88	2.14
Max	3.40	3.10
SD	0.55	0.63
Median	1.90	2.10

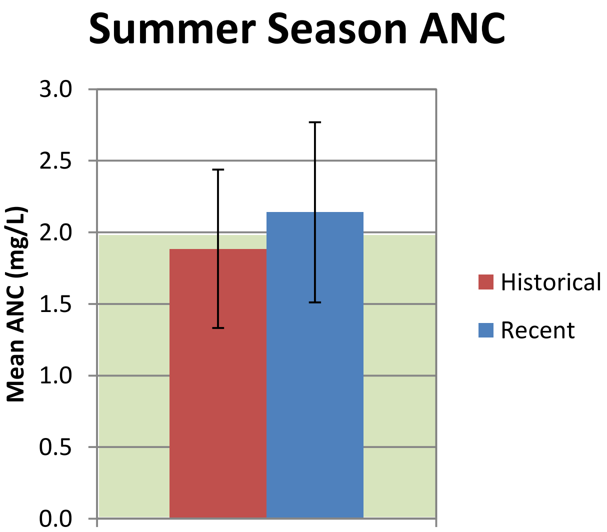


Figure 4.9.2. *Gregg Lake summer season ANC, using data from Table 4.9.1. Mean ANC values were plotted with error bars showing the standard deviation for each sample set. The shaded area represents the Extremely Vulnerable range.*

Table 4.9.2. *Summer ANC data for the Gregg Lake Deep Spot analyzed for long-term trends using rkt package in the R computing environment.*

Mann-Kendall Trend Statistics	ANC
Kendall's Tau	0.21
Kendall's Score	81
Variance in Score	2540
2-sided p-value	0.11
Thiel-Sen's slope	0.021

4.10. Conductivity

New Hampshire lakes usually have low conductivity, a measure of ions present in water, since few salts dissolve from the underlying ground. A rise in conductivity, then, is generally an indicator of man-made disturbance in a watershed.

Conductivity Variation across the Full Season. Conductivity levels in Gregg Lake were measured in samples collected in June, July and August in 2016 and monthly from April through October in 2017 and 2018 (Fig. 4.10.1). Overall, conductivity was quite low. Conductivity values for the epilimnion, metalimnion and the Outlet held relatively constant from spring until fall. Conductivity rose slightly in the Inlet and dramatically in the hypolimnion late in the season.

Upstream Conductivity. Late-summer sampling upstream from the Inlet showed conductivity levels to be lower than those in the lake proper and suggested that the upstream sources do not contribute substantially to lake conductivity (Fig. 4.10.2).

Conductivity is the numerical expression of the ability of water to carry an electrical current. It is determined by the number of ionic particles present. New Hampshire's soft waters have traditionally had low conductivity values. High conductivity may indicate pollution from such sources as road salting, septic systems, wastewater treatment plants or agriculture runoff.

Specific categories of good and bad levels cannot be constructed for conductivity because variations in watershed geology can result in natural fluctuations in conductivity. However, values in NH lakes exceeding 100 μMHOs/cm generally indicate human disturbance.

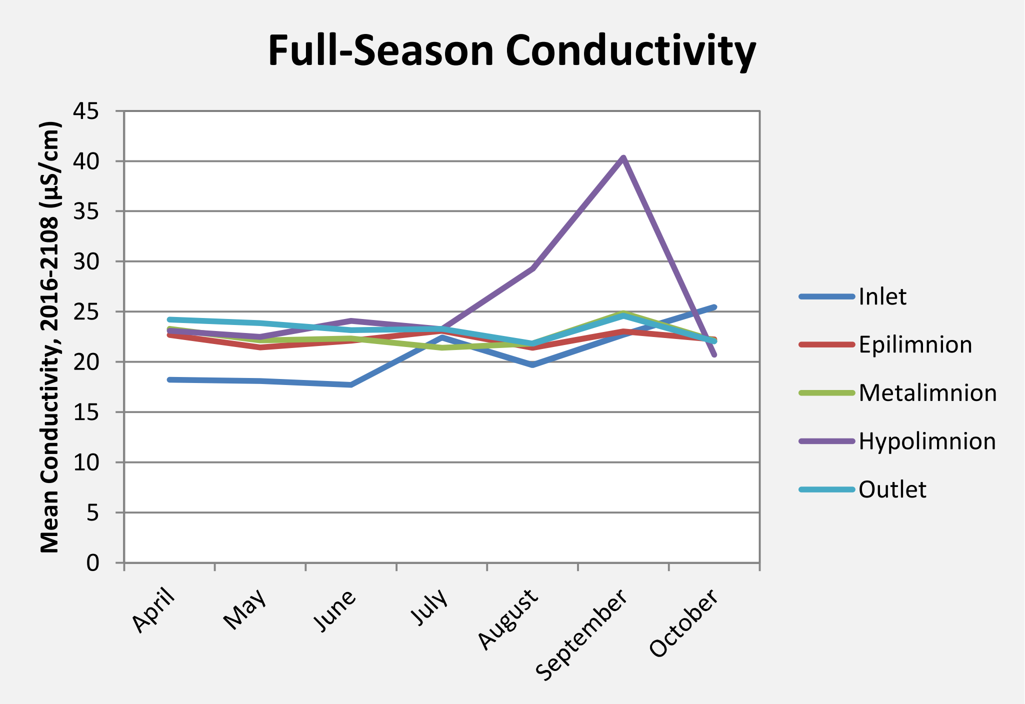


Figure 4.10.1. *Full-season conductivity measured in 2016–2018. Data represent single points or means of 2–3 samples.*

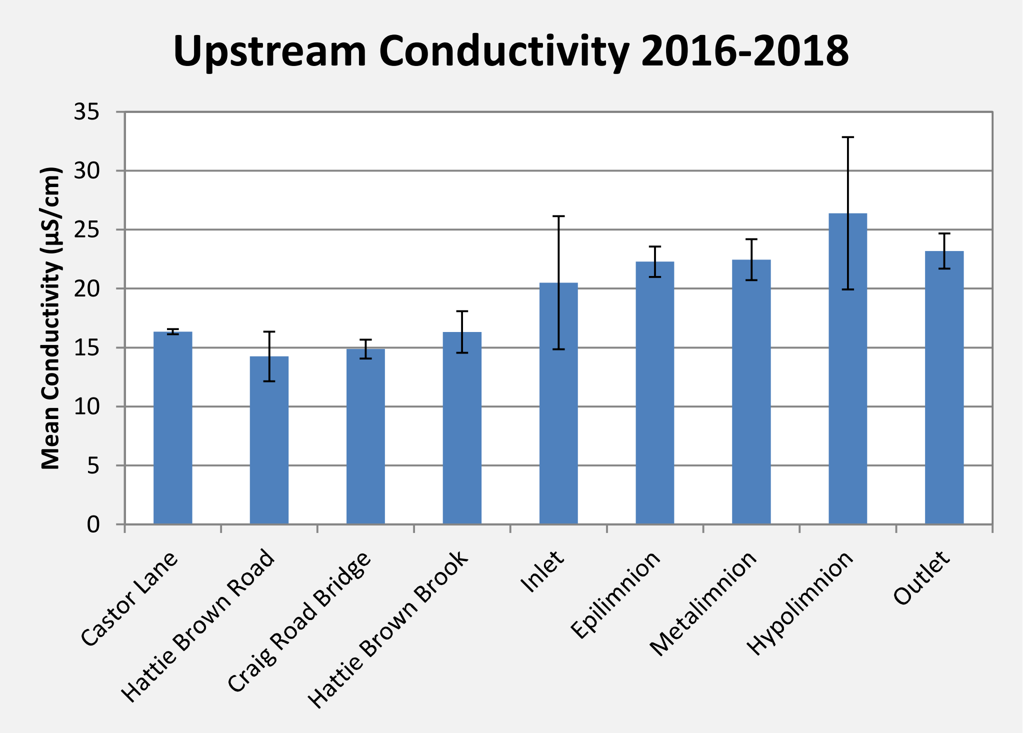


Figure 4.10.2. *Comparison of conductivity at upstream sites with conductivity at the Inlet, Outlet and three depths at the Deep Spot in Gregg Lake. Columns represent means of 3–17 conductivity readings taken at each site from 2016–2018, with error bars representing standard deviations.*

Summer Season Conductivity. Historical (1978–2008) and recent (2009-2018) summer conductivity values were compared (Table 4.10.1). All recent mean and median values were lower than historical values (Fig. 4.10.3), but sample variability suggested that the differences were not significant.

Table 4.10.1. *Analysis of historical and recent summer season conductivity measured at the Inlet, Outlet and Deep Spot.*

Conductivity (µS/cm)										
	Inlet		Epilimnion		Metalimnion		Hypolimnion		Outlet	
Value	Historic	Recent	Historic	Recent	Historic	Recent	Historic	Recent	Historic	Recent
n	10	15	13	15	12	15	13	15	11	15
Min	13.8	14.4	18.9	18.7	19.2	19.6	20.3	20.5	19.4	19.5
Mean	19.6	18.4	24.4	21.8	24.6	22.1	29.0	25.2	25.1	22.1
Max	23.7	29.2	29.4	23.7	29.4	25.5	40.0	35.7	29.4	23.9
SD	3.7	4.2	3.6	1.7	3.4	1.7	5.6	3.6	3.1	1.6
Median	20.6	16.8	24.4	22.4	24.5	22.4	30.0	25.0	25.6	22.5

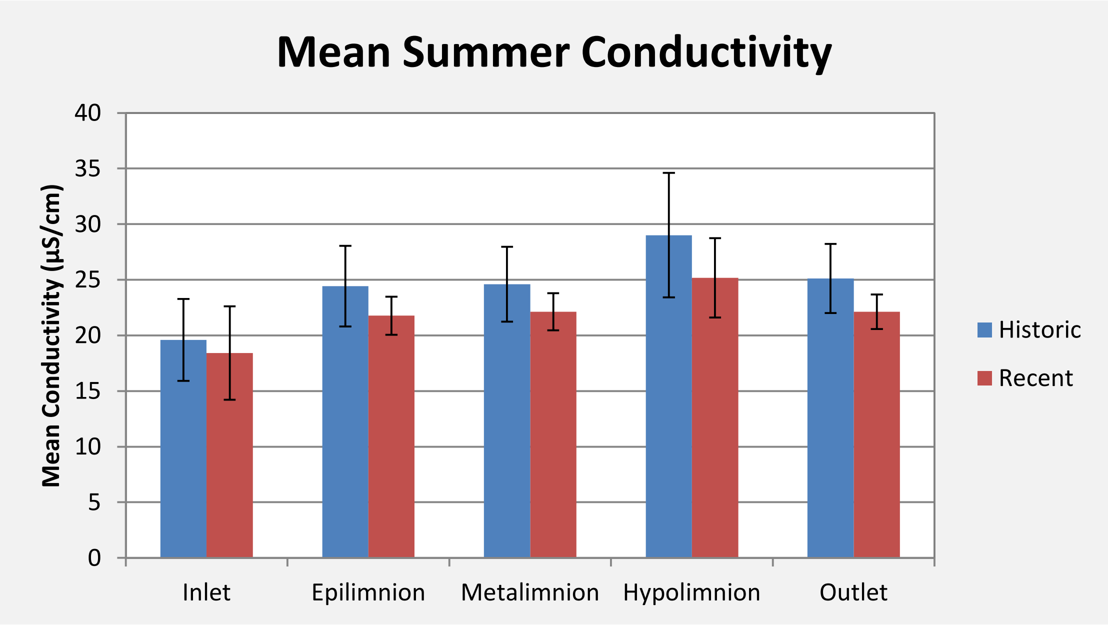


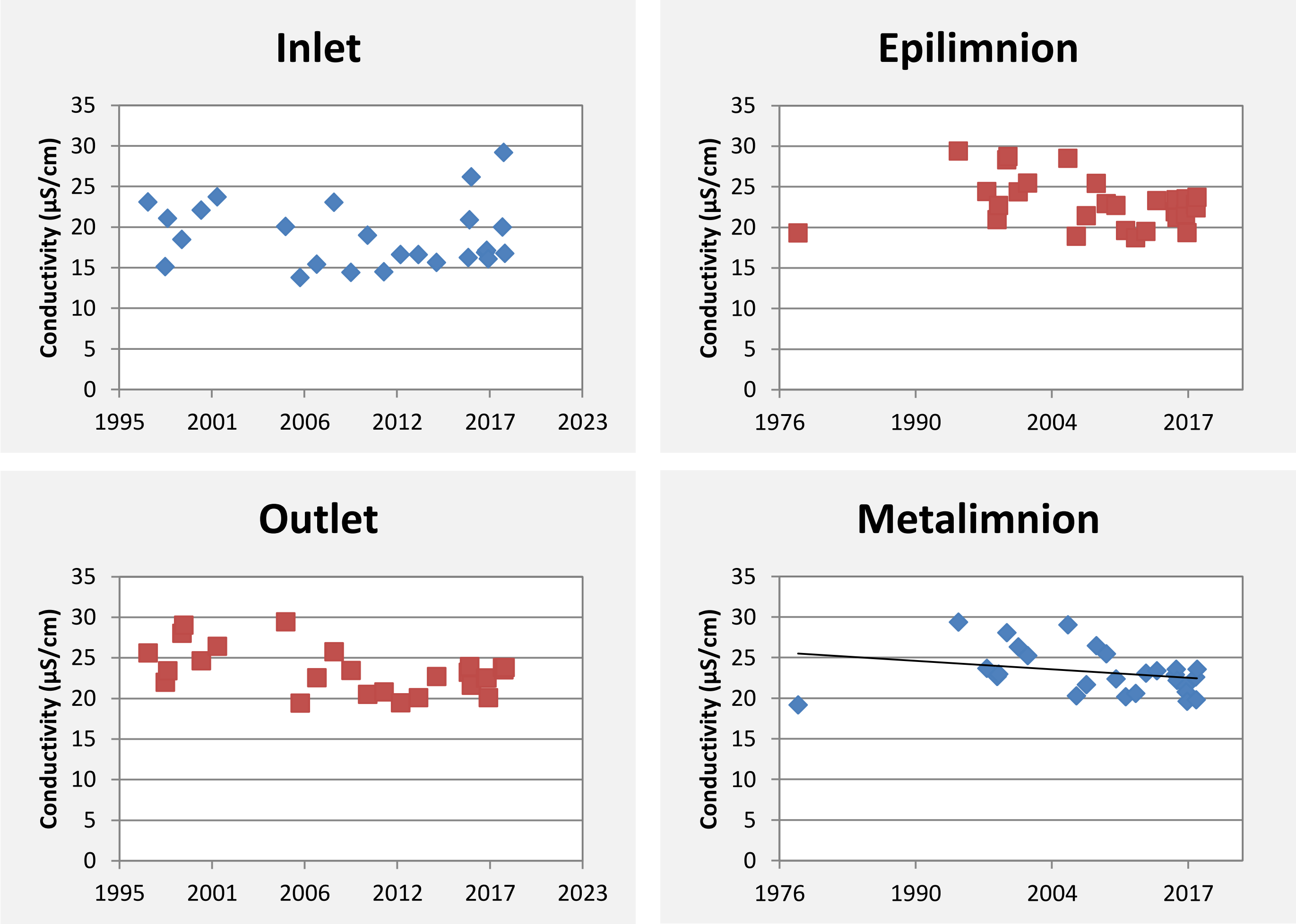
Figure 4.10.3. *Gregg Lake summer season conductivity, using data from Table 4.10.1. Mean conductivity values were plotted with error bars showing the standard deviation for each sample set.*

Long-term Trends in Conductivity. As performed for TP analysis, summer conductivity data were analyzed for long-term trends (Fig. 4.10.4) using the statistical program *rkt* in R (Table 4.10.2). Only the decreasing conductivity trend for the metalimnion was found to be significant.

Table 4.10.2. *Summer conductivity data for the three depths at the Gregg Lake Deep Spot and the Inlet and Outlet analyzed separately for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall Trend Statistic	Sampling Location				
	Inlet	Epilimnion	Metalimnion	Hypolimnion	Outlet
Kendall's Tau	0.02	-0.17	-0.27	-0.24	-0.18
Kendall's Score	5	-63	-96	-90	-58
Variance in Score	1832	2561	2300	2562	2055
2-sided p-value	0.93	0.22	*0.048	0.08	0.21
Thiel-Sen's slope	0.0288	-0.0986	-0.1603	-0.2534	-0.1041

Conductivity Summary. Conductivity was relatively constant across the full season at most locations, with a slight rise in the Inlet and a steep rise in the hypolimnion in August and September. Lower conductivity in upstream samples ruled out excessive salts entering the lake from upstream sources. All recent mean and median conductivity values were lower than the corresponding historic values; however, only the metalimnion showed a significant decreasing conductivity trend.



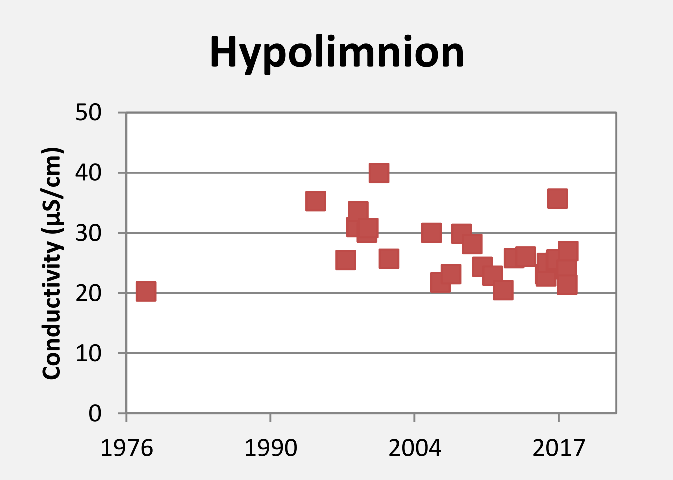


Figure 4.10.4. *Long-term trends in conductivity in Gregg Lake at the Inlet, Outlet and the epilimnion, metalimnion and hypolimnion at the Deep Spot. All data collected between May 24 and September 15 were used for trend analysis. Only the metalimnion showed a significant decreasing trend.*

4.11. Nitrogen

Nitrogen is a plant nutrient that can be of concern in relation to water quality. It is not usually the limiting nutrient in New Hampshire lakes, and is generally present in sufficient quantities to support algal growth, which is then limited by phosphorus levels.

Little nitrogen information is available for Gregg Lake. Kjeldahl nitrogen analysis performed during trophic studies in 1978 and 1994–5 gave a mean nitrogen value of 0.23 mg/L, below the median value of 0.35 mg/L for New Hampshire lakes (Fig. 4.11.1). All measurements of combined nitrite (NO_2^-) and nitrate (NO_3^-) performed during the same studies gave nitrogen values of <0.1 mg/L.

Nitrogen

Nitrite + Nitrate Nitrogen:
A measure of the major inorganic species of nitrogen found in lake waters, and often used as a nitrogen source by algae. The detectable limit of the analytical method used is 0.05 mg/L, a level that can still support algal growth. This is also the median value for New Hampshire lakes. The combined nitrite (NO_2^-) plus nitrate (NO_3^-) were measured and reported as one value prior to 1987 and after 1991. In New Hampshire lakes, nitrite nitrogen is extremely low, so that $NO_2^- + NO_3^-$ is essentially the same as NO_3^-.

Total Kjeldahl Nitrogen:
A measure of inorganic ammonia nitrogen and total organic nitrogen. Higher values generally indicate more eutrophic conditions. The median value for NH lakes is 0.35 mg/L.

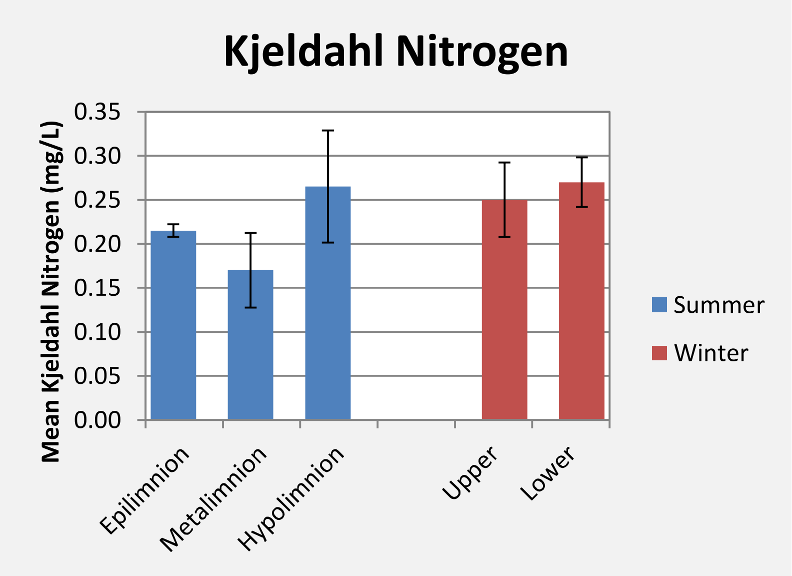


Figure 4.11.1. *Gregg Lake Kjeldahl nitrogen measured at the Deep Spot in 1978 and 1994/5 for trophic studies by NHDES. Each value represents the average of two data points, with error bars showing standard deviations. In winter, when the lake is not stratified, samples were collected at two depths, labelled Upper and Lower.*

Nitrogen Summary. The available data from 1978 and 1994/5 show Gregg Lake nitrogen levels to be below the New Hampshire lake median value.

4.12. Cations and Anions

Cations. Cation levels in Gregg Lake were measured as part of trophic surveys in 1978 and 1994–5 (Table 4.12.1). All were found to be substantially lower than NH lake median values.

Table 4.12.1. *Epilimnion cation levels in Gregg Lake, measured at the Deep Spot as part of trophic surveys. NH lake median values were determined from approximately 760 lakes.*

	Cation Concentration (mg/L)			
Date	Calcium	Magnesium	Potassium	Sodium
7/11/1978	1.7	0.26	0.2	1.4
8/30/1994	1.5	0.27	0.32	2.6
NH Lake Median	2.6	0.54	0.5	3.1

Anions. Chloride ion levels were measured at the Deep Spot in 1978, 1994 and 1995, and again in 2016–2018. All values were below 4.2 mg/L, and most were below the 3 mg/L limit of detection.

Sulfate is naturally low in New Hampshire lakes, and is generally carried in with acid rain. Low sulfate ion concentrations of 2 and 3 mg/L were measured in the epilimnion and hypolimnion, respectively, at the Deep Spot in 1994.

Calcium, Magnesium, Potassium and Sodium Cations (Ca^{2+}, Mg^{2+}, K^{+} & Na^{+}) are the four major cations present in water. Calcium levels are sometimes used to predict the sensitivity of waters to acid rain; lakes containing less than 2.5 mg/L of calcium are considered to be sensitive.

Chloride Ion (Cl^{-}) The chloride ion is found naturally in some surface ground waters. Research has shown that elevated chloride levels can be toxic to freshwater aquatic life. In order to protect freshwater aquatic life in New Hampshire, the state has adopted acute and chronic chloride criteria of 860 and 230 mg/L, respectively. The chloride content in New Hampshire lakes is naturally low, generally less than 2 mg/L in surface waters located in remote areas away from habitation. Higher values are generally associated with salted roadways and, to a lesser extent, with septic inputs.

Summary of Cations and Anions. Low calcium ion levels in Gregg Lake are predictive of sensitivity to acid rain, in agreement with data for acid neutralizing capacity. Low chloride and sulfate ion concentrations indicate minimal man-made disturbance in the watershed.

4.13. E. coli

E. coli counts are used as an indicator of fecal bacteria present in lake water. Samples are collected into sterile containers and the count of *E. coli* in 100 mL is reported.

Antrim Town Beach. NHDES monitored bacteria levels three times each summer at the Antrim Town Beach, each time taking samples at three different locations, indicated as Left, Center and Right. Sporadic samples taken since 1985 showed elevated *E. coli* counts (Fig. 4.13.1), but the issues were always resolved by the time testing was repeated a few days later.

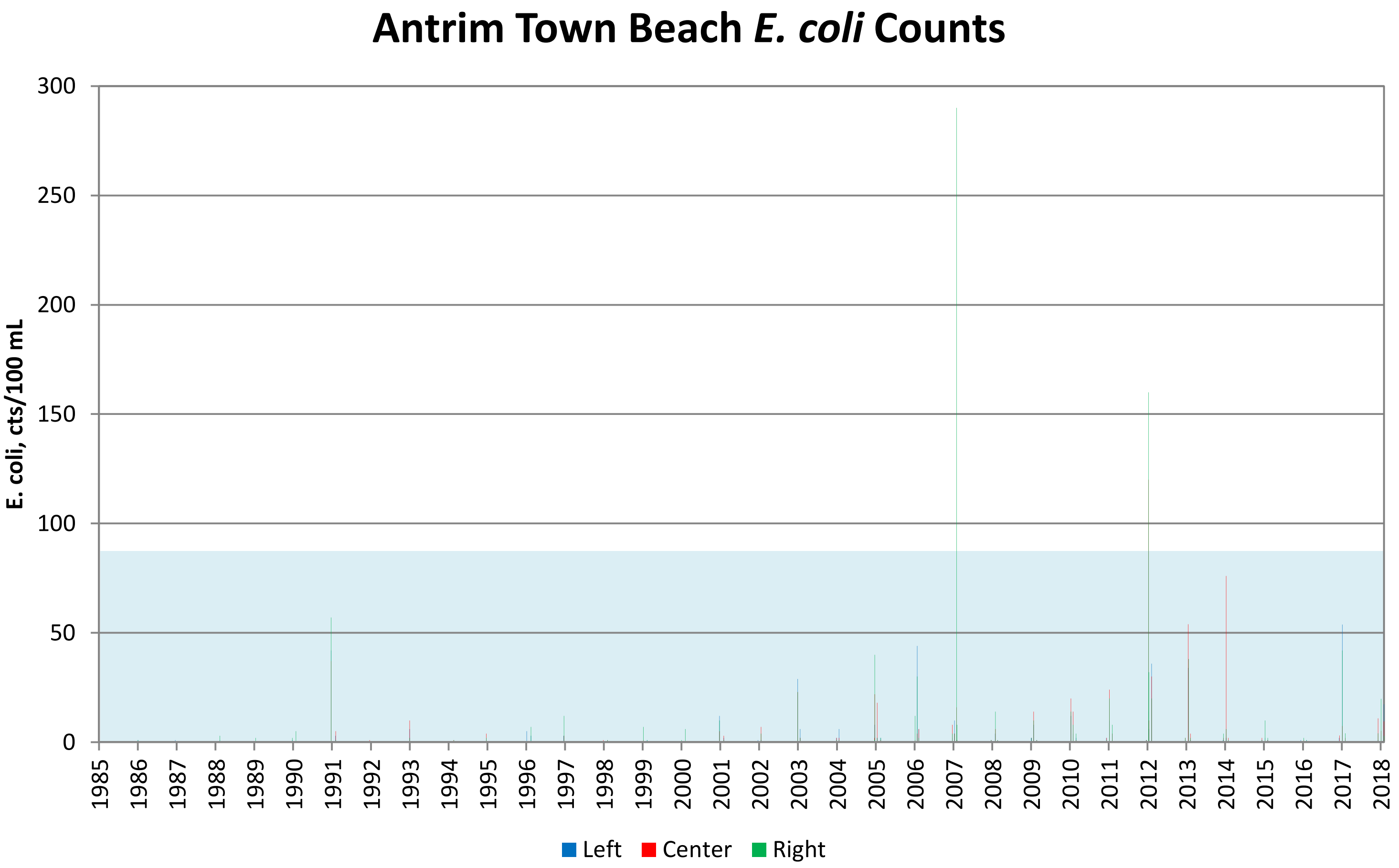


Figure 4.13.1. *Bacteria (E. coli) levels measured at the Antrim Town Beach since 1985 three times each summer at three different spots—Right, Center and Left, when facing the beach from the water. The shaded area represents acceptable single-measurement values for public swimming beaches. If higher values are obtained, a public beach will be closed until lower values are obtained in repeat testing.*

Both mean and median recent (2009–2018) *E. coli* counts were higher than historical (1985–2008) counts at all three locations at the Town Beach (Table 4.13.1). In this case, in which a few high values skew the arithmetic mean, the geometric mean can be more useful for data comparison (Fig. 4.13.2), and NHDES has recently moved to using the geometric mean to assess beach *E. coli* levels for support of Primary Contact Recreation. All analytical methods indicated a slight rise in *E. coli* levels.

Table 4.13.1. *Analysis of E. coli counts at the Antrim Town Beach on Gregg Lake from 1985–2008 (historical) and 2009–2018 (recent), including the geometric mean.*

Town Beach E. coli (cts/100 mL)						
	Historical			Recent		
Value	Left	Center	Right	Left	Center	Right
n	49	35	49	31	31	31
Min	0.0	0.0	0.0	0.5	0.5	0.5
Mean	4.3	5.7	11.6	7.3	13.8	13.6
Max	43.0	37.0	290.0	53.4	120.0	160.0
SD	9.2	8.1	42.0	12.2	25.8	29.4
Median	1.0	2.0	2.0	2.0	3.1	4.0
GeoMean	2.0	2.9	2.9	2.7	4.4	4.3

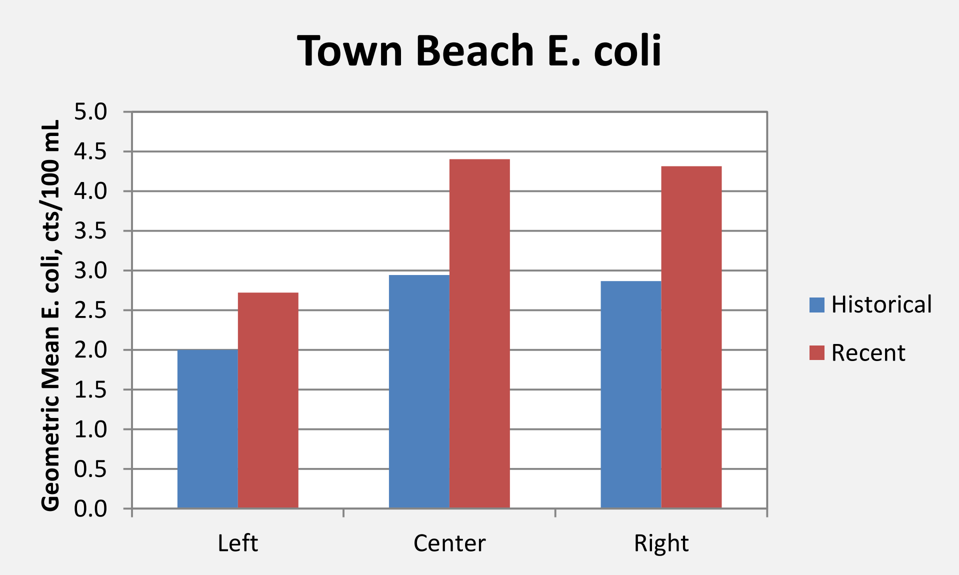


Figure 4.13.2. *Historical (1985–2008) and recent (2009–2018) geometric mean E. coli counts at left, center and right locations at the Antrim Town Beach.*

Bacteria, such as ***E. coli,*** are a natural component of the intestines in humans and other warm-blooded animals. *E. coli* is used as an indicator organism for bacteriological monitoring because it is easily cultured and its presence in the water in defined amounts indicates that sewage MAY be present. If sewage is present in the water, potentially harmful pathogens may also be present.

The state standards for Class B waters specify no more than 406 *E. coli* counts/100 mL in any one sample, or a geometric mean based on at least three samples obtained over a 60-day period be greater than 126 *E. coli* cts/100 mL. For designated beach areas, more stringent standards apply: 88 *E. coli* cts/100 mL in any one sample, or a geometric mean of 3 samples over 60 days of 47 *E. coli* cts/100 mL.

Long-term trends in *E. coli* at Town Beach. Trend analysis using *rkt* in R showed significant increasing *E. coli* trends for the left and right stations at the Town Beach (Table 4.13.2).

Table 4.13.2. *Antrim Town Beach E. coli data analyzed for long-term trends using the rkt package in the R computing environment.*

Mann-Kendall Trend Statistics	Left	Center	Right
Kendall's Tau	0.22	0.10	0.22
Kendall's Score	684	214	695
Variance in Score	54911	31962	56810
2-sided p-value	*0.004	0.23	*0.004
Thiel-Sen's slope	0.040	0.031	0.077

Camp Beach. Low bacteria counts were routinely found at the Harbor Camp (formerly Camp Chenoa) private beach, monitored annually from 1997-2013 (Fig. 4.13.3).

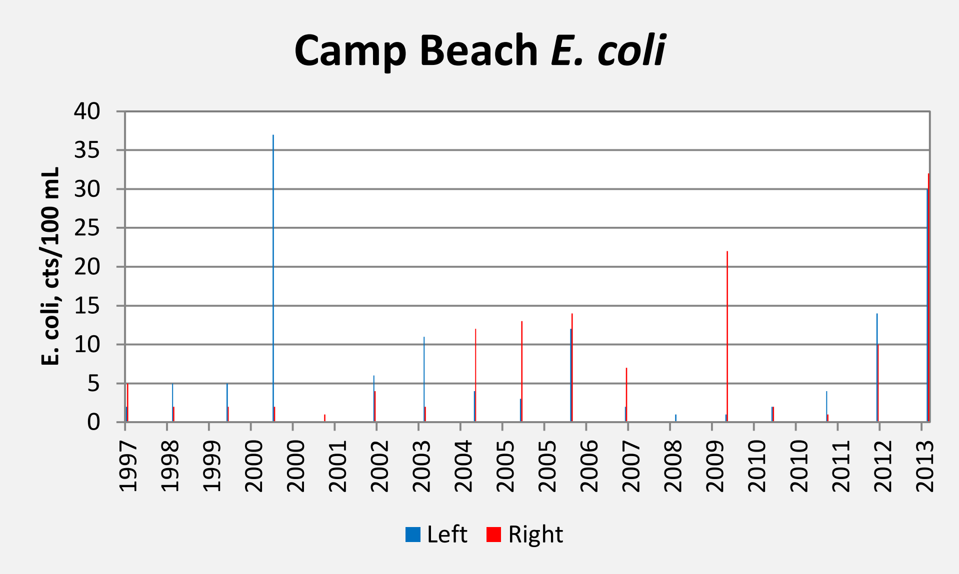


Figure 4.13.3. *E. coli counts at left and right locations at the Harbor Camp private beach.*

Recent mean and median Camp Beach bacteria counts were higher than historical counts (Table 4.13.3, Fig. 4.13.4); however, the beach has not been monitored since 2013.

Table 4.13.3. *Analysis of Camp Beach E. coli data from 1999–2008 (historical) and 2009–2013 (recent).*

Camp Beach *E. coli* (cts/100mL)				
	Historical		Recent	
Value	Left	Right	Left	Right
n	12.0	12.0	5.0	5.0
Min	0.0	0.0	1.0	1.0
Mean	7.3	5.3	10.2	13.4
Max	37.0	14.0	30.0	32.0
SD	10.0	5.0	12.2	13.4
Median	4.5	3.0	4.0	10.0

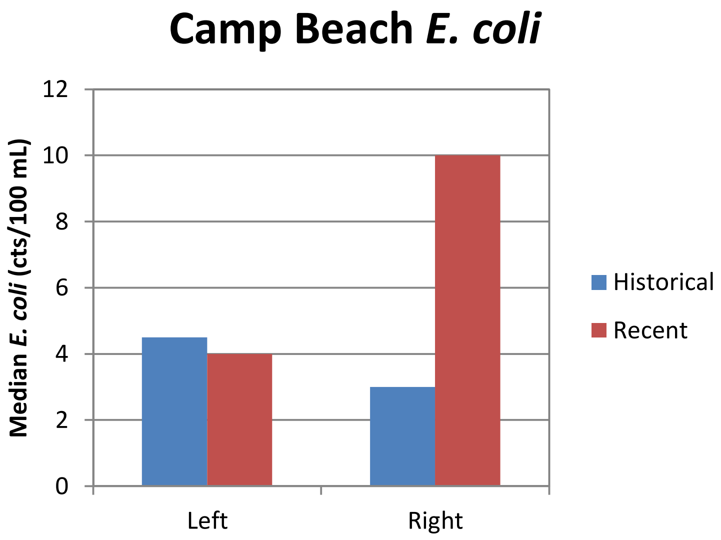


Figure 4.13.4. *Median historical and recent E. coli counts at the private Camp Beach on Gregg Lake.*

VLAP samples collected at the White Birch Point beach in 1999 and 2000 showed no detectable *E. coli*. Samples collected from 2005–2018 have consistently found *E. coli* levels to be low (Fig. 4.13.5, Table 4.13.4). A sample collected at the Sawyer beach in 2011 also gave low bacteria counts.

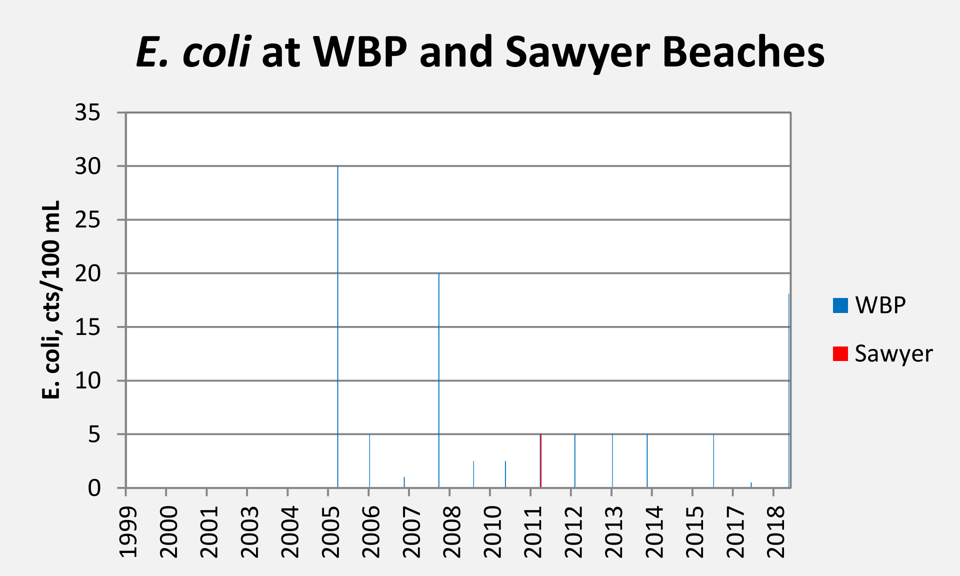


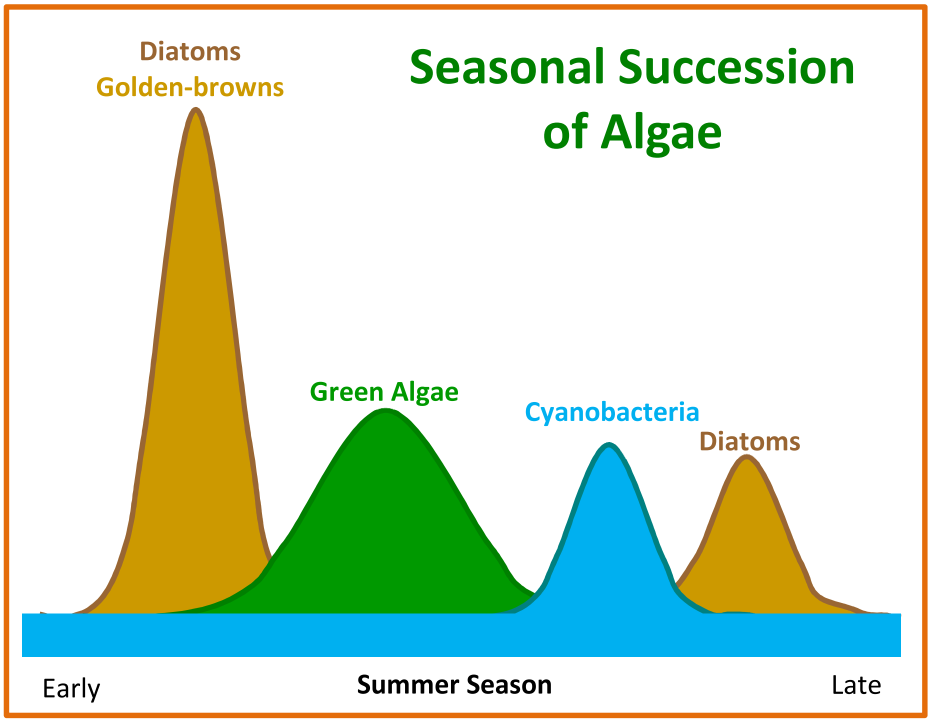
Figure 4.13.5. *E. coli counts at White Birch Point and Sawyer private beaches in samples collected by VLAP monitors in 1999, 2000, 2005–2014, and 2016–2018.*

Table 4.13.4. *Analysis of E. coli counts at White Birch Point beach.*

	WBP Beach *E. coli* (cts/100 mL)	
Value	Historical	Recent
n	6.0	9.0
Min	0.0	0.5
Mean	9.3	5.4
Max	30.0	18.1
SD	12.7	5.0
Median	3.0	5.0

Summary of *E. coli* Counts at Gregg Lake beaches. On rare occasions, bacteria counts have been above desired values at one station out of three at the Antrim Town Beach. Repeat testing within a few days has always shown a return to normal bacteria levels. The arithmetic mean, median and geometric mean of recent *E. coli* counts at all Town Beach stations, although low, are higher than the corresponding historic *E. coli* counts, and statistical analysis shows significant increasing trends at both the left and right stations. Bacteria counts have not been a concern at the Harbor Camp, White Birch Point and Sawyer beaches.

4.14. Phytoplankton Analysis



Algal populations in lakes change with the seasons (Diagram). When the lake water "turns over," or mixes vertically, at ice-out, plant nutrients, especially phosphorus and silica, are brought up from the bottom at the same time as light levels increase. Diatoms, which are encased in glass-like shells made of silica, and golden-brown algae thrive in these conditions and "bloom" until the silica is used up. They then die or "crash" and fall to the bottom, carrying silica and some phosphorus to the bottom.

In lakes with low nutrient levels, the early diatom/golden-brown/ cryptomonad bloom is the period of lowest water clarity and there are few nutrients left for successive waves of green algae, cyanobacteria and diatoms. In lakes with higher nutrient loads or continuous sources of nutrients, phosphorus can be released from decaying diatoms and algae or enter the lake from other sources and lead to substantial successive blooms of green algae and cyanobacteria.

Cyanobacteria

Cyanobacteria, sometimes referred to as blue-green algae, are characteristic of eutrophic conditions. Cyanobacteria blooms often occur in polluted waters. Some strains produce toxins that can kill fish and sicken or kill other animals, including dogs and cattle. Worrisome possible links between cyanobacteria toxins and several neurological diseases, including ALS, are being studied. Beach cyanobacteria advisories are issued when cyanobacteria counts exceed 50% of the total cell count at a beach or the number of cyanobacteria exceeds 70,000 cells per mL of water.

Green algal blooms are both a nuisance and an indication of increased nutrient availability in the lake water. Cyanobacteria can release toxins hazardous to humans, domestic and wild animals and aquatic organisms. Swimming beaches are closed if cyanobacteria blooms are detected or if cyanobacteria counts reach unsafe levels specified by NHDES. Warm, dry summers and increasing nutrient loads lead to increases in populations of green algae, and, if conditions further allow, cyanobacteria. A late bloom of diatoms is frequently seen in New Hampshire lakes.

Mid- to late-summer blooms of green algae in Gregg Lake's shallow waters in recent years suggest the release of phosphorus from lake-bottom sediments or an influx of phosphorus into the lake water as the summer progresses. Algal blooms were likely aggravated by warmer than normal conditions in 2016–2018. In September 2018, Gregg Lake experienced a likely, though unconfirmed, mild cyanobacteria bloom on a calm, sunny day following heavy rains—the first reported cyanobacteria bloom.

Dominant Phytoplankton Genera. Annual analysis of microscopic algae and cyanobacteria (collectively called phytoplankton) from 1997-2001 and 2005-2010 identified the dominant phytoplankton as primarily diatoms and golden-brown algae, with some green algae and dinoflagellates (Fig. 4.14.1). In those years, only the three (or once four) most dominant phytoplankton genera were reported. Cyanobacteria were not found to be a major phytoplankton component. These samples were collected at different times throughout the summer—between late June and early September—and thus represented different phases of the seasonal succession of algae.

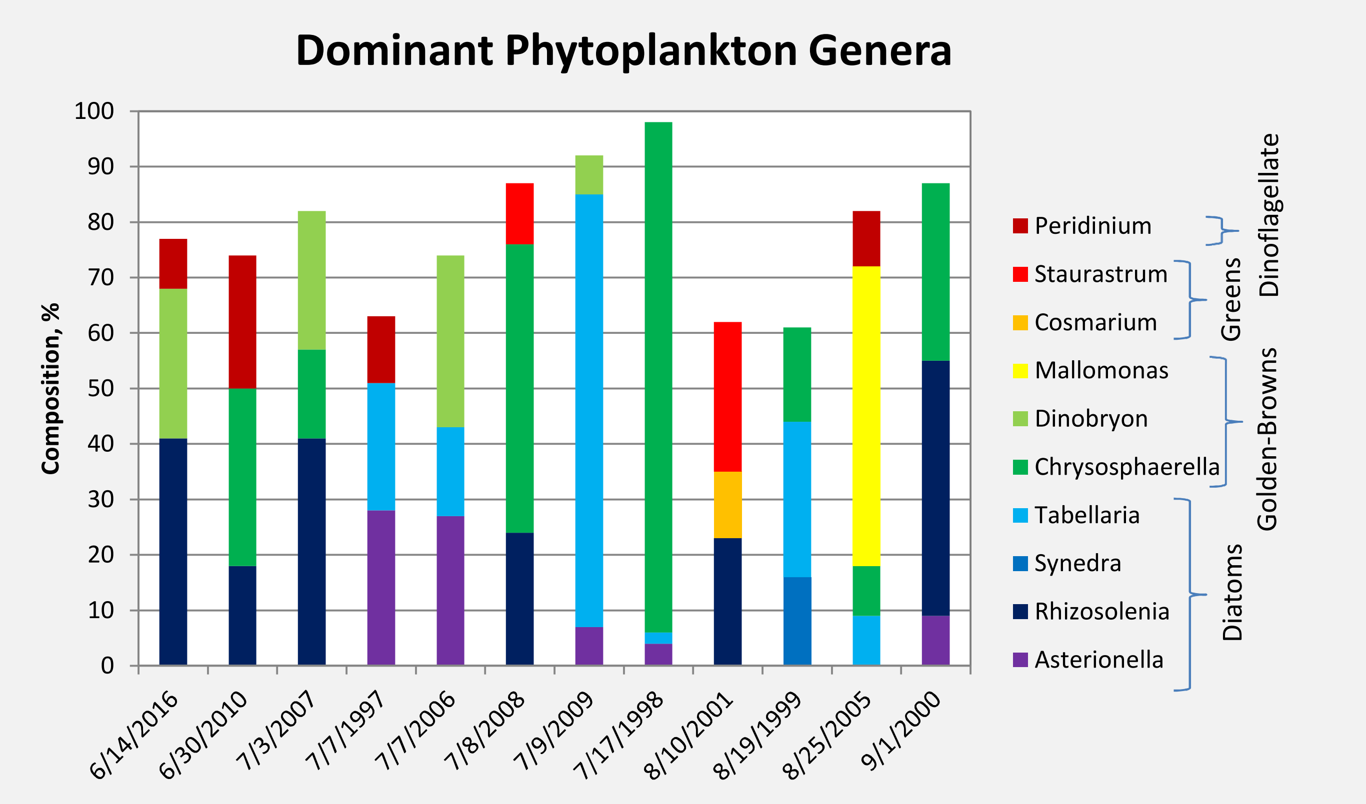


Figure 4.14.1. *The most abundant phytoplankton genera identified between 1997 and 2016 in samples filtered vertically through the water column from the middle of the metalimnion to the surface at the Deep Spot in Gregg Lake. Asterionella, Rhizosolenia, Synedra and Tabellaria are diatoms; Chrysosphaerella, Dinobryon and Mallomonas are golden-brown algae; Cosmarium and Staurastrum are green algae; and Peridinium is a dinoflagellate. Analyses are arranged by month and day, rather than year, for comparison with the seasonal succession of algae.*

Phytoplankton Divisions. After a gap of 6 years, phytoplankton analysis was again performed Gregg Lake in mid-June in both 2016 and 2018 (Fig. 4.14.2). Rather than reporting dominant genera, these analyses reported phytoplankton populations by division and included less dominant forms of phytoplankton. As expected in mid-June, more than 80 % of the phytoplankton divisions identified represented those in the early “diatom” wave of algae succession, which also includes golden-brown algae and cryptomonads. In 2016, approximately 10 % were green algae and 10 % were dinoflagellates, whereas cyanobacteria and euglenoids, if present, comprised less than 0.0 % of the phytoplankton population. Euglenoids, like cyanobacteria, can produce toxins harmful to humans and animals. However, by June 20, 2018, cyanobacteria already comprised 16 % of the phytoplankton population, whereas green algae contributed only 1% and dinoflagellates were not found.

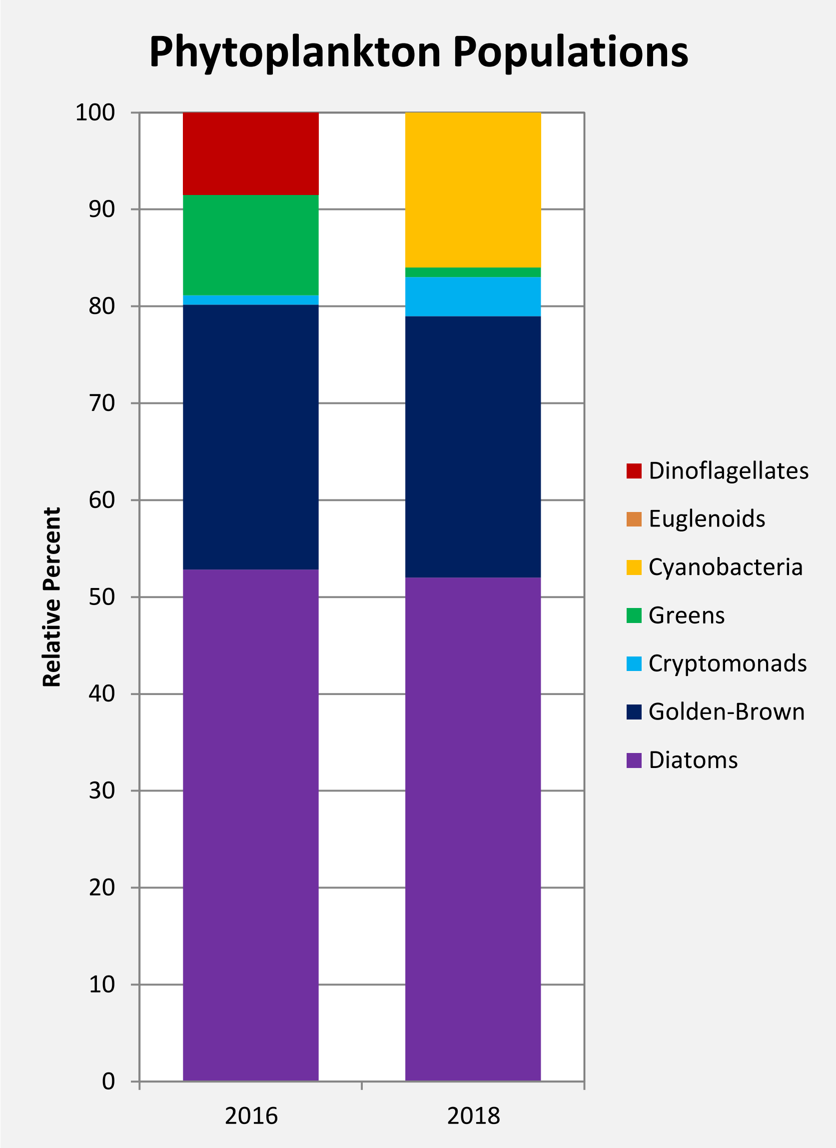


Figure 4.14.2. *Phytoplankton filtered from the water column vertically from the middle of the metalimnion to the lake surface at the Deep Spot in Gregg Lake on June 14, 2016 and June 20, 2018 identified by division. Diatoms, golden-brown algae and cryptomonads generally make up the early stage in the algal seasonal succession; green algae make up the second wave; cyanobacteria and euglenoids, the third; and dinoflagellates and diatoms generally make up the final phytoplankton wave of the season.*

Phytoplankton Summary. Gregg Lake has experienced algal blooms in shallow waters in the last few years. Phytoplankton analysis by genus at the Deep Spot at different times during the summer revealed primarily diatoms and golden-brown algae, with some green algae, as expected in early and mid-successional algal waves. Phytoplankton analysis by division in June 2016 revealed predominantly early-succession phytoplankton (diatoms, golden-browns and cryptomonads), along with some green algae. In 2018, nearly identical amounts of early-succession phytoplankton were found, but a large fraction of the remainder was made up of cyanobacteria. In September 2018, Gregg Lake likely experienced its first recorded cyanobacteria bloom.

4.15. Fish and Other Biological Studies

Biological data for Gregg Lake is scarce. NHFGD performed a fish population census in 2004 and again in 2008, in which fish caught by electrofishing were identified by species and counted (Table 4.15.1).

Table 4.15.1. *Fish population census data acquired in 2004 and 2008 by the NH Fish & Game Department.*

Fish Population		Count		Percentage	
Species	**Common Name**	**8/11/2004**	**7/15/2008**	**8/11/2004**	**7/15/2008**
Lepomis auritus	Redbreasted sunfish	34	13	8.7	2.4
Lepomis gibbosus	Common sunfish	13	8	3.3	1.5
Lepomis macrochirus	Bluegill	1	0	0.3	0.0
Micropterus dolomieu	Smallmouth bass	31	11	7.9	2.0
Micropterus salmoides	Largemouth bass	33	53	8.4	9.7
Perca flavescens	Yellow perch	271	452	69.1	83.1
	Total	**392**	**544**		

Sizes of yellow perch (*Perca flavescens*) harvested for studies of mercury levels in fish tissues were compared in 2008 and 2009 (Table 4.15.2).

Table 4.15.2. *Sizes of yellow perch caught in 2008 and 2009 NHFGD surveys for mercury levels in fish tissues.*

Perca flavescens	Number of fish	Mean length (cm)	Mean weight (g)
7/15/2008	8	19.1	81.4
8/4/2009	5	23	144.6

Black bass (largemouth, *Micropterus dolomieu*, and smallmouth, *Micropterus salmoides*) were also assessed in Gregg Lake in 2008 and 2009 to determine fish condition, size and population structure, relative abundance, young-of-year bass size and age, and growth in relation to statewide population parameters. Based on higher growth rates than the average bass waters of New Hampshire, Gregg Lake was selected as one of four Quality Bass Waters in southwestern New Hampshire, and new regulations were put in place in 2011 to try to create trophy bass waters (NHFGD 2008, 2009). To assess the effects of the new regulations on bass populations, a follow-up fish survey was performed in Summer 2018; results will be available in Summer 2019.

Metals. Although mercury (Hg) occurs naturally in the environment, about 60% of the mercury released into the atmosphere is derived from coal-fired power plants and incinerators that burn household and industrial waste. Mercury that enters lake waters accumulates in tissues of aquatic organisms, including fish. NHFGD regularly issues guidelines for fish consumption intended to limit mercury accumulation to toxic levels in human tissues. Mean mercury levels measured in *Perca flavescens* (yellow perch) in Gregg Lake in 2008 and 2009 studies (Table 4.15.3) were higher than the reported recent (1992-2016) state mean of 0.35 mg/kg of wet tissue. Because of the limited number of samples, the apparent decrease between 2004 and 2008 cannot be considered significant. Mercury levels in yellow perch are consistent with state-wide levels and a decreasing statewide trend (NHDES R-WD-17-22).

Table 4.15.3. *Mercury levels assessed in Gregg Lake yellow perch tissue by NHFGD.*

Mercury Levels in Yellow Perch		
Date	n	Mean Hg (mg/kg wet)
8/11/2004	1	0.74
7/15/2008	8	0.47
8/4/2009	5	0.48
NH Mean		0.35

Local anglers report declines in hornpout, pickerel, sunfish and perch over the past 50 years. Freshwater sponges are regularly observed in several locations. No biological data, such as phytoplankton or zooplankton surveys, appear to be available for upstream tributaries to Gregg Lake.

Fish Summary. Gregg Lake is being managed by NHFGD as a Quality Bass Water. Local anglers report declines in hornpout, pickerel, sunfish and perch. Mercury levels in yellow perch are consistent with state-wide levels and a decreasing statewide trend (NHDES R-WD-17-22).

4.16. Assimilative Capacity Summary

Assimilative capacity analysis was conducted in accordance with the Standard Operating Procedure for Assimilative Capacity Analysis for New Hampshire Waters (Appendix B in the NHDES Guidance for Developing Watershed Management Plans in New Hampshire for Section 319 Nonpoint Source Grant Program Project, revised April 14, 2010). Data acquisition and analysis followed protocols set forth in the Site Specific Project Plan. Water quality monitoring data were accessed through the NHDES OneStop Environmental Monitoring Database (EMD). Melanie Cofrin of NHDES provided all physical/chemical and biological data from two NHDES trophic studies and eighteen years of VLAP sampling from the EMD in a single Excel spreadsheet.

Water quality data were sorted by date and station for Quality Assurance/Quality Control in order to avoid duplicate data sets. All duplicates were removed, and multiple samples collected on the same day were averaged. Any data not marked as "valid" were excluded and any data below the detection limit were replaced with half the detection limit. For comparisons of historic (1978–2008) and recent (2009–2018) data and for long-term trend analyses, only "Summer Season" data, collected between May 24 and September 15, were used. For Deep Spot data collected in different depth zones, data were sorted by sampling depth (epilimnion, metalimnion and hypolimnion). Values representing the "Existing Median Water Quality" were applied to the NHDES Assimilative Capacity Analysis for determining if a waterbody is Impaired, Tier 1 or Tier 2, using aquatic life use nutrient criteria for an oligotrophic lake (Table 4.16.1).

Table 4.16.1. *New Hampshire aquatic life use nutrient criteria ranges by trophic class.*

Trophic State	TP (µg/L)	Chl-*a* (µg/L)
Oligotrophic	<8.0	<3.3
Mesotrophic	>8.0–12.0	>3.3–5.0
Eutrophic	>12.0–28.0	>5.0–11.0

Assimilative Capacity for Phosphorus

Median total phosphorus for recent (2009–2018) summer epilimnetic samples (highlighted in Table 4.16.2) represented the Existing Median Water Quality applied to the assimilative capacity analysis. Formulas for the calculations are shown in Table 4.16.3.

Table 4.16.2. *Gregg Lake summer season TP in the epilimnion (Epi), metalimnion (Meta) and hypolimnion (Hypo) layers at the Deep Spot and at the Inlet and Outlet. Values are given for the number of samples (n) and the minimum (Min), mean, maximum (Max), standard deviation (SD) and median values for each data set.*

Summer Season TP (µg/L)										
	Historical					Recent				
Value	Inlet	Epi	Meta	Hypo	Outlet	Inlet	Epi	Meta	Hypo	Outlet
n	11	14	13	14	12	15	15	15	15	15
Min	7.0	1.0	2.0	6.0	1.0	12.0	2.5	5.5	6.2	5.3
Mean	16.7	6.5	7.5	14.2	7.0	16.5	6.7	8.3	13.2	7.0
Max	27.0	16.0	18.0	32.0	20.0	28.2	11.3	12.9	19.6	9.8
SD	6.2	4.3	4.3	7.4	5.7	4.0	2.5	2.1	4.3	1.3
Median	18.0	5.9	6.0	11.5	5.0	16.0	6.8	7.8	13.0	6.8

Table 4.16.3. *Assimilative Capacity Formulas*

Assimilative Capacity Calculations
Total Assimilative Capacity = WQ Standard – Best Possible Water Quality
Reserve Assimilative Capacity = (0.10) * (Total Assimilative Capacity)
Remaining Assimilative Capacity = (WQ Standard – Reserve Assimilative Capacity) – Existing Median WQ

The Existing Median WQ for phosphorus (6.8 µg/L) was below the criterion for an oligotrophic lake (8.0 µg/L), and below the 10% reserve capacity requirement for a Tier 1 lake (7.2 µg/L), putting Gregg Lake in the Tier 2 category based on phosphorus alone (Table 4.16.4).

Table 4.16.4. *Gregg Lake assimilative capacity for phosphorus calculated using the median recent epilimnion TP as the Existing Median Water Quality.*

Calculation of Gregg Lake Assimilative Capacity for Phosphorus			
WQ Standard for Oligotrophic Lake	<	8.0	µg/L
Best Possible Water Quality		0.0	µg/L
Total Assimilative Capacity		8.0	µg/L
Reserve Assimilative Capacity (10% of Total)		0.8	µg/L
Existing Median WQ		6.8	µg/L
Remaining Assimilative Capacity for Gregg Lake		0.4	µg/L
Remaining Assimilative Capacity (% of Standard)		5.0	%

Assimilative Capacity for Chlorophyll-*a*

The recent median Chl-*a* value (highlighted in Table 4.16.5) represented the Existing Median Water Quality applied to the assimilative capacity analysis for chlorophyll-*a* using the same formulas as used for calculating the assimilative capacity for phosphorus (Table 4.16.3). The Existing Median WQ for Chl-*a* (3.93 µg/L) exceeds the Chl-*a* threshold of 3.3 µg/L for an oligotrophic lake, and gives a remaining assimilative capacity of -29% (Table 4.16.6). A negative value for remaining assimilative capacity indicates an exceedance, in this case 29% over the threshold value, and thus indicates “Impaired” status for supporting aquatic life for Gregg Lake.

Table 4.16.5. *Historical and recent summer season Chl-a values measured at the Gregg Lake Deep Spot.*

	Chl-*a* (µg/L)	
Value	Historical	Recent
n	13	15
Min	2.13	1.53
Mean	3.70	4.34
Max	6.05	7.47
SD	1.27	1.78
Median	3.46	3.93

Table 4.16.6. *Gregg Lake assimilative capacity for chlorophyll-a calculated using the recent median Chl-a value as the Existing Median Water Quality for chlorophyll-a.*

Calculation of Gregg Lake Assimilative Capacity for Chlorophyll-*a*			
WQ Standard for Oligotrophic Lake	<	3.30	µg/L
Best Possible Water Quality		0.00	µg/L
Total Assimilative Capacity		3.30	µg/L
Reserve Assimilative Capacity (10% of Total)		0.33	µg/L
Existing Median WQ		3.93	µg/L
Remaining Assimilative Capacity for Gregg Lake		-0.96	µg/L
Remaining Assimilative Capacity (% of Standard)		-29.1	%

For aquatic life integrity assessment, Chl-*a* and TP results are combined according to a decision matrix (Table 4.16.7), based on the strong association between TP as the "stressor" and Chl-a as the "response." Chl-*a*, being the response readout, dictates the assessment if both Chl-*a* and TP data are available and the assessments differ. For Gregg Lake, since the Chl-*a* assessment exceeds the threshold for an oligotrophic lake, the lake is considered "Impaired" for aquatic life use, and there is no assimilative capacity for phosphorus.

Table 4.16.7. *Decision matrix for aquatic life use assessment determinations in New Hampshire.*

Nutrient Assessments	TP Threshold Exceeded	TP Threshold NOT Exceeded	Insufficient Info for TP
Chl-*a* Threshold Exceeded	Impaired	Impaired	Impaired
Chl-*a* Threshold NOT Exceeded	Potential Non-support	Fully Supporting	Fully Supporting
Insufficient Info for Chl-*a*	Insufficient Info	Insufficient Info	Insufficient Info

Dissolved Oxygen

Gregg Lake undergoes thermal stratification in the summer, with dissolved oxygen reaching low levels in the hypolimnion (Table 4.16.8).

Table 4.16.8. *Summary of summer season DO and DO % Saturation data obtained at the Gregg Lake Deep Spot, with measurements taken at a depth of 1 meter representing the top and measurements taken at 9 meters (1-2 meters above the actual bottom) representing the bottom.*

	DO (mg/L)				DO % Saturation			
	Historical		Recent		Historical		Recent	
Depth	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
n	10	10	15	15	10	10	15	15
Min	7.18	0.20	4.98	0.12	83.0	1.0	58.5	1.1
Mean	7.97	0.96	7.93	1.42	92.8	8.6	94.8	13.1
Max	8.50	1.98	8.78	4.01	101.1	17.6	102.8	35.1
SD	0.52	0.53	0.92	1.20	6.0	4.9	10.5	10.9
Median	8.20	0.85	8.17	1.49	93.7	7.6	98.1	13.0

Dissolved oxygen thresholds are based on waterbody class. Gregg Lake is considered a Class B water, for which the minimum water quality criterion is 5 mg/L dissolved oxygen and 75 % oxygen saturation. The shallowest depth for which there was a DO or DO % violation was determined for all recent years (Table 4.16.9), and the mean was used to calculate the mean percent of the lake volume that was affected and thus impaired for supporting aquatic life use. During the summer months, approximately 20% of the lake volume (that deeper than 6.1 meters, or 20 feet) has a dissolved oxygen level too low to support aquatic life. Similarly, based on the mean DO % Saturation, approximately 30 % of the lake volume (that deeper than 4.9 meters, or 16 feet) has a DO % Saturation too low to support aquatic life. The mean minimum DO value was 0.8 mg/L, less than the anoxic criterion of 1 mg/L, considered to be the point at which sediment in contact with the water will release bound phosphorus.

Table 4.16.9. *The shallowest depths at which DO was measured to be below 5 mg/L and DO % Saturation was measured to be below 75 % were determined for all recent summer recordings. The minimum DO and DO % values (obtained at or near the bottom) are also shown. The mean shallowest depth for each parameter was used to calculate the percentage of the lake volume not supporting aquatic life due to either DO or DO % Saturation being below the criterion.*

Date	Shallowest DO Violation (m)	Minimum DO (mg/L)	Shallowest DO < 1 mg/L	Shallowest DO % Violation (m)	Minimum DO %
7/9/2009	6	0.2	9	5	1.9
6/30/2010	7	0.29	9	6	2.8
6/21/2011	6	1.41	-	5	13.3
6/14/2012	8	0.22	9.5	4	2.1
7/2/2013	6	1.49	-	5	13
7/29/2014	6	0.28	9	5	2.6
6/14/2016	8	2.36	-	7	22.2
7/13/2016	0.1	2.13	-	0.1	29
8/17/2016	7	0.29	8	6	2.7
6/21/2017	7	2.37	-	5	21.7
7/19/2017	5	0.11	9	4	1
8/17/2017	5	0.11	6	4	1
6/20/2018	8	0.2	11	6	1.75
7/18/2018	8	0.27	10	6	2.4
8/15/2018	5	0.12	9	5	1.1
Mean	**6.1**	**0.8**	**9.0**	**4.9**	**7.9**
% of Lake Volume Affected	**20**		**2.4**	**30**	

Assimilative Capacity Summary

- The remaining assimilative capacity for chlorophyll-*a* is -0.96 µg/L, 29 % above the criterion, indicating “Impaired” status.
- Chlorophyll-*a*, as the response indicator, determines the “Impaired” status, and thus there is no remaining assimilative capacity for phosphorus.
- In the summer months, 20 % of the lake volume is below the criterion for DO and 30 % is below the criterion for DO %.
- In summer, bottom sediments in the deepest areas are frequently exposed to anoxic conditions that may lead to internal phosphorus loading.

5. SUMMARY

5.1. Gregg Lake Water Quality Parameters

Weather. Total annual precipitation in southwestern New Hampshire has shown a statistically significant increase since 1978. It is important to recognize that Gregg Lake will be subjected to more extreme weather events in the future. Heavy storms will carry more sediment, phosphorus and nitrogen into the water. Nutrients are washed into Gregg Lake from a relatively large watershed area (15 times the area of the lake), and are flushed out at a relatively low rate of only 1.6 lake volumes per year.

Temperature. Mean summer air temperatures have remained approximately the same in southwestern NH since 1978, and recorded Gregg Lake water temperatures do not show a difference between historical and recent mean temperatures, either at the Town Beach or at the Deep Spot. However, many of the historical temperature recordings were taken in July and August, whereas a higher proportion of recent recordings were taken in June, when the water is likely to be cooler. With Gregg Lake consistently being kept higher than historical levels, the fraction of shallow water has increased and will likely contribute to warmer water temperatures. Increased color in the water will also lead to further warming.

The length of time each year that the lake is free of ice may also affect the growth of aquatic plants and algae. Long-term data for Gregg Lake are not available; however, data for other New England lakes show clear trends toward later ice-in and earlier ice-out dates. Thus, the lake “growing season” is likely increasing, even if water temperatures have not yet risen significantly.

Gregg Lake thermally stratifies over the course of each summer in response to changing air temperatures, forming the **epilimnion**—a warm, oxygen-rich stirred layer at the top, the **metalimnion**—a layer of rapidly-changing water temperature in the middle, and the **hypolimnion**—a cold, oxygen-poor unstirred layer at the bottom.

Phosphorus. Phosphorus can occur naturally in lakes, but human activities have resulted in excessive amounts of phosphorus entering many lakes and streams, resulting in elevated nutrient loads. Phosphorus is usually the limiting plant nutrient in New Hampshire lakes, and too much phosphorus can impair water quality by promoting excess growth of algae. The recent median total phosphorus (TP) in the epilimnion in Gregg Lake—the value used as the “Existing Median Water Quality” for assessing the lake water quality status—was calculated to be 6.8 µg/L, below the “Impaired” threshold of 8 µg/L for an oligotrophic (low-nutrient) lake, but not far below the 7.2 µg/L threshold marking the 10% reserve, or assimilative, capacity recommended by NHDES “Antidegradation” provisions designed to protect our surface waters from degrading. However, since phosphorus is the nutrient “stressor” for the chlorophyll-a “response,” chlorophyll-*a* levels above the “Impaired” threshold determine that there is no assimilative capacity for phosphorus in Gregg Lake.

TP in the deeper thermal layers at the Deep Spot and at the Gregg Lake Inlet was above the 8 µg/L threshold. High TP in the hypolimnion may be the result of phosphorus carried into the lake by stormwater, bottom disruption, shoreline erosion, upstream sources settling in the deeper waters and/or the release of phosphorus from bottom sediments under anoxic conditions (internal loading). A late-summer rise in the hypolimnion TP suggests internal loading. Sampling at the Inlet and at new stations established farther upstream showed phosphorus entering Gregg Lake from the extensive upstream wetlands.

Statistical analysis showed no significant increasing or decreasing trends in phosphorus levels in the epilimnion or the hypolimnion at the Deep Spot, or at the Gregg Lake Inlet and Outlet sampling stations. The only significant long-term trend was a slight increasing trend in TP in the metalimnion.

Measured phosphorus amounts in Gregg Lake water samples, along with models of phosphorus carried into lakes with stormwater runoff, allow estimation of the contributions made to Gregg Lake phosphorus loading from various sources. Using bathymetry data to estimate volumes at different depths and recent summer median TP values for the thermal layers at the Deep Spot, the total phosphorus content in Gregg Lake was calculated to be 32 kg (70 lb), with 19, 8 and 5 kg in the epilimnion, metalimnion and hypolimnion, respectively. Calculation of the phosphorus content due to internal loading, using the difference between the late-summer TP values in the epilimnion and hypolimnion as the amount of TP released from bottom sediments, gave an estimate of 5 kg/yr, or 16 % of the estimated total phosphorus in the lake.

Chlorophyll-*a*. Chlorophyll-a, a green pigment found in nearly all plants, is used as an indicator of algae. Peaks of Chl-*a* in June and again in October were consistent with normal seasonal cycles of algal growth. Historic and recent mean and median summer Chl-*a* values were above the threshold of 3.3 µg/L for an oligotrophic lake, with the existing median chlorophyll-*a* calculated to be 3.93 µg/L, indicating that Gregg Lake is “Impaired” for supporting aquatic life. Algal growth is usually a response to nutrient loading, especially of phosphorus. There was no apparent difference between historic and recent Chl-*a* values and no significant long-term trend.

Dissolved Oxygen. Oxygen dissolved in the water is critical for supporting aquatic life. Dissolved oxygen, measured either as oxygen concentration (DO, in mg/L) or as a fraction of the total possible dissolved oxygen (DO % Saturation), levels at the bottom of Gregg Lake fall below those supporting aquatic life (5 mg/L and 75 % saturation, respectively) early in the summer and remain low through October. There were no apparent differences between historical and recent DO or DO % values, and there were no significant trends in either DO or DO % from 1994–2018. Using mean values for the minimum depth supporting aquatic life, it was estimated that during the summer months Gregg Lake does not support aquatic life below a depth of about 6 meters (20 % of the lake volume), based on DO criteria and below a depth of about 5 meters (30 % of the lake volume), based on DO % criteria. Extremely low DO levels (below 1 mg/L) at depths below 9 meters—covering about 4% of the lake bottom—likely contribute to internal phosphorus loading by promoting release of bound phosphorus.

Secchi-Disk Transparency. Secchi-disk transparency fluctuated through the full season in approximate correlation with changes in chlorophyll-*a* and apparent color levels, with an overall loss of transparency through the season. Readings taken with a viewscope were consistently higher than those taken without a viewscope. The recent mean and median SDT values taken without a viewscope were 4.1 m, considered to be “good,” but below the “exceptional” cutoff of 4.5 m. Mean and median historical readings were consistently higher than recent readings, but the apparently decreasing trends in summer SDT were not statistically significant.

Turbidity. Turbidity varied across the full season, with a steep rise in the hypolimnion in August and September. Significant long-term increasing turbidity trends were found for the Inlet, Outlet, epilimnion and metalimnion. Similar or lower turbidity levels in upstream samples ruled out excessive turbidity entering the lake from upstream sources. Other likely sources include motorboat traffic stirring up sediment, high boat wake eroding the shoreline and stormwater runoff.

Apparent Color. Gregg Lake apparent color increased across the full season. Apparent color in recent samples was substantially higher than that in historical samples, but too few data points were available for a statistically valid trend analysis.

Acidity (pH). pH varied somewhat across the full season, with nearly all values being below the satisfactory range (pH 6.5–8). The recent median pH was 6.52 in the epilimnion, 6.01 in the metalimnion and 5.81 in the hypolimnion. The median Inlet pH was 5.72, and that at the Outlet was 6.37. Upstream wetlands are more acidic than the lake itself and likely contribute to low lake pH. There was no apparent difference between historical and recent pH, and no significant long-term trend in pH.

ANC. ANC hovered close to the Extremely Vulnerable range, and appeared to dip during the peak of the summer, but limited data make it hard to draw conclusions. No apparent differences were found between historic and recent ANC values, and the long-term trend was not significant.

Conductivity. Conductivity was relatively constant across the full season at most locations, with a slight rise in the Inlet and a steep rise in the hypolimnion in August and September. Lower conductivity in upstream samples ruled out excessive salts entering Gregg Lake from upstream sources. All recent mean and median conductivity values were lower than corresponding historic values, but only the metalimnion showed a statistically significant decreasing conductivity trend.

Nitrogen. The available data from 1978 and 1994/5 showed Gregg Lake nitrogen levels to be below the New Hampshire lake median value.

Cations and Anions. Low calcium ion levels in Gregg Lake were predictive of sensitivity to acid rain, in agreement with data for acid neutralizing capacity. Low chloride and sulfate ion concentrations indicated minimal man-made disturbance in the watershed.

***E. coli* Counts at Gregg Lake beaches.** On rare occasions, bacteria counts have been above desired values at one station out of three at the Antrim Town Beach. Repeat testing within a few days has always shown a return to normal bacteria levels. The arithmetic mean, median and geometric mean of recent *E. coli* counts at all Town Beach stations, although low, were higher than the corresponding historic *E. coli* counts, and the trend appeared to be toward increasing bacteria counts. Bacteria counts have not been a concern at the private Harbor Camp, White Birch Point and Sawyer beaches.

Phytoplankton. Gregg Lake has experienced algal blooms in shallow waters in the last few years. Phytoplankton analysis by genus at the Deep Spot at different times during the summer revealed primarily diatoms and golden-brown algae, with some green algae, as expected in early and mid-successional algal waves. Phytoplankton analysis by division in June 2016 revealed predominantly early-succession phytoplankton (diatoms, golden-browns and cryptomonads), along with some green algae. In 2018, nearly identical amounts of early-succession phytoplankton were found, but a large fraction of the remainder was made up of cyanobacteria, and in September 2018, Gregg Lake likely experienced its first recognized cyanobacteria bloom.

Fish. Gregg Lake is being managed by NHFGD as a Quality Bass Water. Local anglers reported declines in hornpout, pickerel, sunfish and perch. Mercury levels in fish tissue are consistent with state-wide levels and determine strict consumption advisories. No zooplankton data is available for Gregg Lake.

Comparison with NH lake median values. Gregg Lake ranks better than the New Hampshire lake median for total phosphorus, chlorophyll-*a*, Secchi-disk transparency, turbidity, conductivity and chloride concentration, whereas it is the same as the median for pH and ranks worse than the median for hypolimnion dissolved oxygen, apparent color, and acid neutralizing capacity (Fig. 5.1).

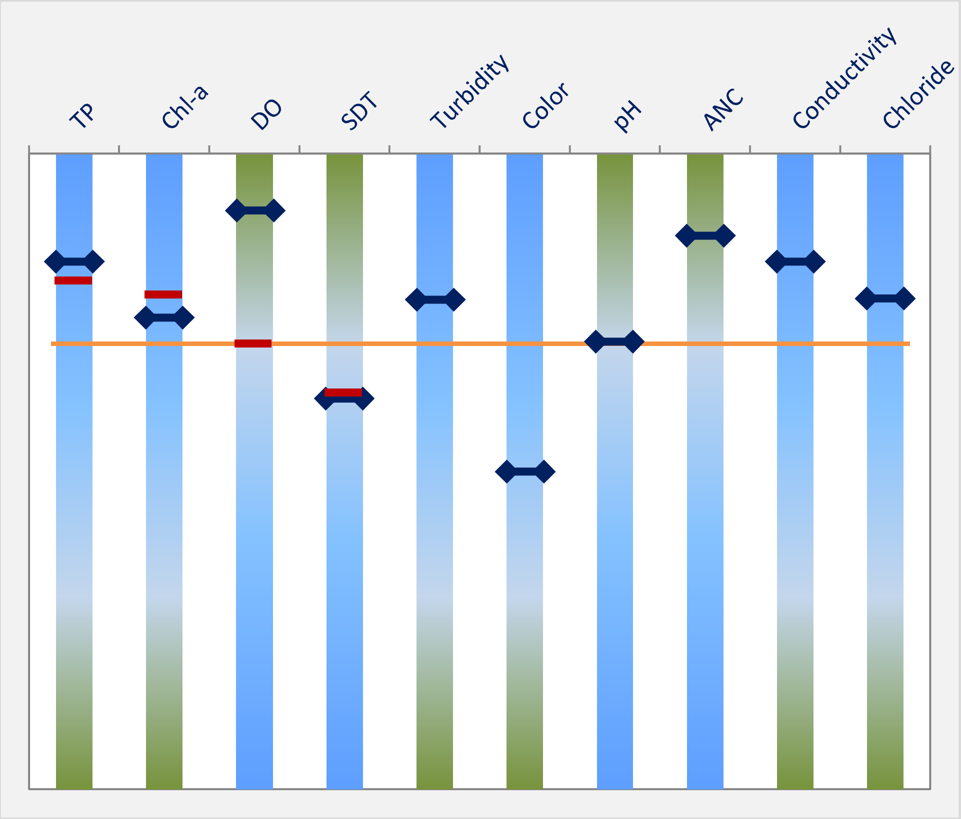


Figure 5.1. *Gregg Lake water quality parameters (blue arrows) compared with oligotrophic lake criteria (red bars) and New Hampshire lake median values (orange bar). Blue shading represents desirable range; green represents undesirable range.*

5.2. Gregg Lake Designated Uses

Aquatic Life Integrity. Under its classification as an oligotrophic lake, Gregg Lake is impaired for Aquatic Life Integrity.

- The remaining assimilative capacity for chlorophyll-*a* is -0.96 µg/L, 29 % above the criterion.
- Chlorophyll-*a*, as the response indicator, determines the "Impaired" status, and thus there is no remaining assimilative capacity for phosphorus.
- In the summer months, 20 % of the lake volume is below the criterion for DO and 30 % is below the criterion for DO % Saturation; approximately 4 % of the bottom area is anoxic.
- Although the recent median epilimnetic pH was 6.52, the pH in the epilimnion, as well as at all other sampling stations, frequently falls below the pH 6.50 threshold for Aquatic Life Integrity.

Primary Contact Recreation. For Primary Contact Recreation, the first indicator is bacteria or pathogens in the water, as indicated by *E. coli* counts. Acceptable bacteria levels at designated public beaches, such as the Antrim Town Beach, are set at a geometric mean criterion of 47 per 100 mL sample, or a single sample maximum criterion of 88 per 100 mL for Class B fresh water. Single sample exceedances of 290 and 160 were found in 2007 and 2012, respectively, at Gregg Lake; and three samples, in 2013, 2014 and 2017, were above 47/100 mL, but in all cases, repeat testing showed low *E. coli* counts. Recent geometric mean *E. coli* counts of 2.7, 4.4 and 4.3/100 mL at the Left, Center and Right stations, respectively, although low, are higher than the corresponding historic *E. coli* counts, and significant increasing trends were found for the Left and Right stations. Bacteria counts have not been a concern at the private Harbor Camp, White Birch Point and Sawyer beaches.

The second indicator for Primary Contact Recreation is the discharge of raw sewage, for which there is no indication at Gregg Lake. The third indicator is Chl-*a*, for which the criterion is 15 µg/L in fresh water; the recent median Chl-*a* at Gregg Lake was 3.93 µg/L, and the maximum recent value was 7.47 µg/L, well below the threshold. Other indicators include "Color, Foam, Debris, Scum, Slicks, Odors, and Surface-Floating Solids," which have rarely been a concern at Gregg Lake in the past. In 2018, suspected floating particles of cyanobacteria were observed several feet offshore at the mid-point of the lake.

Secondary Contact Recreation. For Secondary Contact Recreation use, higher bacteria (pathogen) levels are tolerated. Other indicators are raw sewage discharge and navigational obstructions to boating. Gregg Lake has not had any exceedances for this designated use.

Fish Consumption. For Fish Consumption, the primary indicator is mercury levels in fish tissues. Fish consumption advisories are posted for Gregg Lake fish, which have mercury levels slightly above the state mean.

5.3. Data Comparisons

Relationship of chlorophyll-*a* and phosphorus. Studies in New Hampshire lakes have shown that phosphorus is a nutrient indicator or "stressor," with chlorophyll-*a* as the linked response indicator. For oligotrophic lakes in New Hampshire, median TP values below 8 µg/mL are usually associated with median Chl-*a* values of less than 3.3 µg/L. In Gregg Lake, Chl-*a* values were relatively high compared to phosphorus levels—whereas Gregg Lake's existing median TP was found to be 6.8 µg/mL, the existing median chlorophyll-*a* was found to be 3.93 µg/L. The reason for this disequilibrium is unclear; Gregg Lake may simply not fall near the median values for NH lakes, or there may be other nutrients released, for instance methane or ammonia coming from anoxic decaying vegetation. However, the "Impaired" status determined by the Chl-a levels dictate that there is no remaining assimilative capacity for phosphorus.

Relationship of transparency with apparent color, chlorophyll-*a* and turbidity. Apparent color and chlorophyll-*a* showed clear inverse relationships with Secchi-disk transparency across the full season (Fig. 5.2). The relationship of SDT with turbidity across the full season was not so apparent, as turbidity rose in July and August, perhaps due to motorboat traffic, fell in September, and rose sharply again in October.

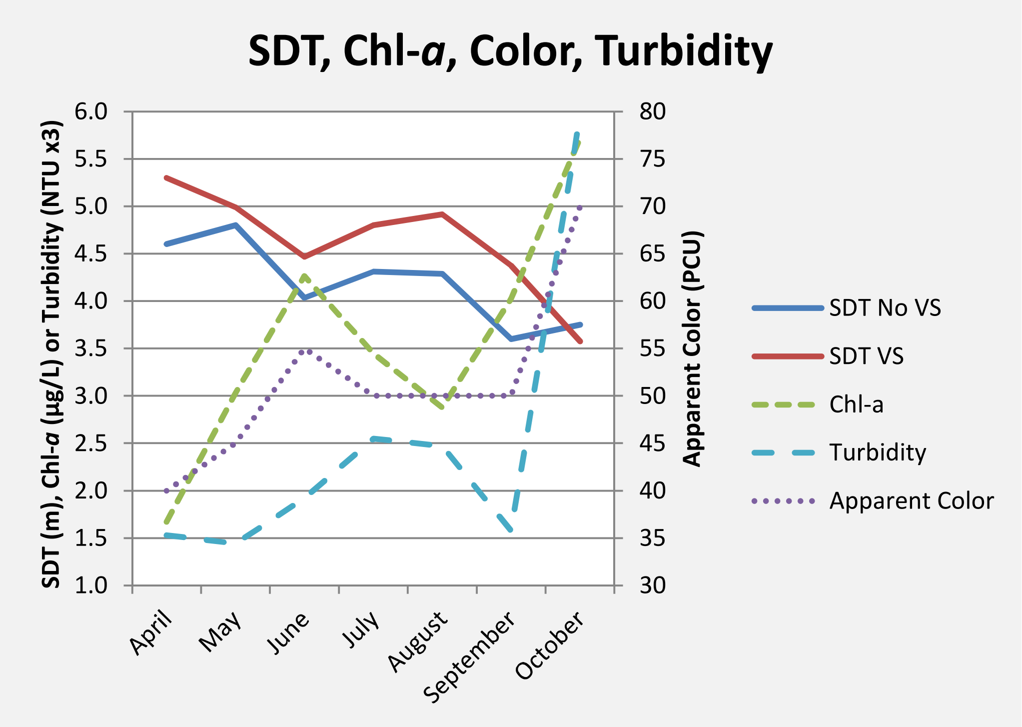


Figure 5.2. *Relationship between Secchi-disk transparency, measured either with or without a viewscope (VS), chlorophyll-a, epilimnion apparent color and turbidity at the Deep Spot in Gregg Lake over the full season, using mean data for 2016–2018.*

Although not statistically significant when analyzed by *rkt* in *R*, SDT appears to be decreasing over time (Fig. 5.3). Long-term increasing trends in turbidity were statistically significant at the Inlet and Outlet, as well as in the epilimnion (Fig 5.3) and metalimnion at the Deep Spot. Suspended sediment, such as silt and clay stirred up from the bottom, eroded from the shoreline or carried in with stormwater, and algae, as measured by Chl-*a*, both contribute to turbidity. The long-term Chl-*a* trend over the same period of time does not show an increase analogous to that of turbidity. Although there are too few points for valid statistical analysis, it seems clear that apparent color has increased in Gregg Lake over the past 40 years. These data suggest that increasing color and turbidity contribute more to the decreasing SDT in Gregg Lake than algal growth contributes.

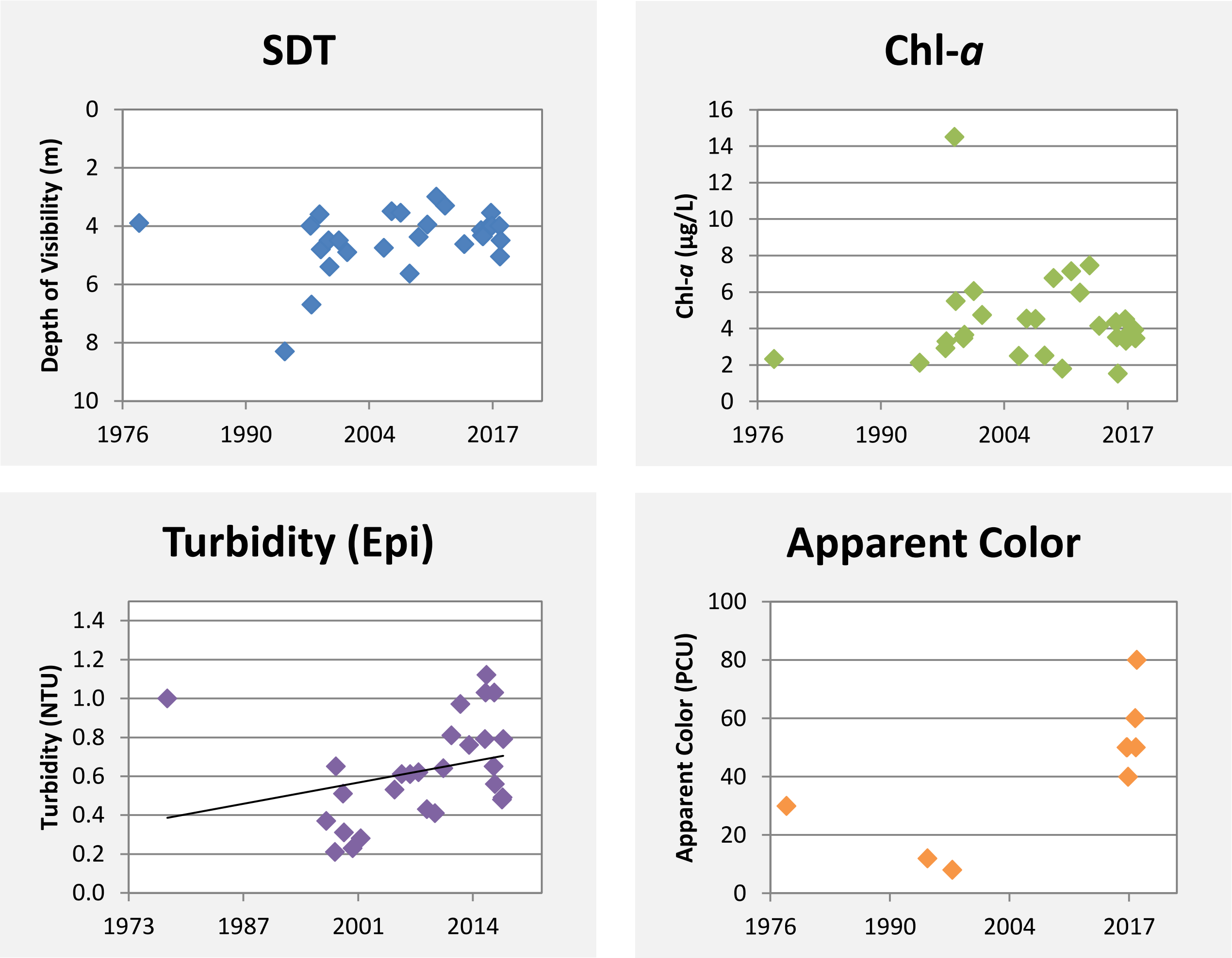


Figure 5.3. *Comparison of long-term trends in Secchi-disk transparency, epilimnion turbidity, chlorophyll-a and apparent color at the Deep Spot in Gregg Lake. Each data set used summer-season data only. Only turbidity showed a statistically significant trend; a linear trendline using all the data was applied in the figure. Statistical analysis for trends was performed using the rkt package in the R computing environment.*

Other Factors. Beaver-impounded wetlands feed the Gregg Lake Inlet. The beaver dams likely trap large amounts of sediment that would otherwise enter the lake. These wetlands are marshes of mixed classifications, and include some plants characteristic of very acidic bog and poor fen communities, such as cranberries and pitcher plants growing on floating peat mats. The farthest upstream beaver ponds are rarely disturbed.

However, beaver dams are periodically breached under the Craig Road and Gregg Lake Road bridges, and a large volume of sediment and debris is carried into the lake, along with acidic and highly colored water.

The water level in Gregg Lake was first raised by a dam in 1793. Successive dams have gradually raised the water level. The area known as "The Meadows," which was mowed for hay in the memory of some area residents, is now under water year-round and the dominant vegetation has changed from grasses to aquatic plants, which die back each fall and release nutrients into the water as they decay. Construction of the new public beach in the meadows area in the late 1960s added incentive to keep the water level high, and since the dam was rebuilt in 1982, the water has routinely been kept at even higher levels.

Gregg Lake has a relatively large watershed-to-lake area ratio of 15.3 and a flushing fate of only 1.6/yr, which means nutrients are washed into Gregg Lake from a relatively large area and are flushed at a relatively low rate.

5.4. Summary

Gregg Lake appears to have reached a critical point in which algae growth has uncoupled from a direct correlation with the usually-limiting nutrient phosphorus. With the exception of a statistically significant slightly increasing trend in TP in the metalimnion, there is no evidence that Gregg Lake has experienced a significant rise in phosphorus levels over the past 40 years. Chlorophyll-*a* levels at the Deep Spot have not shown a significant increase, but are holding at a level above the criterion for an oligotrophic lake, and unprecedented algal blooms have appeared in shallow water over the past several years. Turbidity has increased significantly at nearly all locations; apparent color has almost certainly increased and transparency appears to be decreasing. All of these factors suggest that Gregg Lake is experiencing an influx of sediment, which contributes to turbidity, phosphorus and nitrogen loading. The sediment can be coming from stormwater runoff, disruption of the lake bottom and/or erosion of the shoreline due to boat wake. Phosphorus can also enter the lake from septic systems and internal loading.

Calculations give an estimate of a total load of 32 kg of phosphorus in Gregg Lake, with 5 kg coming from internal phosphorus loading due to anoxic conditions near the lake bottom. Estimates of sediment, phosphorus and nitrogen loads entering the lake through stormwater runoff "hotspots" suggest that implementing management practices for the top ten "hotspots" would potentially reduce the phosphorus load to Gregg Lake by 10 kg/yr. Reducing the phosphorus load by 10 kg/yr would give an overall average TP value of 5.2 µg/L, as compared to the current overall average TP of 7.6 µg/L. Enforcement of boating laws (speed and distance from shoreline) and management of beaver dams under the two bridges at the lake inlet would also substantially cut the amount of sediment entering the lake water. Septic upgrades will also contribute to reducing the phosphorus load on the lake. Reduction of sediment may also lead to improving dissolved oxygen concentrations in the deepest waters and thus reduce internal loading.

Water quality monitoring monthly from April through October for two consecutive years illustrated processes that go on in the lake over the course of the full season. The addition of four upstream stations gave a much better picture of the quality of the water entering Gregg Lake at the Inlet. Monitoring should be continued at least monthly from June through August in the future, with upstream monitoring included.

To address the issue of internal loading, which appears to contribute approximately 5 kg/yr (or 16%) to the phosphorus load, it would be useful to try to collaborate with researchers at Plymouth State University to analyze bottom sediment core samples. Assessment of the biological health of the Gregg Lake ecosystem might be enhanced by undertaking zooplankton analysis.

6. REFERENCES

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APPENDICES

A. VLAP Report 2017
B. NHFGD F50R25 Job 10 Report
C. NHFGD F50R26 Job 10 Report