LAKE HOPATCONG – 2021 WATER QUALITY REPORT

MORRIS AND SUSSEX COUNTIES, NEW JERSEY

JANUARY 2022

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1.0 INTRODUCTION

Princeton Hydro, LLC conducted general water quality monitoring of Lake Hopatcong during the 2021 growing season (May through September). This monitoring program represents a continuation of the long-term monitoring program of Lake Hopatcong. While the 2010 through 2012 water quality monitoring programs were conducted with funds awarded to the Lake Hopatcong Commission by NJDEP through the Non-Point Source (319(h) of the Clean Water Act) grant program (Project Grant RP10-087), the water quality monitoring program of 2013 was funded through the Lake Hopatcong Foundation as a monetary match toward the grant. Remaining funds in the 319(h) grant were made available for the 2014, 2015, and 2016 water quality monitoring programs. The annual water quality monitoring program was funded by the Lake Hopatcong Commission from 2018 through 2021.

The current water quality monitoring program is a modified version of the program that was originally initiated in the Phase I Diagnostic / Feasibility Study of Lake Hopatcong (PAS, 1983) and continued through the Phase II Implementation Projects. Both the Phase I and Phase II projects were funded by the US EPA Clean Lakes (314) Program. The modified monitoring program also continued through the development, revision, and approval of the TMDL-based Restoration Plan, as well as through the installation of a series of watershed projects funded through two NJDEP 319 grants and a US EPA Targeted Watershed grant. Finally, some additional monitoring was conducted during each sampling event in 2020 and 2021, as part of the HAB grant awarded in 2020 as well as a 319 grant (*WQR-2019-LHC00130)* awarded in 2021. The recent 319 grant involved modeling efforts to better quantify the internal phosphorus load on a seasonal and monthly basis under varying hydraulic conditions and will also involve the implementation of various in-lake and watershed-based projects to reduce nutrient loading to the waterbody.

The current water quality monitoring program is valuable in terms of continuing to assess the overall "health" of the lake on a year-to-year basis, identifying long-term trends or changes in water quality, and quantifying and objectively assessing the success and potential impacts of restoration efforts. In addition, the in-lake water quality monitoring program continues to be an important component in the evaluation of the long-term success of the implementation of the phosphorus TMDL-based Restoration Plan, which was approved by NJDEP in April of 2006. The monitoring program also provides the data necessary to support the Foundation's and Commission's requests for grant funding to implement both watershed-based and in-lake projects to improve the water quality of Lake Hopatcong. Finally, much of the data collected in 2021 will be used to assess the relative effectiveness of in-lake and watershed-based projects, designed to prevent or minimize the impacts of HABs in Lake Hopatcong.

2.0 MATERIALS AND METHODS

In-lake water quality monitoring was conducted at the following eleven (11) locations in Lake Hopatcong (represented as red circles in Figure 1, Appendix A) during the 2021 study period:

Station Number	Location
1	Woodport Bay
2	Mid-Lake
3	Crescent Cove/River Styx
4	Point Pleasant/King Cove
5	Outlet
6	Henderson Cove
7	Inlet from Lake Shawnee
8*	Great Cove
9*	Byram Cove
10	Northern Woodport Bay
11	Jefferson Canals

* *In-situ* monitoring only

During the 2021 season, sampling was conducted on 19 May, 9 June, 13 July, 17 August and 14 September. An Aqua TROLL 500 multi-probe unit was used to monitor the *in-situ* parameters dissolved oxygen (DO), temperature, pH, and specific conductance during each sampling event. Data were recorded at 1.0 m increments starting at 0.1-0.2 m below the water's surface and continued to within 0.5-1.0 m of the lake sediments at each station during each sampling date. In addition, water clarity was measured at each sampling station with a Secchi disk.

Discrete water quality samples were collected with a Van Dorn sampling device at 0.5 m below the lake surface, mid-depths and 0.5 m above the sediments at the mid-lake sampling site (Station 2). Discrete samples were collected from a sub-surface (0.5 m) position at the remaining six (6) original sampling stations (Stations 1, 3, 4, 5, 6 and 7) and additionally at the Northern Woodport Bay and Jefferson Canals sites (Stations 10 and 11, respectively) on each date. Discrete water samples were appropriately preserved, stored on ice, and transported to a State-certified laboratory for the analysis of the following parameters:

- total suspended solids
- total phosphorus-P
- soluble reactive phosphorus-P
- nitrate-N
- ammonia-N
- chlorophyll *a*

All laboratory analyses were performed in accordance with *Standard Methods for the Examination of Water and Wastewater, 18th Edition* (American Public Health Association, 1992). Monitoring at the Great Cove (Station 8) and Byram Cove (Station 9) sampling stations consisted of collecting *in-situ* and Secchi disk data; no discrete water samples were collected from these two stations for laboratory analyses. It should be noted that prior to 2005, Station 10 had been monitored for *in-situ* observations only, but the decision was made to include discrete sampling following observations made by the Lake Hopatcong Commission operation staff.

During each sampling event, phytoplankton and zooplankton samples were collected at the surface and mid-depths at the deep sampling station (Station 2). Phytoplankton samples were collected at the surface and mid-depths utilizing a Van Dorn sampling device and quantitatively assessed, while zooplankton samples were collected utilizing a Schindler sampling device at each of those depths and qualitatively assessed. Phytoplankton grab samples were also collected at the surface of Station 3 for the quantitative assessment of cyanobacteria.

3.0 RESULTS AND DISCUSSION

3.1 IN-SITU PARAMETERS

THERMAL STRATIFICATION

Thermal stratification is a condition where the warmer surface waters (called the epilimnion) are separated from the cooler bottom waters (called the hypolimnion) through differences in density, and hence, temperature. Thermal stratification separates the bottom waters from the surface waters with a layer of water that displays a sharp decline in temperature with depth (called the metalimnion or thermocline). In turn, this separation of the water layers can have a substantial impact on the ecological processes of a lake (for details see below). Thermal stratification tends to be most pronounced in the deeper portions of a lake. Thus, for convenience, the discussion on thermal stratification in Lake Hopatcong focuses primarily on the deep, mid-lake (Station 2) sampling station.

Strong and extensive amounts of thermal stratification can effectively "seal off" the bottom waters from the surface waters and overlying atmosphere, which can result in a depletion of dissolved oxygen (DO) in the bottom waters. With the exception of a few groups of bacteria, all aquatic organisms require measurable amounts of DO (> 1 mg/L) to exist. Thus, once the bottom waters of a lake are depleted of DO, a condition termed anoxia, that portion of the lake is no longer available as viable habitat.

Surface temperatures observed at Station 2 during the 2021 season exhibited seasonal variation, with minimum temperatures of 18.26 °C noted during the 19 May event increasing to maximum temperatures of 25.93 °C on 17 August (Appendix B). Thermal stratification was noted during the first sampling event, with a shallow epilimnion extending from the surface to 2 m. A short thermocline was noted from approximately 2 m to 4 m, before temperatures gradually and steadily declined through the hypolimnion. The epilimnion increased in size during the next three sampling events as surface water temperatures increased, extending through 3 m in June, and 4 m in July and August. The thermoclines were variable during each of these events, but yielded sharp declines to depths of 8-10 m. By the 14 September sampling event, water temperatures were relatively uniform through 7 m before declining to the bottom. Thermal stratification was noted at Station 2 throughout the 2021 sampling period.

Thermal stratification was variable among the shallower stations throughout the 2021 season. Overall, a total of eight (8) stations were stratified or displayed sharp thermal gradients during the May sampling event. Many of these stations became stratified or displayed sharp thermal gradients within 1 m of the surface. By the 9 June event, seven (7) stations exhibited varying degrees of thermal stratification. The majority of these stations became stratified withing the bottom 1-2 m of the water column. These early season thermal gradients in the shallower stations are a result of the rapid warming of the surface waters as ambient air temperatures increase in late spring and early summer. Only Stations 8 and 9 were stratified during the July and August events due to their deeper nature, while the shallower stations were well-mixed by the height of the season. Station 9 was the only station, other than Station 2, that was stratified throughout the entirety of the 2021 season.

In addition to collecting temperature data over the 2021 growing season, the long-term, surface water temperatures from Station 2 during the month of July have been graphed and shown below in Figure 1. This exercise was conducted to assess the potential impacts of climate change on Lake Hopatcong. The Station 2, mid-lake, data were used since there was no chance of shading from near-shore trees or structures at this location and the July data were used since it is typically the warmest month of the year in the Mid-Atlantic States.

As shown in Figure 1, there has been a statistically significant increase in surface water temperatures at Lake Hopatcong over the past 33 years. Additionally, the July 2021 surface water temperature at Station 2 was the fifth highest recorded at 26.87°C. The highest surface water July temperature at Station 2 was recorded in 2005 and was 28.52°C. These data provide evidence that climatic change is impacting Lake Hopatcong. In turn, increasing water temperatures makes the lake more favorable for larger and more frequent Harmful Algal Blooms (HABs).

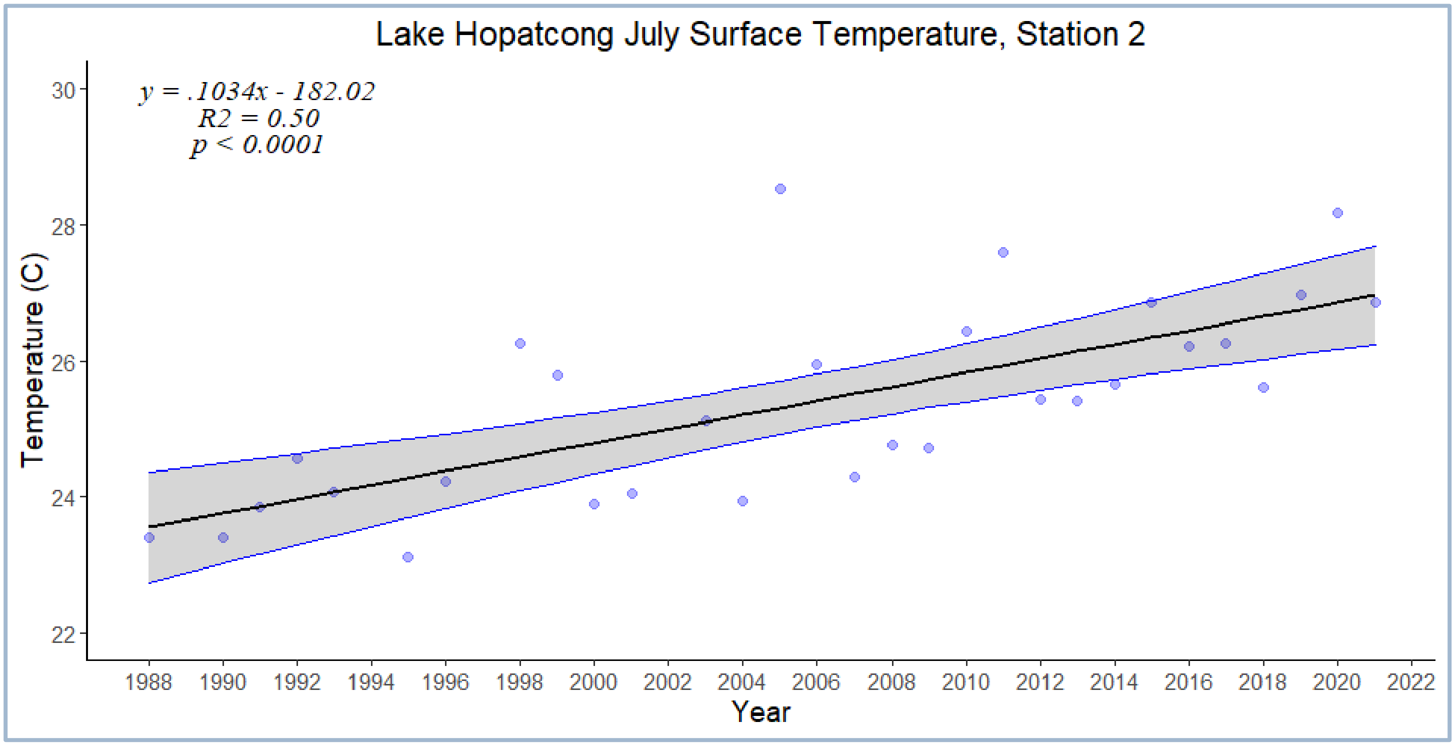


Figure 1: Long-term, July, surface water temperatures at the mid-lake sampling station at Lake Hopatcong, New Jersey. The shaded area between the blue lines represents he upper and lower 95% confidence intervals.

DISSOLVED OXYGEN

Atmospheric oxygen enters water by diffusion from the atmosphere, facilitated by wind and wave action and as a by-product of photosynthesis. Adequate dissolved oxygen (DO) is necessary for acceptable water quality. Oxygen is a necessary element for most forms of life. As DO concentrations fall below 5.0 mg/L, aquatic life is put under stress. DO concentrations that remain below 1.0 – 2.0 mg/L for a few hours can result in large fish kills and loss of other aquatic life. Although some aquatic organisms require a minimum of 1.0 mg/L of DO to survive, the NJDEP State criteria for DO concentrations in surface waters is 5.0 mg/L or greater, for a healthy and diverse aquatic ecosystem.

In addition to a temporary loss of bottom habitat, anoxic conditions (DO < 1 mg/L) can produce chemical reactions that result in a release of dissolved phosphorus from the sediments and into the overlying waters. In turn, a storm event can transport this phosphorus to the upper waters and stimulate additional algal growth. This process is called internal loading. Given the temporary loss of bottom water habitat and the increase in the internal phosphorus load, anoxic conditions are generally considered undesirable in a lake.

Surface DO at Station 2 was ample during the May sampling, yielding concentrations of 11.70 mg/L. DO increased in the first few meters of the water column to 12.80 mg/L at a depth of 3 m before declining steadily with depth. This phenomenon is known as a positive heterograde oxygen curve and occurs when a pocket of elevated oxygen forms in the thermocline and cannot disperse up or down due to thermal stratification. This often occurs early in the season when transparency is high enough to permit algal photosynthesis in the thermocline, as active photosynthesis produces oxygen. DO fell below the NJDEP threshold of 5.00 mg/L at 11 m through the bottom of the lake. Despite a decline in DO, anoxia was not observed during this event. By June, surface concentrations declined from the first event to 9.45 mg/L, remaining consistent through the first few meters. DO fell below 5.00 mg/L at 7 m and became anoxic at 11 m. Surface concentrations declined further to 8.75 mg/L by the July event. Due to the persistent thermal stratification, DO declined rapidly through the water column, dropping below 5.00 mg/L at 5 m. The water column became anoxic by 6 m in July and remained so through the bottom of the lake. DO concentrations remained ample in the surface waters during the August sampling event with concentrations of 8.19 mg/L. Similar to previous sampling events DO fell below the recommended threshold, dropping to 2.13 mg/L mg/L at 6 m, declining further to anoxic conditions at 7 m. A slight increase to 8.91 mg/L was noted in the surface waters during the final event. DO remained above 5.0 mg/L through 7 m at this time, before declining to 2.86 mg/L at 8 m. The waterbody remained anoxic in the bottom 6 meters of the water column. Supersaturated concentrations (DO>100%) were noted in the surface waters throughout the 2021 season, while anoxia persisted in the deep waters through the majority of the season due to the thermal stratification observed during each event.

Dissolved oxygen concentrations among the shallower stations were variable throughout the 2021 season. During the May event, DO concentrations remained above the NJDEP threshold at each sampling station, with surface concentrations ranging from 8.85 mg/L to 11.93 mg/L. DO declined overall in the surface by June to measures between 6.14 mg/L and 10.07 mg/L. During this event, Stations 4, 7, 9, and 11 yielded concentrations below the 5.00 mg/L threshold in the bottom waters of each station. By the July event, Stations 7 and 11 remained below the threshold throughout their respective water columns. The bottom waters of both Stations 8 and 9 were anoxic during this event, due to persistent thermal stratification. Surface DO concentration ranged from 4.84 mg/L to 8.58 mg/L during the August sampling, with concentrations once again falling below the threshold in the bottom waters of Stations 8 and 9 and the entire water column of Station 11. Anoxia persisted in the deep waters of Station 9 at this time. Oxygen concentrations were replenished at each sampling station during the September event, with exception to the deep waters of Station 9 which remained anoxic. Supersaturated surface concentrations were noted at multiple stations throughout the majority of the season.

Overall, a depression of DO was mainly limited to the hypolimnion of Station 2, as seen in previous years, with instances of anoxia in the bottom meters of various stations, such as Stations 8 and 9. A few shallower stations fell just below recommended thresholds during the height of the season. Thus, the majority of the lake had a sufficient amount of DO to support a diverse and healthy aquatic ecosystem.

To better understand the relationship between thermal stratification and DO concentrations across the growing season, isopleth figures are presented below (Figure 2 and 3).

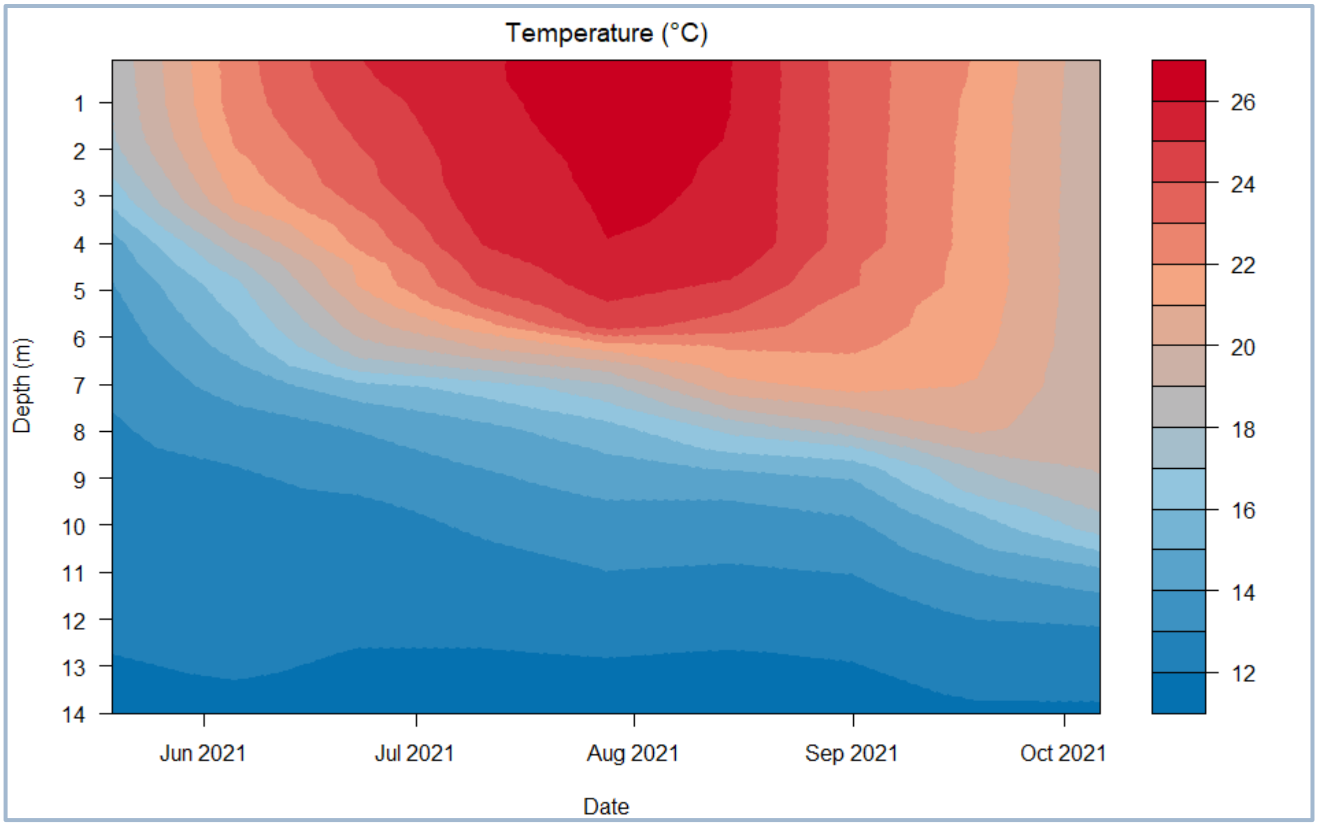


Figure 2: Temperature isopleths at Station 2 throughout the 2021 season

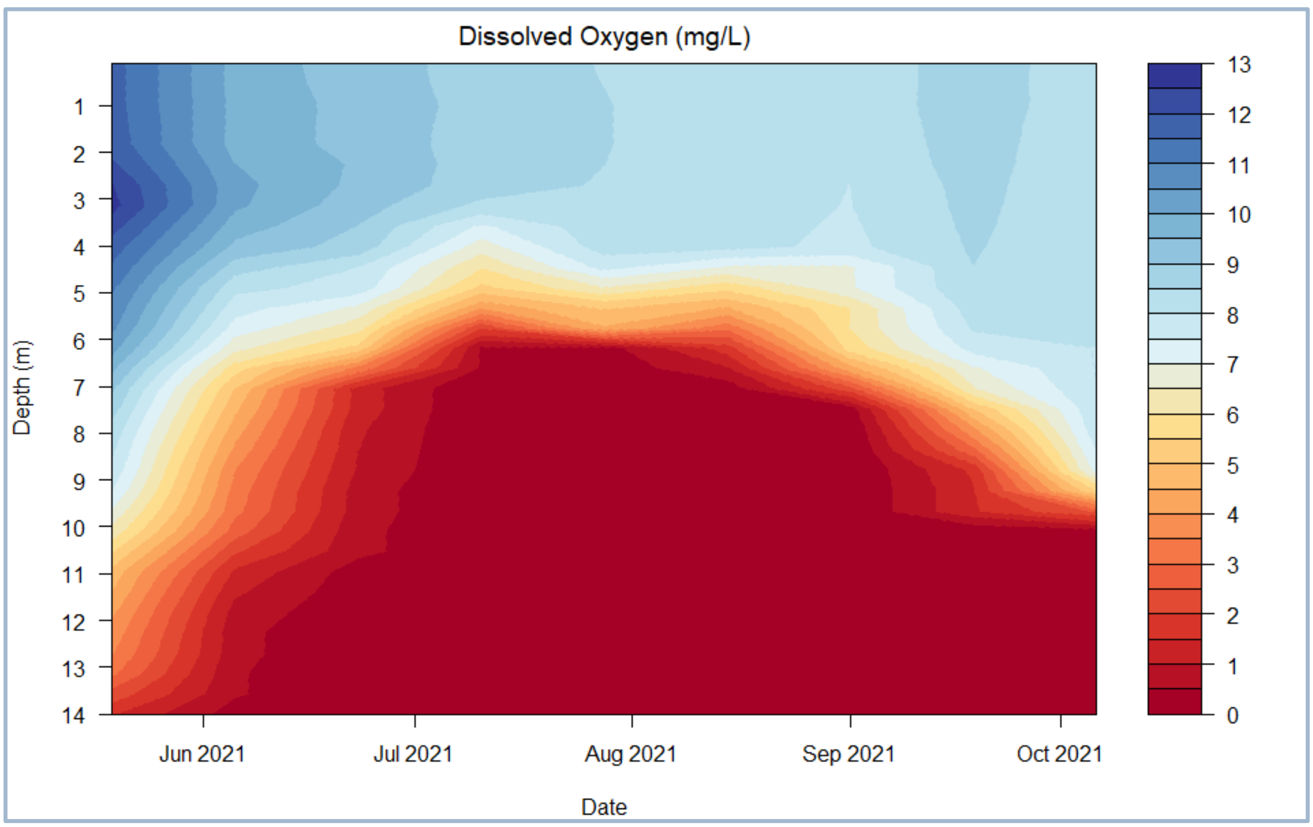


Figure 3: Dissolved oxygen isopleths at Station 2 throughout the 2021 season

PH

The pH is defined as the negative logarithm of the hydrogen ion concentration in water. When pH values are greater than 7, they are termed alkaline while those less than 7 are acidic; a pH value of 7 is neutral. The optimal range of pH for most freshwater organisms is between 6.0 and 9.0. However, the NJDEP State water quality standard for pH is for an optimal range between 6.5 and 8.5.

pH values were highest across the lake during the May sampling event, with a range of 7.37 to 8.97. During this time, seven (7) stations exceeded the optimal range of 6.5 – 8.5. Cyanobacteria densities at Station 2 were elevated compared to other sampling events, with total cell counts at the surface of 32,019 cells/mL. This increased productivity likely aided in the higher pH values at this time. The range declined overall by June, dropping to values between 6.98 and 8.56. Only Station 10 contravened the optimal range during this event with a measure of 8.56. pH values fell within the optimal range for the remaining three sampling events at each station. A slight increase in pH was often observed in the epilimnion at Station 2 before declining with depth, which was likely caused by an increase in productivity at the thermocline as mid-depth samples often yielded higher phytoplankton densities.

Water Clarity (as measured with a Secchi disk)

Transparency in lakes is generally determined through the use of a Secchi disk. The Secchi disk is a contrasting white and black disk that is lowered into the lake until no longer visible then retrieved until visible again. The average of those two lengths is termed the Secchi depth. This depth may be influenced by algal density, suspended inorganic particles, organic acid staining of the water or more commonly a combination of all three. This parameter is often times used to calculate the trophic status (productivity) of a lake and as such is a critical tool in lake evaluation. Secchi depths less than 1.0 m are generally associated with reduced water quality due to high concentrations of algae or suspended inorganic sediments and as such is generally associated with impaired quality.

Water clarity or transparency was measured at each in-lake monitoring station, during each monitoring event, with a Secchi disk. Based on Princeton Hydro's in-house, long-term database of lakes in northern New Jersey, water clarity is considered acceptable for recreational activities when the Secchi depth is equal to or greater than 1.0 m (3.3 ft).

Secchi depths were highly variable throughout the waterbody during each sampling event. Both the May and June sampling events yielded Secchi depths above the recommended 1.0 m threshold, ultimately ranging from 1.1 m (Station 7) to 2.6 m (Station 2) across both events. Clarity declined by the height of the season, with Secchi depths ranging from 0.9 m to 2.0 m. Station 11 was the only station to fall below the 1.0 m threshold at this time, however, three other stations dropped to 1.0 m. By the August event, clarity declined further at the shallower stations, with Stations 1, 3 and, 10 all yielding Secchi depths of 0.9 m. During the September event, Station 3 was the sole station to fall below the recommended threshold. The range of Secchi depth declined during this event, with maximum clarity of 1.7 m noted at Station 2. Clarity reached a seasonal low at Station 2 at this time.

3.2 DISCRETE PARAMETERS

AMMONIA-NITROGEN (NH_3-N)

Surface water NH_3-N concentrations above 0.05 mg/L tend to stimulate elevated rates of algal growth. Surface ammonia concentrations remained low during the majority of sampling events during the 2021 season. The May sampling event yielded either non-detectable concentrations (ND<0.01 mg/L) or 0.01 mg/L across all stations. By the June event concentrations ranged from 0.01 mg/L to 0.07 mg/L, only exceeding the recommended threshold of 0.05 mg/L at Station 1. The remainder of the season yielded NH_3-N concentrations at or below the 0.05 mg/L threshold (Appendix C).

Mid-depth samples collected throughout the sampling season at Station 2 varied between non-detectable concentrations (May) and 0.04 mg/L (June). These mid-depth samples were typically consistent with their surface counterparts. Similarly, deep-water ammonia was consistently at or below the 0.05 mg/L threshold during the first four sampling events, with measures between 0.02 mg/L (May) and 0.05 mg/L (June and July). Concentrations spiked to a high of 0.60 mg/L during the final September sampling event. The excessively high concentration of NH_3-N in the deep (hypolimnetic) waters at Station 2 during the final event was attributed to the depletion of DO and the bacterial decomposition of the organic matter raining to the bottom from the surface waters.

In summary, surface NH_3-N concentrations were low across the lake throughout the season. Deep samples at Station 2 only became elevated in September after the lake had been anoxic for four months.

NITRATE-NITROGEN (NO_3-N)

Nitrate-N concentrations greater than 0.10 mg/L are considered excessive relative to algal and aquatic plant growth. Typically, lakes with concentrations above 0.30 mg/L indicates elevated nitrogen-loading, however, concentrations below 0.50 mg/L are still considered acceptable water quality.

During the 11 May event, nitrate-N concentrations at the surface ranged from 0.02 mg/L to 0.12 mg/L. Stations 3 and 10 yielded concentrations greater than the recommended 0.10 mg/L threshold. Nitrates greatly increased across the lake by the June event, ranging from measures of 0.14 mg/L to 0.32 mg/L. During this event, each sampling stations exceeded 0.10 mg/L, with Station 11 yielding measures above the 0.30 mg/L threshold that is indicative of nitrogen loading. It should be noted that Station 11 is located in an area close to near-shore septic systems, which may explain the elevated concentrations. Rain events may have also influenced this increase, as approximately 1.49" of precipitation fell the day of sampling and a 1.58" storm occurred a few days prior; this influx of precipitation in June came after a relatively dry May (CLIMOD, Jefferson Twp. 4.4 SW, NJ). Concentrations declined by the July sampling event to a range of 0.04 mg/L to 0.15 mg/L. Stations 3, 7, and 11 all exceeded 0.10 mg/L at this time. Concentrations continued to decline through August with measures between 0.01 mg/L and 0.12 mg/L. Station 11 was once again above the 0.10 mg/L threshold at this time. This range widened during the final event, with maximum concentrations of 0.28 mg/L observed. Four stations exceeded the 0.10 mg/L threshold during this event, while the remaining stations yielded very low concentrations. Station 11 exceeded recommended thresholds through four of the five sampling events in 2021.

Mid-depth and deep-water samples at Station 2 were also analyzed for nitrates during the 2021 season. Overall, the majority of sampling events yielded low concentrations at a mid-depth of Station 2, only contravening 0.10 mg/L during the June sampling event (0.17 mg/L). The remaining samplings ranged between non-detectable concentrations (ND<0.01 mg/L) and 0.03 mg/L at the mid-depth. Conversely, deep-water nitrate-N concentrations exceeded the 0.10 mg/L during all but the May sampling event (0.06 mg/L), with maximum concentrations noted in August (0.32 mg/L). August concentrations were the only measures to exceed 0.30 mg/L.

In summary, all in-lake nitrate-N concentrations were consistently below the State and Federal drinking water standard of 10.0 mg/L. Nitrate-N concentrations at the surface exceeded the 0.10 mg/L threshold (has the potential to stimulate elevated amounts of algal and aquatic plant growth) during each event at a select few stations. Station 11 and the hypolimnion of Station 2 yielded elevated concentrations that exceeded 0.30 mg/L in June and August, respectively. Exceedances often occurred in near-shore sections of the lake immediately adjacent to lands that have homes using septic systems (Borough of Hopatcong around Crescent Cove / River Styx; Township of Jefferson around Woodport and in the Canals). This indicates that aged (greater than 50 years old), near-shore septic systems contribute to the pollutant load of Lake Hopatcong and thus have a direct impact on its water quality. A significant amount of rainfall was recorded during the second half of the growing season in the Lake Hopatcong watershed and surrounding region which likely influenced near-shore surface nitrate-N concentrations.

TOTAL PHOSPHORUS (TP)

Phosphorus has been identified as the primary limiting nutrient for algae and aquatic plants in Lake Hopatcong. Essentially, a small increase in the phosphorus load will result in a substantial increase in algal and aquatic plant growth. For example, one pound of phosphorus can generate as much as 1,100 lbs of wet algae biomass. This fact emphasizes the continued need to reduce the annual phosphorus load entering Lake Hopatcong, as detailed in the lake's revised TMDL and associated Restoration Plan.

The State's Surface Water Quality Standard (SWQS, N.J.A.C. 7:9B – 1.14(c) 5) for TP in the surface waters of a freshwater lake or impoundment is 0.05 mg/L. This established TP concentration is for any freshwater lake or impoundment in New Jersey that does not have an established TMDL. Lake Hopatcong has established a phosphorus TMDL, which was revised and approved by NJDEP in June 2006. Based on its refined phosphorus TMDL, the long-term management goal is to maintain an average growing season TP concentration of 0.03 mg/L or less within the surface waters of Lake Hopatcong. Based on Princeton Hydro's in-house database on northern New Jersey lakes, TP concentrations equal to or greater than 0.03 mg/L have an increasing change of developing of algal blooms / mats.

Surface TP concentrations remained low during the May sampling event, with concentrations ranging from 0.01 mg/L to 0.03 mg/L. All concentrations remained at or below the Princeton Hydro recommended threshold of 0.03 mg/L at this time. This range persisted through the June event, with each station remaining at or below the recommended threshold of 0.03 mg/L. TP concentrations increased across the lake by the July sampling, with surface TP ranging from 0.02 mg/L to 0.05 mg/L. Stations 3, 7, and 11 each contravened 0.03 mg/L, but remained at or below the NJ water quality standard of 0.05 mg/L. By the August sampling, six sampling stations exceeded 0.03 mg/L at the surface, with concentrations ultimately ranging between 0.02 mg/L and 0.06 mg/L during this event. Station 3 was the only station to exceed the NJ water quality standard during the 2021 season. A slight reduction in TP was noted during the final sampling, but Stations 1, 3, and 7 yielded elevated concentrations between 0.04 mg/L and 0.05 mg/L. Elevated concentrations at these stations may have been influenced by near-shore septic systems. As noted above, the second half of the growing season was extremely wet in the Lake Hopatcong watershed and likely influenced nearshore surface TP concentrations.

Mid-depth and deep-water TP samples were also collected at Station 2 throughout the 2021 season. Mid-depth concentrations were low throughout the season, with concentrations of 0.02 mg/L during each event. Mid-depth concentrations were typically consistent with their surface counterparts. Deep-water concentrations generally increased as the season progressed, with concentrations ranging from 0.02 mg/L (June) to 0.25 mg/L (August and September). Extremely high values were noted from July through September, with elevated TP concentrations persisting in the bottom waters of this station due to the extended thermal stratification and prolific anoxia observed causing internal loading of phosphorus.

The mean TP concentration was calculated for each surface water sampling station to determine if they each complied with the concentration of 0.03 mg/L established under the lake's TMDL. Of the nine, long-term water quality monitoring stations, five stations were compliant with this TMDL. Stations 1, 2, 4, 5, and 6 yielded average concentrations ranging from 0.018 mg/L (Station 2) to 0.028 mg/L (Station 1). The remaining sampling stations had a mean 2021 growing season concentration that exceeded 0.03 mg/L to varying degrees. Stations 7, 10, and 11 all yielded averages of 0.034 mg/L, while Station 3 yielded the highest average of 0.040 mg/L. It should be noted that some of these stations are notable for being in an area with a substantial number of near-shore septic systems. Please also note that none of the four stations that had seasonal mean TP concentrations exceeding the TMDL had a monthly concentration above 0.03 mg/L until July, at which point they remained elevated until the end of the season. The majority of the growing season precipitation in the Lake Hopatcong region fell between July and October, and much of this rain fell during discrete severe weather events that had the potential to wash a significant amount of nutrients into the lake from the watershed.

SOLUBLE REACTIVE PHOSPHORUS (SRP)

Soluble reactive phosphorus (SRP) represents the dissolved inorganic portion of total phosphorus metrics. This species of phosphorus is readily available for assimilation by all algal forms for growth and is therefore normally present in limited concentrations except in very eutrophic lakes. Princeton Hydro recommends concentrations of SRP not exceed 0.005 mg/L to prevent nuisance algal blooms.

Overall, SRP concentrations were typically low throughout the 2021 season at the surface stations of Lake Hopatcong. The May, August, and September sampling events yielded non-detectable concentrations (ND<0.002 mg/L) across each of these stations. Stations 1, 7, and 11 each yielded concentrations of 0.002 mg/L during the June sampling, while the remaining stations had non-detectable measures. The only stations that contravened the 0.005 mg/L threshold were Stations 7 and 11 during the July event, both yielding concentrations of 0.008 mg/L. The remaining stations all had non-detectable SRP concentrations at this time.

Mid-depth samples collected at Station 2 yielded non-detectable concentrations throughout the 2021 season. Deep-water SRP was more variable than its surface and mid-depth counterparts. Concentrations ranged from non-detectable during the June sampling to 0.024 mg/L during the July sampling. Deep-water measures contravened the 0.005 mg/L threshold during July and September (0.010 mg/L). Increases in the deep waters can be attributed to the extended thermal stratification and resulting anoxia causing a release of dissolved phosphorus from the sediments.

CHLOROPHYLL A

Chlorophyll-*a* is a pigment possessed by all algal groups, used in the process of photosynthesis. Its measurement is an excellent means of quantifying algal biomass. In general, an algal bloom is typically perceived as a problem by the layperson when chlorophyll-*a* concentrations are equal to or greater than 25.0 to 30.0 µg/L. In contrast, the <u>targeted</u> average and maximum chlorophyll-*a* concentrations, once Lake Hopatcong is in complete compliance with the TMDL, are predicted to be 8 and 14 µg/L, respectively.

Overall, low chlorophyll-*a* concentrations were noted across the waterbody during the May event, ranging from 2.7 µg/L at Station 5 to 8.6 µg/L at Station 3. Each sampling station remained below the 14 µg/L maximum threshold during this event. A similar range was observed during the June sampling event, with concentrations between 1.6 µg/L (Station 6) and 8.8 µg/L (Station 1). By the height of the season in July, chlorophyll-*a* concentrations spiked at each station with measures ranging from 16.0 µg/L at Station 5 to a seasonal maximum of 63.0 µg/L at Station 3. Each sampling station exceeded the TMDL maximum threshold during this event. While elevated concentrations were noted, cyanobacteria cell counts (collected at stations 2 and 3) were not noted in extreme densities during this event. Concentrations declined overall during the August event with a range of 6.0 µg/L (Station 6) to 25.0 µg/L (Station 3). Three stations yielded elevated chlorophyll-*a* measurements during this event. A similar range was noted during September, with measures between 6.9 µg/L (Station 11) and 25.0 µg/L (Station 7), with three stations exceeding the TMDL target. Mid-depth samples were also collected at Station 2, with measures ranging between 9.0 mg/L during the August event to 17.0 mg/L during the July event. Mid-depth chlorophyll-*a* concentrations at Station 2 were higher than respective surface concentrations at Station 2 during three of the five sampling events. This indicates that phytoplankton were often congregating immediately over or in the metalimnion at Station 2. Stations 1, 3, and 10 typically yielded the highest chlorophyll-*a* concentrations through the 2021 season.

Monthly chlorophyll-*a* averages across all stations were lowest during the May and June sampling events, with averages of 5.6 µg/L and 5.0 µg/L, respectively. These were the only two samplings to fall below the TMDL targeted average of 8 µg/L. The average spiked to 31.8 µg/L by the July sampling event due to lake-wide elevations. Averages declined by the August and September sampling events, yielding averages of 13.2 µg/L and 14.2 µg/L, respectively. The latter three sampling events exceeded the recommended average. Growing season averages for each station were all above the recommended 8 µg/L TMDL average, ranging from 9.2 µg/L (Station 11) to 24.0 µg/L (Station 3).

TOTAL SUSPENDED SOLIDS

The concentration of suspended particles in a waterbody that will cause turbid or "muddy" conditions, total suspended solids often a useful indicator of sediment erosion and stormwater inputs into a waterbody. Because suspended solids within the water column reduce light penetration through reflectance and absorbance of light waves and particles, suspended solids tend to reduce the active photic zone of a lake while contributing a "muddy" appearance at values over 25 mg/L. Total suspended solids measures include suspended inorganic sediment, algal particles, and zooplankton particles.

Overall, TSS concentrations remained low throughout the 2021 season. Surface concentrations ranged from non-detectable concentrations (ND < 2 mg/L) to a maximum of 17 mg/L throughout the season. Each of the sampling events yielded TSS concentrations below the 25 mg/L recommended threshold. Similarly, low TSS measurements were noted in the mid and deep waters at Station 2 during each sampling event, ranging from non-detectable concentrations (ND< 2 mg/L) to 11 mg/L.

3.3 BIOLOGICAL PARAMETERS

PHYTOPLANKTON

Phytoplankton are algae that are freely floating in the open waters of a lake or pond. These algae are vital to supporting a healthy ecosystem since they are the base of the aquatic food web. However, high densities of phytoplankton can produce nuisance conditions. The majority of nuisance algal blooms in freshwater ecosystems are the result of cyanobacteria, also known as blue-green algae. Some of the more common water quality problems created by blue-green algae include bright green surface scums, taste and odor problems and the generation of cyanotoxins. Phytoplankton samples were collected from the surface and mid-depths of Station 2 during the 2021 season and were quantitatively analyzed to be compared to NJDEP standards. Surface samples were also collected at Station 3 for quantitative analysis during each event. New Jersey implemented advanced harmful algal bloom (HAB) screening and response protocols in 2020 and as such may be utilized as a surrogate in this instance. NJ HAB standards are provided below in Figure 2.

Surface grab samples at Station 2 collected during the 11 May sampling event were characterized by seasonal maximum cyanobacteria densities, totaling 32,019 cells/mL (Appendix D). This cyanobacteria community was comprised of *Aphanizomenon*, *Planktothrix,* and *Pseudanabaena*. This event would be categorized as 'Watch" by NJDEP standards due to cell densities. The remainder of the community was comprised of low to moderate densities of diatoms, green algae, and euglenoids. By the June sampling event, surface cyanobacteria counts at Station 2 declined to 1,814 cells/mL, indicating a HAB was not present at this time. This event yielded moderate densities of the diatom *Tabellaria* with lower densities of other diatoms, chrysophytes, green algae, and euglenoids. Cyanobacteria counts increased to 17,869 cells/mL during the July event, with four cyanobacteria genera identified, including *Aphanizomenon* and *Dolichospermum*. A diverse community was observed during this event yielding twenty identified genera. Moderate densities of green algae were noted with *Eudorina*, *Gloeocystis,* and *Staurastrum* all listed as 'Common.' By the 17 August event, species richness remained high, and the community was represented by diatoms, dinoflagellates, chrysophytes, green algae, cyanobacteria, and euglenoids. Cyanobacteria densities remained below the 20,000 cells/mL "Watch" threshold, only totaling 11,627 cells/mL. An increase to 18,995 cyanobacteria cells/mL was noted during the final September event, comprised of five cyanobacteria genera; the cyanobacteria community was dominated by *Aphanizomenon* during this event. The final event was otherwise characterized by moderate densities of diatoms with lower densities of green algae, chrysophytes, euglenoids, and cryptomonads. Cell counts only warranted a 'Watch' alert level during the first sampling event at the surface of Station 2, with cell counts indicating no HABs were present for the remainder of the season.

HAB Alert Level	Criteria	Recommendations
HAB Not Present	**HAB reported and investigated. No HAB present.**	**None**
WATCH *Suspected or confirmed HAB with potential for allergenic or irritative health effects*	Suspected HAB based on field survey **OR** Confirmed cell counts ≥20K - <80K cells/mL **AND** No known toxins above public health thresholds	**Public Bathing Beaches Open** Waterbody Accessible: Use caution during **primary contact (e.g. swimming) and secondary (e.g. non-contact boating)** activities Do not ingest water (people/pets/livestock) Do not consume fish
ADVISORY *Confirmed HAB with moderate risk of adverse health effects and increased potential for toxins above public health thresholds*	Lab testing for toxins Microcystins: ≥2 µg/L Cylindrospermopsin: ≥5 µg/L Anatoxin-a: ≥15 µg/L Saxitoxin: ≥0.6 µg/L **OR** Confirmed cell counts ≥80K cells/mL	**Public Bathing Beaches Closed** Waterbody Remains Accessible: Avoid primary contact recreation Use caution for secondary contact recreation Do not ingest water (people/pets/livestock) Do not consume fish
WARNING *Confirmed HAB with high risk of adverse health effects due to high toxin levels*	Toxin (microcystins) ≥20 - <2000 µg/L	**Public Bathing Beaches Closed** Cautions as above May recommend against secondary contact recreation.
DANGER *Confirmed HAB with very high risk of adverse health effects due to very high toxin levels*	Toxin (microcystins) ≥2000 µg/L	**Public Bathing Beaches Closed** Cautions as above. Possible closure of all or portions of waterbody and possible restrictions access to shoreline.

Figure 4: NJDEP HAB Response Guidelines

Mid-depth samples collected during the 2021 season at Station 2 varied somewhat from their surface counterparts. During the May sampling event, cyanobacteria densities were greater at mid-depth with a total cyanobacteria cell count of 44,475 cells/mL. Other genera, such as *Tabellaria*, *Chlorella,* and *Trachelomonas*, were also noted in greater densities at mid-depths at this time. By the June sampling event, mid-depth cyanobacteria concentrations were far greater than those noted at the surface, exceeding them by approximately 28,000 cells/mL, with a total cyanobacteria cell count of 30,154 cells/mL. While a HAB was not identified in the surface waters, mid-depth concentrations would be categorized as a 'Watch' by NJDEP standards. The remainder of the sampling events yielded lower cyanobacteria densities at the mid-depths compared to the surface, ranging between 5,355 cells/mL (July) and 13,952 cells/mL (September).

Surface grabs were also collected at Station 3 during each sampling event. Overall, low cyanobacteria densities were noted during the first three sampling events, with counts ranging from 1,696 cells/mL in June to 13,375 cells/mL in May, indicating that HABs were not present at this station during these sampling events. By the August sampling, densities spiked to 54,797 cells/mL, categorizing this event as 'Watch' by NJDEP standards. These counts continued to increase during the September sampling, totaling cyanobacteria densities of 75,042 cells/mL. While designated as 'Watch,' this sampling event yielded cell counts bordering the 'Advisory' alert. The August and September samples were dominated by *Aphanizomenon*, but *Dolichospermum* and *Microcystis* were also identified. The August cyanotoxin sampling event, conducted separately from the standard water quality monitoring, showed elevated cell counts at the two stations further into the cove, warranting an 'Advisory' alert.

In addition to the cyanobacteria cell counts at Station 2, Turner handheld fluorometers were utilized to measure phycocyanin at the surface during these main water quality sampling events. Phycocyanin is a pigment that is produced solely by cyanobacteria and is currently being assessed by NJDEP in terms of monitoring and eventually predicting HABs. While standards have yet to be set for phycocyanin, this parameter will be sampled and entered into the historic database for the waterbody. Overall, phycocyanin concentrations were lower than observed in 2020, with a range of 4 ppb in May to 10 ppb in July and August.

Designated cyanobacteria monitoring events were conducted on near-shore sampling stations during July and August that consisted of quantifying cyanobacteria cell densities and cyanotoxin (microcystins, cylindrospermopsin and anatoxin-a). Separate reports were prepared including the results and analysis of this data.

ZOOPLANKTON

Zooplankton are the micro-animals that live in the open waters of a lake or pond. Some large-bodied zooplankton are a source of food for forage and/or young gamefish. In addition, many of these large-bodied zooplankton are also herbivorous (i.e. algae eating) and can function as a natural means of controlling excessive algal biomass. Given the important role zooplankton serve in the aquatic food web of lakes and ponds, samples for these organisms were collected at the surface and mid-depths of Station 2 during each monitoring event.

The zooplankton community in the surface water of Station 2 was characterized by low densities during the May sampling. The cladoceran *Bosmina* and rotifers *Keratella*, *Polyarthra,* and *Trichocerca* were each noted as 'Rare' or 'Present' at this time. Densities increased by the June sampling, with co-dominance exerted by *Bosmina* and the rotifer *Conochilus*. The cladoceran *Daphnia* was noted in low densities at this time. Peak species richness was observed in July with a total of ten identified genera. This event was characterized by moderate to high rotifer densities. By the August event, dominance was exerted by both *Bosmina* and *Keratella*, with moderate densities of various copepods and rotifers. Species richness declined to five identified genera during the final sampling event, represented by cladocerans, copepods, and rotifers. Moderate densities of *Polyarthra* were noted, with low densities of the remaining four genera.

Mid-depth samples were often highly variable from the community observed at the surface. The May sampling event was comprised of a mixture of cladocerans, copepods, and rotifers. Co-dominance was exerted by *Bosmina* and *Keratella* during this event with moderate densities of *Polyarthra* noted. By the June sampling event, five genera were identified as 'Common,' including *Bosmina*, *Cyclops*, *Conochilus*, *Polyarthra,* and copepod nauplii. The remaining four genera were observed in low densities. Peak species richness was noted during the July event with eleven identified genera. High densities were noted during this time, with *Cyclops* and copepod nauplii both listed as 'Abundant,' and five genera listed as 'Common.' Richness declined to seven genera during August, with co-dominance exerted by *Bosmina*, *Keratella* and *Polyarthra*. By the September event, the community was characterized by a low to moderate density mixture of cladocerans, copepods and rotifers. The rotifers *Ascomorpha* and *Keratella* and copepod nauplii were identified as 'Common' during this sampling. *Daphnia* was not observed at this depth during the 2021 season, but other large-bodied and smaller herbivores were identified.

Herbivorous zooplankton were present within Lake Hopatcong during the 2021 sampling period. Low densities of the large-bodied cladoceran *Daphnia* were noted during the June event, while other smaller herbivores were noted in various densities throughout. Such conditions are indicative of a fishery community dominated by a large number of small, zooplankton-feeding fishes, such as golden shiners, alewife, young perch, where a large population of large-bodied zooplankton cannot exert a high degree of algal control through grazing.

3.4 RECREATIONAL FISHERY AND POTENTIAL BROWN TROUT HABITAT

Of the recreational gamefish that reside or are stocked in Lake Hopatcong, trout are the most sensitive in terms of water quality. For their sustained management, all species of trout require DO concentrations of at least 4 mg/L or greater. However, the State's designated water quality criteria to sustain a healthy, aquatic ecosystem is a DO concentration of at least 5 mg/L.

While all trout are designated as cold-water fish, trout species display varying levels of thermal tolerance. Brown trout (*Salmo trutta*) have an optimal summer water temperature range of 18 to 24 °C (65 to 75 °F) (USEPA, 1994). However, these fish can survive in waters as warm as 26 °C (79 °F) (Scott and Crossman, 1973), defined here as acceptable habitat. The 2021 temperature and DO data for Lake Hopatcong were examined to identify the presence of optimal and acceptable brown trout habitat. As with previous monitoring reports, this analysis focused primarily on *in-situ* data collected at the mid-lake sampling station (Station 2).

For the sake of this analysis, sections of the lake that had DO concentrations equal to or greater than 5 mg/L and water temperatures less than 24°C were considered optimal habitat for brown trout. In contrast, sections of the lake that had DO concentrations equal to or greater than 5 mg/L and water temperatures between 24 and 26°C were considered acceptable or carry over habitat for brown trout.

Optimal brown trout habitat was present throughout the majority of the water column of Station 2 during the May event, but due to a decline in DO in the deeper waters, trout habitat was not present between 11 m and the lake bottom. The range of optimal brown trout habitat declined during the June sampling and was present in the surface waters through 6 m. By the July sampling, carry over habitat was present from the surface through 4 meters, before oxygen concentrations declined below 5 mg/L. Optimal habitat was not noted at Station 2 during this time. Carry over habitat persisted through the August sampling, ranging from the surface through 5 m. Optimal habitat was not reestablished during this sampling event. By the September sampling event optimal habitat was observed at the surface through 7 m, before depressed oxygen caused unsuitable trout habitat in the bottom waters.

Optimal brown trout habitat was found throughout the water column at the remaining stations during the May sampling. By the June sampling, optimal habitat was noted in portions of the water columns of Stations 3 (2 m), 4 (1-2 m), 5 (2-3 m), 8 (1-6 m) and 9 (1-6 m). Carry over habitat was noted in the entirety of Station 1 while the remaining stations yielded carry over habitat at the surface, 1 m, or both. Any unsuitable habitat observed during this time was caused by depressed dissolved oxygen concentrations, with exception to Station 10 which had elevated temperatures in the surface waters. During the July event, trout habitat was not observed at Stations 1, 7, 10, and 11. Only Carry over habitat was observed at this time, noted throughout the entirety of Stations 3, 4, and 5 and portions of Stations 6 (3 m), 8 (0.1-4 m) and 9 (3-5 m). Carry over trout habitat was identified at all but Station 11 during the August event. Stations 3, 4, 5, 6, 7 and 10 all yielded carry over habitat throughout the water column during this event, while only portions of Stations 1 (2 m), 8 (0.1-4 m) and 9 (2-6 m) contained this habitat. Optimal habitat was reestablished throughout the entirety of all but one sampling station during the September event. The bottom meter of Station 9 became anoxic, indicating brown trout habitat was not present at this time.

3.5 MECHANICAL WEED HARVESTING PROGRAM

Many of the shallower sections of Lake Hopatcong are susceptible to the proliferation of nuisance densities of rooted aquatic plants. Given the size of Lake Hopatcong, the composition of its aquatic plant community, and its heavy and diverse recreational use, mechanical weed harvesting is the most cost effective and ecologically sound method of controlling nuisance weed densities. Thus, the weed harvesting program has been in operation at Lake Hopatcong since the mid-1980's with varying levels of success. However, one consistent advantage mechanical weed harvesting has over other management techniques, such as the application of aquatic herbicides, is that phosphorus is removed from the lake along with the weed biomass. In fact, based on a plant biomass study conducted at Lake Hopatcong in 2006 and the plant harvesting records from 2006 to 2008, approximately 6-8% of the total phosphorus load targeted for reduction under the established TMDL was removed through the mechanical weed harvesting program.

In sharp contrast to the 2006 – 2008 harvesting years, only 1.2% of the phosphorus load targeted for reduction under the TMDL was removed through mechanical weed harvesting during the 2009 growing season. This substantial reduction in the amount of plant biomass and phosphorus removed in 2009 was due to severe budgetary cuts that resulted in laying off the Commission's full time Operation Staff, as well as initiating the harvesting program later in the growing season. In turn, this resulted in only 1.2% of the phosphorus associated with plant biomass being harvested in 2009. However, the 2010 harvesting season resulted in the estimated removal of approximately 6% of the phosphorus load targeted for reduction under the TMDL, similar to the percentages removed in 2006 – 2008.

In contrast to the 2012 growing season, the mechanical weed harvesting program ran longer in 2013 through 2016. This was primarily due to the fact that the program was initiated earlier in these years relative to 2012. NJDEP has directly overseen the operation of the weed harvesting program for the last seven years and each year displays a higher rate of removal, which was attributed to hired staff becoming more familiar with the operations and lake-specific conditions. In addition, the operations staff has been excellent at maximizing high rates of efficiency during harvesting operations.

Due to an extremely unfortunate accident at the initiation of the 2020 harvesting season, the harvesting of aquatic vegetation at Lake Hopatcong was largely postponed over the 2020 growing season. The removal of only 35 cubic yards (16 tons) of plant biomass from Lake Hopatcong in 2020 resulted in the removal of only 3 kgs (6 lbs) of TP from the lake. This was less than 0.1% of the TP load targeted for removal under the TMDL.

Mechanical weed harvesting was not conducted during the 2021 season. A combination of working through insurance and ownership / operation of the equipment, as well as the lower amounts of aquatic vegetation found throughout the lake in 2021 contributed toward the lack of harvesting. More specifically, the more normal winter of 2020 – 2021 coupled with the heavy amounts of rainfall in the second half of the summer season, resulted in a smaller crop of aquatic vegetation. Thus, no phosphorus was removed from the lake through mechanical weed harvesting.

3.6 INTERANNUAL ANALYSIS OF WATER QUALITY DATA

Annual mean values of Secchi depth, chlorophyll *a*, and total phosphorus concentrations were calculated for the years 1991 through 2021. The annual mean values for Station 2 were graphed, along with the long-term, "running mean" for the lake and can be found in Figures 2 – 4 in Appendix A.

The 2021 mean Secchi depth increased from those observed during the 2019 and 2020 season, yielding a measure of 2.0 m. A marked decline in clarity was noted in 2019 and 2020, which yielded historically low clarity due to the moderate to high cyanobacteria densities. An increase in clarity during the 2021 season was mainly attributed to the lack of these dense cyanobacteria blooms, which largely remained below levels of concern. The 2021 average Secchi depth still fell below the long-term mean of 2.07 m, but significantly closed the gap from previous years.

Mean chlorophyll-*a* concentrations sharply declined from the year prior (20.2 µg/L), yielding an average of 10.3 µg/L. Increasing chlorophyll-*a* concentrations were noted during the past two years, reaching historic highs in 2020, due to the increased presence of cyanobacteria blooms. These blooms were less frequent if not fully absent from the 2021 water quality monitoring program. The 2021 mean value still exceeded the targeted average of 8 μg/L, but they fell below the long-term mean of 10.6 μg/L for the second time in the past 6 years. The 2021 growing season was characterized as very wet, depositing 36.04" of rain between May and September (Climod2: Jefferson TWP 4.4 SW). This is over 13" more than normal values (22.39") seen during this time period, indicating that flushing rates were very high. In concert, extreme temperatures were not present in the waterbody for extended periods of time during the 2021 growing season. Ideal conditions for cyanobacteria blooms were overall less common during the 2021 season than in previous years, likely leading to lower chlorophyll-*a* concentrations.

The 2021 mean TP concentration declined slightly from the previous sampling years, with a measure of 0.018 mg/L. This average fell below the long-term average of 0.021 mg/L Overall, surface TP concentrations at Station 2 remained below the 0.03 mg/L State and TMDL standard. TP concentrations noted throughout the 2021 season did not exceed 0.02 mg/L, despite the elevated rainfall observed during the growing season.

3.7 WATER QUALITY IMPAIRMENTS, ESTABLISHED TMDL CRITERIA AND EVALUATION

As identified in N.J.A.C. 7:9B-1.5(g)2 "Except as due to natural condition, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation or otherwise render the waters unsuitable for the designated uses." For Lake Hopatcong, these objectionable conditions specifically include both algal blooms and nuisance densities of aquatic vegetation.

As described in detail in the Lake Hopatcong TMDL Restoration Plan, a targeted mean TP concentration, as well as mean and maximum chlorophyll-*a* ecological endpoint, was established to identify compliance with the TMDL. For the sake of this 2021 analysis, the mid-lake (Station 2), Crescent Cove / River Styx (Station 3) and Northern Woodport Bay (Station 10) monitoring stations were reviewed. To provide guidance for this review, the criteria developed under Lake Hopatcong's TMDL are provided below:

TMDL Criteria for Lake Hopatcong

Targeted mean TP concentration	0.03 mg/L
Targeted mean chlorophyll *a* concentration endpoint	8 μg/L
Targeted maximum chlorophyll *a* concentration endpoint	14 μg/L

Surface TP concentrations remained low throughout the 2021 season at Station 2, with the seasonal mean (0.018 mg/L) and each individual event remaining below the targeted mean concentration of 0.03 mg/L recognized under the TMDL. Overall, TP concentrations ranged from 0.01 mg/L during May to 0.02 mg/L for the remainder of the season. The 2021 seasonal mean chlorophyll-*a* concentration declined from 2020 with an average of 10.3 μg/L. While a reduction was observed, the 2021 average exceeded the targeted mean chlorophyll-*a* concentration of 8.0 μg/L. Chlorophyll-*a* concentrations ultimately ranged from 6.3 μg/L during 9 June to 22.0 μg/L during 13 July. Only the July sampling event exceeded the targeted maximum chlorophyll-*a* concentration endpoint of 14.0 μg/L during the 2021 season.

Elevated chlorophyll-*a* and TP concentrations were noted at Station 3 during multiple sampling events during the 2021 season. The 2021 mean TP concentration was 0.040 mg/L, exceeding the targeted mean of 0.030 mg/L. Despite this elevation, a slight decline in the seasonal average was noted in comparison to the 2019 and 2020 values. The 2021 concentrations ranged between 0.02 mg/L and 0.06 mg/L, exceeding 0.03 mg/L during the latter three sampling events. Seasonal mean chlorophyl-*a* concentrations at Station 3 were the highest compared to the other sampling stations, with an average of 24.0 μg/L. This average tripled the targeted TMDL average of 8.0 μg/L. Overall, chlorophyl-*al* concentrations ranged from 3.6 μg/L to 63.0 μg/L. Only the May and June sampling events fell below the maximum target of 14.0 μg/L.

At Station 10, the seasonal TP average was 0.034 mg/L, slightly exceeding the targeted mean. While somewhat elevated, a large decline was noted from 2020 values (0.06 mg/L). Each of the 2021 sampling events yielded TP concentrations of 0.03 mg/L, with exception to August, which was elevated at 0.05 mg/L. Only August exceeded the recommended 0.03 mg/L threshold. Chlorophyll-*a* concentrations were variable throughout the 2021 season, ranging between 6.6 µg/L during May and 49.0 µg/L during July. Concentrations exceeded the maximum target during July (49.0 µg/L) and August (20.0 µg/L). The 2021 seasonal average exceeded the 8.0 µg/L targeted mean, yielding concentrations of 19.3 µg/L.

4.0 SUMMARY

This section provides a summary of the 2021 water quality conditions, as well as recommendations on how to preserve the highly valued aquatic resources of Lake Hopatcong.

1. Thermally stratified waters were noted throughout the 2021 growing season at Station 2. Dissolved oxygen declined with depth, ultimately declining below the 5.0 mg/L threshold during each event in the deeper waters. By June, anoxic conditions were present in the bottom waters of this station. Anoxic conditions persisted through the September sampling event.

2. While the previous long-term water quality database had value, the HABs experienced in 2019 identified the need to slightly expand the monitoring program. Specifically, soluble reactive phosphorus (SRP) was added to the monitoring parameters at each sampling station, more detailed plankton monitoring, including phytoplankton counts (in particular with the cyanobacteria) were conducted at surface and mid-depths and additional vertical sampling at Station 2 to cover surface, mid-depth and deep-water samples were added to the program in 2020. This increased sampling scope was continued during 2021 and allowed for a more detailed look at nutrients and the affected phytoplankton communities through the lake. This increased scope should be continued for future sampling years to continue to bolster the historic database for Lake Hopatcong.

3. It has been well documented that phosphorus is the primary limiting nutrient in Lake Hopatcong. That is, a slight increase in phosphorus will result in a substantial increase amount of algal and/or aquatic plant biomass. TP concentrations in the surface waters throughout Lake Hopatcong were variable across the lake ranging between 0.01 mg/L and 0.06 mg/L. Elevated TP concentrations at surface stations were often noted in areas with near-shore septic systems. Surface and mid-depth TP concentrations were low throughout the season, with maximum concentrations of 0.02 mg/L. Deep water concentrations were elevated during the majority of the season with extreme elevations noted from July through September progressing to maximum concentrations of 0.25 mg/L. Elevated TP in the deep waters is attributed to extended periods of anoxia causing internal loading of phosphorus.

4. 2021 was characterized as a wet year depositing a total of 36.04" of rain during the growing season. This is over 13.00" more than normal values. Overall, flushing rates were very high, which likely aided in the reduced presence of planktonic blooms. Ideal conditions for cyanobacteria blooms were overall less common during the 2021 season relative to previous years.

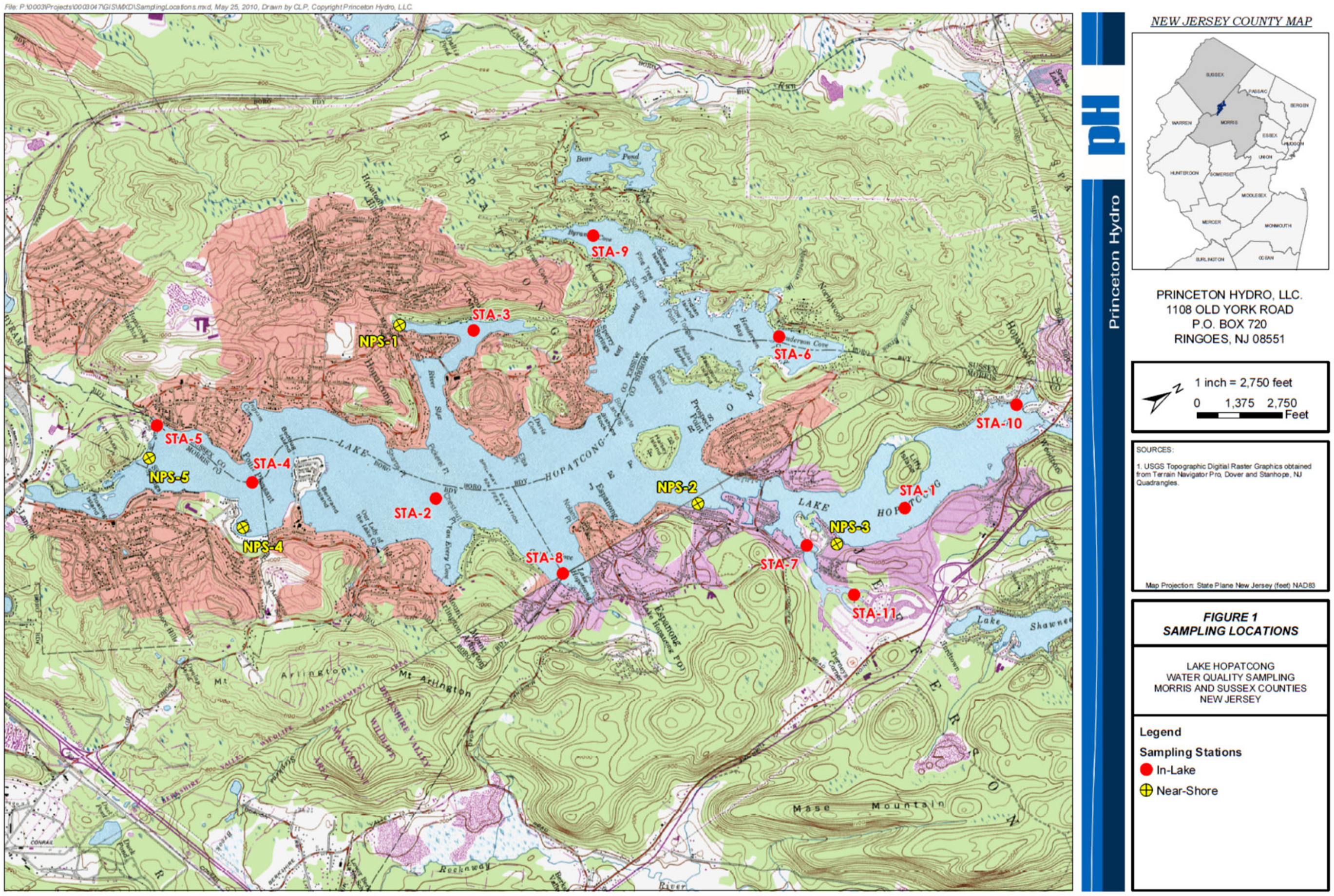
5. Major lake-wide cyanobacteria blooms were not identified during the 2021 monitoring year. At the main lake station, cyanobacteria densities were highest during the May event, warranting a 'HAB Watch' alert by NJDEP standards. The remainder of the growing season was characterized by lower cyanobacteria densities, remaining below thresholds of concern. Station 3 yielded more elevated cyanobacteria densities during the August and September events. While categorized as 'Watch' alerts during this event, the August cyanotoxin sampling event showed elevated cell counts further into the cove, warranting an 'Advisory' alert.

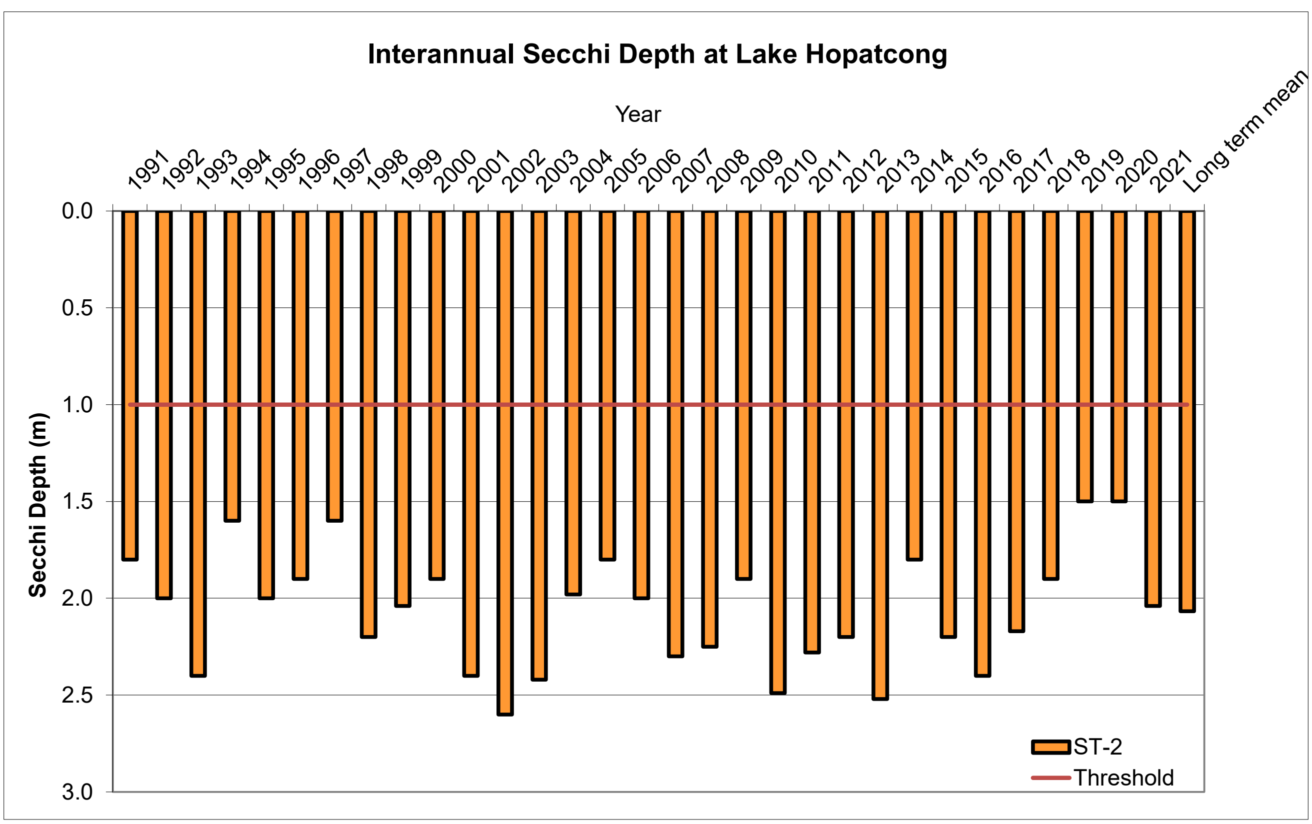
6. Based on the *in-situ* conditions, optimal brown trout habitat was present in varying degrees in May, June, and September 2021 at Station 2. Carry-over brown trout habitat was present during the July and August sampling events at this station. Optimal brown trout habitat was observed in the remaining stations during the May sampling, and portions of the water column of Stations 3, 4, 5, 8, and 9 in June, and the majority of stations in September. Carry over habitat was identified at various stations from June through August. The main reason for loss of trout habitat during the 2021 season was due to depressed oxygen in the deeper waters caused by thermal stratification.

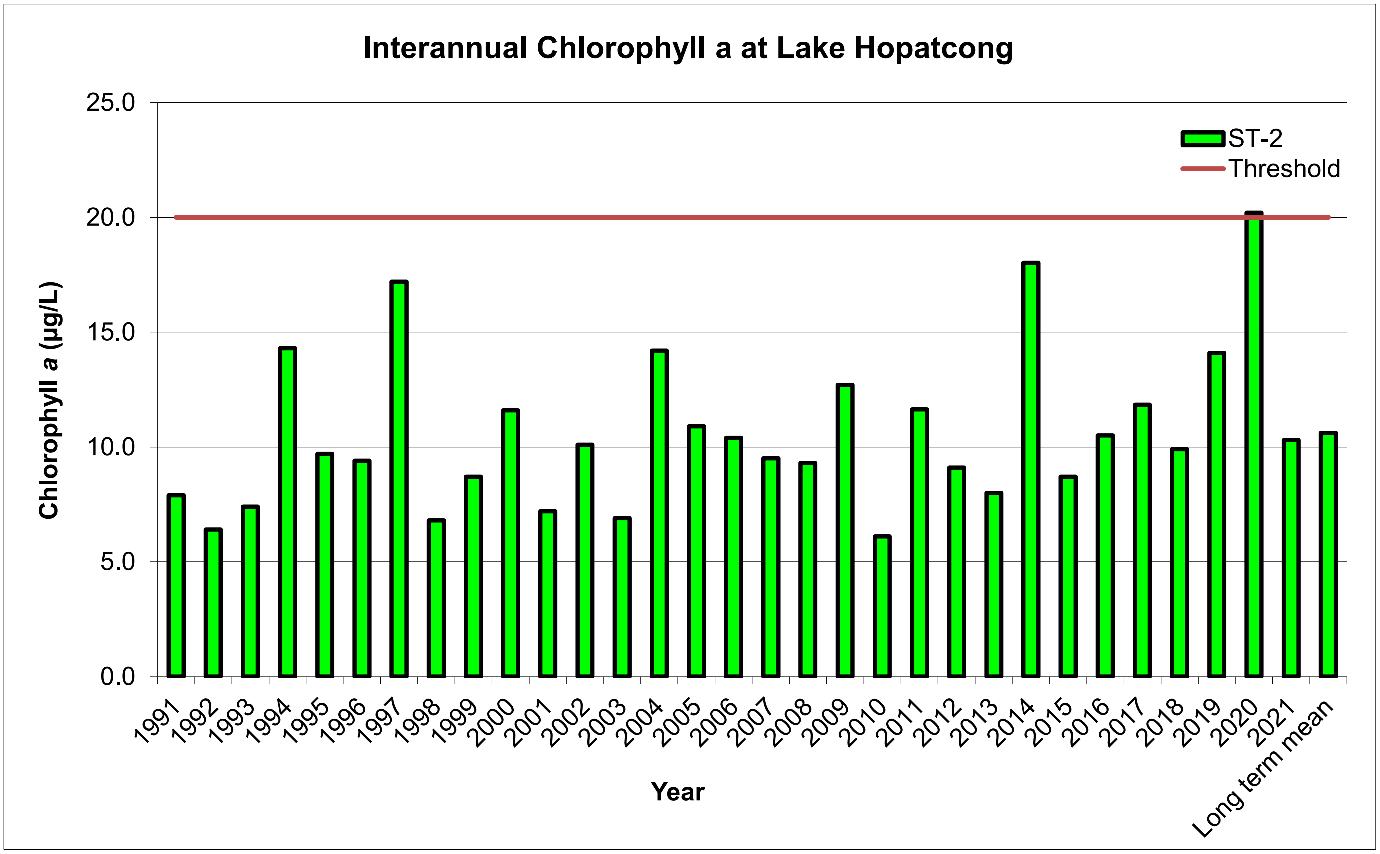
7. A mechanical weed harvesting program has been in place since the mid-1980's, which to varying degrees has helped remove phosphorus loads in an attempt to reach TMDL targets. Mechanical weed harvesting was not conducted during the 2021 season.

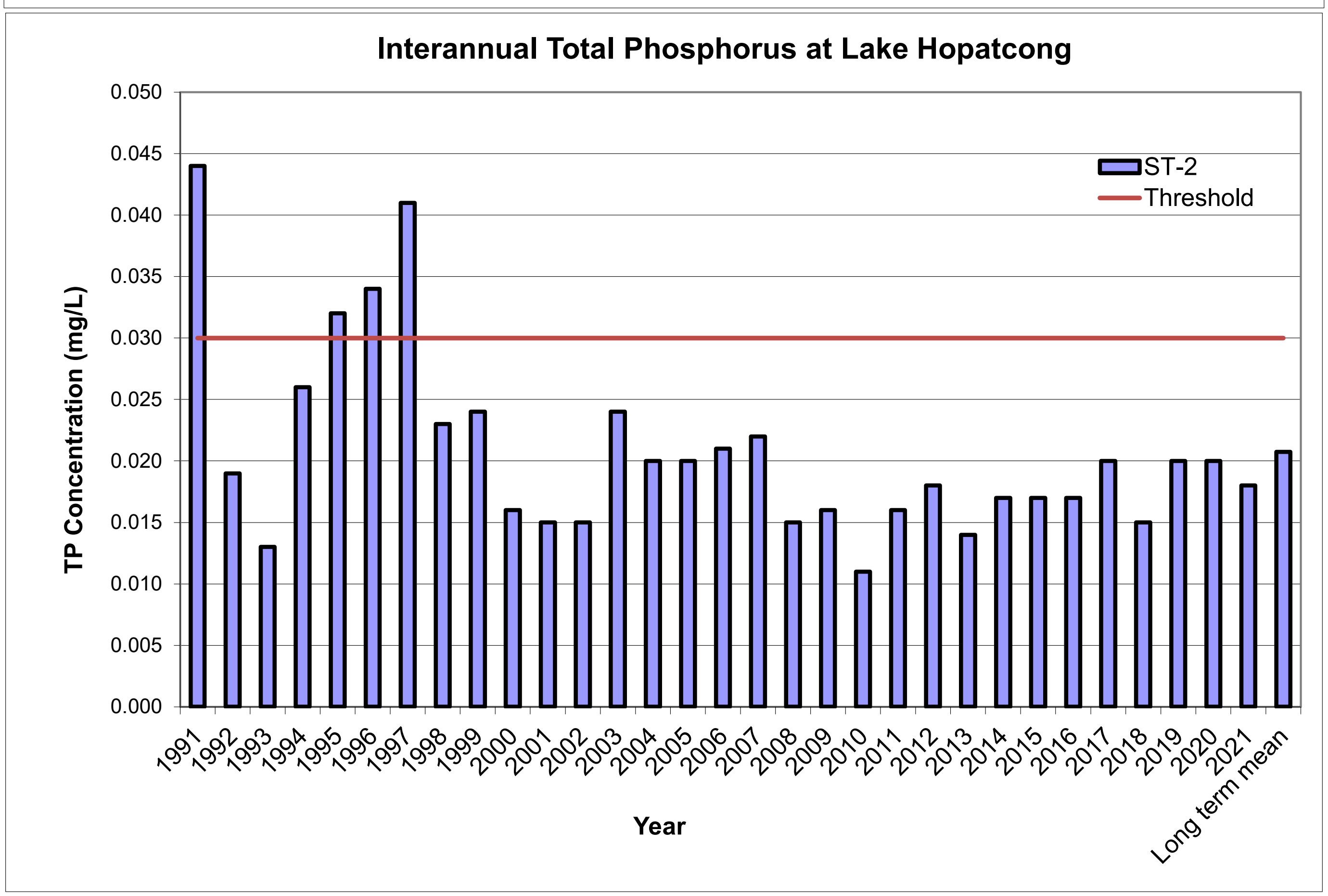
APPENDIX A

FIGURES


STA-9
STA-3
NPS-1
STA-6
STA-10
STA-5
NPS-5
STA-4
STA-2
NPS-2
STA-1
NPS-3
NPS-4
STA-8
STA-7
STA-11
Princeton Hydro
NEW JERSEY COUNTY MAP
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
1 inch = 2,750 feet
0 1,375 2,750 Feet
SOURCES:
1. USGS Topographic Digital Raster Graphics obtained from Terrain Navigator Pro, Dover and Stanhope, NJ Quadrangles.
Map Projection: State Plane New Jersey (feet) NAD83
FIGURE 1
SAMPLING LOCATIONS
LAKE HOPATCONG
WATER QUALITY SAMPLING
MORRIS AND SUSSEX COUNTIES
NEW JERSEY
Legend
Sampling Stations
In-Lake
Near-Shore


Interannual Secchi Depth at Lake Hopatcong
Year
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 Long term mean
Secchi Depth (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0
ST-2
Threshold


Interannual Chlorophyll a at Lake Hopatcong
25.0
20.0
15.0
10.0
5.0
0.0
Chlorophyll a (µg/L)
ST-2
Threshold
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 Long term mean
Year


Interannual Total Phosphorus at Lake Hopatcong
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
TP Concentration (mg/L)
ST-2
Threshold
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 Long term mean
Year

APPENDIX B

***In-situ* Data**

In-Situ Monitoring for Lake Hopatcong 5/19/2021								
Station	**DEPTH (meters)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**mS/cm**	**mg/L**	**% Sat.**	**S.U.**
STA-1	**2.20**	**1.60**	**0.1**	21.00	0.384	9.93	113.6	7.49
			1.0	20.72	0.385	9.95	113.2	7.46
			2.0	20.41	0.381	9.73	109.0	7.42
STA-2	**14.30**	**1.80**	**0.1**	18.26	0.422	11.70	126.7	8.73
			1.0	18.10	0.422	11.70	126.1	8.73
			2.0	17.81	0.422	11.81	127.1	8.77
			3.0	16.43	0.418	12.81	133.3	8.93
			4.0	14.58	0.417	11.77	117.1	8.53
			5.0	13.85	0.419	11.01	108.2	8.08
			6.0	13.38	0.417	10.44	101.8	7.79
			7.0	13.13	0.415	9.11	88.4	7.56
			8.0	12.90	0.416	8.26	19.9	7.36
			9.0	12.75	0.416	7.80	74.9	7.27
			10.0	12.30	0.417	6.45	61.6	7.12
			11.0	12.30	0.419	4.78	45.1	6.95
			12.0	12.09	0.420	3.96	37.5	6.87
			13.0	11.97	0.420	3.35	31.5	6.83
			14.0	11.75	0.437	1.52	14.3	6.80
STA-3	**2.20**	**1.70**	**0.1**	20.86	0.854	11.86	135.2	8.97
			1.0	19.53	0.687	12.32	136.3	9.07
			2.0	17.99	0.615	12.15	130.9	8.98
STA-4	**3.20**	**2.10**	**0.1**	18.62	0.422	11.40	124.3	8.78
			1.0	18.46	0.424	11.40	123.8	8.75
			2.0	17.25	0.420	12.30	130.9	8.87
			3.0	15.90	0.415	12.32	124.2	8.75
STA-5	**2.50**	**2.20**	**0.1**	18.75	0.434	11.25	122.4	8.83
			1.0	18.58	0.433	11.35	123.7	8.76
			2.0	17.75	0.429	11.13	119.4	8.49
STA-6	**3.10**	**1.70**	**0.1**	20.63	0.425	11.70	132.2	8.65
			1.0	19.00	0.423	12.00	130.8	8.56
			2.0	17.73	0.424	12.53	134.2	8.65
			2.8	15.20	0.420	11.66	117.6	8.18
STA-7	**2.10**	**1.60**	**0.1**	22.41	0.262	8.85	103.9	7.37
			1.0	20.83	0.257	8.90	100.9	7.35
			2.0	19.83	0.253	9.20	103.3	7.35
STA-8	**5.80**	**1.90**	**0.1**	19.50	0.422	11.34	125.9	8.58
			1.0	19.09	0.422	11.31	124.6	8.54
			2.0	18.13	0.419	11.81	127.3	8.63
			3.0	16.71	0.418	10.38	107.7	8.02
			4.0	13.55	0.415	9.95	97.6	7.73
			5.0	13.20	0.416	9.13	88.3	7.44
			5.5	13.09	0.417	8.51	82.4	7.31
STA-9	**8.50**	**1.70**	**0.1**	18.85	0.420	11.93	130.9	8.76
			1.0	18.56	0.422	12.01	130.7	8.73
			2.0	16.98	0.423	12.85	135.1	8.77
			3.0	16.23	0.424	13.18	136.9	8.78
			4.0	15.58	0.421	13.12	134.9	8.73
			5.0	14.15	0.417	12.47	123.6	8.55
			6.0	13.35	0.416	10.36	100.2	7.86
			7.0	12.94	0.417	8.68	78.0	7.47
			8.0	12.72	0.421	6.22	59.8	7.33
STA-10	**1.40**	**1.20**	**0.1**	22.50	0.397	11.07	130.3	8.47
			1.0	20.21	0.392	10.29	115.4	7.84
STA-11	**1.20**	**1.20+**	**0.1**	21.66	0.173	10.45	123.2	7.65
			1.0	19.89	0.180	9.36	104.3	7.32

In-Situ Monitoring for Lake Hopatcong 6/9/2021									
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	2.20	1.70	0.1	25.88	0.268	9.19	116.0	7.73
			1.0	25.39	0.281	9.28	116.4	7.74
			2.0	24.65	0.294	8.20	102.1	7.51
STA-2	14.50	2.50	0.1	23.43	0.410	9.45	114.5	8.02
			1.0	23.36	0.410	9.48	114.5	8.02
			2.0	22.87	0.412	9.40	112.5	8.00
			3.0	22.22	0.417	9.73	115.1	7.97
			4.0	19.48	0.416	8.91	99.9	7.74
			5.0	17.19	0.413	7.46	79.7	7.51
			6.0	16.12	0.413	6.41	67.0	7.35
			7.0	14.75	0.413	4.21	42.7	7.12
			8.0	13.62	0.413	3.35	33.2	6.95
			9.0	12.95	0.413	2.50	24.2	6.81
			10.0	12.64	0.414	2.16	20.9	6.75
			11.0	12.38	0.416	0.65	6.1	6.67
			12.0	12.21	0.417	0.00	0.0	6.64
			13.0	12.10	0.419	0.00	0.0	6.62
			14.0	11.82	0.427	0.00	0.0	6.61
STA-3	2.40	1.90	0.1	24.53	0.859	8.48	104.9	8.02
			1.0	24.04	0.828	8.34	102.3	7.98
			2.0	23.21	0.731	7.29	87.9	7.71
STA-4	3.20	2.40	0.1	24.24	0.299	9.60	117.5	8.17
			1.0	23.93	0.411	9.57	116.9	8.16
			2.0	23.18	0.410	9.43	113.5	8.06
			3.0	20.50	0.421	4.90	56.1	7.53
STA-5	3.20	2.60	0.1	24.56	0.418	9.17	113.6	7.94
			1.0	24.35	0.418	9.23	114.1	7.91
			2.0	22.56	0.419	9.45	112.1	7.83
			3.0	20.56	0.420	6.20	70.8	7.47
STA-6	3.10	2.00	0.1	25.64	0.412	9.02	113.8	7.69
			1.0	24.09	0.421	9.85	120.1	7.81
			2.0	21.36	0.424	10.01	116.2	7.76
			2.8	10.25	0.424	9.22	104.5	7.59
STA-7	2.10	1.10	0.1	24.97	0.203	6.24	77.9	7.06
			1.0	24.21	0.211	5.53	68.9	7.01
			1.7	23.67	0.223	4.56	55.3	6.93
STA-8	6.50	2.50	0.1	24.17	0.411	9.41	115.4	8.03
			1.0	23.86	0.410	9.43	114.9	8.01
			2.0	23.78	0.411	9.43	114.9	7.99
			3.0	23.64	0.411	9.20	111.7	7.92
			4.0	19.48	0.412	7.82	87.7	7.62
			5.0	18.26	0.413	7.32	79.7	7.55
			6.0	17.06	0.413	6.78	72.5	7.35
STA-9	8.50	2.20	0.1	24.44	0.416	9.23	113.8	7.72
			1.0	23.83	0.419	9.31	114.1	7.68
			2.0	22.42	0.447	9.56	113.1	7.65
			3.0	20.58	0.427	9.16	104.5	7.58
			4.0	18.35	0.416	8.26	90.2	7.41
			5.0	17.35	0.421	7.79	83.6	7.26
			6.0	16.43	0.419	6.42	67.5	7.11
			7.0	14.97	0.416	3.76	38.6	6.89
			8.0	13.95	0.419	1.52	15.1	6.74
STA-10	1.40	1.30	0.1	26.12	0.396	10.07	127.7	8.56
			1.0	25.01	0.391	10.37	128.4	8.28
STA-11	1.40	1.30	0.1	25.49	0.156	6.14	77.4	6.98
			1.0	23.65	0.178	4.33	52.1	6.75

In-Situ Monitoring for Lake Hopatcong 7/13/2021								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	2.20	1.00	0.1	26.23	0.358	7.65	96.6	7.46
			1.0	26.20	0.358	7.66	96.9	7.51
			2.0	26.20	0.358	7.64	96.5	7.50
STA-2	14.50	2.00	0.1	25.85	0.422	8.75	109.8	8.08
			1.0	25.90	0.421	8.74	109.9	8.13
			2.0	25.89	0.420	8.65	108.8	8.12
			3.0	25.89	0.421	8.59	107.9	8.05
			4.0	25.40	0.431	6.34	78.7	7.39
			5.0	24.44	0.421	4.76	58.2	7.20
			6.0	20.82	0.418	0.00	0.0	6.85
			7.0	16.58	0.420	0.00	0.0	6.82
			8.0	14.76	0.422	0.00	0.0	6.72
			9.0	13.91	0.425	0.00	0.0	6.68
			10.0	13.23	0.423	0.00	0.0	6.66
			11.0	12.76	0.426	0.00	0.0	6.64
			12.0	12.19	0.430	0.00	0.0	6.68
			13.0	11.87	0.439	0.00	0.0	6.77
			14.0	11.58	0.450	0.00	0.0	6.83
STA-3	2.40	1.00	0.1	25.85	0.781	8.04	101.2	7.74
			1.0	25.85	0.782	7.81	98.2	7.70
			2.0	25.69	0.793	7.14	88.2	7.58
STA-4	3.20	1.70	0.1	25.48	0.390	7.80	97.8	7.85
			1.0	25.47	0.410	7.78	96.4	7.85
			2.0	25.50	0.413	7.48	93.0	7.70
			3.0	25.50	0.421	6.99	86.7	7.65
STA-5	3.20	1.40	0.1	25.82	0.420	8.90	111.9	7.94
			1.0	25.76	0.420	8.87	111.8	7.91
			2.0	25.70	0.419	8.68	109.4	7.83
			3.0	25.64	0.421	8.55	107.6	7.47
STA-6	3.30	1.50	0.1	26.26	0.408	8.74	110.4	7.84
			1.0	26.24	0.405	8.72	110.5	7.86
			2.0	26.23	0.405	8.45	106.9	7.78
			3.0	25.87	0.408	6.65	83.6	7.49
STA-7	2.10	1.20	0.1	25.10	0.225	4.41	54.3	6.85
			1.0	25.09	0.225	4.43	54.7	6.84
			2.0	25.00	0.231	3.71	45.8	6.87
STA-8	7.20	1.70	0.1	25.57	0.417	7.84	98.2	7.59
			1.0	24.45	0.417	7.82	97.6	7.65
			2.0	25.26	0.417	7.48	93.0	7.60
			3.0	25.15	0.418	6.99	86.7	7.52
			4.0	24.97	0.419	5.97	78.1	7.30
			5.0	24.04	0.421	4.12	49.9	7.12
			6.0	22.69	0.421	2.22	27.3	6.97
			7.0	18.00	0.420	0.00	0.0	6.91
STA-9	8.50	1.70	0.1	26.11	0.418	8.85	111.9	8.05
			1.0	26.10	0.418	8.84	111.8	8.08
			2.0	26.04	0.417	8.68	109.4	8.00
			3.0	25.97	0.417	8.55	107.6	7.96
			4.0	25.90	0.417	8.39	105.3	7.88
			5.0	25.86	0.418	8.16	102.5	7.78
			6.0	22.36	0.421	1.24	14.2	7.12
			7.0	17.42	0.419	0.00	0.0	6.91
			8.0	15.31	0.425	0.00	0.0	6.90
STA-10	1.40	1.00	0.1	26.55	0.366	8.49	108.2	7.77
			1.0	26.55	0.365	8.49	108.1	7.77
STA-11	1.40	0.90	0.1	24.88	0.171	4.27	52.7	6.72
			1.0	24.88	0.171	4.09	50.5	6.72

In-Situ Monitoring for Lake Hopatcong 8/17/21								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**2.20**	**0.90**	**0.1**	26.20	0.364	6.37	80.6	7.23
			1.0	26.20	0.364	6.38	80.7	7.23
			2.0	25.93	0.360	6.90	86.9	7.29
STA-2	**13.90**	**2.20**	**0.1**	25.93	0.427	8.19	103.0	7.77
			1.0	25.93	0.426	8.18	102.9	7.80
			2.0	25.91	0.426	8.16	102.8	7.80
			3.0	25.91	0.426	8.17	102.8	7.79
			4.0	25.90	0.426	8.14	102.4	7.77
			5.0	24.67	0.422	5.14	63.1	7.33
			6.0	22.82	0.420	2.13	25.4	7.02
			7.0	21.18	0.416	0.21	2.4	6.90
			8.0	17.26	0.423	0.00	0.0	6.88
			9.0	14.47	0.427	0.00	0.0	6.87
			10.0	13.41	0.430	0.00	0.0	6.76
			11.0	12.89	0.432	0.00	0.0	6.79
			12.0	12.34	0.440	0.00	0.0	6.88
			13.0	11.79	0.450	0.00	0.0	6.95
			13.5	11.52	0.456	0.00	0.0	7.03
STA-3	**2.10**	**0.90**	**0.1**	25.70	0.670	6.67	83.7	7.56
			1.0	25.75	0.665	6.62	83.8	7.57
			2.0	25.68	0.634	6.39	80.1	7.54
STA-4	**3.00**	**1.10**	**0.1**	25.43	0.426	7.31	91.3	7,46
			1.0	25.64	0.429	7.23	96.7	7.46
			2.0	25.70	0.428	7.22	90.5	7.46
			2.5	25.70	0.428	7.10	88.9	7.44
STA-5	**1.20**	**1.00**	**0.1**	25.45	0.432	6.95	86.8	7.46
			1.0	25.84	0.429	6.64	83.6	7.44
STA-6	**3.20**	**1.60**	**0.1**	25.82	0.373	8.11	101.7	7.64
			1.0	25.86	0.372	8.04	101.1	7.68
			2.0	25.73	0.371	7.87	98.7	7.58
			3.0	25.67	0.371	7.69	96.4	7.53
STA-7	**1.70**	**1.00**	**0.1**	25.49	0.344	5.99	74.8	7.19
			1.0	25.54	0.344	5.36	67.1	7.14
STA-8	**6.20**	**2.10**	**0.1**	25.99	0.429	8.27	103.8	7.76
			1.0	25.98	0.426	8.23	103.8	7.81
			2.0	25.97	0.426	8.23	103.8	7.87
			3.0	25.94	0.426	7.90	99.8	7.75
			4.0	25.88	0.428	7.54	94.8	7.67
			5.0	24.66	0.422	4.58	55.6	7.29
			6.0	22.55	0.415	1.41	16.6	7.12
STA-9	**8.00**	**1.90**	**0.1**	26.04	0.427	8.58	108.2	7.83
			1.0	26.04	0.426	8.59	108.4	7.83
			2.0	25.97	0.426	8.57	108.1	7.83
			3.0	25.93	0.425	8.05	101.4	7.64
			4.0	25.90	0.425	8.15	102.5	7.68
			5.0	25.89	0.425	8.11	101.9	7.66
			6.0	25.04	0.422	5.84	72.4	7.88
			7.0	18.92	0.429	0.13	13.0	6.96
			7.5	17.60	0.435	0.00	0.0	6.95
STA-10	**1.20**	**0.90**	**0.1**	25.75	0.374	7.65	95.1	7.59
			1.0	25.75	0.375	7.60	99.4	7.55
STA-11	**1.20**	**1.20**	**0.1**	24.76	0.262	4.84	59.7	6.98
			1.0	24.52	0.258	4.34	53.0	6.92

In-Situ Monitoring for Lake Hopatcong 9/14/21								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**2.20**	**1.10**	**0.1**	23.32	0.313	9.87	119.1	8.00
			1.0	23.03	0.311	9.78	117.1	7.98
			2.0	22.73	0.311	9.18	109.4	7.83
STA-2	**14.20**	**1.70**	**0.1**	22.61	0.397	8.91	105.7	7.81
			1.0	22.39	0.397	8.94	105.9	7.84
			2.0	22.31	0.397	8.89	105.1	7.82
			3.0	22.27	0.387	8.77	103.6	7.77
			4.0	22.26	0.396	8.67	102.2	7.75
			5.0	22.23	0.394	8.54	100.7	7.71
			6.0	21.97	0.396	8.02	94.2	7.58
			7.0	21.45	0.396	6.25	72.6	7.34
			8.0	20.56	0.398	2.86	32.6	7.04
			9.0	17.74	0.429	0.00	0.0	6.97
			10.0	14.86	0.437	0.00	0.0	6.98
			11.0	13.75	0.436	0.00	0.0	6.96
			12.0	12.85	0.443	0.00	0.0	6.98
			13.0	12.29	0.453	0.00	0.0	7.00
			14.0	11.86	0.463	0.00	0.0	7.04
STA-3	**2.20**	**0.90**	**0.1**	22.93	0.514	9.32	111.6	8.17
			1.0	22.63	0.582	9.09	108.3	8.12
			2.0	22.56	0.586	8.99	106.9	8.08
STA-4	**3.10**	**1.60**	**0.1**	22.33	0.408	8.73	103.4	7.82
			1.0	22.27	0.408	8.74	103.2	7.80
			2.0	22.17	0.407	8.62	102.3	7.77
			3.0	22.65	0.405	7.87	92.8	7.67
STA-5	**2.40**	**1.30**	**0.1**	22.19	0.408	9.20	108.5	7.95
			1.0	22.12	0.408	9.16	107.8	8.00
			2.0	22.07	0.408	8.90	104.7	7.95
STA-6	**3.20**	**1.60**	**0.1**	23.16	0.333	9.65	116.9	8.05
			1.0	23.10	0.382	9.71	116.6	8.08
			2.0	22.52	0.385	9.32	110.4	7.90
			3.0	22.22	0.389	7.87	92.9	7.50
STA-7	**1.50**	**1.10**	**0.1**	23.08	0.222	9.60	115.4	7.28
			1.0	22.23	0.209	8.96	99.6	7.20
STA-8	**7.00**	**1.40**	**0.1**	22.63	0.417	9.11	108.2	7.92
			1.0	22.52	0.409	9.09	107.9	7.92
			2.0	22.42	0.409	9.01	106.5	7.90
			3.0	22.26	0.409	8.66	102.3	7.79
			4.0	21.99	0.413	7.39	86.8	7.52
			5.0	21.79	0.412	7.52	87.9	7.46
			6.0	21.63	0.412	7.17	83.6	7.41
			6.8	21.47	0.412	6.41	74.5	7.31
STA-9	**8.20**	**1.50**	**0.1**	22.81	0.397	9.77	116.6	8.17
			1.0	22.62	0.397	9.88	117.5	8.22
			2.0	22.34	0.395	9.67	114.6	8.12
			3.0	22.10	0.396	8.53	100.3	7,73
			4.0	21.97	0.396	8.00	94.3	7.57
			5.0	21.89	0.397	7.50	88.0	7.47
			6.0	21.75	0.397	7.10	83.1	7.38
			7.0	21.56	0.399	5.84	68.0	7.25
			8.0	20.30	0.402	0.00	0.0	6.98
STA-10	**1.10**	**1.00**	**0.1**	23.81	0.323	9.75	118.1	8.02
			0.6	22.34	0.356	10.57	125.4	8.25
STA-11	**1.10**	**1.10+**	**0.1**	22.41	0.139	7.76	91.9	6.87
			1.0	21.90	0.145	7.43	86.9	6.85

APPENDIX C

Discrete Data

Discrete Data 5/19/2021						
STATION	**Chlorophyll a (ug/L)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**SRP (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	6.2	0.01	0.07	ND<0.002	0.02	9
ST-2 SURFACE	7.1	0.01	0.02	ND<0.002	0.01	6
ST-2 MID	15.0	ND <0.01	0.03	ND<0.002	0.02	10
ST-2 DEEP		0.02	0.06	0.002	0.05	8
ST-3	8.6	0.01	0.12	ND<0.002	0.02	10
ST-4	4.0	ND <0.01	0.02	ND<0.002	0.02	5
ST-5	2.7	0.01	0.02	ND<0.002	0.02	8
ST-6	4.7	0.01	0.08	ND<0.002	0.02	9
ST-7	6.5	0.01	0.05	ND<0.002	0.02	9
ST-10	6.6	0.01	0.11	ND<0.002	0.03	10
ST-11	4.2	0.01	0.10	ND<0.002	0.02	8
Surface Mean	**5.6**	**0.01**	**0.066**	**ND<0.002**	**0.020**	**8.2**

Discrete Data 6/9/21						
STATION	**Chlorophyll a (ug/L)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**SRP (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	8.8	0.07	0.19	0.002	0.01	< 2
ST-2 SURFACE	6.3	0.04	0.17	< 0.002	0.02	2
ST-2 MID	10.0	0.04	0.17	< 0.002	0.02	2
ST-2 DEEP		0.05	0.16	< 0.002	0.02	6
ST-3	3.6	0.04	0.29	< 0.002	0.02	3
ST-4	1.9	0.02	0.14	< 0.002	0.01	< 2
ST-5	2.5	0.02	0.14	< 0.002	0.01	< 2
ST-6	1.6	0.02	0.15	< 0.002	0.02	< 2
ST-7	7.7	0.02	0.25	0.002	0.03	6
ST-10	7.0	0.01	0.21	< 0.002	0.03	3
ST-11	6.0	0.01	0.32	0.002	0.03	2
Surface Mean	**5.0**	**0.03**	**0.20**	**ND<0.002**	**0.020**	**3.4**

Discrete Data 7/13/21						
STATION	**Chlorophyll a (ug/L)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**SRP (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	46.0	0.02	0.08	< 0.002	0.03	11
ST-2 SURFACE	22.0	0.01	0.04	< 0.002	0.02	4
ST-2 MID	17.0	0.01	0.01	< 0.002	0.02	3
ST-2 DEEP		0.05	0.15	0.024	0.17	6
ST-3	63.0	0.01	0.11	< 0.002	0.05	6
ST-4	18.0	0.01	0.05	< 0.002	0.02	5
ST-5	16.0	0.01	0.05	< 0.002	0.02	5
ST-6	25.0	0.01	0.07	< 0.002	0.02	6
ST-7	29.0	0.01	0.15	0.008	0.04	5
ST-10	49.0	0.01	0.09	< 0.002	0.03	12
ST-11	18.0	0.01	0.11	0.008	0.05	6
Surface Mean	**31.8**	**0.011**	**0.083**	**0.008**	**0.031**	**6.7**

Discrete Data 8/17/21						
STATION	**Chlorophyll a (ug/L)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**SRP (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	18.0	0.02	0.05	<0.002	0.04	6
ST-2 SURFACE	6.2	0.01	0.01	<0.002	0.02	<2
ST-2 MID	9.0	0.01	<0.01	<0.002	0.02	<2
ST-2 DEEP		0.04	0.32	0.004	0.25	11
ST-3	25.0	0.01	0.06	<0.002	0.06	10
ST-4	9.6	0.01	0.01	<0.002	0.03	5
ST-5	12.0	0.01	0.02	<0.002	0.04	8
ST-6	6.0	0.01	0.01	<0.002	0.02	4
ST-7	11.0	0.01	0.09	<0.002	0.04	4
ST-10	20.0	0.01	0.07	<0.002	0.05	17
ST-11	11.0	0.01	0.12	<0.002	0.04	<2
Surface Mean	**13.2**	**0.011**	**0.049**	**ND<0.002**	**0.038**	**7.7**

Discrete Data 9/14/21						
STATION	**Chlorophyll a (ug/L)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**SRP (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	17.0	0.02	0.05	<0.002	0.04	5
ST-2 SURFACE	10.0	0.02	0.02	<0.002	0.02	<2
ST-2 MID	9.4	0.03	0.02	<0.002	0.02	2
ST-2 DEEP		0.60	0.22	0.01	0.25	5
ST-3	20.0	0.05	0.14	<0.002	0.05	6
ST-4	11.0	0.05	0.02	<0.002	0.02	<2
ST-5	14.0	0.02	0.02	<0.002	0.03	3
ST-6	9.6	0.04	0.02	<0.002	0.02	<2
ST-7	25.0	0.03	0.13	<0.002	0.04	3
ST-10	14.0	0.05	0.28	<0.002	0.03	8
ST-11	6.9	0.02	0.20	<0.002	0.03	5
Surface Mean	**14.2**	**0.033**	**0.098**	**ND<0.002**	**0.031**	**5.0**

APPENDIX D

Plankton Data

Phytoplankton and Zooplankton Community Composition Analysis																	
Sampling Location: Lake Hopatcong						**Sampling Date: 5/19/21**						**Examination Date: 5/22/21**					
Site 1: ST-2 Surface Phyto			**Site 2: ST-2 Mid Phyto**			**Site 3: ST-3 Surface Phyto**						**Site 4: ST-2 Surface Zoo**	**Site 5: ST-2 Deep Zoo**				
Phytoplankton																	
Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**	**Chlorophyta (Green Algae)**	**1**	**2**	**3**	**4**	**5**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**	**3**	**4**	**5**
Asterionella	P	P	P			*Chlorella*	P	C	P			*Aphanizomenon*	12,507	6739	7165		
Fragilaria	P	P	P			*Atractomorpha*	P	P	P			*Planktothrix*	4503	5391			
Melosira		P	P			*Dictyosphaerium*	P					*Pseudanabaena*	15009	32345	6210		
Stephanodiscus	R	P	R			*Eudorina*		R									
Synedra	C	C	C			*Pediastrum*			P								
Tabellaria	P	A	P			*Scenedesmus*	P	P	P								
						Staurastrum	R		P			**Euglenophyta (Euglenoids)**					
												Trachelomonas	P	C	P		
Chrysophyta (Golden Algae)												**Pyrrhophyta (Dinoflagellates)**					
						Cryptomonads											
Zooplankton																	
Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**	**Copecoda (Copepods)**	**1**	**2**	**3**	**4**	**5**	**Rotifera (Rotifers)**	**1**	**2**	**3**	**4**	**5**
Bosmina				P	A	*Cyclops*					P	*Conochilus*					R
Chydorus					P	*Diaptomus*					P	*Keratella*				P	A
						Nauplii					P	*Polyartha*				P	C
												Trichocerca				R	P
Sites:	**1**	**2**	**3**	**4**	**5**	**Comments: All cyanobacteria filaments and cells were extremely small and difficult to count.**											
Total Phytoplankton Genera	14	14	14														
Total Cyanobacteria (cells/mL)	32,019	44,475	13,375														
Total Zooplankton Genera				4	9												
						Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)											
						Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)											

Phytoplankton and Zooplankton Community Composition Analysis																	
Sampling Location: Lake Hopatcong						**Sampling Date: 6/9/21**						**Examination Date: 6/11/21**					
Site 1: ST-2 Surface Phyto			**Site 2: ST-2 Mid Phyto**			**Site 3: ST-3 Surface Phyto**						**Site 4: ST-2 Surface Zoo**	**Site 5: ST-2 Deep Zoo**				
Phytoplankton																	
Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**	**Chlorophyta (Green Algae)**	**1**	**2**	**3**	**4**	**5**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**	**3**	**4**	**5**
Asterionella	R	P				*Chlamydomonas*	P	P	P			*Aphanizomenon*	1,411	8284	96		
Fragilaria	P	P				*Akinstrodesmus*		P				*Dolichospermum*	403		1600		
Melosira			R			*Atractomorpha*			R			*Planktothrix*		18935			
Synedra	R	P				*Coelastrum*	P					*Pseudanabaena*		2935			
Tabellaria	C	P				*Pediastrum*	P		P								
						Scenedesmus	P		R								
						Staurastrum			R			**Euglenophyta (Euglenoids)**					
												Trachelomonas	P	P	P		
Chrysophyta (Golden Algae)																	
Mallomonas	P		P			**Cryptomonads**											
						Cryptomonas		P	P								
Zooplankton																	
Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**	**Copecoda (Copepods)**	**1**	**2**	**3**	**4**	**5**	**Rotifera (Rotifers)**	**1**	**2**	**3**	**4**	**5**
Bosmina				A	C	*Cyclops*				P	C	*Asplanchna*					R
Ceriodaphnia				P		*Diaptomus*					P	*Conochilus*				A	C
Daphnia				P		Nauplii				P	C	*Keratella*				P	P
												Polyartha				C	C
												Trichocerca				P	P
Sites:	**1**	**2**	**3**	**4**	**5**	**Comments: All cyanobacteria filaments and cells were extremely small and difficult to count.**											
Total Phytoplankton Genera	12	11	11														
Total Cyanobacteria (cells/mL)	1,814	30,154	1,696														
Total Zooplankton Genera				9	9												
						Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)											
						Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)											

Phytoplankton and Zooplankton Community Composition Analysis																	
Sampling Location: Lake Hopatcong						**Sampling Date: 7/13/21**						**Examination Date: 7/16/21**					
Site 1: ST-2 Surface Phyto			**Site 2: ST-2 Mid Phyto**			**Site 3: ST-3 Surface Phyto**						**Site 4: ST-2 Surface Zoo**		**Site 5: ST-2 Deep Zoo**			
Phytoplankton																	
Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**	**Chlorophyta (Green Algae)**	**1**	**2**	**3**	**4**	**5**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**	**3**	**4**	**5**
Asterionella	P	P	P			*Akinstrodesmus*	P	P				*Aphanizomenon*	216	4310	1326		
Fragilaria	P	P	R			*Chlorella*	P	P	C			*Coelosphaerium*	7769	1045	294		
Melosira	P	P	C			*Coelastrum*	R	R	P			*Dolichospermum*	9754		2564		
Stephanodiscus		R				*Eudorina*	C		C			*Lyngbya*	130		884		
Synedra	P	R	C			*Gleocystis*	C		P			*Aphanocapsa*			442		
Tabellaria	P		R			*Oocystis*	R										
						Pandorina		R				**Euglenophyta (Euglenoids)**					
						Pediastrum	P	C	P			*Euglena*			P		
						Scenedesmus		P	C			*Trachelomonas*			P		
						Staurastrum	C	P	P								
						Atractamorpha			P								
						Crucigenia			P								
Chrysophyta (Golden Algae)																	
Dinobryon	P					**Cryptomonads**											
Mallomonas	P					*Cryptomonas*	P	C	A								
Zooplankton																	
Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**	**Copecoda (Copepods)**	**1**	**2**	**3**	**4**	**5**	**Rotifera (Rotifers)**	**1**	**2**	**3**	**4**	**5**
Bosmina				P	C	*Cyclops*				P	A	*Asplanchna*				P	
Ceriodaphnia				P	P	*Diaptomus*					P	*Conochilus*				C	C
Chydorus					R	Nauplii				C	A	*Keratella*				C	C
Daphnia												*Notholca*				C	C
Diaphanosoma				R	P							*Polyartha*				C	C
Sites:	**1**	**2**	**3**	**4**	**5**	**Comments:**											
Total Phytoplankton Genera	20	15	22														
Total Cyanobacteria (cells/mL)	17,869	5,355	5,510														
Total Zooplankton Genera				10	11												
						Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)											
						Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)											

Phytoplankton and Zooplankton Community Composition Analysis																	
Sampling Location: Lake Hopatcong						**Sampling Date: 8/17/21**						**Examination Date: 8/18/21**					
Site 1: ST-2 Surface Phyto			**Site 2: ST-2 Mid Phyto**			**Site 3: ST-3 Surface Phyto**						**Site 4: ST-2 Zooplankton Tow**		**Site 5: ST-2 Deep Zoo**			
Phytoplankton																	
Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**	**Chlorophyta (Green Algae)**	**1**	**2**	**3**	**4**	**5**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**	**3**	**4**	**5**
Asterionella	P	C				*Scenedesmus*	P	P	C			*Aphanizomenon*	6,581	3860	36130		
Fragillaria		P	R			*Akinstrodesmus*	P	P				*Coelosphaerium*	940				
Melosira		P	P			*Chlorella*	P	P	C			*Dolichospermum*	1755	468	10839		
Stephanodiscus			P			*Coelastrum*	P	P	R			*Lyngbya*	627	234			
Synedra	P	C	A			*Golenkinia*	R		C			*Microcystis*			7828		
Tabellaria			P			*Koliella*	R					*Pseudanabaena*	1724	2106			
						Oocystis	P					**Euglenophyta (Euglenoids)**					
						Pediastrum	R		P			*Euglena*			R		
Dinoflagellates						*Staurastrum*	P	P	C			*Lepocinclis*			P		
Ceratium	R		R			*Tetradesmus*			R			*Phacus*			P		
												Trachelomonas	P	P	P		
Chrysophyta (Golden Algae)																	
Dinobryon	P	R				**Cryptomonads**											
Mallomonas	C	C	C			*Cryptomonas*		P	A								
Zooplankton																	
Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**	**Copecoda (Copepods)**	**1**	**2**	**3**	**4**	**5**	**Rotifera (Rotifers)**	**1**	**2**	**3**	**4**	**5**
Bosmina				A	A	*Cyclops*				C	C	*Asplanchna*				P	
Leptodora					R	*Diaptomus*				P		*Conochilus*				C	C
Chydorus						Nauplii				C	C	*Keratella*				A	A
Daphnia												*Notholca*					
Diaphanosoma												*Polyartha*				C	A
												Trichocerca				P	
Sites:	**1**	**2**	**3**	**4**	**5**	**Comments:**											
Total Phytoplankton Genera	20	17	22														
Total Cyanobacteria (cells/mL)	11,627	6,668	54,797														
Total Zooplankton Genera				9	7												
						Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)											
						Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)											

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Lake Hopatcong						Sampling Date: 9/14/21						Examination Date: 9/28/21					
Site 1: ST-2 Surface Phyto			Site 2: ST-2 Mid Phyto			Site 3: ST-3 Surface Phyto						Site 4: ST-2 Zooplankton Tow	Site 5: ST-2 Deep Zoo				
Phytoplankton																	
Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**	**Chlorophyta (Green Algae)**	**1**	**2**	**3**	**4**	**5**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**	**3**	**4**	**5**
Asterionella	C		R			*Scenedesmus*	P		A			*Aphanizomenon*	8,915	9685	72898		
Cyclotella	P		P			*Actinastrum*		P				*Dolichospermum*	4800	2564	2144		
Melosira		P	C			*Chlorella*	P	P	C			*Aphanocapsa*	1714				
Synedra	C	A	P			*Coelastrum*	P		C			*Merismopedia*	137	278			
Tabellaria	P	C				*Gleotila*	P	P	P			*Oscilltoria*		855			
						Pandorina	R					*Pseudanabaena*	3429	570			
						Pediastrum	P	P	P			**Euglenophyta (Euglenoids)**					
						Staurastrum	P	P	P			*Colacium*	R				
Dinoflagellates						*Ooycstis*	R					*Euglena*	R				
Ceratium			C									*Phacus*		R	R		
												Trachelomonas		P			
Chrysophyta (Golden Algae)																	
Dinobryon	R	R	R			**Cryptomonads**											
Mallomonas			C			*Cryptomonas*	C	P	A								
Zooplankton																	
Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**	**Copecoda (Copepods)**	**1**	**2**	**3**	**4**	**5**	**Rotifera (Rotifers)**	**1**	**2**	**3**	**4**	**5**
Bosmina				R	P	*Cyclops*				R	P	*Ascomorpha*					C
						Diaptomus					P	*Euchlanis*					P
						Nauplii					C	*Keratella*				P	C
												Monostyla				R	
												Polyartha				C	P
												Pompholyx					P
												Trichocerca					R
Sites:	**1**	**2**	**3**	**4**	**5**	**Comments:**											
Total Phytoplankton Genera	21	17	17														
Total Cyanobacteria (cells/mL)	18,995	13,952	75,042														
Total Zooplankton Genera				5	10												
						Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)											
						Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)											