

2012 FINAL REPORT

Lake Wallenpaupack Water Quality Monitoring Program



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Prepared for:



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Management District**

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Picture of Lake Wallenpaupack taken by Aqua Link.

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EXECUTIVE SUMMARY

Lake Wallenpaupack, a 5,700-acre reservoir, is an extremely valuable multi-recreational and economic resource for Northeastern Pennsylvania. The lake is nestled within the Pocono Mountains in Pike and Wayne Counties. Lake Wallenpaupack is used extensively for a wide variety of water-related activities including swimming, fishing, boating, water skiing, and snowmobiling.

Over the years, the water quality of Lake Wallenpaupack has been routinely monitored since 1980. In 2012, the Lake Wallenpaupack Watershed Management District retained Aqua Link to analyze the 2012 lake water quality data and prepare the 2012 annual report. As part of this report, Aqua Link also compared the 2012 data to the historical data collected from 1980 through 2011 to determine whether lake water quality has improved or degraded over the past 33 years.

Lake Wallenpaupack was classified as a border line mesotrophic - eutrophic reservoir in 2012. The mean 2012 Carlson TSI values for total phosphorus, chlorophyll-a, and Secchi disk transparency were 53, 56, and 50, respectively. The lake was thermally stratified in 2012 from May through September. In turn, the dissolved oxygen concentrations were strongly stratified when the lake was thermally stratified. Phytoplankton data indicate that blue-green algae (Cyanophyta) were dominant during most of the growing season. The most common genera were *Anabaena* and *Aphanizomenon*. Zooplankton biomass increased in 2012, but remained moderately low and may be related to intense grazing pressure of larger zooplankton by predators (planktivorous fish).

Based upon trend analysis, the water quality of Lake Wallenpaupack has generally improved since over the past 33 years since 1980. Total phosphorus concentrations in surface and bottom waters and Secchi transparency (water clarity) have gradually improved. Total nitrogen concentrations in surface and bottom waters, chlorophyll-a concentrations, and phytoplankton biomass marginally increased over time.

Lake water clarity (Secchi transparency) has improved even though chlorophyll-a concentrations and phytoplankton biomass have slightly increased. This appears to be related to a shift in the phytoplankton community, where blue-green algal dominance is less prevalent. The shift in the phytoplankton community may be attributed to decreases in total phosphorus and increases in total nitrogen in the lake. In general, higher nitrogen to phosphorus concentration ratios in lakes often favor green (Chlorophyta) over blue-green (Cyanophyta) algae resulting in more species diversity and improved water clarity and aesthetics.

1. Introduction

Lake Wallenpaupack, a 5,700-acre reservoir, is an extremely valuable multi-recreational and economic resource for Northeastern Pennsylvania. The lake is nestled within the Pocono Mountains in Pike and Wayne Counties. Lake Wallenpaupack is used extensively for a wide variety of water-related activities including swimming, fishing, boating, water skiing, and snowmobiling. Lake Wallenpaupack is within vacationing distance of millions of inhabitants of the mid Atlantic states. Philadelphia, New York City, Trenton, Scranton and Wilkes-Barre are all located within 100 miles of Lake Wallenpaupack, and the lake receives substantial use by these city residents. The Lake Wallenpaupack watershed is quite extensive and encompasses 219 square miles spread over four counties and 14 townships as shown in Figure 1.1 (LWWMD website at www.wallenpaupackwatershed.org).

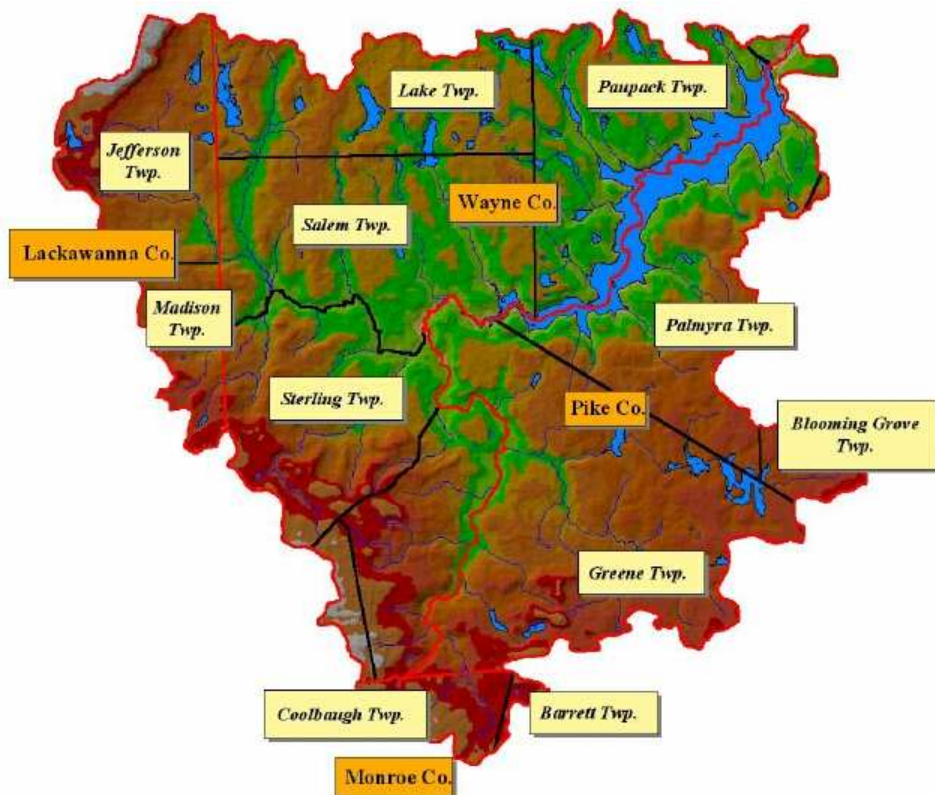


Figure 1.1 Lake Wallenpaupack Watershed

In 1926, the Pennsylvania Power & Light Co. (PP&L) dammed the creek and built the lake to supply water for a hydroelectric power plant. Building the lake was a monumental task, considering that mules and steam engines were the only source of power for construction projects in those days. It took 2,700 people about two years to do the job. Farms, barns and houses in the lake bed were demolished or moved, trees were cut down, utility poles and 17 miles of roadway were moved, and a cemetery was relocated. Wallenpaupack Creek was rerouted while the concrete dam was being built. PP&L also built a dike in Tafton to impound Wallenpaupack Creek. Once the dam and dike were completed, the stream was allowed to resume its course and fill the lake with water (LWWMD website at www.wallenpaupackwatershed.org).

Over the years, the water quality of Lake Wallenpaupack has been routinely monitored since 1980. In 2012, the Lake Wallenpaupack Watershed Management District (hereinafter referred to as the LWWMD) retained Aqua Link to analyze the 2012 lake water quality data and prepare this report, which provides our conclusions and recommendations. As part of this report, Aqua Link also compared the 2012 to the historical data collected from 1980 through 2011 to determine whether lake water quality has improved or degraded over the past 33 years.

In the Winter 2009-10, the District retained Aqua Link to develop the historical water quality data for the period of 1980 through 2009. This historical water quality database served as the foundation for this report and will subsequently be used to analyze all newly acquired lake water quality data from this point forward.

2. Lake Water Quality Monitoring Program

Aqua Link and LWWMD monitored the water quality of Lake Wallenpaupack in 2012. The lake was monitored at Stations 3 and 5 in 2012 (Figure 2.1). These monitoring stations were monitored once a month during May through October.

In 2012, *insitu* data were collected at the designated lake stations on each study date. These *insitu* water quality data were measured and recorded. *In-situ* water quality data (pH, dissolved oxygen, temperature, conductivity, specific conductivity, and oxidation reduction potential) were measured and recorded simultaneously using a YSI Model 600XL Sonde and a YSI 600D data logger. These data were collected at one-meter intervals from the surface to the bottom of the lake at each station. In addition, Secchi disk transparency (water clarity) was measured and recorded using a standard 8-inch (20 cm) freshwater Secchi disk at the lake stations on each study date.

In 2012, water samples were collected at two different depths on each study date at Stations 3 and 5. Surface samples were collected one meter (3.3 feet) below the lake's surface and bottom

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samples were collected one meter (3.3 feet) above the lake sediments. All water samples were collected using a Kemmerer water sampler unit. Once collected, all water samples were placed in bottles, preserved accordingly in the field, and then shipped to the certified contract laboratory for further analysis. The collected surface water samples were analyzed for alkalinity, total phosphorus, soluble reactive phosphorus (namely orthophosphorus), nitrate, nitrite, total Kjeldahl nitrogen, ammonia, total suspended solids, and chlorophyll-a. The bottom water samples were analyzed for alkalinity, total phosphorus, soluble reactive phosphorus, nitrate, nitrite, total Kjeldahl nitrogen, ammonia, and total suspended solids. In addition, composite samples of the photic zone were collected for phytoplankton and zooplankton analysis (identification and enumeration) at Station 3 on each study date. Discrete water samples were collected using the Kemmerer sampler and placed into a bucket to form composited samples for later phytoplankton identification and enumeration. The composite sample for zooplankton identification and enumeration was obtained by vertically towing the lake water column using a 80 um (micron) mesh plankton net. The photic zone was represented as twice the Secchi disk depth on each study date.

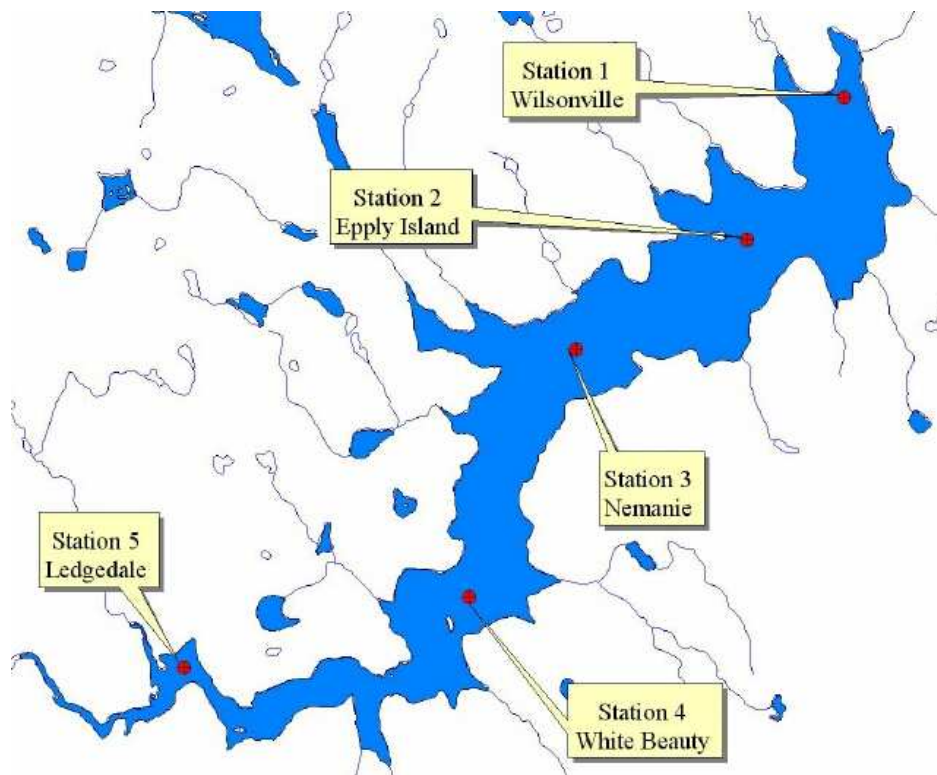


Figure 2.1 Lake Monitoring Stations

All collected water chemistry samples were shipped directly to the contract laboratory, ECM (Environmental Compliance Monitoring, Inc.) in Hillsborough, New Jersey, for analysis. All phytoplankton and zooplankton samples were preserved in the field and subsequently analyzed by Dr. Kenneth Wagner of Wilbraham, Massachusetts.

3. Local Climatological Data

Aqua Link acquired and analyzed local climatological data, which are representative for Northeastern Pennsylvania (Figures 3.1 and 3.2). Overall, 2012 was considered a very warm year with average precipitation when compared to data presented over the previous 32 years.

Figure 3.1 shows the average (mean) air temperatures for the growing season (May through October) from 1980 through 2012. Monthly temperature data were obtained via the Internet at the Pennsylvania State Climatologist website. Information at this website is provided by the College of Earth and Mineral Sciences at Penn State. Data were collected by averaging temperature data (in degrees Fahrenheit) for the months of May through October for each of the study years.

Figure 3.2 shows the total precipitation amounts from 1980 through 2012. Annual precipitation data was obtained via the Internet at the NOAA national weather service website. Precipitation measurements (recorded in inches) were report for Avoca, Pennsylvania from 1980 through 2012.

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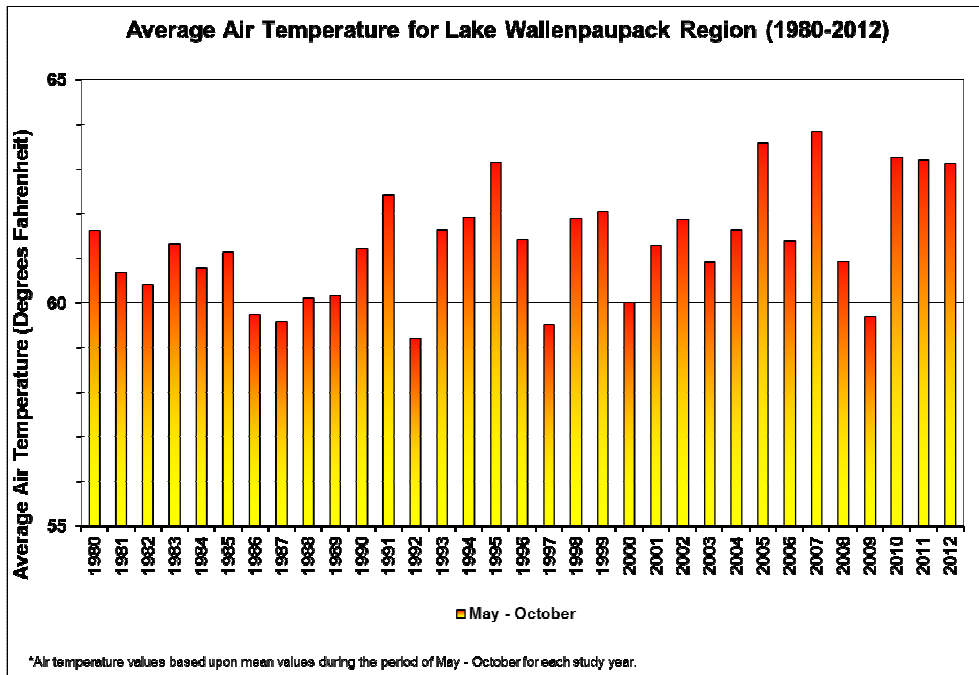


Figure 3.1 Historical Air Temperature Data in the Lake Wallenpaupack Region

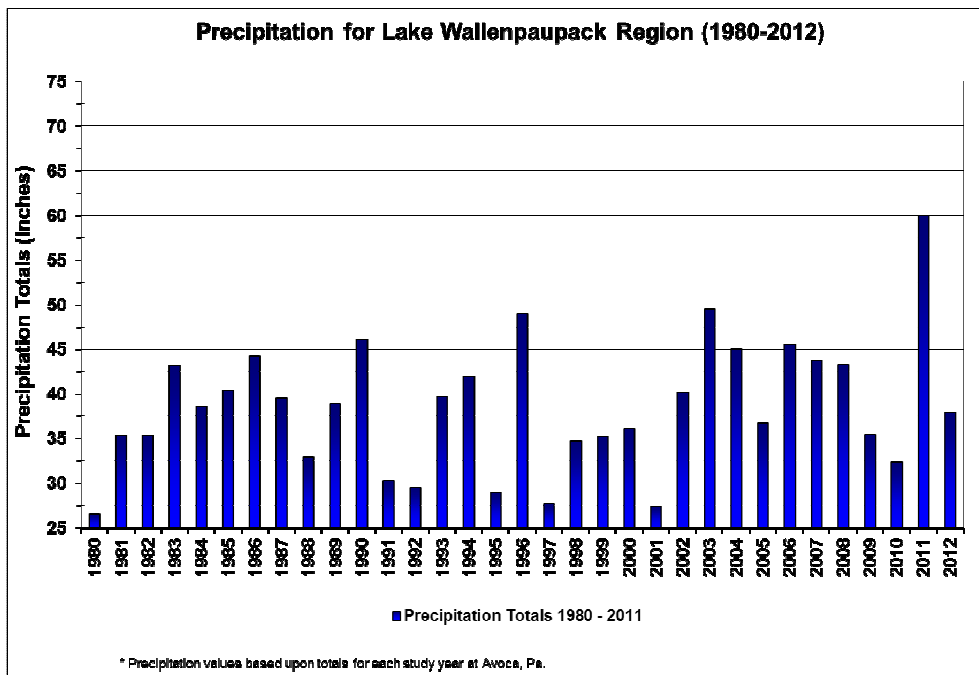


Figure 3.2 Historical Precipitation Data in the Lake Wallenpaupack Region

4. Lake Water Quality Data Results for 2012

The water quality data for Lake Wallenpaupack in 2012 are presented in this section of the report. As discussed in Section 2, the lake was monitored at Stations 3 and 5 in 2012 (Figure 2.1). The majority of this report focuses on the water quality data collected at Station 3, which is centrally located within the lake. This station has historically been used to describe the overall water quality of Lake Wallenpaupack and this appears to be quite logical based upon our review of data since 1980. In contrast, Station 5 is located uplake near the confluence of Wallenpaupack Creek and represents more eutrophic conditions – especially with respect to nutrients. Wallenpaupack Creek is the major tributary to the lake and drains a substantial portion of the massive Lake Wallenpaupack watershed (Figure 1.1).

With the exception of dissolved oxygen and water temperature, the water quality data at Station 3 are presented as average (mean) values for the growing season (May through October). The growing season is a very important time period since this is the time when the lakes are most heavily used (e.g. recreation, aesthetics) and most water quality problems, as related to eutrophication, occur. All of the lake data that were collected and analyzed in 2012 are presented in Appendix C.

4.1. Temperature and Dissolved Oxygen

In late spring or the beginning of summer, many moderately deep to deep temperate lakes develop stratified layers of water. Under stratified conditions, warmer and colder waters are near the lake's surface (epilimnion) and the lake's bottom (hypolimnion), respectively. As the temperature differences become greater between these two water layers, the resistance to mixing increases. During lake stratification, the epilimnion is usually oxygen-rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion may become depleted of oxygen due to the respiration of aquatic organisms. As previously discussed, aquatic organisms (e.g., bacteria, fungi, protozoan, zooplankton, macroinvertebrates, fish) consume dissolved oxygen in order to metabolize prey or detritus (U.S. EPA 1980, U.S. EPA 1990 and U.S. EPA 1993).

Conversely, shallow temperate lakes may only become weakly stratified during the summer months or some lakes may never stratify at all. The overall degree and duration of stratification in weakly stratified lakes are largely dependent upon local wind conditions and the morphological characteristics of the lake itself. During windy days, surface wave action may be sufficient to partially or completely destratify (mix) a lake. Conversely, a shallow lake may become partially stratified on windless days.

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Overall, water temperatures and dissolved oxygen concentrations are very important with regards to a lake's fishery. In general, the optimal water temperature for salmonid fish (i.e., trout) is 55 to 60 EF (12.8 to 15.6 EC). Trout may withstand water temperatures above 80 EF (26.7 EC) for several hours, but if water temperatures exceed 75 EF (23.9 EC) for extended periods, high trout mortality is expected (Pennsylvania State University). Conversely, non-salmonid fish such as golden shiners, bass, bluegills, can grow well even when water temperatures exceed 80 EF (26.7 EC). In general, safe minimum dissolved oxygen concentrations for adult salmonid and non-salmonid fish are 5.0 and 3.0 mg/L, respectively. When dissolved oxygen concentrations fall below these concentrations, production impairment of the lake's fishery can be expected.

In addition to impacting the lake's fishery, low dissolved oxygen levels in the bottom waters of a lake will often accelerate the release of nutrients such as soluble orthophosphorus (analytically measured as dissolved reactive phosphorus) and ammonia nitrogen, from anoxic (oxygen depleted) in-lake sediments. In particular, the accelerated release rates of nutrients (referred to as internal loading) can represent a substantial portion of all incoming nutrients to a lake. Increased nutrient loadings via in-lake sediments may further degrade lake water quality by increasing the production of both phytoplankton and aquatic macrophytes (vascular plants).

Lake Wallenpaupack

The 2012 water temperature and dissolved oxygen profile data for Lake Wallenpaupack are graphically presented in Figures 4.1 through 4.2. The maximum water depth at Station 3 was 12.50 meters (41.0 feet) in 2012. The lake was strongly, thermally stratified during the months of June, July, and August. Moderate thermal stratification was observed in May and September (Figure 4.1). Figure 4.2 shows that dissolved oxygen levels rapidly decreased within deeper lake waters (hypolimnion). The thermocline, which is the point where the temperature change is the greatest, divides the epilimnion (surface waters) and the hypolimnion (bottom waters), was located at a depth of approximately 6 to 8 meters (20 to 26 feet) during the period of June through August.

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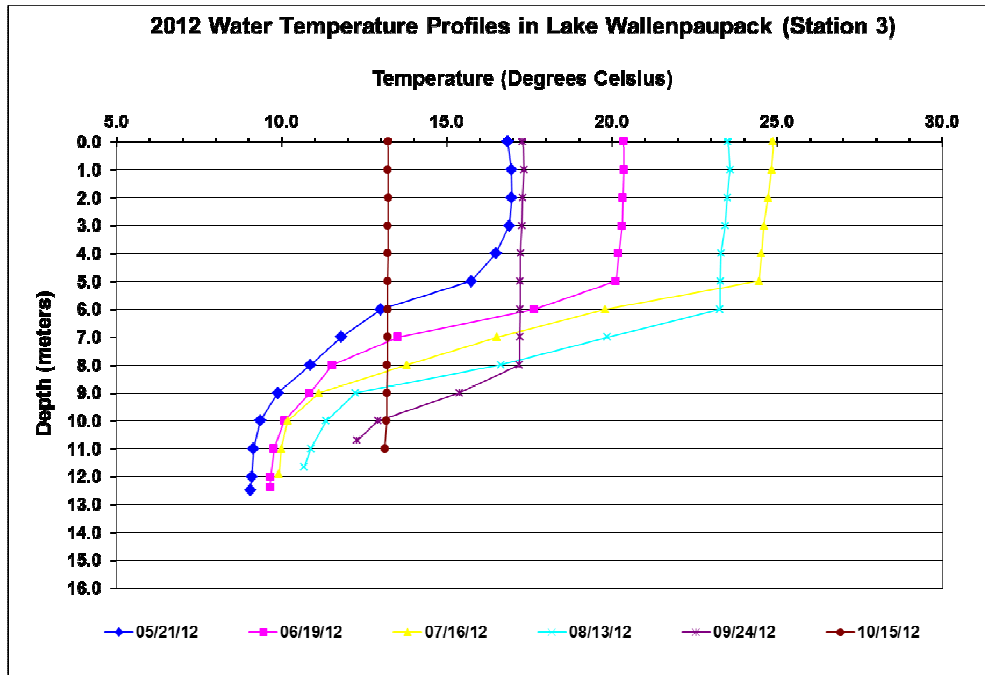


Figure 4.1 Water Temperature Profiles at Station 3 in 2012

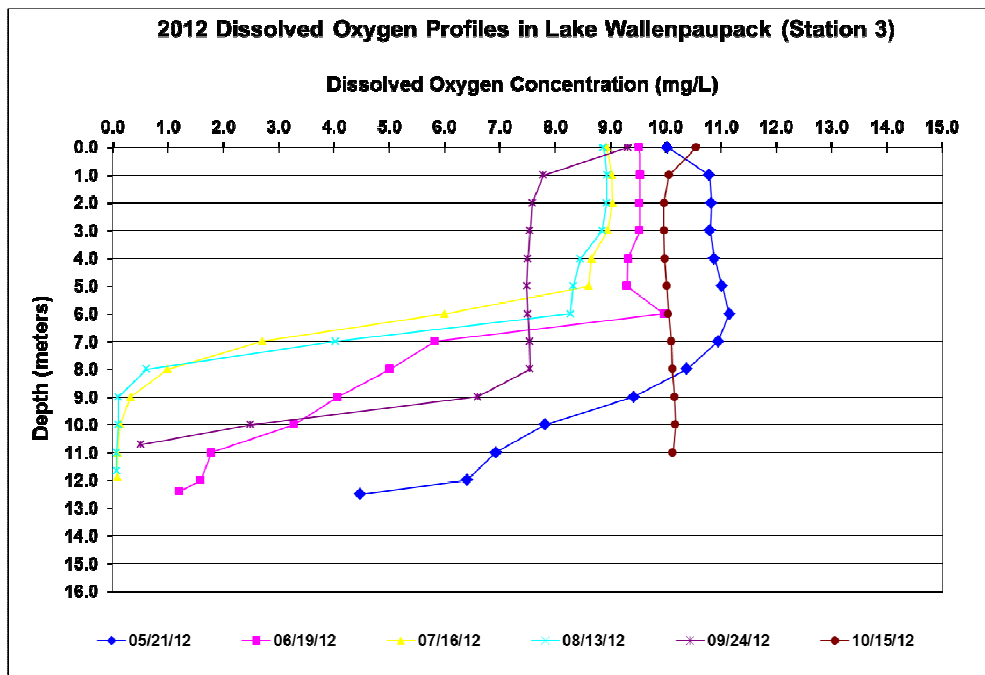


Figure 4.2 Dissolved Oxygen Profiles at Station 3 in 2012

4.2. pH & Alkalinity

The pH and alkalinity of water are directly related to one another. In general, as alkalinity increases, the pH of the water also increases. The acidity or basicity of a solution is most often expressed as pH. The term pH is defined as the logarithm of the reciprocal (or its negative logarithm) of the hydrogen ion concentration. Therefore, a one unit change in pH represents a ten-fold increase or decrease in the hydrogen ion concentration (as pH decreases, the hydrogen ion concentration increases). The pH scale ranges from 0 to 14 standard units where a value of 7 indicates neutral conditions. Water becomes more acidic when pH values fall below 7 and more basic when pH values rise above 7. In general, most natural waters usually have a pH values between 6.5 and 8.5.

Aquatic life in lakes can be adversely impacted when pH levels drop too low in lakes. When pH concentrations fall below 6.0 standard units, there is a greater risk to increase the concentration of heavy metals, in particular aluminum. High concentrations of hydrogen and aluminum ions are known to adversely affect the ion regulation of aquatic organisms, a condition referred to as "osmoregulatory failure". When osmoregulatory failure occurs, high hydrogen and aluminum concentrations induce the leaching of sodium and chloride ions from the body fluids of fish and other aquatic organisms (U.S. EPA, 1990). As summarized by J. Baker, pH values ranging from 5.5 to 6.0 standard units can result in the loss of sensitive minnows and dace, which may be important as forage fish for game fish. In addition, the pH levels below 6.0 are also known to adversely affect the reproductive success rates of game fish, such as walleye (U.S. EPA, 1990).

Alkalinity refers to the capacity of water to neutralize (or buffer against) acid inputs. Alkalinity of natural waters is due primarily to the presence of hydroxides (OH^-), bicarbonates (HCO_3^-), carbonates (CO_3^{2-}) and occasionally borates, silicates and phosphates. Therefore, the carbonate–bicarbonate equilibrium system ($\text{CO}_2 - \text{HCO}_3^- - \text{CO}_3^{2-}$) is the major buffering mechanism in freshwater lakes (Wetzel 1983).

Alkalinity is typically expressed in units of milligrams per liter (mg/l) of CaCO_3 (calcium carbonate). Waters having a pH below 4.5 contain no alkalinity. Low alkalinity is the main indicator of susceptibility of aquatic organisms to acidic inputs (e.g., acid rain and acidic dry fallout). Waters with pH values ranging from 6 to 9 are largely comprised of bicarbonate (HCO_3^-). At higher pH values, carbonate (CO_3^{2-}) plays a more important role in the buffering capacity of the water. Lakes with watersheds that contain sedimentary carbonate rocks are high in dissolved carbonates (hard-water lakes). Conversely, lakes in granite or igneous rocks are low in dissolved carbonates (soft water lakes). In the Northeastern U.S., the alkalinity of natural surface waters typically ranges from 5 to over 200 mg/L as CaCO_3 .

Lake Wallenpaupack

The 2012 mean pH values for surface and bottom waters are presented in Table 4.1. Overall, the surface and bottom waters are considered to be relatively neutral to slightly acidic. The slightly higher mean values for the surface waters were due to increased levels of photosynthesis by phytoplankton in the epilimnion (surface waters).

The mean alkalinity concentrations for surface and bottom waters in 2012 are presented in Table 4.1. The mean values are considered somewhat low, but typical for lakes within the Pocono Mountain region and the Northeastern U.S. Overall, the mean alkalinity concentrations should be sufficiently high enough to regulate or maintain stable pH levels in the lake. This simply means that the lake is not highly susceptible to acidic inputs such as, acid rain, acidic runoff from snowmelt and acidic dry deposition. Conversely, when acidic inputs are episodically high, the pH levels in the lake may decline, thereby providing additional stress on acid intolerant aquatic organisms.

Table 4.1 Mean pH & Alkalinity Concentrations at Station 3 in 2012

<i>Year</i>	<i>pH (standard units, s.u.)</i>		<i>Alkalinity (mg/l as CaCO₃)</i>	
	<i>Surface</i>	<i>Bottom</i>	<i>Surface</i>	<i>Bottom</i>
2012	6.99	6.35	12.4	13.7

4.3. Phosphorus

Total phosphorus represents the sum of all forms of phosphorus. Total phosphorus includes dissolved and particulate organic phosphates (e.g., algae and other aquatic organisms), inorganic particulate phosphorus as soil particles and other solids, polyphosphates from detergents and dissolved orthophosphates. Soluble (or dissolved) orthophosphate (determined analytically as dissolved reactive phosphorus) is the phosphorus form that is most readily available for algal uptake. Soluble orthophosphate is usually reported as dissolved reactive phosphorus because laboratory analysis takes place under acid conditions and may result in the hydrolysis of some other phosphorus forms. Total phosphorus levels are strongly affected by the daily phosphorus loadings to a lake, while soluble orthophosphate levels are largely affected by algal consumption during the growing season.

Based on criteria established by Nurnberg (2001), a lake is classified as oligotrophic, mesotrophic, eutrophic and hypereutrophic when surface total phosphorus concentrations are less than 0.010 mg/l as P, 0.010 to 0.030 mg/l as P, 0.031 to 0.100 mg/l as P and greater than 0.100 mg/l as P, respectively.

Lake Wallenpaupack

The 2012 mean total phosphorus concentrations for surface and bottom waters were 0.030 and 0.047 mg/L as P, respectively (Table 4.2). The higher concentrations in the bottom waters are likely due to the settling of dead algae and the release of phosphorus from anoxic sediments (sediments containing no dissolved oxygen). Based upon the above criteria, the mean total phosphorus concentrations for surface waters suggest that Lake Wallenpaupack is classified as mesotrophic in 2012.

The 2012 mean dissolved reactive phosphorus concentrations for surface and bottom waters were 0.004 and 0.015 mg/L as P, respectively (Table 4.2). Low dissolved reactive phosphorus concentrations in the surface waters indicate that this form of phosphorus is rapidly used by phytoplankton as soon as it becomes available within the lake.

Table 4.2 Mean Phosphorus Concentrations at Station 3 in 2012

<i>Year</i>	<i>Total Phosphorus (mg/L as P)</i>		<i>Dissolved Reactive Phosphorus (mg/L as P)</i>	
	<i>Surface</i>	<i>Bottom</i>	<i>Surface</i>	<i>Bottom</i>
2012	0.030	0.047	0.004	0.015

4.4. Nitrogen

Nitrogen compounds are also important for the growth and reproduction of phytoplankton and aquatic macrophytes. The common inorganic forms of nitrogen in water are nitrate (NO_3^-), nitrite (NO_2^-) and ammonia (NH_3). In water, ammonia is present primarily as ammonium (NH_4^+) and undissociated ammonium hydroxide (NH_4OH). Of these two forms, undissociated ammonium hydroxide is toxic and its toxicity increases as pH and water temperature increase. Overall, the most dominant form of inorganic nitrogen present in lakes depends largely on the dissolved oxygen

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concentrations. Nitrate is the form usually found in surface waters, while ammonia is only stable under anaerobic (low oxygen) conditions. Nitrite is an intermediate form of nitrogen, which is generally considered unstable. Nitrate and nitrite (referred to as total oxidized nitrogen) are often analyzed together and reported as NO₃ + NO₂-N, although nitrite concentrations are usually insignificant as noted previously. Total Kjeldahl nitrogen (TKN) concentrations include ammonia and organic nitrogen (both soluble and particulate forms). Organic nitrogen can be easily estimated by subtracting ammonia nitrogen from total Kjeldahl nitrogen concentrations. Total nitrogen is calculated by summing the nitrate-nitrite, ammonia and organic nitrogen fractions together.

According to Nurnberg (2001), lakes with surface total nitrogen concentrations less than 0.350 mg/l as N are classified as oligotrophic, from 0.350 to 0.650 mg/l as N are classified as mesotrophic, from 0.651 to 1.200 mg/L are classified as eutrophic and greater than 1.200 mg/l as N are classified as hypereutrophic.

Lake Wallenpaupack

The 2012 mean total nitrogen, total Kjeldahl nitrogen (TKN), nitrate plus nitrite nitrogen, and ammonia nitrogen concentrations for surface and bottom waters are presented in Table 4.3. Overall, the 2012 mean total nitrogen concentration for the bottom waters was moderately higher than the mean concentration for the surface waters. This higher value in the bottom waters is most likely attributed to higher levels of ammonia nitrogen and nitrate plus nitrite nitrogen. Higher ammonia concentrations in the bottom waters are due to low dissolved oxygen concentrations plus the accelerated release rates by anoxic sediments (sediments containing no dissolved oxygen).

Table 4.3 Mean Nitrogen Concentrations at Station 3 in 2012

Year	Total Nitrogen (mg/L as N)		Total Kjeldahl Nitrogen (mg/L as N)		Nitrate + Nitrite (mg/L as N)		Ammonia (mg/L as N)	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2012	0.548	0.744	0.517	0.655	0.031	0.089	0.062	0.152

Based upon the Nurnberg criteria (2001), the mean total nitrogen concentrations for surface waters are at a moderate level and thereby suggesting that Lake Wallenpaupack was classified as mesotrophic in 2012.

4.5. Secchi Disk Transparency & Chlorophyll-a

The transparency, or clarity, of a lake is most often reported as the Secchi disk depth. This measurement is taken by lowering a circular black-and-white disk, which is 20 cm (8 inches) in diameter, into the water until it is no longer visible. Observed Secchi disk depths range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes (Wetzel, 1983). Although somewhat simplistic and subjective, this field monitoring method probably best represents those lake conditions that are most often perceived by lake users and the general public.

Secchi disk transparency is related to the transmission of light in water, and depends on both the absorption and scattering of light. The absorption of light in dark-colored waters reduces light transmission. Light scattering is usually a more important factor than absorption in determining Secchi depths. Scattering can be caused by water discoloration or by the presence of both particulate organic matter (e.g., algal cells) and inorganic materials (e.g., suspended clay particles).

In general, a lake is classified as oligotrophic, mesotrophic, eutrophic and hypereutrophic when Secchi disk transparency values are greater than 4.0 meters, 4.0 to 2.0 meters, 1.9 to 1.0 meters and less than 1.0 meter, respectively (Nurnberg 2001).

Chlorophyll-a is a pigment that gives all plants their green color. The function of chlorophyll-a is to convert sunlight to chemical energy in the process known as photosynthesis. Because chlorophyll-a constitutes about 1 to 2 percent of the dry weight of planktonic algae, the amount of chlorophyll-a in a water sample is an indicator of phytoplankton biomass. According to Nurnberg (2001), a lake is generally classified oligotrophic, mesotrophic, eutrophic and hypereutrophic when chlorophyll-a concentrations are less than 3.5 ug/l, 3.5 to 9.0 ug/l, 9.1 to 25.0 ug/l and greater than 25.0 ug/l (micrograms per liter), respectively.

Lake Wallenpaupack

The 2012 mean Secchi disk transparency value for Lake Wallenpaupack was 2.0 meters. Secchi disk transparency values ranged from 1.3 to 2.6 meters for all study dates. Based upon Nurnberg (2001), the lake is classified as mesotrophic.

The 2012 mean chlorophyll-a concentration in Lake Wallenpaupack was 13.1 ug/L. Chlorophyll-a concentrations ranged from 5.4 to 31.0 ug/L during the study period. According to the Nurnberg criteria, the mean chlorophyll-a concentration indicates slightly eutrophic conditions.

Table 4.4 Mean Secchi & Chlorophyll-a Values at Station 3 in 2012

<i>Year</i>	<i>Secchi Disk Transparency (m)</i>	<i>Chlorophyll-a (ug/l)</i>
2012	2.0	13.1

4.6. Total Suspended Solids

The concentration of total suspended solids in a lake is a measure of the amount of particulate matter in the water column. Suspended solids include both organic matter including phytoplankton and inorganic materials like soil particles.

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The 2012 mean total suspended solids concentrations for surface and bottom waters are presented in Table 4.5. The concentrations for surface and bottom waters are considered moderately low. These concentrations are typical for lake systems containing moderate levels of aquatic productivity in the form of phytoplankton and/or sediment loadings from the surrounding watershed.

Table 4.5 Mean Total Suspended Solids Concentrations at Station 3 in 2012

<i>Year</i>	<i>Total Suspended Solids (mg/l)</i>	
	<i>Surface</i>	<i>Bottom</i>
2012	3.5	3.3

4.7. Phytoplankton & Zooplankton Biomass

The quantity of phytoplankton (free floating, microscopic aquatic plants commonly referred to as algae) and macrophytes (vascular aquatic plants) are primary biological indicators of lake trophic conditions. Small aquatic animals, namely zooplankton and macroinvertebrates, graze upon algae and fragments of aquatic plants. Larger invertebrates and fish then consume the above grazers and to a lesser extent, some aquatic plants.

Information about the plankton community composition and succession is extremely useful when attempting to gain a better understanding about various lake problems. For example, eutrophic lakes often support unbalanced phytoplankton communities characterized by very large numbers of relatively few species. The number of larger zooplankton will tend to decrease during periods when blue-green algae are dominant. Conversely, oligotrophic lakes and acidic lakes often have smaller populations of both phytoplankton and zooplankton. Acidic lakes typically will also have lower species diversity.

4.7.1. Phytoplankton

Phytoplankton are free floating, microscopic aquatic plants that have little or no resistance to currents and live suspended in open water. Their forms may be unicellular, colonial or filamentous. As photosynthetic organisms (primary producers), phytoplankton form the base of aquatic food chain and are grazed upon by zooplankton and herbivorous fish.

A healthy lake should support a diverse assemblage of phytoplankton, in which many algal species are represented. Excessive growth of a few species is usually undesirable. Such growth can result in dissolved oxygen depletion during the night, when the algae are respiring rather than photosynthesizing. Dissolved oxygen depletion also can occur shortly after a massive “algal bloom” due to increased levels of respiration by bacteria and other microorganisms that are metabolizing dead algal cells. Excessive growth of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances to the water, or give the water an unattractive green soupy or scummy appearance.

Planktonic productivity is commonly expressed in terms of density and biomass. Phytoplankton densities are most frequently expressed as cells per milliliter (cells/ml). Biomass is commonly expressed on a mass per volume basis as micrograms per liter ($\mu\text{g/l}$). Of the two, biomass provides a better estimate of the actual standing crop of phytoplankton in lake systems.

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The phytoplankton community in 2012 was represented by genera from seven different taxa: Bacillariophyta (diatoms), Chlorophyta (green algae), Chrysophyta (golden-brown algae), Cryptophyta (cryptomonads), Cyanophyta (blue-green algae), Euglenophyta (euglenoids), and Pyrrophyta (fire algae). The phytoplankton biomasses in Lake Wallenpaupack ranged from 1,915 to 16,113 ug/L (micrograms per liter) for 2012, as shown in Figure 4.3. The highest phytoplankton biomass value was reported in June of 2012. In general, phytoplankton biomass below 2,500 ug/l are considered low, ranging from 2,500 to 7,500 ug/l are moderately low to moderately high, ranging from 7,500 to 10,000 ug/l are high and above 10,000 are considered very high. Biomasses often exceeding 5,000 ug/l are perceived by many as “algal bloom” conditions.

Phytoplankton biomass peaked in June 2012 and was largely dominated by *Anabaena* (Cyanophyte), but *Tabellaria* (Bacillariophyta) and *Teilingia* (Chlorophyta) also had significant biomass during June, as shown in Figure 4.3. It should also be noted that *Anabaena* (Cyanophyte) biomass values were substantially high during June through September. Conversely, during September, *Tabellaria* was most dominant followed by *Aphanizomenon* (Cyanophyte) and *Anabaena*. As previously mentioned, biomass values for 2012, ranged from a minimum of 1,915 to a maximum value of 16,113 ug/L (Figure 4.3). Overall, the phytoplankton assemblages, with some exception during the months of July, August, and September of 2012, were considered moderately well distributed among taxa during the 2012 study period.

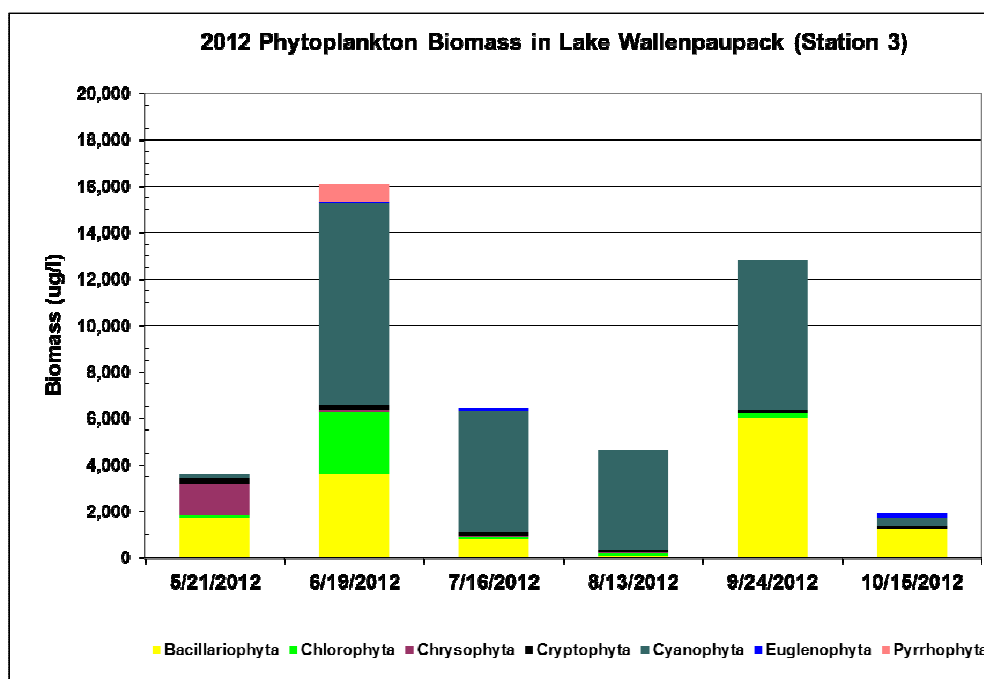


Figure 4.3 Phytoplankton Biomass at Station 3 in 2012

4.7.2. Zooplankton

Zooplankton are suspended microscopic animals whose movements in a lake are primarily dependent upon water currents. The zooplankton of freshwater ecosystems are dominated primarily by four major groups: the protozoa, the rotifers and two subclasses of crustacea, the cladocerans (i.e., water fleas) and the copepods. Zooplankton are generally smaller than 2 millimeters (one-tenth of an inch) in size and primarily feed on algae, other zooplankton, and plant and animal particles. Zooplankton grazing can have a significant impact on phytoplankton species composition and productivity (i.e. biomass) through selective grazing (e.g., size of zooplankton influences what size phytoplankton are consumed) and nutrient recycling. Zooplankton are then consumed by fish, waterfowl, aquatic insects, and others, thereby playing a vital role in the transfer of energy from phytoplankton to higher trophic levels.

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Zooplankton communities in 2012 were represented by genera from four different taxa: Protozoa (protozoans), Rotifera (rotifers), Copapoda (crustacean), and Cladoceran (crustacean). Zooplankton biomass values between May through October of 2012 are shown in Figure 4.4.

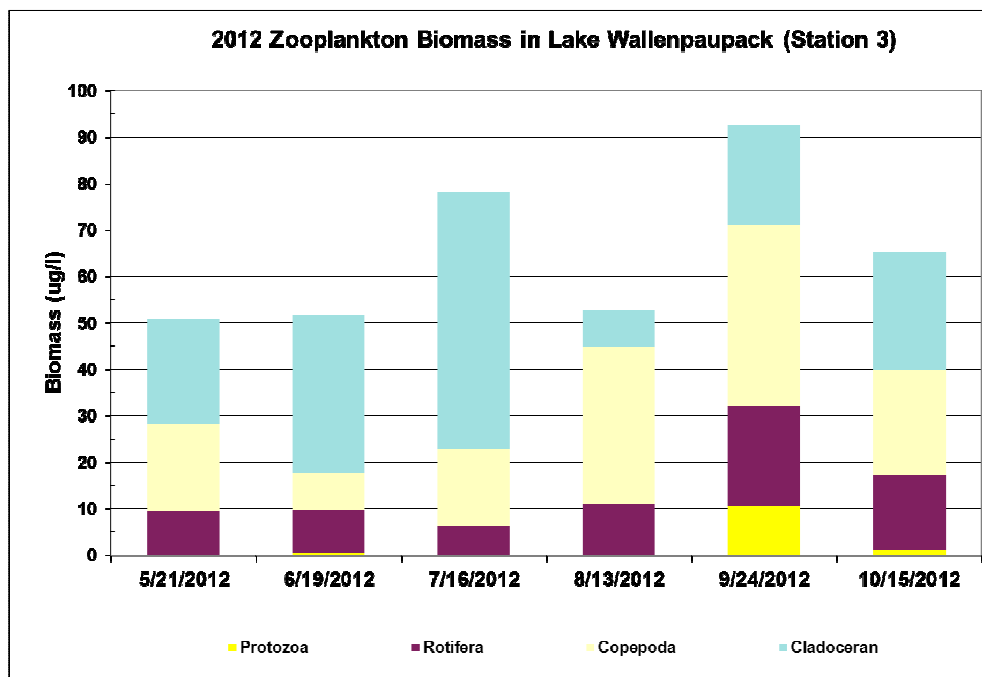


Figure 4.4 Zooplankton Biomass at Station 3 in 2012

Similarly to the phytoplankton, zooplankton populations were considered fairly well distributed among taxa during the 2012 growing season as shown in Figure 4.4. Cladocerans were most abundant during the months of May, June, July, and October. Copepods were most dominant in August and September.

4.8. Carlson's Trophic State Index Values

The Trophic State Index (TSI) developed by Carlson (1977) is among the most commonly used indicators of lake trophic state. This index is actually composed of three separate indices based on measurements of total phosphorus concentrations, chlorophyll-a concentrations and Secchi disk depths for many lakes. Total phosphorus was chosen for the index because phosphorus is often the nutrient limiting for phytoplanktonic growth in lakes. Chlorophyll-a is a plant pigment present in all algae and is used to provide an indication of the biomass of phytoplankton and Secchi disk depth is a common measure of lake transparency.

As part of this study, TSI values were determined for total phosphorus, chlorophyll-a, and Secchi depth data for each of the study dates. Total phosphorus concentrations, chlorophyll-a concentrations, and Secchi disk depths were logarithmically converted to a trophic state scale ranging from 1 to 100. Increasing values for the Trophic State Index are indicative of increasing lake trophic states.

In general, trophic state index values less 35 to 40 are indicative of oligotrophic conditions, while index values greater than 50 to 55 are indicative of eutrophic lake conditions. The Pennsylvania Department of Environmental Protection (PA DEP) classifies lakes according to the following: oligotrophic (less than 40), mesotrophic (40 to 50), eutrophic (50 to 65) and hyper-eutrophic (greater than 65) as noted in its 2002 PA Water Quality Assessment 305(b) Report.

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The calculated 2012 mean Carlson TSI values for Secchi depth, chlorophyll-a, and total phosphorus are presented in Table 4.6. The Secchi depth transparency TSI value suggests highly mesotrophic to slightly eutrophic conditions, while the TSI values for total phosphorus and chlorophyll-a suggest eutrophic conditions. Based upon the above, Lake Wallenpaupack is best classified as boarder line mesotrophic – eutrophic.

Table 4.6 Mean Carlson’s TSI Values at Station 3 in 2012

Year	Trophic State Index (TSI) Values		
	Secchi Depth	Chl-a	Total P
2012	50	56	53

Note: Mean TSI values determined by averaging the individual TSI values for each parameter during the 2012 study period.

4.9. Summary of Lake Assessment Data

Lake Wallenpaupack was classified as boarder line mesotrophic – eutrophic reservoir in 2012. The mean Carlson TSI values for total phosphorus, chlorophyll-a, and Secchi disk transparency were 53, 56, and 50, respectively, for 2012. The TSI value of Secchi depth indicates highly mesotrophic to slightly eutrophic conditions, while the TSI values for total phosphorus and chlorophyll-a indicate eutrophic conditions.

The lake thermally stratified in 2012 and therefore is considered a moderately deep, dimictic reservoir (lake). Dimictic lakes are those lakes that thermally stratify during most of the growing season (May through October). In this study, Lake Wallenpaupack was thermally stratified from May through September. In turn, the dissolved oxygen concentrations were strongly stratified when the lake was thermally stratified.

The lake was the most thermally stratified during the months of June, July and August in 2012. As in the past, the dissolved oxygen levels rapidly decreased within deeper lake waters (hypolimnion). The thermocline, which is the point where the temperature change is the greatest, divides the epilimnion (surface waters) and the hypolimnion (bottom waters), was located at a depth of approximately 6 to 8 meters (20 to 26 feet) during the period of June through August.

Phytoplankton data indicate that blue-green algae (Cyanophyta) were dominant during most of the growing season. The most common genera were *Anabaena* and *Aphanizomenon*.

5. Historical Lake Water Quality Trends

Aqua Link evaluated historical water quality data collected in Lake Wallenpaupack from 1980 through 2012. Key water quality parameters that are discussed in Sections 5.1 through 5.6 are total phosphorus, total nitrogen, Secchi disk transparency, chlorophyll-a, plankton biomass (phytoplankton and zooplankton), and Carlson Trophic State Index (TSI) values. Total phosphorus and total nitrogen data are presented for surface (epilimnion) and bottom (hypolimnion) waters.

The comparison of recently acquired data to past data is commonly referred to as “water quality trend analysis”. Professional lake and water resource managers commonly evaluate complex historical water quality data using trend analysis. Overall, water quality trend analysis is a very powerful tool in assessing whether lake water quality has improved, degraded or remained unchanged over time.

Lake water quality trends for the key water quality parameters are presented below graphically for Station 3. Station 3, which is centrally located within the lake, has historically been used to describe the overall water quality of Lake Wallenpaupack (Section 4). The graphs contain annual mean (average) concentrations and values for the key water quality parameters for the growing season (May through October). As observed in Figures 5.1 through 5.9, lake water quality often varies seasonally and annually and these variations can be affected by numerous factors including local climatological conditions. To assess any water quality trends, “best fit” lines were determined statistically using linear regression and these lines were plotted on Figures 5.1 through 5.9. The slopes of these regression lines were used to assess the overall degree of water quality improvement or degradation in the lake.

5.1. Phosphorus

The mean total phosphorus concentrations from 1980 through 2012 for surface and bottom waters are shown in Figures 5.1 and 5.2, respectively. The total phosphorus levels in surface and bottom waters slightly increased and decreased, respectively, in 2012 over the 2011 mean values. In terms of trends, Figures 5.1 and 5.2 indicate that total phosphorus concentrations have slightly decreased in the surface waters and significantly decreased in the bottom waters since 1980.

5.2. Nitrogen

The mean total nitrogen concentrations from 1980 through 2012 for surface and bottom waters are shown in Figures 5.3 and 5.4, respectively. The mean total nitrogen concentration for surface waters increased to 0.548 mg/L as N. In addition, the mean total nitrogen concentration for bottom waters increased slightly to a level of 0.744 mg/L as N. Although increases in total nitrogen concentrations were observed for 2012, slight fluctuations are typical from year to year. In terms of

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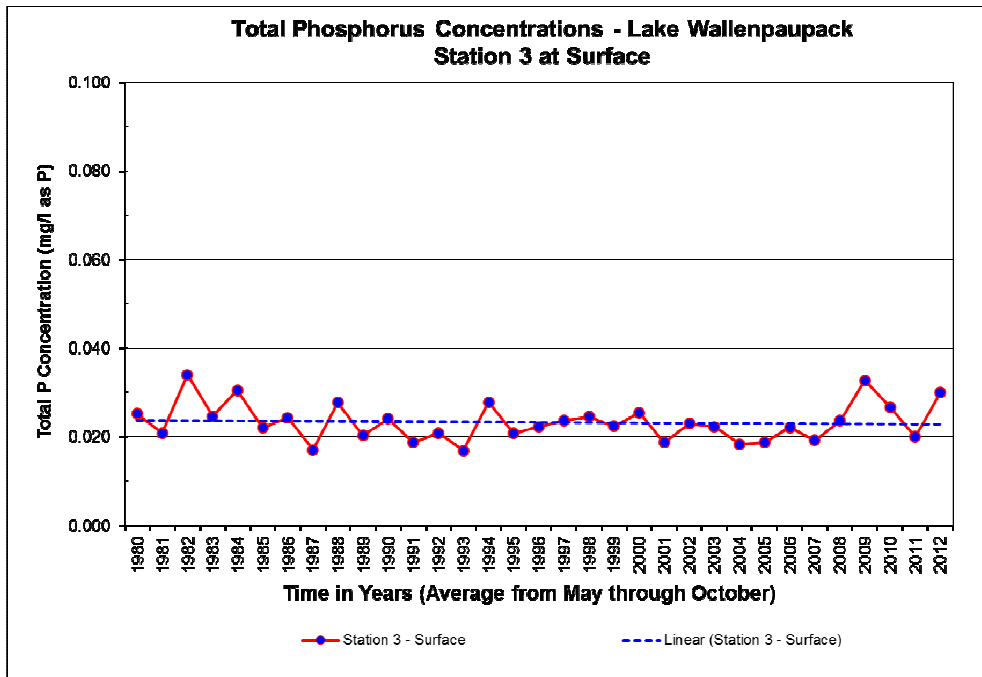


Figure 5.1 Historical Total Phosphorus Concentrations in Surface Waters

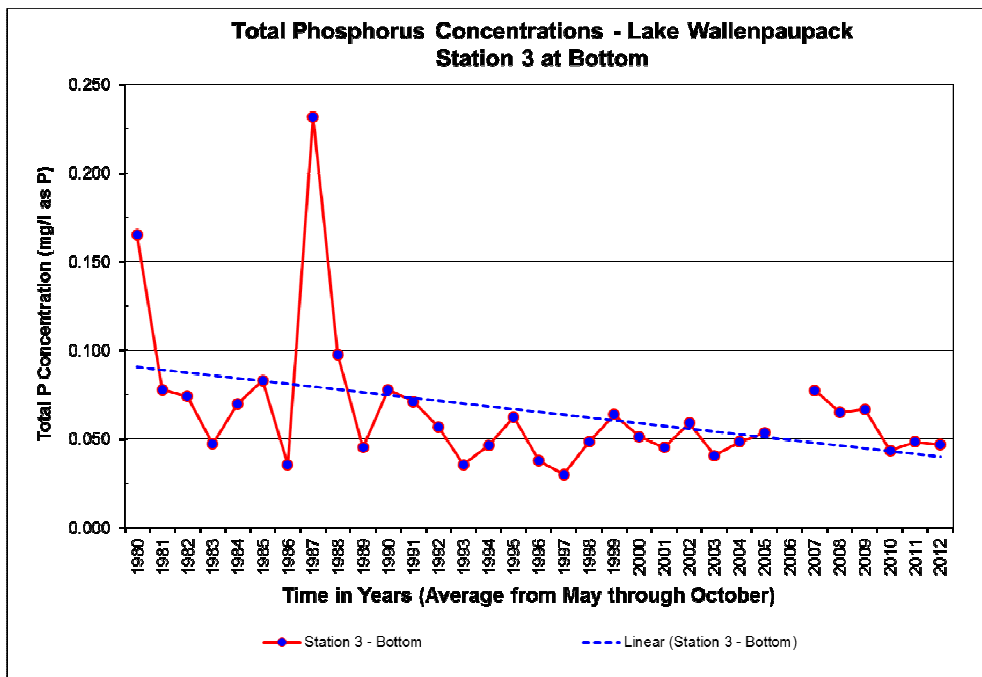


Figure 5.2 Historical Total Phosphorus Concentrations in Bottom Waters

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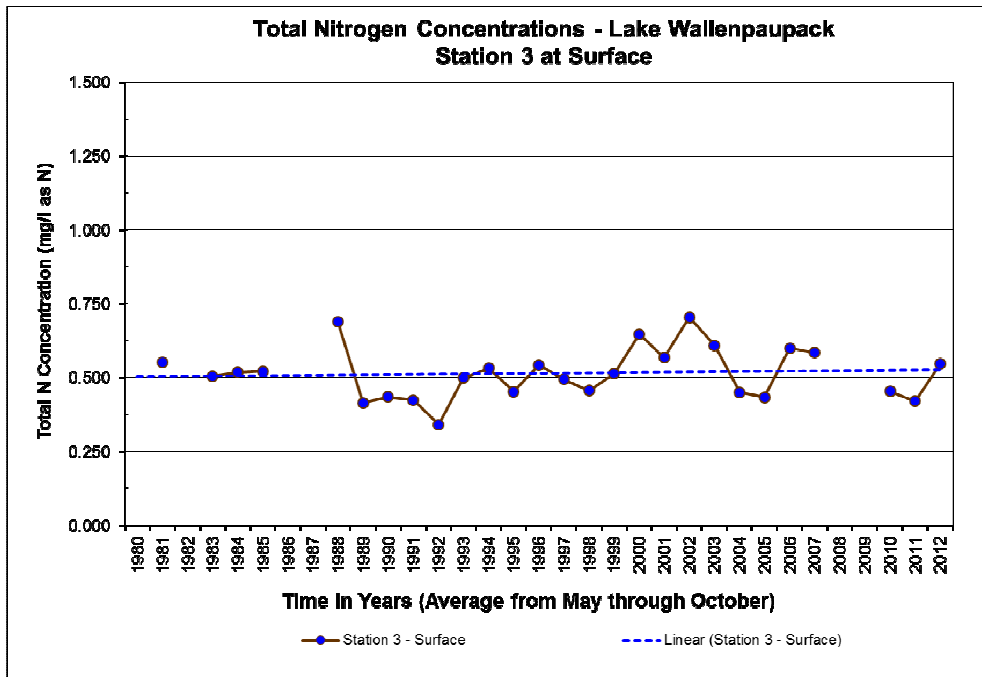


Figure 5.3 Historical Total Nitrogen Concentrations in Surface Waters

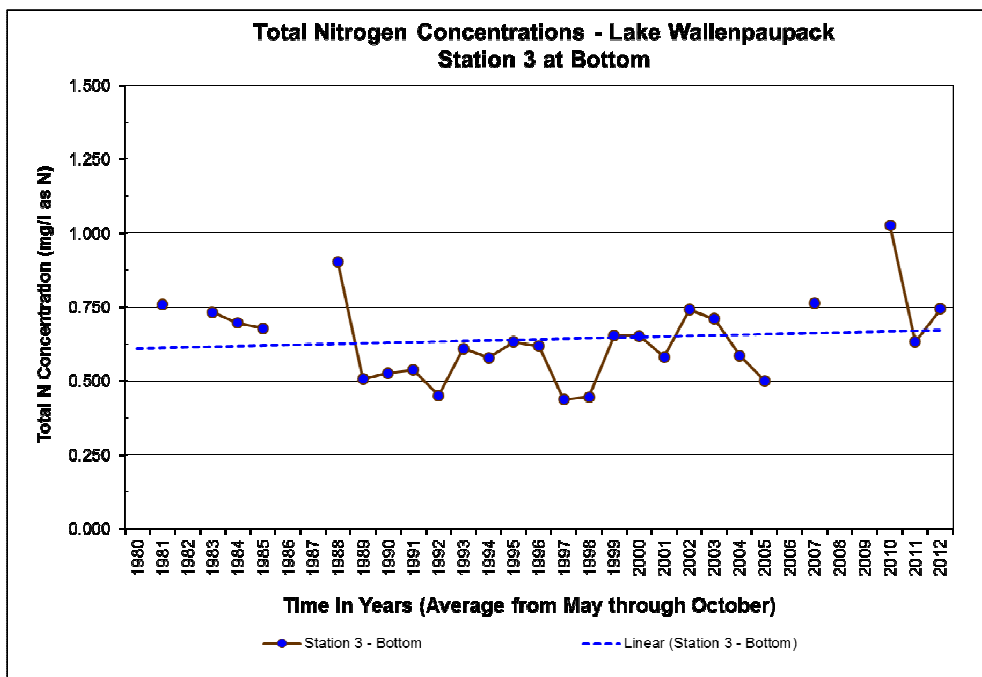


Figure 5.4 Historical Total Nitrogen Concentrations in Bottom Waters

trends, Figures 5.3 and 5.4 indicate that total nitrogen concentrations in the lake have slightly increased since 1980.

5.3. Secchi Transparency

The mean Secchi disk transparency from 1980 through 2012 is shown in Figure 5.5. The mean Secchi depth slightly decreased in 2012. In terms of trends, Figure 5.5 indicates that lake transparency has steadily improved since 1980.

5.4. Chlorophyll-a

The mean chlorophyll-a concentrations from 1980 through 2012 is shown in Figure 5.6. The mean chlorophyll-a concentration in 2012 was very similar to the previous two years and still remained below 15.0 ug/L. In terms of trends, Figure 5.6 shows that chlorophyll-a concentrations have slightly increased since 1980.

5.5. Phytoplankton & Zooplankton Biomass

The mean phytoplankton and zooplankton biomass values from 1980 through 2012 are shown in Figures 5.7 and 5.8, respectively. Both phytoplankton and zooplankton biomass values increased in 2012. Overall, Figures 5.7 and 5.8 show that phytoplankton and zooplankton biomass values have fluctuated widely since 1980. In terms of trends, the plotted regression lines suggest that phytoplankton and zooplankton biomass have slightly increased and decreased, respectively, over the past 33 years. Zooplankton biomass decreases may be related to more intense grazing pressure by predators (planktivorous fish).

It is interesting to note that blue-green algal biomass (Cyanophyta) increased at a slower rate when compared to total phytoplankton biomass (Figure 5.7) over the past 33 years. As noted in Section 5.3, lower blue-green dominance may be related to decreases in total phosphorus concentrations (Figures 5.1 and 5.2) and increases in total nitrogen concentrations (Figures 5.3 and 5.4). In general, higher nitrogen to phosphorus concentration ratios in lakes often favor green (Chlorophyta) over blue-green algae (Cyanophyta) resulting in more species diversity and improved water clarity and aesthetics.

5.6. Carlson Trophic State Index Values

The mean Carlson Trophic State Index (TSI) values for total phosphorus, chlorophyll-a, and Secchi depth transparency from 1980 through 2012 is shown in Figures 5.9. As expected, the total phosphorus and Secchi transparency have gradually improved, while chlorophyll-a has marginally increased over the past 33 years.

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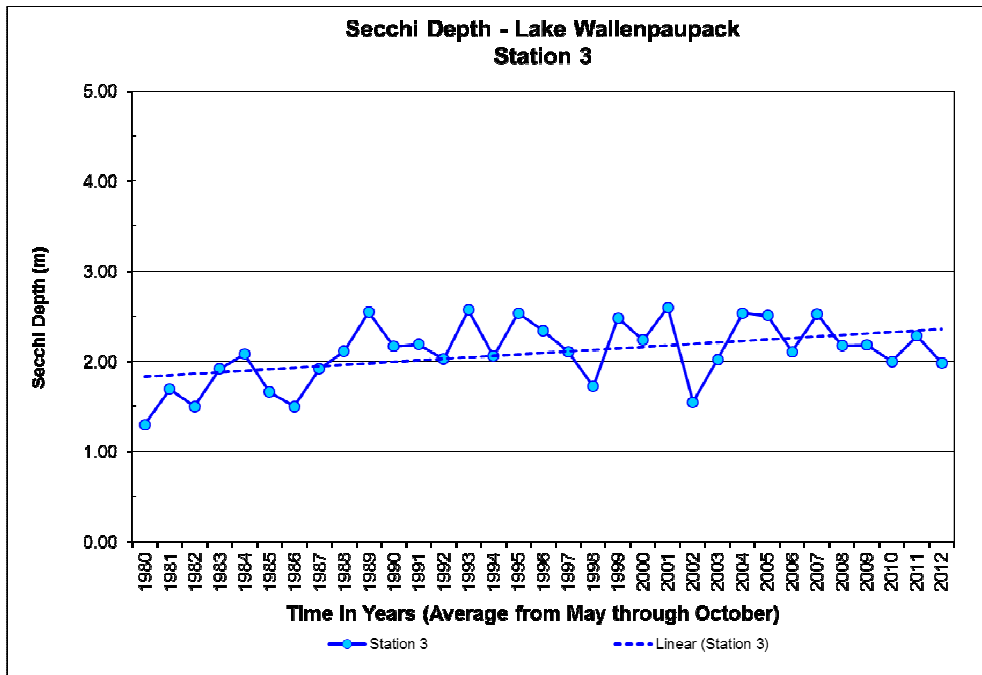


Figure 5.5 Historical Secchi Disk Transparency

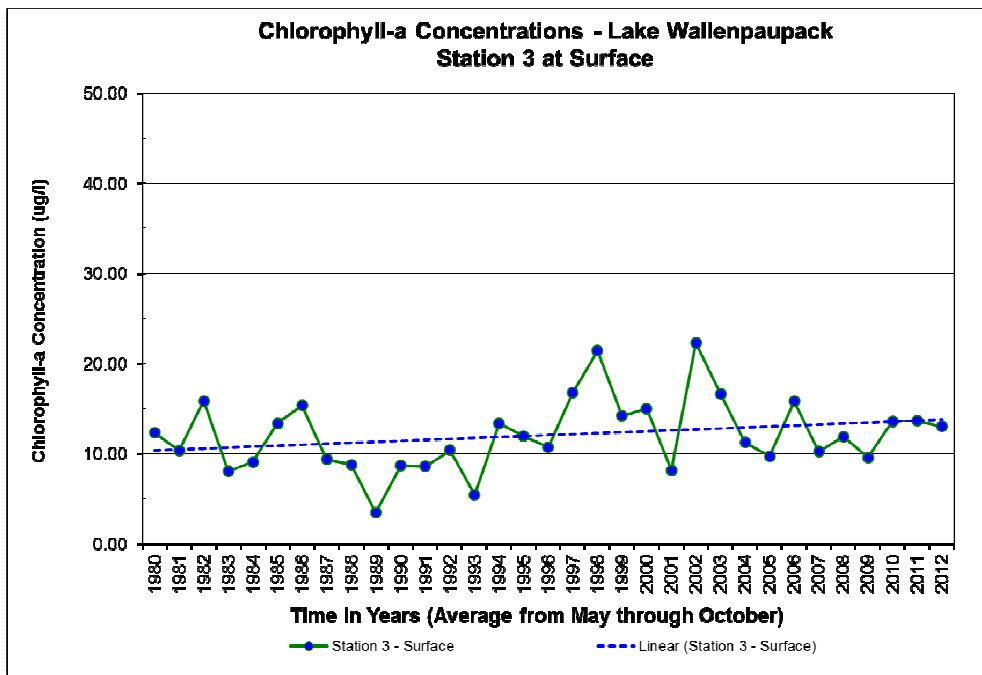


Figure 5.6 Historical Chlorophyll-a Concentrations

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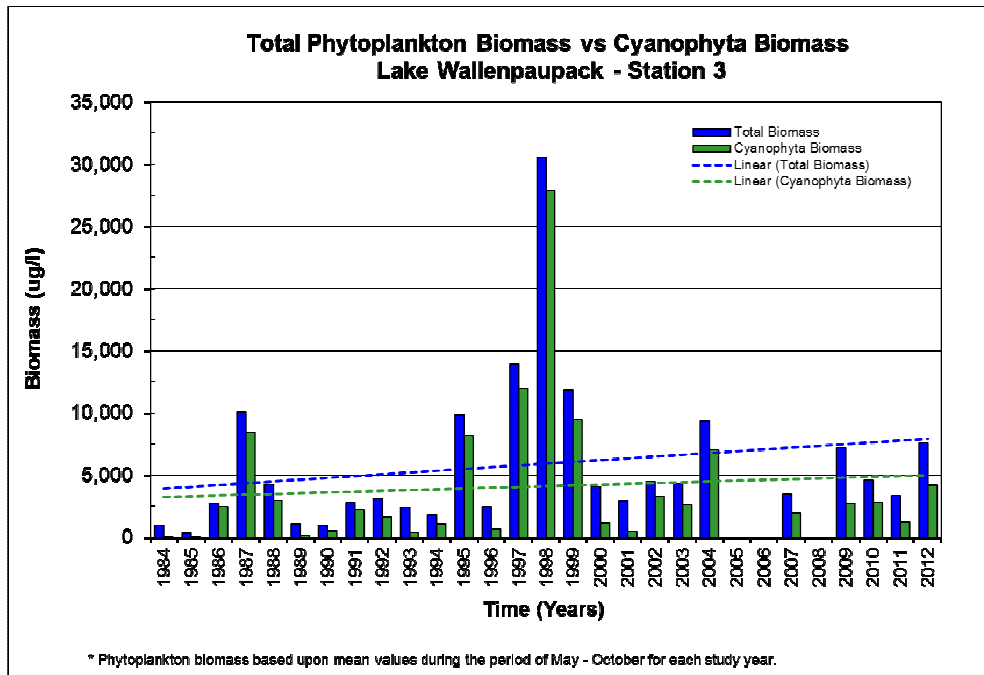


Figure 5.7 Historical Phytoplankton Biomass

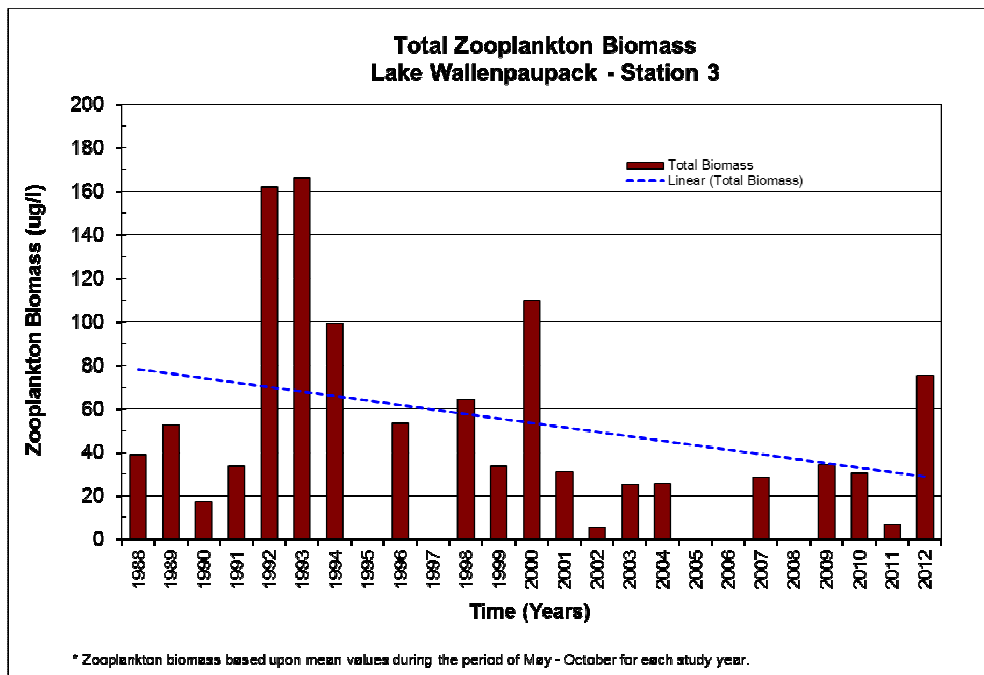


Figure 5.8 Historical Zooplankton Biomass

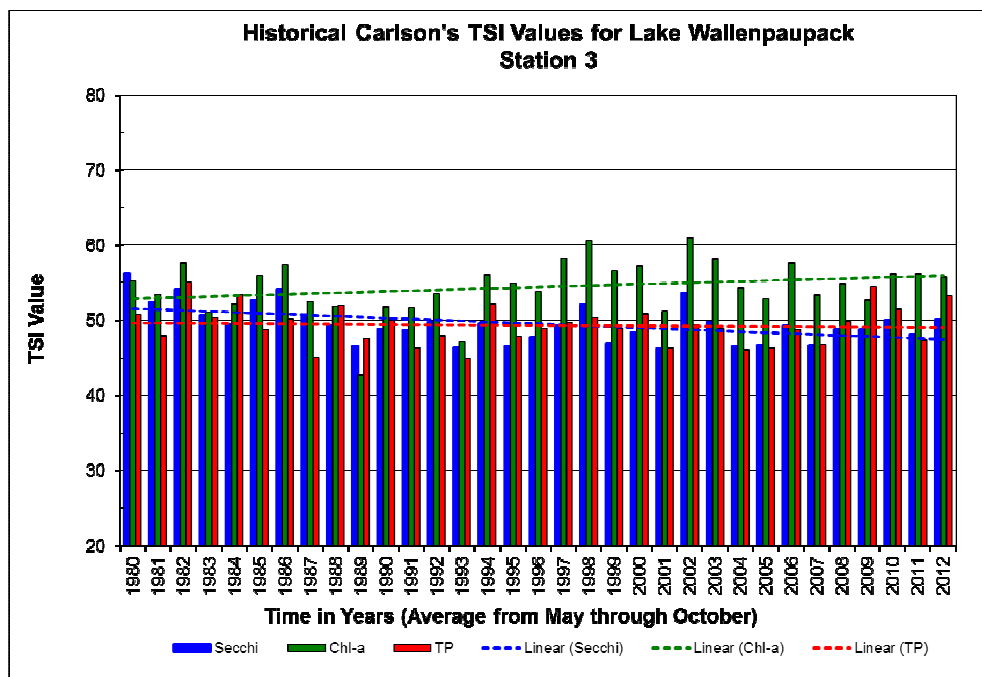


Figure 5.9 Historical Carlson's TSI Values

5.7. Summary of Historical Lake Data

Based upon trend analysis, the water quality of Lake Wallenpaupack has generally improved since 1980. Total phosphorus concentrations in surface and bottom waters and Secchi transparency (water clarity) have gradually improved over the past 33 years. In contrast, total nitrogen concentrations in surface and bottom waters marginally increased along with chlorophyll-a concentrations and phytoplankton biomass. Zooplankton biomass has steadily decreased over the years and may be related to more intense grazing pressure of larger zooplankton by predators (planktivorous fish).

It should be noted that water clarity (Secchi transparency) actually improved even though chlorophyll-a concentrations and phytoplankton biomass increased. Improved water clarity may be related to a shift in the phytoplankton community, where nuisance blue-green algal dominance appears to be decreasing. This shift may be attributed to decreases in total phosphorus and increases in total nitrogen in the lake. In general, higher nitrogen to phosphorus concentration ratios in lakes often favor green (Chlorophyta) over blue-green (Cyanophyta) algae.

6. Conclusions and Recommendations

Lake Wallenpaupack was classified as a border line mesotrophic - eutrophic reservoir in 2012. The mean Carlson TSI values for total phosphorus, chlorophyll-a, and Secchi disk transparency were 53, 56, and 50, respectively, for 2012. The lake was thermally stratified in 2012 from May through September. In turn, the dissolved oxygen concentrations were strongly stratified when the lake was thermally stratified.

The lake was the most thermally stratified during the months of June, July and August in 2012. As in the past, the dissolved oxygen levels rapidly decreased within deeper lake waters (hypolimnion). The thermocline, which is the point where the temperature change is the greatest, divides the epilimnion (surface waters) and the hypolimnion (bottom waters), was located at a depth of approximately 6 to 8 meters (20 to 26 feet) during the period of June through August.

Phytoplankton data indicate that blue-green algae (Cyanophyta) are dominant during the months of July through September in 2012. The most common genera were *Anabaena* and *Aphanizomenon*. Zooplankton biomass increased in 2012, but remained moderately low and may be related to intense grazing pressure of larger zooplankton by predators (planktivorous fish).

Based upon trend analysis, the water quality of Lake Wallenpaupack has generally improved since 1980. Total phosphorus concentrations in surface and bottom waters and Secchi transparency (water clarity) have gradually improved. Total nitrogen concentrations in surface and bottom waters marginally increased along with chlorophyll-a concentrations and phytoplankton biomass.

Over the past 33 years, water clarity (Secchi transparency) increased although chlorophyll-a and phytoplankton biomass have slightly increased. This appears to be related to a shift in the phytoplankton community, where blue-green algal dominance is less prevalent. The shift in the phytoplankton community may be attributed to decreases in total phosphorus and increases in total nitrogen in the lake. In general, higher nitrogen to phosphorus concentration ratios in lakes often favor green (Chlorophyta) over blue-green (Cyanophyta) algae resulting in more species diversity and improved water clarity and aesthetics.

Based upon the above conclusions, Aqua Link offers the following recommendations to the District:

1. The District should continue to retain Aqua Link to analyze future lake water quality data and prepare future annual lake reports. All lake water quality data would be entered into the newly created historical lake water quality database, as developed by Aqua Link, and subsequently analyzed by Aqua Link.

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2. The District should continue to retain Aqua Link to assist in all future lake monitoring activities. As in 2012, Aqua Link would be responsible for collecting all *insitu* water quality data using our instrumentation and data loggers.
3. The District should continue to retain ECM, Inc. as the contract laboratory for all water quality analysis. ECM will be responsible for analyzing water samples for the following parameters: alkalinity, total phosphorus, dissolved reactive phosphorus, total Kjeldahl nitrogen, ammonia, nitrate, nitrite, total suspended solids and chlorophyll-a. The District should request that ECM use all Method Detection Limits (MDL) as established by Aqua Link for the 2010 lake monitoring program.
4. All phytoplankton and zooplankton samples should continue to be analyzed using the same methods used by Dr. Kenneth Wagner. All plankton data should be sent directly to Aqua Link in a Microsoft Excel format, thereby allowing us to easily import any newly acquired data into the water quality database for data analysis.
5. The lake should continue to be monitored at Stations 3 and 5. These stations should be monitored at least monthly from May through October. On each study date at each station, *insitu* water quality data (pH, dissolved oxygen, temperature, conductivity, specific conductance, total dissolved solids, and ORP) should be collected at one-meter intervals throughout the water column. Secchi disk transparency should also be measured and recorded.
6. Lake water samples should be collected at two sampling depths (surface and bottom) at each lake station. Surface water quality samples should be collected and analyzed for the following parameters: alkalinity, total phosphorus, dissolved reactive phosphorus, total Kjeldahl nitrogen, ammonia, nitrate, nitrite, total suspended solids and chlorophyll-a. Bottom water quality samples will be collected and analyzed for the following parameters: alkalinity, total phosphorus, dissolved reactive phosphorus, total Kjeldahl nitrogen, ammonia, nitrate, nitrite, and total suspended solids. In addition, lake water samples should be collected for phytoplankton and zooplankton analysis. Phytoplankton samples should be collected as composited samples of the photic zone – defined as twice the Secchi depth. Zooplankton samples should be collected as vertical tows of the entire water column with a 80 micron plankton net.

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APPENDIX A

Glossary of Lake & Watershed Management Terms

Glossary

Algae - Mostly aquatic, non-vascular plants that float in the water or attach to larger plants, rocks, and other substrates. Also called phytoplankton, these individuals are usually visible only with a microscope. They are a normal and necessary component of aquatic life, but excessive numbers can make the water appear cloudy and colored.

Alkalinity - The acid-neutralizing capacity of water. It is primarily a function of the carbonate, bicarbonate, and hydroxide content in water. The lower the alkalinity, the less capacity the water has to absorb acids without becoming more acidic.

Ammonia (NH₃) - A nitrogen-containing substance which may indicate recently decomposed plant or animal material.

Benthos - The communities of aquatic life which dwell in or on the bottom sediments of a water body.

Chlorophyll - Pigments (mostly green) in plants, including algae, that play an important part in the chemical reactions of photosynthesis. A measurement of chlorophyll-a (one type of chlorophyll) is commonly used as a measure of the algae content of water.

Conductivity (Cond) - A measure of water's capacity to convey an electric current. It is related to the total amount of dissolved charged substances in the water. Therefore, it can be used as a general indicator of the quality of the water and can also suggest presence of unidentified material in the water. It is often used as a surrogate for salinity measurements.

Combined Sewer Overflow (CSO) - Discharges of combined sewage and stormwater into water bodies during very wet or storm weather. These discharges occur to relieve the sewer system as it becomes overloaded with normal sewer flow and increased storm run-off. The term is also used to denote a pipe that discharges those overflows.

Dissolved oxygen (DO) - Oxygen that is dissolved in the water. Certain amounts are necessary for life processes of aquatic animals. The oxygen is supplied by the photosynthesis of plants, including algae, and by aeration. Oxygen is consumed by animals and plants at night, and bacterial decomposition of dead organic matter (plant matter and animal waste).

Effluent - Liquids discharged from sewage treatment plants, septic systems, or industrial sources to surface waters.

Epilimnion - The warmer, well-lit surface waters of a lake that are thermally separated from the colder (hence denser), water at the bottom of the lake when a lake is stratified.

Eutrophication - The acceleration of the loading of nutrients to a lake by natural or human-induced causes. The increased rate of delivery of nutrients results in increased production of algae and consequently, poor water transparency. Human-induced (cultural) eutrophication may be caused by input of treated sewage to a lake, deforestation of a watershed, or the urbanization of a watershed.

Fecal Coliform Bacteria - Bacteria from the intestines of warm-blooded animals. Most of the bacteria are not in themselves harmful, so they are measured or counted as an indicator of the possible presence of harmful bacteria.

Groundwater - Water stored beneath the surface of the earth. The water in the ground is supplied by the seepage of rainwater, snowmelt, and other surface water into the soil. Some groundwater may be found far beneath the earth surface, while other groundwater may be only a few inches from the surface. Groundwater discharges into lowland streams to maintain their baseflow.

Hydrology -The science dealing with the properties, distribution and circulation of water. The term usually refers to the flow of water on or below the land surface before reaching a stream or man-made structure.

Hypolimnion - The dark, cold, bottom waters of a lake that are thermally separated from the warmer (hence less dense) surface waters when a lake is stratified.

Invertebrates - Animals without internal skeletons. Some require magnification to be seen well, while others such as worms, insects, and crayfish are relatively large. Invertebrates living in stream and lake sediments are collected as samples to be identified and counted. In general, more varied invertebrate communities indicate healthier water bodies.

Limiting nutrient - The nutrient that is in lowest supply relative to the demand. The limiting nutrient will be exhausted first by algae which require many nutrients and light to grow. Inputs of the limiting nutrient will result in increased algal production, but as soon as the limiting nutrient is exhausted, growth stops. Phytoplankton growth in lake waters of temperate lowland areas is generally phosphorus limited.

Limnology - Scientific study of inland waters.

Littoral zone - portion of a water body extending from the shoreline lakeward to the greatest depth occupied by rooted plants.

Loading rate - Addition of a substance to a water body; or the rate at which the addition occurs. For example, streams load nutrients to lakes at various rates as in "500 kilograms per year (500 kg/yr)" or "227 pounds per year (227 lb/yr)."

Macrophytes - rooted and floating aquatic plants, larger (macro-) than the phytoplankton.

Mesotrophic - A condition of lakes that is characterized by moderate concentrations of nutrients, algae, and water transparency. A mesotrophic lake is not as rich in nutrients as a eutrophic lake, but richer in nutrients than an oligotrophic lake.

Monomictic - A lake which has one mixing and one stratification event per year. If a lake does not freeze over in the winter, the winter winds will mix the waters of the lake. In summer, the lake resists mixing and becomes stratified because the surface waters are warm (light) and the bottom waters are cold (dense). Deep lakes in the Puget lowlands are monomictic lakes.

Nitrate, nitrite (NO₃, NO₂) - Two types of nitrogen compounds. These nutrients are forms of nitrogen that algae may use for growth.

Nitrogen - One of the elements essential as a nutrient for growth of organisms.

Non-point source pollution - Pollution that originates from diffuse areas and unidentifiable sources, such as agriculture, the atmosphere, or ground water.

Nutrients - Elements or compounds essential for growth of organisms.

Oligotrophic - A condition of lakes characterized by low concentrations of nutrients and algae and resulting good water transparency. An oligotrophic lake has less nutrients than a mesotrophic or eutrophic lake.

Pathogens -Microorganisms that can cause disease in other organisms or humans, animals, and plants. Pathogens include bacteria, viruses, fungi, or parasites found in sewage, in runoff from farms or city streets, and in water used for swimming. Pathogens can be present in municipal, industrial, and nonpoint source discharges.

Pelagic Zone - Deep, open water area of a lake away from the edge of the littoral zone towards the center of the lake.

pH - Measure of the acidity of water on a scale of 0 to 14, with 7 representing neutral water. A pH less than 7 is considered acidic and above 7 is basic.

Phosphorus - One of the elements essential as a nutrient for the growth of organisms. In western Washington lakes, it is usually the algae nutrient in shortest supply relative to the needs of the algae. Phosphorus occurs naturally in soils, as well as in organic material. Various measures of phosphorus in water samples are made, including total-phosphorus (TP) and the dissolved portion of the phosphorus (orthophosphorus).

Photic zone - The lighted region of a lake where photosynthesis occurs.

Phytoplankton - Floating, mostly microscopic algae (plants) that live in water.

Point-source Pollution - An input of pollutants into a water body from discrete sources, such as municipal or industrial outfalls.

Primary Treatment - The first stage of wastewater treatment involving removal of debris and solids by screening and settling.

Pump Station -A structure used to move wastewater uphill, against gravity.

Regulator -A structure that controls the flow of wastewater from two or more input pipes to a single output. Regulators can be used to restrict or halt flow, thus causing wastewater to be stored in the conveyance system until it can be handled by the treatment plant.

Salmonids - Salmon, trout, char and whitefish species of fish.

Secchi depth - Measure of transparency of water obtained by lowering a 10 cm black and white disk into water until it is no longer visible.

Secondary Treatment - Following primary treatment, bacteria are used to consume organic wastes. Wastewater is then disinfected and discharged through an outfall.

Separation -A method for controlling combined sewer overflow whereby the combined sewer is separated into both a sanitary sewer and a storm drain, as is the practice in new development.

Sewage -That portion of wastewater that is composed of human and industrial wastes from homes, businesses, and industries.

Standard - A legally established allowable limit for a substance or characteristic in the water, based on criteria. Enforcement actions by the appropriate agencies can be taken against parties who cause violations.

Stratification of lakes - A layering effect produced by the warming of the surface waters in many lakes during summer. Upper waters are progressively warmed by the sun and the deeper waters remain cold. Because of the difference in density (warmer water is lighter), the two layers remain separate from each other: upper waters "float" on deeper waters and wind induced mixing occurs only in the upper waters. Oxygen in the bottom waters may become depleted. In autumn as the upper waters cool, the whole lake mixes again and remains mixed throughout the winter, or until it freezes over.

Stormwater -Water that is generated by rainfall and is often routed into drain systems.

Thermocline - Depth in a stratified lake where the greatest change in temperature occurs. Separates the epilimnion from the hypolimnion

Total suspended solids (TSS) - Particles, both mineral (clay and sand) and organic (algae and small pieces of decomposed plant and animal material), that are suspended in water.

Toxic -Causing death, disease, cancer, genetic mutations, or physical deformations in any organism or its offspring upon exposure, ingestion, inhalation, or assimilation.

Transparency - A measure of the clarity of water in a lake, which is measured by lowering a standard black and white Secchi disk into the water and recording the depth at which it is no longer visible. Transparency of lakes is determined by the color of the water and the amount of material suspended in it. Generally in colorless waters of the Puget lowland, the transparency of the water in summer is determined by the amount of algae present in the water. Suspended silt particles may also have an effect, particularly in wet weather.

Trophic status - Rating of the condition of a lake on the scale of oligotrophic-mesotrophic-eutrophic (see definition of these terms).

Turbidity - Cloudiness of water caused by the suspension of minute particles, usually algae, silt, or clay.

Wastewater -Total flow within the sewage system. In combined systems, it includes sewage and stormwater.

Water Column - Water in a lake between the surface and sediments. Used in vertical measurements used to characterize lake water.

Watershed - The areas that drain to surface water bodies, including lakes, rivers, estuaries, wetlands, streams, and the surrounding landscape.

Water of Statewide Significance - Legal term from the state Shoreline Management act, which recognizes particular bodies of water and sets criteria and standards for their protection.

Zooplankton - Small, free swimming or floating animals in water, many are microscopic.

APPENDIX B

Primer on Lake Ecology & Watershed Concepts

Primer on Lake Ecology & Watershed Dynamics

Prepared by:

Aqua Link, Inc.

The water quality of a lake is often described as a reflection of its surrounding watershed. The term lake collectively refers to reservoirs (man-made impoundments), natural lake systems and smaller ponds (man-made or naturally created). Water from the surrounding watershed enters a lake as streamflow, surface runoff and groundwater. The water quality of these water sources is greatly influenced by the characteristics of the watershed such as, geology, soils, topography and land use. Of these characteristics, changes in land use (e.g., forested, agriculture, silviculture, residential, commercial, industrial) can significantly alter the water quality of lakes.

Nutrients (e.g., phosphorus, nitrogen, carbon, silicon, calcium, potassium, magnesium, sulfur, sodium, chloride, iron) are primarily transported to lakes via streamflow, surface runoff and groundwater, while sediments are mainly conveyed by streamflow and surface runoff. As streamflow and surface runoff enter a lake, their overall velocity decreases, which allow transported sediments to settle to the lake bottom. Many of these incoming nutrients may be bound to sediment particles and subsequently will also settle to the lake bottom. Very small sediment particles such as, clays, may resist sedimentation and subsequently pass through the lake without settling.

Once within the lake, water quality is further modified through a complex set of physical, chemical and biological processes. These processes are significantly affected by the lake's morphological characteristics (morphology). Some of the more important morphological characteristics of lakes are surface area, shape, depth, volume and bottom composition. In addition, the hydraulic residence time (i.e., the lake's flushing rate) also greatly affects these processes and is directly related to the lake's volume and the annual volume of water flowing into the lake.

With respect to nutrients, phosphorus and nitrogen are generally considered the most important nutrients in freshwater lakes. Phosphorus and, to a lesser degree, nitrogen typically determine the overall amount of aquatic plants present. Aquatic plants adsorb and convert available nutrients into energy, which is then used for additional growth and reproduction. In lakes, aquatic plants are mainly comprised of phytoplankton (free-floating microscopic plants or algae) and macrophytes (higher vascular plants). The most readily available form of phosphorus is dissolved orthophosphate (analytical determined as dissolved reactive phosphorus), while ammonia (NH₃-N) and nitrate (NO₃-N) are the most readily available forms of nitrogen.

The transfer and flow of energy in lakes is ultimately controlled by complex interactions between various groups of aquatic organisms (both plants and animals). A simplistic diagram of these interactions among aquatic organisms is shown as Figure 1. In Figure 1, algae (phytoplankton) and aquatic macrophytes (plants) capture energy from the sun and convert this energy into chemical energy through the process known as photosynthesis. During photosynthesis, carbon dioxide, nutrients, water and captured sunlight energy are used to produce organic compounds (chemical energy), which are then used to support further growth and reproduction.

Energy continues to flow upward through the food chain. Algae are primarily grazed upon by zooplankton. Zooplankton are tiny aquatic animals that are barely visible to the naked eye. Next, zooplankton serve as prey for planktivorous (plankton-eating) fish and larger invertebrates (macroinvertebrates). In turn, planktivores are consumed by piscivorous (fish-eating) fish. Overall, these aquatic organisms (zooplankton, macroinvertebrates and fish) derive energy by breaking down organic matter through the process known as respiration. During respiration, organic matter, water and dissolved oxygen are converted into carbon dioxide and nutrients.

At the bottom of the food chain (Figure 1), particulate organic waste products (excrement) from aquatic organisms along with dead aquatic organisms settle to the lake bottom and are subsequently feed upon by other organisms. Organisms that live or reside along the lake bottom are referred to as benthivores. After settling to the lake bottom, dead organic materials and organic waste products are now called detritus. Some benthivorous fish (catfish and carp) and microorganisms (bacteria, fungi and protozoans) feed upon detritus. Aquatic organisms that feed upon detritus in lakes are referred to as decomposers. Decomposers obtain energy by breaking down detritus (dead organic matter) via the process of respiration. During decomposition, some of the nutrients are recycled back into lake water and can now once again be used by algae and aquatic plants for growth and reproduction. Any unused detritus will accumulate and eventually become part of the lake sediments, thereby increasing the organic content of these sediments.

Ultimately, the amount of nutrients in lakes controls the overall degree of aquatic productivity (Figure 1). Lakes with low levels of nutrients and low levels of aquatic productivity are referred to as oligotrophic. Oligotrophic lakes are typically clear and deep with low quantities of phytoplankton and rooted aquatic plants. In these lakes, the deeper, colder waters are generally well-oxygenated and capable of supporting coldwater fish such as trout. Conversely, lakes with high nutrient levels and high levels of aquatic productivity are referred to as eutrophic. Eutrophic lakes are generally more turbid and shallower due to the deposition of sediments and the accumulation of detritus. If deep enough, the bottom waters of eutrophic lakes are generally less oxygenated or may be devoid of dissolved oxygen (anoxic). Eutrophic lakes are often capable of supporting warmwater fish such as bluegill and bass. Mesotrophic lakes lie somewhere in between oligotrophic and eutrophic lakes. These lakes contain moderate levels of nutrients and moderate levels of aquatic productivity.

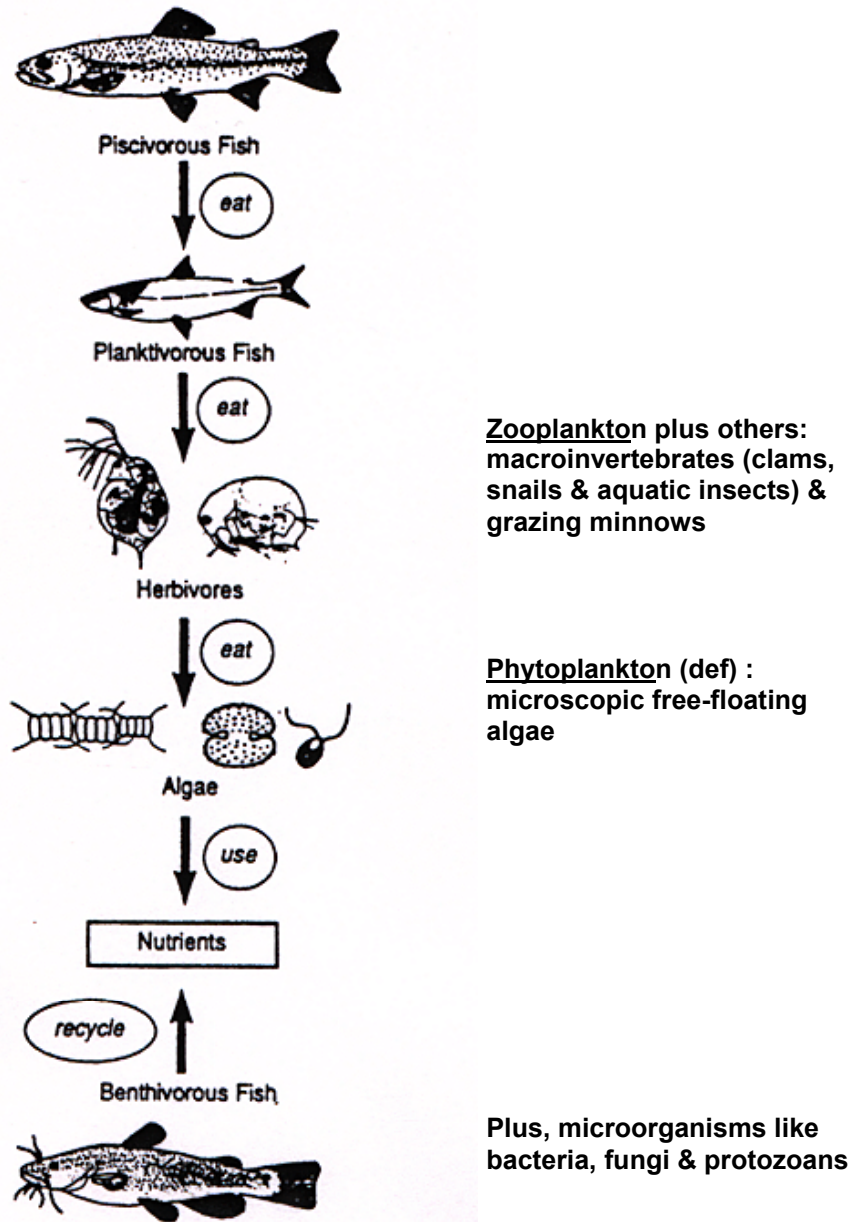


Figure 1 Aquatic Food Chain

In some instances, the flow of energy through the food web may be disrupted. In hyper-eutrophic (highly eutrophic) lakes, aquatic productivity is extremely high and is dominated by very large numbers of a few, undesirable species. The phytoplankton community is typically comprised largely by blue-green algae during the summer months. Many species of blue-green algae are not readily grazed upon by the zooplankton community. Under these conditions, the blue-green algae community is allowed to flourish due to the lack of predation, while the zooplankton community collapses. Decreases in zooplankton biomass in a lake may in turn adversely affect the lake's fishery. In addition, shallow lake areas may be completely infested with dense stands of aquatic macrophytes and dominated by common carp, catfish or other rough fish.

APPENDIX C

2012 Lake Water Quality Data

Key to Water Quality Parameters and Units of Measure

Parameter:	Units of Measure:
pH (pH)	Expressed in Standard Units (s.u.)
Alkalinity (Alk)	Expressed in milligrams per liter as calcium carbonate(mg/l as CaCO ₃)
Hardness	Expressed in milligrams per liter as calcium carbonate(mg/l as CaCO ₃)
Conductivity (Cond)	Expressed in micromhos per cm (umhos/cm)
Conductivity (Cond)	Expressed in microsiemens per cm (uS/cm)
Specific Conductance (Sp Cond)	Expressed in micromhos per cm (umhos/cm) @ 25.0 degrees Celsius
Total Phosphorus (TP)	Expressed as milligrams per liter as phosphorus (mg/l as P)
Dissolved Reactive Phosphorus (DRP)	Expressed in milligrams per liter as phosphorus (mg/l as P)
Nitrate (NO ₃)	Expressed in milligrams per liter as nitrogen (mg/l as N)
Nitrite (NO ₂)	Expressed in milligrams per liter as nitrogen (mg/l as N)
Ammonia nitrogen (NH ₃)	Expressed in milligrams per liter as nitrogen (mg/l as N)
Total Kjeldahl Nitrogen (TKN)	Expressed in milligrams per liter as nitrogen (mg/l as N)
Total Suspended Solids (TSS)	Expressed in milligrams per liter (mg/l)
Turbidity	Expressed in ntu's (nephelometric turbidity units)
Color	Expressed in Pt/Co Units
Oil & Grease	Expressed in milligrams per liter (mg/l)
Iron (Fe) total/dissolved	Expressed in milligrams per liter (mg/l)
Manganese (Mn) total/dissolved	Expressed in milligrams per liter (mg/l)
Dissolved Oxygen (Dissol Oxy)	Expressed in milligrams per liter (mg/l)
Temperature (Temp)	Expressed in degrees Celsius (degrees C)
Secchi Disk Depth	Expressed in meters (m)
Chlorophyll-a	Expressed in micrograms per liter (ug/l)
Fecal coliform bacteria (FC)	Expressed as number of organisms per one hundred milliliters (No./100 ml)
Fecal streptococcus bacteria (FS)	Expressed as number of organisms per one hundred milliliters (No./100 ml)
Phytoplankton	Expressed as number of organisms per liter (No.per ml)
Phytoplankton	Expressed as biomass in micrograms per liter (ug/l)
Zooplankton	Expressed as number of organisms per liter (No.per liter)
Zooplankton	Expressed as biomass in micrograms per liter (ug/l)

Notes: TN denotes total nitrogen and is the sum of total Kjeldahl nitrogen, nitrite, and nitrate nitrogen
 NO₂/NO₃ (nitrate + nitrite nitrogen) can be determined directly by laboratory or by summing nitrate & nitrite concentration
 (b) denotes below detection limit, therefore data reported as the detection limit
 (*) indicates calculated value
 (**) indicates *in-situ* field data collected on the study date (also refer to *in-situ* data)

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 3

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
05/21/12	9:37:46	3	0.00	16.84	103.5	10.03	62	73	7.13	47.45	0.03	85	0.0	62.3
05/21/12	9:38:29	3	1.00	16.95	111.4	10.78	64	75	7.11	48.75	0.03	96	3.3	62.5
05/21/12	9:39:05	3	2.00	16.96	111.8	10.82	64	75	7.17	48.75	0.03	98	6.6	62.5
05/21/12	9:40:31	3	3.00	16.89	111.4	10.79	63	74	7.26	48.10	0.03	100	9.8	62.4
05/21/12	9:41:02	3	4.00	16.48	111.2	10.87	60	71	7.28	46.15	0.03	101	13.1	61.7
05/21/12	9:41:49	3	5.00	15.74	110.9	11.01	58	71	7.29	46.15	0.03	102	16.4	60.3
05/21/12	9:43:20	3	6.00	13.00	105.7	11.14	57	73	7.25	47.45	0.03	107	19.7	55.4
05/21/12	9:44:02	3	7.00	11.80	101.1	10.94	59	78	7.2	50.70	0.04	110	23.0	53.2
05/21/12	9:44:38	3	8.00	10.88	93.8	10.37	59	80	7.13	52.00	0.04	113	26.2	51.6
05/21/12	9:45:14	3	9.00	9.89	83.1	9.41	53	74	7.05	48.10	0.03	115	29.5	49.8
05/21/12	9:46:03	3	10.00	9.35	68.2	7.81	56	80	6.91	52.00	0.04	120	32.8	48.8
05/21/12	9:46:42	3	11.00	9.15	60.1	6.92	57	82	6.81	53.30	0.04	123	36.1	48.5
05/21/12	9:47:20	3	12.00	9.10	55.5	6.40	53	77	6.72	50.05	0.04	125	39.4	48.4
05/21/12	9:48:29	3	12.50	9.06	38.7	4.47	54	77	6.45	50.05	0.04	33	41.0	48.3
<<insert>>														
Min			0.00	9.06	38.7	4.47	53	71	6.45	46.15	0.03	33	0.00	48.3
Max			12.50	16.96	111.8	11.14	64	82	7.29	53.30	0.04	125	41.0	62.5
Max - Min			12.50	7.90	73.1	6.67	11	11	0.84	7.15	0.01	92	41.0	14.2
Count			14	14	14	14	14	14	14	14	14	14	14	14

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 3

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
06/19/12	10:35:30	3	0.00	20.35	105.5	9.52	73	80	7.36	52.00	0.04	104	0.0	68.6
06/19/12	10:37:01	3	1.00	20.35	105.5	9.53	70	77	7.49	50.05	0.04	108	3.3	68.6
06/19/12	10:37:38	3	2.00	20.32	105.4	9.52	69	75	7.52	48.75	0.03	112	6.6	68.6
06/19/12	10:38:04	3	3.00	20.30	105.3	9.52	75	82	7.53	53.30	0.04	115	9.8	68.5
06/19/12	10:39:02	3	4.00	20.19	102.8	9.31	72	79	7.51	51.35	0.04	121	13.1	68.3
06/19/12	10:39:23	3	5.00	20.11	102.4	9.29	72	79	7.48	51.35	0.04	124	16.4	68.2
06/19/12	10:39:44	3	6.00	17.64	104.4	9.96	67	78	7.46	50.70	0.04	126	19.7	63.8
06/19/12	10:40:48	3	7.00	13.51	55.9	5.82	60	77	7.23	50.05	0.04	136	23.0	56.3
06/19/12	10:41:35	3	8.00	11.54	46.0	5.01	58	78	7.01	50.70	0.04	143	26.2	52.8
06/19/12	10:41:57	3	9.00	10.85	36.8	4.07	58	80	6.89	52.00	0.04	147	29.5	51.5
06/19/12	10:42:18	3	10.00	10.08	29.0	3.27	57	80	6.76	52.00	0.04	151	32.8	50.1
06/19/12	10:43:13	3	11.00	9.77	15.7	1.78	55	78	6.44	50.70	0.04	161	36.1	49.6
06/19/12	10:43:52	3	12.00	9.66	14.0	1.59	57	80	6.31	52.00	0.04	164	39.4	49.4
06/19/12	10:45:52	3	12.40	9.65	10.6	1.20	56	79	6.23	51.35	0.04	69	40.7	49.4
<<insert>>														
Min			0.00	9.65	10.6	1.20	55	75	6.23	48.75	0.03	69	0.00	49.4
Max			12.40	20.35	105.5	9.96	75	82	7.53	53.30	0.04	164	40.7	68.6
Max - Min			12.40	10.70	94.9	8.76	20	7	1.30	4.55	0.01	95	40.7	19.3
Count			14	14	14	14	14	14	14	14	14	14	14	14

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 3

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
07/16/12	9:25:20	3	0.00	24.87	107.8	8.93	75	75	7.3	48.75	0.03	76	0.0	76.8
07/16/12	9:26:04	3	1.00	24.82	108.8	9.02	74	74	7.45	48.10	0.03	80	3.3	76.7
07/16/12	9:27:02	3	2.00	24.71	108.7	9.03	78	78	7.58	50.70	0.04	83	6.6	76.5
07/16/12	9:27:34	3	3.00	24.59	107.4	8.94	77	77	7.59	50.05	0.04	85	9.8	76.3
07/16/12	9:28:44	3	4.00	24.51	103.7	8.65	77	78	7.5	50.70	0.04	89	13.1	76.1
07/16/12	9:29:30	3	5.00	24.44	103.0	8.60	78	79	7.48	51.35	0.04	90	16.4	76.0
07/16/12	9:30:22	3	6.00	19.79	65.8	6.00	70	78	7.29	50.70	0.04	99	19.7	67.6
07/16/12	9:31:01	3	7.00	16.51	27.7	2.70	64	77	7.06	50.05	0.04	107	23.0	61.7
07/16/12	9:31:32	3	8.00	13.79	9.5	0.99	57	72	6.86	46.80	0.03	114	26.2	56.8
07/16/12	9:32:17	3	9.00	11.13	2.9	0.32	58	80	6.58	52.00	0.04	66	29.5	52.0
07/16/12	9:33:03	3	10.00	10.19	1.2	0.13	60	84	6.32	54.60	0.04	28	32.8	50.3
07/16/12	9:34:12	3	11.00	9.99	0.8	0.09	60	84	6.2	54.60	0.04	19	36.1	50.0
07/16/12	9:34:50	3	11.90	9.92	0.7	0.08	63	89	6.17	57.85	0.04	15	39.0	49.9
<<insert>>														
Min			0.00	9.92	0.7	0.08	57	72	6.17	46.80	0.03	15	0.00	49.9
Max			11.90	24.87	108.8	9.03	78	89	7.59	57.85	0.04	114	39.0	76.8
Max - Min			11.90	14.95	108.1	8.95	21	17	1.42	11.05	0.01	99	39.0	26.9
Count			13	13	13	13	13	13	13	13	13	13	13	13

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 3

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
08/13/12	8:55:10	3	0.00	23.51	104.4	8.87	84	87	6.38	56.55	0.04	57	0.0	74.3
08/13/12	8:55:52	3	1.00	23.57	105.3	8.93	86	88	6.72	57.20	0.04	69	3.3	74.4
08/13/12	8:57:11	3	2.00	23.48	104.9	8.92	85	88	7.14	57.20	0.04	84	6.6	74.3
08/13/12	8:57:44	3	3.00	23.42	103.9	8.84	84	86	7.24	55.90	0.04	88	9.8	74.2
08/13/12	8:58:36	3	4.00	23.29	99.1	8.45	85	88	7.22	57.20	0.04	93	13.1	73.9
08/13/12	8:59:15	3	5.00	23.27	97.5	8.32	85	88	7.16	57.20	0.04	97	16.4	73.9
08/13/12	8:59:52	3	6.00	23.26	96.8	8.27	85	88	7.12	57.20	0.04	100	19.7	73.9
08/13/12	9:00:28	3	7.00	19.85	44.2	4.03	80	89	6.92	57.85	0.04	107	23.0	67.7
08/13/12	9:01:16	3	8.00	16.63	6.2	0.61	80	96	6.53	62.40	0.04	-16	26.2	61.9
08/13/12	9:03:57	3	9.00	12.24	0.9	0.10	75	100	6.11	65.00	0.05	-86	29.5	54.0
08/13/12	9:04:49	3	10.00	11.34	0.9	0.10	75	101	6.07	65.65	0.05	-89	32.8	52.4
08/13/12	9:05:28	3	11.00	10.89	0.6	0.07	78	107	6.05	69.55	0.05	-89	36.1	51.6
08/13/12	9:06:07	3	11.65	10.68	0.6	0.07	97	134	6.08	87.10	0.06	-125	38.2	51.2
<<insert>>														
Min			0.00	10.68	0.6	0.07	75	86	6.05	55.90	0.04	-125	0.00	51.2
Max			11.65	23.57	105.3	8.93	97	134	7.24	87.10	0.06	107	38.2	74.4
Max - Min			11.65	12.89	104.7	8.86	22	48	1.19	31.20	0.02	232	38.2	23.2
Count			13	13	13	13	13	13	13	13	13	13	13	13

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 3

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
09/24/12	11:54:38	3	0.00	17.30	97.1	9.32	67	79	6.99	51.35	0.04	36	0.0	63.1
09/24/12	11:55:20	3	1.00	17.33	81.1	7.78	68	79	6.88	51.35	0.04	38	3.3	63.2
09/24/12	11:56:10	3	2.00	17.29	78.9	7.58	69	81	6.85	52.65	0.04	45	6.6	63.1
09/24/12	11:56:45	3	3.00	17.27	78.5	7.54	67	79	6.86	51.35	0.04	47	9.8	63.1
09/24/12	11:57:19	3	4.00	17.23	78.0	7.50	68	80	6.86	52.00	0.04	48	13.1	63.0
09/24/12	11:58:00	3	5.00	17.22	77.7	7.48	67	79	6.86	51.35	0.04	50	16.4	63.0
09/24/12	11:58:41	3	6.00	17.21	77.9	7.50	67	79	6.85	51.35	0.04	50	19.7	63.0
09/24/12	11:59:16	3	7.00	17.20	78.2	7.53	65	76	6.84	49.40	0.04	50	23.0	63.0
09/24/12	11:59:47	3	8.00	17.19	78.3	7.54	65	76	6.84	49.40	0.04	51	26.2	62.9
09/24/12	12:00:18	3	9.00	15.37	65.9	6.59	84	103	6.65	66.95	0.05	-8	29.5	59.7
09/24/12	12:00:47	3	10.00	12.91	23.6	2.49	84	109	6.51	70.85	0.05	-63	32.8	55.2
09/24/12	12:01:43	3	10.70	12.28	4.8	0.51	96	127	6.42	82.55	0.06	-88	35.1	54.1
<<insert>>														
Min			0.00	12.28	4.8	0.51	65	76	6.42	49.40	0.04	-88	0.00	54.1
Max			10.70	17.33	97.1	9.32	96	127	6.99	82.55	0.06	51	35.1	63.2
Max - Min			10.70	5.05	92.3	8.81	31	51	0.57	33.15	0.02	139	35.1	9.1
Count			12	12	12	12	12	12	12	12	12	12	12	12

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 3

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
10/15/12	12:29:19	3	0.00	13.23	100.6	10.55	63	81	6.27	52.65	0.04	96	0.0	55.8
10/15/12	12:29:45	3	1.00	13.22	95.9	10.05	64	83	6.27	53.95	0.04	97	3.3	55.8
10/15/12	12:30:11	3	2.00	13.23	95.0	9.96	65	84	6.29	54.60	0.04	97	6.6	55.8
10/15/12	12:30:34	3	3.00	13.22	95.0	9.96	61	78	6.28	50.70	0.04	97	9.8	55.8
10/15/12	12:31:03	3	4.00	13.22	95.1	9.97	63	81	6.28	52.65	0.04	98	13.1	55.8
10/15/12	12:31:34	3	5.00	13.21	95.4	10.01	63	82	6.28	53.30	0.04	98	16.4	55.8
10/15/12	12:31:59	3	6.00	13.21	95.7	10.04	65	84	6.28	54.60	0.04	99	19.7	55.8
10/15/12	12:32:34	3	7.00	13.20	96.2	10.09	64	83	6.28	53.95	0.04	99	23.0	55.8
10/15/12	12:33:04	3	8.00	13.19	96.3	10.11	62	80	6.29	52.00	0.04	99	26.2	55.7
10/15/12	12:33:56	3	9.00	13.18	96.7	10.15	62	80	6.3	52.00	0.04	99	29.5	55.7
10/15/12	12:34:25	3	10.00	13.17	96.9	10.17	62	80	6.3	52.00	0.04	99	32.8	55.7
10/15/12	12:34:48	3	11.00	13.12	96.3	10.12	63	81	6.25	52.65	0.04	-14	36.1	55.6
<<insert>>														
Min			0.00	13.12	95.0	9.96	61	78	6.25	50.70	0.04	-14	0.00	55.6
Max			11.00	13.23	100.6	10.55	65	84	6.30	54.60	0.04	99	36.1	55.8
Max - Min			11.00	0.11	5.6	0.59	4	6	0.05	3.90	0.00	113	36.1	0.2
Count			12	12	12	12	12	12	12	12	12	12	12	12

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 5

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
05/21/12	9:00:14	5	0.00	18.18	106.4	10.04	68	79	7.91	51.35	0.04	82	0.0	64.7
05/21/12	9:01:19	5	1.00	18.18	106.4	10.03	68	79	7.76	51.35	0.04	83	3.3	64.7
05/21/12	9:02:07	5	2.00	18.15	106.3	10.03	67	77	7.67	50.05	0.04	83	6.6	64.7
05/21/12	9:03:08	5	3.00	17.90	103.1	9.77	68	78	7.57	50.70	0.04	83	9.8	64.2
05/21/12	9:03:42	5	4.00	17.21	99.9	9.61	65	76	7.53	49.40	0.03	84	13.1	63.0
05/21/12	9:04:34	5	5.00	15.48	89.6	8.94	64	79	7.42	51.35	0.04	86	16.4	59.9
05/21/12	9:05:33	5	6.00	13.32	77.6	8.12	59	76	7.28	49.40	0.03	89	19.7	56.0
05/21/12	9:06:35	5	7.00	11.91	72.3	7.80	63	83	7.14	53.95	0.04	94	23.0	53.4
05/21/12	9:08:50	5	7.75	11.18	64.6	7.09	65	88	6.63	57.20	0.04	67	25.4	52.1
<<insert>>														
Min			0.00	11.18	64.6	7.09	59	76	6.63	49.40	0.03	67	0.00	52.1
Max			7.75	18.18	106.4	10.04	68	88	7.91	57.20	0.04	94	25.4	64.7
Max - Min			7.75	7.00	41.8	2.95	9	12	1.28	7.80	0.01	27	25.4	12.6
Count			9	9	9	9	9	9	9	9	9	9	9	9

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 5

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
06/19/12	9:56:59	5	0.00	21.10	108.1	9.62	83	90	7.41	58.50	0.04	87	0.0	70.0
06/19/12	9:57:35	5	1.00	21.00	107.7	9.60	79	86	7.39	55.90	0.04	87	3.3	69.8
06/19/12	9:58:00	5	2.00	20.68	106.6	9.56	84	92	7.36	59.80	0.04	87	6.6	69.2
06/19/12	9:58:22	5	3.00	18.88	97.1	9.03	82	93	7.33	60.45	0.04	88	9.8	66.0
06/19/12	9:58:46	5	4.00	18.02	83.2	7.87	79	91	7.28	59.15	0.04	88	13.1	64.4
06/19/12	9:59:18	5	5.00	17.14	70.9	6.83	74	88	7.19	57.20	0.04	89	16.4	62.9
06/19/12	10:00:21	5	6.00	16.23	60.8	5.97	73	88	7.00	57.20	0.04	93	19.7	61.2
06/19/12	10:00:59	5	7.00	14.50	41.1	4.19	73	92	6.75	59.80	0.04	32	23.0	58.1
<<insert>>														
Min			0.00	14.50	41.1	4.19	73	86	6.75	55.90	0.04	32	0.00	58.1
Max			7.00	21.10	108.1	9.62	84	93	7.41	60.45	0.04	93	23.0	70.0
Max - Min			7.00	6.60	67.0	5.43	11	7	0.66	4.55	0.00	61	23.0	11.9
Count			8	8	8	8	8	8	8	8	8	8	8	8

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 5

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
07/16/12	8:50:11	5	0.00	24.47	105.0	8.76	91	92	7.76	59.80	0.04	67	0.0	76.0
07/16/12	8:51:06	5	1.00	24.31	104.6	8.75	94	95	7.56	61.75	0.04	69	3.3	75.8
07/16/12	8:51:33	5	2.00	23.58	96.9	8.22	87	89	7.48	57.85	0.04	69	6.6	74.4
07/16/12	8:52:24	5	3.00	22.39	50.7	4.40	83	87	7.26	56.55	0.04	72	9.8	72.3
07/16/12	8:53:03	5	4.00	21.65	29.5	2.59	79	85	7.07	55.25	0.04	75	13.1	71.0
07/16/12	8:54:27	5	5.00	20.61	10.8	0.97	80	87	6.74	56.55	0.04	80	16.4	69.1
07/16/12	8:55:30	5	6.00	18.51	2.2	0.21	88	101	6.5	65.65	0.05	41	19.7	65.3
07/16/12	8:55:56	5	6.70	16.42	1.3	0.13	86	103	6.4	66.95	0.05	4	22.0	61.6
<<insert>>														
Min			0.00	16.42	1.3	0.13	79	85	6.40	55.25	0.04	4	0.00	61.6
Max			6.70	24.47	105.0	8.76	94	103	7.76	66.95	0.05	80	22.0	76.0
Max - Min			6.70	8.05	103.7	8.63	15	18	1.36	11.70	0.01	76	22.0	14.5
Count			8	8	8	8	8	8	8	8	8	8	8	8

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 5

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
08/13/12	8:10:25	5	0.00	23.18	94.2	8.05	100	104	5.98	67.60	0.05	103	0.0	73.7
08/13/12	8:11:59	5	1.00	23.11	95.6	8.19	97	101	6.22	65.65	0.05	100	3.3	73.6
08/13/12	8:12:48	5	2.00	22.94	96.1	8.26	102	106	6.29	68.90	0.05	99	6.6	73.3
08/13/12	8:13:47	5	3.00	22.85	93.4	8.04	96	100	6.34	65.00	0.05	98	9.8	73.1
08/13/12	8:14:15	5	4.00	22.48	92.0	7.97	107	112	6.33	72.80	0.05	99	13.1	72.5
08/13/12	8:15:04	5	5.00	21.71	40.3	3.54	103	110	6.25	71.50	0.05	100	16.4	71.1
08/13/12	8:15:42	5	6.00	21.03	57.0	5.08	109	118	6.24	76.70	0.05	102	19.7	69.9
08/13/12	8:16:40	5	7.00	19.05	5.5	0.51	119	135	6.05	87.75	0.06	-34	23.0	66.3
<<insert>>														
Min			0.00	19.05	5.5	0.51	96	100	5.98	65.00	0.05	-34	0.00	66.3
Max			7.00	23.18	96.1	8.26	119	135	6.34	87.75	0.06	103	23.0	73.7
Max - Min			7.00	4.13	90.6	7.75	23	35	0.36	22.75	0.01	137	23.0	7.4
Count			8	8	8	8	8	8	8	8	8	8	8	8

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 5

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
09/24/12	11:01:51	5	0.00	16.40	91.3	8.93	75	90	9.17	58.50	0.04	96	0.0	61.5
09/24/12	11:02:59	5	1.00	16.31	88.9	8.71	74	89	8.59	57.85	0.04	113	3.3	61.4
09/24/12	11:03:40	5	2.00	16.17	88.3	8.68	74	89	8.39	57.85	0.04	117	6.6	61.1
09/24/12	11:04:26	5	3.00	16.13	87.5	8.61	75	90	8.24	58.50	0.04	121	9.8	61.0
09/24/12	11:05:11	5	4.00	16.06	87.0	8.57	74	90	8.09	58.50	0.04	124	13.1	60.9
09/24/12	11:09:01	5	5.00	15.10	84.9	8.54	69	86	7.63	55.90	0.04	86	16.4	59.2
09/24/12	11:09:49	5	6.00	14.47	83.5	8.51	64	80	7.55	52.00	0.04	88	19.7	58.0
09/24/12	11:10:19	5	6.25	14.52	68.3	6.96	83	104	7.39	67.60	0.05	35	20.5	58.1
<<insert>>														
Min			0.00	14.47	68.3	6.96	64	80	7.39	52.00	0.04	35	0.00	58.0
Max			6.25	16.40	91.3	8.93	83	104	9.17	67.60	0.05	124	20.5	61.5
Max - Min			6.25	1.93	23.0	1.97	19	24	1.78	15.60	0.01	89	20.5	3.5
Count			8	8	8	8	8	8	8	8	8	8	8	8

Database Last Modified: 11/14/12
 Staff Initials: arl

Insitu Water Quality Data - Station No. 5

Date M/D/Y	Time hh:mm:ss	Site	Depth m	Temp C	DO% %	DO Conc mg/L	Cond uS/cm	SpCond uS/cm	pH s.u.	TDS g/L	Salinity ppt	ORP mV	Conversions	
													Depth (feet)	Temp (Degrees F)
10/15/12	11:33:09	5	0.00	12.45	110.0	11.73	68	90	6.44	58.50	0.04	128	0.0	54.4
10/15/12	11:36:08	5	1.00	12.43	108.0	11.52	64	85	6.28	55.25	0.04	127	3.3	54.4
10/15/12	11:37:02	5	2.00	12.42	108.1	11.54	69	91	6.3	59.15	0.04	125	6.6	54.4
10/15/12	11:37:41	5	3.00	12.37	108.1	11.55	67	88	6.31	57.20	0.04	124	9.8	54.3
10/15/12	11:39:07	5	4.00	12.02	107.0	11.53	69	92	6.32	59.80	0.04	123	13.1	53.6
10/15/12	11:39:48	5	4.60	11.31	87.6	9.59	71	96	6.11	62.40	0.04	44	15.1	52.4
<<insert>>														
Min			0.00	11.31	87.6	9.59	64	85	6.11	55.25	0.04	44	0.00	52.4
Max			4.60	12.45	110.0	11.73	71	96	6.44	62.40	0.04	128	15.1	54.4
Max - Min			4.60	1.14	22.4	2.14	7	11	0.33	7.15	0.00	84	15.1	2.1
Count			6	6	6	6	6	6	6	6	6	6	6	6

LWWMD Water Quality Data - 2012
ALI Customer No. 1157-07

Secchi Depth & Lab Chla Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 11/14/12
Staff Initials: arl

Lab ID: ECM (Environmental Compliance Monitoring Inc.)

Ref	Lab	Year	Date	Station	Secchi Depth (m)	Sampling Depth (m)	Chlorophyll a (ug/L)	Pheophytin (ug/L)	Ref
89	ECM	2012	05/21/12	3	2.60		5.40	1.90	89
90	ECM	2012	05/21/12	5	1.40		10.00	14.20	90
91	ECM	2012	06/19/12	3	2.30		8.00	1.90	91
92	ECM	2012	06/19/12	5	1.70		9.80	4.40	92
93	ECM	2012	07/16/12	3	2.00		13.70		93
94	ECM	2012	07/16/12	5	1.40		27.50		94
95	ECM	2012	08/13/12	3	1.30		31.00		95
96	ECM	2012	08/13/12	5	1.40		28.00		96
97	ECM	2012	09/24/12	3	2.10		9.20		97
98	ECM	2012	09/24/12	5	1.70		21.00		98
99	ECM	2012	10/15/12	3	1.60		11.00		99
100	ECM	2012	10/15/12	5	1.60		18.00		100

LWWMD Water Quality Data - 2012
ALI Customer No. 1157-07

Laboratory Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 11/14/12
Staff Initials: arl

Lab ID: ECM (Environmental Compliance Monitoring Inc.)

Ref ID	Lab ID	Year	Date	Station	Layer Code	Layer	Depth (m)	SpCond** (uS/cm)	pH** (s.u.)	ALK (mg/L)	SRP (mg/L)	TP (mg/L)	NO3 (mg/L)	NO2 (mg/L)	NO2/NO3* (mg/L)	NH3 (mg/L)	TKN (mg/L)	TN* (mg/L)	TSS (mg/L)	Ref ID
170	ECM	2012	05/21/12	3	1	S		75	7.11	13.0	0.008	0.010	b 0.020	0.002	0.022	b 0.010	0.540	0.562	b 3.0	170
171	ECM	2012	05/21/12	3	3	B		77	6.72	13.0	0.004	0.020	0.050	0.003	0.053	0.040	0.420	0.473	b 3.0	171
172	ECM	2012	05/21/12	5	1	S		79	7.76	15.0	0.004	0.030	0.020	0.005	0.025	0.010	0.760	0.785	5.0	172
173	ECM	2012	05/21/12	5	3	B		83	7.14	14.0	0.003	0.020	0.080	0.003	0.083	0.060	0.270	0.353	5.0	173
174	ECM	2012	06/19/12	3	1	S		77	7.49	11.0	0.002	0.010	0.050	b 0.002	0.052	0.070	0.250	0.302	b 3.0	174
175	ECM	2012	06/19/12	3	3	B		80	6.31	12.0	0.006	0.020	0.230	0.004	0.234	0.100	0.560	0.794	b 3.0	175
176	ECM	2012	06/19/12	5	1	S		86	7.39	14.0	0.003	0.020	0.030	0.002	0.032	0.030	0.420	0.452	3.0	176
177	ECM	2012	06/19/12	5	3	B		88	7.00	15.0	0.004	0.020	0.190	0.006	0.196	0.090	0.420	0.616	b 3.0	177
178	ECM	2012	07/16/12	3	1	S		74	7.45	12.0	0.003	0.020	b 0.020	0.002	0.022	b 0.010	0.430	0.452	6.0	178
179	ECM	2012	07/16/12	3	3	B		84	6.20	16.0	0.007	0.040	b 0.020	0.004	0.024	0.260	0.430	0.454	6.0	179
180	ECM	2012	07/16/12	5	1	S		95	7.56	17.0	0.003	0.030	b 0.020	0.002	0.022	0.010	0.460	0.482	7.0	180
181	ECM	2012	07/16/12	5	3	B		101	6.50	19.0	0.004	0.030	b 0.020	0.004	0.024	0.040	0.390	0.414	8.0	181
182	ECM	2012	08/13/12	3	1	S		88	6.72	6.6	0.003	0.020	b 0.020	0.003	0.023	b 0.010	1.000	1.023	5.0	182
183	ECM	2012	08/13/12	3	3	B		107	6.05	9.6	0.068	0.080	0.130	0.002	0.132	0.200	1.500	1.632	4.0	183
184	ECM	2012	08/13/12	5	1	S		101	6.22	9.2	0.009	0.020	b 0.020	0.002	0.022	0.020	1.000	1.022	4.0	184
185	ECM	2012	08/13/12	5	3	B		118	6.24	11.0	0.007	0.020	0.060	0.004	0.064	0.120	1.500	1.564	4.0	185
186	ECM	2012	09/24/12	3	1	S		79	6.88	16.5	0.002	0.040	0.030	b 0.002	0.032	0.140	0.670	0.702	b 2.0	186
187	ECM	2012	09/24/12	3	3	B		109	6.51	16.0	b 0.002	0.030	0.030	b 0.002	0.032	0.160	0.740	0.772	2.0	187
188	ECM	2012	09/24/12	5	1	S		89	8.59	16.0	0.002	0.040	0.080	0.004	0.084	0.070	0.670	0.754	3.0	188
189	ECM	2012	09/24/12	5	3	B		80	7.55	17.0	0.002	0.050	0.130	0.004	0.134	0.090	0.460	0.594	5.0	189
190	ECM	2012	10/15/12	3	1	S		83	6.27	15.2	0.004	0.080	0.030	0.006	0.036	0.130	0.210	0.246	b 2.0	190
191	ECM	2012	10/15/12	3	3	B		80	6.30	15.8	0.004	0.090	0.050	0.006	0.056	0.150	0.280	0.336	b 2.0	191
192	ECM	2012	10/15/12	5	1	S		85	6.28	16.2	b 0.002	0.060	0.100	0.004	0.104	0.080	0.120	0.224	3.0	192
193	ECM	2012	10/15/12	5	3	B		92	6.32	16.0	0.002	0.050	0.120	0.004	0.124	0.100	0.280	0.404	3.0	193

<insert>

Notes: TN denotes total nitrogen and is the sum of total Kjeldahl nitrogen, nitrite, and nitrate nitrogen
 NO2/NO3 (nitrate + nitrite nitrogen) can be determined directly by laboratory or by summing nitrate & nitrite concentrations
 Total Kjeldahl nitrogen (TKN) determined by adding nitrate, nitrite and ammonia nitrogen fractions
 (b) denotes below detection limit, therefore data reported as the detection limit
 (*) indicates calculated value
 (**) indicates *in-situ* field data collected on the study date (also refer to *in-situ* data)

PHYTOPLANKTON DENSITY (CELLS/ML)

TAXON	LWWMD 3 05/21/12	LWWMD 3 06/19/12	LWWMD 3 07/16/12	LWWMD 3 08/13/12	LWWMD 3 09/24/12	LWWMD 3 10/15/12
BACILLARIOPHYTA						
Centric Diatoms						
<i>Acanthoceras</i>	0	41	0	0	0	0
<i>Aulacoseira</i>	0	0	0	0	816	455
<i>Stephanodiscus</i>	246	82	40	0	51	0
Araphid Pennate Diatoms						
<i>Asterionella</i>	344	948	60	0	0	36
<i>Fragilaria/related taxa</i>	0	865	560	144	408	0
<i>Synedra</i>	476	0	0	0	26	0
<i>Tabellaria</i>	1000	3584	660	18	6911	1238
Monoraphid Pennate Diatoms						
Biraphid Pennate Diatoms						
<i>Nitzschia</i>	33	0	0	0	0	0
CHLOROPHYTA						
Flagellated Chlorophytes						
Cocoid/Colonial Chlorophytes						
<i>Ankistrodesmus</i>	131	0	80	18	26	55
<i>Closteriopsis</i>	230	0	0	0	0	0
<i>Dictyosphaerium</i>	0	494	0	0	0	0
<i>Elakatothrix</i>	33	0	0	0	0	36
<i>Oocystis</i>	0	0	0	0	0	73
<i>Pediastrum</i>	0	0	160	72	153	0
<i>Scenedesmus</i>	131	0	0	0	0	0
<i>Sphaerocystis</i>	0	1648	0	0	306	0
Filamentous Chlorophytes						
Desmids						
<i>Staurastrum</i>	0	0	0	18	26	0
<i>Staurodesmus</i>	16	41	40	18	51	0
<i>Teilingia/related taxa</i>	0	1154	20	54	0	0
<i>Xanthidium</i>	0	0	0	0	26	0
CHRYSOPHYTA						
Flagellated Classic Chrysophytes						
<i>Dinobryon</i>	443	21	20	18	0	0
<i>Uroglena</i>	0	82	0	0	0	0
Non-Motile Classic Chrysophytes						
Haptophytes						
Tribophytes/Eustigmatophytes						
Raphidophytes						
CRYPTOPHYTA						
<i>Cryptomonas</i>	295	247	120	108	179	109

PHYTOPLANKTON DENSITY (CELLS/ML)

TAXON	LWWMD 3 05/21/12	LWWMD 3 06/19/12	LWWMD 3 07/16/12	LWWMD 3 08/13/12	LWWMD 3 09/24/12	LWWMD 3 10/15/12
CYANOPHYTA						
Unicellular and Colonial Forms						
<i>Aphanocapsa</i>	0	37080	2000	3600	0	0
<i>Microcystis</i>	0	0	0	0	15300	0
<i>Woronichinia</i>	1312	32960	1200	1080	50363	1092
Filamentous Nitrogen Fixers						
<i>Anabaena</i>	0	38728	15000	19440	10200	546
<i>Aphanizomenon</i>	0	2060	16800	1440	27540	1820
Filamentous Non-Nitrogen Fixers						
<i>Planktothrix</i>	0	0	2000	11700	0	0
<i>Pseudanabaena</i>	4592	0	0	0	0	0
EUGLENOPHYTA						
<i>Trachelomonas</i>	16	21	40	18	26	36
PYRRHOPHYTA						
<i>Ceratium</i>	0	41	0	0	0	0
<i>Peridinium</i>	0	41.2	0	0	0	0
DENSITY (CELLS/ML) SUMMARY						
BACILLARIOPHYTA	2099.2	5520.8	1320	162	8211	1801.8
Centric Diatoms	246	123.6	40	0	867	527.8
Araphid Pennate Diatoms	1820.4	5397.2	1280	162	7344	1274
Monoraphid Pennate Diatoms	0	0	0	0	0	0
Biraphid Pennate Diatoms	32.8	0	0	0	0	0
CHLOROPHYTA	541.2	3337.2	300	180	586.5	163.8
Flagellated Chlorophytes	0	0	0	0	0	0
Coccioid/Colonial Chlorophytes	524.8	2142.4	240	90	484.5	163.8
Filamentous Chlorophytes	0	0	0	0	0	0
Desmids	16.4	1194.8	60	90	102	0
CHRYSOPHYTA	442.8	103	20	18	0	0
Flagellated Classic Chrysophytes	442.8	103	20	18	0	0
Non-Motile Classic Chrysophytes	0	0	0	0	0	0
Haptophytes	0	0	0	0	0	0
Tribophytes/Eustigmatophytes	0	0	0	0	0	0
Raphidophytes	0	0	0	0	0	0
CRYPTOPHYTA	295.2	247.2	120	108	178.5	109.2
CYANOPHYTA	5904	110828	37000	37260	103402.5	3458
Unicellular and Colonial Forms	1312	70040	3200	4680	65662.5	1092
Filamentous Nitrogen Fixers	0	40788	31800	20880	37740	2366
Filamentous Non-Nitrogen Fixers	4592	0	2000	11700	0	0
EUGLENOPHYTA	16.4	20.6	40	18	25.5	36.4
PYRRHOPHYTA	0	82	0	0	0	0
TOTAL	9298.8	120139.2	38800.0	37746.0	112404.0	5569.2
CELL DIVERSITY	0.77	0.65	0.59	0.54	0.64	0.78
CELL EVENNESS	0.65	0.51	0.49	0.46	0.52	0.72

PHYTOPLANKTON DENSITY (CELLS/ML)

TAXON	LWWMD 3 05/21/12	LWWMD 3 06/19/12	LWWMD 3 07/16/12	LWWMD 3 08/13/12	LWWMD 3 09/24/12	LWWMD 3 10/15/12
NUMBER OF TAXA						
BACILLARIOPHYTA	5	5	4	2	5	4
Centric Diatoms	1	2	1	0	2	2
Araphid Pennate Diatoms	3	3	3	2	3	2
Monoraphid Pennate Diatoms	0	0	0	0	0	0
Biraphid Pennate Diatoms	1	0	0	0	0	0
CHLOROPHYTA	5	4	4	5	6	3
Flagellated Chlorophytes	0	0	0	0	0	0
Cocoid/Colonial Chlorophytes	4	2	2	2	3	3
Filamentous Chlorophytes	0	0	0	0	0	0
Desmids	1	2	2	3	3	0
CHRYSOPHYTA	1	2	1	1	0	0
Flagellated Classic Chrysophytes	1	2	1	1	0	0
Non-Motile Classic Chrysophytes	0	0	0	0	0	0
Haptophytes	0	0	0	0	0	0
Tribophytes/Eustigmatophytes	0	0	0	0	0	0
Raphidophytes	0	0	0	0	0	0
CRYPTOPHYTA	1	1	1	1	1	1
CYANOPHYTA	2	4	5	5	4	3
Unicellular and Colonial Forms	1	2	2	2	2	1
Filamentous Nitrogen Fixers	0	2	2	2	2	2
Filamentous Non-Nitrogen Fixers	1	0	1	1	0	0
EUGLENOPHYTA	1	1	1	1	1	1
PYRRHOPHYTA	0	2	0	0	0	0
TOTAL	15	19	16	15	17	12

PHYTOPLANKTON BIOMASS (UG/L)

TAXON	LWWMD 3 05/21/12	LWWMD 3 06/19/12	LWWMD 3 07/16/12	LWWMD 3 08/13/12	LWWMD 3 09/24/12	LWWMD 3 10/15/12
BACILLARIOPHYTA						
Centric Diatoms						
<i>Acanthoceras</i>	0.0	49.4	0.0	0.0	0.0	0.0
<i>Aulacoseira</i>	0.0	0.0	0.0	0.0	244.8	136.5
<i>Stephanodiscus</i>	418.2	206.0	100.0	0.0	127.5	0.0
Araphid Pennate Diatoms						
<i>Asterionella</i>	68.9	189.5	12.0	0.0	0.0	7.3
<i>Fragilaria/related taxa</i>	0.0	259.6	168.0	43.2	122.4	0.0
<i>Synedra</i>	380.5	0.0	0.0	0.0	20.4	0.0
<i>Tabellaria</i>	800.3	2867.5	528.0	14.4	5528.4	990.1
Monoraphid Pennate Diatoms						
Biraphid Pennate Diatoms						
<i>Nitzschia</i>	26.2	0.0	0.0	0.0	0.0	0.0
CHLOROPHYTA						
Flagellated Chlorophytes						
Cocoid/Colonial Chlorophytes						
<i>Ankistrodesmus</i>	13.1	0.0	8.0	1.8	2.6	5.5
<i>Closteriopsis</i>	114.8	0.0	0.0	0.0	0.0	0.0
<i>Dictyosphaerium</i>	0	49.44	0	0	0	0
<i>Elakatothrix</i>	3.3	0.0	0.0	0.0	0.0	3.6
<i>Oocystis</i>	0.0	0.0	0.0	0.0	0.0	29.1
<i>Pediastrum</i>	0.0	0.0	32.0	14.4	30.6	0.0
<i>Scenedesmus</i>	13.1	0.0	0.0	0.0	0.0	0.0
<i>Sphaerocystis</i>	0.0	329.6	0.0	0.0	61.2	0.0
Filamentous Chlorophytes						
Desmids						
<i>Staurastrum</i>	0	0	0	14.4	20.4	0
<i>Staurodesmus</i>	9.8	24.7	24.0	10.8	30.6	0.0
<i>Teilingia/related taxa</i>	0.0	2307.2	40.0	108.0	0.0	0.0
<i>Xanthidium</i>	0.0	0.0	0.0	0.0	7.7	0.0
CHRYSOPHYTA						
Flagellated Classic Chrysophytes						
<i>Dinobryon</i>	1328.4	61.8	60.0	54.0	0.0	0.0
<i>Uroglena</i>	0.0	8.2	0.0	0.0	0.0	0.0
Non-Motile Classic Chrysophytes						
Haptophytes						
Tribophytes/Eustigmatophytes						
Raphidophytes						
CRYPTOPHYTA						
<i>Cryptomonas</i>	265.68	222.48	108	97.2	178.5	98.28

PHYTOPLANKTON BIOMASS (UG/L)

TAXON	LWWMD 3 05/21/12	LWWMD 3 06/19/12	LWWMD 3 07/16/12	LWWMD 3 08/13/12	LWWMD 3 09/24/12	LWWMD 3 10/15/12
CYANOPHYTA						
Unicellular and Colonial Forms						
<i>Aphanocapsa</i>	0.0	370.8	20.0	36.0	0.0	0.0
<i>Microcystis</i>	0.0	0.0	0.0	0.0	306.0	0.0
<i>Woronichinia</i>	13.1	329.6	12.0	10.8	503.6	10.9
Filamentous Nitrogen Fixers						
<i>Anabaena</i>	0.0	7745.6	3000.0	3888.0	2040.0	109.2
<i>Aphanizomenon</i>	0.0	267.8	2184.0	187.2	3580.2	236.6
Filamentous Non-Nitrogen Fixers						
<i>Planktothrix</i>	0.0	0.0	20.0	117.0	0.0	0.0
<i>Pseudanabaena</i>	137.8	0.0	0.0	0.0	0.0	0.0
EUGLENOPHYTA						
<i>Trachelomonas</i>	16.4	20.6	126.0	18.0	25.5	192.9
PYRRHOPHYTA						
<i>Ceratium</i>	0.0	716.9	0.0	0.0	0.0	0.0
<i>Peridinium</i>	0	86.52	0	0	0	0
BIOMASS (UG/ML) SUMMARY						
BACILLARIOPHYTA	1694.1	3572.0	808.0	57.6	6043.5	1228.5
Centric Diatoms	418.2	255.4	100.0	0.0	372.3	231.1
Araphid Pennate Diatoms	1249.7	3316.6	708.0	57.6	5671.2	997.4
Monoraphid Pennate Diatoms	0.0	0.0	0.0	0.0	0.0	0.0
Biraphid Pennate Diatoms	26.2	0.0	0.0	0.0	0.0	0.0
CHLOROPHYTA	154.2	2711.0	104.0	149.4	153.0	38.2
Flagellated Chlorophytes	0.0	0.0	0.0	0.0	0.0	0.0
Cocoid/Colonial Chlorophytes	144.3	379.0	40.0	16.2	94.4	38.2
Filamentous Chlorophytes	0.0	0.0	0.0	0.0	0.0	0.0
Desmids	9.8	2331.9	64.0	133.2	58.7	0.0
CHRYSOPHYTA	1328.4	70.0	60.0	54.0	0.0	0.0
Flagellated Classic Chrysophytes	1328.4	70.0	60.0	54.0	0.0	0.0
Non-Motile Classic Chrysophytes	0.0	0.0	0.0	0.0	0.0	0.0
Haptophytes	0.0	0.0	0.0	0.0	0.0	0.0
Tribophytes/Eustigmatophytes	0.0	0.0	0.0	0.0	0.0	0.0
Raphidophytes	0.0	0.0	0.0	0.0	0.0	0.0
CRYPTOPHYTA	265.7	222.5	108.0	97.2	178.5	98.3
CYANOPHYTA	150.9	8713.8	5236.0	4239.0	6429.8	356.7
Unicellular and Colonial Forms	13.1	700.4	32.0	46.8	809.6	10.9
Filamentous Nitrogen Fixers	0.0	8013.4	5184.0	4075.2	5620.2	345.8
Filamentous Non-Nitrogen Fixers	137.8	0.0	20.0	117.0	0.0	0.0
EUGLENOPHYTA	16.4	20.6	126.0	18.0	25.5	192.9
PYRRHOPHYTA	0.0	803.4	0.0	0.0	0.0	0.0
TOTAL	3609.6	16113.3	6442.0	4615.2	12830.3	1914.6
BIOMASS DIVERSITY	0.80	0.75	0.62	0.34	0.67	0.71
BIOMASS EVENNESS	0.68	0.59	0.51	0.29	0.55	0.65

ZOOPLANKTON DENSITY (#/L)

TAXON	LWWMD 3 05/21/12	LWWMD 3 6/19/12	LWWMD 3 7/16/12	LWWMD 3 8/13/12	LWWMD 3 9/24/12	LWWMD 3 10/15/12
PROTOZOA						
<i>Ciliophora</i>	7.8	16.4	0.0	0.0	105.6	12.0
<i>Mastigophora</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Sarcodina</i>	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA						
<i>Anuraeopsis</i>	0.0	0.0	0.0	0.0	0.0	3.6
<i>Asplanchna</i>	1.6	2.1	1.0	0.6	2.6	3.0
<i>Conochilus</i>	3.1	3.3	3.5	1.8	7.9	0.0
<i>Filinia</i>	0.0	0.0	0.0	4.8	0.0	0.0
<i>Kellicottia</i>	1.6	0.0	0.0	0.0	4.0	3.0
<i>Keratella</i>	61.6	21.3	25.0	37.2	17.2	21.0
<i>Polyarthra</i>	16.4	32.8	20.0	46.8	64.7	87.0
<i>Ptygura</i>	0.0	0.0	0.0	12.0	0.0	0.0
<i>Synchaeta</i>	4.7	0.0	0.0	0.0	0.0	0.0
<i>Trichocerca</i>	9.4	9.8	5.0	20.4	50.2	0.0
COPEPODA						
Copepoda-Cyclopoida						
<i>Cyclops</i>	4.3	0.8	0.5	3.6	2.6	0.6
<i>Mesocyclops</i>	0.0	2.1	9.0	9.6	5.9	4.8
Copepoda-Calanoida						
<i>Diaptomus</i>	0.0	0.0	0.0	0.6	1.3	1.8
Other Copepoda-Nauplii	3.1	1.2	1.5	4.8	9.2	5.4
CLADOCERA						
<i>Bosmina</i>	21.8	24.6	36.0	4.8	5.3	21.6
<i>Ceriodaphnia</i>	0.0	2.1	4.5	0.6	1.3	1.2
<i>Chydorus</i>	1.2	4.5	4.0	0.6	1.3	1.2
<i>Daphnia ambigua</i>	0.0	0.0	2.5	0.0	0.0	0.0
<i>Diaphanosoma</i>	0.0	0.0	0.5	1.2	0.7	0.0
<i>Leptodora</i>	0.0	0.0	0.0	0.0	0.1	0.0
OTHER ZOOPLANKTON						
Bryozoa	0.0	0.0	0.0	0.0	0.0	0.0
Chaoboridae	0.0	0.0	0.0	0.1	0.0	0.0
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0
Coelenterata	0.0	0.0	0.0	0.0	0.0	0.0
Culicidae	0.0	0.0	0.0	0.0	0.0	0.0
Eubranchiopoda	0.0	0.0	0.0	0.0	0.0	0.0
Gastrotrichia	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0
Mysidacea	0.0	0.0	0.0	0.0	0.0	0.0
Nematoda	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0

ZOOPLANKTON DENSITY (#/L)

TAXON	LWWMD 3 05/21/12	LWWMD 3 6/19/12	LWWMD 3 7/16/12	LWWMD 3 8/13/12	LWWMD 3 9/24/12	LWWMD 3 10/15/12
SUMMARY STATISTICS						
DENSITY						
PROTOZOA	7.8	16.4	0.0	0.0	105.6	12.0
ROTIFERA	98.3	69.3	54.5	123.6	146.5	117.6
COPEPODA	7.4	4.1	11.0	18.6	19.1	12.6
CLADOCERA	23.0	31.2	47.5	7.2	8.7	24.0
OTHER ZOOPLANKTON	0.0	0.0	0.0	0.1	0.0	0.0
TOTAL ZOOPLANKTON	136.5	121.0	113.0	149.5	280.0	166.2
TAXONOMIC RICHNESS						
PROTOZOA	1	1	0	0	1	1
ROTIFERA	7	5	5	7	6	5
COPEPODA	2	3	3	4	4	4
CLADOCERA	2	3	5	4	5	3
OTHER ZOOPLANKTON	0	0	0	1	0	0
TOTAL ZOOPLANKTON	12	12	13	16	16	13
S-W DIVERSITY INDEX	0.78	0.85	0.84	0.85	0.78	0.71
EVENNESS INDEX	0.72	0.79	0.75	0.71	0.65	0.64
MEAN LENGTH (mm): ALL FORMS	0.16	0.17	0.24	0.17	0.15	0.16
MEAN LENGTH: CRUSTACEANS	0.36	0.33	0.37	0.47	0.43	0.36

ZOOPLANKTON BIOMASS (UG/L)

TAXON	LWWMD 3 05/21/12	LWWMD 3 6/19/12	LWWMD 3 7/16/12	LWWMD 3 8/13/12	LWWMD 3 9/24/12	LWWMD 3 10/15/12
PROTOZOA						
Ciliophora	0.2	0.3	0.0	0.0	10.6	1.2
Mastigophora	0.0	0.0	0.0	0.0	0.0	0.0
Sarcodina	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA						
<i>Anuraeopsis</i>	0.0	0.0	0.0	0.0	0.0	0.1
<i>Asplanchna</i>	1.6	4.1	2.0	1.2	5.3	6.0
<i>Conochilus</i>	0.1	0.1	0.1	0.1	0.3	0.0
<i>Filinia</i>	0.0	0.0	0.0	0.2	0.0	0.0
<i>Kellicottia</i>	0.1	0.0	0.0	0.0	0.2	0.1
<i>Keratella</i>	5.5	1.9	2.3	3.3	1.5	1.9
<i>Polyarthra</i>	1.5	3.0	1.8	4.2	5.8	7.8
<i>Ptygura</i>	0.0	0.0	0.0	1.3	0.0	0.0
<i>Synchaeta</i>	0.2	0.0	0.0	0.0	0.0	0.0
<i>Trichocerca</i>	0.4	0.4	0.2	0.8	8.5	0.0
COPEPODA						
Copepoda-Cyclopoida						
<i>Cyclops</i>	10.5	2.0	1.2	8.8	6.4	1.5
<i>Mesocyclops</i>	0.0	2.6	11.3	12.0	7.4	6.0
Copepoda-Calanoida						
<i>Diaptomus</i>	0.0	0.0	0.0	0.3	0.6	0.9
Other Copepoda-Nauplii	8.3	3.3	4.0	12.7	24.5	14.3
CLADOCERA						
<i>Bosmina</i>	21.4	24.1	35.3	4.7	5.2	21.2
<i>Ceriodaphnia</i>	0.0	5.3	11.7	1.6	3.4	3.1
<i>Chydorus</i>	1.1	4.4	3.9	0.6	1.3	1.2
<i>Daphnia ambigua</i>	0.0	0.0	4.1	0.0	0.0	0.0
<i>Diaphanosoma</i>	0.0	0.0	0.5	1.2	0.6	0.0
<i>Leptodora</i>	0.0	0.0	0.0	0.0	10.9	0.0
OTHER ZOOPLANKTON						
Bryozoa	0.0	0.0	0.0	0.0	0.0	0.0
Chaoboridae	0.0	0.0	0.0	60.0	0.0	0.0
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0
Coelenterata	0.0	0.0	0.0	0.0	0.0	0.0
Culicidae	0.0	0.0	0.0	0.0	0.0	0.0
Eubranchiopoda	0.0	0.0	0.0	0.0	0.0	0.0
Gastrotrichia	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0
Mysidacea	0.0	0.0	0.0	0.0	0.0	0.0
Nematoda	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0

ZOOPLANKTON BIOMASS (UG/L)

TAXON	LWWMD 3 05/21/12	LWWMD 3 6/19/12	LWWMD 3 7/16/12	LWWMD 3 8/13/12	LWWMD 3 9/24/12	LWWMD 3 10/15/12
SUMMARY STATISTICS						
BIOMASS						
PROTOZOA	0.2	0.3	0.0	0.0	10.6	1.2
ROTIFERA	9.3	9.5	6.4	11.1	21.6	15.9
COPEPODA	18.7	7.8	16.4	33.8	39.0	22.6
CLADOCERA	22.5	33.9	55.4	8.0	21.5	25.5
OTHER ZOOPLANKTON	0.0	0.0	0.0	60.0	0.0	0.0
TOTAL ZOOPLANKTON	50.8	51.5	78.3	112.9	92.7	65.3