Status of Piseco Lake NY and a Plan for Management

Table of Contents

Executive summary

Piseco Lake is a 2,873-acre Class A lake located in Hamilton County, NY in the southern region of the Adirondack Park. It supports a mix of public and private stakeholder uses including aesthetic enjoyment, boating, contact recreation such as swimming, and fishing. The lake and its surrounding watershed are monitored and managed by the Piseco Lake Association in collaboration with public agencies including the Adirondack Park Agency (APA), Hamilton County Soil and Water Conservation District (HCSWCD), and the New York State Department of Environmental Conservation (NYSDEC). Several long-term data sets have been established through these partnerships, and additional data have been collected by graduate students in the SUNY Oneonta Lake Management program in recent years. This document provides a synthesis of these and other publicly available data along with a long-term management plan that can be updated and adapted in the future.

Most (80%) of the 40,000-acre watershed that surrounds Piseco Lake is forested, which typifies many lakes in the Adirondack Park. While a relatively small acreage is developed (~2%), this development is centered almost exclusively in proximity to the lake and other inflowing waters in the region. This suggests that residential and commercial development in the watershed have the potential to disproportionally influence water quality and other characteristics of the lake. Soil septic suitability ratings, for example, indicate that much of the watershed is poorly suited to conventional onsite wastewater treatment systems (i.e., septic systems), which is common for lakes in the Adirondacks due to hydrogeological features such as shallow depth to bedrock and relatively high water tables near lakes.

Long-term and recent limnological monitoring demonstrate that Piseco Lake is dimictic, meaning that the water mixes from top to bottom twice a year: once during spring after ice melt and then again during fall as temperatures cool. When the lake mixes, atmospheric oxygen is integrated into the water and supplies biological organisms with oxygen at the bottom of the lake. Between these mixing events, water forms layers or stratifies based on the density of water as it changes with temperature (cool, dense water at the bottom in summer and warm dense water at the bottom during ice cover). During stratification, oxygen in the bottom of the lake is gradually depleted due respiration by aquatic organisms, especially decomposers. In Piseco Lake, this did not lead to complete loss of oxygen (anoxia) prior to the fall mixing event in recent years. This allows cold-water fish such as lake trout and salmon to persist in the lake and also prevents release (internal loading) of phosphorus from chemical bonds with iron or other elements in the lake sediments and reduces phosphorus available for photosynthesis. Because of these watershed characteristics and in-lake conditions the lake can be broadly characterized as "mesotrophic", or "moderately productive", meaning that it has limited potential to support aquatic life such as algae, plants, and fish.

Preliminary zooplankton sampling indicated microscopic animals (zooplankton) that feed on algae were abundant and diverse in composition despite the introduction of spiny water flea about a decade ago. While spiny water flea was observed in this preliminary sample, their abundance (2 individuals) was too low to be quantified in the samples that were enumerated. The current or potential impact of this species is poorly characterized, as is the zooplankton community in Piseco Lake more generally. This may present an opportunity to conduct further monitoring of the community in the future.

Fisheries data collected by NYSDEC in 2002 and 2014 show that stocked lake trout reach maximum sizes of about 25 inches or large in Piseco Lake. The plumpness (condition) of these fish has increased in recent years with reduced stocking numbers despite similar catch rates.

Similarly, the proportional representation of large fish in the population appears to have increased. Because these surveys represent only a snapshot of the population in time it will be important to continue to collaborate with NYSDEC should management concerns arise.

The State of Piseco Lake 1993 - 2021

Introduction

Piseco Lake, located in the southern region of the Adirondacks in the town of Arietta in Hamilton County, New York is one of many lakes formed by receding glaciers thousands of years ago. Typical of larger lakes in the Adirondack Park, Piseco Lake is large, deep, and has relatively cooler water than large lakes in other regions of New York State (NYSFOLA 2009). The lake has a surface area of 2,873 acres, a mean depth of 25 feet and a maximum depth of 124 feet. Piseco Lake has 21.3 miles of shoreline and is publicly accessible from three state-owned campgrounds on its west shore (Figure 1).

Piseco Lake is considered to be mesotrophic based on its historic physical and chemical parameters monitored by the Hamilton County Soil and Water Conservation District (HCSCWD) from 1993 to 2021 as well as the Citizen Statewide Lakes Assessment Program (CSLAP) data collected until 2003 (NYSDEC 2004). The classification of mesotrophic was dictated by transparency (Secchi depth) and total phosphorous concentrations in accordance with the Trophic State Index (TSI) outlined by Carlson (1977) during 24 years of monitoring. Chlorophyll *a*, the other variable used in TSI calculation, remained within the parameters of a mesotrophic lake over the course of monitoring (Parslow 2021, Carlson 1977). Alkalinity has been steadily increasing whereas pH showed no significant trend and has remained mostly neutral (Parslow 2021). A 2003 CSLAP report classified Piseco a Class B waterbody, meaning that suitable uses included contact and non-contact recreation such as swimming and boating respectively, but not drinking water (NYSDEC 2004).

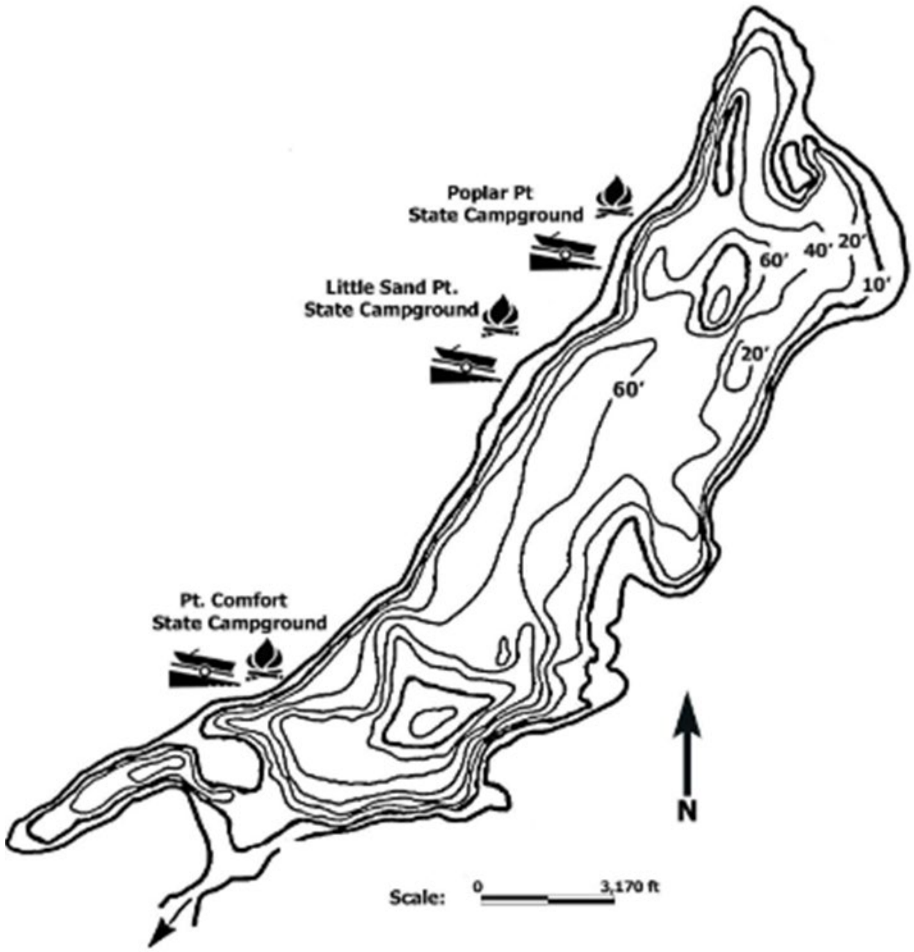

Figure 1: Bathymetric map of Piseco Lake adapted from NYSDEC (2021a).

Piseco Lake is located in a sparsely populated, but widely visited, area of New York State. Hamilton County is the least populated county in New York State with a population of approximately 5107 in 2020 and has increased by about 271 individuals since the 2010 census (U.S. Census Bureau 2021a). The low population is in part due to 67% of the county being state owned land (Laxson et al. 2019). In 2020, the Town of Arietta has an estimated population size 292 (U.S. Census Bureau 2021b).

Watershed Characteristics

Most of Hamilton County and consequently the Piseco Lake watershed is forested and undeveloped and an increase in human land use could significantly alter chemistry of Piseco Lake. Over 80% of Piseco Lake's watershed is forest. Most of what is not forest within the watershed is open water. Farmlands and grasslands are almost nonexistent and less than 2% of the watershed's land use is classified as developed, although the majority of development is concentrated around water, particularly at the northern and southern ends of the lake (Figure 2). According to data from the USDA Web Soil Survey, the soil types present in the Piseco Lake watershed are not well-suited for septic tank absorption fields, with soil suitability either listed as somewhat limited or very limited in all regions (Figure 3 and Table 1). Installing septic tank absorption fields in less suitable soils will be complicated or costly and is unlikely to yield strong positive results. The higher slope of the watershed and poor soil suitability for septic systems can lead to septic seepage into the groundwater (USDA 2021). Development within the watershed can increase the nutrient load in the lake, leading to undesirable results such as algal blooms and increases in aquatic plants, making the lake less aesthetically pleasing and hindering recreational activities.

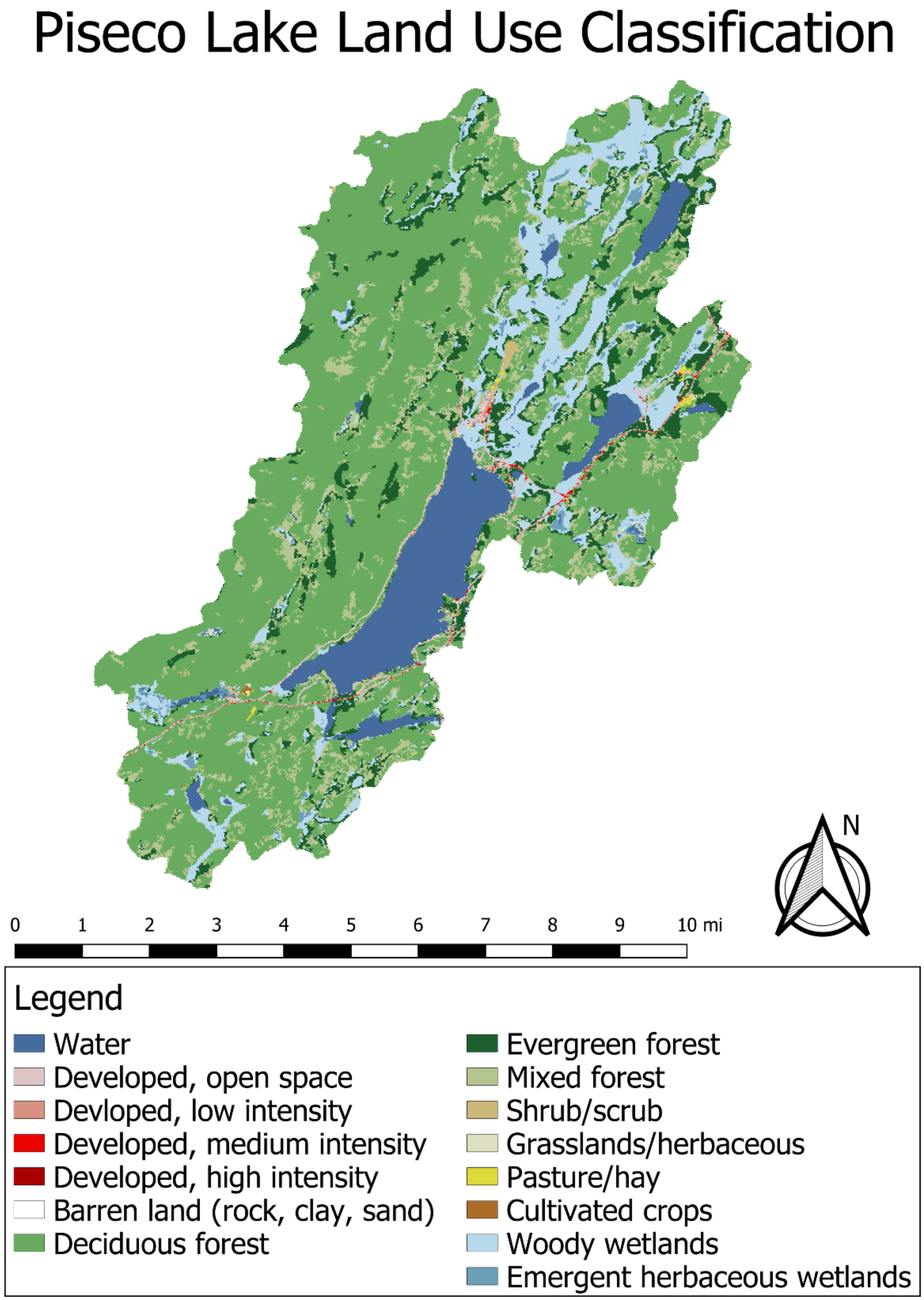

Figure 2: Map of Piseco Lake's watershed land use classification.

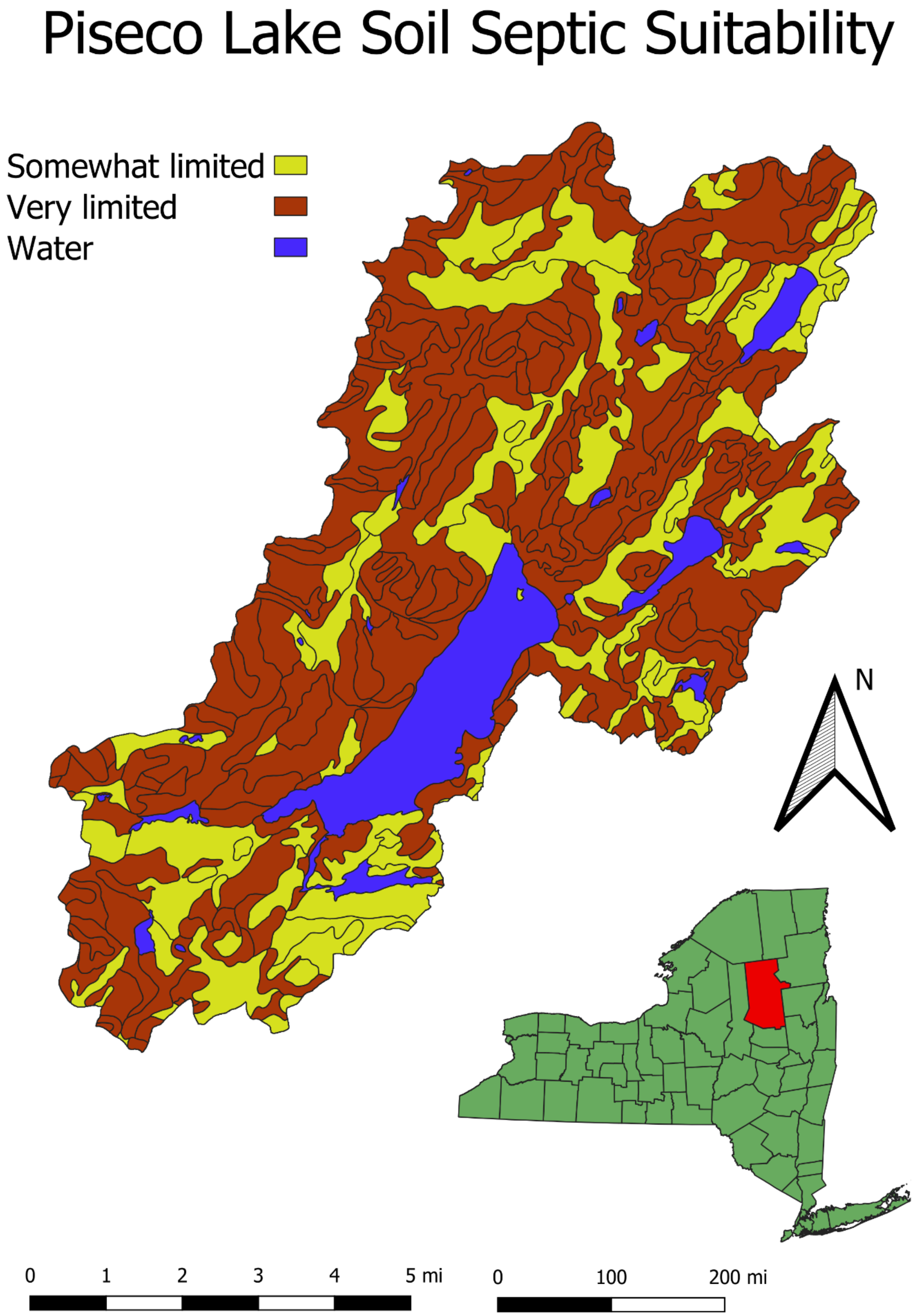

Figure 3: Map of septic absorption field soil suitability ratings for Piseco Lake's watershed.

Table 1: Number of acres and percent of watershed for soil septic suitability rankings within the Piseco Lake watershed (USDA 2021).

Rating	Acres	Percent of watershed
Very limited	25590	62.5
Somewhat limited	11603	28.4
Open water	3731	9.1
Total Watershed Area	40924	100

Anticipating the effects of land use activities and recreation on Piseco Lake may not depend as much on permanent development within the watershed as it does in other parts of the state. New York State's Adirondack Region does not contain as much privately-owned property as the rest of the state and does not have a climate that may be considered by many as suitable for year-round residency (NYSFOLA 2009). Despite lack of commercial or residential development due to lack of private landownership throughout much of the region, public-use facilities such as boat launches and campgrounds are common in the Adirondack Park.

The three state-owned campgrounds on the west shore of the lake provide public access for residents and visitors. As a result, the lake is a popular destination for camping, boating, and angling. The fishery has historically been managed by NYSDEC for lake trout (*Salvelinus namaycush)*, which have been stocked in the past. While public access benefits visitors and local economies, it also provides a vector for the spread of invasive plants and animals from other waterbodies (NYSFOLA 2009). Anglers can potentially spread invasive species if they do not follow rules and regulations. For example, invasive zooplankton, the spiny water flea (*Bythotrephes longimanus*), was likely introduced to the lake through angling tackle or live wells (NYSFOLA 2009). A number of regional boat washing stations have been established to help prevent spread of invasives, including one at the Poplar Point boat launch.

Plan Goals and Objectives

The goal of this study was to determine management strategies for lake conservation based on key ecosystem processes and anthropogenic influences in and around Piseco Lake. In order to accomplish this goal, our objectives were to 1) characterize the watershed based on major soil constituents, land-uses of residents, and public use of the lake, 2) determine historical trends in limnological data and supplement with current data collection, 3) measure and describe key biota in the lake, 4) characterize the lake trout fishery managed by NYSDEC, and 5) identify current management concerns of stakeholders. To accomplish these objectives, we 1) used geographic information systems (GIS) to delineate the watershed and classify important features, 2) collected water column nutrient data and compiled available historical data 1993 – 2021, 3) collected qualitative samples about zooplankton in the lake, 4) analyzed population characteristics of lake trout from fisheries surveys in the NYSDEC database, and 5) conducted a stakeholder meeting to determine current lake use and management concerns.

Limnological characterization of Piseco Lake

Introduction

Water quality monitoring is necessary for determining the condition of a waterbody and its potential management needs. Changes in water quality of a lake can negatively impact recreational activities and aesthetics. Shifts in the utility of a lake stemming from water quality changes can be offset by early detection accomplished by monitoring. The collection of baseline data about physical and chemical parameters makes it possible to determine if a waterbody is changing and the degree to which the waterbody has changed. Long term datasets can be used to help predict water quality changes that may result from human activities such as land use changes and urban development. Though important for lake management decisions, routine measurements of water quality parameters can be costly and time consuming, with their necessity and practicality varying among waterbodies and stakeholder needs.

Physical Parameters

Physical water quality parameters influence chemical and biological processes within lakes. Temperature is arguably the most important physical water quality parameter because it influences several biological processes and determines chemical characteristic throughout the water column. Water has different densities at different temperatures, leading to thermal stratification, or layering of water based on temperature, in deeper lakes. Lakes typically stratify into three distinct layers during certain parts of the year (most commonly during the summer and winter in New York State), the epilimnion (top), metalimnion (middle), and hypolimnion (bottom). These layers are not the same size and do not occur at the same depths in all lakes. Lake water temperature and thermal stratification are influenced by the local climate and the geomorphology of the lake (Fang and Stefan 1999). The metalimnion includes an area of rapid change in water temperature and density (thermocline) that acts as a barrier separating the epilimnion from the hypolimnion. Consequently, the hypolimnion does not receive atmospheric oxygen during periods of stratification and the amount of dissolved oxygen in the hypolimnion decreases during periods of stratification (Antonopoulis and Gianniou 2003). This means that depth and duration of stratification have profound effects on biological processes and nutrient cycling, which are heavily dependent on dissolved oxygen levels near the lake bottom (Antonopoulis and Gianniou 2003).

Transparency, often expressed as Secchi depth, is another physical water quality parameter that can serve as a useful indicator of lake ecology. Measuring lake transparency using a Secchi disk is inexpensive and provides a widely used index that can be used to understand trophic status or identify potential problems in a lake. Secchi depth incorporates influences from inputs such as sediment from the surrounding watershed as well as in-lake factors such as algal growth. Reduced transparency can even influence thermal stratification and oxygen distribution by absorbing more solar radiation than clearer waters and preventing light from penetrating into the hypolimnion, increasing epilimnion temperatures and reducing hypolimnion temperatures, thereby reinforcing stratification (Pilla et al. 2018).

Chemical Parameters

Chemical water quality parameters have strong correlations with physical water quality parameters and commonly include measurements of nutrients, ions, dissolved oxygen, and pH. Chemical compounds in a lake are often sourced from the surrounding watershed and can be heavily influenced by human land use activities. Inputs from activities such as agriculture and development can increase available nutrients and promote primary production in the form of algae or aquatic plants.

The amount of nutrients in a waterbody is a common concern for lake management and is usually measured as concentration of total phosphorus (TP) or total nitrogen (TN). Phosphorus and nitrogen are critical for several biological processes and act as limiting factors for plant and algal growth in lakes. Though algae are an essential part of a balanced lake ecosystem, excessive algal growth can reduce aesthetic value and even present human health risks. Microscopic algae are difficult to measure directly and are therefore commonly expressed as chlorophyll *a* (Chl-*a*) concentration. Measurements of TP and Chl-*a* concentrations are commonly used to determine the trophic status of a lake (Carlson 1977).

Alkalinity is the capacity to resist changes in pH by neutralizing acids via reactions with inorganic compounds (Holdren et al. 2001). Acidic inputs reduce pH and can be delivered to a lake from the watershed through runoff from rainfall (Psenner 1988). Lake acidification can be harmful to organisms and reduce food web complexity (Auclair et al. 1993). Mountain lakes surrounded by granite are often more susceptible to acidification (Psenner 1988), which is a historically common issue in the Adirondacks (NYSFOLA 2009).

Dissolved oxygen (DO) is required by most biota in the lake with concentrations influencing organismal growth and movement, nutrient cycling, and decomposition. Photosynthesis by algae and macrophytes (plants) and atmospheric diffusion at the lake surface increase dissolved oxygen concentrations. Oxygen levels in deeper parts of the lake decrease during summer and winter periods of stratification in many New York lakes. Oxygen depletion occurs in the hypolimnion as biota consume oxygen during periods of stratification. If productivity (algal biomass) in a lake is high, high rates of decomposition in the bottom of the lake by aerobic bacteria can lead to hypoxia (low DO) or anoxia (no DO). Anoxia in bottom sediments can lead to chemical reactions that release nutrients from chemical bonds with sediment and recycle them into the water column, a process called internal loading (Welch and Cooke 2009).

Historical Water Quality and Current Status

Data collection for Piseco Lake began in 1993 as part of the Hamilton County Soil and Water Conservation District (HCSWCD) water-monitoring program (Laxson et al. 2019). Data from a 2003 CSLAP report were first collected in 1999 (NYSDEC 2004). According to recent reports, Piseco Lake is classified as mesotrophic, based on transparency and TP concentrations (NYSDEC 2004, Laxson et al. 2019). Because data collected by HCSWCD are primarily restricted to ice-free season, a compliment of winter data for recent years would provide a more complete understanding of changes in the lake throughout the year.

Study Goals

Long-term data collected by HCSWCD and recent data collected through winter will provide a relatively comprehensive view of lake changes over time and throughout the year. The goals of this study were to 1) evaluate long-term changes in historical water quality data collected by HCSWCD, and 2) measure and report seasonal trends in recent water quality monitoring data collected throughout the year (2017 – 2018).

Methods

Historical Trends Analysis

Water quality parameters

Analysis of long-term trends in parameters from historical data obtained from the HCSWCD was conducted using Microsoft Excel and R Studio computer applications. Summer data collection of chemical and physical water quality parameters by the HCSWCD has been conducted annually since 1993 via YSI water column profiles and surface water samples. We used linear regression to determine whether there were increases or decreases in Secchi depth, chlorophyll *a*, pH, alkalinity, and nutrients 1993 - 2021. We also calculated annual oxygen consumption rates (aerial hypolimnetic oxygen deficit) and trophic status indicators for analysis of long-term trends.

Aerial hypolimnetic oxygen deficit (AHOD)

Aerial hypolimnetic oxygen deficit (AHOD: an index for oxygen consumption rates) is a measure of how much dissolved oxygen is depleted in the hypolimnion during stratification and can be a useful metric for evaluating lake trophic changes through time (Albright et al. 2020). Piseco Lake AHOD was measured from 18 meters (the stratum immediately below the hypolimnion based on available bathymetric maps) to the lake bottom from years when DO profiles were taken in both June and August. Dissolved oxygen concentrations within the hypolimnion were calculated as the sum of the products of DO concentrations and the volume of water within each stratum below the hypolimnion. The difference of DO measurements and number of days between the two sample dates was used determine depletion rates ($g/cm^2/day$) for a stratification period of each year during which it could be calculated.

Trophic Status Indices

The Trophic Status Index (TSI) was developed by Carlson (1977) to better communicate the trophic status of lakes to stakeholders. Prior to the development of the TSI, numerous criteria were measured to determine trophic status, with many of those criteria being poorly defined and changing at different rates. Additionally, the trophic status of lakes (oligotrophic, mesotrophic, or eutrophic) was not clearly delineated and lacked specific values. The TSI simplifies data collection by using predictive equations based on established relationships of trophic criteria to avoid measuring all trophic parameters. The TSI focuses on using values of chlorophyll *a* (Chl-*a*), Secchi depth (SD) and TP as indicators of algal biomass (productivity). Every value of 10 TSI represents a doubling of algal biomass (measured as Chl-*a* in µg/L) and halving of Secchi depth. Total phosphorus is usually a limiting nutrient for algal biomass and is included in TSIs because it lacks seasonal variation unlike Chl-*a* concentrations which peak in the summer. Values based on the equations below from Carlson 1977 are based on empirical relationships and are used for TSI calculations (Carlson 1977).

$$TSI(SD) = 10(6 - \frac{lnSD}{ln2})$$

$$TSI\ (Chl) = 10(6 - \frac{2.04 - 0.68 \ln Chl - a)}{ln2})$$

$$TSI(TP) = 10(6 - \frac{ln\frac{48}{TP}}{ln2})$$

Recent analysis

Volumetric Calculations

An existing bathymetric map for Piseco Lake (NYSDEC 2021a) was used to calculate the volume of water present in each of the strata (between contours). The volume of water (millions of cubic meters) contained within the area of each stratum was calculated based on the scale of the map. Percentage of the lake's volume at a given stratum was determined based on the sum of the volumes of water within each stratum and presented in the form of a hypsographic curve.

Field Sampling

Physical and chemical water quality data were collected at Piseco Lake once a month during September, October, and November 2017, and January, February, March, May, and July 2018. These samples include months that are not represented in the historical data, offering insights for Piseco Lake limnology outside of the field season. Measurements of dissolved oxygen (DO), specific conductivity, pH and temperature were collected at 2-meter depth intervals near the deepest part of the lake using a YSI 6820 V2 Compact Sonde calibrated according to manufacturer recommended procedures before each sampling event. Nutrient samples for total nitrogen (TN), total phosphorus (TP), and nitrate and nitrite (nitrate + nitrite) from Piseco Lake were collected using a Kemmerer bottle at 4-meter depth intervals near the deepest part of the lake once a month during October and November 2017, and January, March, May, and July 2018.

Laboratory Analysis

Nutrient samples were preserved in H_2SO_4 after collection. Total nitrogen was determined using the cadmium reduction method (Pritzlaff 2003) following peroxodisulfate digestion (Ebina et al. 1983). Total phosphorus was determined using persulfate digestion followed by single reagent ascorbic acid (Liao and Marten 2001). Nitrate + nitrite was measured using the cadmium reduction method (Pritzlaff 2003). Samples were analyzed for TP, TN, and nitrate + nitrite using a Lachat autoanalyzer.

Results

Historical Trends

Temperature

Piseco Lake summer temperatures have been steadily increasing since the start of monitoring in 1993. Peak summer temperatures occurred in July, which exhibited the most significant change through time (Linear regression, df = 24, t = 2.53, $p < 0.05$), although surface water temperature increased significantly in all summer months (Figure 4). The mean change in July surface water temperature was approximately 2°C from 1993 through 2021.

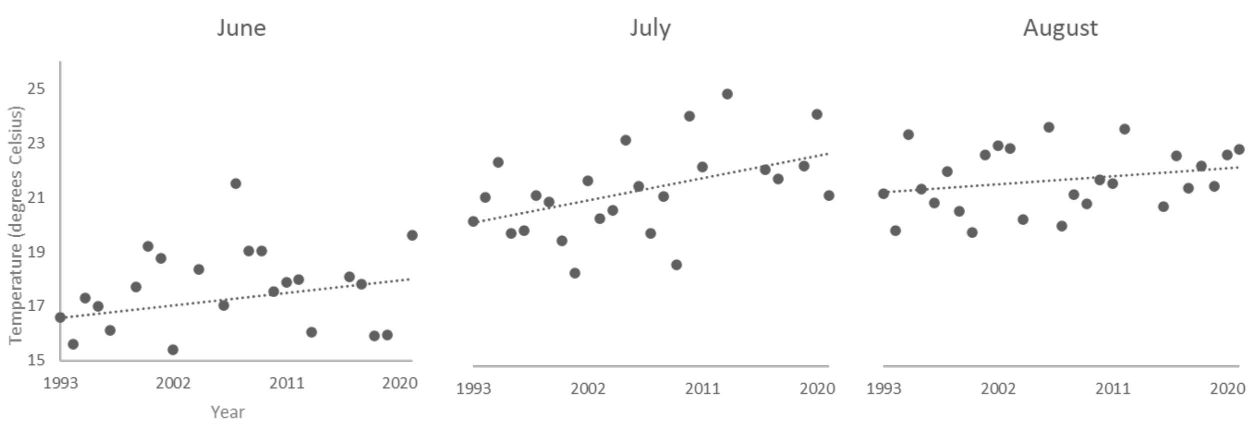

Figure 4: Timeseries analysis of mean summer temperatures of June, July, and August in the top 5 meters of Piseco Lake from 1993-2021.

Transparency

Water transparency (Secchi depth) has exhibited a significant downward trend since 1993 (Linear regression, df = 28, t = - 2.64, $p < 0.05$). Secchi depth decreased from a mean of 4.2 m in 1993 to a mean of 3.0 m in 2021 (Figure 5).

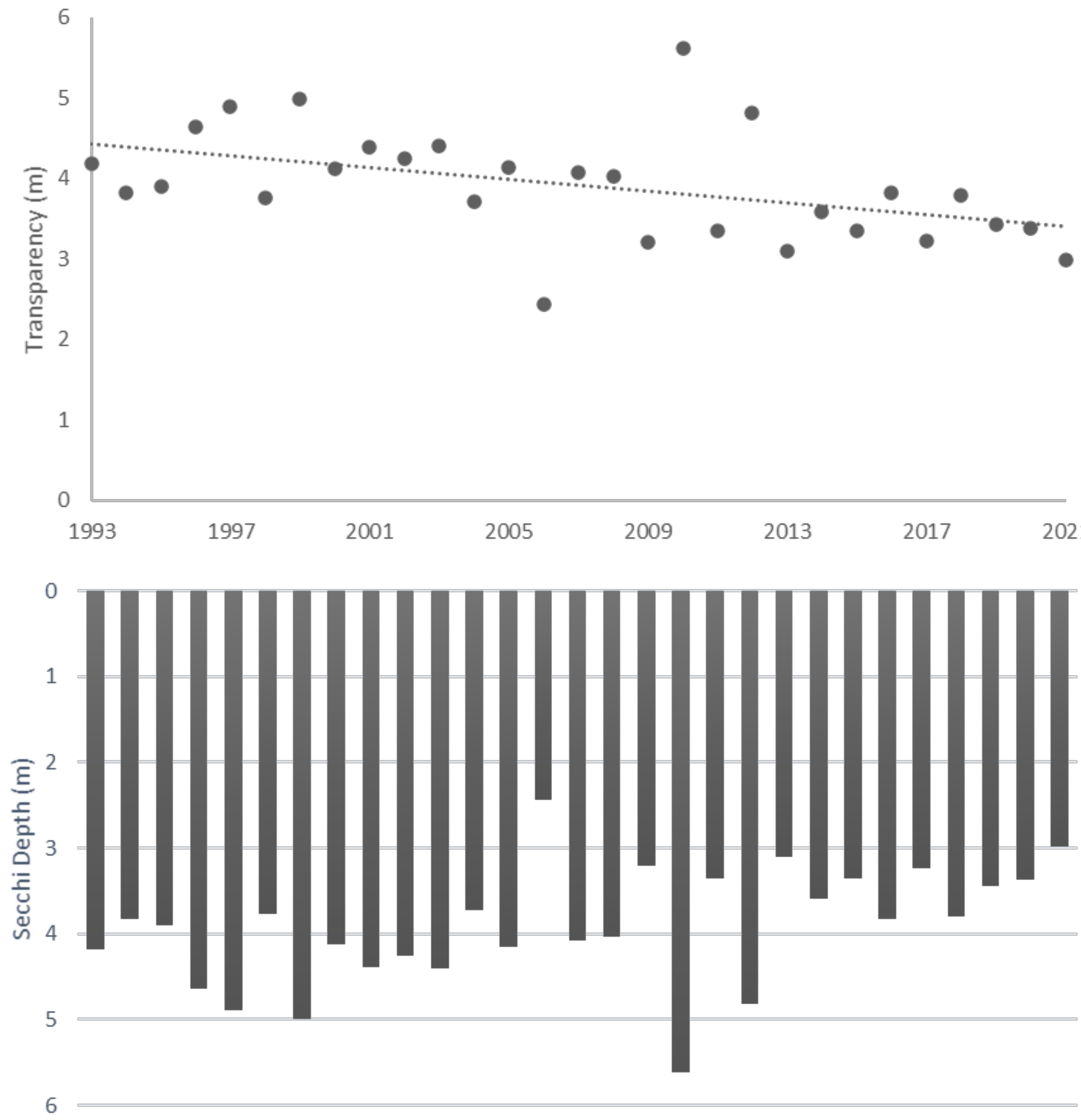

Figure 5: Piseco Lake transparency and Secchi depth in meters 1993 – 2021.

pH and alkalinity

The pH in Piseco Lake has increased since the1990s when it was slightly acidic and has since remained at neutral levels in recent years (Figure 6). Alkalinity increased significantly (Linear regression, df = 28, t = 6.44, $p < 0.05$) from 1993 to 2021 (Figure 7). However, buffering capacity remains low, likely due to underlying geology of the Adirondack region. Average alkalinity was 6.63 mg/L during the most recent monitoring in 2021, suggesting poor ability to buffer changes in pH.

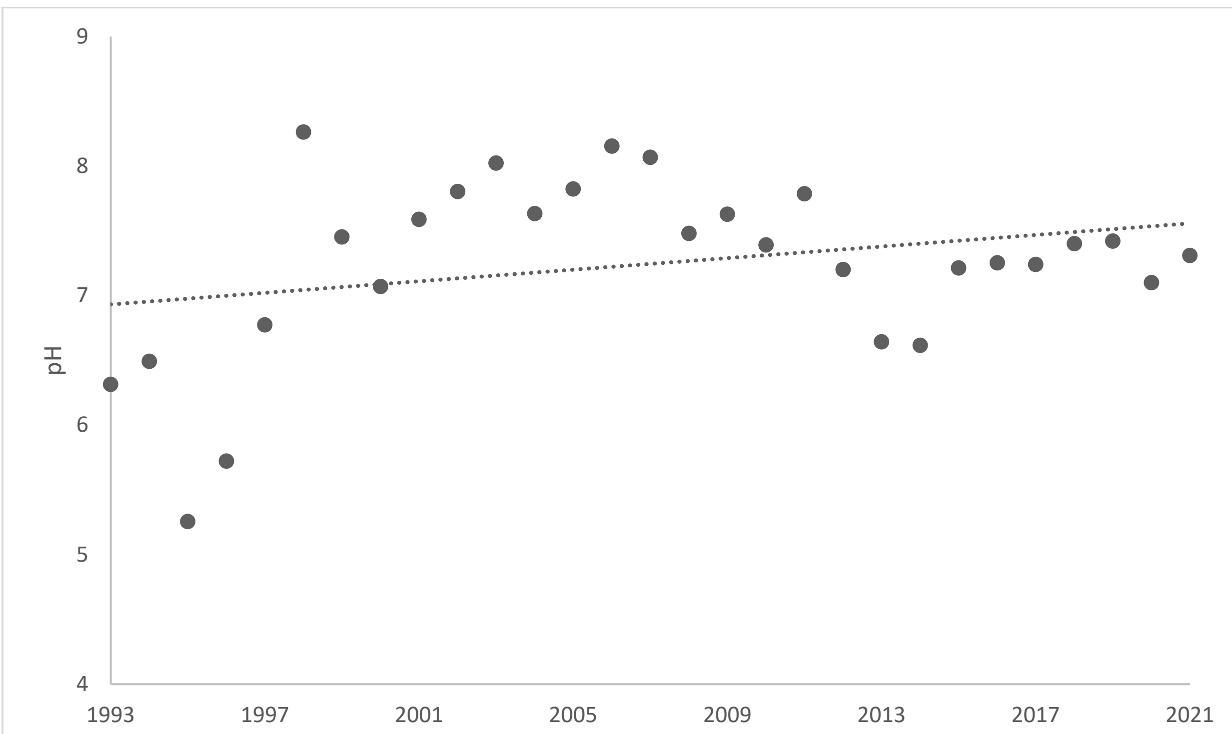

Figure 6: Piseco Lake mean surface pH 1993 – 2021.

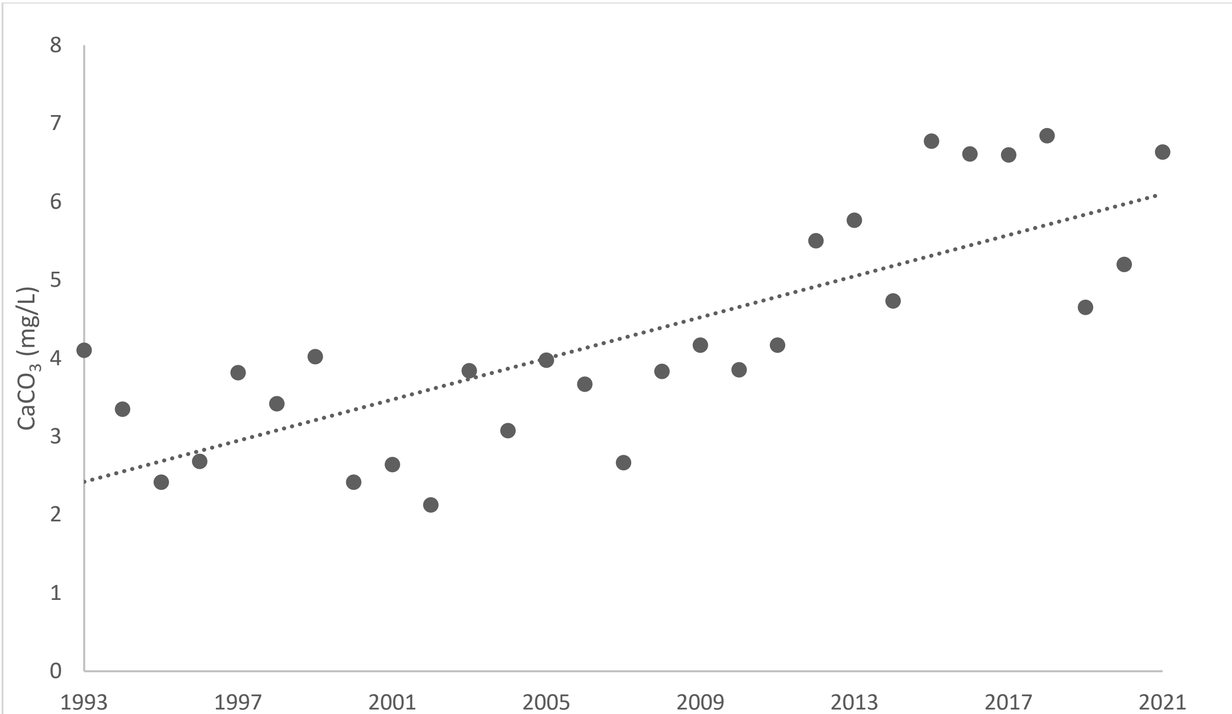

Figure 7: Piseco Lake mean surface alkalinity measured as mg/L $CaCO_3$ from 1993 through 2021.

Chlorophyll a

Chlorophyll *a* concentration remained relatively stable between 1993 and 2020 (Figure 8). The overall mean chlorophyll *a* concentration was 4.05 µg/L. This value suggests low algal productivity. Although chlorophyll *a* has fluctuated across years, we did not detect a linear increase or decrease through time (Linear regression, $df = 23$, $t = 0.01$, $p = 0.99$)

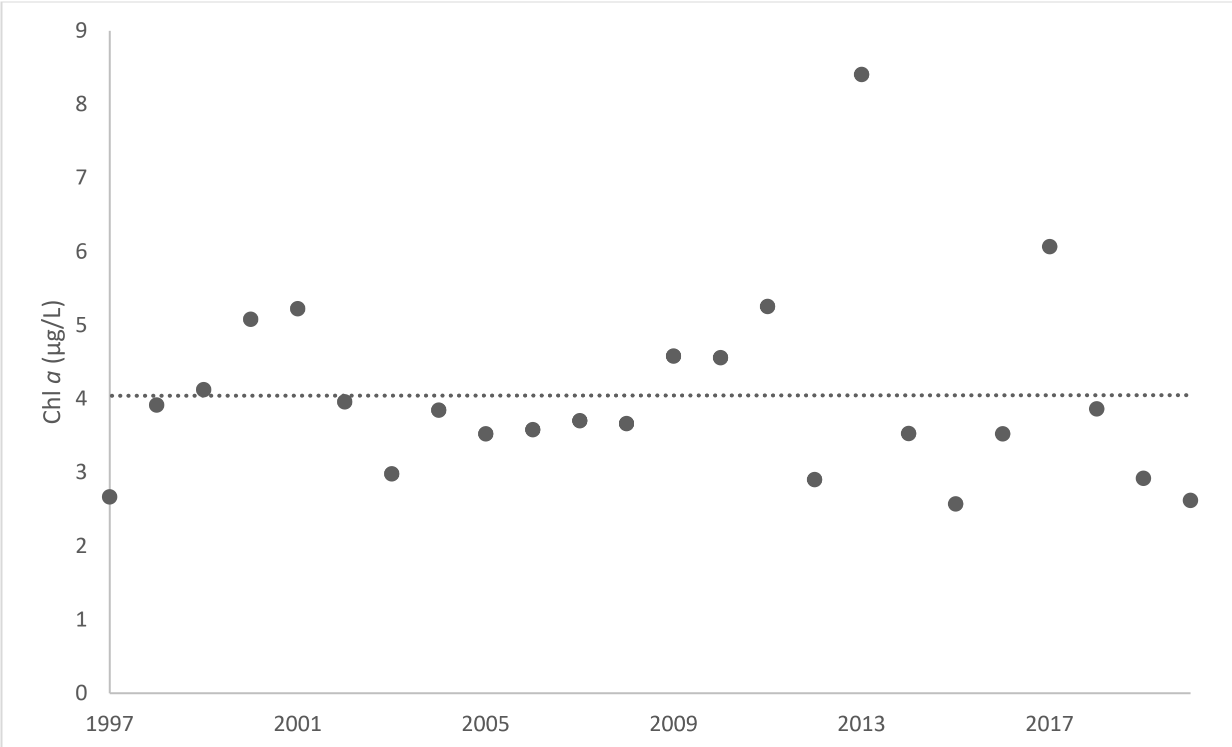

Figure 8: Piseco Lake mean surface chlorophyll-*a* concentrations (µg/L) 1997 – 2020.

Nutrients

Concentrations of total phosphorus (TP) have decreased significantly over the course of monitoring. Notable fluctuations in TP occurred around 1998 and 2006, when TP reached 42.2 and 43 µg/L respectively (Figure 9). Nitrate + nitrite concentrations exhibited a significant downward trend from 1993-2021, showing a strong upward trend between 2005 and 2012, before exhibiting a downward trend (Figure 10). Nitrate + nitrite concentrations were higher at the start of monitoring with average concentrations between 1993 and 1999 at 117.9 µg/L and years 1994, 1996, and 1997 showing concentrations greater than double the overall mean nitrate + nitrite concentration of 64.6 µg/L. Though nitrate + nitrite concentrations exhibited a downward trend over the course of monitoring, they were elevated between 2005 and 2012 (Figure 10).

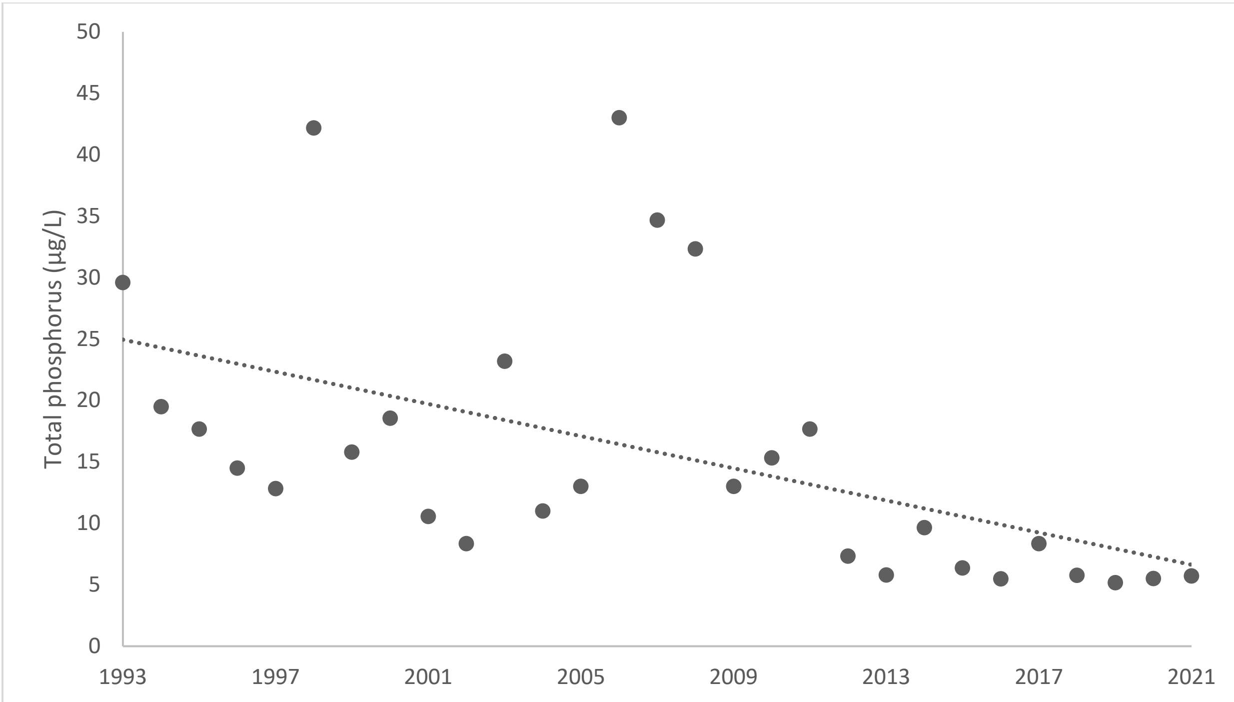

Figure 9: Piseco Lake mean surface total phosphorus concentrations (µg/L) from 1993 – 2021.

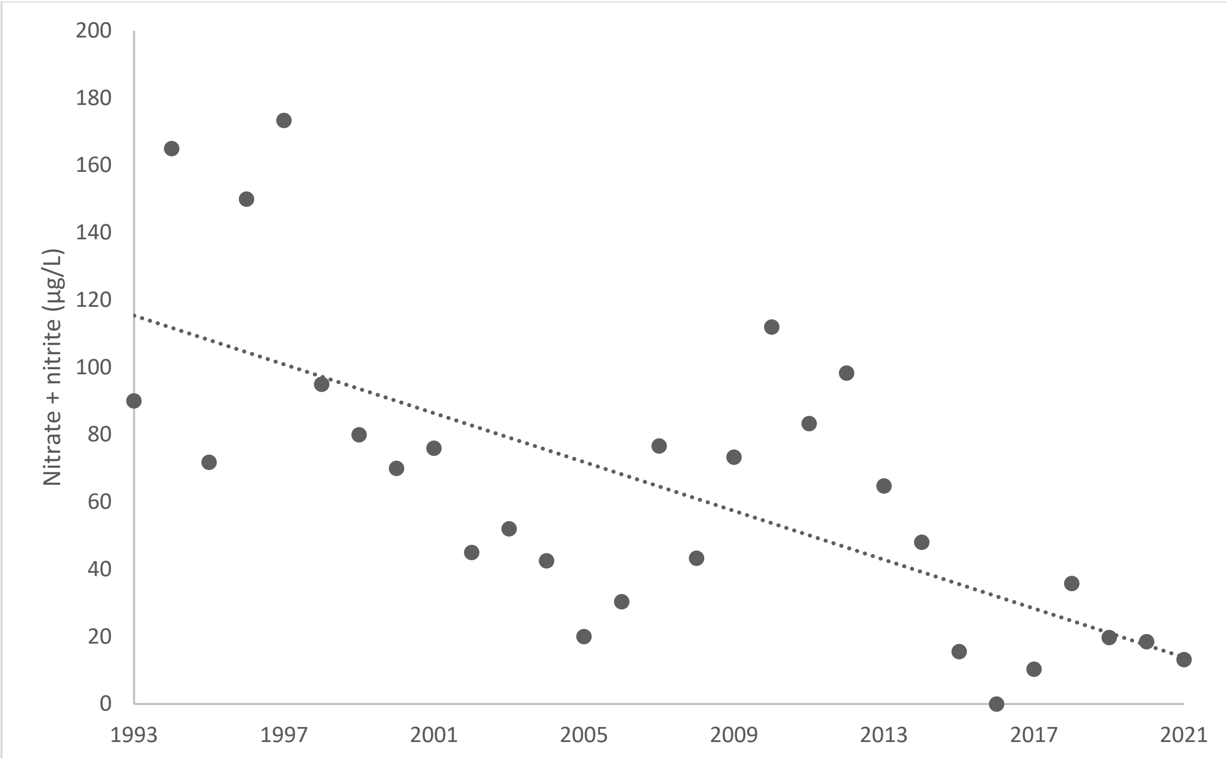

Figure 10: Piseco Lake mean surface nitrate + nitrite concentrations (µg/L) from 1993 – 2021.

Aerial hypolimnetic oxygen deficit (AHOD)

Aerial hypolimnetic oxygen deficit (AHOD) was variable over the course of monitoring. There was a notable drop between 2007 – 2012, but no significant trend overall (Linear regression, $df = 22$, $t = -0.53$, $p > 0.05$). No measurable depletion occurred during the period of interest in 1999, 2007, 2009, or 2012 (Figure 11).

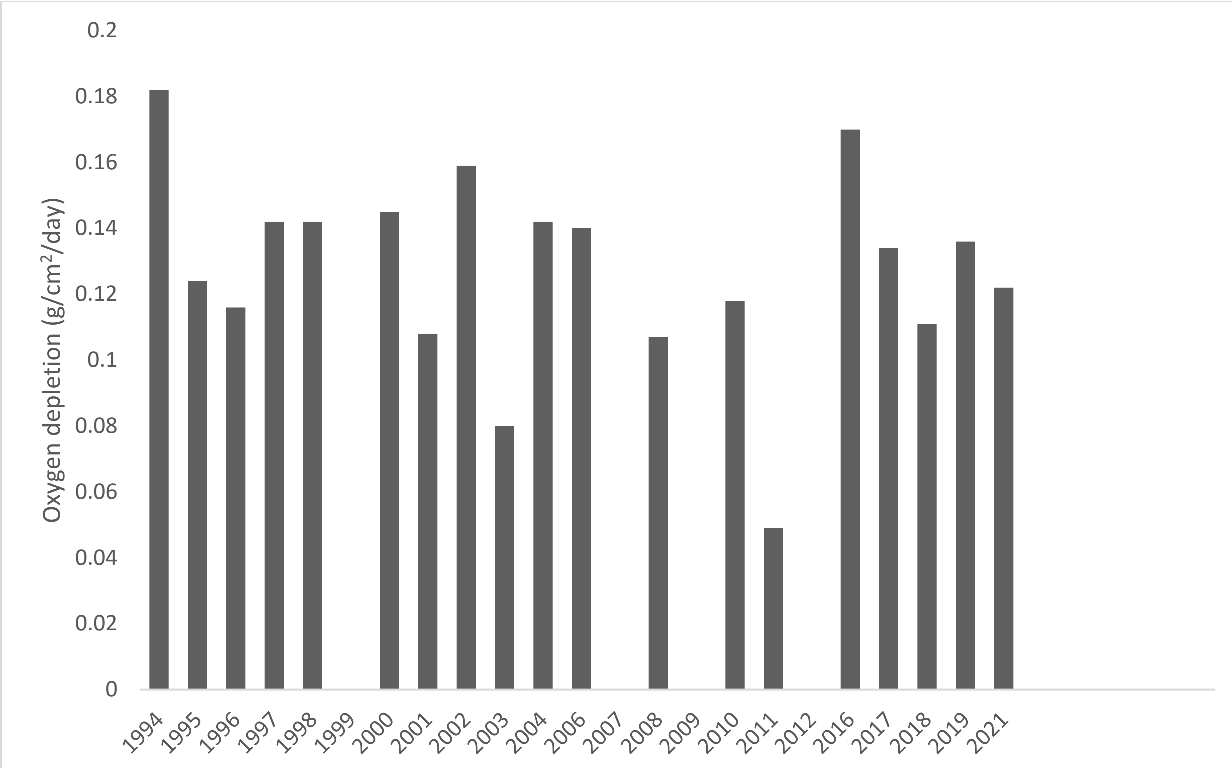

Figure 11: Piseco Lake aerial hypolimnetic oxygen deficit (AHOD) from years when dissolved oxygen profiles were taken during both June and August.

Trophic Status Indices

Transparency TSI has remained in the mesotrophic range through most of the monitoring period, exhibiting an upward trend (Linear regression, df = 28, t = 2.68, $p < 0.05$). Chlorophyll-*a* TSI has remained in the mesotrophic range aside from a drop in 2015 and has not exhibited any statistical trend ($p > 0.05$). Total phosphorus TSI has been the most variable but exhibited a significant downward trend (Linear regression, df = 28, t = -4.13, $p < 0.05$) over the course of monitoring. The downward trend for TP TSI was mainly influenced by years after 2009 with no statistically significant trend from years 1993-2009 (Figure 12).

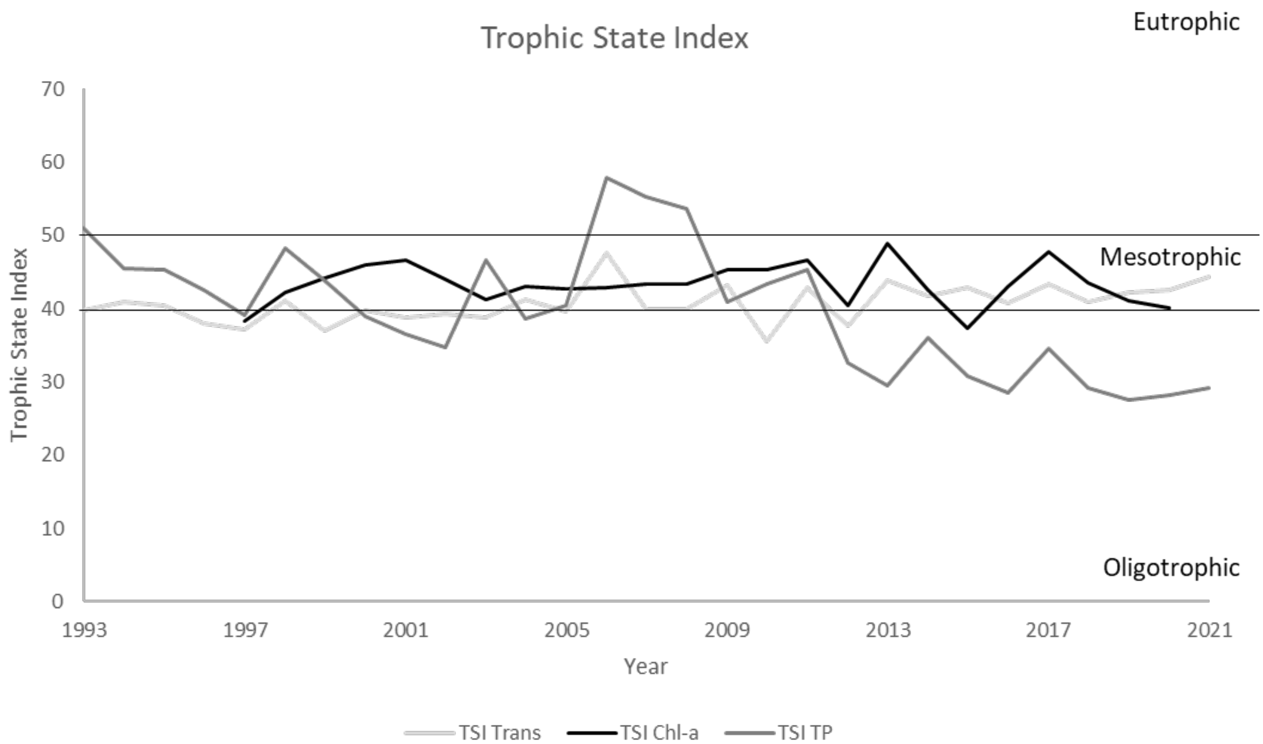

Figure 12: Piseco Lake trophic state indices for transparency (Trans), chlorophyll *a* (Chl-a), and total phosphorus (TP) 1993 – 2021.

Recent Analysis

Volumetric Calculations

The total volume of Piseco Lake was calculated at 145 million m^3. The summer hypolimnion comprised approximately 55% (80 million m^3) of the cumulative lake volume (Figure 13). This means that slightly more than half the volume of the lake is located beneath the thermocline (~12 m) during summer.

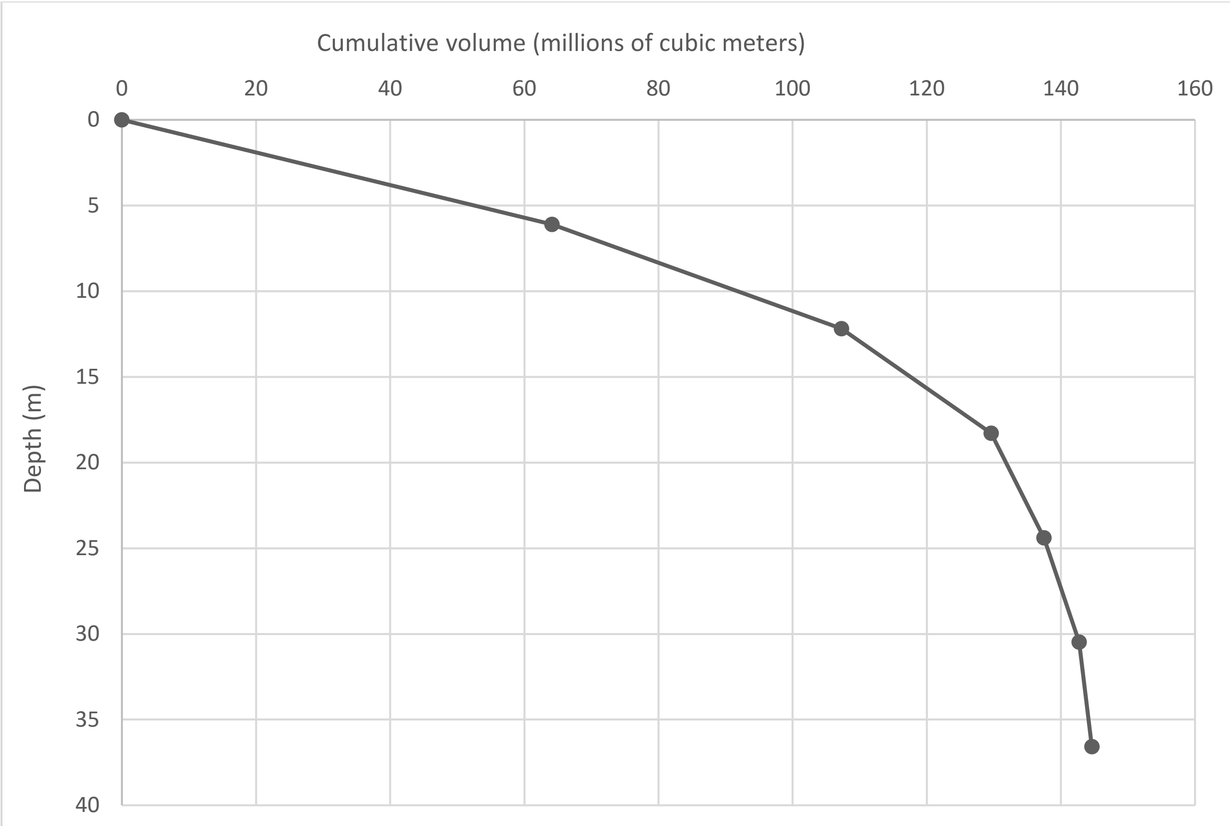

Figure 13: Piseco Lake cumulative water volume at depth (m^3)

Temperature

Piseco Lake remains relatively cool throughout the year with water temperatures in the top 5 meters only reaching 20 degrees Celsius within a few months during the summer. The lake mixes in the fall, producing a uniform water temperature throughout the water column. The lake stratifies in winter, with the warmest water (2.8°C) at the bottom of the lake and mixes again after ice out in early spring. The lake begins to form a thermocline during June, which is maintained and lowers in the water column through early September, at a range of 5 to 15 meters, increasing in depth throughout the growing season (Figure 14).

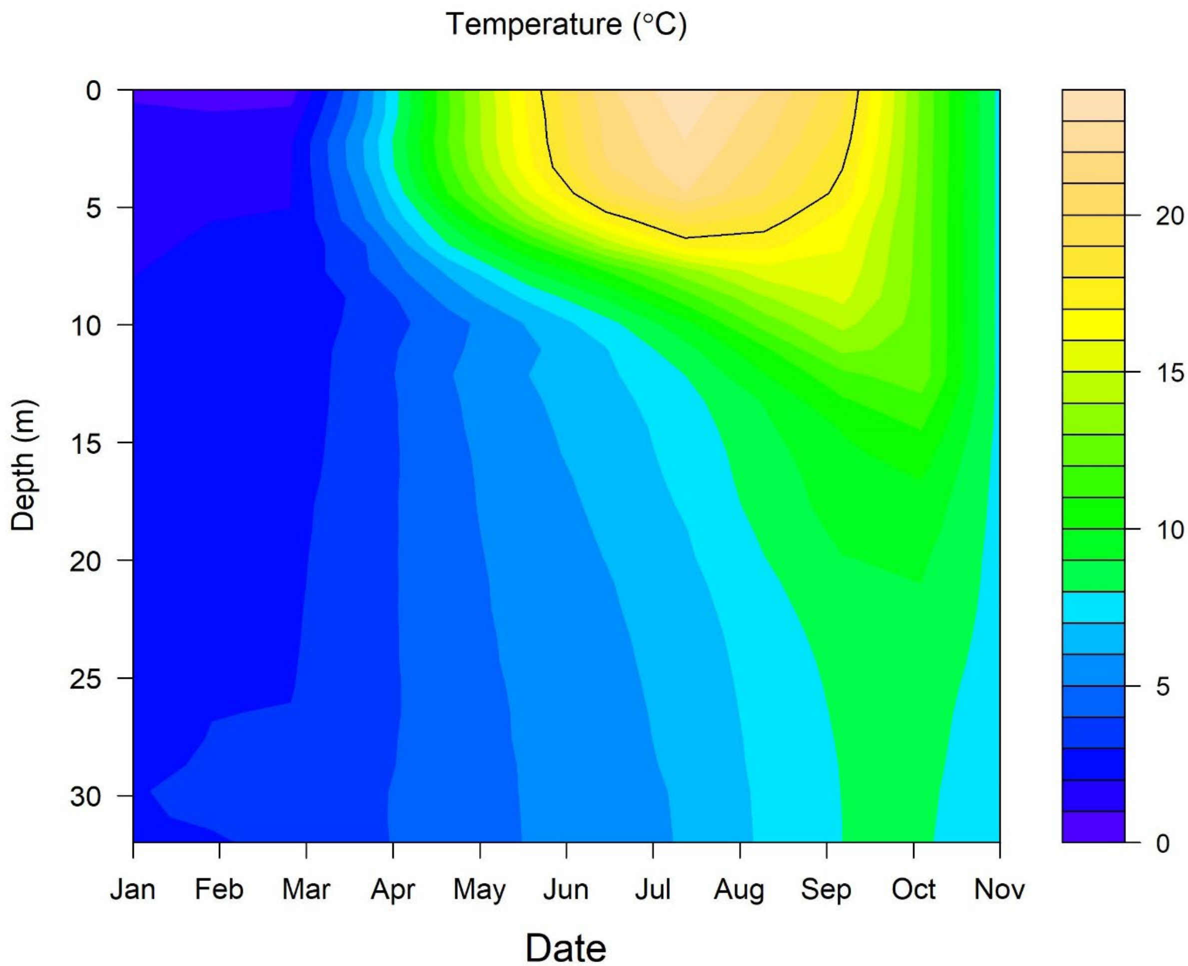

Figure 14: Isopleth of monthly temperature at depth for Piseco Lake 2017 to 2018. The solid, black line indicates upper temperature limits to preferred lake trout habitat (Tibbits 2008).

Dissolved Oxygen

The lake remains well oxygenated throughout the year. Dissolved oxygen levels were stratified from July to October and exhibited less variability from mid-January to mid-March, under the ice. Although there was evidence of oxygen consumption at the bottom of the lake during summer and winter stratification, the lake did not become anoxic any time during data recording in 2017-2018 at any depth (Figure 15).

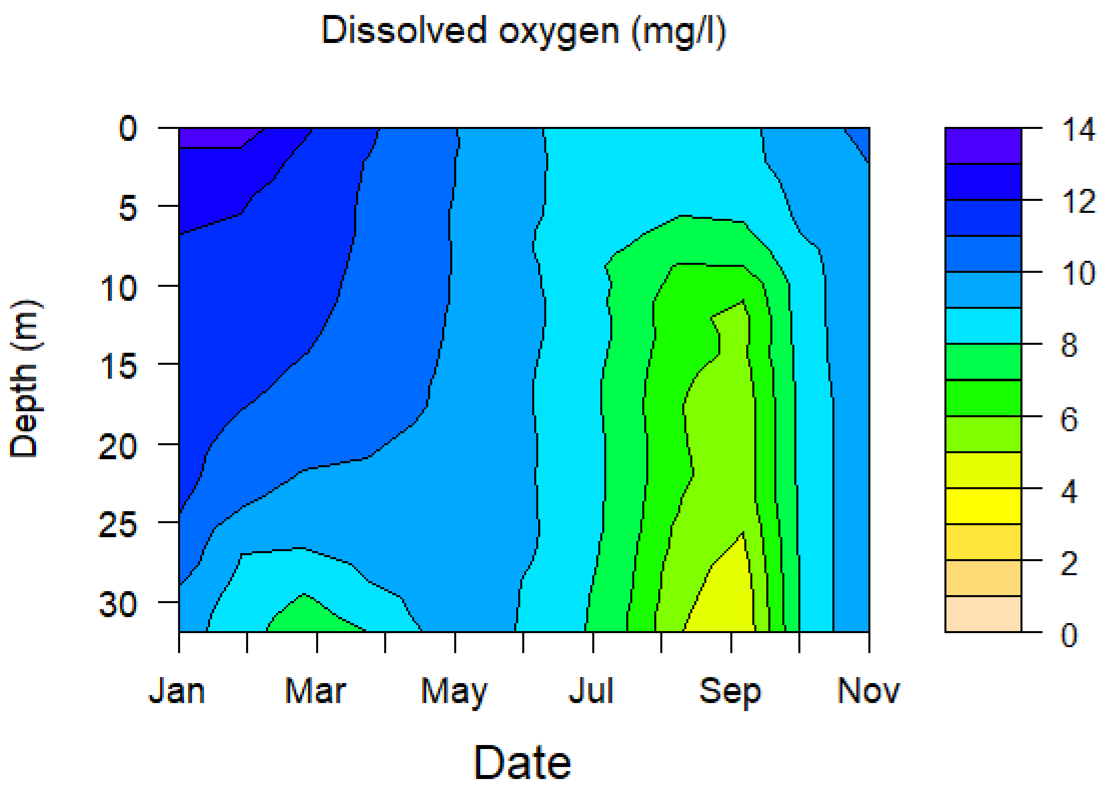

Figure 15: Isopleth of monthly dissolved oxygen (mg/L) at depth in Piseco Lake 2016 to 2018.

Nutrients

Total phosphorus concentrations were highest during November 2017 (11.67 µg/L) and May 2018 (14.42 mg/L). Total nitrogen concentrations were considerably higher during March, May, and July than in October, November, and December, with TN concentrations from May samples doubling those taken during the fall. Nitrate + nitrite concentrations were highest during March and July (Figure 16). All values measured in recent years were within the range of observed historical values.

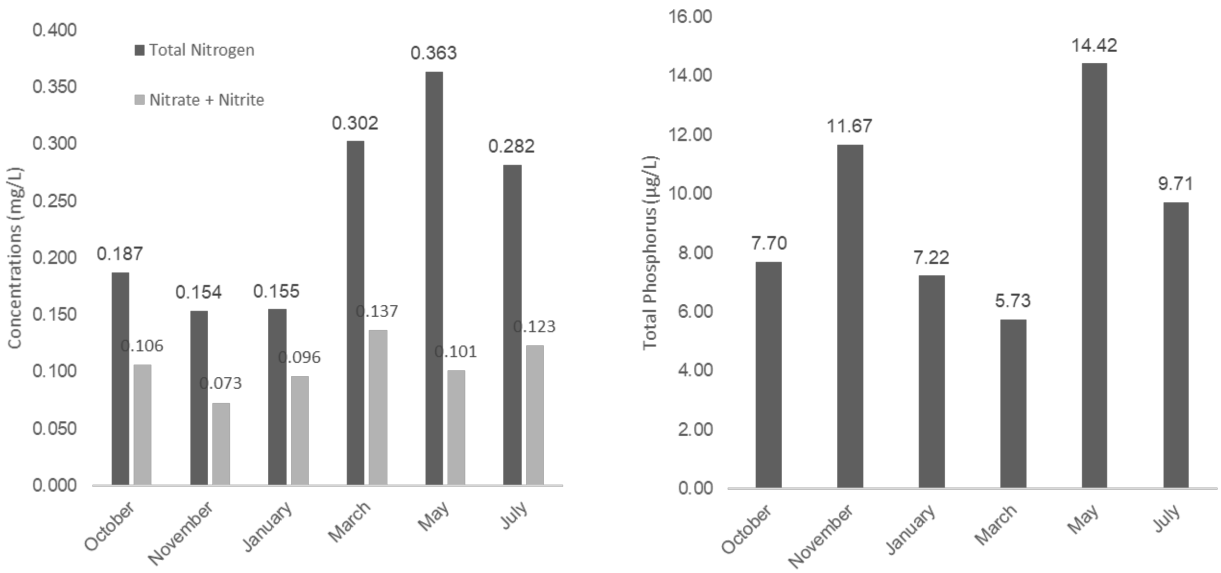

Figure 16: Mean concentrations of total nitrogen, nitrate + nitrite and total phosphorus, nutrient samples collected at 4-meter depth intervals in late 2017 and early 2018 in Piseco Lake.

Trophic Status Indices

Mean TSI for TP from 2017 (October and November) to 2018 (January, March, May, and July) was 35.8, with values ranging from 33.6 to 42.6. Most values of TSI for TP were within the oligotrophic range (TSI < 40). Only a single value (42.6) was within the range for mesotrophic lakes (Table 2 and Figure 17). Secchi depth and chlorophyll *a* were not available from data collection 2017-2018.

Table 2: Trophic status index (TSI) values for average total phosphorus collected at 4-meter depth intervals from monthly samples taken in Piseco Lake from October 2017 to July 2018.

Month	Total phosphorus (μg/L)	TSI(TP)
October	7.70	33.6
November	11.67	39.6
January	7.22	32.7
March	5.73	29.3
May	14.42	42.6
July	9.71	36.9

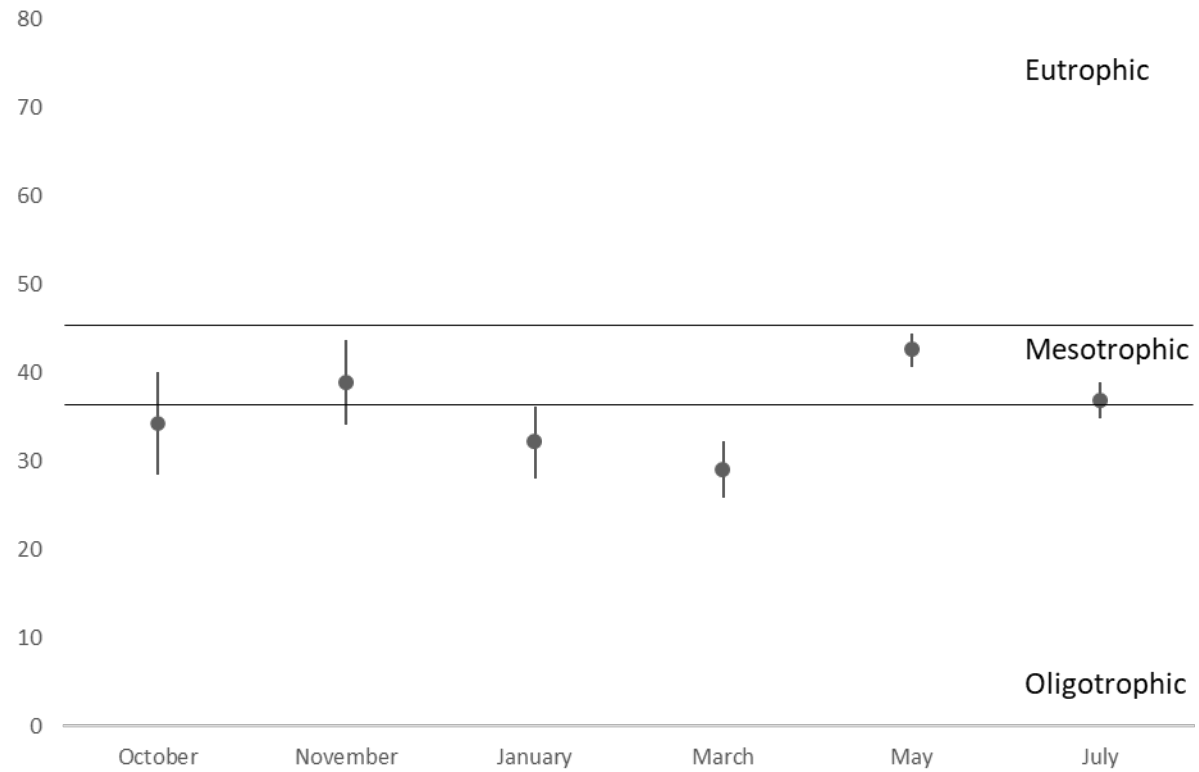

Figure 17: Average monthly values for TSI(TP) collected at 4- meter depth intervals from October 2017 to July 2018 plotted with trophic status ranges for TP.

pH

The pH in Piseco Lake exhibited significant fluctuations throughout the year. Surface pH ranged from 4.39 (May 2018) to 9.29 (January 2018), but remained relatively neutral on average. The pH decreased (became more acidic) with depth during periods of stratification.

Discussion

Piseco Lake has conditions that could be considered representative of a meso-oligotrophic system (low to moderate productivity). Though its TSI parameters are in the mesotrophic range (moderate productivity) on average, the parameters are on the low end and frequently fluctuate into what would be considered oligotrophy (low productivity). A relatively large volume of cold, well oxygenated water in the hypolimnion likewise indicates low to moderate biological production and oxygen demand. Variability in pH, alkalinity, and nutrients over time indicates that the lake may be sensitive to anthropogenic influences, whether stressors, or management activities. Maintaining or reducing nutrient inputs will help preserve the current state of the lake, as larger lakes tend to be efficient at cycling nutrients (Nõges 2009).

Piseco Lake exhibited low nutrient concentrations overall with mean TP concentrations slightly higher than other lakes in Hamilton County (HCSWCD unpublished data 2021). Average TP and TN concentrations indicated relatively low productivity with seasonal fluctuations consistent with expectations of snowfall, rainfall, and primary production patterns in the northeast US. Nutrient levels have exhibited a variable but downward trend since the start of data collection in 1993, but chlorophyll *a* concentrations have remained relatively stable. Even with nutrient spikes, phytoplankton (chlorophyll *a*) concentrations are still too nutrient-limited to increase into the eutrophic range. There do appear to be small spikes in chlorophyll *a* concentrations corresponding with spikes in nutrient concentrations, but they are not significant enough to effect the trend or mean. These patterns may be due to local conditions or larger climatological patterns (e.g. multidecadal oscillations in productivity) and could potentially cause concern should they increase in frequency.

Water temperatures in the lake remained relatively cool throughout the year with only the top 5 meters exceeding 20°C in during the summer months. The lake stratified thermally during the summer and winter months with mixing events in spring and fall as is typical of deep lakes in New York. The proportionally large hypolimnion (~ 55% of water column) indicates that ample thermal habitat is available throughout the year for lake trout (*Salvelinus namaycush*) that support a public fishery (NYSDEC 2021a).

Dissolved oxygen was present in the hypolimnion during all sampling events in 2017 – 2018, which is consistent with TSI values suggesting the lake has low-to-moderate primary productivity. The presence of oxygen near the bottom of Piseco Lake prevents internal loading of nutrients from sediment that frequently occurs in the absence of DO (Welch and Cooke 2009). Low summer AHOD rates suggest that the lake is unlikely to become anoxic or hypoxic during stratification. The lake forms a proportionally large hypolimnion which has enough DO to satisfy consumption needs from the biological processes occurring beneath the metalimnetic barrier during the summer months before the lake mixes again in the fall (Blumberg and Di Toro 1990). This suggests that cool water needed by species such as lake trout also contains sufficient oxygen for their survival.

As a whole, our results suggest that Piseco Lake is a meso-oligotrophic lake capable of sustaining coldwater fishes such as trout throughout the year. Low nutrient concentrations, high Secchi depths, and low chlorophyll-*a* concentrations all indicate that algal production is low. Sustained DO in the bottom of the lake suggests that decomposition is unlikely to lead to internal recycling of nutrients within the lake during summer or winter stratification periods. Timeseries analyses indicated that while temperature has increased since monitoring began, this does not appear to have resulted in increased productivity to date. Continued monitoring of physical and chemical water quality parameters will allow ongoing assessment of change or investigation of potential water quality concerns in this lake. And, in the absence of changes the lake may serve as a reference point for other similar lakes in the region.

Qualitative Assessment and Enumeration of Zooplankton

Introduction

Zooplankton are an important part of a lake ecosystems. As primary consumers, they transfer energy acquired from primary production (algae) to higher trophic levels such as larger invertebrates and fish (Bruce et al. 2006). In lakes, cladocerans, copepods, and rotifers are considered to be the most important zooplankton and are often the primary or sole focus of sampling (Pace and Orcutt 1981). Because of their central role in lake food webs, herbivorous zooplankton can help researchers understand lake ecology (Ismail and Adnan 2016) and their abundance can influence algal levels (Shapiro et al. 1983). Due to their low trophic level, zooplankton diversity and abundance is directly related to components of the biological community such as fish, in addition to physical lake parameters such as surface area, depth, and water transparency. Therefore, understanding zooplankton communities can aid in understanding other aspects of a lake ecosystem.

Zooplankton have not been intensively monitored in Piseco Lake, and no baseline data exist about community composition. An invasive zooplankton with the capability of altering lake ecosystems, the spiny water flea (*Bythotrephes longimanus*) has been established in the waterbody, having been first observed in 2014 (USGS NAS 2021). Invasions of the spiny water flea in inland waters such as Piseco Lake are often from recreational boaters transporting the species from other waterbodies (Colautti et al. 2005, Yan et al. 2011). As a predacious zooplankton that preys on other zooplankton, the spiny water flea may alter plankton composition. In high numbers, it can compete with planktivorous fish, altering lake food webs by disrupting energy transfer to higher trophic levels (Yan et al. 2001, Boudreau and Yan 2003).

The goal of this study was to provide an initial qualitative assessment that can be used to understand current zooplankton assemblages, and that can be reproduced in the future to monitor changes.

Methods

On 23 September 2021, a vertical plankton tow using a Wisconsin plankton net was conducted over a deep point in the northern portion of Piseco Lake. The net was towed vertically in the upper 10 meters of the water column to obtain a representative sample from the epilimnion. The net was metered to calculate of the amount of water sampled so taxon-specific density could be estimated. The sample was preserved by doubling sample volume with 70% ethanol and stored at room temperature prior to analysis. Two 1-mL sub-samples were viewed under a compound microscope. Each individual organism was identified by major taxon, counted, and measured for length (μm). Density was calculated for each group as number per liter. Taxon-specific empirical equations were used to estimate dry weight so that density could also be expressed as mass per liter.

Results

Of the 150 zooplankton counted in 2 mL of sample, rotifers were the most abundant comprising 79.6% of the subsample by number, followed by Copepods (20%) and Cladocerans (1.3%). *Keratella sp.* were the most abundant rotifer taxa and made up 47.3% of the zooplankton present in the sample (Table 3). Spiny water flea were present (observed by the naked eye) in the sample, but apparently not in high enough densities to be counted in the 2 mL of subsamples used for count and measurement protocol. This suggests their relative abundance is far less than

1/150 by number (0.067%), although they may still make substantial contributions to the community by weight because of their large size. Though comprising only 20% of individuals present in the subsample, copepods made up 77.8% of mean dry weight per liter due to their relatively larger size (Table 4). The 2 cladocerans present in the subsample significantly outweighed the 118 rotifers with mean dry weights per liter of 0.58 and 0.0002 ug, respectively (Table 4 and Figure 18).

Table 3: Totals captured, numbers per liter and relative abundance by number of zooplankton sampled from Piseco Lake plankton on 23 September 2021.

Major taxon	Minor taxon	Total	#/L	Relative Abundance
Cladocerans	*Bosmina*	2	0.54	0.01
Copepods	Cyclopoid	3	0.81	0.02
	Calanoid	8	2.15	0.05
	Nauplius	19	5.10	0.13
Rotifers	*Asplanchna priodontus*	18	4.57	0.12
	Gastropus	16	4.30	0.11
	Keratella sp	71	19.1	0.48
	Polyartha vulgaris	13	3.50	0.09

Table 4: Mean lengths and dry weights per liter and relative abundance by mass (RAM) of major groups of Piseco Lake plankton sampled on 23 September 2021.

Major taxon	#/L	Mean length (mm)	Mean dry wt/L (µg/L)	RAM
Cladocerans	0.537	0.352	0.588	0.222
Copepods	8.056	0.177	2.064	0.778
Rotifers	31.69	0.066	< 0.001	< 0.001

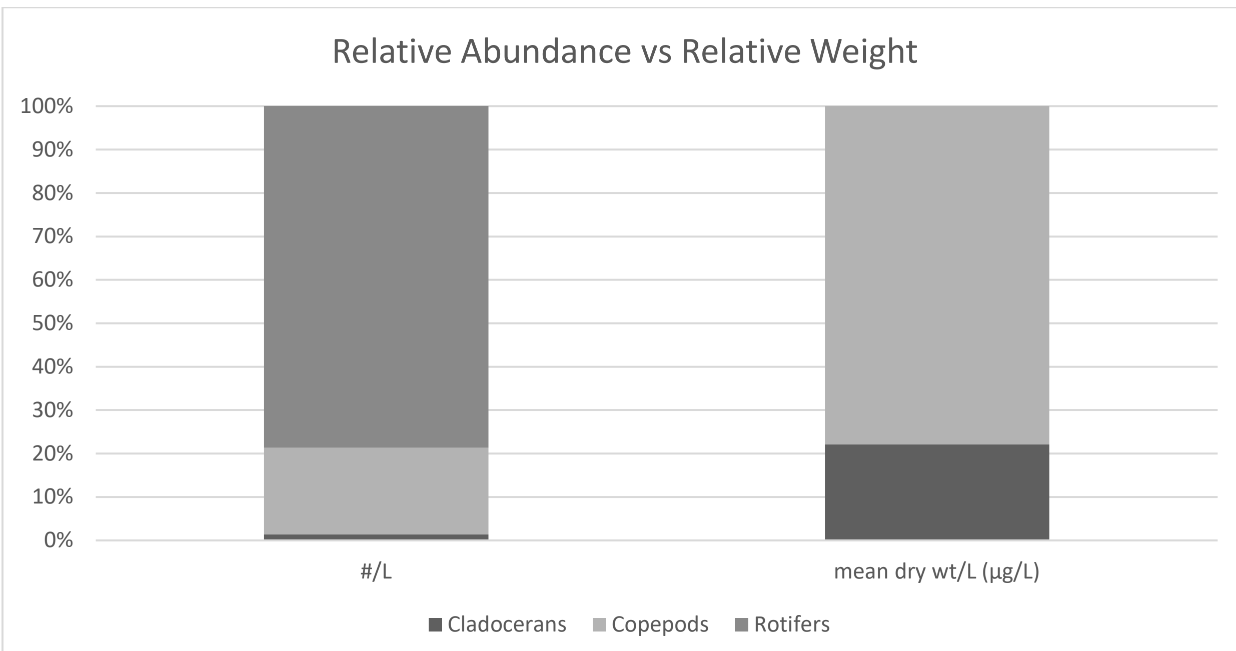

Figure 18: Relative abundance by number (left) and by dry mass (right) of zooplankton. Rotifers exhibited a high relative abundance but constituted less than 1% of the sample by mass.

Discussion

Rotifers were the most abundant zooplankton found in the Piseco Lake sample. Only two cladocerans, of the genus *Bosmina,* were found, with larger cladocerans, such as *Daphnia*, completely absent. Large cladocerans can be highly susceptible to fish predation. Their absence could suggest an abundance of predators such as spiny water flea or fishes, or simply a lack of suitable food and habitat. Their abundance also can vary by season (Sommer et al. 1986) and time of day (Folt and Burns 1999). Rotifers are often too small to be preyed upon by adult fish but can still be consumed by juveniles. If fish are preying on larger-bodied copepods and cladocerans, rotifers may be able to proliferate with the numbers of their competitors reduced (Obertegger et al. 2008). With hypoxic water mostly absent in Piseco Lake, zooplankton may be more inclined to hide from predators in the hypolimnion in the daytime (Rahkola-Sorsa 2008) when the sample occurred and only encompassed the top 10 meters of the water column (the epilimnion of Piseco Lake in September). Other sampling limitations can result from zooplankton potentially not being evenly dispersed in the water column (Folt and Burns 1999) and seasonal variations in zooplankton abundance (Sommer et al. 1986). Thus, more monitoring would be needed for a full characterization of this community throughout the year.

Though present in the sample, spiny water flea abundance was too low to be quantified based on the sample analysis protocol. Rapid expansion of the spiny water flea has been occurring in North America since they became established in the Great Lakes around the 1980s (Colautti et al. 2005, Jansen et al. 2017). Native to Eurasia, spiny water flea are thought to prefer deep oligotrophic lakes (Jansen et al. 2017, Yan et al. 2001). Although mesotrophic, Piseco Lake exhibits some physical and chemical characteristics that are similar to oligotrophic waterbodies. Though considered to greatly effect plankton community structures and lake food webs, it cannot be determined if or how spiny water flea are altering the ecology of Piseco Lake, especially without pre-invasion sample data. To better understand the effects of spiny water flea in Piseco Lake, future zooplankton studies could be compared to similar lakes in the same region where spiny water flea are not established.

With relatively short lifespans, zooplankton can be valuable indicators of small changes in lake trophic state, as their community structure is greatly influenced by nutrients and other biota (Ejsmont-Karabin 2012, Rahkola-Sorsa 2008). More routine zooplankton sampling should be conducted on Piseco Lake to monitor changes.

Fisheries

Introduction

Freshwater fish play an important role in lake ecosystems, with some piscivores (fish eaters) acting as apex predators, the highest trophic level within a system, only falling prey to birds, mammals, and humans. Large freshwater fish have profound impacts on lake ecology enforcing top-down biological control of lower trophic levels. Planktivorous fish (often smaller "baitfish") control herbivorous zooplankton (grazers) that control phytoplankton (algae) from the bottom up in a food web. Having too few large piscivorous fish can lead to excessive numbers of planktivorous fish and decreased numbers of zooplankton. Low numbers of zooplankton can lead to excessive algae, meaning that fish can indirectly influence algal levels. Large fish are also desired as sportfish by recreational anglers. A good sport fishery can attract anglers from near and far, benefiting local economies while also being indicative of a healthy lake ecosystem. Fisheries management therefore has broad economic and ecological implications for a lake and its surrounding area.

There are limitations that fisheries managers face in terms of data collection with surveys being limited to particular times and locations in waterbodies. Data are useful for providing snapshots of fish populations and can be helpful for understanding population status at a given time. Though valuable for comparison with regional or global standards, data are limited in that their results cannot necessarily be extrapolated to answer questions at finer or longer scales than are included in the data. Goals of surveys are often limited to monitoring and managers may not have the resources to routinely investigate and collect fisheries data. Although there is some seasonal predictability of fish movement, there are many unknown variables influencing fish populations and lake ecology.

Piseco Lake has historically been managed by the NYSDEC as a coldwater fishery with some of the first of few targeted fisheries surveys occurring in the 1960s in an effort to inform management of the native lake trout (*Salvelinus namaycush*) population. More recent, sparsely conducted surveys began in 2002 after angler complaints of few legal size (≥ 18 inches at that time) lake trout being caught (Preall 2011). Two notable lake trout surveys were conducted in 2002 and 2014. Recent stocking efforts in Piseco Lake included landlocked Atlantic salmon (*Salmo salar sebago*) and lake trout. Annual stocking of 2000 Landlocked Atlantic Salmon fingerlings 1996-2015 yielded poor returns and was discontinued. Lake trout stocking in Piseco Lake has been going on for decades and has been largely successful with the current rate at 3500 fingerlings/year (Table 5). Historically, the native round whitefish (*Prosopium cylindraceum*) was found in Piseco Lake but has not been detected in decades and is presumed extirpated. The closely related lake whitefish (*Coregonus clupeaformis*) was introduced to Piseco Lake in the 1900s and is still present today. The goal of this study was to summarize recent fisheries data from Piseco Lake, quantify the effects of fish stocking, and suggest strategies for future fisheries management.

Table 5. New York State Department of Environmental Conservation (NYSDEC) lake trout stocking efforts, Piseco Lake 2011-2020. From fish stocking list dataset NYSDEC (NYSITS, 2021).

Year	Month	Number	Species	Size (inches)
2011	May	1,660	Lake trout	6.1
2013	May	2,530	Lake trout	7.4
2014	June	1,600	Lake trout	6.7
2014	June	3,500	Lake trout	6.7
2015	May	3,500	Lake trout	6.3
2016	April	1,970	Lake trout	6.9
2017	May	3,500	Lake trout	6.7
2018	May	3,500	Lake trout	6.7
2019	May	3,280	Lake trout	6.2
2020	April	3,500	Lake trout	6.8

Methods

Data obtained from NYSDEC Statewide Fisheries Database were assessed using Microsoft Access and Excel computer applications to determine catch per unit effort (CPUE), length frequencies, proportional size distribution (PSD), and relative weights (W_r) of lake trout in Piseco Lake. Comparisons were made between gill net surveys targeting lake trout conducted in 2002 and 2014.

Catch per Unit Effort (CPUE)

Standardized data collection in fisheries provides a means to compare surveys conducted on different dates or waterbodies. Catch per unit effort (CPUE) is a means of quantifying the number of fish caught for a given unit of effort, which is often measured as time spent sampling or number of nets set. For example, if a single angler caught 10 fish in a waterbody over the course of a year, there would be no way to effectively express the significance of that without taking into consideration how much time that angler spent fishing. If the angler spent 10 hours, the CPUE would 1 fish/hour; if the angler spent 100 hours fishing, the CPUE would be 0.1 fish/hour. If the angler did not record the amount of time spent fishing, data could not be compared from year to year or trip to trip accurately (Bonar et al. 2009). Gill net surveys conducted on Piseco Lake in 2002 and 2014 followed standardized sampling protocols utilizing identical net types, allowing for comparison of CPUE between years. Comparisons made should take into consideration that perfectly replicating a survey is nearly impossible with netting locations, depths, soak times, and scheduling often varying.

Proportional Size Distributions

Complementary to standardized sampling methods was the development of standardized length categories for catchable fish species. Gabelhouse (1984) developed a length categorization system based on predetermined length values specific to different fish species. Length ranges for this system are categorized as “stock”, “quality”, “preferred”, “memorable”, and “trophy”. These values are based on proportion of the fish length to the length of the world record for that species, with “stock” size representing the minimum size of a species that an angler is likely to catch and are calculated as:

$$PSD = \frac{Number\ of\ fish\ \geq\ Quality\ size}{Number\ of\ fish\ \geq Stock\ size} * 100$$

Within this system, fish that are greater than equal to “quality” size also are by definition greater than or equal to “stock” size. Therefore, PSD is defined as the proportion of stock sized fish that are also of “quality” size (or of larger size classes depending upon groups used). The definitions of these size groupings vary from one species to another (Table 6), but the interpretation of the index remains fixed since the categories are relative size groupings. A balanced PSD range for a desirable predatory fish, such as lake trout is 30-60 (Willis et al. 1993, Gabelhouse 1984).

Table 6: Length category definitions and corresponding sizes of lake trout based on Gabelhouse (1984).

Length Category	Percent of World Record Length	Lake Trout Length (inches)
Stock	21	12
Quality	38	20
Preferred	49	26
Memorable	61	31
Trophy	76	39

Relative Weight

Evaluating fish populations by proportional distribution in length categories alone may not represent the overall condition of a species, and a given PSD may have different interpretations depending on other indicators (Murphy et al. 1991). Information about other characteristics such as fish condition can reduce ambiguity in the interpretation of PSD. Previously, relative condition (plumpness) of sportfish were limited to long-term data from a single population. Species-specific standard weights (W_s) were developed for several sportfish to compare relative weights (W_r) of a particular population to global or regional standards based on the actual weight of a fish (W) compared to the expected 75th percentile of weights (standard weight) for a fish of the same length and species (Murphy et al. 1991):

$$Wr = \frac{W}{Ws} * 100$$

The following standard weight formula for lake trout was defined by Piccolo et al (1993) with the required minimum total length of lake trout for calculations at 280 mm (11 in).

$$log_{10}(Ws) = -5.681 + \ 3.246(log_{10}Total\ Length)$$

The calculated W_r of a fish gives insight into the overall condition of fish relative to global or regional standards. For example, a fish with a W_r of 100 is at the 75th percentile of global weights for other fish of that size within a species, meaning that it is in better condition than 75% of fish at the same length. Relative weights < 70 may indicate less than ideal growing conditions and may be the result of regional or lake-specific conditions, increasing the importance of relative condition for determining causes. The mean W_r for lake trout in the eastern Adirondacks (NYSDEC Region 5) calculated from measured lake trout in the NYSDEC fisheries database (n = 4694, years 2000 - 2020) is 92.5 which may be used as a baseline for more comparisons.

Length Frequencies and Age Data

Proportional densities of fish of different lengths provide some information about year classes but determining size structures of fish populations must also include size classes shorter than the minimum "stock" sizes from the Gabelhouse (1984) categorization. Similar sized fish are often the same age and can give cues into plights of certain year classes of fish populations and their spawning success in recent years. Length at age data compared to that of multiple waterbodies can be used to calculate relative growth rates. Fish can be aged from annuli, clusters of overlapping growth rings present on their scales or in cross-sections of hard structures viewed and counted under a microscope. Long-term age data can be used to detect changes in growth rates and give cues to changes in fecundity when length at spawning age is compared (Schill et al. 2010).

Results

CPUE

Gill net surveys were conducted on Piseco Lake by NYSDEC in 2002 and 2014 (Table 7). A total of 106 lake trout were collected in 9 nets in 2002, resulting in an estimated CPUE of 11.8 fish per hour. In 2014, 12 net sets yielded a total of 139 fish for a similar CPUE of 11.6 fish per net.

Table 7: Number of gillnets set, and lake trout captured in 2002 and 2014 NYSDEC surveys, with catch per unit effort (CPUE) expressed as fish per net.

Year	Number of nets set	Total lake trout captured	CPUE (fish/net)
2002	9	106	11.8
2014	12	139	11.6

Proportional Size Distributions

Most (n = 227) of the lake trout captured in both surveys were "stock" size or shorter in total length (Figure 19). In 2002, 2 fish were that were longer than stock size were longer than quality size (PSD_Q = 3, 95% confidence interval = 0-7). This is far lower than what would be expected in a population balanced between large and small fish (PSD_Q 30-70). The estimated PSD_Q was higher in 2014 (PSD_Q = 13, 95% confidence interval = 7-20) than in the 2002 sample, but still indicative of a population skewed toward small fish. In 2014, 16 fish captured that were longer than stock size were also longer than quality size. The overall PSD_Q from the 2014 sample suggested that larger lake trout were more common than in 2002. Lake trout in larger length categories (preferred, memorable, and trophy) were not captured in either survey.

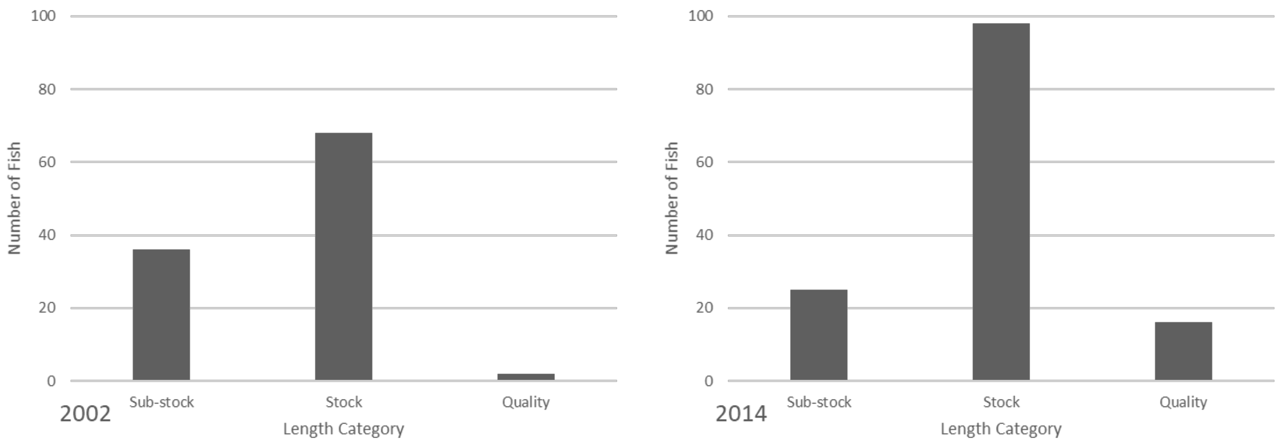

Figure 19: Number of fish caught in each length category from 2002 and 2014 Piseco Lake surveys.

Length Frequencies

The 2002 survey captured a higher proportion of smaller lake trout with 22.6% percent of the catch longer than 400 mm (16 in) in 2002 compared to 63.3% in 2014. Likewise, the 2002 survey also resulted in collection of more fish in smaller size classes, with 34% of fish being less than 300 mm (12 in) in 2002 and 18% of fish less than 300 mm in 2014. The length-frequency histograms indicated presence of multiple size (age) classes in both years of sampling. Fish in the 460-600 mm length range were absent in the 2002 sample (Figure 20).

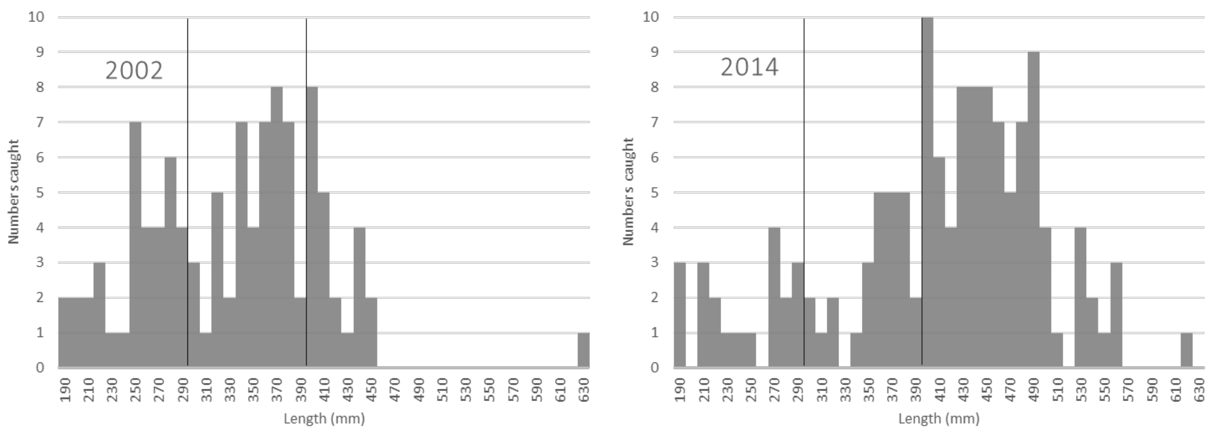

Figure 20: Length-frequency histograms of fish captured in Piseco Lake in 2002 and 2014 with lines indicating 300 mm and 400 mm length cutoffs.

Length at Age

Lake trout captured in 2014 grew faster than those collected in 2002, meaning they reached larger sizes at younger ages (Figure 21). Fish as young as 1 year and as old as 11 years were collected in 2002, consistent with the wide range of sizes observed. Although there was a greater proportion of large fish collected in 2014, only ages 2-8 were represented in the data. This may be due to smaller proportion of captured lake trout being aged in 2014 (56/139 fish) than in 2002 (104/106 fish).

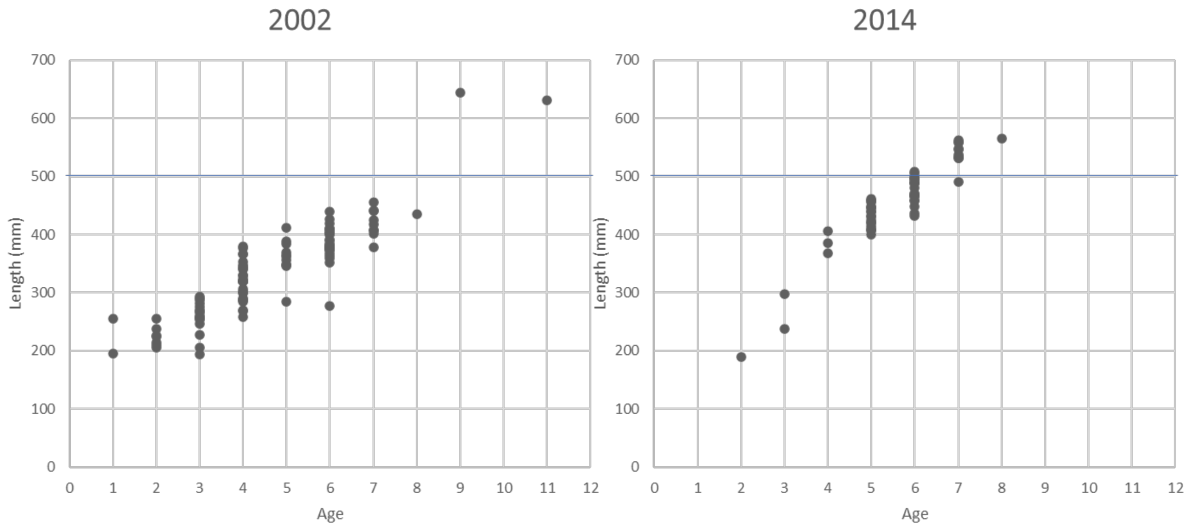

Figure 21: Length at age for lake trout collected in NYSDEC gillnet surveys in 2002 and 2014. Fish above the 500 mm line are "quality" size or larger.

Relative Weights

Relative weight of lake trout varied between years and across size ranges in 2002 and 2014. The mean W_r of lake trout was lower in 2002 (88.0) than in 2014 (100.1). In 2002, Lake trout between 300 and 370 mm had a mean (standard deviation) Wr of 88.0 (± 1.25), whereas fish smaller than 300 mm ($W_r = 93.9 \pm 4.3$) were in better condition and fish longer than 370 mm ($W_r = 85.1 \pm 3.7$) were in poorer condition. Although W_r was highly variable in 2014, it was higher on average across all size groups (mean $W_r = 100.1$), with a general decrease in W_r as fish grew longer (Figure 22).

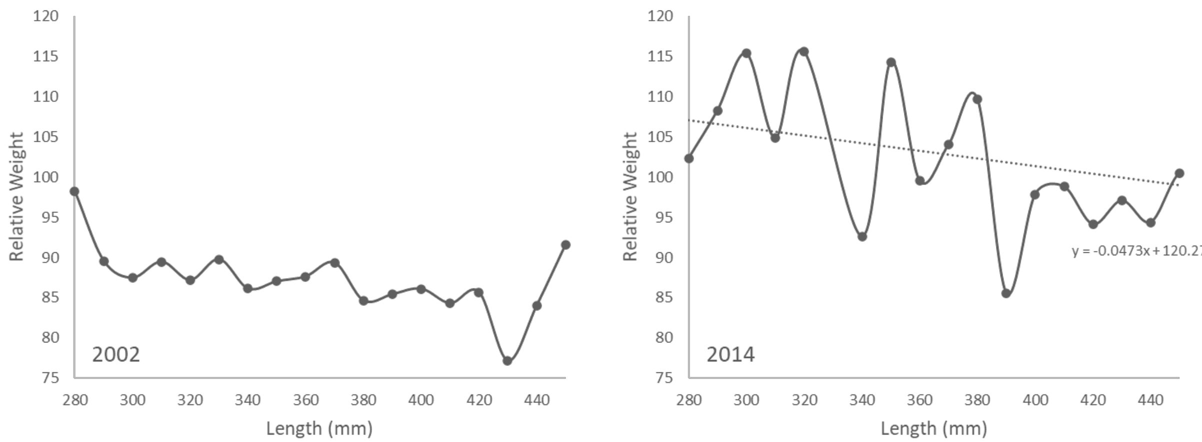

Figure 22: Relative weight (W_r) of lake trout captured in Piseco Lake 2002 and 2014. A trendline denotes the more variable 2014 data.

Discussion

Though native to Piseco Lake, lake trout have been stocked in the waterbody for decades with varying perceptions of success. The 2002 gill net survey was initiated in response to angler concerns about lack of legal size (≥ 18 inches in 2002) lake trout being caught. These concerns were supported in the data, with only 3 (2.5%) of the 106 lake trout captured being at least legal size. The gill net catch rate for that survey was relatively high compared to other lake trout gill net surveys in the Adirondacks (NYSDEC Bureau of Fisheries 2003) such as those conducted in Lake George and Schroon Lake (5.1 and 7.8 lake trout/net in 2013 and 2014 respectively). However, smaller sizes, slower growth rates, and lower relative weights in 2002 suggested that an overabundance of lake trout was resulting in competition among smaller lake trout for food resources (Cox et al. 2013). Stocking numbers were reduced in 2010 from 4700 fingerlings/year to 3500 to improve growth and condition of the fish. The legal minimum size of lake trout in

Piseco Lake was changed from ≥ 18 inches to ≥ 21 inches in 2004 (Preall 2011), restricting the harvest of smaller fish and potentially aiding in their survival to larger sizes.

Lake trout collected during the 2014 gillnet survey of Piseco Lake were larger on average, grew faster, and were in better condition (measured as W_r) than those collected during the 2002 survey, even with similar high catch rates. This is likely a result of reducing the annual lake trout stocking numbers in 2010, and seems to support the notion that competition was previously limiting growth and recruitment to larger size classes. Fewer smaller individuals being stocked at a given time likely led to less competition for food and improved growth. Increased W_r of smaller individuals, in particular, suggests that fish are now achieving more optimal growth conditions at young ages. A reduced proportion of younger and smaller fish captured in the 2014 survey could suggest reduced recruitment, but could also be consistent with decreases in stocking numbers and the reduced proportion of age data collected in 2014.

There were some notable inconsistencies in the surveys that may have influenced the differences in results. The 2002 survey included nets set exclusively on the lake bottom (n = 9) whereas the 2014 survey featured 4 nets set suspended in the water column at depths ranging from 16 to 26 feet that captured no lake trout. Had those unsuccessful suspended nets been excluded from CPUE calculations, the 2014 survey would have resulted in significantly higher catch rates than the 2002 survey (17.4 vs. 11.8 fish/net) from its 8 bottom set nets. Additionally, successful 2014 net sets had deeper minimum set depths (60 ft) than those in 2002 (45 ft) which may have selected for larger fish. There was also a difference in scheduling between the two surveys which could have influenced fish movement with the 2002 survey occurring in late August and the 2014 survey occurring in mid-July.

The lake trout fishery in Piseco Lake, like many other coldwater fisheries, is necessarily balanced on a continuum between low numbers of very large fish and high numbers of very small fish. Neither of the extremes on either end are sustainable or necessarily satisfying to all anglers. According to limnological monitoring conducted by Hamilton County Soil and Water District during the past several years, and data collected in previous sections of the current report, Piseco Lake is moderately to highly unproductive based on commonly used indicators such as nutrient concentrations (phosphorus and nitrogen), chlorophyll *a*, and Secchi depth. On the one hand, this confers several qualities that benefit humans and the biota that live in the lake, such as good water quality for swimming and recreation, and an oxygenated hypolimnion that remains cool enough to support the lake trout themselves. However, these same characteristics mean that the lake is limited in the biomass of fish it can support. Because energy is lost through food webs from primary producers to consumers, apex predators tend to be the most limited in numbers by low productivity in oligotrophic waterbodies. Thus, as expected, natural production of lake trout appears to be low in Piseco Lake, so some stocking is needed to maintain the fishery if angler harvest is to occur (NYSDEC Bureau of Fisheries 2015). This is an especially important consideration for long-lived, late maturing species such as lake trout that do not become sexually mature until 6-7 years (Tibbits 2008). With increased growth in recent years, natural production may increase as fecundity (number of eggs per fish) increases with size in salmonids (Schill et al. 2010). In addition to natural limitations of a relatively unproductive lake, lake trout populations may also be limited by interspecific interactions such as competition with stocked fish or egg predation, or human alterations to the lake that affect spawning habitat.

Continued monitoring is necessary to continue managing the fishery of Piseco Lake sustainably in the future. Only two major lake trout surveys (12 years apart) have been conducted by the NYSDEC since 1988, limiting inferences that can be made about the population. Routine monitoring to establish standardized baseline data and monitor population changes would aid in future management efforts. Collecting data about diet and reproduction, for example, would be useful in identifying potential resource limitations or population-specific life history considerations (e.g., age at reproduction) that could improve management. Given the large number of lakes and populations managed by NYSDEC Region 5 Fisheries, responsible for managing Piseco Lake among several other waters, this may require coordination with interested academic institutions or private companies in the future. Because this fishery constitutes a public fishery managed in public trust, any future monitoring or study will need to be closely coordinated with NYSDEC and will benefit from inclusion of interested public users including both residents and visiting users of the lake.

A Plan for the Management Piseco Lake

Introduction

Located in New York State Adirondack Park, Piseco Lake has less development-based obstacles than lakes in other regions. Most of the Piseco Lake watershed is either forest or open water with development mostly limited to roads and private lots (Figure 2). Long term limnological monitoring suggests that the lake is moderately unproductive, likely experiencing relatively low nutrient input. Unproductive waterbodies are less likely to exhibit excessive algae and plant growth or low transparency. Piseco Lake is exhibiting a downward trend in total phosphorus, which is often considered the limiting nutrient in lakes. Nutrient limitation is reflected in the fisheries data, with the low abundance of larger lake trout. Chlorophyll-*a* levels remained in the mesotrophic range throughout monitoring, which is another indication of low nutrients. More zooplankton sampling should be conducted as the lack of larger bodied zooplankton could be a result of poor food resources related to nutrients, disturbance from spiny water fleas, or high fish predation. Information on aquatic plants of Piseco Lake can be found in the "Identification Guide for Wetland and Aquatic Plants of Piseco Lake", by David L. Moore, with copies available through the Piseco Lake Association.

Conservation of the watershed is necessary to protect and properly manage the Piseco Lake. Land use within the watershed should employ best management practices (BMPs), "any procedure that reduces the availability, detachment, or transport of pollutants" (NYSFOLA 2009). Main objectives of any lake management strategy concerning watershed and lake use are prevention of erosion and any sort of anthropogenic input. Educating the public is one of the most effective measures as governmental institutions and mandates are greatly limited with regards to the broad range of local human activities affecting a lake.

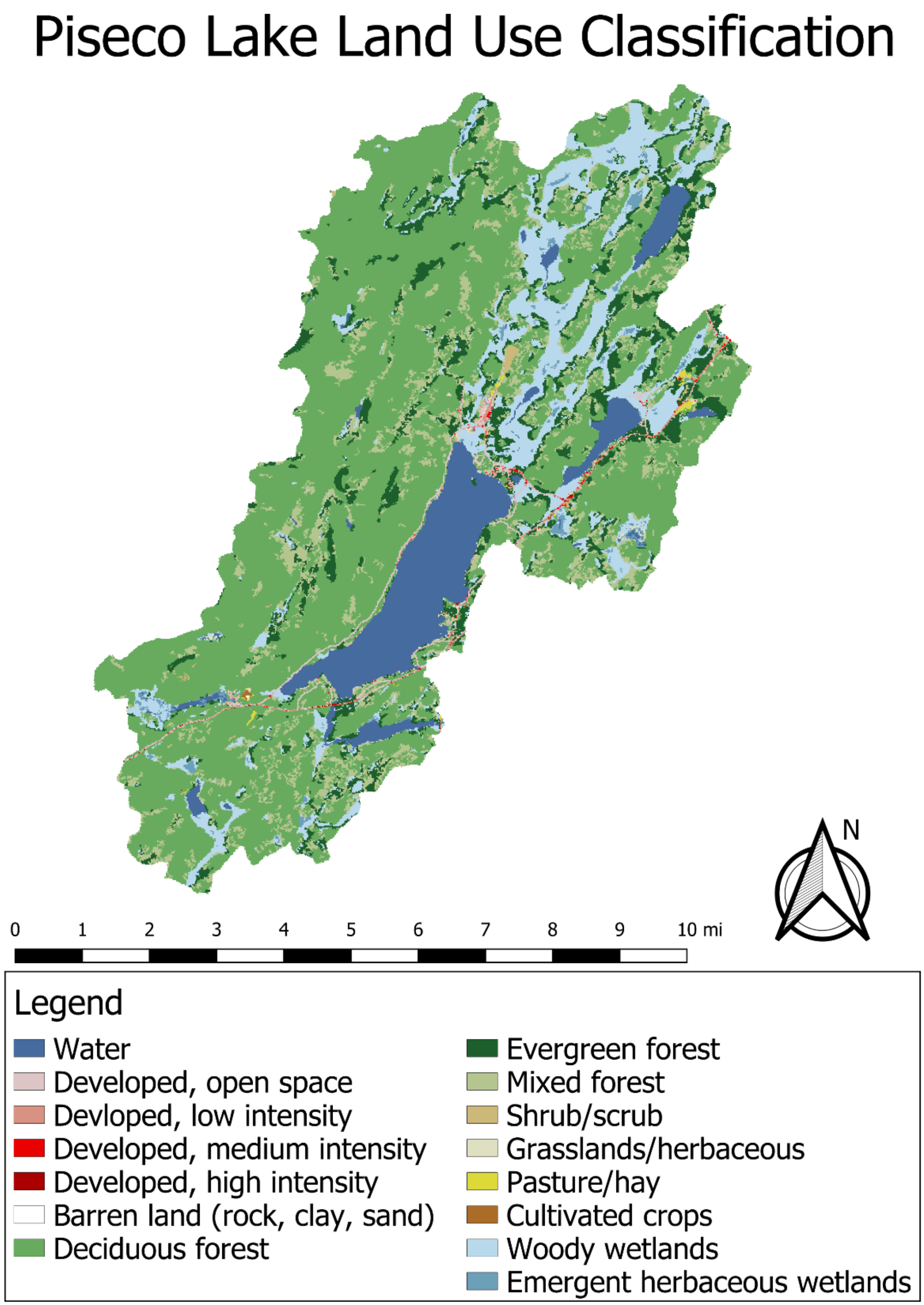

Figure 2: Map of Piseco Lake's watershed land use classification.

Goal 1. Maintain existing water quality

Objective 1.1 Minimize pollutants and erosion

Management Alternative 1.1.1 Maintain terrestrial vegetation and riparian buffers in watershed

Vegetation is a beneficial component of watersheds, helping reduce erosion and pollutant input. With root systems holding the soil together and canopies slowing the velocity of precipitation, forest vegetation can reduce erosion. Plant cover makes water more likely to infiltrate soils, rather than dislodge and transport soil particles as surface runoff. Human alteration often leads to a reduction of natural vegetation cover, encouraging erosion and transfer of pollutants in the resulting modified watersheds.

Forested land and vegetation should be preserved wherever possible, especially near the edges of lakes and streams. Vegetated buffer zones on water edges can reduce erosion caused by wave action in lakes and high flows in streams. In addition to preventing erosion, vegetation can also reduce the transport of pollutants in a watershed. Plants along a streamside can reduce sediment loads, filter out and pollutants, and improve habitat for organisms in and around a stream. A riparian buffer of 100 feet is recommended for streams with distinct zones to maximize effectiveness. More detailed information and potential funding sources for riparian buffers can be found on the DEC website (https://www.dec.ny.gov/chemical/106345.html).

Management Alternative 1.1.2 Future development

Establishing BMPs beforehand can be easier than retroactively trying to reform practices that are not necessarily beneficial to a watershed. Existing structures within the watershed should be reviewed to determine any oversights that could be affecting water quality. Alternatives to nonporous walkways and driveways such as gravel should be encouraged to reduce surface runoff. Stakeholders should encourage local legislation limiting the proportion of land allowed to be made up of nonporous structures, preventing unnecessarily large homes to help reduce surface runoff. Building on steeper slopes should be discouraged or prevented, as it would lead to less soil infiltration from rainwater. Naturally forested areas should be maintained as suggested above; zoning laws can help limit land alteration in key areas. Cluster zoning, designating human usage areas, can help preserve forested areas and prevent the addition of impervious surfaces in a watershed. Such objectives can also be encouraged through education and financial incentives rewarding beneficial practices. Conservation easements are a great way for landowners to permanently protect natural resources, even after the sale of their property. Several BMPs are addressed in the Town of Arietta Land Use Code with an emphasis on preserving natural forested areas.

Management Alternative 1.1.3 Homeowners practices

Educating landowners about the effects of their actions can help them avoid activities that can degrade water quality. Extensive lawns should be discouraged as they are less capable of holding rainwater and stabilizing soils than trees or shrubs. Landowners should be encouraged maintain patches of trees and shrubs rather than large areas of open space to aid in rainwater infiltration and reduce erosion. Redirecting rainwater from nonporous structures into raingardens or drainage basins through vegetated swales can aid in soil infiltration and reduce surface runoff. Rain barrels beneath downspouts can allow rainwater to be recycled. Chemicals of any kind should not be dumped outside as anything added to the soil will eventually end up in the lake. Lawn fertilizers can contribute to lake nutrient levels and should be applied sparingly during times of the year when they are more likely to contribute to lawn growth and less likely to be washed away.

Management Alternative 1.1.4 Septic

On-site wastewater treatment systems (septic) can be one of the greatest nonpoint source pollutant contributors. Soil septic suitability in the Piseco Lake watershed is limited, meaning that conventional septic systems are less likely to be effective (Figure 3). Alternatives to conventional septic systems include the mound system and the sand-filtration system. More information about alternative systems can be found through United States Environmental Protection Agency (USEPA) at https://www.epa.gov/septic/types-septic-systems.

Homeowners should be aware of the location of their septic system constituents and have a basic idea of how it functions to be able to identify and remedy issues. The EPA recommends household septic systems should be inspected every 3 years and pumped every 3-5 years to maintain proper functionality (EPA 2021). Septic systems are designed to trap human waste and the addition of any other substance which can be harmful to both the system and the environment. Household chemicals and unused pharmaceuticals should never be poured down the drain because they can have detrimental effects on lake ecology and septic functionality, which relies on wastes being broken down by living microbes. Conserving water and avoiding use of a garbage disposal will help maintain the system and prevent the addition of excess nutrients. Homeowners may not be aware of simple practices that can help prevent water quality degradation and can be informed through newsletters, handouts, programs, and other means. Additional information about septic system care can be found through USEPA at https://www.epa.gov/septic/how-care-your-septic-system.

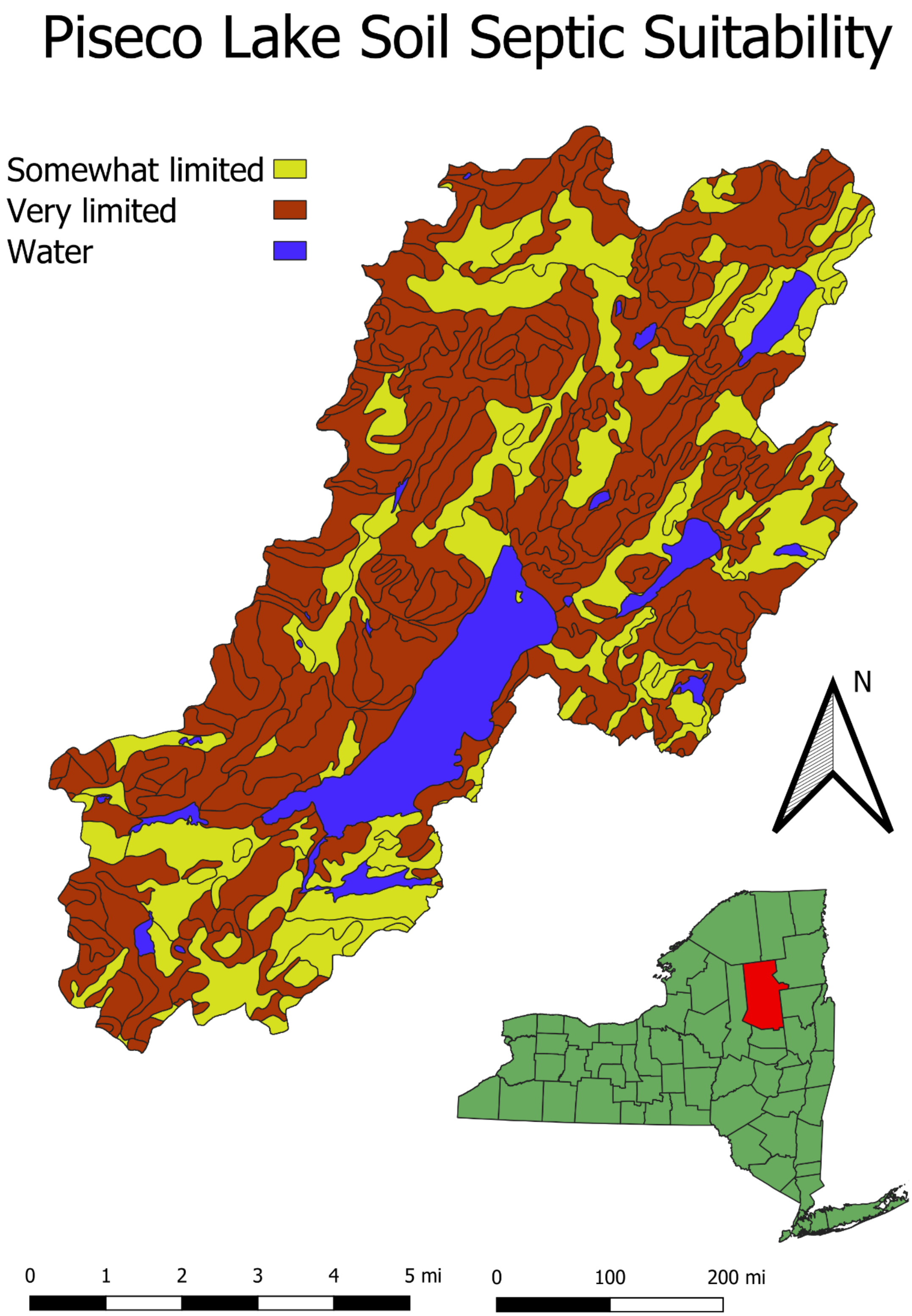

Figure 3: Map of septic absorption field soil suitability ratings for Piseco Lake's watershed.

Management alternative 1.1.5 Review land use codes to ensure best management

The Town of Arietta has a land use code that should be reviewed to make sure that BMPs beneficial to Piseco Lake are being employed and any necessary modifications can be properly coordinated. Briefly, the Town of Arietta Land Use Code was designed with the preservation of the Adirondack Park in mind, promoting the preservation of existing native vegetation and natural scenic beauty of the area. The land use code has many practical provisions to reduce environmental impacts of development without being too restrictive. Clustered development is encouraged for the preservation of open space (undeveloped areas). Provisions are mindful of the effects of development on hydrology and limit slopes on which roads and sewage disposal systems may be built. The land use code requires vegetative buffers along roadways, waterways, and shorelines, with limitations in place for how many plants are allowed to be removed. The land use code includes environmentally conscious criteria for the sewage disposal systems, limiting the potential of wastes entering waterways and requiring designing by a licensed professional.

Objective 1.2 Control invasives

Management Alternative 1.2.1 Boat stewards and education

Education is the best means to prevent the spread of aquatic invasive species. Boats and other aquatic recreational equipment can transport invasive species if they are not properly dried or disinfected. New York State law requires boaters take steps to avoid the spread of invasive species, with a recommended drying time of boats and equipment between waterbodies of 5-7 days. More detailed information about preventing the spread of aquatic invasive species can be found at https://www.dec.ny.gov/animals/50121.html. Some organizations with useful resources to help prevent the spread of aquatic invasives include NYSDEC, Partnership for Regional Invasive Species Management (PRISM), Adirondack Watershed Institute (AWI), and Adirondack Park Invasive Plant Program (APIPP). The AWI established a stewardship program to prevent the spread of aquatic invasive species throughout the Adirondack Park. The program employs boat stewards at several waterbodies in the region to educate boaters about watercraft decontamination practices and intercept invasive species that they may be inadvertently transporting.

As a publicly accessible waterbody, Piseco Lake has a risk of invasive species introductions by uninformed users. In 2014, an established population of the invasive spiny water flea was detected in Piseco Lake. In 2020, the AWI deployed boat stewards at three Piseco Lake public access points at Little Sand Campground, Poplar Point Campground, and Point Comfort Campground from late May through Early September that inspected over 1800 boats. The conjunction of their efforts around the state led to a reported 84% of Piseco Lake boaters interviewed by the AWI boat stewards showing aquatic invasive species prevention awareness (Kelting et al. 2021). The AWI Stewardship Program is partnered with the Piseco Lake Association and the Town of Arietta. Signage, proactive education, and stewardship funding should continue to be employed to keep the lake users aware of risks.

Goal 2. Prevent swimmer’s itch

Objective 2.1 Prevent exposure to the parasite

Management Alternative 2.1.1 Reduce parasite habitat

Swimmer’s itch (cercarial dermatitis) is caused by exposure to schistosome cercariae (larva) entering the skin. The presence of this parasitic larva causes an uncomfortable immune response, itching, and blisters. The intended hosts of the parasite are birds, which are required for the parasites to complete their lifecycle and reproduce. Snails are the intermediate host of the parasite and are also required for their lifecycle. Preventing waterfowl from frequenting an area intended for swimming can help reduce parasite numbers (Kolářová et al. 2013). This can be accomplished by informing people not to feed them with signage and the implementation of other means designed to deter the birds, such as placing dog silhouettes on beaches.

Controlling snail populations can help reduce the prevalence of the parasite. Removal of vegetation preferred by snails around swimming areas can reduce their abundance. Vegetation removal can be accomplished mechanically (by hand) or through the controlled use of herbicides. Snails may also be controlled chemically (pesticides) in some cases (Kolářová et al. 2013), but that method harbors the same ecological risks. Use of any pesticides within the Adirondack Park requires close collaboration with and authorization by the APA and NYSDEC.

Management Alternative 2.1.2 Avoid parasite habitat or effects

Infections of cercarial dermatitis can be avoided or reduced by adopting habits to limit exposure. Snails are more abundant in shallow weedy waters than in deeper water. Spending shorter amounts of time in areas of the lake more likely to harbor the parasite (near shore) and recreating in open water can reduce infection rates and intensity which are directly correlated with exposure time (Kolářová et al. 2013). Other means of reducing the risk of swimmer's itch include rinsing off after leaving the water, avoiding infected waters, and posting signage informing people of risks (CDC 2021).

Goal 3. Road maintenance and drainage

Objective 3.1 Ensure roadways are not negatively impacting Piseco Lake

Management Alternative 3.1.1 Review roadways and road maintenance plans and recommend necessary changes

Roads often make up most of the impervious surfaces in undeveloped watersheds. Designed to prioritize public safety rather than environmental quality, roads and their accompanying drainage structures and ditches increase surface runoff. Road development also leads to the removal of plants, aiding in erosion and pollutant transfer. Roadside ditches should be designed to reduce sediment transfer without reducing their functionality. When maintained with rocks or vegetation rather than bare soil, roadside ditches are less likely to susceptible to erosion. Roadside runoff should not flow directly to streams but towards depressions in the landscape to aid in soil infiltration. Piseco Lake stakeholders should review roadways within the watershed and coordinate with the Town of Arietta if any modifications could be beneficial.

The use of deicers, particularly sodium chloride, on roadways can have negative effects on the watershed. Impacts of road salts on the environment include increasing salinity of ground water and surface runoff, degrading soils, and enervating plants (Kelting and Laxson 2010). The latter two of those effects contribute to sedimentation and pollutant transport. With road salts considered one of the main pollutants in the Adirondacks, Piseco Lake stakeholders expressed concerns of its effect on the waterbody. A conductivity sweep of Piseco Lake was conducted in 2020 by the HCSWCD, finding nothing concerning or unusual (Parslow 2020). Conductivity in many Adirondack lakes has increased over time, and increased ion levels have been associated with use of road salts in the region. These concentrations are slightly higher in Piseco Lake than some other lakes in proximity based on HCSWCD data. The average levels of chloride ions in Piseco Lake pose no immediate threat to biological organisms and would need to increase by orders of magnitude before presenting any acute lake-wide influence on even the most sensitive aquatic organisms. There is, however, potential for less obvious impacts on regional soils, plants, and wildlife although much of the research surrounding these impacts is ongoing. For more information, the AWI prepared an extensive review of the effects of road salt in the Adirondacks complete with road management recommendations (https://www.adkwatershed.org/sites/default/files/road_salt-_final_dlk.pdf).

Goal 4. Fisheries management

Objective 4.1 Improve the fishery

Management Alternative 4.1.1 Encourage angler use, data collection, and participation

Fish are an important part of lake ecology, with the apex predators, such as lake trout, correlated with both zooplankton and algal biomass through food chain interactions. A change in the quality of a fishery could be indicative of an ecological disturbance in the lake. Coldwater Adirondack lakes offer unique fishing opportunities that should be preserved. The Piseco Lake fishery is lacking in data.

Preservation and improvement of a fishery has similar goals as lake water quality improvement. The Federal Sportfish Restoration Fund created in 1950 established excise taxes on fishing equipment designated to be spent on improving and maintaining fisheries resources. New York State uses those monies to fund habitat restoration, fisheries research, aquatic education, and fishing and boating access maintenance (NYSDEC 2021). Supporting fisheries can aid in watershed management and help produce valuable allies for lake stakeholder goals. Piseco Lake stakeholders should welcome angler input and encourage the use of the fishery. A popular fishery can help improve the local economy and is more likely to acquire government resources associated with lake preservation and data collection.

Goal 5. Identify and prevent future problems

Objective 5.1 Understand management concerns

Management Alternative 5.1.1 Communicate with and educate stakeholders

Lake management is a community effort that relies on forces of local governments, organizations, and individuals. Education and communication are the most effect means of making sure that every interested party can understand and express their lake management goals. The state already has environmentally focused mandates that can prove beneficial to Piseco Lake, but people directly interacting with the lake are able to provide better insight into management gaps. Lake associations are very focused local institutions capable of tackling specific issues through informal and collaborative strategies (Snell et al. 2013). The Piseco Lake Association (PLA) has been exploring several means of educating and engaging with the community, reaching out to residents of the Town of Arietta. Focusing on community involvement and acquiring input from stakeholders of all kinds allows lake associations to acquire more intimate knowledge of concerns and develop better management strategies. Piseco Lake has a lot of seasonal users, from seasonal homeowners to summer campers. Seasonal users may have different expectations of the lake than the permanent residents. High numbers of seasonal lake users can engage in activities that directly affect the watershed over a short time period. Explicitly conveying the consequences of poor practices in and around the lake, such as potential excessive weed growth, can help personalize the need for better practices among seasonal lake users. The PLA has supported the implementation of a boat steward program through ongoing partnerships and have had signs printed and posted at lake access points directing lake users to decontaminate their watercrafts. Proactively communicating with seasonal lake users can help reduce future conflicts and maintain water quality. It is important for lake associations to establish a friendly rapport with their community because the success of their actions may ultimately rely on the efforts and funding from multiple stakeholders.

Objective 5.2 Continued monitoring

Management Alternative 5.1.1 Continue current data collection

Piseco Lake currently has 27 years of historical limnological data collected by the HCSWCD, complete with established water quality trends through time. Limnological monitoring should be continued as this dataset is invaluable for all the lakes stakeholders. The Piseco Lake plant identification guide produced by David L. Moore provides extensive qualitative data on plants in and around the waterbody.

Management Alternative 5.1.1 Explore additional monitoring opportunities

Biological monitoring

Despite the wealth of data available for Piseco Lake, biological information about taxa other than plants is missing or lacking. Very little fisheries data are available for the lake, and it would benefit from more studies. Stakeholders can request more frequent surveys from the NYSDEC, but should keep in mind that the organization covers a vast amount of waterbodies and is resource limited, prioritizing popular sportfishing destinations. Communication with the NYSDEC and academic institutions to explore research topics associated with Piseco Lake can lead to fisheries data collection. Defining a specific project such as the production of a fish and invertebrate catalog similar to the plant identification guide produced by David L. Moore can help facilitate the involvement of academic institutions. Zooplankton data are limited to a single sample and zooplankton sampling should be conducted alongside limnological data collection to establish a long-term dataset, especially with the presence of the invasive spiny water flea. Volunteers or the HCSWCD can establish routine zooplankton sampling to estimate the relative abundance of zooplankton species as a complement to water quality data.

Characterize watershed inputs

Piseco Lake watershed input data collection could be a complicated but insightful investment, such as estimating the amount of external phosphorus loading. Stakeholders can request metadata, such as number of individuals per season, regarding the use of the state campgrounds on Piseco Lake to provide insights on potential nutrient additions. Voluntary surveys of seasonal residents can help quantify the usage of seasonal homes around the lake and estimate nutrient contributions.

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