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Ecology and Condition of South Twin Lake,

Town of Livingston, Columbia County, New York

Report to the Twin Lakes Association

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Introduction

Lakes and ponds are important as scenery and for their recreational amenities; they also make important contributions to biological diversity. These water bodies often develop populations of higher plants or algae that compromise their recreational and scenic values, and both natural factors and human activities can contribute to this condition. Understanding the water quality and the kinds of organisms living in a lake allows an assessment of lake condition and potential management actions.

At the request of the Twin Lakes Association, Hudsonia and Bard College performed a water quality and biodiversity assessment of South Twin Lake (Town of Livingston, Columbia County, New York). This assessment was predicated on lake owners' concerns about aquatic weeds (higher plants) and algae in the lake. The assessment also intended to compare 2019 conditions with water quality data collected for the Twin Lakes Association two decades ago. Hudsonia is a non-advocacy, nonprofit, ecological research and education institute sharing space with Bard College in Annandale, New York. We conduct studies, often in partnership with other organizations, make observations and collect data, and make recommendations about reducing and solving environmental problems. The study of South Twin Lake was conducted in collaboration with the Bard College Environmental and Urban Studies Program.

Study Area

South Twin Lake has a surface area of approximately 32 acres. The lake is bordered by woodland on the northeast and southwest, with facilities of a summer children's camp on the southeast and south, and a hillside subdivision on the west and northwest. More than 20 subdivision homes are directly on the lakeshore. According to the New York State Geologic Map (Fisher et al. 1970), most of the lake is bordered, and probably underlain, by a bedrock formation called Taconic Mélange, comprising variable mixtures of graywacke (carbonaceous sandstone), shale, quartzite, chert, limestone, and other rocks, not necessarily all present at South Twin Lake (see Fisher and Warthin 1976). A second bedrock formation, Stuyvesant Falls, comprising shale and siltstone, adjoins the southeastern portion of the lake. Soils surrounding South Twin Lake are mentioned below.

Columbia County Route 19 runs between South Twin Lake and, to the north, the approximately 28 acre North Twin Lake; the two lakes are about 690 feet apart. North Twin Lake is at an elevation of 266 feet above sea level (above the Hudson River estuary), and South Twin Lake is at elevation 263 feet. The Roeliff Jansen Kill (or "Ro-Jan") winds east to west about one-half mile south of South Twin Lake. There are no obvious surface water connections between the two Twin Lakes. There is a culverted outlet at the south end of South Twin Lake that only flows when the lake level is high; we only observed flow during winter sampling. Possibly there is also subsurface flow from South Twin Lake to the Ro-Jan along a fault between the two bedrock formations depicted in Fisher et al. (1970).

Methods

We identified plants by observation in the field as much as possible. Specimens of difficult-to-identify species, including most of the submergent species, were pressed and identified in the laboratory. Fishes were observed by angling along most of the shoreline. Water transparency was measured with a Secchi disk. Conductivity and temperature were measured with a YSI Pro 2030 multiprobe to a maximum depth of 4 meters (13 feet). Water samples were collected for the top 0.5 m (1.6 feet) with a depth-integrated sampler. Bacterial testing was carried out on 30 October 2018 using the IDEXX Quanti-Tray system. Water quality indicators (chlorophyll a and optical brightener fluorescence) were measured with a Turner

*Aqua*Fluor handheld fluorometer. Water samples from 3 April 2019 were titrated with sulfuric acid using bromocresol green for alkalinity, and with silver nitrate and potassium chromate for chloride. Other ions (sodium, calcium, potassium, and magnesium) were measured with inductively coupled plasma mass spectrometry.

Results

Water chemistry and clarity

Basic water chemistry parameters measured in 1986 and 1995 and reported in Grim (1995) were re-sampled and are shown in Table 1. The lake is basic and alkaline, as expected from the bedrock. Of note is the near tripling of conductivity (a measure of dissolved salts in the water) since the mid-90s. This finding is consistent with regional trends in freshwater salinization discussed below. Transparency, as measured with a Secchi disk, was 5 ± 1 m (about 16.4 feet).

Parameter	**1986**	**1995**	**2019**
pH	9	8	8.1
Alkalinity (mg/L)	68	33	93
Conductivity (µS/L)	138	140	427

Table 1. Water quality parameters measured by Grim in 1986 and 1995 compared to current conditions.

Plants

A list of the plants we identified is shown below. We focused on the submergent species which are the “weeds” of concern in many residential lakes (these species are bolded in the list). Many of the aquatic plants found in South Twin Lake are generally associated with alkaline conditions, including waterweed (*Elodea canadensis*), curly pondweed (*Potamogeton crispus*), leafy pondweed (*Potamogeton foliosus*), Illinois pondweed (*Potamogeton illinoensis*), and flat-stemmed pondweed (*Potamogeton zosteriformis*) (Crow and Hellquist, 2000; Heegaard et al., 2001; Capers et al., 2010). Illinois pondweed and curly pondweed are also associated with high conductivity, while leafy pondweed has been found associated with smaller, eutrophic lakes (Capers at al., 2010). These habitat affinities accord with water quality in South Twin Lake (see below).

Algae

Surface scums of filamentous green algae were observed in the late summer and fall in shallow regions of the lake, particularly the northeastern (predominantly downwind) end of the lake. Water samples collected on 30 October 2018 and 3 February 2019 from the middle of the lake were run through the FlowCam at the Bard Water Lab to generate an image archive of the microorganisms present in the lake water. Complete analysis of this archive, which contains hundreds of images, is beyond the scope of this report. However, the occurrence of potentially-toxin producing cyanobacteria (*Anabaena* spp.) was noted in the images from South Twin Lake. The implications of this are discussed further in the Eutrophication section below.

List of plants identified in South Twin Lake. We consider this list representative but it is not a complete list.

Scientific name	**Common name**	**Notes**
Acer rubrum	Red maple	
Berberis thunbergii	Japanese barberry	
Betula populifolia	Gray birch	
Callitriche	Water starwort	
Carex stricta	Tussock sedge	Specimen
Ceratophyllum demersum	Common coontail	
Cornus amomum	Silky dogwood	
Cornus racemosa	Gray dogwood	
Elodea canadensis	Common waterweed	Specimen
Epilobium	Willow-herb	
Ilex verticillata	Winterberry	
Impatiens capensis	Orange jewelweed	
Juncus effusus	Soft rush	
Lythrum salicaria	Purple loosestrife	
Mimulus ringens	Common monkeyflower	Specimen
Mitchella repens	Partridgeberry	
Nyssa sylvatica	Tupelo	
Onoclea sensibilis	Sensitive fern	
Parthenocissus	Virginia creeper	
Pinus rigida	Pitch pine	One seen
Pinus strobus	White pine	On slope
Potamogeton crispus	Curly pondweed	
Potamogeton foliosus	Leafy pondweed	Specimen
Potamogeton illinoensis	Illinois pondweed	Specimen
Potamogeton pusillus	Small pondweed	Specimen
Potamogeton zosteriformis	Flat-stemmed pondweed	Specimen
Quercus rubra	Red oak	
Rhus typhina	Staghorn sumac	
Salix	Willow	Tree
Sassafras albidum	Sassafras	
Scirpus cyperinus	Wool-grass	
Spiraea japonica	Japanese spiraea	
Thelypteris palustris	Marsh fern	
Typha	Cattail	Southeast
Viburnum lentago	Nannyberry	
Vitis	Wild grape	

Fish

Fish biologist Robert E. Schmidt accompanied Erik Kiviat on a canoe circuit around the shoreline of South Twin Lake on 3 September 2018, although this was not part of the original scope of work. Bob wrote the following note about his observations:

“I saw bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) on our tour of the lake. Additionally we were told that brown trout (*Salmo trutta*) were being stocked and chain pickerel (*Esox niger*) were caught in the lake. Of these fishes, only the chain pickerel is native. Additionally we were told that alewife (*Alosa pseudoharengus*) are present in the lake. We did not see them ourselves, but were on the lake in daylight when alewife are hiding. These landlocked herring can enhance the growth of predatory fishes but there is a risk having [alewife] in a lake. In large numbers, alewife can eat up the zooplankton and cause a "trophic cascade." With low zooplankton numbers [the plankton algae are not controlled, and the] algae can bloom. The lake owners should keep track of the alewife population and try to maintain a high density of predatory fishes.” (Bob added that the main predators are largemouth bass and chain pickerel, and these species will maintain themselves. Brown trout are being stocked and cannot reproduce in the lake; this stocking can continue.)

Water quality and algae

From the limited data available, we find South Twin Lake is in “good” condition, with moderately high water clarity and moderately diverse submergent vegetation. We recommend the Twin Lakes Association give further consideration to two water quality issues, eutrophication and salinization, that are common in this region and likely to impair South Twin Lake eventually if management interventions are not taken.

Eutrophication

Eutrophication, the nutrient enrichment and “greening” of lakes, is a widespread problem. This greening results from the overgrowth of algae, microscopic organisms that usually form the base of food webs in lakes. Just like crops, algae can be fertilized by additions of nitrogen and phosphorus, transforming a lake from a blue to green trophic state (Figure 1). While it is natural for some lakes to become greener over long time periods, human activities that add nitrogen and phosphorus (collectively called nutrients) are accelerating eutrophication in lakes worldwide. Sources of nutrients in lakes include fertilizers used in agriculture and lawn care, animal waste, and sewage. In the United States, half of all lakes are currently defined as eutrophic of which 20% are considered hypereutrophic (USEPA, 2016).

Increasing algae growth causes a variety of problems in a lake. Low oxygen conditions can result when algae die and decompose, harming the biological community and in some cases causing fish kills. Excessive algae growth also makes a lake an unappealing place for swimming or boating. Of particular concern is the occurrence of harmful blooms of cyanobacteria (bluegreen “algae”) that can produce toxins that can affect the skin, liver and nervous system (Bláha et al, 2009). Harmful algae blooms associated with eutrophication cause economic losses up to $1 billion a year due to lost recreational opportunities and possibly another $1 billion in decreased property values (Dodds et al., 2009). Harmful algae blooms are a growing problem in New York State, where they increasingly cause beach closings and disrupt drinking water sources (NYSDEC, 2019 https://www.dec.ny.gov/chemical/69489.html). Eutrophication can also cause loss of species of plants and animals that are adapted to low nutrient levels.

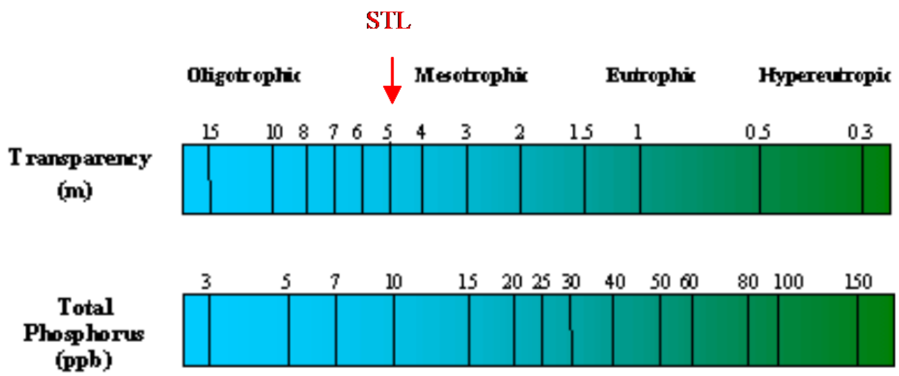

Figure 1. Trophic status is used to describe lakes on a gradient from oligotrophic "blue" to hypereutrophic "green." South Twin Lake (STL) transparency (measured with Secchi disk) ranged between 4 and 5 m (13 and 16 feet) suggesting the lake is approaching the transition from oligotrophic to mesotrophic. Spring total phosphorus measurements (pending laboratory analysis) will provide a second indication of lake trophic status. The Lake Trophic Status Index graphic is adapted from *Lake Access*, a lake education website (*http://www.lakeaccess.org*).

South Twin Lake is showing early signs of eutrophication. This study began because of concerns about algal surface scums on the lake, and submergent weed beds in the shallows, that interfere with recreational activities. Visiting the lake in September, we observed overgrowth of filamentous green algae, mainly at the shallow northeastern end of the lake. The algae were primarily attached to submergent aquatic plants and the algae were dense enough to form a surface scum. Filamentous algae in South Twin Lake seem to be a long-standing problem. In 1995, Grim observed filamentous algae earlier in the summer, but not in September as we observed in 2018. Last fall, the algae persisted well into October, probably due to warmer fall temperatures.

To get an approximation of the amount of algae in the middle of the lake, we measured the abundance of chlorophyll a (a pigment used in photosynthesis that gives algae and other plants their green color). As shown in Figure 2, algae biomass spiked during the winter when the lake was iced over. Normally, algae abundance is highest in the spring and summer and lower under the ice because of cold temperatures and other factors (Bertilsson et al., 2013). The algae bloom under the ice indicates nutrients are being mixed upward from the bottom of the lake through a process called internal loading. This occurs because some of the nutrients added to the lake sink to the bottom and accumulate over time. As the lake cools during the fall and winter, the water mixes deeply bringing a portion of those nutrients back to the surface where they can feed an algae bloom. The occurrence of an algae bloom under the ice indicates that nutrients are building up in the lake. Surface water samples from South Twin Lake collected in spring 2019 have been sent to a lab for nitrogen and phosphorus analysis (at Bard's expense) and results are expected soon.

South Twin Lake is over 80 feet deep in some areas. This depth has allowed it to absorb nutrients over the decades with little change in water quality at the surface of the lake. Once nutrients get into a lake, they tend to accumulate there. This is especially true for South Twin Lake because it has a very small outlet which only runs when the lake level is high. As nutrients build up over time, there will come a point where the visual character of the lake changes and algae blooms dominate rather than the submergent plants currently present. Figure 1 shows the trophic gradient from clear or "blue" "oligotrophic" lakes to algae dominated "green" "eutrophic" lakes. South Twin Lake is still on the blue end of this scale, but is likely getting greener based on the description given in the Grim report. Once a lake becomes algae dominated, it is very difficult and expensive to reverse. Minimizing nutrient inputs into the lake is key to maintaining a blue lake.

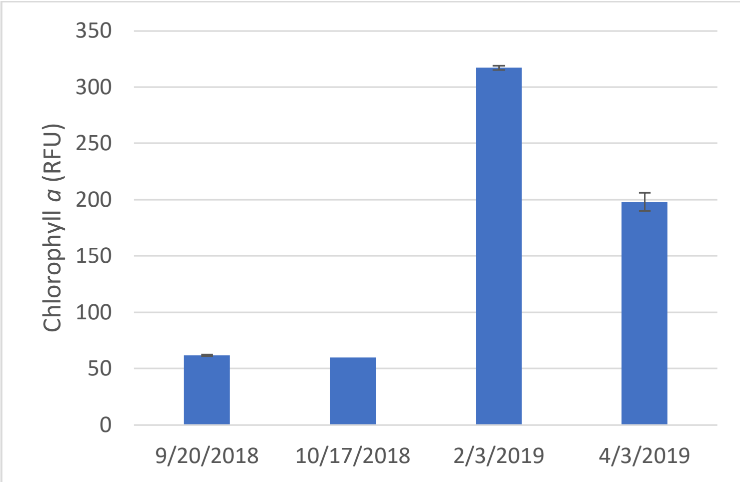

Figure 2. Chlorophyll a fluorescence measurements from fall 2018 through spring 2019. Chlorophyll a was measured from samples taken at the surface in the middle of the lake. The values are averages of three measurements from each water sample, except for the 17 October 2018 sample from which a single measurement was made. Error bars represent standard deviation. Note that summer water samples were not collected.

For South Twin Lake, septic systems are likely a source of nutrients. The houses along Shore Drive and in the surrounding neighborhood are close together, and some are close to the lake, so their septic systems may not have enough space for the leach fields to work properly. In addition, some of the soil types around the lake are not ideal for septic systems. Specifically, the soil type marked NbC in Figure 3 (see caption for description) is not ideal because of a shallow depth to bedrock and restricted permeability (Soil Survey Staff, no date). Septic systems in that soil type may require a lot of maintenance and they may not work well (Soil Survey Staff, no date). The steepness of the land along the shoreline may further "short circuit" septic systems. To look for evidence of leaking septic systems, we measured the presence of optical brighteners (OBs) around the lake (Dubber and Gill, 2017; Tavares et al., 2008). OBs are compounds found in many laundry detergents and other personal care products that are used to indicate human water use. OB measurements from around the shoreline of the lake are shown in Figure 4. The south end of the lake had higher values than other parts of the lake, although the differences were small. The results suggest some generalized impact of leaky septic systems, but no particular hotspot was found with the shoreline survey on 17 October 2018.

In addition to OBs, we also tested for bacteria that indicate contamination from human waste (Figure 4; Table 2). Samples taken on 30 October 2018 showed that most areas of the lake had low levels of these bacteria, below the detection limit in most cases. Fecal bacteria were detected, but not at alarming levels, at the downwind (northeast) end of the lake as well as the higher use areas at the community beach and the camp. The embayment by the camp had detectable levels of all three kinds of bacteria tested. OBs were also higher there, suggesting that might be a problem area worth monitoring further, especially in the summer when bacteria grow faster and there is more use of the lake.

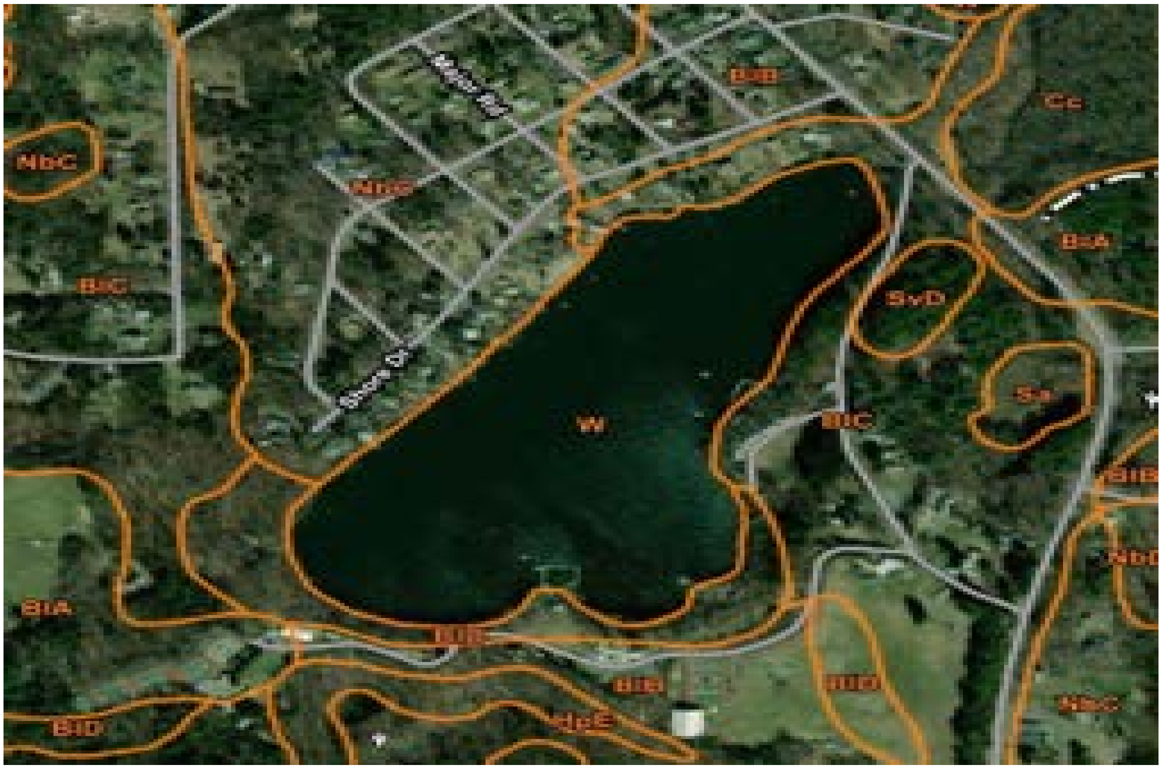

Figure 3. Locations of different soils around South Twin Lake. The unit marked NbC (Nassau channery silt loam, rolling, very rocky) is not well suited for septic systems. As the map shows, many houses are located on this soil type and their septic systems may not function well. The unit marked BiC (Blasdell channery loam, rolling) is also not ideal for septic systems. This figure is taken from the Web Soil Survey which is provided by the Natural Resources Conservation Service of the United States Department of Agriculture. North is at the top of the map; the horizontal dimension is exaggerated.

Figure 4. Optical brightener measurements (RFU) for each area of the lake. The numbers around the perimeter of the lake are averages of a number of measurements that were taken along that stretch of the shoreline. The value for the middle of the lake is a single measurement. The difference between the lowest value along the forested edge on the top left of the map, 10.8 RFU, and the embayment at 13.9 is equivalent to almost 1 ppm (part per million) of Tide detergent based on a serial addition experiment with lake water (results not shown). Northeast is at the left of the map.

Figure 5. Sites where IDEXX bacteria testing was done on 30 October 2018. Northeast is at the left.

Once in the lake, fertilizing nutrients can be retained and recycled from the bottom back to the surface where they can once again stimulate algae growth that in turn dies, sinks to the bottom and is decomposed back into nutrients. Without a continuously flowing outlet, nutrient retention and recycling in South Twin Lake is likely high. The lake association should consider approaches for removing nutrients from the lake to counteract the long-term nutrient loading that occurs in all lakes with human activities.

One approach is to encourage the growth of rooted plants which remove some nutrients by locking them into their biomass; harvesting (removing) biomass then removes nutrients. Greater biomass of submergent plants might be undesirable because of their effects on swimming, boating, and fishing. However, the installation and proper maintenance of floating marsh modules could be considered. There are many kinds of floating treatment wetlands (e.g., Headley and Tanner 2008; Reinsel 2012; Wang et al., 2015), and this method of removing nutrients might be adapted to South Twin Lake. Removal of submergent plants by frequent raking in selected areas, as practiced by at least one South Twin Lake landowner, makes a modest contribution to nutrient removal. Removing or killing submergent plants lake-wide would not be desirable, however, because moderate amounts of these plants help maintain water quality by taking up nutrients that will otherwise go to algae and provide habitat for fish, turtles, and other animals. Another option would be to develop a wetland with emergent plants such as cattails in the northeast end of the lake where algae scum is concentrated. That area is already very shallow and has an accumulation of organic matter on the bottom at least 1 m (3.3 feet) deep. Aesthetic improvement and nutrient removal can be achieved through rooted or floating wetland plantings.

Recommendations to reduce eutrophication: To maintain the good water quality of South Twin Lake, it is important for all septic systems around the lake to be well maintained and routinely pumped. Keeping septic systems in working order will help prevent more nutrients from entering the lake. Maintaining a vegetated shoreline buffer wherever possible is also important for capturing nutrients, sediment, and other pollutants prior to entering the lake (Borre et al. 2016). Guidance and support mechanisms for planting shoreline buffers are available at the New York State Department of Environmental Conservation (https://www.dec.ny.gov/chemical/106345.html). Ultimately, a central sewage treatment plant with nutrient removal may be necessary; however, this would be expensive and potentially would promote additional land use development.

Location	Total Coliform (colonies / 100 mL)	E. coli (colonies / 100 mL)	Enterococcus (colonies / 100 mL)
1	< 10	< 10	No data
2	40	< 10	< 1
3	202	97	2.0
4	< 10	< 10	<1
5	< 10	< 10	< 1
6	96	< 10	1.0
7	144	10	< 1
8	43	< 10	< 1

Table 2. Results of IDEXX bacterial testing from 30 October 2018. See Figure 4 for sampling locations. For comparison, New York State guidelines specify that acceptable levels for bathing beaches are not to exceed 235 *E. coli* per 100 mL and 61 enterococci per 100 mL from a single sample (NYS Department of Health https://www.health.ny.gov/regulations/nycrr/title_10/part_6/subpart_6-2.htm). There is no single sample standard for total coliforms.

Salinization

Over 15-30 million metric tons of de-icing salt are applied to roads each year in the U.S (Kelly et al. 2019). In New York, over 800,000 tons are applied to state highways alone. Wherever road salt is used, lakes and streams are becoming saltier. Salt concentrations are especially high near roads or in urban and suburban areas (Findlay and Kelly, 2011). In the Hudson Valley, increasing salt concentrations have been shown, for example, with long-term monitoring of the Fishkill Creek and Wappinger Creek (Findlay and Kelly, 2011). In South Twin Lake, we found several indications of increasing salinity. Conductivity is a measure of all the ions (atoms or groups of atoms that carry an electric charge) in water. Lakes and rivers have natural variation in these ions due to difference in bedrock weathering and other factors that result in variation in conductivity. However, road salt application is causing increases in conductivity over natural levels in surface waters and groundwaters near roads across the northern region. In South Twin Lake, conductivity was 146 µS/L in the middle of the lake in 1995 and almost tripled to 410 µS/L by 2018 (Figure 6). Both measurements were made around 1 September, prior to seasonal salt application, and in the middle of the lake. This is a significant increase.

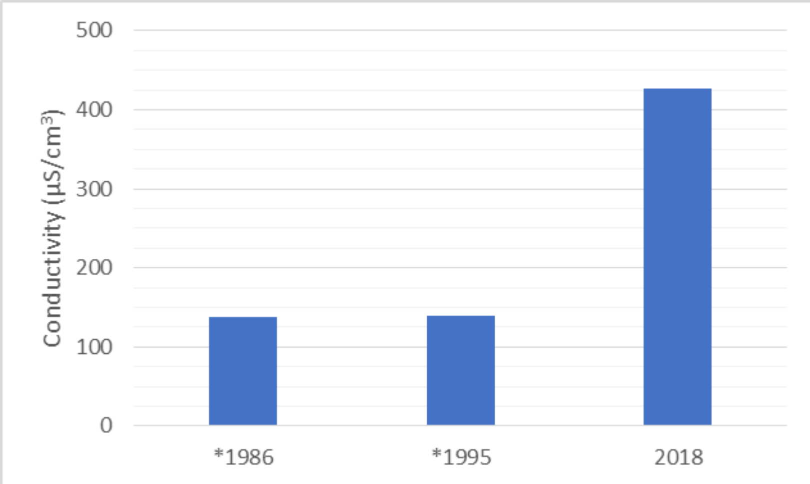

Figure 6. Surface conductivity in South Twin Lake in 1986, 1995, and 2018. The values for 1986 and 1995 (marked *) are from Grim (1995). Conductivity was measured on 1 September in 1995, and on 3 September in 2018. In 2018 conductivity was much higher than previously.

To compare across seasons, temperature-corrected specific conductance was determined from follow up measurements of temperature and conductivity taken from September 2018 – April 2019 (Figure 7). It remained above 400 µS/cm, rising slightly during the winter and spring when road salt runoff is entering the lake.

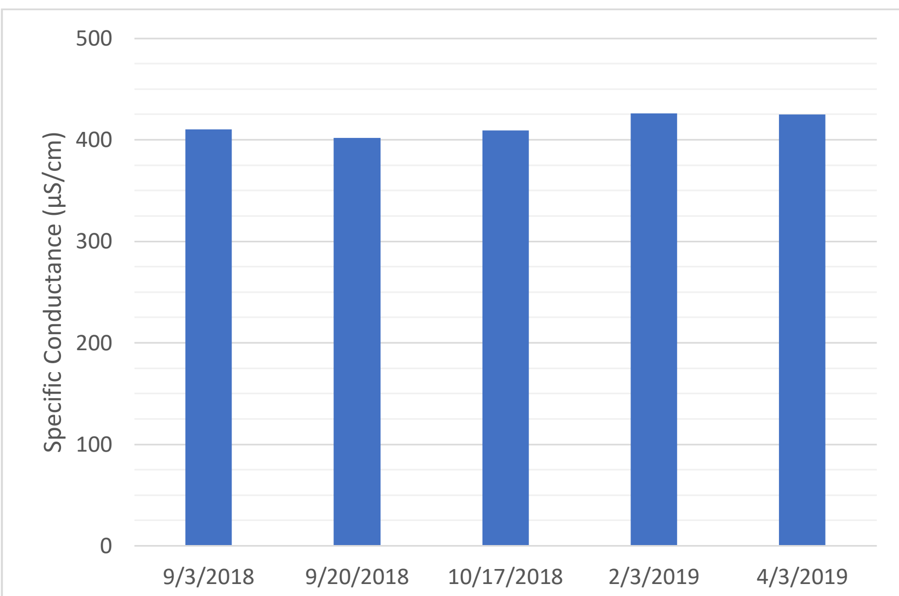

Figure 7. Specific conductance at South Twin Lake over the year.

We expect much of the observed increase in conductivity is due to road salt, sodium chloride (NaCl). We measured chloride concentrations in the middle of the lake and at the northeast end on 3 April 2019 (Figure 8). In the middle of the lake the chloride concentration was 86 (± 9.1) mg/L and in the northeastern end near County Route 19 it was 79 (± 0.69) mg/L. No historical data on chloride in South

Twin Lake exist to our knowledge. However, 80 mg/L is much higher than we would expect. For context, chloride levels ranged from 0.1 to 58.4 mg/L in a 2012 study of 82 Adirondack lakes (Kelting et al. 2012) while annual average chloride levels ranged from 30 to 500 mg/L in 38 lakes in the Minneapolis-St. Paul metropolitan area (Novotny et al. 2008). Although we do not know how South Twin Lake compares to other lakes in this region, the observed 80 mg/L is indicative of road salt impact. Concentrations of some other ions that contribute to conductivity are shown in Table 3. The lake has less sodium than chloride because sodium is retained in the soil and used by biota more than chloride.

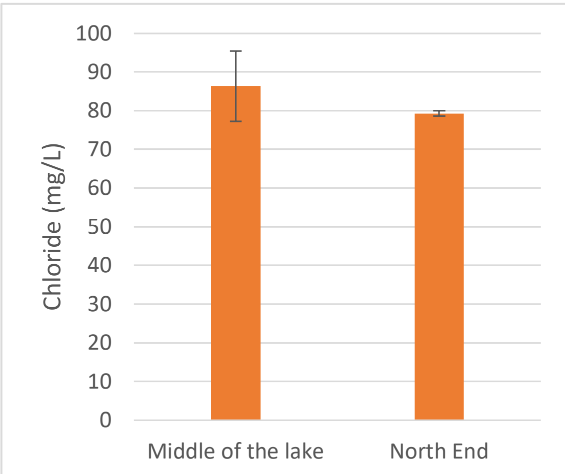

Figure 8. Chloride concentrations at in the middle of the lake and at the northeastern end where the lake approaches County Road 19. Chloride concentrations are an average of three measurements from the same water sample, and error bars represent standard deviation. The Middle and Northeastern values do not differ statistically.

Ion	**Concentration (mg/L)**
Chloride	86 (± 9.1)
Sodium	32.38
Calcium	33.78
Potassium	0.92
Magnesium	5.24

Table 3. Ion concentrations from a sample collected on 3 April 2019. All ions were measured with inductively coupled plasma mass spectrometry, except chloride, which was measured with a titration.

Given road salting practices, we expect the salinity in South Twin Lake to continue to increase. This could affect the ecosystem in a number of ways. Chloride concentrations of about 100 mg/L affect amphibians and higher concentrations have impacts on plants, invertebrates, and even fish (Findlay and Kelly, 2011). Some types of algae are affected by chloride levels much lower than what is already present in South Twin Lake (Findlay and Kelly, 2011). As a result, salinization may already be impacting the algae community, or in other words, how much of what types of algae are present. Some cyanobacteria are especially tolerant of salt, so rising salinity may favor cyanobacteria growth in the lake. The combination of increasing salinity, increasing nutrients, and rising temperatures are favorable conditions for cyanobacteria blooms (Paerl and Otten, 2012). Preventing further additions of salt and nutrients as much as possible is important for preventing harmful algae blooms.

Recommendations to slow salinization: The best way to prevent increasing salt levels is to apply less salt near the lake. Some towns designate sections of roads near sensitive places like lakes or wetlands as no salt or low salt areas. The lake association could pursue such a designation for roads around South Twin Lake. For problematic areas, sand and kitty litter (clay) can be used sparingly instead of salt-based products to provide traction. For further information on de-icing best practices for municipalities and individuals, we recommend *Road salt: The problem, the solution, and how to get there*, a report from the Cary Institute of Ecosystem Studies (Kelly et al., 2019).

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