HOBART & WILLIAM SMITH (HWS) RESEARCH VESSEL TRIP

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INTRODUCTION

The purpose of this cruise aboard the Hobart and William Smith Colleges' 65-ft research vessel the *William Scandling* is to investigate the chloride geochemistry and zebra/quagga mussel distributions in Seneca Lake, and how they relate to water quality and the ecology of the lake, and discuss their implications. Our field trip, i.e., cruise, aboard the *William Scandling*, will focus on water quality measurements and surface sediment samples in the northern part of the lake. We will advance Mike Wing's and Bill Ahrnbrak's understanding for the high chloride concentrations in Seneca Lake in comparison to the other Finger Lakes (Wing et al., 1995; Ahrnsbrak, 1974). Finally, we will discuss the impact zebra and quagga mussels and nutrient loading have had on the ecology of the lake, especially on how it may relate to the recent outbreak of blue green algae blooms and their associated toxins.

The Finger Lakes of central New York State consist of 11 elongated, north-south trending basins just south of Lake Ontario (Fig. 1). The basins were scoured into the northern edge of the Appalachian Plateau by glacial scour and glacial meltwaters under the retreating ice sheet (Coates, 1968, 1974; Mullins and Hinchey, 1989; Mullins et al., 1996). The bedrock underlying Seneca Lake is primarily Devonian shales (Hamilton Group in the northern end of the lake), and lesser amounts of sandstones and carbonates that gently dip to the south-southwest. Silurian carbonates, shales and most importantly evaporites (mostly halite) are found below the Devonian section.

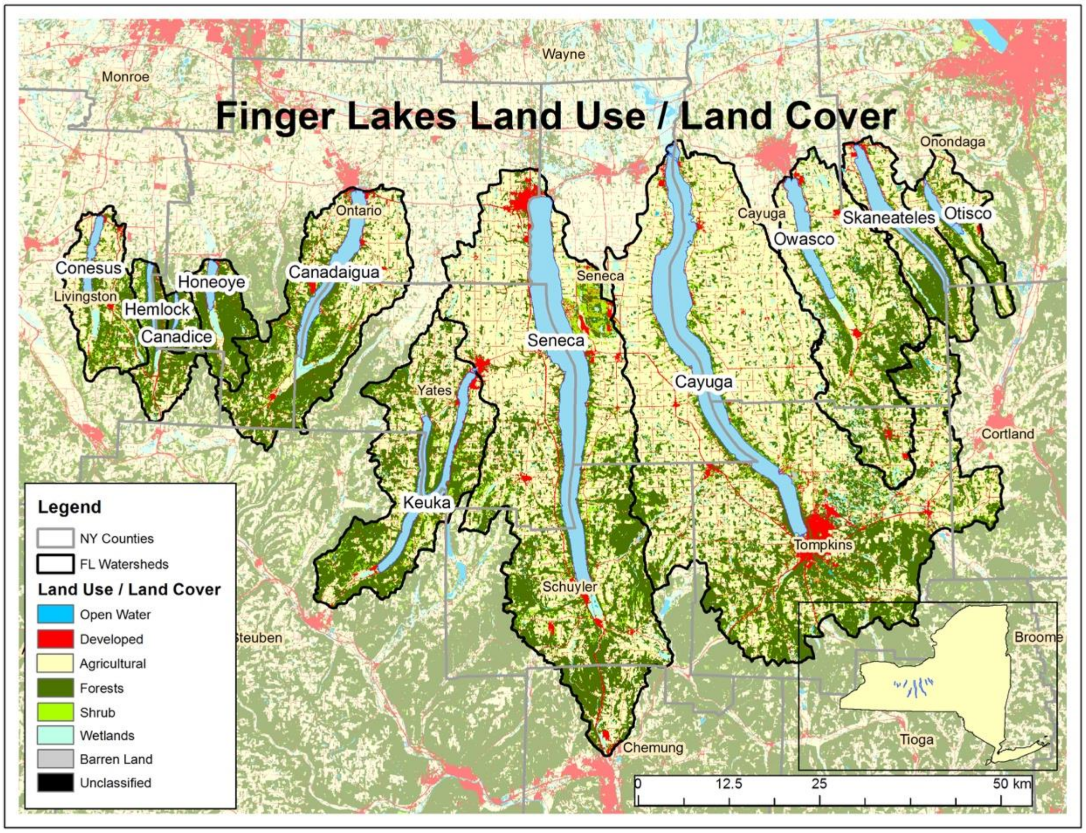


Fig. 1. The Finger Lakes of central and western New York. This fieldtrip explores the chloride chemistry, and the zebra/quagga mussel density in the lake, and the impact of both on the water quality and ecology of Seneca Lake.

Seneca Lake is the largest (by volume) and deepest of the Finger Lakes (Fig. 1, Table 1). Only Cayuga Lake immediately to the east of Seneca is longer (61 km) and almost as deep (132 m). The other basins are smaller, ranging in length from 5 to 32 km and maximum water depth from 9 to 84 m. The present-day lake drains to the north-northeast through the Seneca River (New York State Cayuga-Seneca Barge Canal). Its large volume influences its large residence time of 18 years, 2 to 10 times larger than the smaller neighboring Finger Lakes (Callinan, 2001). Seneca Lake is mesotrophic (moderate productively, sandwiched between oligotrophic and eutrophic systems). Annual mean, surface/bottom water algae and nutrients concentrations using 2018 data are: chlorophyll-a 4.8/0.4 µg/L, Secchi disc depth 3.3 m, total suspended solids 2.0/0.6 mg/L, total phosphate 18.5/13.2 µg/L, soluble reactive phosphate 1.8/2.4 mg/L, nitrate 0.1/0.2 mg/L, and dissolved silica 220/420 µg/L. Algal growth in the lake is phosphorus limited, diatoms occasionally limited by limited silica. The trophic state for Seneca Lake is in between the oligotrophic (low productivity) Skaneateles, Keuka and Canandaigua Lakes, and the eutrophic (high productivity) Honeoye, Conesus and Otisco Lakes. Seneca, unlike its neighbors rarely freezes in the winter. Instead it is a warm monomictic lake that thermally stratifies each May through November and is isothermal and thus overturns, i.e., the entire water column vertically mixes, all winter (Hawley and Halfman, 2018).

Seneca Lake is classified as a Class AA water resource by the New York State Department of Environmental Conservation (NYS DEC), except for a few locations along the mid-eastern shore (http://www.dec.ny.gov/regs/4592.html; Callinan, 2001; Halfman et al., 2012). The lake supplies drinking water to approximately 100,000 people through municipal and private systems. The lake, the rural countryside and internationally known wineries in the watershed drive the tourism industry that provides a major portion of the economy for the region. Thus, water quality of the lake is a concern to many.

Table 1. Seneca Lake Statistics (Bloomfield, 1978)

Length	57 km
Maximum Width	5.2 km
Surface Elevation	136 m above mean sea level
Water Volume	15.54 km^3
Surface Area	175 km^2
Maximum Water Depth	186 m
Water Residence Time	18-20 years

SENECA LAKE CHLORIDE CONCENTRATIONS (AFTER HALFMAN, 2014)

Berg (1963) and Schaffner and Oglesby (1978) noted that chloride concentrations were significantly larger in Seneca Lake, and to a lesser extent in Cayuga Lake, than the other Finger Lakes (Fig. 2). Mass balance, steady state arguments by Wing et al. (1995) indicated that the elevated chloride concentrations required an extra source of chloride beyond the measured fluvial fluxes to the lake. They expanded and substantiated arguments by Berg (1963) and Ahrnsbrak (1974), and hypothesized that the extra source of chloride originated from the Silurian beds of commercial grade rock salt (Halite) some 450 to 600 m below the lake's surface. Measured concentration gradients in the sediment pore waters indicated that chloride diffuses into the lake from the lake floor, perhaps from the Silurian evaporites below. Seismic reflection profiles revealed an extensive thickness of glacial till that filled half of the basin down to the bedrock floor under Seneca Lake. The bedrock floor is deep enough to intersect the Silurian beds of rock salt (Mullins and Hinchey, 1989, and Mullins et al., 1996). The most likely location for this intersection is not well defined, but projected to be located under the northern portion of the lake based on a uniform 1° southerly dip of the bedrock and the depth profile of the basin's bedrock floor. Wing et al. (1995) hypothesized that this connection provided an avenue for brine to migrate from these rock salt beds into these two lakes, and not the other Finger Lakes.

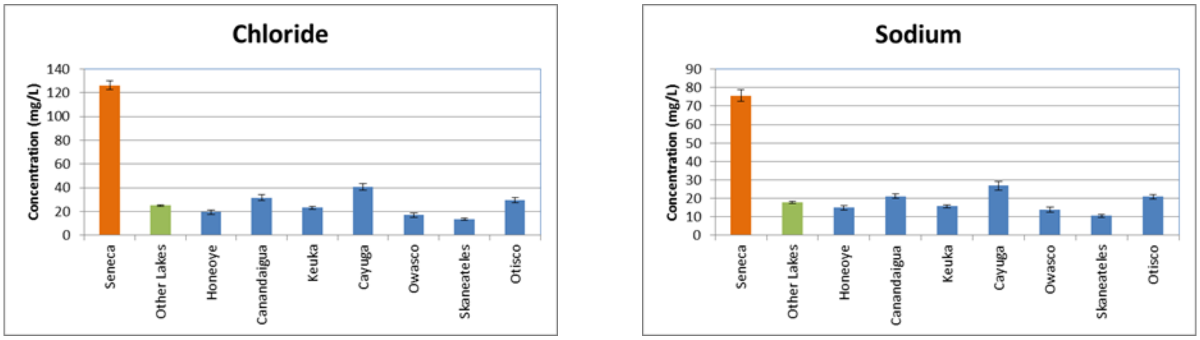


Fig. 2. Mean chloride (left) and sodium (right) concentrations in various Finger Lakes (Halfman, 2014).

Halfman et al. (2006) expanded the salinity investigation of Seneca Lake to include all of the major ions: chloride, sulfate, sodium, potassium, calcium and magnesium (Fig. 2). No horizontal spatial-scale trends in major ion concentrations were observed in the well-mixed lake. Vertically, the epilimnion (surface waters) was slightly less saline than the hypolimnion (bottom water). Mass-balance calculations assuming steady state conditions subdivided the major ions into three populations. Chloride, sodium, and to a lesser extent sulfate, were up to four times greater in the lake than the streams (Cl^- 140 vs. 33 mg/L, Na^+ 80 vs. 20 mg/L, SO_4^{2-} 40 vs. 30 mg/L, respectively). Thus, these ions required another source to attain the concentration detected in the lake. Conversely, calcium and magnesium were more concentrated in the streams than the lake and required a mechanism to remove a portion of these ions from the lake (Ca^{2+} 60 vs. 42 mg/L, Mg^{2+} 17 vs. 11 mg/L, respectively). Finally, the fluvial flux of potassium was at equilibrium with the lake. The mean molar ratio of chloride and sodium for all the analyses was nearly 1:1, suggesting a common Halite (NaCl) source for these two ions. All of these observations were consistent with a substantial groundwater source to explain the elevated concentration detected in the modern lake.

Steady-state conditions are critical, if Seneca Lake is to remain a potable drinking water supply. The EPA's total dissolved salt (TDS) drinking water advisory concentration is 500 mg/L, and 250 mg/L for chloride (EPA 822-S-12-001, 2012). The drinking water advisory concentration for sodium is between 30 and 60 mg/L, and the threshold is lowered to 20 mg/L for those on low-salt diets (<500 mg/day) and newborn infants (EPA 822-R-03-006, 2003). NYS DEC regulations use the 250 mg/L limit for chloride and 20 mg/L for sodium as drinking water guidelines (http://www.dec.ny.gov/regs/4590.html). Thus, any increase in the current chloride (122/128 mg/L, surface/bottom) and/or sodium concentrations (75/79 mg/L) for the lake would be a concern, as sodium already exceeds its 20 mg/L drinking advisory limit. Here, we borrow heavily from Halfman (2014) to update the major ion hydrogeochemistry of Seneca Lake focusing on the conductivity (salinity) and historical chloride data collected since the earlier publications.

Salinity profiles and chloride data collected over the past two decades refute the steady state conditions (Halfman 2014). Sea-Bird SBE-25 conductivity (salinity), temperature and depth (CTD) profiles collected weekly from April through November each year since the early 1990s revealed a systematic seasonal decrease in epilimnetic (surface water) salinities by approximately 50 µS/cm (~20 mg/L) each year during the stratified summer seasons. Fig. 3 plots CTD profiles from 2018, a typical year. During each year, uniform concentrations with water depth are detected during the isothermal spring. With the onset of thermal stratification, the epilimnion salinity decreased through the summer season. This concentration difference would dissipate during the breakdown of the thermal stratification to isothermal conditions in the fall. The epilimnetic decrease in salinity during summer stratification is interpreted to reflect the dilution of the epilimnion by less saline rainfall and surface runoff. The seasonal decrease is consistent with adding ~50 cm of rain to the lake. Subsequent mixing due to the late fall through early spring overturn yields a salinity somewhere between the end of summer epilimnion and hypolimnion concentrations (Fig. 4). It is proportionally closer to the hypolimnion salinity because the hypolimnion is approximately twice as large as the typical epilimnion (~10 vs 5 km^3, respectively).

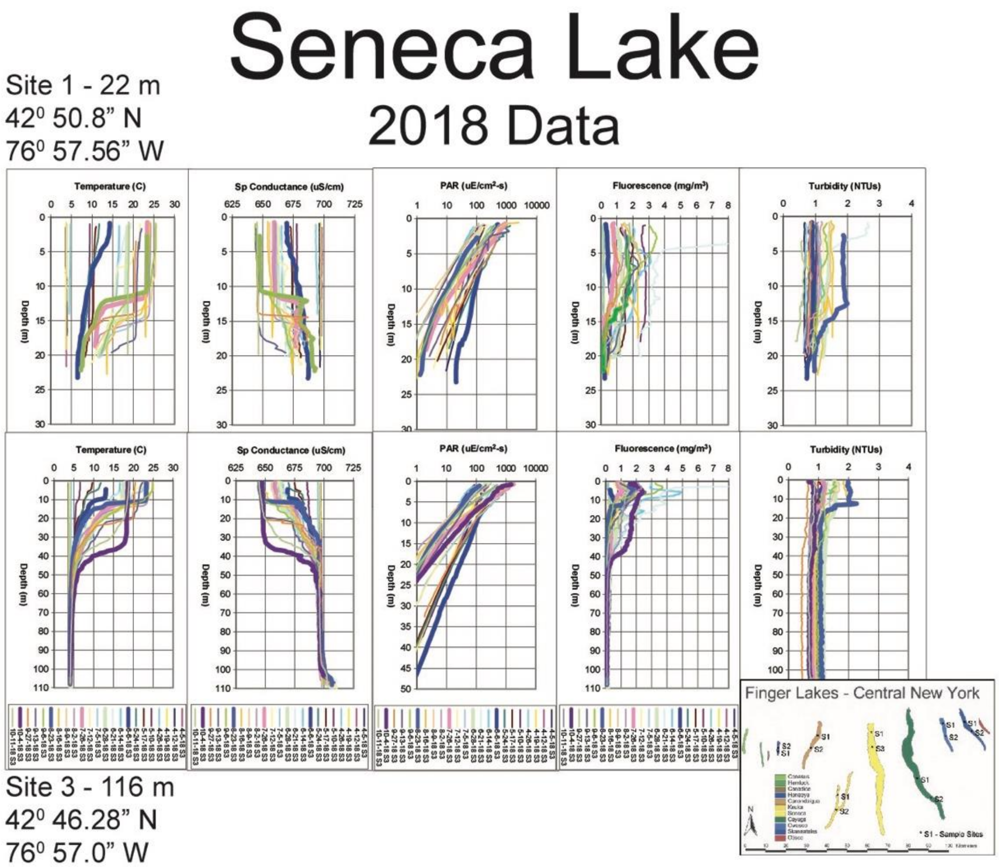
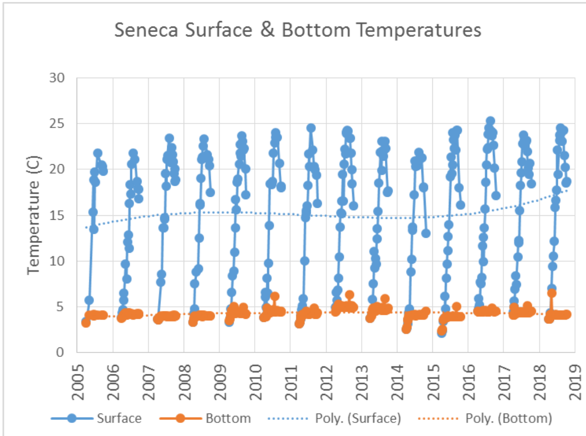


Fig. 3. Weekly CTD profiles from two sites in Seneca Lake collected during 2018. Note the decreasing epilimnetic salinities and nearly constant hypolimnetic salinities through the stratified summer season.

In contrast, the CTD profiles did not reveal a significant increase in salinity in the hypolimnion (bottom waters) of the lake during the summer stratified period (Figs. 3 & 4). A significant increase would be expected if the sediments provided a substantial flux of salt to the lake. Its absence indicates that a lake floor source for the chloride has not been substantial over the past two decades. Thus, the observed multiyear epilimnetic decrease and hypolimnetic uniformity is counter to a significant source of salts from the lake floor.



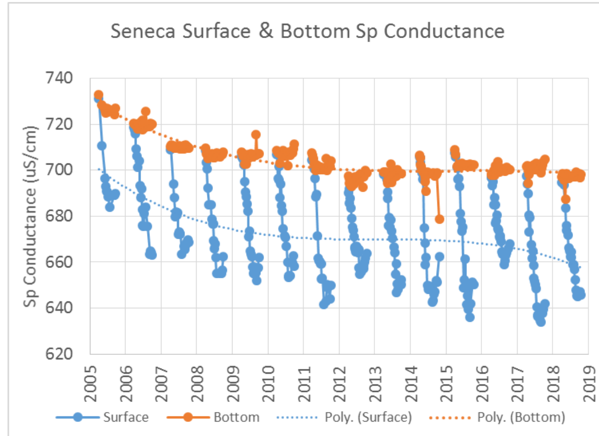
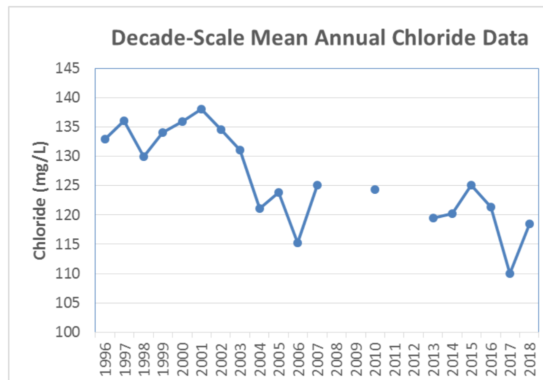


Fig. 4. Mean epilimnetic and hypolimnetic CTD temperatures (left) and salinities (upper right) since 2005 (Halfman, 2014 and unpublished data). Chloride concentration data confirm a declining trend since 1992 (lower right).



The decade-scale chloride ion data reveal decreasing chloride (and sodium) concentrations from 1992 to today as well (Fig. 4). Annual mean chloride concentrations remained between 130 and 140 mg/L from 1992 to 2001, rose to 150 mg/L in 2002 and decreased since to 125 mg/L in 2013 with a noticeable dip to 117 mg/L in 2006. The annual mean epilimnetic CTD specific conductance data also consistently decreased from 698 µS/cm in 2005 to 672 µS/cm in 2014. This decrease does not correlate to changes in rainfall, changes in chloride concentrations in streams (thus changes in road salt runoff), changes in the flow out the outlet, and changes in chloride wastes dumped into Seneca Lake from the salt mines in Watkins Glen over this two-decade time period (Halfman, 2014). It suggests that chloride in Seneca Lake is not in steady-state.

Century-scale chloride concentrations for Seneca, Cayuga, Hemlock, Canadice, and Skaneateles Lakes reveal two trends (Fig. 5). These data are reproduced with permissions from the Hemlock Water Quality Laboratory for the City of Rochester, Oneonta County Water Authority for the City of Syracuse, and Glenn Jolly, USGS, Reston (Jolly, 2005, Jolly, 2006, Jolly, 2012, Sukerfort & Halfman, 2005, 2006, Sukerfort et al., 2006). The chloride concentrations measured from Hemlock, Canadice and Skaneateles Lakes reveal two periods of time when the chloride concentration noticeably increased from under ~10 mg/L to ~15 in the 1960s and again to ~30 mg/L in the 1990s. These concentration trends are typical of basins influenced by rising road salt applications throughout northeastern US. They are also in steady state with the fluvial inputs (Halfman, 2014).

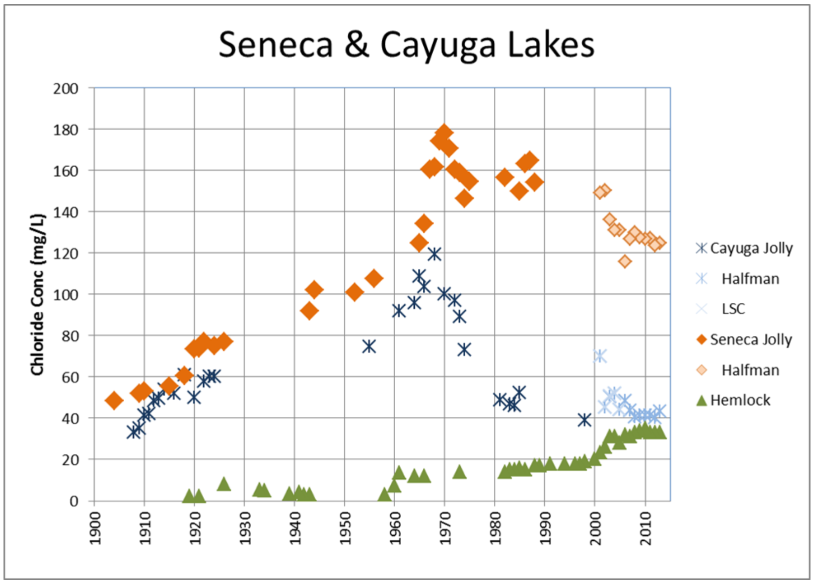


Fig. 5. Century-scale, annual mean, chloride concentrations in Seneca, Cayuga and Hemlock Lakes (Halfman 2014). The concentration trend in Hemlock parallels those measured in Canadice and Skaneateles Lakes.

Century-scale chloride concentrations in Seneca and Cayuga Lakes were consistently larger (up to 200 mg/L) and follow a different temporal trend. In Seneca, and to a lesser extent in Cayuga Lake, chloride concentrations steadily increased from 40 mg/L in the early 1900s to a pronounced peak starting at 1965 that lasted for 5 to 10 years. Chloride concentrations declined afterwards, the decreasing trend is consistent with the decade-scale data. Some scatter is observed in the raw data, especially during the 1965 to 1975 concentration peak, but the century-scale trend is unique from records elsewhere in the region. The decline since 1975 is notable because it declined in both lakes despite likely increased fluvial inputs of chloride from road salt runoff over time.

In the Cayuga Lake watershed, Effler et al. (1989) showed that the decrease in chloride concentrations since the 1965 to 1975 peak is consistent with an abrupt decrease in salt mine wastes input into the lake in the 1960s, and subsequent freshening of the lake since. Currently, the lake is near equilibrium with the entering fluvial and mine waste fluxes. The 1970s timing corresponds with a major change in the disposal methods for salt tailings from the Cargill Rock-Salt Plant in the Cayuga watershed. This change significantly decreased chloride disposal into the lake. Now, chloride concentrations in Cayuga Lake are similar to the saltier members of other Finger Lakes, and suggest that the chloride in Cayuga Lake reached equilibrium from its 1960s slug and has now returned to steady-state conditions as predicted by Effler. It also implies that mining practices probably controlled the pre-1960 elevated chloride concentrations. Thus, Cayuga Lake may never have received any groundwater inputs over the past century.

In the Seneca Lake watershed, chloride concentrations were modeled using a non-steady state, mass balance approach to determine the input of chloride required to attain to historical chloride concentrations (Fig. 16, Halfman et al., 2012). The model assumed a constant inflow of water (863 x 10^6 m^3/yr), a constant evaporation rate (103 x 10^6 m^3/yr) and a constant surface water outflow (760 x 10^6 m^3/yr) as before. It also assumed an initial input of chloride (30,000 mtons/yr) to attain an assumed pre-1900 chloride concentration of 40 mg/L in the lake. The model could not differentiate one chloride source from another due to a lack of information. Rather it lumped all sources together into one to determine the total quantity of chloride, in units of the initial input (30,000 mton/yr), that must be added to, or removed from, the lake to mimic the concentration distribution over time.

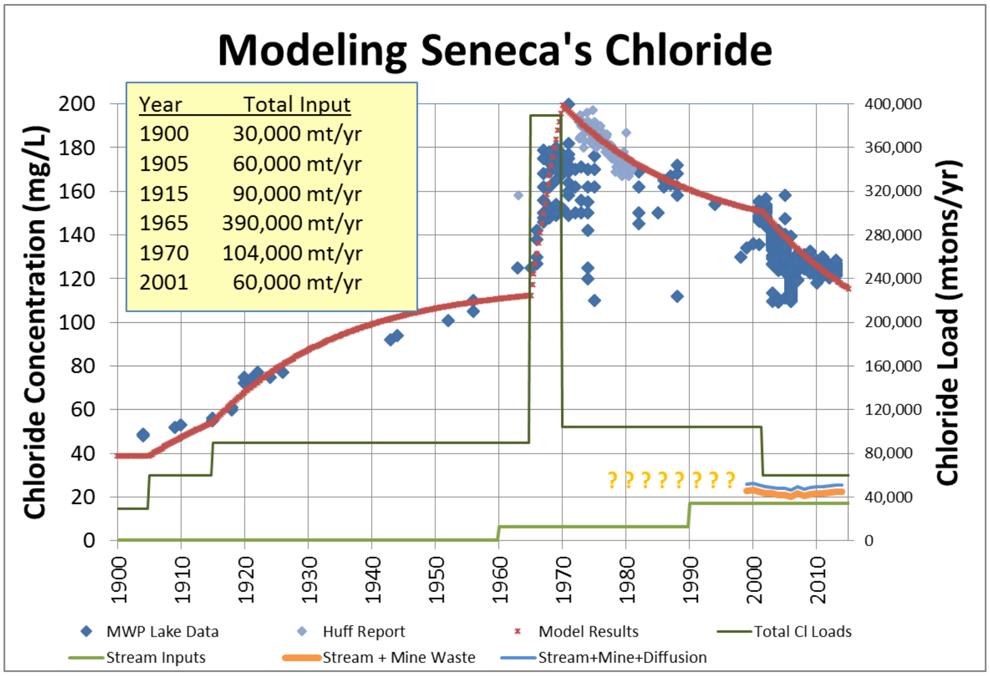


Fig. 6. Modeling chloride inputs to attain Seneca's chloride concentrations over the past century (Halfman 2014). The green line depicts the total annual load of chloride required to "match" the historical concentrations in the lake. Note the huge spike of chloride that must enter the lake in the late 1960s to balance the observed concentrations in the lake at that time.

Some intriguing generalizations are possible from this model. Today's concentration is currently close to equilibrium concentrations with the current inputs from the streams and solution salt mines in Watkins Glen. More importantly, the decrease in concentration from the 1960s and 1970s reflects the time required to naturally flush out the chloride from the lake due to its 18-year residence time. The concentrations in the early 1900s were presumably from inputs of chloride from streams and mine wastes. Assuming similar stream and lake concentrations detected in the historical records for Fall Creek and Hemlock, Canadice and Skaneateles Lakes, the amount of mine wastes must have been larger in the early 1900s to attain the lake's chloride concentration. Mine discharge data are unavailable to confirm this possibility.

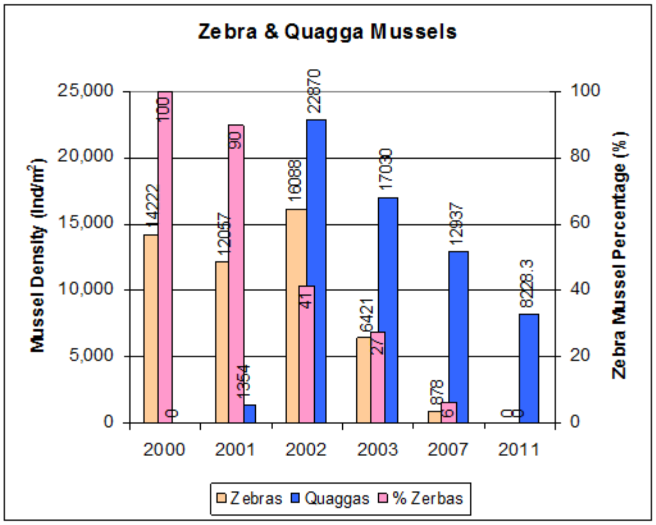
Finally, chloride inputs peaked significantly in the 1960 and 1970s. The peak required approximately 400,000 metric tons of salt to be added to the lake for five years. The source is not completely understood. Brine pool leaks, injection of saline wastes into leaky fractured bedrock (carbonates, sandstones and shales), dust from piles of rock salt and other issues at the abandoned hard-rock Morton-Himrod mine located in the Plum Point subwatershed partially influenced the 1965 to 1975 chloride peak detected in the lake. Unfortunately, those inputs do not explain the entire peak in chloride inputs. It is suspected that the input of salt wastes from the salt mines in Watkins Glen were significantly larger at this time, and only decreased after the mid-1970s when regulations by the EPA and NYS-DEC through the Clean Water Act forced a reduced in the tonnage of mine wastes discharged into Seneca Lake. Data are not publicly available to answer this question. We use this dataset to model the time required (multiple residence times) to flush of a "pollutant" from a lake in various courses at HWS.

ZEBRA/QUAGGA MUSSELS IN SENECA LAKE

The lake floor benthic community is dominated by the invasive zebra/quagga mussels (*Dreissena polymorpha*, and *D. rotriformis bugensis*, respectively), with lesser amounts of diporia and various other clams, midges and worms (Halfman et al., 2012). Zebra mussels were first detected in the lake in 1992, and soon afterwards they were firmly established on suitable substrates throughout the lake. Quagga mussels were first detected in 2001. Both mussels originated from Eastern Europe to the Great Lakes and probably travelled through the Erie Canal and the Seneca River to Seneca Lake.

Unfortunately, only a few studies investigated the density of zebra and quagga mussels in Seneca Lake. Lake wide investigations in 2002, in 2007, and a third duplicated a N-S, mid-lake transect in 2001 and 2011 (Shelley et al., 2003; Zhu, unpublished data; Dittman, unpublished data, Halfman et al., 2012, Halfman unpublished data, Fig. 7). In each study, lake-floor densities (individuals/m^2) were determined for live zebra and quagga mussels. Spatially, zebra mussels preferred the shallow water, less than 40 meters depth, whereas quagga mussels preferred the shallow water depths but were also recovered from deeper depths, some from depths of 160 m. Both mussel populations declined in water depths shallower than 5 m, presumably from significant wave action stirring up the lake floor sediments and substrate. Temporally, zebra mussel populations between 10 and 40 m declined since 2002 and were rarely detected since 2011. Presumably, quagga mussels out competed the zebra mussel for this ecological niche. If found in recent years, zebra mussels are attached to a hard substrate, like a monitoring buoy, mooring ball, anchor line, piling or dock, as quagga mussels dominate the populations in the sediments. The population of quagga mussels at 10 to 40 m depths declined from 2002 but the total population probably increased if deeper depths are included in the tally.

Zebra and quagga mussels are filter-feeding organisms. They remove particles from the water column. Each zebra mussels processes up to one liter of water per day. Some particles are consumed as food, whereas nonfood and "yucky" particles are combined with mucus and are deposited on lake floors as pseudofeces. They therefore effectively remove plankton from the water column, and increase lake clarity over time. The increased clarity allows sunlight to penetrate deeper, enabling growth of submerged macrophytes at deeper depths. These plants, when decaying, wash up on shorelines, and foul beaches and cause other water quality problems. The filtering of open water algae and deposition of feces in the nearshore sediments effectively transports the major source of phosphorus, the limiting nutrient in the lake, from algae in open pelagic waters to the sediments, macrophytes and other organisms in shallow water locations (Hecky et al., 2004).



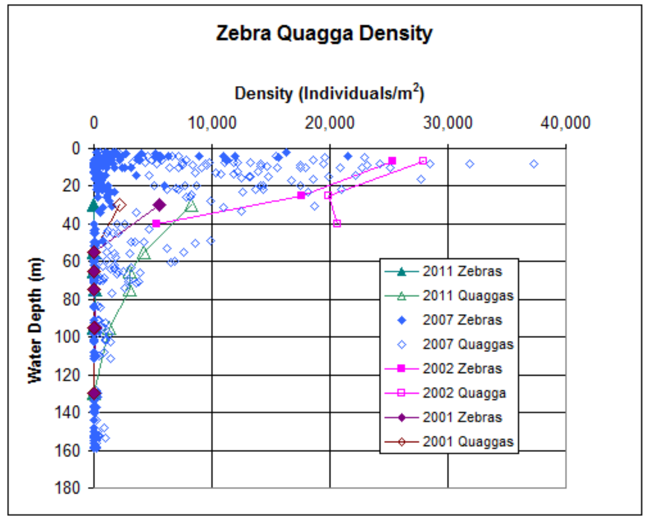


Fig. 7. Zebra and quagga mussel populations from 10 to 40 meters (left) and depth distributions (right) over the past decade. The 2001 to 2011 data exhibited a significant increase in quagga mussel densities at depths deeper than 40 m (D Dittman, unpublished data, not shown here).

Similar processes are inferred from basic Secchi disc depths and other limnological data collected from Seneca Lake. Secchi disk data since 1990 reveal two major temporal trends (Fig. 8). From 1992 through 1997, annual average Secchi disc depths were progressive deeper from 3 or 4 meters in the early 1990s to 7 to 8 meters by the end of 1997. Similar trends were detected in the Seneca River, the outlet to Seneca Lake over the same time frame (Effler et al., 1996). Subsequently, mean annual Secchi disc depths during the stratified season in Seneca Lake have shallowed up to 2 to 5 meters by 2018. Interestingly, the isothermal Secchi disc depths have deepened, up to 20+ meters, in the past decade. Presumably light limited algae during the isothermal winter months result in scarce food supplies for and perhaps regulate the mussel populations. Consistent changes were observed in chlorophyll-a data (Halfman et al., 2012 & Halfman unpublished data).

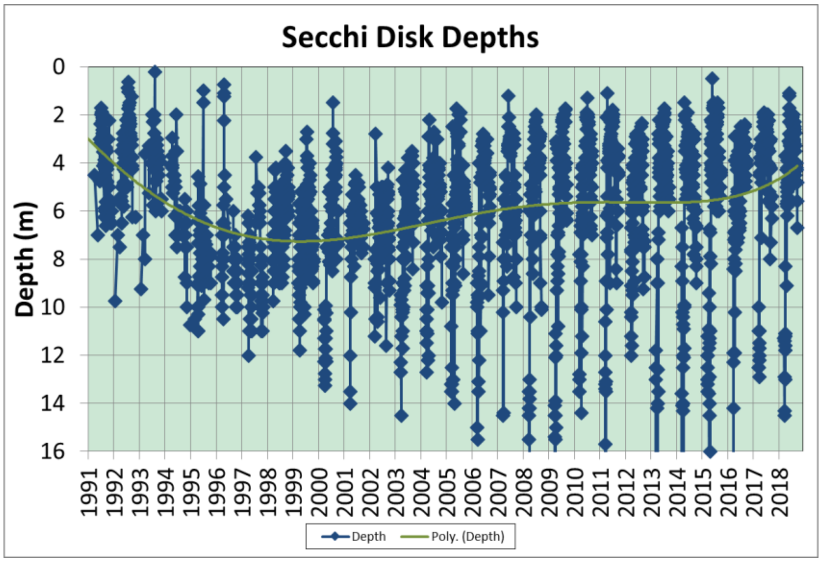


Fig. 8. Weekly Secchi disc depths from four sites in the northern end of Seneca Lake. The green line is a fifth order polynomial through the raw data.

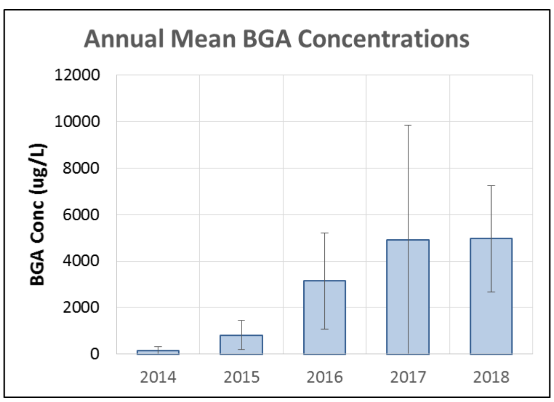
The 1992 through 1997 trend is consistent with increased grazing by the growing population of filter-feeding zebra mussels in the early 1990s (Halfman et al., 2001; Halfman and Franklin, 2008) and consistent with findings elsewhere (e.g., Strayer, 2010). The trend reversed after the initial major die off of zebra mussels in 1998. The die off and associated bacterial decomposition of the mussel biomass released the previously sequestered nutrients back into the water column during 1998 and 1999, as reflected in increasing TP, N, SRP and algal concentrations and decreasing Secchi disc depths. The lake became progressively more impaired since, as shown by shallower Secchi dish depths and larger chlorophyll concentrations (Halfman et al., 2010, Halfman et al., 2012 & Halfman unpublished data).

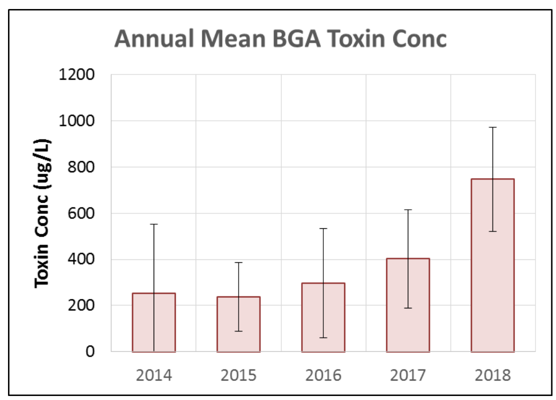
Various factors may have contributed to the decline in water quality over the past decade. First, the available but sparse mussel density data suggest that both zebra and quagga mussel populations declined since 2002 (B Zhu, unpublished data; D. Dittman, unpublished data; Shelley et al., 2003). Zebra mussels posted the largest decline, from 100% to 0% of the total mussel population between 10 and 40 meters of water from 2000 to 2011. Thus, the mussel impact on and reduction of the algal populations probably decreased as well. Unfortunately, these conclusions are speculative at this time because the data were collected from a variety of water depths and site locations, and mussel densities are depth and site sensitive and the surveys excluded water depths greater than 40 m where large populations of quagga are suspected to exist. Second, nutrient loading could have stimulated algal growth and decreased Secchi disc depths. Stream hydrogeochemistry data and preliminary basin-wide phosphorus budgets highlight a nutrient loading issue (Halfman et al., 2012).

Evidence from several Finger Lakes watersheds studies linked nutrient loading to water quality degradation (e.g., Halfman et al., 2008; Makarewicz et al., 2009; Effler et al., 2010; Halfman et al., 2012; UFI et al, 2014; Halfman et al., 2016; Halfman 2016; Halfman, 2017). For example, annual mean SRP concentrations in the Seneca Lake watershed are consistently 10 to 100 times larger in tributaries draining the watershed than in the lake, indicative of a nutrient loading problem. Estimated inputs typically exceed outputs by 45 metric tons of phosphorus each year, about a third of the total amount of phosphorus in the lake (Halfman et al., 2012). The phosphorus sources to Seneca Lake are multifaceted and included: runoff from agricultural fields, municipal wastewater treatment facilities, soil, road ditch and stream bank erosion, construction activities, lakeshore septic systems, and atmospheric deposition. More research is required to quantify the contributions from each source.

Research in the Owasco watershed highlights the importance of precipitation events on nutrient loads (Halfman et al., 2018a). Event vs. base flow measurements at Dutch Hollow Brook, an agricultural-intense subwatershed, revealed that over 90 percent of the nutrient and sediment loads were transported during precipitation-induced runoff events as compared to base flow inputs, especially in the spring season (e.g., Halfman et al., 2018). Annual nutrient and sediment loads positively correlate to precipitation totals as well, especially precipitation totals during the spring months ($r^2 = 0.8$, Halfman et al., 2018). Thus, rainfall events and runoff from agricultural areas are significant to the delivery of nutrient and sediments to the lake.

The recent rise in BGA blooms and their associated toxins, with toxin concentrations occasionally above MCL thresholds in many Finger Lakes, is disturbing (R. Gorney and S Kishbaugh, NYSDEC, 2018, Fig. 9). To date BGA blooms have been detected in every Finger Lake. The most disturbing aspect is that BGA blooms were detected in some very oligotrophic (Canandaigua, Skaneateles) and mesotrophic (Cayuga, Owasco, Otisco, and Seneca) lakes as well as the expected eutrophic (Honeoye) systems. Data from Owasco Lake and bloom histories for all the Finger Lakes are shown below (Fig. 9). Perhaps the pervasive nutrient loading issues combined with the nearshore shunt by the invasive mussels have contributed to the recent rise in blue green algae blooms (Halfman et al., 2018b). More research is required to conform this hypothesis.





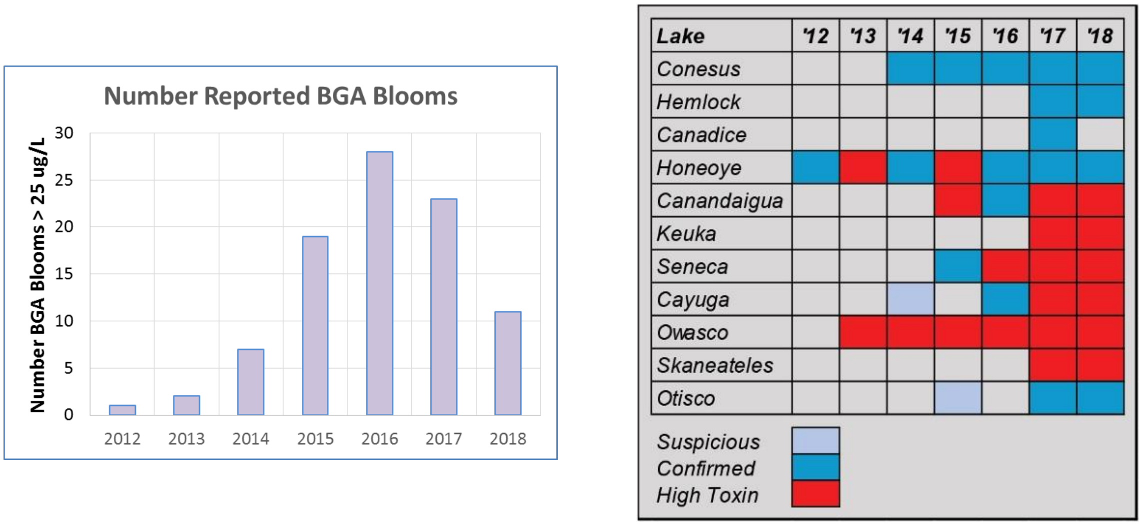


Fig. 9. Annual mean (±1σ) blue green algae (left top) and toxin (right top) concentrations and the number of conformed blooms (bottom left) reported in Owasco Lake (HABs Shoreline Surveillance volunteers and the Owasco Lake Watershed Inspector's office). The number of Finger Lakes with reported blue green algae blooms since 2012 (bottom right, by permission DEC).

WILLIAM SCANDLING

The *William Scandling* (formerly the *H-WS Explorer*) is a 65-ft long, steel hulled, single screw, 200 hp diesel powered vessel built in 1954 for the United States Navy. Hobart and William Smith Colleges acquired the vessel in 1976 after it had also been used in, e.g., the lobster and fishing industries. The vessel is documented "Oceanographic" by the United States Coast Guard and meets all of the standards applicable to such a vessel. In 1989, major renovations resulted in the construction of a 20 by 10 ft laboratory on the main deck to complement the growing list of standard oceanographic/limnologic equipment including multiple Sea Bird CTD's (Conductivity, Temperature, Dissolved Oxygen, pH, Turbidity and Depth sensors), EdgeTech (EG&G) X-Star high-resolution seismic reflection system, EdgeTech sidescan sonar, piston and box corers, computers, flume hood, weather station and other equipment. The pilot house has a full complement of safety, navigation and communication equipment including up-to-date radar, satellite navigation, marine radio-telephone, cellular phone and other equipment. Most importantly, the vessel is operated by a licensed captain and mate. It provides a safe, well-equipped platform useful under most weather conditions experienced on Seneca Lake.

CRUISE LOG

This field trip starts and stops dockside aboard the *William Scandling*, and investigates the water chemistry and surface sediment character at a number of locations in the northern portion of the lake. No specific "Road Log" is required.

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