BLUE-GREEN ALGAE IN OWASCO LAKE, THE 2017 UPDATE.
THE 2017 ANNUAL REPORT TO THE FRED L. EMERSON FOUNDATION

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INTRODUCTION

The recent onset of blue-green algae (BGA) blooms and their associated toxins has heightened awareness about water quality issues in Owasco and neighboring Finger Lakes. In 2016, BGA toxins were even detected in the Auburn and Owasco municipal drinking water supplies that draw water from Owasco Lake. The largest measured concentrations throughout the lake were typically at shoreline locations, where lakeshore residents want to use the lake. A three-year research award from the Fred L. Emerson Foundation to Halfman and others at FLI/HWS was designed to investigate the limnological factors controlling the growth and persistence of BGA. The award also supported the deployment of FLI's water quality monitoring buoy at its mid-lake site to provide a daily record of the open water limnology and an open-water reference point for the nearshore sites.

Here we report on our first-year findings of this three year award. This first year was a reconnaissance effort that collected data from a suite of nearshore environments to test and derive additional testable hypotheses to mold and improve our investigation during the next two years. This work complimented and dovetailed nicely with the lake/watershed monitoring effort supported by Cayuga County through the Owasco Lake Watershed Municipal Council. A number of annual reports on the Owasco Lake/watershed monitoring effort are available online at Halfman's web site (http://people.hws.edu/halfman/)[1]. Pertinent to this research, the lake and watershed monitoring program highlighted the following conclusions:

- Owasco Lake's trophic status (level of productivity) is a borderline oligotrophic/mesotrophic system (low/medium productivity), and is not eutrophic (highly productive). Yet, the lake has recently experienced BGA blooms typically restricted to eutrophic systems.
- Algal growth is limited by phosphorus. Annual mean, open-water, total phosphorus concentrations are insufficient to support the significant BGA blooms detected to date.
- Since 2011, the estimated phosphorus budget for the lake revealed larger inputs than outputs. Nonpoint sources dominated the phosphorus loads, delivered to the lake by streams.

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[1] Halfman, et al., 2018. The 2017 water quality monitoring report for Owasco Lake, NY. Finger Lakes Institute, Hobart & William Smith Colleges.

- BGA blooms favored warm, calm waters, and were detected in the late summer and early fall. The largest blooms were concentrated along the shoreline, highlighting the need to better understand the nearshore environment.

METHODS

This project focused on the limnology and lake-sediment character of six nearshore sites in Owasco Lake. The nearshore results are also compared to the open-water reference point provided by the water quality and meteorological monitoring buoy and identical limnological and sediment data collected at two additional mid-lake, offshore sites.

Site Locations: The 2017 fieldwork focused on six nearshore sites, Sites A-F, sampled from May through the end of September (Table 1, Fig. 1). The survey dates increased in frequency from bi-weekly intervals at the start at the field season, to weekly surveys through July, August and September. The sample design enabled a comparison when BGA blooms were least likely and most likely to be present, and maximized sampling during the late summer and early fall when blue-green algae blooms were most likely to be present. The specific 2017 survey dates were: 5/23, 6/14, 6/21, 7/5, 7/11, 8/1, 8/8, 8/15, 8/25, 8/29, 9/6, 9/12, 9/20 and 9/27. The nearshore sites were also selected based on the lake-floor morphology and the presence and/or absence of BGA blooms in the past. The largest morphological variant along the nearshore locations was the extent of the shallow water shelf extending from the shoreline to depths of 3 to 5 m before sloping to depths greater than 5 m (Fig. 2).

Table 1. Owasco Lake Site Locations and Water Depths.

Site Name	Latitude	Longitude	Water Depth
Nearshore Sites:			
A – Fire Lane 20	42° 48.69’ N	76° 30.92’ W	2 - 3 m
B – Wyckoff Rd	42° 50.61’ N	76° 31.58’ W	2 - 3 m
C – Stone School Rd	42° 52.01’ N	76° 31.98’ W	2 - 3 m
D – Burtis Pt	42° 51.89’ N	76° 30.96’ W	2 - 3 m
E – Martin Pt	42° 53.64’ N	76° 31.59’ W	4 - 5 m
F – Buck Pt	42° 53.35’ N	76° 32.65’ W	2 - 3 m
Offshore Sites:			
Site 1	42° 52.40’ N	76° 31.35’ W	34 m
Site 2	42° 49.15’ N	76° 30.45’ W	52 m
Buoy Site	42° 50.35’ N	76° 30.85’ W	49 m

Fieldwork: The fieldwork routinely collected a CTD water quality profile, fluoroprobe profile, Secchi disk depth, vertical plankton tow (80-μm mesh), and surface water samples at each site. A bottom water sample was also collected from each offshore site. The CTD electronically measures water column profiles of temperature (°C), conductivity (reported as specific conductance, μS/cm, a measurement proportional to salinity), dissolved oxygen (mg/L), pH, turbidity (NTUs), photosynthetic active radiation intensities (PAR, $\mu E/cm^2$-s), and fluorescence (a measure of chlorophyll-a, μg/L) using a SeaBird SBE-25 CTD. The CTD was lowered from the surface to the lake floor, collecting data every 0.5 seconds (~0.1 meters) along the downcast. The bbe fluoroprobe electronically measures four different algal groups based on their accessory pigments and distinguished among: ‘green’ algae (Chlorophyta and Euglenophyta), ‘brown’ algae (diatoms: Baccillariophyta, Chyrsophyta, and Dinophyta), ‘blue-green’ algae (Cyanophyta), and ‘red’ algae (Cryptophyta). The fluoroprobe was attached to the CTD and deployed on every CTD cast. Phytoplankton was collected using a 80 μm mesh net towed between 1 m and the surface; the net contentswere preserved in an alcohol-formalin solution and typically enumerated to genus level back in the laboratory under a microscope. Water samples were analyzed onsite for temperature (°C), conductivity (specific conductance, μS/cm), pH, dissolved oxygen (mg/L), and alkalinity (mg/L, $CaCO_3$) using hand-held probes and field titration kits, and analyzed back in the laboratory for total phosphate (μg/L, P), dissolved phosphate (SRP, μg/L, P), nitrate (mg/L, N), chlorophyll-a, dissolved silica (μg/L, Si), and total suspended solid (mg/L) concentrations. Lab samples were stored at 4°C until analysis.

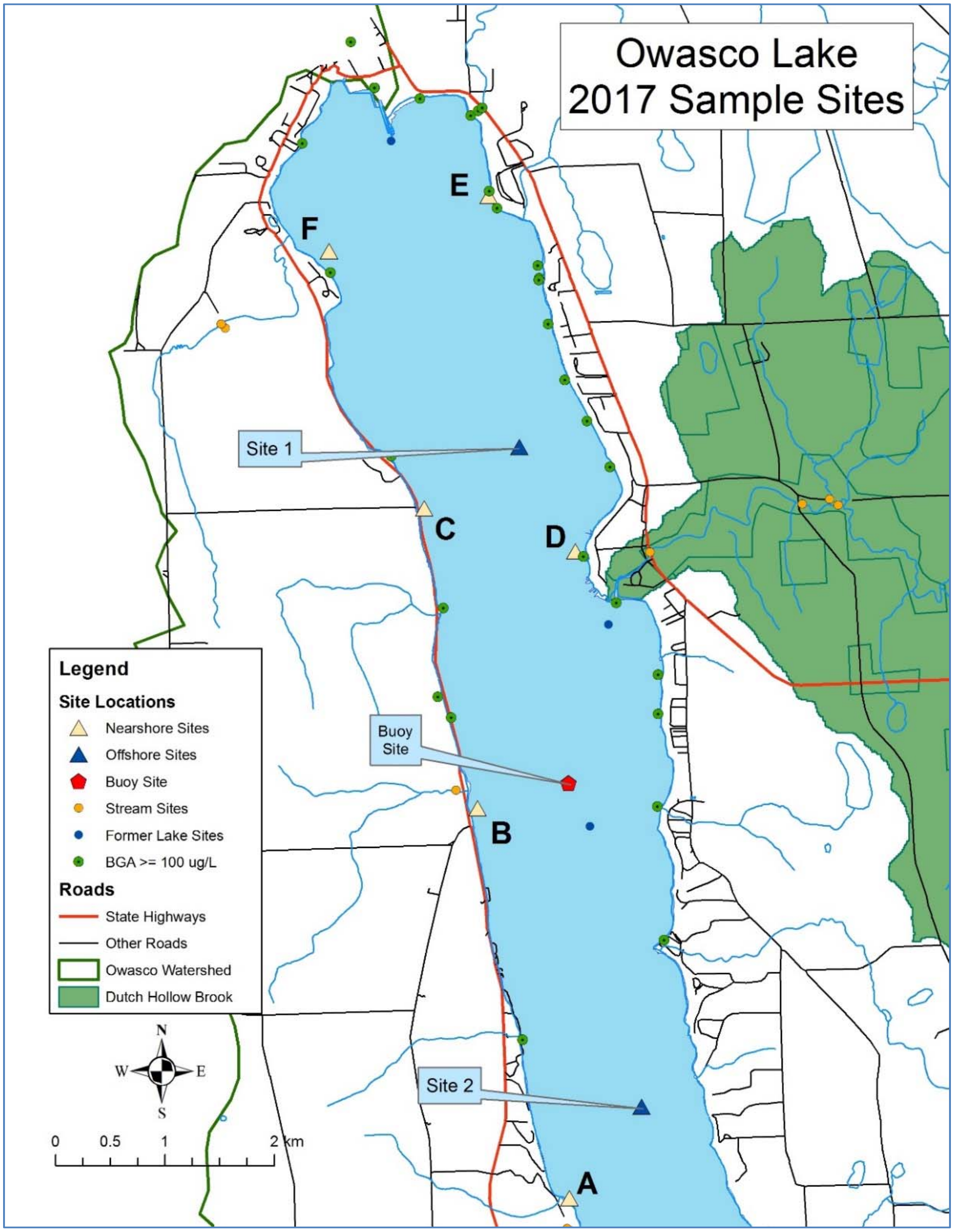

Fig. 1. The 2017 Owasco Lake nearshore and offshore survey sites. 2014 – 2017 BGA bloom sample locations with bloom concentrations >= 100 μg/L are also shown.

Other analyses included the following: One *ONSET* HOBO U290L-04 data logger was deployed from a dock near each nearshore site from 6/16 through 10/10. The six loggers were programmed to record water temperature every hour at approximately 1 m below the lake's surface to determine if any site experienced unique temperature swings from the rest of the lake. Sediment grab samples were collected using a ponar dredge at each site on two separate surveys, and a subsample was brought back to the lab for grainsize, total phosphorus, organic matter and carbonate content analyses. Rake tosses were also completed at each site on each survey date to qualitatively determine the aquatic plant assemblages, abundance and potential changes over time through the summer season.

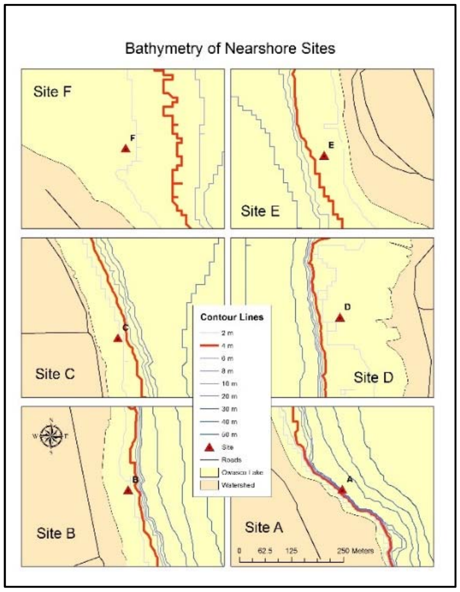

Fig. 2. The nearshore bathymetry. The contour interval shown is 2 m, in shallow water (< 10m), and 10 m in deeper water. Each map was drawn at the same scale. The two meter bathymetric contour is highlighted in red for comparison between sites.

On 7/31/17, SCUBA divers performed a more quantitative analysis of the macrophyte dry-weight biomass and mussel populations at sites C, D, and F using triplicate tosses of a 0.5x0.5 m quadrant. Each quadrant's plant and mussel matter was brought back to the lab for processing. The plants were identified to species and oven dried at 100°C for 24 hours for dry-weight biomass. The samples were then placed in a muffle furnace at 500°C for 1 hour for ashed-weight biomass. Zebra mussels and quagga mussels were present at all sampling locations and were separated by species and each species into four size classes by length. The length categories were 0-8 mm, 8-15 mm, 15-22 mm, and 22 mm+.

Drone Flights: Drones were flown at an altitude of 100 m at the six nearshore sites to investigate the extent of nearshore attached algae, macrophytes, and BGA blooms (Fig. 3). Specifically, DJI's Phantom 3 Advanced with a Sony EXMOR gimbaled camera was used, which captured 12 megapixel digital images. Each image spanned an area of ~200 by 300 meters at a flight altitude of 100 m. Multiple (~15), overlapping nearshore images were collected at each site that were spatially assembled in Adobe Photoshop. The composite image was georeferenced in ArcGIS to 2015 satellite digital orthoimagery (NYS Clearinghouse data). Flights dates were: 7/11, 7/18, 8/1, 8/8, and 8/15, plus a few additional flights at Burtis Point later in the summer.

Fig. 3. The drone used in this study, a Phantom 3 Advanced by DJI.

Owasco Buoy: The FLI meteorological and water quality monitoring buoy manufactured by YSI/Xylem was redeployed at its mid-lake site from 4/13 through 11/3 (Table 1 & Fig. 1). The buoy was programmed to collect water column profiles every 12 hours (noon and midnight) of temperature (°C), conductivity (µS/cm, reported as specific conductance), dissolved oxygen (mg/L & % saturation, by optical sensor), turbidity (NTUs by backscattering), and fluorescence measuring both total chlorophyll and blue-green algae phycocyanin (μg/L, by specific pigment excitation at different wavelengths of light). Data was collected every 1.5 meters down the water column starting at 1 m using a YSI/Xylem EXO2 water quality sonde. The buoy also has a standard suite of meteorological sensors that recorded five-minute mean air temperature, barometric pressure, relative humidity, light intensity and wind speed and direction data every 30 minutes. All of the data were periodically transferred to HWS by cellular phone ~1 hour after collection and made available on the internet soon afterwards[2]. Buoy hardware and software issues prevented collection of water quality data from 5/11 to 5/14, 5/22 to 5/26, 6/7 to 6/8, 8/6 to 8/9, 9/12 to 9/13, 10/3 to 10/5 and 10/7 to 10/9, and an occasional 30 minute meteorological data point.

Laboratory Analyses: Laboratory analyses for nutrient, chlorophyll-a, and total suspended sediment concentrations followed standard limnological techniques[3]. Briefly, an aliquot of each sample was processed for total phosphate colorimetric analysis by a spectrophotometer after digestion of any organic-rich particles in hot (100ºC) persulfate for 1 hour. Additional sample water was filtered through pre-weighed, 0.45 μm glass-fiber filters. The filter and residue were dried at 80°C for at least 24 hours. The weight gain and filtered volume determined the total suspended sediment concentration. A known volume of sample water was also filtered through a Gelman HA 0.45 μm membrane filter, and the filtered residue was kept frozen until chlorophyll-a analysis by spectrophotometer after pigment extraction in 90% acetone. The filtrate was saved and stored at 4°C until dissolved phosphate (SRP), nitrate and dissolved silica colorimetric analyses by spectrophotometer. Laboratory precision was calculated by periodic replicate analyses resulting in the following mean standard deviations: total suspended sediments ±0.2 mg/L, phosphate ±0.1 μg/L (both TP and SRP), silica ±5 μg/L, and nitrate ±0.1 mg/L. For the plankton enumerations, over 100 individuals were identified to genus (and typically species) level and reported as date averaged relative percentages. Multiple reagent blanks and standards were run during each analysis for a continual check on data quality. Nitrate blank and standard results occasionally yielded concerns.

Sediment total phosphorus content (μg/g dry wt.) was analyzed on samples of ~0.1 g of dry sediment. The weighed sample was dispersed in distilled water, and phosphorus determined using the total phosphate procedure above. The sediment P results may be underestimates as some of the phosphate absorbed back onto particles during the spectrophotometric analysis. Grainsize analyses determined the relative percent sand, silt and clay by wet sieving (63 μm) the sand from the silt and clay, and the remaining silt and clay by settling tube. The organic matter and carbonate weight percent (wt. % dry wt.) was determined by loss on ignition, first at 110°C for 2 hours to dry the sediment sample, then at 550°C for 1 hour to oxidize (remove) the organic matter, and finally at 1,000°C for 2 hours to oxidize the carbonates (mostly calcite, $CaCO_3$).

BLUE-GREEN ALGAE AND HARMFUL ALGAL BLOOMS

Owasco Lake has experienced significant surface-water, shoreline-hugging, blue-green algae (BGA) blooms in the past few years (Fig. 4). BGA contain gas vacuoles that enable them to float at or near the surface of a lake resulting smelly, green scums on the surface of the water. Other algae typically live at deeper depths within the epilimnion, and are not typically observed

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[2] http://fli-data.hws.edu/buoy/owasco/

[3] Wetzel and Likens, 2000. Limnological Analyses, 3rd Edition. Springer-Verlag, New York.

by humans in boats or onshore. Unlike other algae, BGA can vertically migrate during a 24-hour day, to take advantage of optimum levels of light and nutrients. Daily vertical migrations are common, especially in ponds. During the daytime, photosynthesis of dense carbohydrates forces BGA to sink by mid-day or late afternoon. After sinking to low light levels (or at night), BGA respire and consume their carbohydrates, creating carbon dioxide gas. The gas accumulates in their cell wall enabling them to buoyantly rise to the lake's surface by early to late morning during calm days. Mixing by wind-driven waves can retard the migrations, and prevent the accumulation of cyanobacteria and the formation of a bloom at the lake's surface.

Many species of BGA exist, each trying to gain an ecological advantage over the others. For example, some species in the *Dolichospermum* (*Anabaena)* genus can "fix" atmosphere nitrogen (N_2) for their source of nitrogen, whereas most other forms of algae including some forms of BGA like *Microcystis* cannot "fix" N_2, and are instead dependent on the dissolved forms of nitrogen like nitrate (NO_3^-) and/or ammonium (NH_4^+) for photosynthesis. Nitrogen fixing BGA have an ecological edge in nitrogen-limited lakes like Honeoye. Nitrogen limitation should not be a concern in Owasco and the other phosphorus-limited Finger Lakes, especially in the open water, but understanding the dynamics of both phosphorous and nitrogen need additional study. Both *Dolichospermum* (*Anabaena)* and *Microcystis* have been detected in Owasco Lake.

More importantly, some species of BGA produce a variety of toxins that in turn are health threats to humans and other warm blooded animals (e.g., dogs). The toxin story is complicated. BGA taxa that produce toxins do not synthesize toxins all the time. The environmental triggers to produce toxins are poorly understood. When toxins are produced, the cyanobacterial blooms are called harmful algal blooms (HABs). To complicate the situation, different toxins are synthesized by different BGA taxa and each toxin impacts different parts of the body, most notably, the skin, liver, nervous system and/or gastrointestinal systems. Liver cyanotoxins like microcystins are most commonly found in HAB blooms, and can cause organ damage, heart failure and death at high doses in lab animals. Microcystins can be synthesized by various species of *Microcystis* and *Dolichospermum* (*Anabaena)*, and this group of toxins is most commonly measured in New York State. Another common toxin group, anatoxins, impact the nervous system and can be synthesized by *Dolichospermum* (*Anabaena)* and other BGA genera but not *Microcystis* species.

Their impact on humans at low concentrations still remains unclear. The World Health Organization (WHO) has issued a provisional finished drinking water guideline of 1 μg/L for chronic exposure to microcystin, and recreational exposure limit of 20 μg/L[4]. The EPA's drinking water guideline for microcystin is 0.3 μg/L for infants and 1.6 μg/L for school-age children and adults; their recreational contact limit is 4 μg/L. No thresholds are set for anatoxins yet, although 0.5 μg/L is used by Vermont in their drinking water guidelines[5]. The half-life, time interval for decomposition, of anatoxin is very short, less than 24 hours, which makes detection in the water column difficult. The NYSDEC defines a BGA bloom when the blue-green chlorophyll or phycocyanin concentration exceeds 25 μg/L, and a bloom is considered harmful when microcystin concentrations exceed 20 μg/L in nearshore areas and 10 μg/L in offshore areas.

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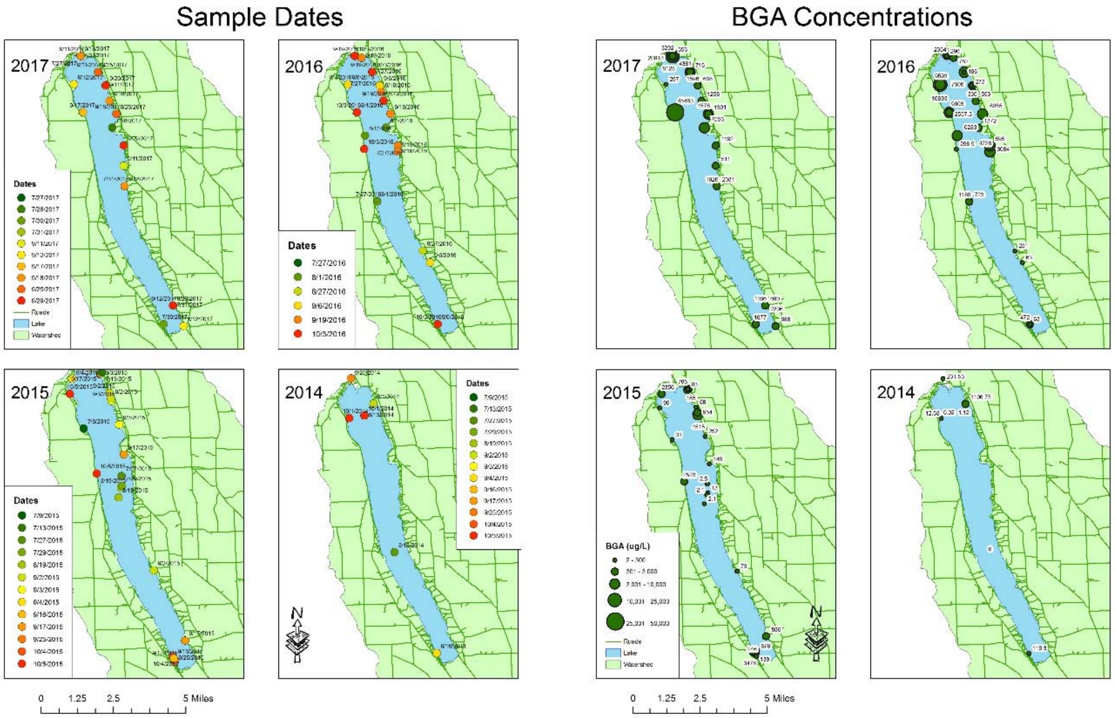
[4] WHO, 2011. Guidelines for Drinking Water Quality. 4th Edition. World Health Organization. Switzerland.

[5] https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations



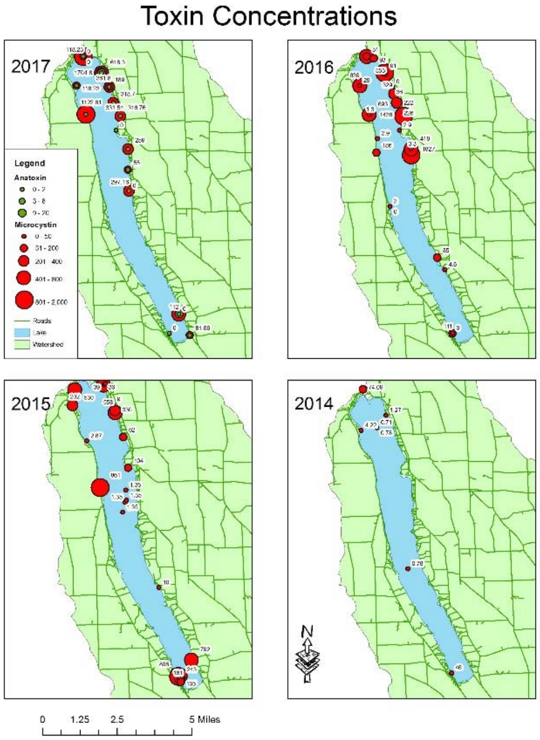


Fig. 4. Maps of the 2014 – 2017 shoreline BGA bloom dates, concentrations and microcystin and anatoxin (2017 only) toxin concentrations. Data by permission from the Owasco Lake Watershed Inspector & DEC.

Harmful algal blooms are not unique to Owasco Lake. In 2017, major BGA blooms were also confirmed in all of the Finger Lakes (weeks on DEC's notification page): Conesus (8 weeks), Honeoye (14 weeks), Canandaigua (4 weeks), Keuka (6 weeks), Seneca (5 weeks), Cayuga (10 weeks), Owasco (10 weeks), Skaneateles (5 weeks) and Otisco (2 weeks)[6]. Over 150 lakes in

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[6] www.dec.ny.gov/docs/water_pdf/habsarchive2016.pdf

New York State had confirmed BGA blooms in 2017 out of the tens of thousands of lakes in the state (Rebecca Gorney, DEC, person. comm.).

In Owasco Lake, events with DEC confirmed blooms has increased from one in 2012 (9/6 – 9/27), two in 2013 (8/25 – 10/3), six in 2014 (8/22 – 10/12), nine in both 2015 (7/10 – 10/16) and 2016 (7/29 – 10/14), to ten in 2017 (7/21 – 10/20). The time interval in (brackets) is the length of time DEC listed the lake on its notification web site. Caution is warranted when analyzing this information as the time periods when blooms are observed might only reflect the intensity, diligence and number of people looking for blooms. Notwithstanding, the past four years have seen increasingly larger concentrations of BGAs and HABs (Fig. 5). Measured BGA concentrations in Owasco Lake ranged from 0 to 1,100 μg/L and averaged 165 μg/L in 2014, from 2 to 4,500 μg/L and averaged 820 μg/L in 2015, from 60 to 16,800 μg/L and averaged 3,150 μg/L in 2016, and from 297 to 45,463 μg/L and averaged 4,910 μg/L in 2017 (Fig. 4). The nearshore blooms were most common along the northern and northeastern margins of the lake although this may be an artifact of the locations where individuals reported and/or searched for blooms.

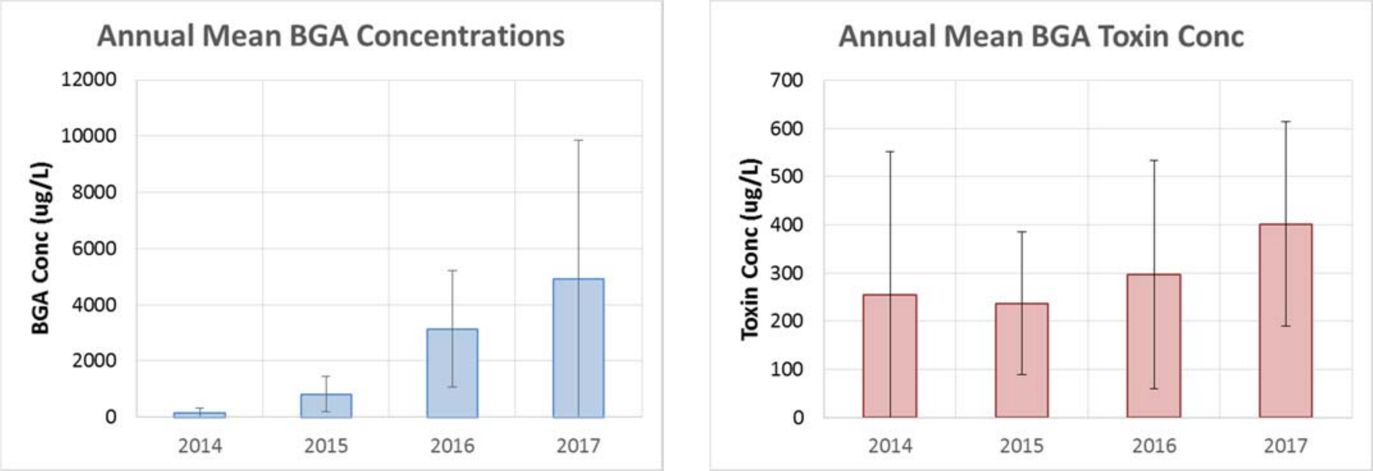

Fig. 5. Annual mean BGA (left) and toxin (right) concentrations at shoreline areas in Owasco Lake as reported by the Owasco Lake Watershed Inspection Program. The error bars reveal the standard deviations of the means.

Toxin concentration measurements ranged from 0 to 75 μg/L in 2014, 1 to 860 μg/L in 2015, 0 to 1,800 μg/L in 2016, and from 55 to 1,704 μg/L in 2017. Toxin concentrations up to 0.22 μg/L were detected in the Auburn and/or Town of Owasco finished drinking water supplies, water that is drawn from Owasco Lake and distributed to ~45,000 residents, eleven (11) times between 9/22/2016 through 10/10/2016. All detections were just below the EPA's drinking water threshold of 0.30 μg/L for the most vulnerable populations, the elderly and those under 3-years of age. Strategies to eliminate BGA from the municipal drinking water supplies were implemented in 2017. Lakeshore residents with private water systems should make sure that their systems can remove BGAs from the water without busting cell walls. Citizens should also use bottled water during BGA outbreaks along their shoreline[7].

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[7] A Water Utility Manger's Guide to Cyanotoxins. 2015. Water Research Foundation, American Water Works Association, 18 pgs. www.waterrf.org

RESULTS & DISCUSSION

CTD and Fluoroprobe Profiles: The nearshore sites revealed similar water temperatures both temporally and spatially as the surface water (upper 5m) mean temperature at the offshore sites (Fig. 6). The lake floor at the nearshore sites was always within the epilimnion (warm surface water) of the lake. The spatial and temporal similarity in surface temperatures across the lake was confirmed by the nearshore HOBO data loggers (see below).

Fig. 6. Nearshore to offshore temporal and spatial comparison of 2017 CTD data. The CTD has its own fluorometer.

The nearshore sites revealed similar salinities both temporally and spatially as the surface water (upper 5m) mean salinities at the offshore sites (Fig. 6). The dissolved oxygen sensor malfunctioned in 2017, and resources were not available to fix it. Photosynthetically available radiation (PAR) was also spatially and temporally similar across the lake. Light levels were sufficient at the lake floor for plant growth at every nearshore site.

The nearshore sites revealed similar or slightly less algae (CTD fluorescence) than the surface water (<5m) mean fluorescence at the offshore sites (Fig. 6). The larger mean algal concentrations in offshore locations is probably an artifact of the 5 m average. The 5 m interval occasionally included larger values at depth in the water column as the offshore algal concentrations were largest between 5 and 15 m below the lake's surface. Some of the nearshore sites occasionally experienced much larger algal concentrations as indicated by larger positive whiskers on the box and whisker (B&W) plots (Fig. 6). The turbidity profiles revealed uniform or nearly uniform turbidities across all sites. The offshore sites occasionally revealed larger turbidities, specifically on 7/9 and 7/18. These survey dates followed intense precipitation events. Survey dates did not coincide with strong onshore winds and waves that would have stirred up the lake floor sediments and increased the nearshore turbidity.

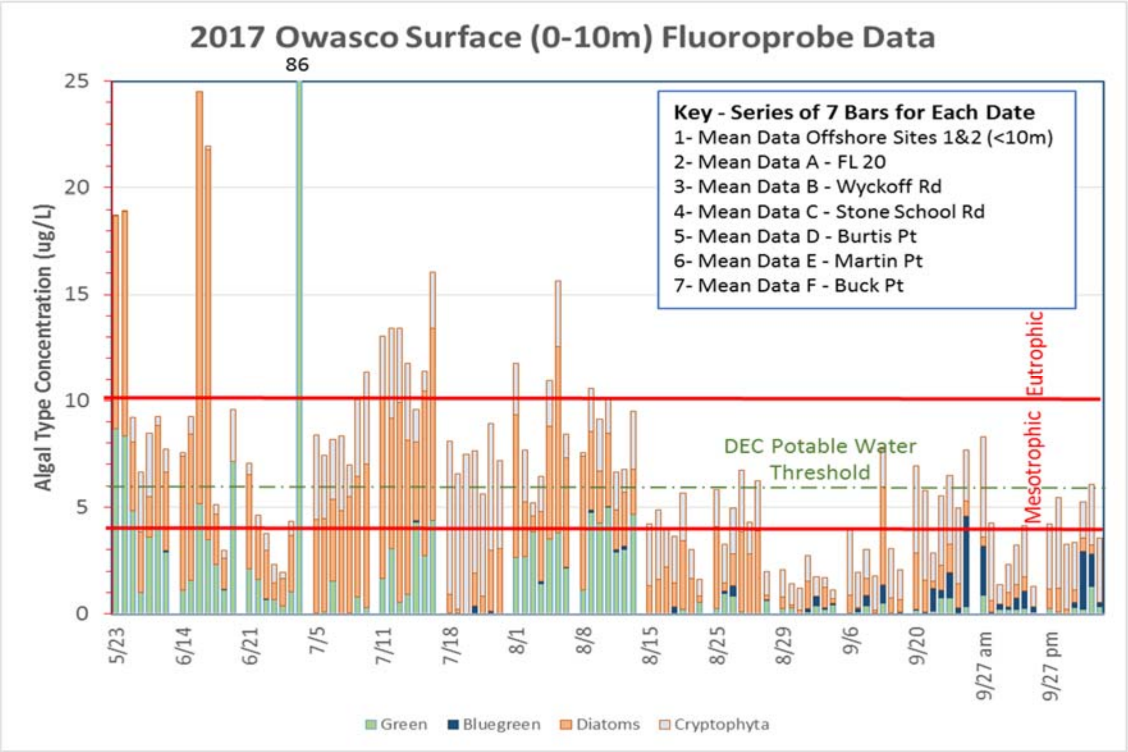

Fig. 7. Fluoroprobe data from each site on each survey date.

The fluoroprobe surface water data revealed the dominance of green algae, diatoms and cryptophytes throughout the lake. Mean epilimnetic total fluorescence concentrations exceeded 10 μg/L (mesotrophic/eutrophic threshold) at one or more sites on six of the fifteen surveys of the lake (Fig. 7). BGA were detected by the fluoroprobe in the late summer and early fall surveys, with typically more BGA at the nearshore than the offshore sites. BGA concentrations at the nearshore sites never exceeded 15 μg/L, even though some of the sample dates were during shoreline BGA blooms, where shoreline bloom concentrations were significantly larger (~300 to

45,500 μg/L in 2017 as measured by the Owasco Lake Watershed Inspectors Program). This highlights the shoreline hugging distribution of the majority of the BGA blooms.

Total phosphate, nitrate, chlorophyll-a and suspended solids concentrations were similar across all sites (Fig. 8). Secchi disk depths and soluble reactive phosphate were the exceptions. The B&W plot of Secchi disk depths suggests that the Secchi disk depths were shallower at the nearshore sites than the offshore sites. This observation, however, is an artifact of the Secchi disk hitting the lake bottom at most of the nearshore sites, and thus only occasionally recorded depths shallower than the depth of the lake floor. Site E was slightly deeper (5m) than the other nearshore sites (~2m) and the deeper water depth enabled detection of a slightly deeper mean Secchi depth. Soluble reactive phosphorus revealed the largest 2017 concentrations in the lake, i.e., the upper whiskers on the plots, at four nearshore sites (A, C, E & F). This suggests that the nearshore environment occasionally has higher concentrations of bioavailable nutrients.

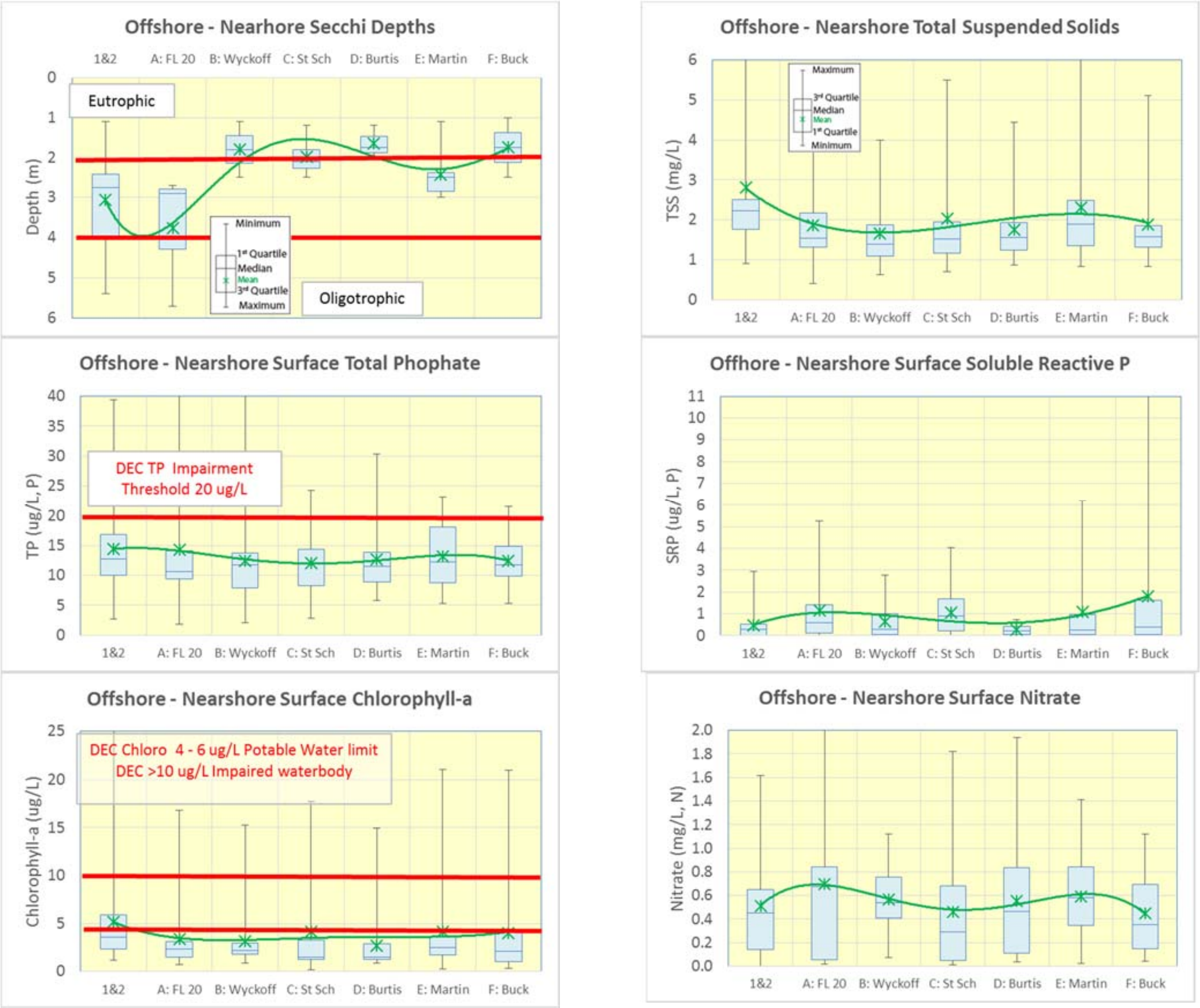

Fig. 8. Nearshore to offshore spatial comparison of limnological data. When appropriate, boundaries for oligotrophic, mesotrophic and eutrophic concentrations are marked.

Plankton Data: The offshore phytoplankton (algal) community in Owasco Lake during 2017 was dominated by diatoms, primarily *Fragilaria* and *Asterionella*, with smaller numbers of *Diatoma*, *Melosira*, *Tabellaria*, and *Rhizoselenia*, (Fig. 9). *Dolichospermum* (*Anabaena)* was more abundant in the in the late summer and *Microcystis* in the early fall. In comparison, the nearshore plankton tows on any sample date recovered fewer diatoms, and more dinoflagellates and blue greens than the offshore assemblages. It may reflect the ecological preference planktonic diatoms have for deeper water with less light. The nearshore diatoms were typically benthic forms. Nearshore plankton analyses have yet to be performed on the September tows.

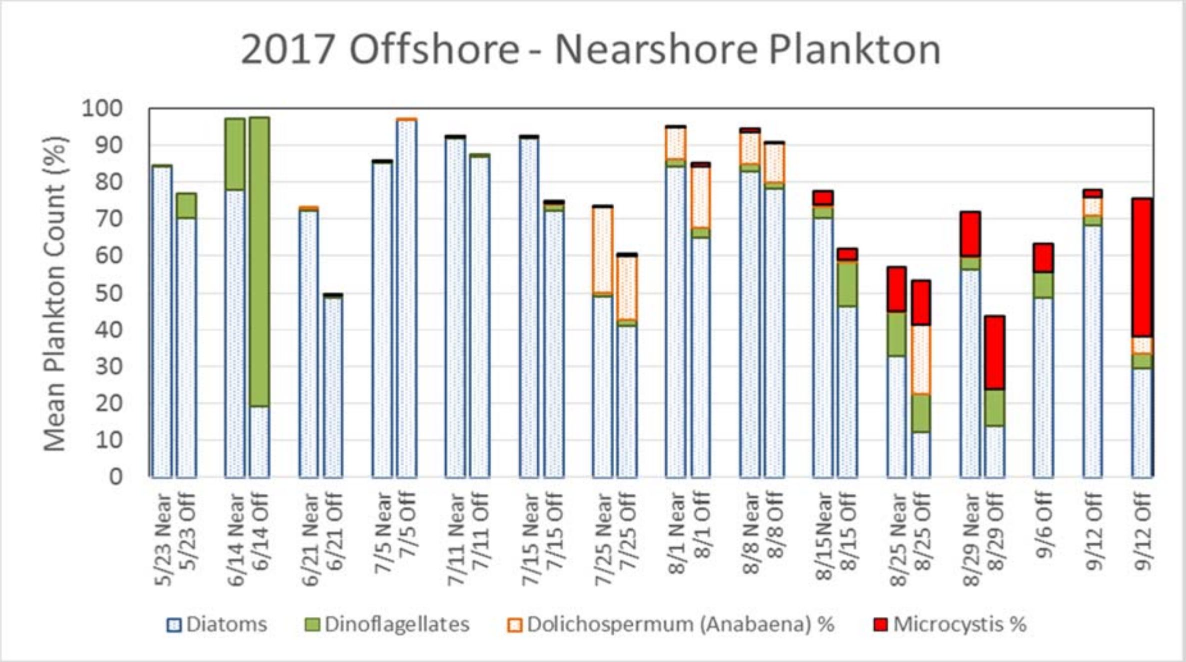

Fig. 9. Nearshore to offshore comparison of the plankton counts by dominant plankton groups.

DRONE FLIGHTS

Drone photographs mapped the distribution and aerial extent of algae and macrophytes along the shoreline (Fig. 10)[8]. The impact of numerous variables, e.g., glare from the sun, camera tilt angle, cloudiness, and extent and size of wind driven waves, still needs further investigation. Drone flights at 100 meters detected only a few of the shoreline BGA blooms. The shoreline blooms typically extended only a few meters from the shoreline into the lake, and were occasionally masked by the shade of trees, docks and other obstacles along the shoreline. Subsequent flights at lower altitudes (75, 50 and especially 25 m) however, did detect BGA blooms along the shoreline, concentrated in little indentations along the shore. Interestingly, those shoreline areas with larger BGA blooms also had more extensive shallow water shelves (< 4m depths), and larger populations of macrophytes.

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[8] Swete, B., Bradt, S., Halfman, J.D., I. Dumitriu, 2016. Exploratory drone research on water quality of the Finger Lakes. Rochester Academy of Science 43rd Annual Fall Conference.

Fig. 10. Spliced drone images from Burtis Pt on 6/18 (left), Burtis Pt from 100m altitude on 9/23 (top right) and Burtis Pt from 25 m altitude (bottom right). The BGA blooms are barely visible at 100 m but are visible from 25 m.

SEDIMENT ANALYSES

Total phosphorous mean concentrations in the sediments at each site ranged from 60 to 140 μg/g dry mud and did not reveal consistent offshore to nearshore trends (Fig. 11). These concentrations may be minimum values due to lab procedural challenges. Duplicate analyses detected some variability at each site, reflecting variability of the lake floor substrate, especially at Sites A and C. The larger sediment TP concentrations were large enough to support the typical BGA bloom, but only if a mechanism is available to release these nutrients bound to the sediments. Sand dominated the grainsize (>50% at A & C, > 80% at D, E and F) in the nearshore sites, whereas silt and lesser amounts of clay dominated the grainsize at the offshore sites (Fig. 11). Duplicate samples revealed substrate variability at Sites A and C. Lake-floor grainsize is a function of turbulence at each location. Large waves and other turbulent motions in nearshore areas (all depths touched by the warm epilimnion, i.e., shallower than ~10m) preferentially resuspend finer grained materials (e.g., silts and clays) and leave behind the coarser grained materials (e.g., sands, gravels and larger particles). The resuspended materials are eventually deposited in the deeper portions of the lake at depths below wave base where wave turbulence is absent.

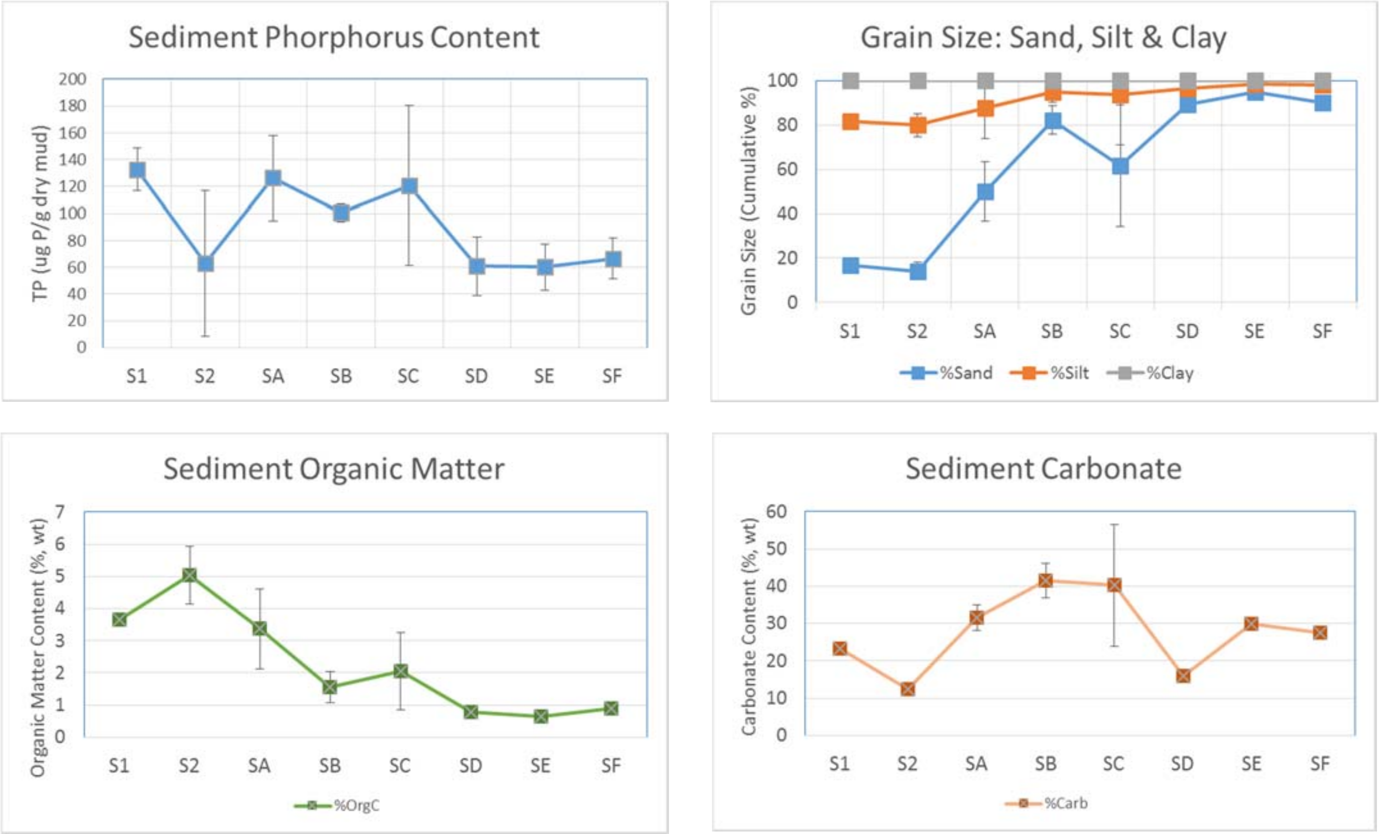


Fig. 11. Offshore (Sites 1 & 2) and nearshore (sites A-F) to comparison of sediment character, total phosphorus, organic matter, carbonate contents and grain size (sand, silt clay). The symbols plot the mean of every sample at each site. The whiskers extend to the mean values for individual sample dates.

The nearshore sites revealed less organic matter, 1 to 2 % wt., than the offshore sites, 3 to 5 % wt., with the largest variability at Sites A & C. The organic matter, once decomposed by bacteria, may also provide a source of nutrients to the water column, but only if a mechanism is available to release the nutrients bound to the sediments. Organic matter is typically attached to fine grained particles, e.g., clays, and thus preferentially accumulates with the clays, i.e., in the deeper portions of the lake. Finally, the nearshore sites typically revealed more carbonate, 30 to 40 % wt., than the offshore sites, 10 to 20 % wt., except for Site D at 16 % wt. The carbonate source typically is twofold, fine-grained precipitates associated with intense algal blooms and broken bits of zebra, quagga and other carbonate shells. Sediment variability at Sites A and C may reflect the lack of an extended nearshore shelf, and a large range of water depths near these sites. These sediment character distributions are typical of most lakes.

A suitable mechanism to release the phosphates in the sediments is not straightforward. Bacteria decompose (respire) organic matter in the sediments. The bacterial respiration consumes all of the oxygen from the upper centimeter or two of the sediment column. Bacteria continue to decompose the organics using other oxidants available in the sediments (e.g., reduced forms of Fe, Mn, S). This facilitates an upper, oxygenated, brown, centimeter-scale, sediment layer above the lower, anoxic, black sediments. The oxygenated cap is critical to phosphate mobility. The bacterial decomposition releases dissolved nutrients to the sediment pore waters. If the sediments are oxygenated, the phosphates typically precipitate with/in the sediments and stay buried in the mud. If the sediments are anoxic, phosphates remain dissolved and diffuse freely through the sediment pore waters. The anoxic phosphates typically diffuse upward and precipitate at or near the oxygen/no oxygen boundary. Thus, the boundary traps a potential sediment source of phosphates. If this boundary is disturbed, or in a eutrophic lake when the hypolimnion is anoxic, then phosphates freely diffuse into the water column fertilizing algal growth (i.e., internal nutrient loading). Two mechanisms provide access to these nutrients in nearshore areas where the water column is always oxygenated. Macrophyte roots tap into the anoxic sediments and utilize this sediment supply of nutrients for their photosynthesis. Waves and other turbulent motions can also disturb the oxygen/no oxygen boundary and release dissolved phosphates to the water column.

As an aside, as bacteria respire, oxygen can be quickly consumed where there are stagnant piles of weeds along the shoreline (or in a backyard compost pile). Once anoxic, bacteria then use other elements to respire the organic matter and release gases like hydrogen sulfide (rotten egg smell) and methane. This is why a stagnant pile of weeds along the shoreline, once disturbed, stink. A well-mixed, i.e., aerated, pile of compost does not stink. The aeration provides a continual supply of oxygen for respiration.

NEARSHORE TEMPERATURES

Mean, daily, surface water temperatures revealed consistent temperature records among the nearshore data loggers (deployed at 1 m) and the surface water (1m) temperatures detected offshore by the buoy (Fig. 12). This indicates consistent thermal changes across the surface of the lake. Interestingly, the July and early September shoreline BGA blooms were preceded by lake-wide, multi-day, decrease (~1°C) in temperature. Temperature declines in the surface water result from cooler air and cloudier conditions, and/or wind events that generate waves and mix colder hypolimnetic water into the epilimnion. The buoy data confirm all three meteorological events happened just before the late July and early September blooms. Wave turbulence/mixing of the nutrient-rich hypolimnion and onshore winds/waves stirring/disturbing the nearshore sediments and macrophyte beds could have introduced additional nutrients to the shoreline locations and enabled algal growth. The sampled shoreline BGA blooms were detected when the winds became calm, and the BGA could float to the lake's surface forming a surface scum. The later September blooms occurred while water temperatures were increasing. However, these blooms happened when the lake was calm, perhaps utilizing the nutrients stirred up by earlier events, runoff od more nutrients, and/or by the bacterial decomposition of the algae in the earlier blooms. These results are consistent with those detected in earlier years. Mixing by wind/waves should only release nutrients at shallow-water (epilimnetic) depths because wave turbulence decreases exponentially with water depth and ceases by the base of the epilimnion (~15 m).

Not all temperature dips and subsequent calm weather resulted in BGA blooms, especially those earlier in the summer. The bloom absence at these times may reflect a lack of nutrients. Perhaps nutrients released by bacterial decay need more time and the summer's warmth to sufficiently increase the nutrient concentrations in the sediments to promote the BGA blooms, as bacteria are more prolific at decomposing organic matter in warmer conditions. This hypothesis outlines a direction for further study.

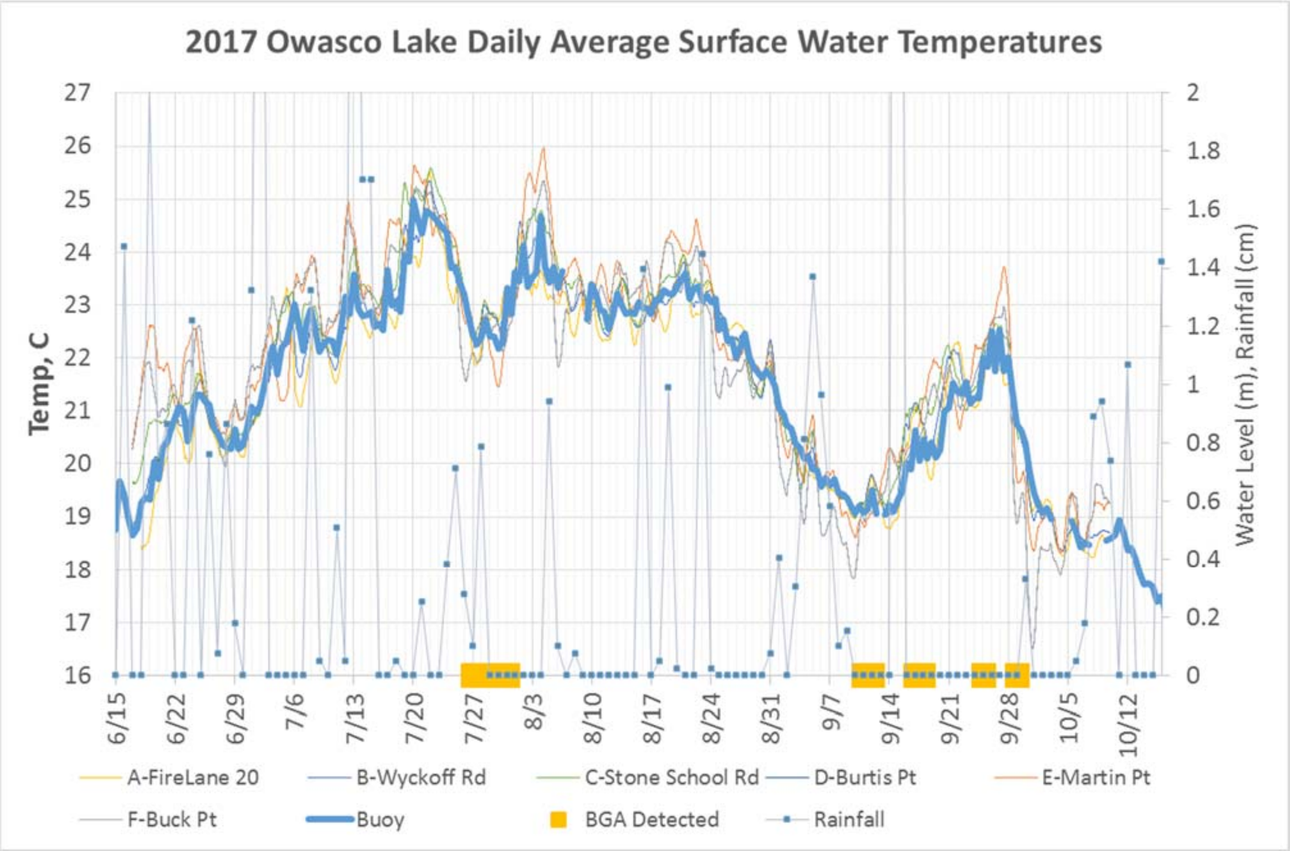


Fig. 12. Nearshore and buoy 1m water temperatures.

The mixing scenario is consistent with data recorded by a YSI/Xylem EXO2 water quality sonde deployed on a dock in Seneca Lake last fall (Fig. 13). This site experienced BGA shoreline blooms earlier in the year. When the wind blew onshore (e.g., 10/14, 10/15, 10/23, 10/24 & 10/28), the associated waves disturbed the sediments and made the water column turbid. The other strong wind events (e.g., 10/18 – 10/21) during the deployment were offshore, and waves moved away from this site and thus did not disturb the sediments and result in turbid water. More importantly, algal concentrations, both total and BGA concentrations, increased during and just after the nearshore, wave-induced turbulence. The turbulence probably stirred up any algae attached to the lake floor and any BGA resting within the sediments. These detected events did not result in significant algal blooms. The water during this October deployment was between 12 and 18°C, and perhaps too cold for sufficient bacterial generation of nutrients to promote a bloom. Nonetheless, perhaps BGA resting stage cells wait in the sediments for the right conditions, i.e., warm, calm and nutrient-rich waters, to bloom. This highlights the need to upgrade the temperature loggers on Owasco Lake to YSI/Xylem water quality EXO2 sondes, and deploy them with meteorological sensors at the Owasco nearshore sites to duplicate the Seneca experiment in Owasco Lake.

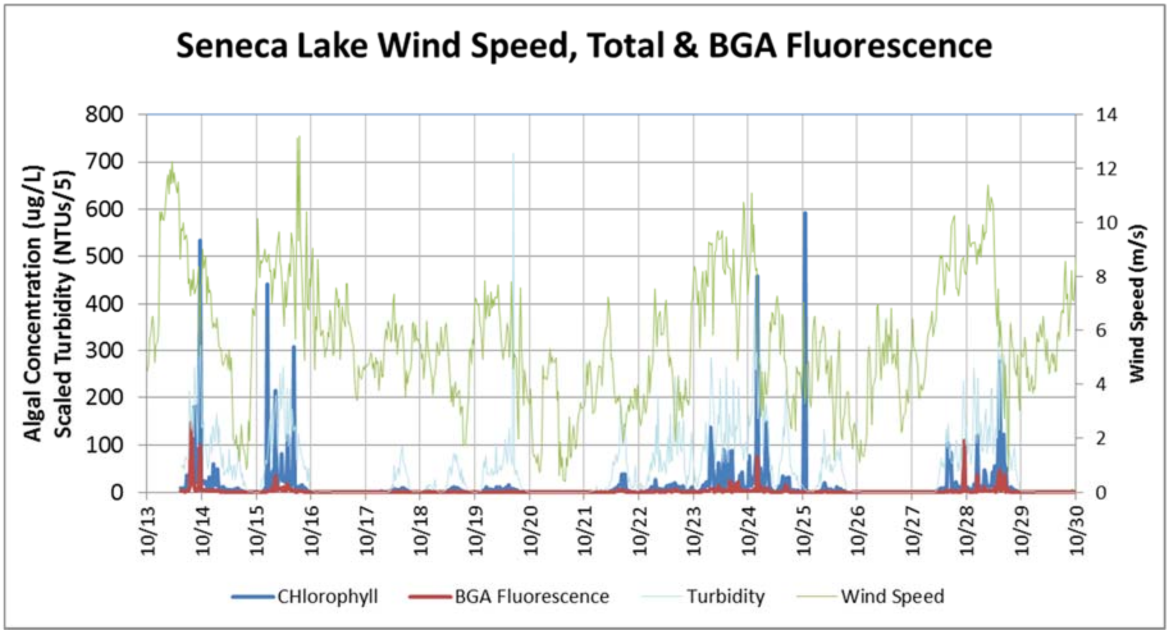


Fig. 13. Water turbidity, total and BGA fluorescence measured at a dock in Emerson Cove, Seneca Lake by a YSI EXO2 sonde. Wind speed was measured by the Seneca Lake monitoring buoy, just offshore of this shoreline location.

The magnitude of the largest BGA and TP concentrations are, at first glance, staggering. In the open water, algal and TP concentrations rarely exceed 10 to 20 μg/L. However, some of the measured BGA concentrations exceeded these "typical" concentrations by nearly 10,000 times. It is a limnological challenge to increase a localized algal population with nutrients or other growth stimulants by 10,000 times using normal ecological scenarios. Existing BGA can be concentrated into smaller volumes of water and are better adapted at nutrient utilization.

Two mechanisms have been suggested to concentrate algae into a smaller volume of water. First, when BGA buoyantly rise from deeper depths to the surface of the lake, they concentrate in smaller volumes of water. Second, light winds may push the surface scum of algae against the shoreline to accumulate and concentrate in smaller volumes of water. However, wind events and the associated waves typically break down surface algal accumulations and mix the BGA into the water column.

The nearshore data collected by this project suggested a third scenario is possible. The nutrients required to stimulate the bloom may be within the shoreline sediments waiting for a wind event to be released into the water column and promote a bloom. Once calm conditions prevail, the BGA float to the surface. The source of the nutrients was most likely bacterial decomposition of the sediment organic matter, like former BGA blooms, especially during the warmest days of the summer. In fact, the dead BGA are probably the easiest fraction of organic matter to decompose, perhaps recycling these nutrients in time for the next shoreline bloom. Sediment disturbance by wave action then liberates the nutrients to the water column and stimulated a BGA bloom along the shoreline. The surface scums then drift, at the mercy of surface currents. These possibilities provide another testable hypotheses to pursue next year.

In support of this hypothesis are the following observations. Once an area has a BGA bloom, it usually has additional blooms. BGA resting stage cells might provide this temporal linkage, as they are probably deposited into the sediments from the previous bloom, waiting for the next ideal mix of nutrient-rich, calm and warm waters to foster the next bloom. This wait and bloom scenario could also increase the BGA concentrations in the shoreline areas from one bloom to next and from one year to next as the sediment nutrient reservoir increases over time.

Fig. 14. A sediment plume from Veness Brook on 4-21-17 (image taken by Joe Leonardi, by permission).

Other sources of nutrients are available in and/or are released to nearshore locations. For example, macrophyte roots tap directly into the sediment nutrient supply, and the plants release nutrients to the water column. Once the plant dies, bacterial decomposition releases the nutrients sequestered by the plants to the water column as well, especially downwind where the unrooted, decomposing plant matter accumulates due to wave action. It opens the possibility that perhaps BGA blooms wait until late summer for this additional source of nutrients, as the largest blooms occurred after the first plants began to die in 2017. Zebra & quagga mussels provide another source of organic matter to the nearshore sediments. The mussels filter feed on algae, "poop" undigested organics to the sediments, and thus transport open-water algal biomass and their nutrients to nearshore areas. Asian clams are a source of nutrients to the water column as well. Finally, heavy rains, especially those during spring, create plumes of nutrient-rich sediment in the lake and some of the sediments are deposited along the shoreline (Fig. 14). Exactly where the plume travels depends on the relative density of the plume and the lake, and the direction of the wind-driven, surface currents.

BUOY DATA

Scientists have generalized that BGA blooms prefer the following conditions:

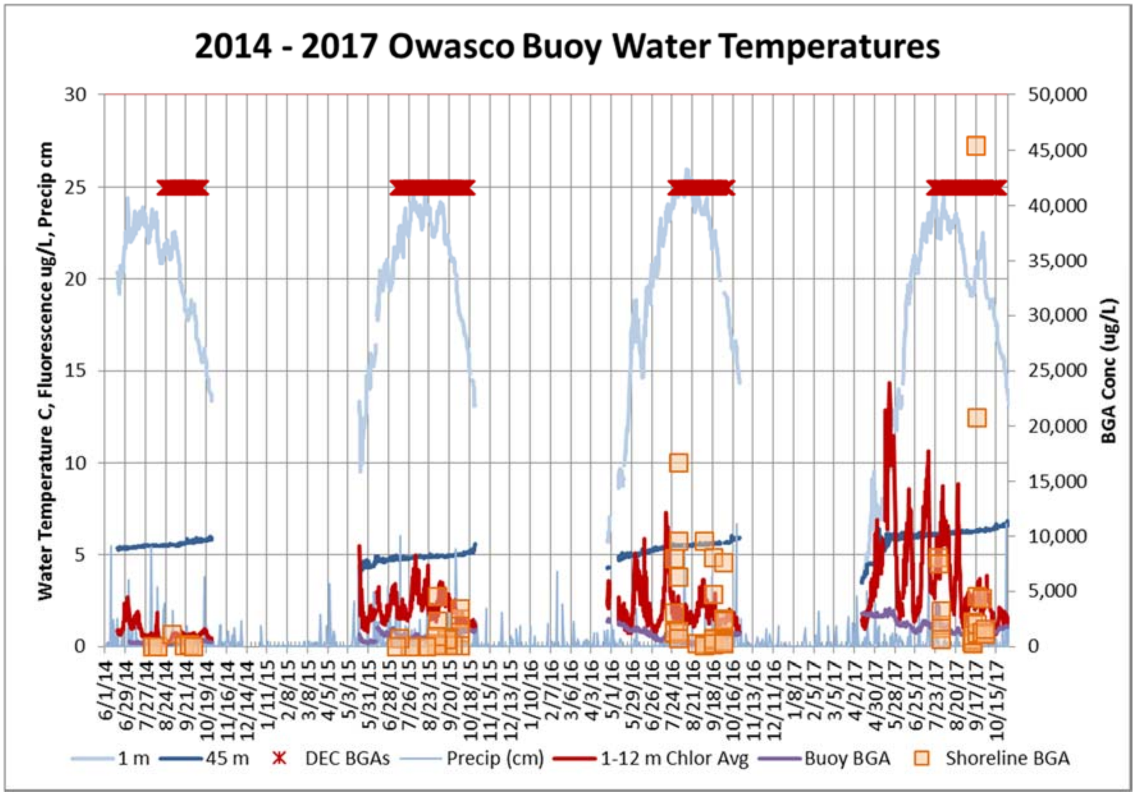
- warm water, temperatures between 15 to 30°C (60 and 80° F);
- elevated (eutrophic) concentrations of nutrients, especially waters rich in phosphorus, the limiting nutrient for many BGAs;
- light levels that are sufficient for photosynthesis and growth;
- lake stratification, as BGA buoyancy regulation provides a competitive edge in a warm, stratified water column;
- calm or near-calm conditions as turbulence disrupts BGA buoyancy and light limits their growth;
- rainfall, as rain events deliver nutrients to the lake; and,
- and perhaps pH.

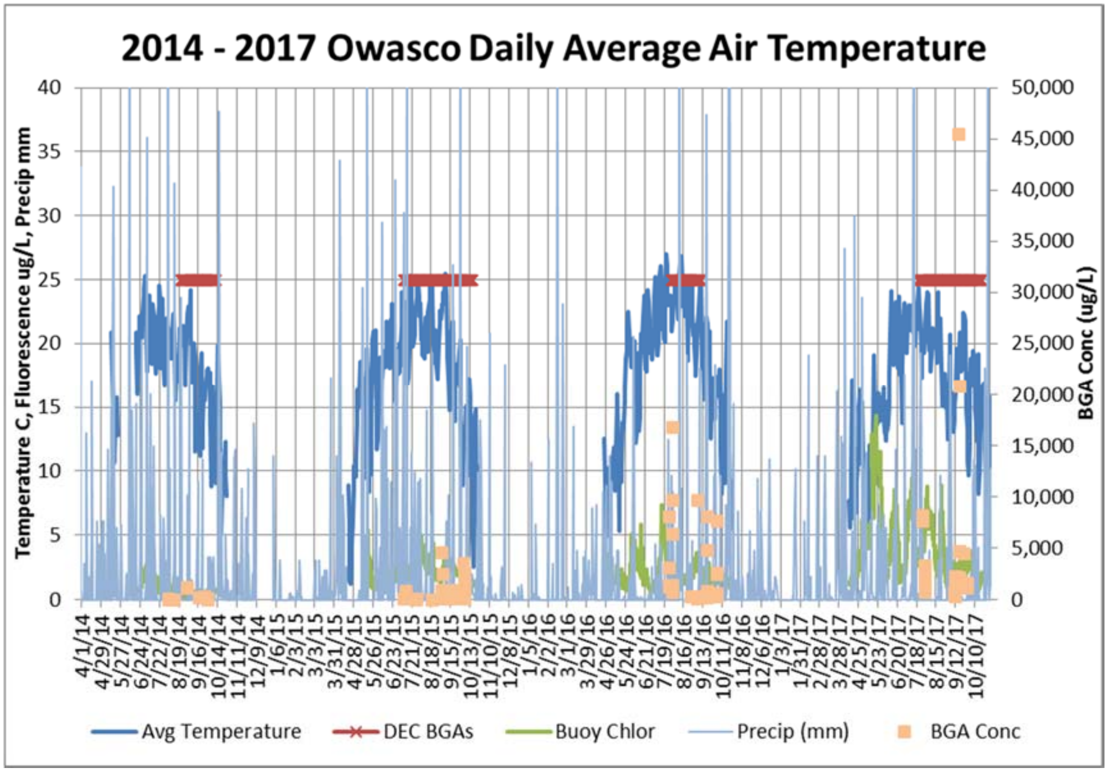
However, predicting their occurrence remains a challenge due to the large number of BGA species and the diversity of their habitats. BGA blooms in the Finger Lakes are a larger challenge because most of these lakes are oligotrophic or mesotrophic systems, and not the nutrient-rich, eutrophic lakes that BGA blooms were more commonly detected a decade ago.

The last four years of buoy data shed some light on the occurrence and development of BGA blooms in Owasco Lake (Fig. 15). These figures plot the buoy's mean epilimnetic total algal and BGA fluorescence, average surface and bottom water temperatures, mean daily air temperatures, mean daily available sunlight, and mean daily wind speeds from 2014 through 2017. Each plot also reveals how many weeks Owasco Lake was on DEC's notification list, the BGA concentrations at shoreline areas collected by the Watershed Inspector, FLI or the public, and daily rainfall totals to look for any obvious correlations (or lack thereof).

Buoy Total Algae and BGA Fluorescence: Minimal correlations were observed between the buoy fluorescence data and the nearshore BGA occurrence and concentration data (Fig. 15). The lack of a correlation is not disturbing because the buoy measures open water parameters, and the bulk of the BGA blooms were at shoreline locations, especially those with large concentrations. In fact, it highlights the need for a unique and larger shoreline nutrient source to foster the shoreline BGA blooms. The buoy detected consistently larger algal concentrations and more frequent offshore blooms from 2014 through 2017.

Buoy Lake Temperature: In all four years, BGA blooms occurred in warm water, 22 or 23°C (70 – 75°F, Fig. 15). However, the 2014, 2016 and 2017 blooms did not appear until a week or two after the warmest water was detected, indicating that warm water by itself does not trigger bloom activity. The warm water does promote faster bacterial decomposition of the nearshore sediment organic matter, however and the time lag may reflect the time required for bacterial decomposition. Blooms did not reappear after the surface water cooled below 15°C (60°F).




2014 - 2017 Owasco Daily Average Air Temperature
Temperature C, Fluorescence ug/L, Precip mm
BGA Conc (ug/L)
0
5
10
15
20
25
30
35
40
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
4/1/14
4/29/14
5/27/14
6/24/14
7/22/14
8/19/14
9/16/14
10/14/14
11/11/14
12/9/14
1/6/15
2/3/15
3/3/15
3/31/15
4/28/15
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6/23/15
7/21/15
8/18/15
9/15/15
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4/26/16
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6/21/16
7/19/16
8/16/16
9/13/16
10/11/16
11/8/16
12/6/16
1/3/17
1/31/17
2/28/17
3/28/17
4/25/17
5/23/17
6/20/17
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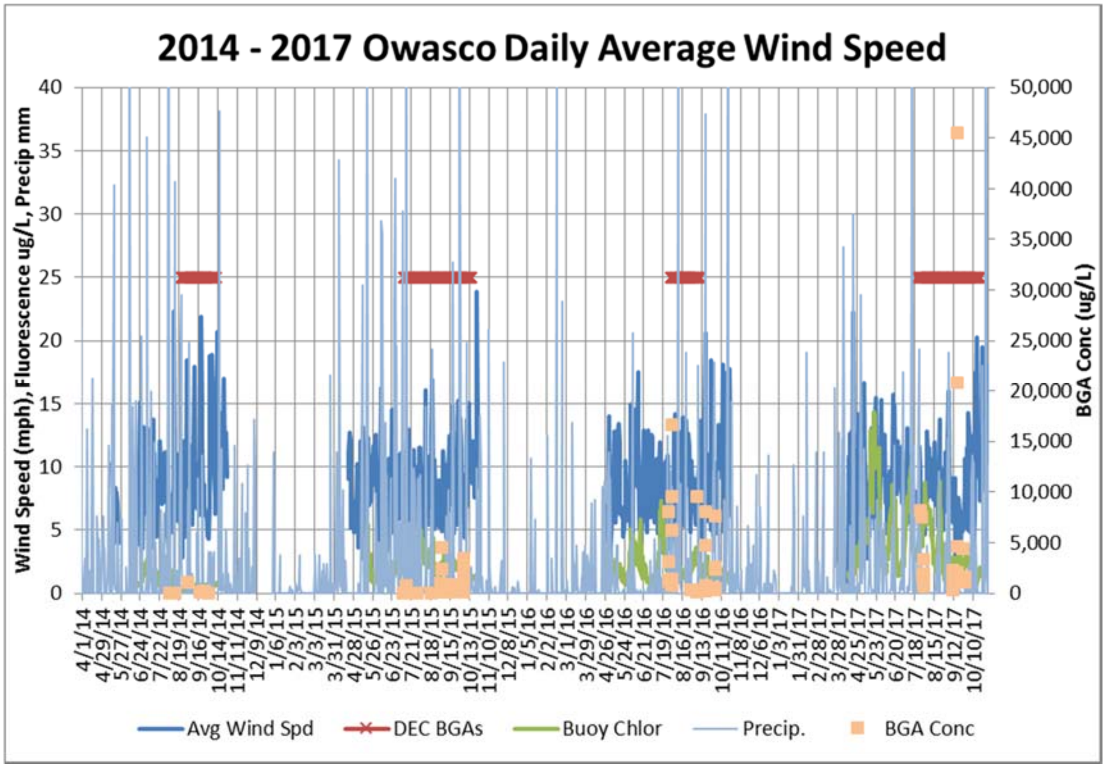
Avg Temperature
DEC BGAs
Buoy Chlor
Precip (mm)
BGA Conc


2014 - 2017 Owasco Daily Average Wind Speed
Wind Speed (mph), Fluorescence ug/L, Precip mm
BGA Conc (ug/L)
0
5
10
15
20
25
30
35
40
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
4/1/14
4/29/14
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12/6/16
1/3/17
1/31/17
2/28/17
3/28/17
4/25/17
5/23/17
6/20/17
7/18/17
8/15/17
9/12/17
10/10/17
Avg Wind Spd
DEC BGAs
Buoy Chlor
Precip.
BGA Conc

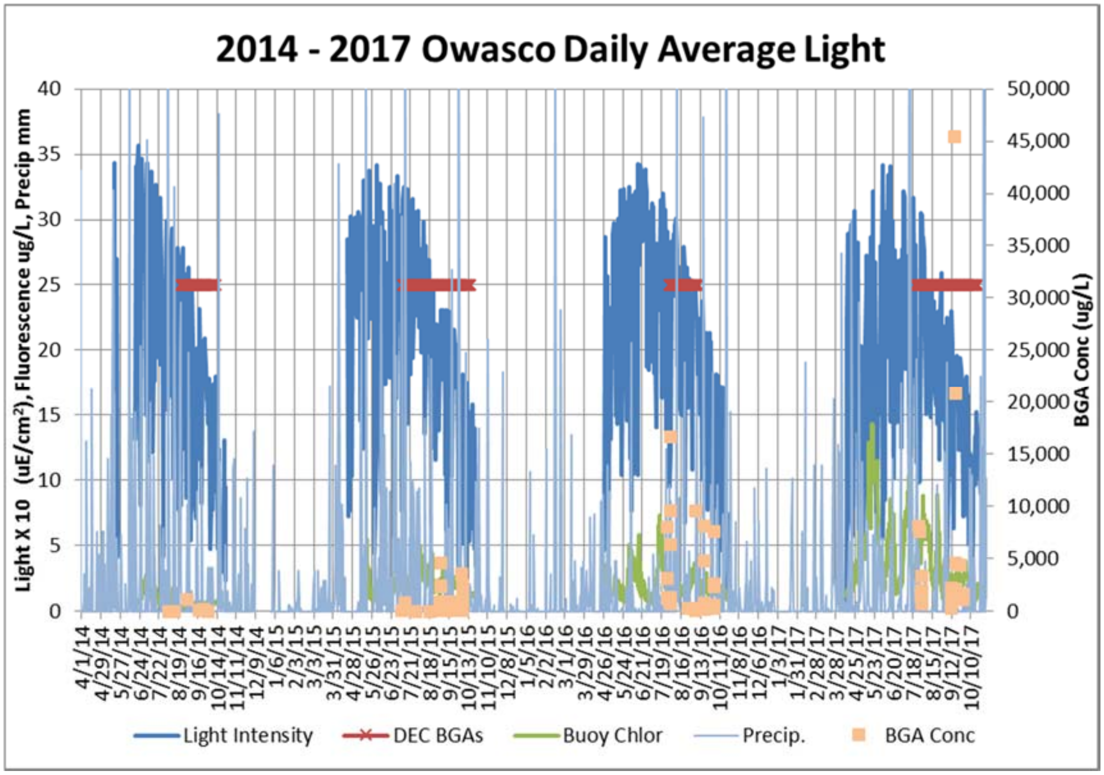

Fig. 15. Four years of water temperature, total and BGA fluorescence, and daily mean air temperature, wind speed and light intensity data. The weeks Owasco Lake was on DEC's notification web site, the measured concentration of shoreline BGA blooms and daily precipitation totals are also shown.

Buoy Air Temperature: Like water temperatures, the BGA blooms occurred at or a few weeks after peak (23 to 24°C, 70-75°F) air temperatures (Fig. 15). Blooms did not reappear after air temperatures cooled below 10°C (50°F). Thus, blooms prefer warm air and water temperatures, and are terminated by cold air and water temperatures. The parallel nature for air and water temperatures is not surprising because both air and water temperatures are linked to and ultimately forced by changes in solar insolation.

Buoy Sunlight Intensity: The first BGA blooms for the season happened after summer solstice, and BGA blooms were no longer detected when daily average insolation (sunlight) decreased below 150 μE/cm^2 (Fig. 15). Warmest water and air temperatures also peaked after summer solstice and all three peaked before the BGA blooms. Lower light levels might favor BGA blooms because BGA can float closer to the lake's surface, water depths with more light. However, blooms were not pervasive throughout the late summer and early fall. Thus, solar intensity, air and water temperatures were associated with but not the sole trigger for a bloom.

Rainfall: In all four years, BGA blooms appeared after a rain storm (Fig. 15). It suggests that the rainfall and associated storm induced runoff brought in nutrients to help stimulate a bloom or disturbed the lake sediments and facilitated nutrient release and transfer from the anoxic sediment layer. Wind/wave turbulence scenario also suggests that the storm's winds stir up the sediments and release nutrients to the water column to foster bloom development. Interestingly, the algae appeared to "wait" for the subsequent calm, sunny day after the rain event to bloom. In support, the bloom activity in 2016 was absent until mid-August, and only detected after the first rain events, late in the summer season. The decreased spring and summer rainfall in 2016 compared to 2014 and 2015 suggests that high annual rainfall totals, “wet” years, are not important for individual bloom genesis. However, the significant spring rains of 2014, 2015 and again in 2017 with their associated nutrient/sediment loads may have provided enough nutrients to the lake to trigger the intermittent BGA blooms along the shoreline in Owasco and all other Finger Lakes during the past four years.

Buoy Wind Speed & Direction: The summers of 2015, 2016 and 2017 were not as windy as 2014, especially when BGA blooms were detected (Fig. 15). The mean daily wind speeds in 2015, 2016 and 2017 were at or below 10 mph (small waves) with only a few days with wind speeds above 15 mph (large waves with white caps). 2014 had fewer calm to light-breeze days and multiple days with wind speeds above 15 mph. This suggests that BGA bloom development is more likely during calm or light-breeze days. However, BGA blooms are not detected on every available calm or nearly calm day, so calm days by themselves are not the sole trigger for BGA blooms. Winds above 20 mph (very large waves with white caps) coincide with the end of the bloom activity in 2015, 2016 and 2017 but not 2014. Larger wind speeds probably mixed any BGA throughout the epilimnion and towards open water resulting in decreasing BGA concentrations and disruption of a surface bloom.

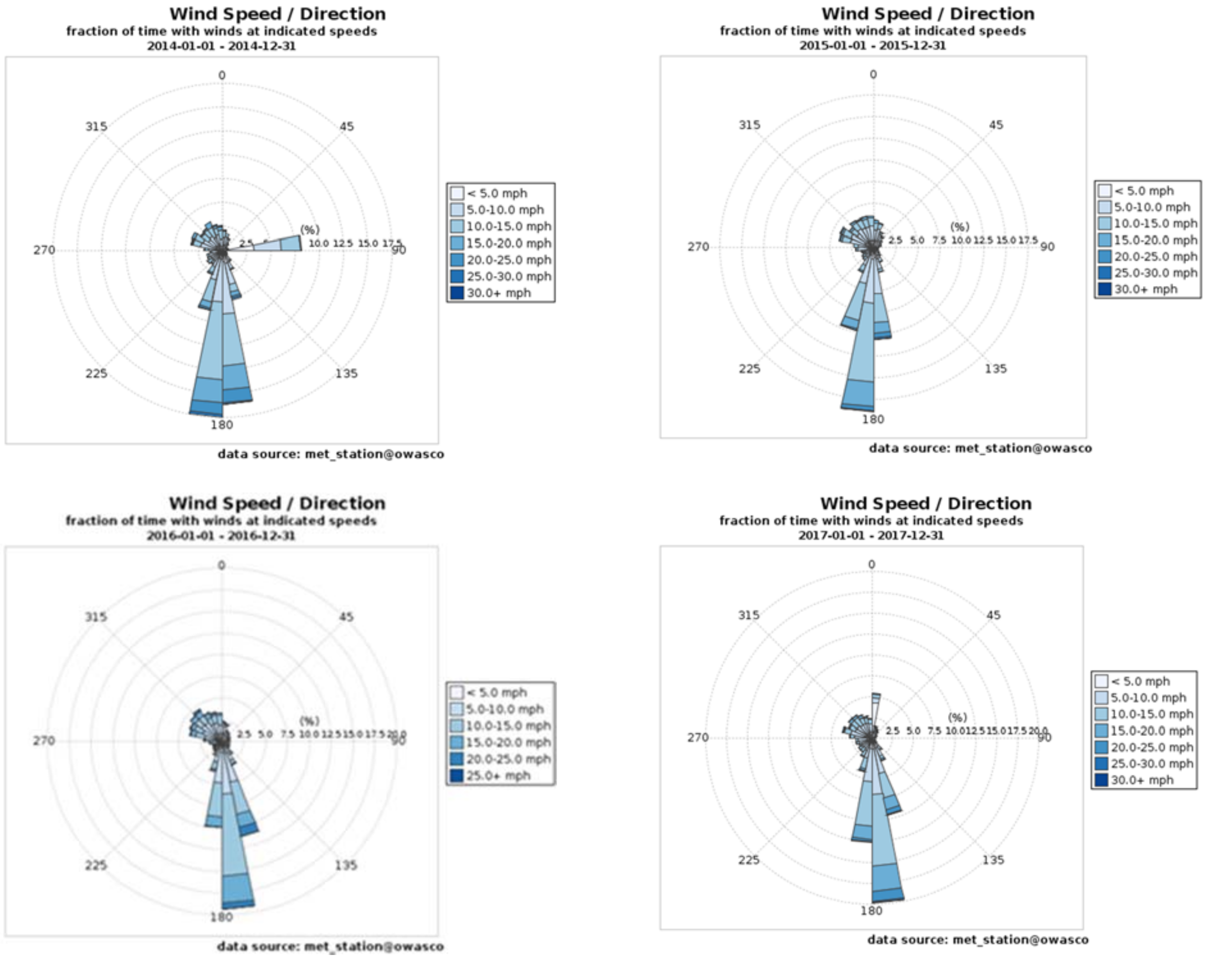

Fig. 16. Wind rose diagrams showing frequency of wind direction and speed for 2014 (upper left), 2015 (upper right), 2016 (lower left) and 2017 (lower right) from the Owasco Lake buoy.

The dominant wind direction measured at the buoy was from the south, with the next common wind directions from the west and northwest over the past four years (Fig. 16). These directions are consistent with the majority of the BGA detections along the northern and northeastern margins of Owasco Lake (Fig. 1). A similar BGA lakeshore bloom distribution and wind direction connection has been observed in Seneca Lake. Perhaps the winds concentrated decaying macrophyte and other organic matter along the downwind shoreline to be decomposed by bacteria and the recycled nutrients stimulated the next round of BGA activity.

These observations/correlations and their coincident with BGA blooms does not mean causation. These associations also lacked a consistent and unique event to trigger the large blooms detected since 2014, as previous summers also experienced calm sunny days after some rain near the end of the summer but lacked intense BGA blooms. This indicates the importance of the significant rain events and the associated nutrient delivery during 2014 and 2015 to initiate the intense blooms, and the additional rain events in 2017 triggered an increase in the bloom concentrations.

Do not lose sight of the bigger picture! The focus should not only be predicting blooms and understanding their ecology but more importantly eliminating blooms from the lake. The ultimate means to limit any algae bloom is to limit nutrients in the lake and remove and/or remediate nutrient sources in the watershed.

MUSSEL AND BIOTA DATA

SCUBA sampling found more zebra than quagga mussels at all sites. Site D had the highest total number of both zebra mussels and quagga mussels (Fig 17 & Fig 18). Additionally, while all three sites had similar numbers of quagga mussels found in the 0-8mm range, Site D showed an average of 19 in the 15-22 mm size range per quadrant (Fig. 18). Site C had an average of 1 quagga mussel in the 15-22 mm size range while Site F had zero (Fig. 18). Site D had more plant biomass collected during SCUBA sampling than Site C and Site F (Fig. 19). In addition, Site D had over 4 times greater mass of mussels collected than Site C and Site F (Fig 19).

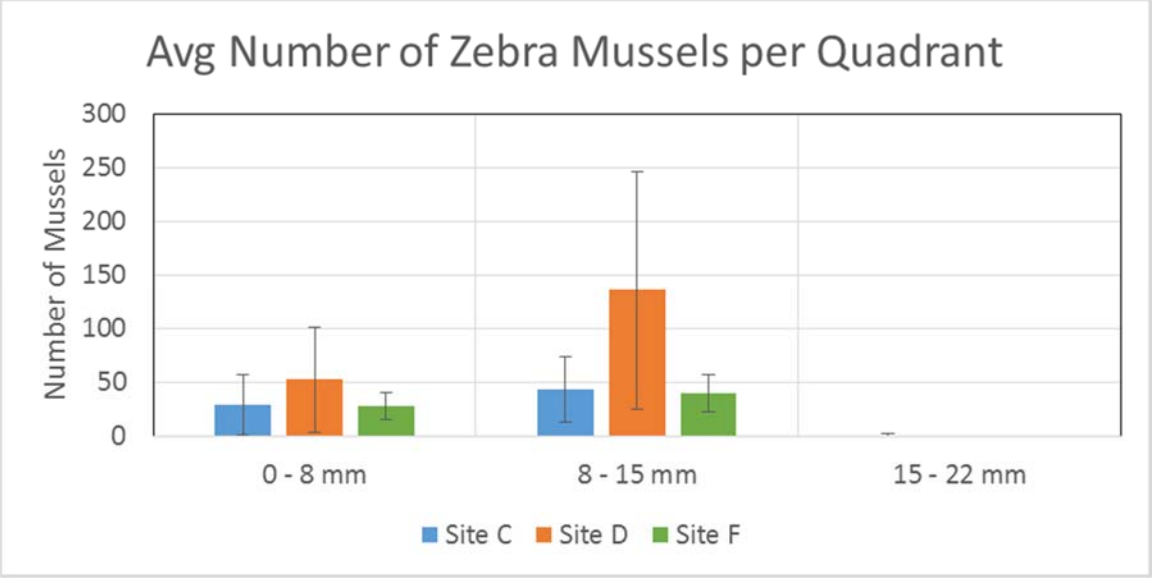

Fig. 17. The average number of zebra mussels found in triplicate $0.25m^2$ quadrat at sites C, D and F on Owasco Lake.

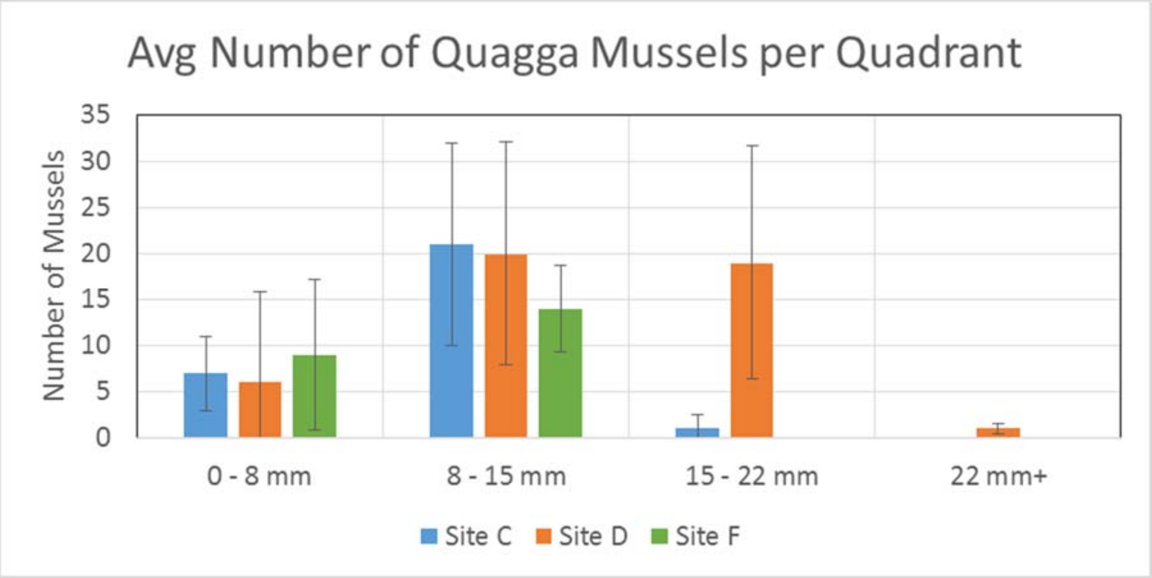

Fig. 18. The average number of quagga mussels found in triplicate 0.25m^2 quadrat at sites C, D and F on Owasco Lake.

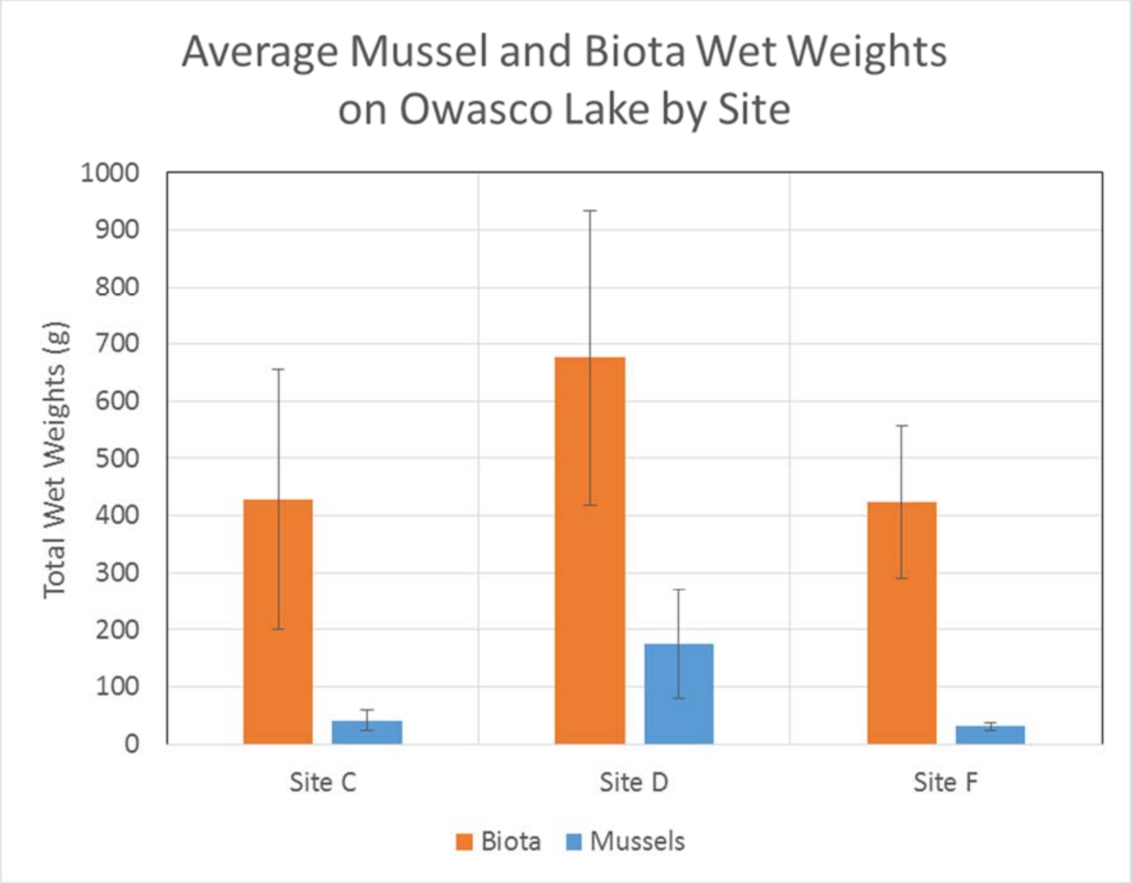

Fig. 19. The average mussel (shell included) and biota wet weights from sites C, D and F on Owasco Lake. Biota included plants and detritus including epiphytic algae and dreissenid shell fragments,

When collecting the SCUBA samples, most of the mussels present in any given quadrat were attached to the plant material. Site D had notably more plant material than the other sites, possibly contributing to the larger number and wet weight of mussels. Plant material provides a reliable substrate for mussels to bind to, significantly adding to the surface area provided by the sediment and rocks below on the lake floor.

The type of plants varied among the sampling sites. Sites D and F were nearly 100% represented by chara (*Chara spp.*), a macroalgae, while Site C contained mostly horned pondweed (*Zannichellia palustris*) with a small amount of elodea (*Elodea canadensis*). While removing the mussels from the plant material, the horned pondweed (*Zannichellia palustris*), typically had a significant number of 4-8 mm and 8-15 mm zebra mussels in a line along the stem of the plant. While ultimately the total number of zebra mussels present appeared to be quite similar for almost all sites and categories regardless of the dominant plant, it is likely that different species of plants and macroalgae provide differences in substrate quantity and quality. In the future, it would be valuable to study how mussel populations attach to different plant materials and if there is a discernable difference beyond a visual observation.

In addition to SCUBA sampling, 12 weekly rake tosses were performed at each site in order to assess changes to the plant community over time. At the nearshore sites, eleven species of plants were sampled at least once: Eurasian watermilfoil (*Myriophyllum spicatum*), eelgrass (*Vallisneria americana*), elodea (*Elodea canadensis*), chara (*Chara spp.*), horned pondweed (*Zannichellia palustris*), starry stonewort (*Nitellopsis obtusa*), curly leaf pondweed (*Potamogeton crispus*), leafy pondweed (*Potamogeton foliosus),* coontail (*Ceratophyllum demersum*), water stargrass (*Heteranthera dubia*), and brittle naiad (*Najas minor*).

- Site A consistently contained Eurasian watermilfoil (*Myriophyllum spicatum*), eelgrass (*Vallisneria americana*) and curly leaf pondweed (*Potamogeton crispus*), but all eight species were sampled at least once.
- At Site B, chara (*Chara spp.*), eelgrass (*Vallisneria americana*), and horned pondweed (*Zannichellia palustris*) were sampled at least 8 of the 12 weeks. Eight species were sampled in total.
- Site C demonstrated change over time. Early samples were dominated by elodea (*Elodea canadensis*), horned pondweed (*Zannichellia palustris*) and curly leaf pondweed (*Potamogeton crispus*) and this assemblage gave way to chara (*Chara spp.*), starry stonewort (*Nitellopsis obtusa*). All eight species were sampled at Site C at least once.
- Site D was typically dominated by chara (*Chara spp.*), but each of the 5 August sampling also showed Eurasian watermilfoil (*Myriophyllum spicatum*). In total, six species were collected at least once from Site D.
- Site E was the least diverse of the nearshore sites. Chara (*Chara spp.*) represented 100% of the sample in 8 of the 12 weeks. Only three species were collected at least once at Site E.
- Site F was consistently dominated by chara (*Chara spp.*). Seven species were collected at least once at Site F.

Only chara (*Chara spp.*) was sampled at every site at least once. Eurasian watermilfoil (*Myriophyllum spicatum*), horned pondweed (*Zannichellia palustris*), starry stonewort (*Nitellopsis obtusa*), and curly leaf pondweed (*Potamogeton crispus*) were all sampled at five of the six nearshore sites. Leafy pondweed (*Potamogeton foliosus*), water stargrass (*Heteranthera dubia*), and brittle naiad (*Najas minor*) all only appeared in the samples one time.

2017 HIGHLIGHTS & RECOMMENDATIONS:

Highlights of the 2017 Report

- Annual mean shoreline BGA bloom concentrations steadily rose from 2014 through 2017. Many of the shoreline blooms contained life-threatening concentrations of toxins, both microcystins and anatoxins in 2017.
- In contrast, BGA concentrations were small at the open-water sites, typically much smaller (up to 10,000 x's smaller) than the nearshore blooms.
- Lakeshore owners that draw drinking and/or bathing water from the lake need affordable mechanisms (or financial support) to reduce their risks from the BGA toxins.
- The 2017 research highlighted a number of interesting observations/hypotheses to test in 2018 and 2019. These include:
  - The relationship between wind events and the hypothesized release of nutrients from the shoreline sediments.
  - The relationship between the extent and type of macrophytes at nearshore regions and the occurrence of BGA blooms.
  - The quantity and quality of organic matter in the shoreline sediments and its hypothesized relationship to bloom activity.
  - The bioavailability of the organic matter in the sediments.
- Funds to purchase and deploy water quality sondes and meteorological suites at a number of shoreline locations to help investigate the wave-turbulence-nutrient release hypothesis will be pursued. They are not cheap. Commercially available sondes are ~$15,000/each. The interface to near real-time display of the data on the web is much more.

Remediation Recommendations

- Bubblers, ultrasonic vibrators, benthic mats and other in-lake strategies might provide stop-gap measures to reduce the extent of the BGA blooms until the nutrient loading issue is resolved. NEVER use herbicides because Owasco Lake is a drinking water source, and herbicides are also toxic to humans.
- Nutrients should also be removed from the lake, when feasible, especially from along the shoreline. For example, macrophytes should be harvested from the nearshore areas in the late summer before they start to die and decay. Those macrophytes and attached algae that wash up along the shoreline should be gathered before they decompose completely. The BGA surface blooms should be vacuumed from the water before they disappear. All of the removed organic material could be composted, and not allowed back into the lake.
- Ultimately, the nutrient loading issues in the watershed MUST be resolved and the lake placed in a negative nutrient loading balance for a number of years before these issues go away. The Cayuga County Water quality monitoring report addresses a number of nutrient loading reduction strategies, so they are not duplicated here.

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