2019 Long Island Sound Hypoxia Season Review

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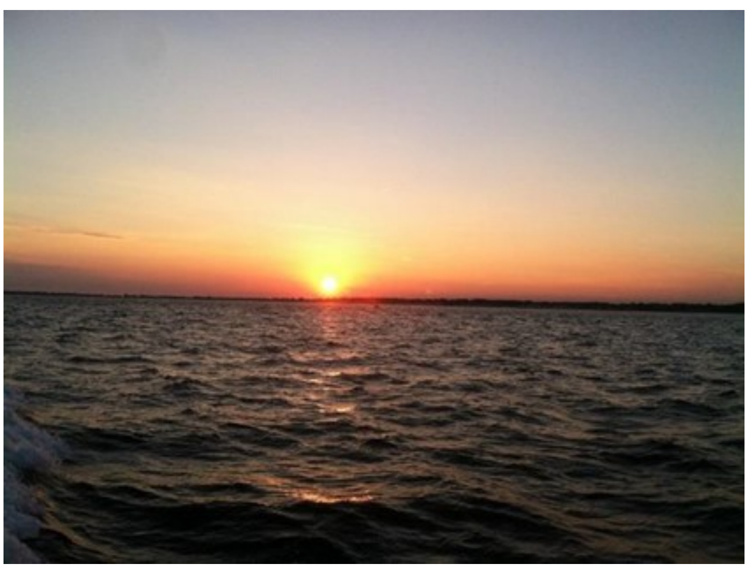
Introduction

Designated as an estuary of national significance by Congress in 1987, Long Island Sound (LIS) is home to a diverse network of flora and fauna, with over four (4) million people living in the Sound's coastal communities. It is an estuary of recreational, commercial, and socioeconomic value. The Sound is bordered by the states of Connecticut and New York and has a watershed area extending through Massachusetts, New Hampshire, Vermont, Maine, and Quebec that encompasses over 16,000 square miles. Nearly nine (9) million people live within the watershed. Over time, the Sound has been subject to the effects of increased stress, including nutrient loading, as a result of changes in land use , especially urbanization, habitat alterations, and climate change (Latimer *et al.*, 2014).

The term "hypoxia" means low dissolved oxygen (DO) concentrations in the water. Marine organisms need oxygen to live, and low concentrations, depending on the duration and the size of the area affected, can have serious consequences for a marine ecosystem. As defined by the Long Island Sound Study (LISS), hypoxia exists when DO drops below a concentration of 3 milligrams per liter (mg/L), although ongoing national research suggests that there may be adverse effects to organisms even above this level. Nutrients, especially nitrogen, fuel the growth of microscopic algae called phytoplankton in the Sound. The phytoplankton die and settle to the bottom. Bacteria break down the organic material from the algae for food and fuel while using up oxygen. Seasonal weather patterns, particularly during the summer months, exacerbate the effects of nutrient loading. Calm weather patterns limit the mixing of the water column and replenishment of oxygen to the bottom waters, resulting in a decrease in bottom water DO over the course of the summer. Hypoxic conditions are mainly confined to the western Sound.

In response to the critical need to document summer hypoxic conditions in Long Island Sound, the Connecticut Department of Energy and Environmental Protection (CT DEEP) and the Interstate Environmental Commission (IEC) have monitored dissolved oxygen, as well as other key water quality parameters relevant to hypoxia, since 1991. This report presents a summary of data collected by CT DEEP and IEC during the 2019 hypoxia season.



Methods Overview

Since 1991, CT DEEP has conducted an intensive year-round water quality monitoring program on LIS. In situ physico-chemical parameters, nutrient samples, and plankton samples are collected monthly from 17 sites on a year-round basis. Beginning in mid-June and extending through mid-September, an additional survey is added that samples up to 48 stations every other week for physico-chemical parameters (Figure 1).

IEC has conducted summer season monitoring in the far Western LIS (WLIS, Figure 1, map inset) and the Upper East River since 1991. Since 2014, IEC's monitoring program has implemented modifications, including the collection of nutrients, to align it with CT DEEP's program. IEC collects physico-chemical data from 22 stations weekly along with nutrient data biweekly (Figure 1). Beginning in October 2018, IEC expanded its WLIS monitoring program to sample year-round.

The Long Island Sound Integrated Coastal Observing System (LISICOS) was established in 2003 as a component of a regional/national ocean observing system. The system was conceptualized as part of a water quality monitoring program that combined the traditional ship-based point sampling surveys with continuous, real-time sampling stations. LISICOS continuously monitors in situ water quality parameters and meteorological parameters at up to eight stations across the Sound. Sensors are attached to moored buoys at surface, middle, and bottom depths. Data are transmitted every 15 minutes in real-time via satellite where they are stored in a database and uploaded to the LISICOS website. The system is maintained by the University of Connecticut.

CT DEEP and IEC data provide a snapshot of hypoxic conditions during a specific timeframe while the LISICOS data provide a continuous measurement of hypoxia at specific buoy locations. Together, these monitoring programs are better able to characterize the extent and duration of hypoxia across LIS. Both types of data contribute to a better understanding of hypoxia in LIS.

Further information on sampling and analytical methods for water quality parameters can be found in the EPA-approved DEEP, IEC, and LISICOS Quality Assurance Project Plans.

Dissolved oxygen data from 13 of IEC's 22 stations and all of CT DEEP's stations are incorporated into hypoxia maps to provide areal estimates presented in this report. The 13 IEC stations (A1, A2M, A3, A4, HA-3, HB, A5, HC1, HC, B1S, B2, B3M, B4) represent open water portions of the Western Narrows. DO data collected from IEC's embayment stations are not utilized in areal estimates.

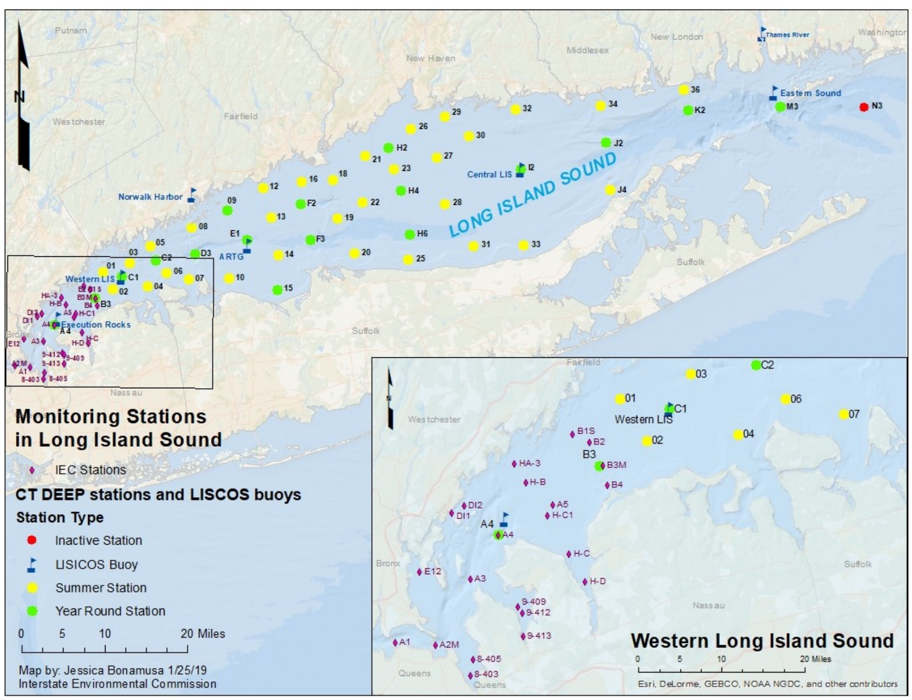


Figure 1. Hypoxia Monitoring Stations in Long Island Sound

CT DEEP collects monthly surface and bottom water samples from ten stations (Figure 2) distributed across LIS for phytoplankton community analyses. Stations were chosen to examine the "spatial distribution and temporal dynamics of phytoplankton population structure and diversity in LIS" as well as to "investigate the potential contribution of the settlement of the phytoplankton materials from the surface water to hypoxia/ anoxia in the bottom water" (Zhang and Lin 2018). CT DEEP also collects monthly composite water samples and conducts oblique plankton tows from six stations (triangles, Figure 2) for zooplankton community analyses. Samples are processed and analyzed by researchers with the Marine Sciences Department at the University of Connecticut. Collection methods and processing methods are available in EPA approved Quality Assurance Project Plans. Results are detailed in project reports submitted to CT DEEP annually. Results from 2019 are not yet available.

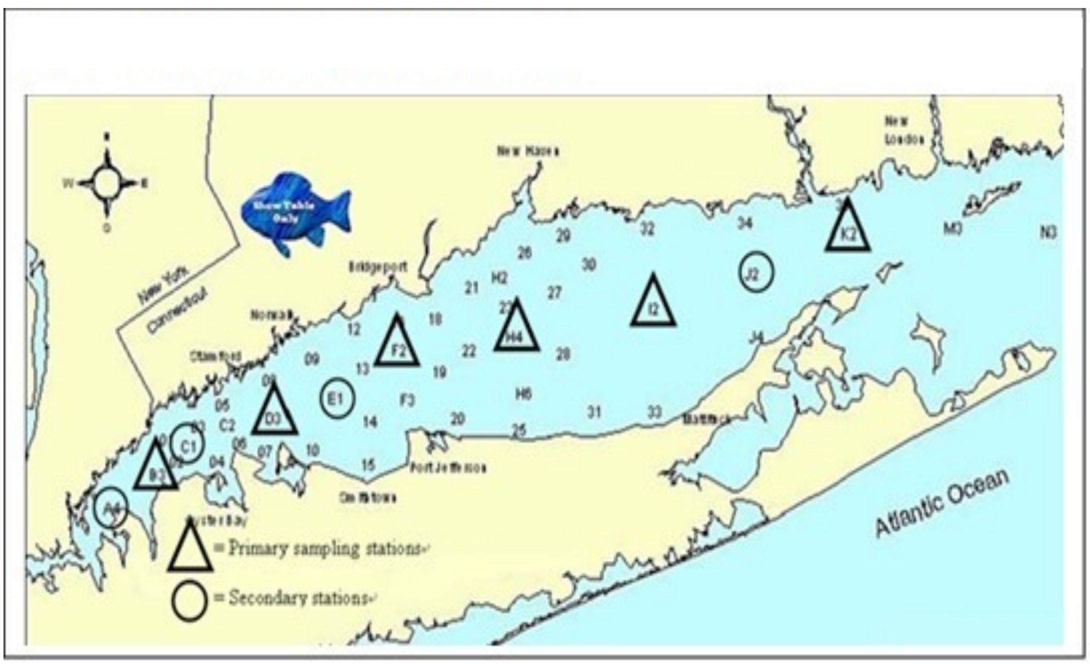


Figure 2. Location of Plankton Sampling Stations across Long Island Sound.

Triangles= zooplankton and phytoplankton locations Circles = phytoplankton locations

Quality Assurance

The IEC and CTDEEP have been collecting data from the Sound since 1991. Both IEC and CTDEEP programs are designed to collect high quality data. IEC and CTDEEP sample collection and handling procedures are outlined in EPA-approved Quality Assurance Project Plans (QAPPs) and method-specific standard operating procedures (SOPs, see Methods section for hyperlinks to program quality assurance documents). Shared program goals include maintaining a long-term database of collected information and monitoring the extent of hypoxia within the Sound throughout the summertime (late June through mid-September) to assess achievement of the Comprehensive Conservation and Management Plan (CCMP) for restoring LIS.

Primary measures of data quality include completeness, representativeness, and comparability. IEC and CT DEEP met data quality objectives for completeness, representativeness and comparability as specified in their respective QAPPs. Station locations for both programs were chosen to be representative of ambient conditions Sound-wide. Since the expansion of IEC's program to year-round monitoring in the fall of 2018, both programs now sample representative temporal conditions over the whole year. Most sampling and analytical procedures have remained unchanged over the course of the monitoring program. Consistent field and laboratory procedures, well-documented by the appropriate SOPs, help ensure consistent and reproducible data. Quality Control checks performed by the programs' analytical laboratories, including continuing calibration verifications (CCV), blanks, duplicates, and spike samples, are used to flag suspect data and to ensure accuracy and precision of the results. Additionally, CT DEEP's analytical laboratory participates in a multi-lab comparison program that provides data specifically to assess its ability to produce data comparable to several other laboratories located in the Northeast and Mid-Atlantic regions of the United States. IEC began participating in this multi-lab comparison program in the fall of 2019. Additionally, IEC participates semi-annually in the New York State Department of Health's proficiency testing program.

RESULTS

During the summer of 2019, CT DEEP conducted eight surveys between May 29th and 10 September 10th while IEC conducted ten surveys between June 25th and September 10th (Table 1). Hypoxia maps and in situ profiles from stations in WLIS are available in Appendix A. All data are available electronically upon request. Summaries of CT DEEP bi-weekly sampling are available on the Department's website, and summaries of IEC weekly sampling are available on the Commission's website.

Dissolved Oxygen

DO levels below 3.0 mg/L are considered hypoxic, causing mobile animals to emigrate from impacted areas and sessile animals to die or be physically or behaviorally impaired. However, early studies in LIS by CT DEEP Marine Fisheries biologists found that DO can become limiting below 4.8 mg/L for sensitive fish species, while more tolerant species are not affected until DO falls below 2.0 mg/L (Simpson et al, 1995, 1996). That study documented a 4% reduction in finfish biomass when DO levels were between 3.0-3.9 mg/L, a 41% reduction occurs at 2.0-2.9 mg/L DO, and an 82% reduction in waters with concentrations between 1.0 and 1.9 mg/L. Finfish biomass was reduced by 100% (total avoidance) in waters with DO less than 1.0 mg/L (Simpson et al, 1995, 1996).

Hypoxic conditions were documented during four CT DEEP surveys (Table 1), with stations A4, B3, C1, 09, E1, 15, 01, 02, 03, and 14 exhibiting dissolved oxygen concentrations below 3.0 mg/L at some point during the course of the season.

Hypoxic conditions were observed during six IEC surveys (excluding embayment stations). All 13 of IEC's open-water stations exhibited hypoxic conditions at some point over the course of the season. (Table 1).

Timing and Duration

The 2019 hypoxic event lasted an estimated **48 days**, beginning on July 12th and ending on August 28, based on CT DEEP and IEC data. Compared to the previous 31 years, 2019 was below the average of 55 days (Figure 3). The LISICOS Execution Rocks Buoy estimated the duration was 45.03 days.

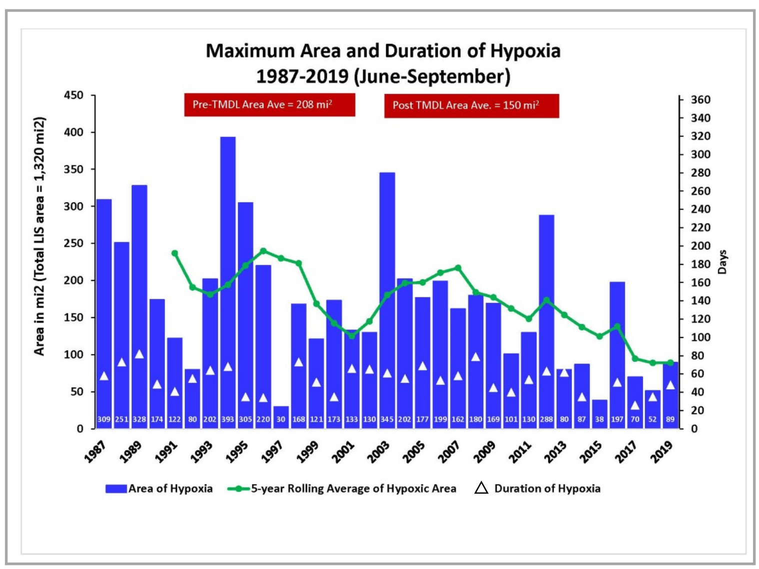


Figure 3. Maximum Area and Duration of Hypoxia. Blue bars represent area, white triangles represent duration, and the green line is the five-year rolling average of hypoxic area. The total area of Long Island Sound is 1,320 mi^2.

Table 1. CT DEEP and IEC Cruise Summary Information. See Figure 1 for station locations.

Cruise	Start Date	End Date	Number of Stations Sampled	Number of Hypoxic Stations	Hypoxic Area (mi^2)	Minimum DO	Station Where Minimum DO Occurred
WQJUN19	5/29/2019	5/31/2019	17	0	0	6.86	B3
HYJUN19	6/12/2019	6/12/2019	22	0	0	6.29	B3
IEC RUN #1	6/25/2019	6/25/2019	22	0	NA	3.96	HC1*
WQJUL19	7/1/2019	7/3/2019	35	0	0	4.23	15
IEC RUN #2	7/2/2019	7/2/2019	22	0	NA	3.31	H-D*
IEC RUN #3	7/9/2019	7/9/2019	22	1	NA	2.89	9-413*
HYJUL19	7/15/2019	7/17/2019	39	1	17.8	2.47	A4
IEC RUN #4	7/15/2019	7/15/2019	22	4	NA	2.05	HC*
IEC RUN #5	7/24/2019	7/24/2019	22	14	NA	1.28	HC*
WQAUG19	7/29/2019	8/1/2019	42	4	**89.42**	1.29	A4
IEC RUN #6	7/30/2019	7/30/2019	22	18	NA	0.5	9-413*
IEC RUN #7	8/7/2019	8/7/2019	22	11	NA	1.19	B4
HYAUG19	8/12/2019	8/14/2019	41	7	74.13	0.89	A4
IEC RUN #8	8/13/2019	8/13/2019	22	15	NA	0.88	A4
IEC RUN #9	8/22/2019	8/22/2019	22	16	NA	0.33	9-413*
WQSEP19	8/27/2019	8/30/2019	41	2	20.31	2.74	E1
IEC RUN #10	9/3/2019	9/3/2019	22	0	NA	3.16	9-413*
HYSEP19	9/10/2019	9/10/2019	23	0	0	4.99	14

Bold= Maximum Extent of Hypoxia

NA= Not Applicable

Area estimates

To maintain the continuity and comparability of the long-term data set, areal estimates are based on CT DEEP data only. Re-interpolation using both the CT DEEP and IEC stations data from 1991-2019 is planned. CT DEEP and IEC data are synoptic over the sampling area, providing a snapshot of conditions for each survey period, while the LISICOS data provide continuous measurements at specific buoy locations throughout the year. This often results in disparity between the datasets.

Estimated Maximum Area Between 3.0 and 4.8 mg/L

In 2019, the maximum area of LIS bottom waters between 3.0 and 4.8 mg/L occurred during the HYAUG19 survey conducted (August 12-14) and was estimated at 409 mi^2. From 1991-2019, the area affected by concentrations between 3.0 and 4.8 mg/L averaged 581 mi^2 and varied from 414 to 730 mi^2.

Estimated Maximum Area Below 3.0 mg/L

The 2019 peak hypoxic event occurred during IEC Run #6 and the WQAUG19 cruises between July 29 and August 1. The maximum hypoxic area was **89.4 square miles**. Compared to the previous 31-year average (160.2 mi^2), 2019 was below average in area (Figure 3). The lowest dissolved oxygen concentration (0.89 mg/L) documented by CT DEEP during 2019 occurred on August 12 at Station A4 (Appendix A, pg. A3). The lowest dissolved oxygen concentration documented by IEC during 2019 at an open water station was 0.51 mg/L and occurred on July 30 at Station H-C1 (Appendix A). The Execution Rocks Buoy recorded its lowest reading, 0.07 mg/L, on 8/10/19.

Estimated Maximum Area Below 2.0 mg/L

Based on CT DEEP data, in 2019 the maximum area below 2.0 mg/L was **21.1 square miles** .and occurred during the HYAUG19 cruise. The average area with concentrations less than 2.0 mg/L, calculated from 1991-2019, was 48.14 mi^2. The IEC documented concentrations below 2.0 mg/L at eight of their open-water stations on 24 July, nine of their open-water stations on 30 July, seven of their open-water stations on 7 August, and five of their open-water stations on 13 August. At the LISICOS Execution Rocks buoy, there was 35.06 cumulative days below 2.0 mg/L.

Estimated Maximum Area Below 1.0 mg/L

The maximum area below 1.0 mg/L based on CT DEEP data in 2019 was **14.75 square miles**. At the LISICOS Execution Rocks buoy there were 19.65 cumulative days of DO concentrations less than 1.0 mg/L. The overall average area with concentrations less than 1.0 mg/L from 1991-2019 is 11.19 mi^2. The greatest area with DO below 1 mg/L (62 square miles) occurred during the summer of 2003.

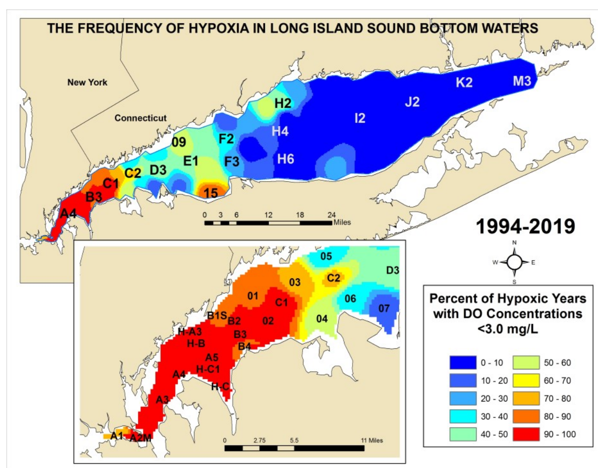


Figure 4. Frequency of Hypoxia in Long Island Sound Bottom Waters

Frequency

Figure 4 shows the frequency of hypoxia occurrence for stations over the 1994 -2019 period. The percent of WLIS stations (inset Figure 4) that experience hypoxic conditions continues to be between 90 and 100% (Figure 4). However, stations C2, D3, E1, 09, and 15 have exhibited signs of improvement; in the 1990's these stations were hypoxic about 60-80% of the time, while over the past four years they were hypoxic only about 10-30% of the time.

WATER TEMPERATURE

Water temperature plays a major role in the timing and severity of the summer hypoxia events. Water temperature differences in the Western Sound during the summer months are particularly influential in contributing to the difference in dissolved oxygen content between surface and bottom waters. Density stratification in the water column creates a barrier between the surface and bottom waters, and it is this barrier, the pycnocline (where the change in density with depth is at its greatest), that prevents mixing between the layers.

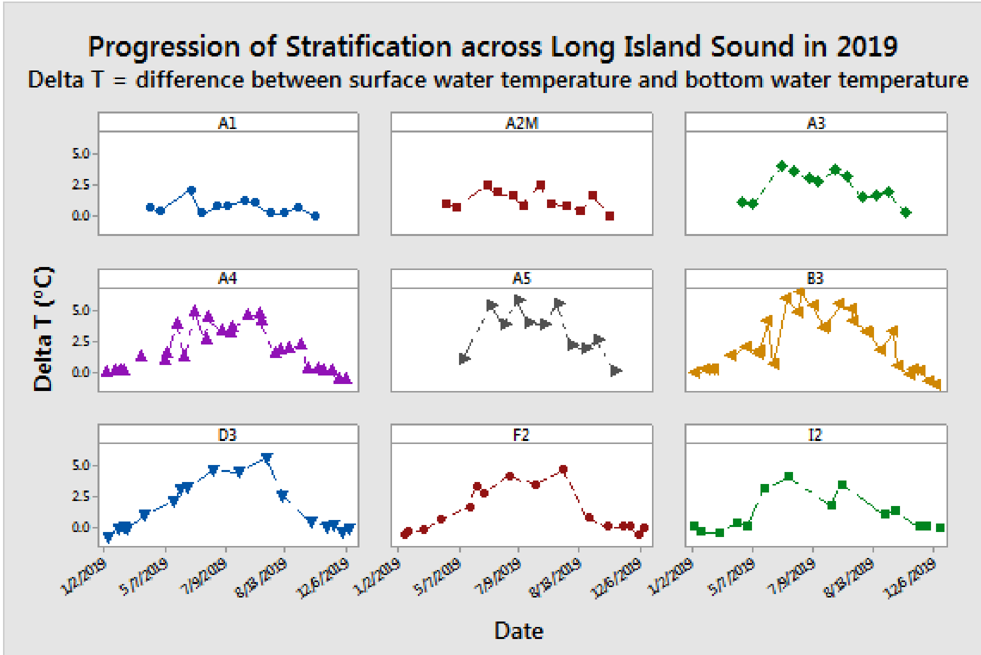


Figure 5. Progression of stratification across Long Island Sound in 2019, where Delta T= surface water temperature minus bottom water temperature.

In 2019, stratification began to set up in May (Figure 5), when the difference between surface and bottom water temperatures (Delta T) ranged from 0.16ºC to 3.71ºC, and peaked in the Western Narrows in early July. The maximum Delta T (based on CT DEEP data) in 2019 was 7.25ºC and occurred on July 16 at Station H6. Destratification (fall turnover) began around mid–August. The 2019 maximum surface temperature was 25.57ºC recorded on July 30 at Station 06. The minimum surface temperature was 1.37ºC, recorded on March 7 at Station I5 . The 2019 maximum bottom temperature was 22.96ºC, recorded on August 13 at Station I5. The minimum bottom temperature was 1.35ºC, recorded on March 7 at Station I5 .

Both surface and bottom water temperatures in LIS appear to be increasing. The surface and bottom temperatures from four of CT DEEP's 17 year round monitoring stations are plotted in Figure 6.

Additional information is available on the LISS website.

2019 temperature data are available by station in Appendix A.

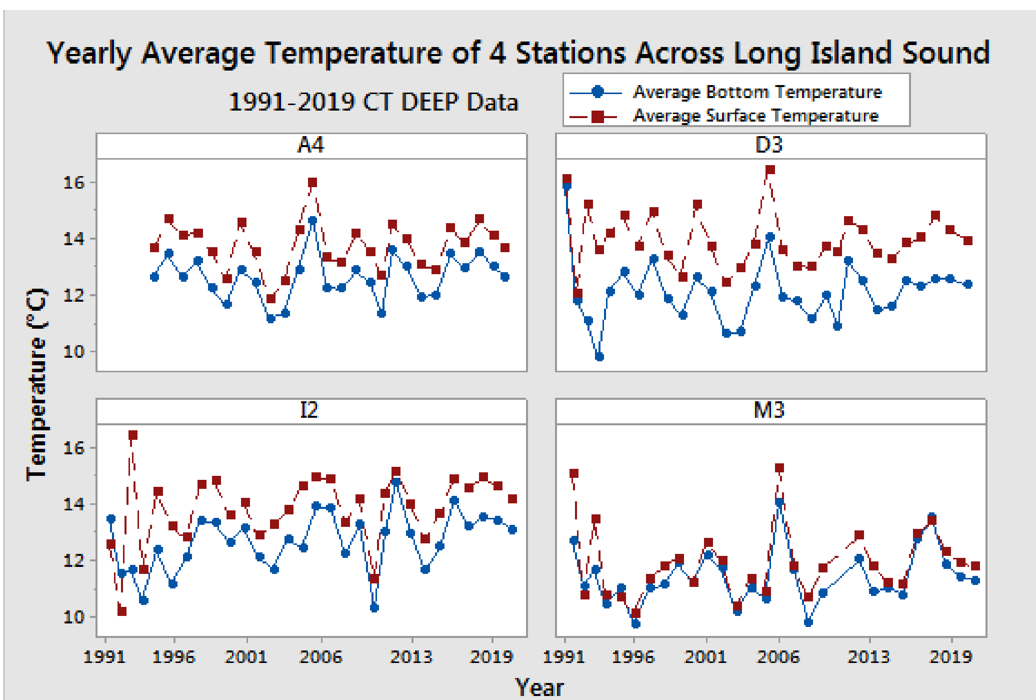
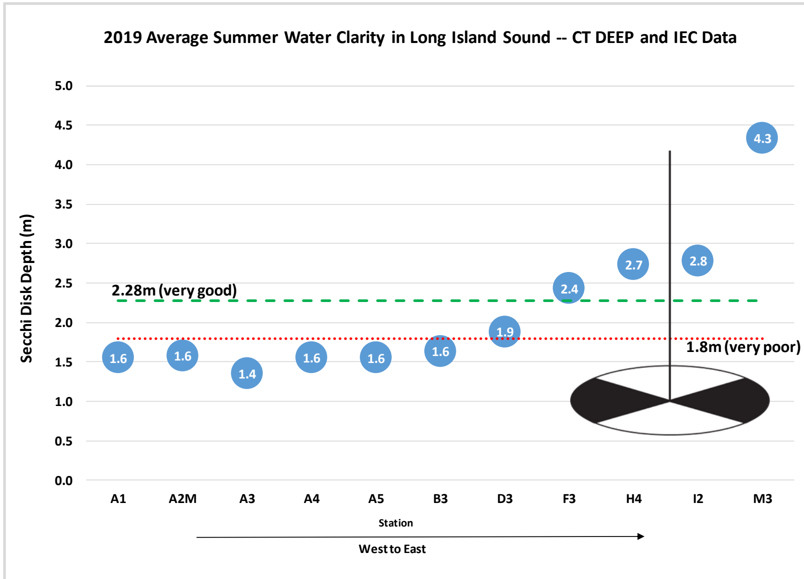


Figure 6. Yearly Average Water Temperatures of Long Island Sound.

Water Clarity

Water clarity, a measure of light penetration through the water column, is an important indicator of the health of seagrass beds, and, thus, the ecosystem as a whole (see page 16). In Long Island Sound, water clarity improves as you move eastward. The eastern portion of the Sound is a wide and deep channel with considerable influx from the Atlantic Ocean, whereas the Western Sound is more narrow and shallow, and its surrounding land is densely populated and developed with many sewage treatment facilities on or near the coast. This results in less of an exchange of waters on the western end and also increases the concentrations of pollutants in the water that may affect water clarity.

Figure 7 highlights the west-east water clarity gradient. In 2019, the western-most axial station (A1, near Whitestone Bridge) had an average summer Secchi disk depth of 1.6 meters (Figure 7a) and a year-round average of 1.5 meters (Figure 7b). The average Secchi disk depths gradually increased, with the eastern-most axial station (M3 near Fishers Island), having a summer average Secchi disk depth of 4.3 meters and a yearly average of 3.9 meters. Individual station data from 2019 are available in Appendix B.



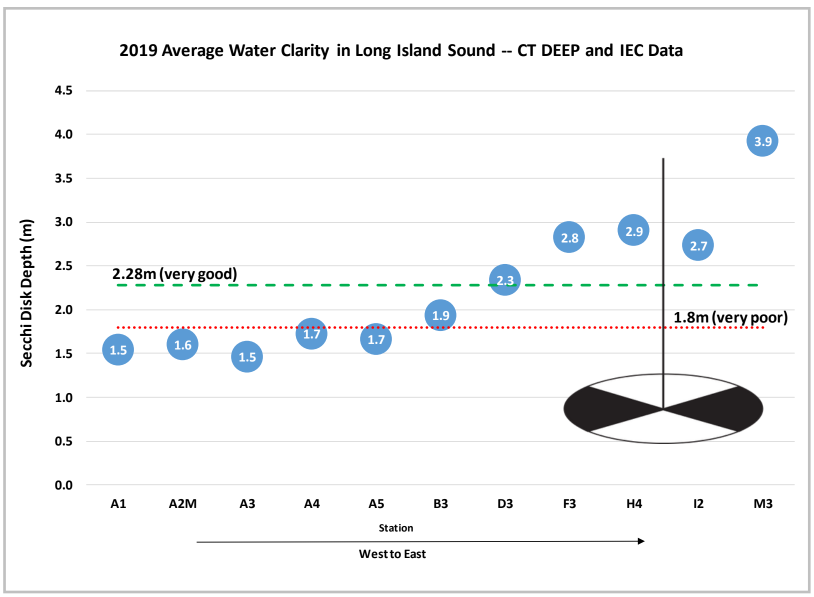


Figure 7. Average water clarity across Long Island Sound in 2019.
a) Summer and b) Year-round

pH

In Long Island Sound, eutrophication can contribute to coastal acidification (Wallace et. al., 2014). Excess nutrients fuel algae and phytoplankton growth, and as the phytoplankton die and decay, carbon dioxide (CO_2) is released. This release has the same effect on pH as carbon dioxide from atmospheric deposition (NECAN undated; Appendix D, pg. D4). EPA guidelines for measuring changes in pH and carbonate chemistry in eastern coastal waters (Pimenta and Grear, 2018) indicate that two of four parameters are needed to describe the seawater carbonate system - pCO2 (partial pressure of carbon dioxide), DIC (dissolved inorganic carbon), total alkalinity, and pH, along with temperature and salinity measurements. CT DEEP and IEC only collect one of the four needed parameters - pH. pH data from 2019 are available upon request.

In 2018, the LISICOS Western Sound buoy was equipped with near bottom pH (SeaBird Hydrocat) and pCO2 (SunBurst) sensors. The sensors were installed at a depth of ~21 meters. The Central LIS Buoy is also equipped with near bottom pCO2 and pH sensors. UCONN is still performing internal QA/QC on the data. However, preliminary data show prolonged periods of decreased pH and increased pCO2 concentrations over the summer months. The sensors were taken out of service in early 2019 for reconditioning and recalibration by the manufacturer and will be reinstalled as soon as possible.

Researchers from UCONN began sampling in May 2019 for the RESPIRE Project. Piggybacking on CT DEEP cruises, the study aims to quantify components of the respiration process by examining key parameters including organic matter degradation rates, nutrients, DO, pCO2, pH, total alkalinity, and temperature. The project is expected to last two years.

Chlorophyll-a

The spring phytoplankton bloom occurs in Long Island Sound between February and April. Historically high levels of chlorophyll-a in the Western Sound during this time have been linked to summertime hypoxia conditions. In 2019, the spring bloom occurred in March. Year-round chlorophyll-a data collected by CT DEEP in 2019 show smaller blooms in May and September. IEC began collecting year round data in October 2018. The maximum chlorophyll a concentration measured at an axial station was 23.1 ug/L at Station A4 on March 5.

Western Sound data collected by IEC between March and September 2019 and CT DEEP data collected between January and September 2019 are available in Appendix G. Data from additional stations and years are available upon request.

Nutrients

DEEP has collected monthly nutrient data from 17 stations year round since 1991. IEC began collecting bi-weekly nutrient data in the summer of 2014 at 11 of their 22 stations. Samples are analyzed for dissolved organic carbon (DOC), dissolved inorganic phosphorus (DIP), dissolved silica (SiO2), and nitrate + nitrite (NOx), particulate silica, particulate carbon, particulate nitrogen, ammonia, particulate phosphorus, orthophosphate, and total suspended solids . Data for these nutrient parameters from all 17 of DEEPs stations and 11 IEC stations are available upon request. The Western Sound LISICOS Buoy is equipped with near surface (~3 meters deep) SUNA v2 Nitrate and Cycle Phosphate sensors. The Execution Rocks and CLIS Buoys are also equipped with near surface SUNA Nitrate sensors.

Discussion

Weather

The Northeast Regional Climate Center (NRCC) at Cornell University is tasked with disseminating climate data and information for 12 states, including NY and CT. The summer of 2019 was relatively warm and dry (Figures 8 and 9). While average June temperatures were only slightly above the normals (e.g., 68.7ºF in Bridgeport and 72.2ºF at LaGuardia), the last 10 days of the month and the beginning of July saw a consistent increase in temperature. The trend continued, producing the all-time warmest month for Hartford, when 19 days in July recorded maximum temperatures above 90ºF. The first half of August remained exceptionally hot, though the second half cooled considerably, resulting in an average monthly temperature about ~1ºF above the normal. Both June and August were drier than usual. Precipitation in July, on the other hand, was significantly above normal (e.g., Bridgeport received 219% of its 3.46 in. normal), due to storm events.

Climate information is useful as physical processes influence the timing and duration of hypoxia. Bratton et. al. (2015), Wilson et. al., (2015), and O'Donnell et. al., (2008) note that the frequency of high pressure systems traveling north through LIS during the summer months impacts hypoxia, particularly that westerly winds increase stratification and easterly winds reduce stratification.

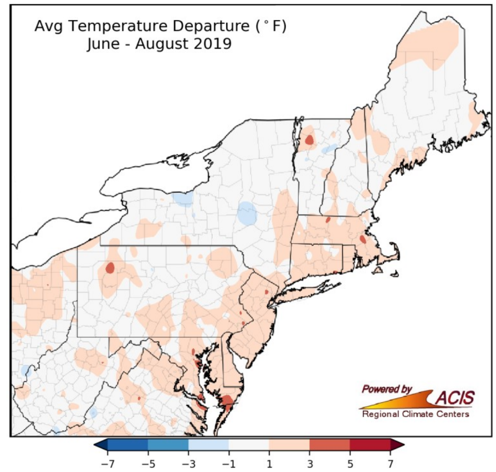


Figure 8. 2019 Northeast Average Summer Temperature Departure in ºF. From NRCC.

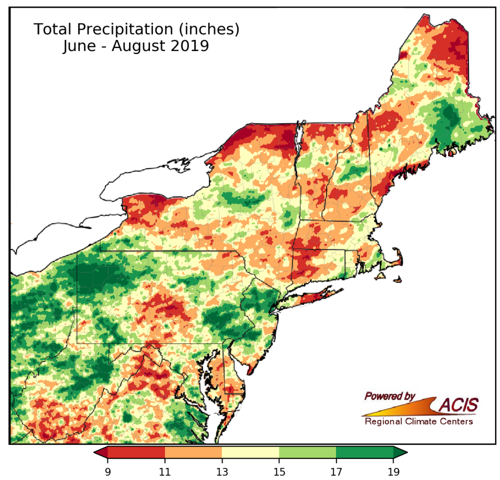


Figure 9. 2019 Northeast Total Summer Precipitation in Inches. From NRCC.

CCMP Goals

The Long Island Sound Study (LISS) updated the Comprehensive Conservation and Management Plan (CCMP) for LIS in 2015. One of the four CCMP Goals is to improve water quality by reducing contaminant and nutrient loads to the Sound. To achieve the goals, the LISS identified ecosystem targets and indicators related to **hypoxia, nitrogen loading, and water clarity**.

Hypoxia

- *The maximum area of hypoxia in the bottom waters of LIS (shall) measurably be reduced from pre-2000 TMDL averages to increase attainment of water quality standards for dissolved oxygen by 2035, as measured by the five-year running average size of the zone.*

Meeting the ecosystem target for maximum area of hypoxia is ahead of schedule. The LIS pre-2000 baseline for maximum area of hypoxia is 208 square miles. The 2015-2019 five-year running average is 89 square miles (Figure 3), a 57% reduction from the pre-TMDL baseline. However, further management action will need to be taken to achieve water quality standards and meet the CCMP goal. Considerable variability from year to year still occurs, influenced by weather patterns.

A better indicator of progress towards DO criteria attainment would be to examine representative stations for attainment of water quality standards with respect to the 3.0 mg/L threshold, as well as the 4.8 mg/L threshold. Additionally, LISS is considering examining the duration of DO in the 3.0 –4.8 mg/L tiers and the water column profiles at each station to better quantify deviations from water quality standards.

Nitrogen Loading

Another goal of the CCMP is to reduce to point source nitrogen loading from waste water treatment plants (WWTPs). The LIS 2000 Dissolved Oxygen TMDL specifies the primary pollutant contributing to hypoxia in LIS is nitrogen. The major sources of nitrogen to LIS are WWTPs, combined sewer overflows, nonpoint sources including stormwater, and atmospheric deposition.

The TMDL requires a 58.5% reduction in nitrogen entering LIS via point source discharges (i.e., WWTPs).

- *Attain wastewater treatment facility nitrogen loading at the recommended 2000 Dissolved Oxygen Total Maximum Daily Load allocation level by 2017 and maintain the loading cap. Have all practices and measures installed to attain the allocations for stormwater and nonpoint source inputs from the entire watershed by 2025.*

Figure 10 illustrates the reduction in hypoxic area as well as a downward trend in nitrogen discharges from both NY and CT WWTPs. Connecticut began requiring nitrogen reductions in WWTP discharges in 1998, the CT Nitrogen Trading program began in 2002, and the New York nitrogen reductions began in 2010, all identified in Figure 10.

In 2019 the wetter than normal winter and spring decreased the efficiency of nitrogen removal of the treatment systems resulting in an increase in loads to LIS; precipitation in Connecticut was 4.33 inches above the normal annual average while New York was 5.58 inches above normal. In CT, the combined waste water treatment plant (WWTP) discharge to LIS was 8,848 equalized pounds/day (lbs/day) of nitrogen, slightly below the TMDL target of 9,507 lbs/day. NY WWTP's discharged 13,364 TE lbs/day of nitrogen to LIS in 2019, which is slightly above their TMDL target of 13,228 lbs/day. However, the total combined 2019 loading to LIS was still well below the early 1990s baseline, and over 500 lbs/day below the TMDL target of 22,774 TE bs/day.

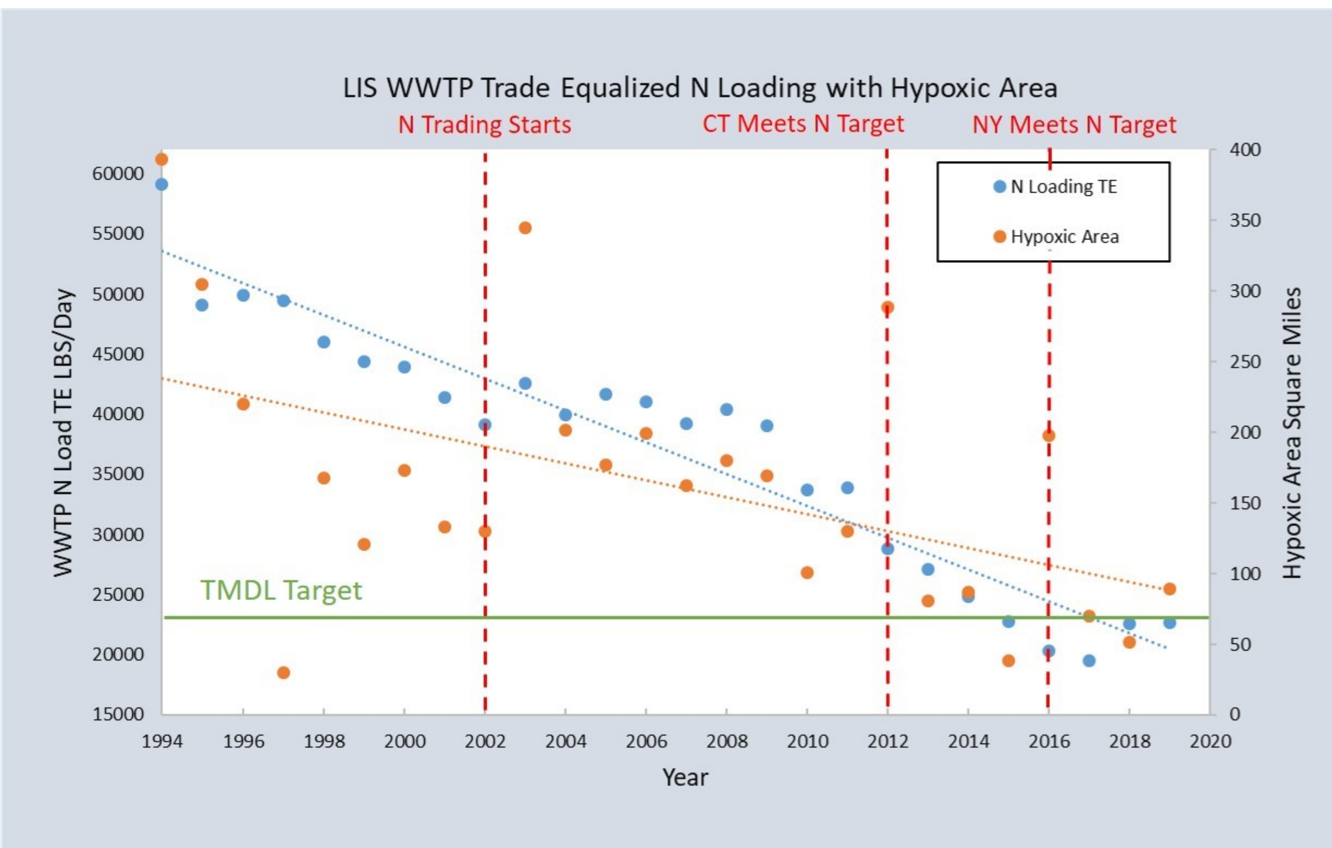


Figure 10. Graph of WWTP Nitrogen Discharge versus Hypoxic Area

Water Clarity

- *Improve water clarity by 2035 to support healthy eelgrass communities and attainment of the eelgrass extent target.*

The CCMP targets 2015 annual Secchi disk depth data as the baseline against which improvements are measured. Threshold values developed as part of the Long Island Sound Report Card are used to track progress. Annual average Secchi disk depths greater than 2.28 meters are considered very good while depths less than 1.8 meters are considered very poor.

Eelgrass in Long Island Sound is currently limited to embayments in the far eastern Sound, having disappeared from most of its historic range. Most of the eelgrass in Long Island Sound is found in <4 m of water, except where water quality is exceptionally good (i.e. seagrass beds near Fisher's Island). IEC and CT DEEP do not monitor embayments under their LIS monitoring programs; therefore, open water data are currently used to evaluate this indicator until data collected from embayments by the Unified Water Study in 2018 and 2019 are quality checked and graded.

Generally, with the exception of stations in the Western Narrows, water clarity across LIS is good (Figure 7b and 11). Water clarity in the Western Sound is especially impacted by suspended sediments, organic matter, and plankton in the water column.

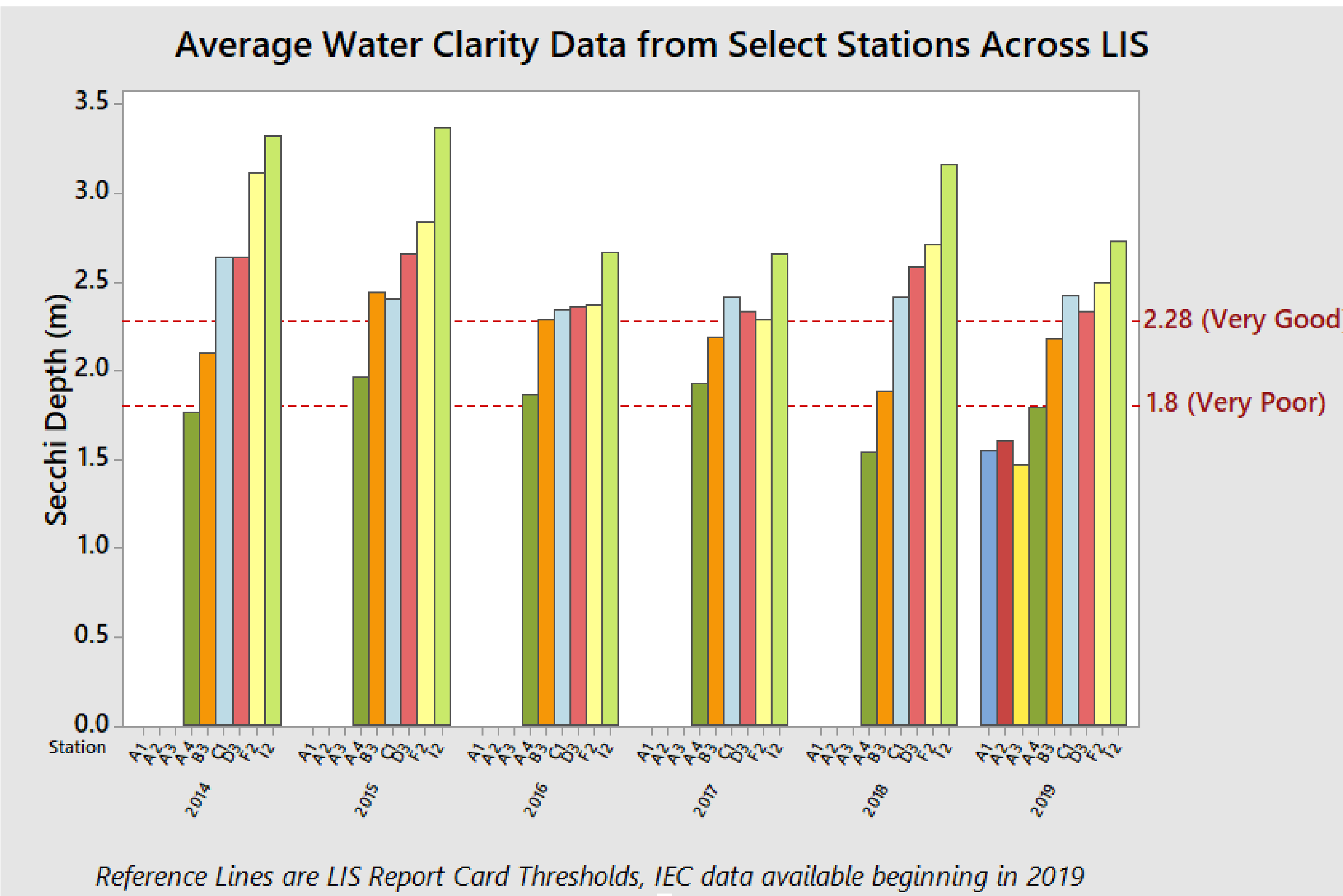


Figure 11. Year round average water clarity data from select stations across Long Island Sound.

Phytoplankton and chlorophyll

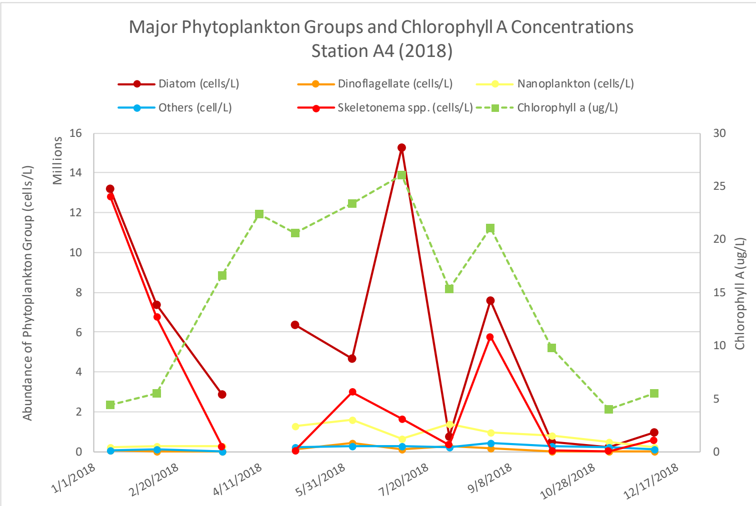


Figure 12. Comparison of Major Phytoplankton Groups and chlorophyll a concentrations at Station A4 during 2018.

CT DEEP collects and delivers phytoplankton and chlorophyll samples to researchers at UCONN for abundance analysis and species identification. The graphs below examine the relationship between surface chlorophyll a and phytoplankton abundance (cell counts) at Station A4 in the Western Narrows. In 2018, the most recent year phytoplankton data are available, diatoms were the dominant species (Figure 12). The long term trend in chlorophyll-a and cell counts is shown in Figure 13. Additional data analyses at multiple stations are needed to tease out relationships to hypoxia and water quality.

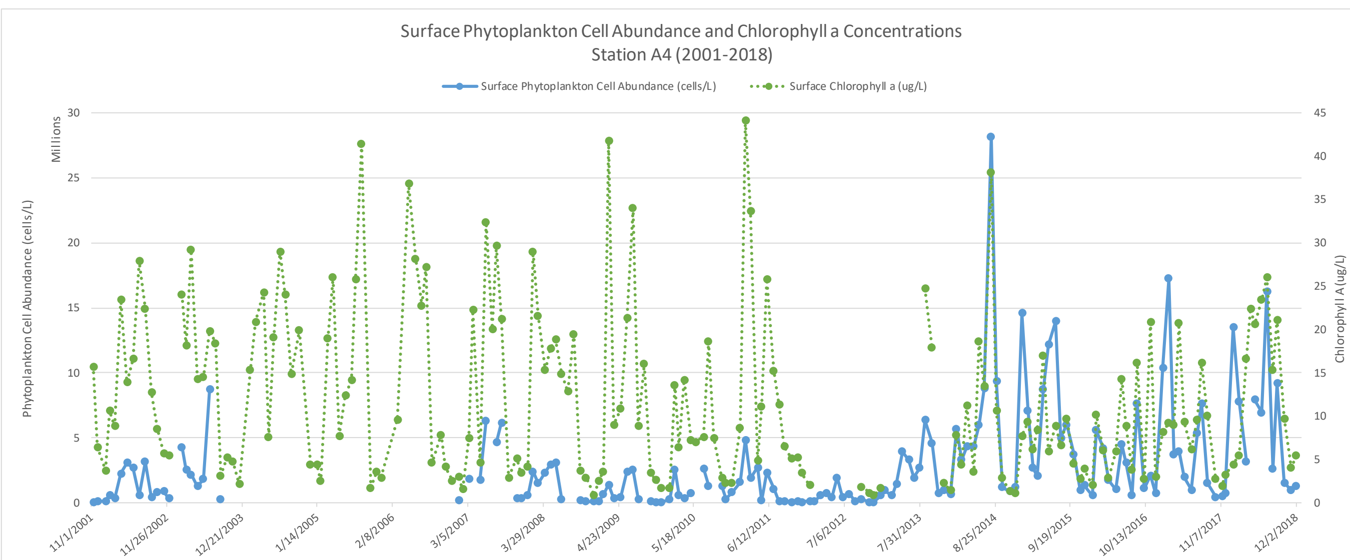


Figure 13. Time series (2001-2018) plot of surface chlorophyll a concentrations and phytoplankton cell abundance at Station A4, Western LIS.

Future Monitoring Plans

Carbonate Chemistry Parameters

In March 2018, EPA released guidelines for measuring changes in carbonate chemistry in eastern coastal waters (Grear and Pimenta 2018). Likewise, the National Oceanic and Atmospheric Administration (NOAA) published a list of considerations for managers to consider when developing acidification monitoring programs (Goldsmith et. al., in press). Two of four parameters are needed to describe the seawater carbonate system– pCO2, dissolved Inorganic Carbon (DIC), total alkalinity (TA), and pH, along with temperature and salinity measurements. The CT DEEP and IEC monitoring programs only measure one of those parameters– pH. Two of the four LISICOS buoys are equipped with pCO2 and pH sensors. New projects to examine productivity and carbonate chemistry across LIS (the RESPIRE Project, Vlahos 2018 and Shell Day 2019 , NECAN) highlight the need for the LISWQMP and IEC WSMP to collect sufficient data to effectively assess changes to the LIS carbonate system. Following the completion of the RESPIRE Project, the flow through TA analyzer utilized by UCONN will remain on the research vessel and CT DEEP will continue to collect TA measurements during LIS WQMP cruises.

Embayments

While LIS proper has been well sampled for decades, LIS embayments have not. This is beginning to change; the 2015 update of the CCMP recognized the importance of characterizing nutrient loading and hypoxia impacts within the embayments. The Unified Water Study, a citizen science based monitoring program administered by Save the Sound, began in 2017 and has successfully completed its third year of sampling. In late 2019, CTDEEP began a project to examine the benthic macroinvertebrate communities in embayments as a way to assess the biological community response to management actions, including nutrient reductions. In 2020, as part of an intensification of the EPA National Coastal Condition Assessment probabilistic sampling program, 60 sites in embayments across Connecticut and Long Island will be sampled to provide additional data for validating the Index of Biological Integrity developed as part of the aforementioned CT DEEP project. In 2018 and 2019, USGS and EPA Region 1 conducted monitoring in the Pawcatuck Watershed in support of model development to address nutrient loading and hypoxia. In 2020, USGS will conduct upland monitoring with an emphasis on the watersheds of embayments identified in the CT Integrated Water Resource Management Plan in support of a project to upgrade the existing statewide HSPF model.

East River

During the summer of 2020, researchers from UCONN will deploy an Acoustic Doppler Current Profiler (ADCP) in the East River, near Throgs Neck. The project, funded by CT Sea Grant, will gather data on the magnitude and timing of tides to inform managers on positive and negative impacts of flood protection strategies proposed across the East River. The project will also improve LIS models and potentially assist with refining volume transport rate estimates. Flux measurements at East River/Throgs Neck have been identified as necessary to constrain the LIS sound wide model. The addition of nutrient sensors at the location of the ADCP would allow for the calculation of nitrogen flux estimates. Funding for the nutrient sensors is being explored.

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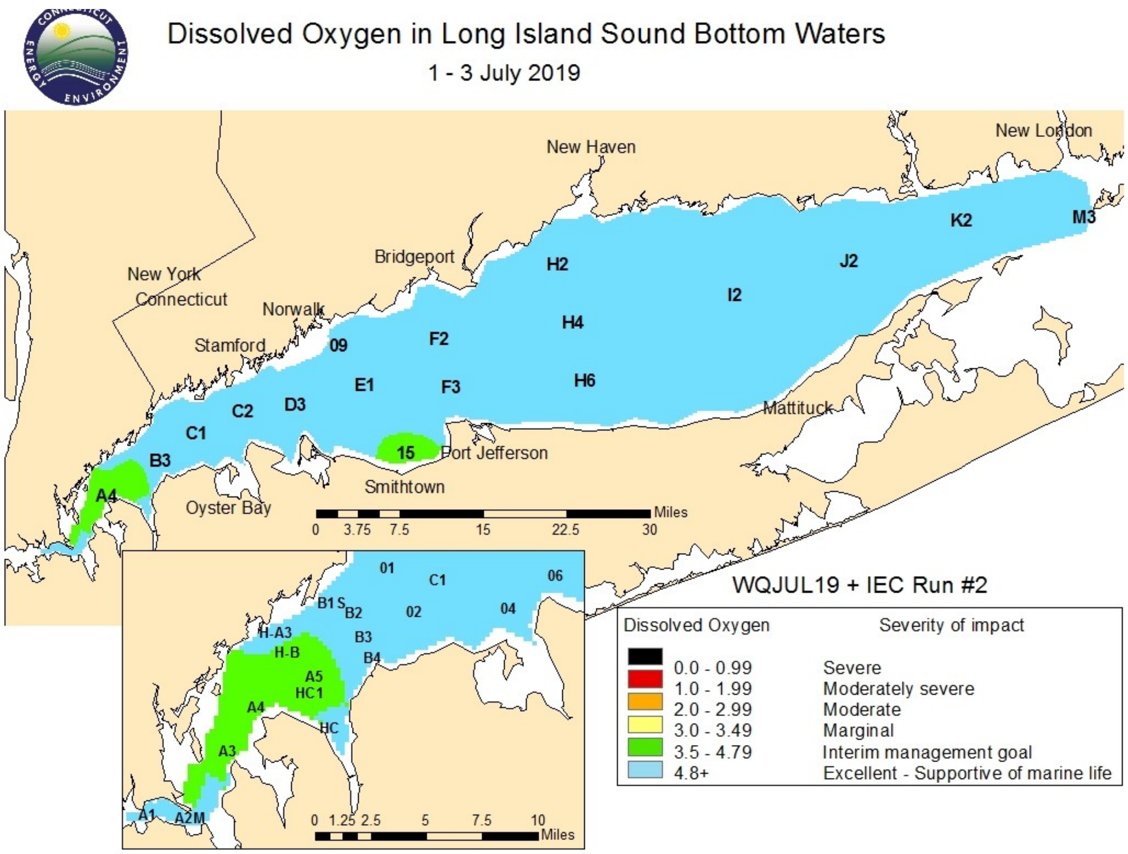
Appendix A – 2019 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP WQJUL19 and IEC Run #2

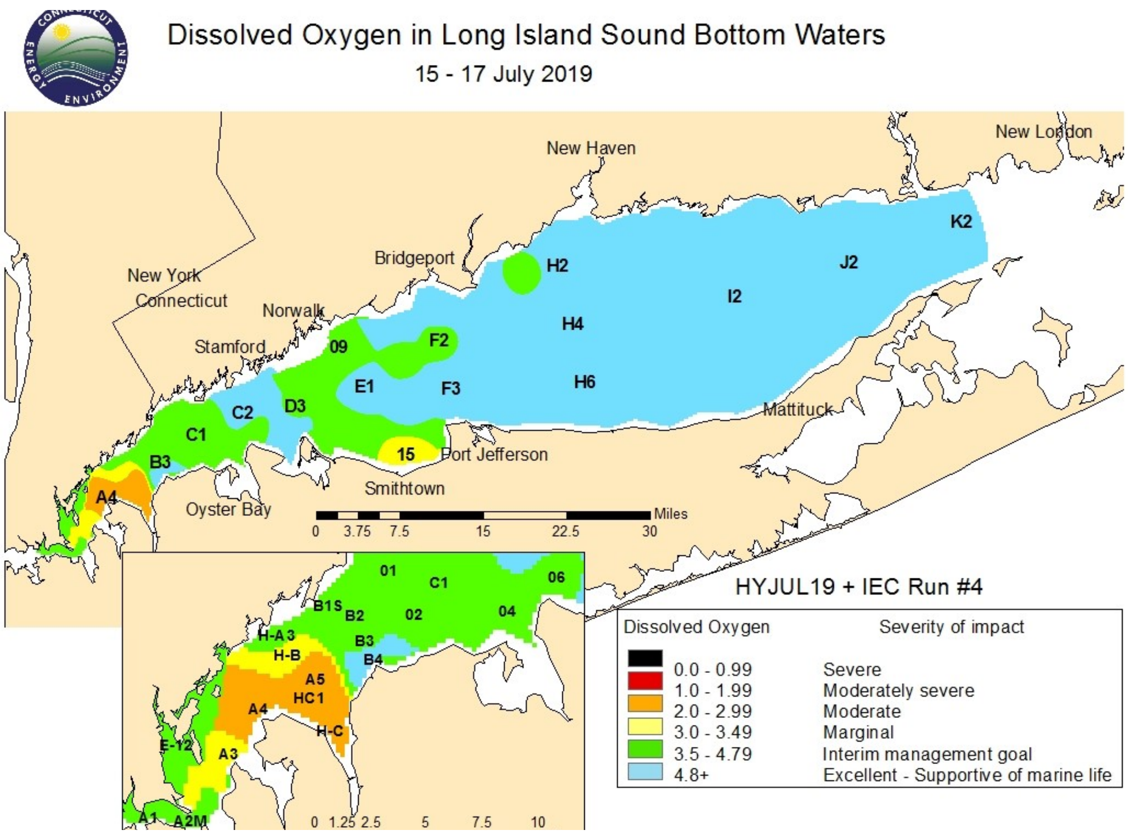
Select a station name to open a new window that contains profile data.



A1	H-C1	02	D3
A2M	H-C	C1	07
A3	B1S	03	09
A4 (DEEP)	B2	04	E1
A4 (IEC)	B3 (DEEP)	05	10
H-A3	B3M (IEC)	C2	15
H-B	B4	06	14
A5	01	08	Excel file of all stations

Appendix B – 2019 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP HYJUL19 and IEC Run #4

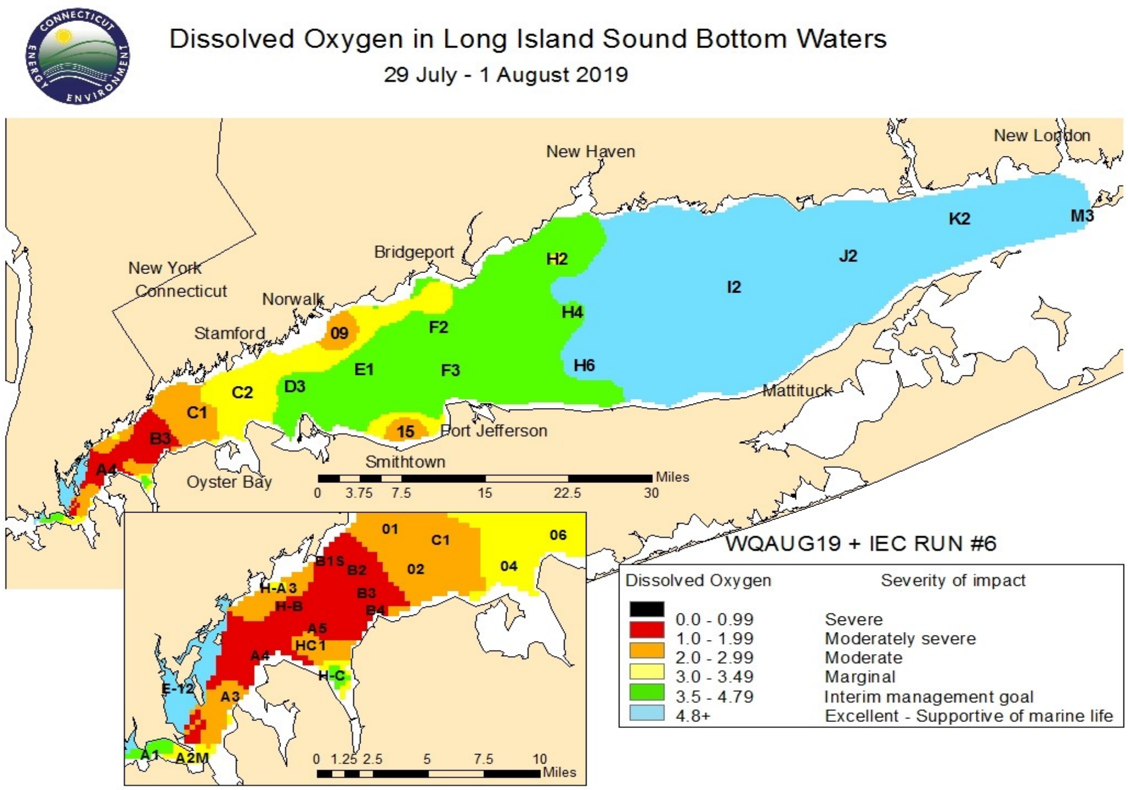
Select a station name to open a new window that contains profile data.



A1	H-C1	02	D3
A2M	H-C	C1	07
A3	B1S	03	09
A4 (DEEP)	B2	04	E1
A4 (IEC)	B3 (DEEP)	05	10
H-A3	B3M (IEC)	C2	15
H-B	B4	06	14
A5	01	08	Excel file of all stations

Appendix C – 2019 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP WQAUG19 and IEC Run #6

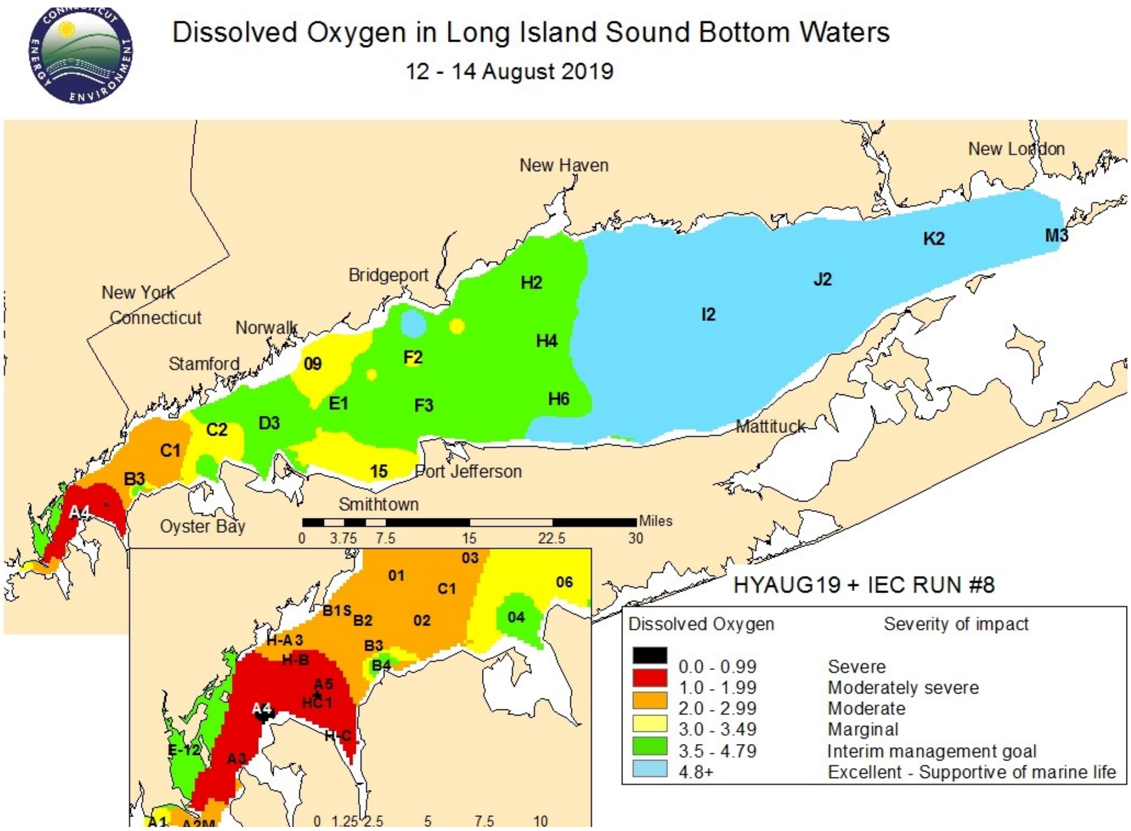
Select a station name to open a new window that contains profile data.



A1	H-C1	02	D3
A2M	H-C	C1	07
A3	B1S	03	09
A4 (DEEP)	B2	04	E1
A4 (IEC)	B3 (DEEP)	05	10
H-A3	B3M (IEC)	C2	15
H-B	B4	06	14
A5	01	08	Excel file of all stations

Appendix D – 2019 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP HYAUG19 and IEC Run #8

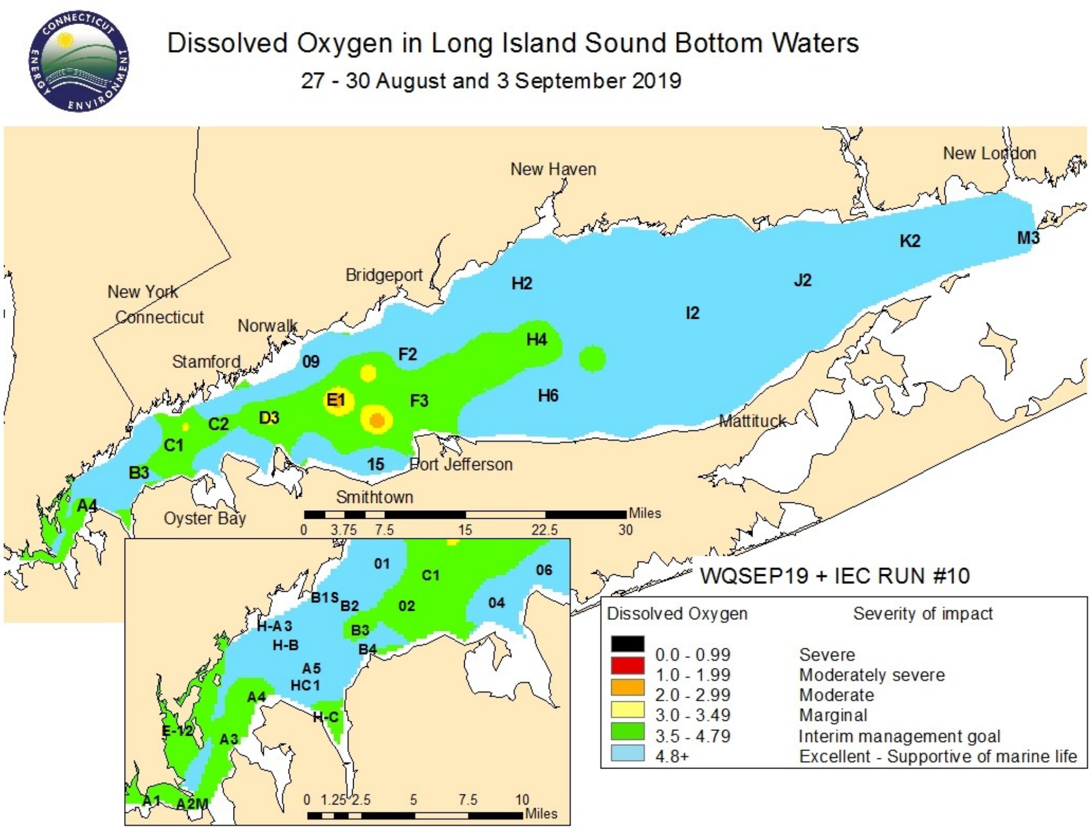
Select a station name to open a new window that contains profile data.



A1	H-C1	02	D3
A2M	H-C	C1	07
A3	B1S	03	09
A4 (DEEP)	B2	04	E1
A4 (IEC)	B3 (DEEP)	05	10
H-A3	B3M (IEC)	C2	15
H-B	B4	06	14
A5	01	08	Excel file of all stations

Appendix E – 2019 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP WQSEP19 and IEC Run #10

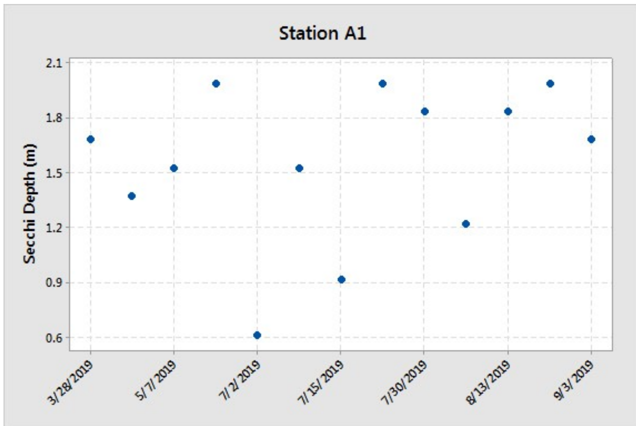
Select a station name to open a new window that contains profile data.

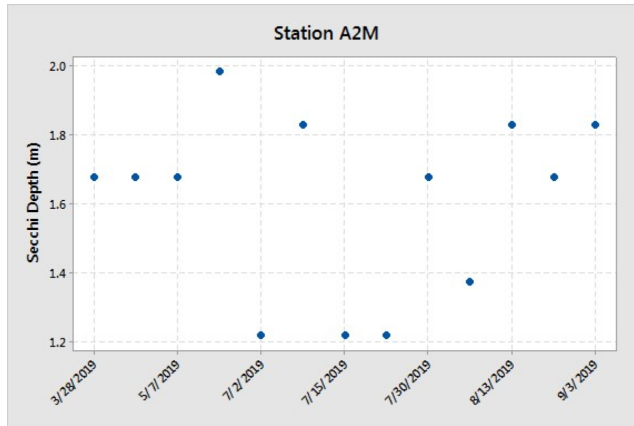


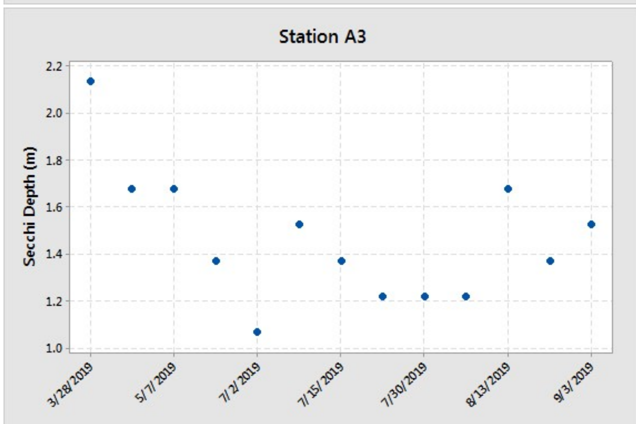
A1	H-C1	02	D3
A2M	H-C	C1	07
A3	B1S	03	09
A4 (DEEP)	B2	04	E1
A4 (IEC)	B3 (DEEP)	05	10
H-A3	B3M (IEC)	C2	15
H-B	B4	06	14
A5	01	08	Excel file of all stations

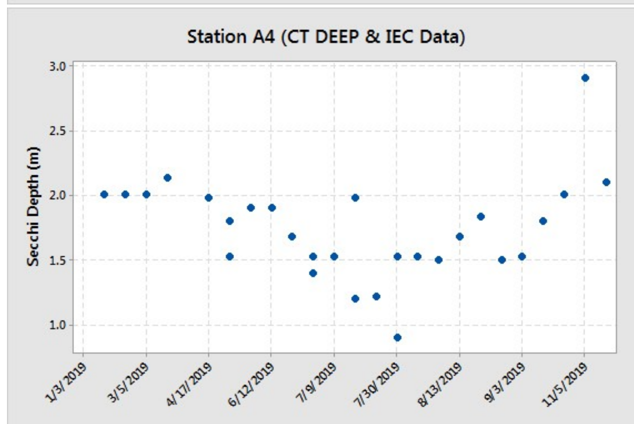
Appendix F – 2019 Year-Round Water Clarity Data

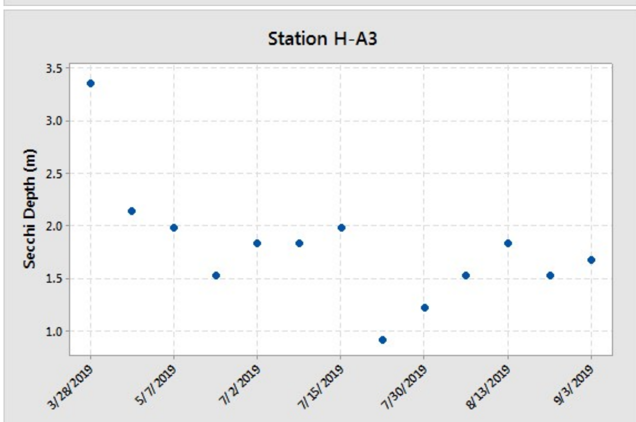
Individual value plots showing each Secchi disk depth recorded by the IEC and CT DEEP in 2019.
Additional stations are available upon request. See Figure 1 for station locations.

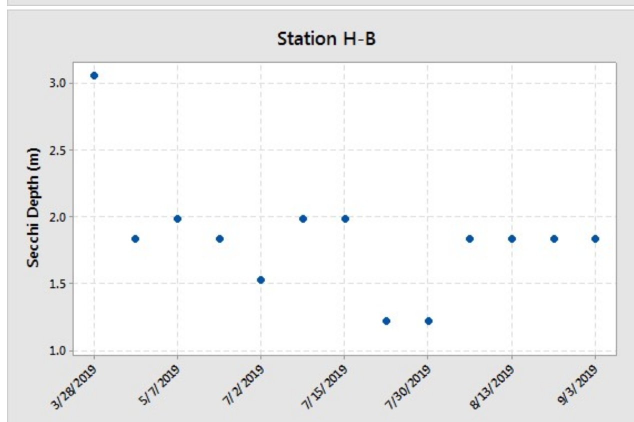


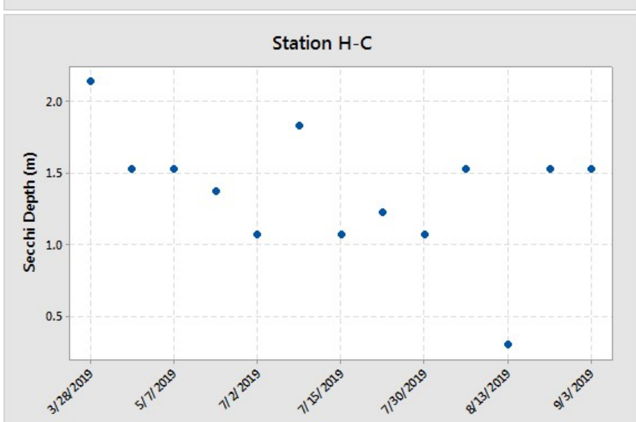


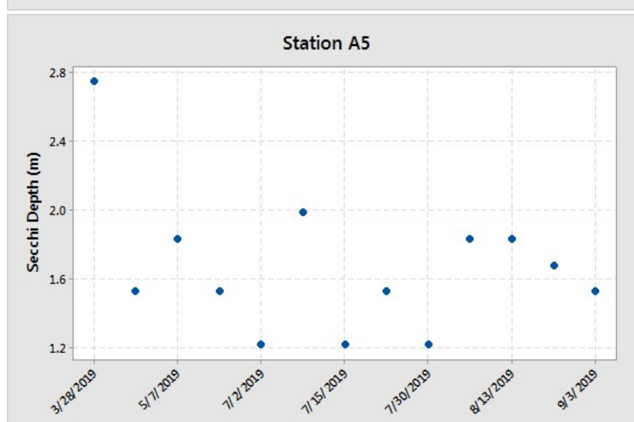


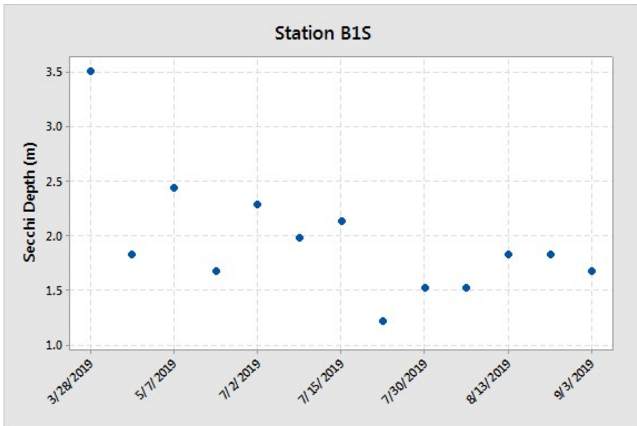


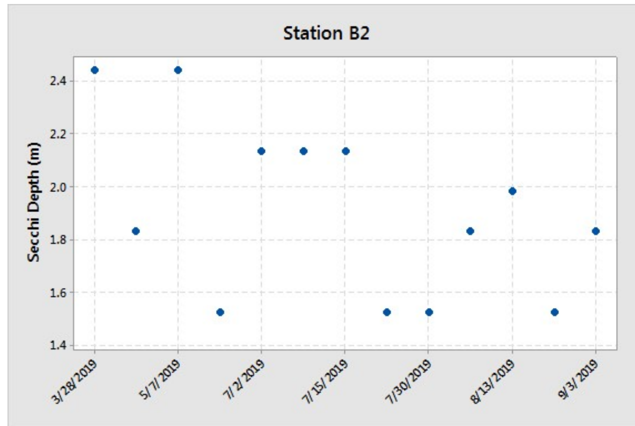


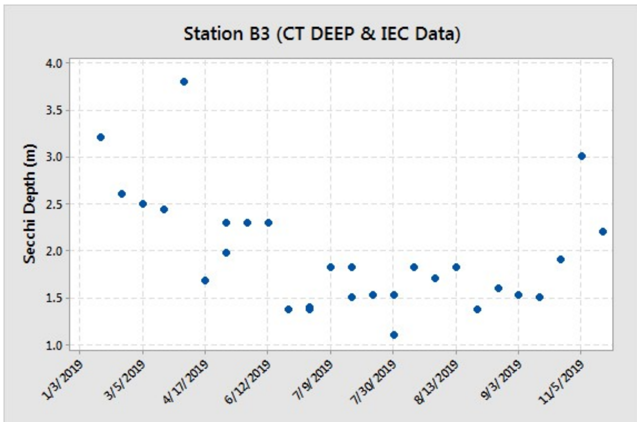


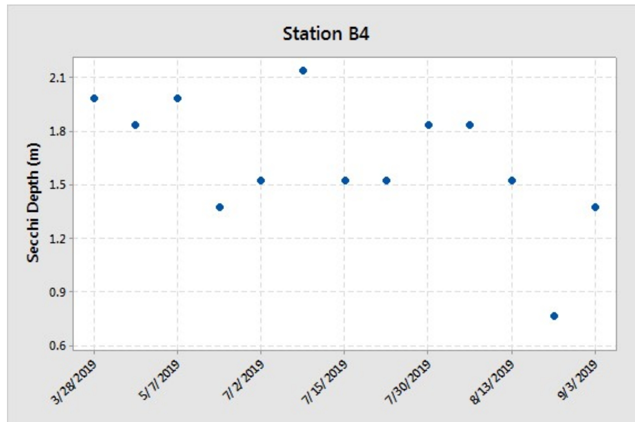


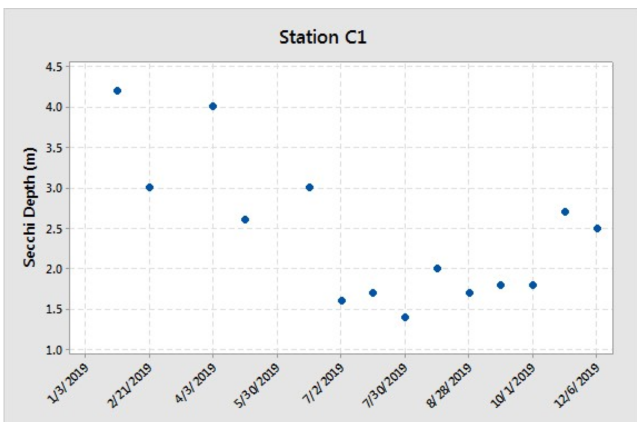


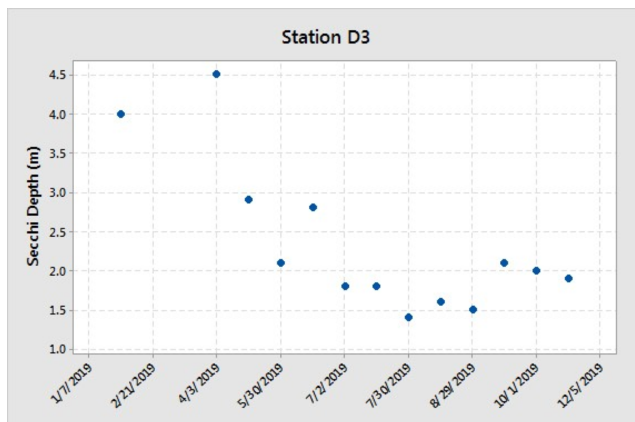

Station B1S
Secchi Depth (m)
3/28/2019
5/7/2019
7/2/2019
7/15/2019
7/30/2019
8/13/2019
9/3/2019

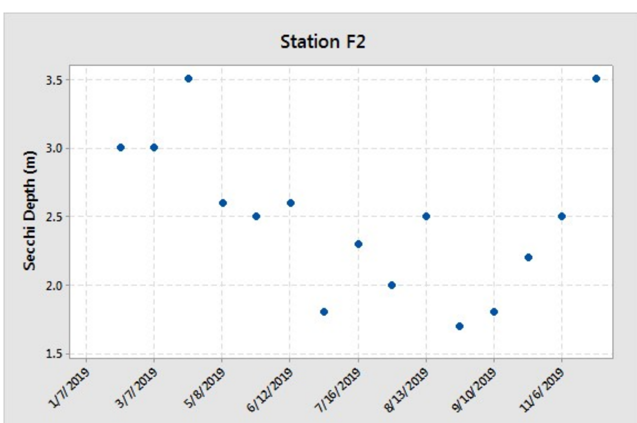

Station B2
Secchi Depth (m)
3/28/2019
5/7/2019
7/2/2019
7/15/2019
7/30/2019
8/13/2019
9/3/2019

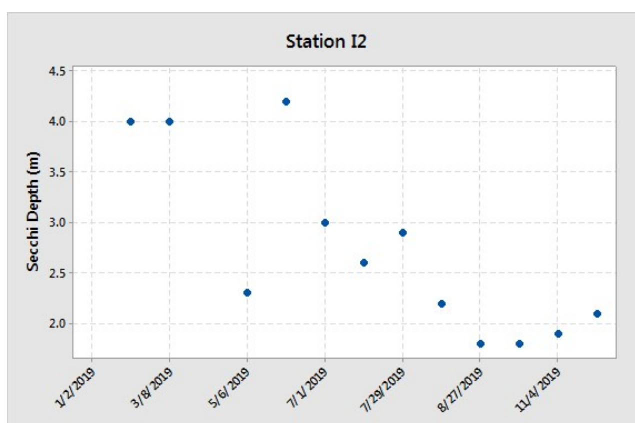

Station B3 (CT DEEP & IEC Data)
Secchi Depth (m)
1/3/2019
3/5/2019
4/17/2019
6/12/2019
7/9/2019
7/30/2019
8/13/2019
9/3/2019
11/5/2019


Station B4
Secchi Depth (m)
3/28/2019
5/7/2019
7/2/2019
7/15/2019
7/30/2019
8/13/2019
9/3/2019


Station C1
Secchi Depth (m)
1/3/2019
2/21/2019
4/3/2019
5/30/2019
7/2/2019
7/30/2019
8/28/2019
10/1/2019
12/6/2019

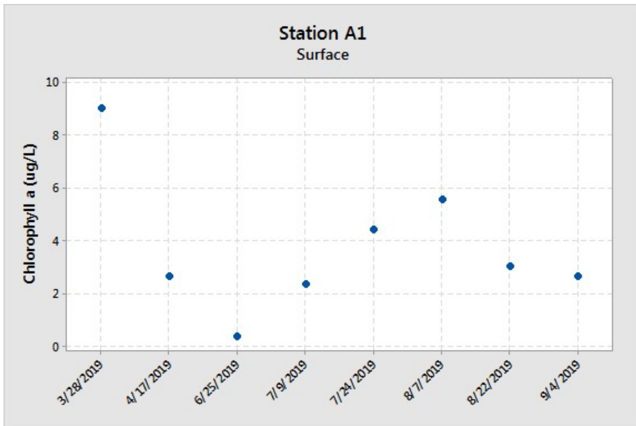

Station D3
Secchi Depth (m)
1/7/2019
2/21/2019
4/3/2019
5/30/2019
7/2/2019
7/30/2019
8/29/2019
10/1/2019
12/5/2019

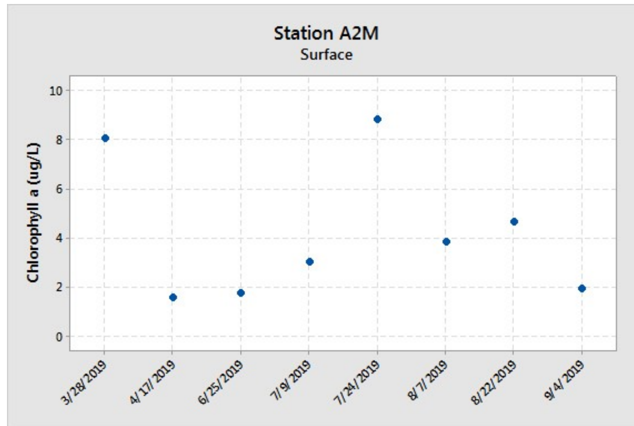

Station F2
Secchi Depth (m)
1/7/2019
3/7/2019
5/8/2019
6/12/2019
7/16/2019
8/13/2019
9/10/2019
11/6/2019

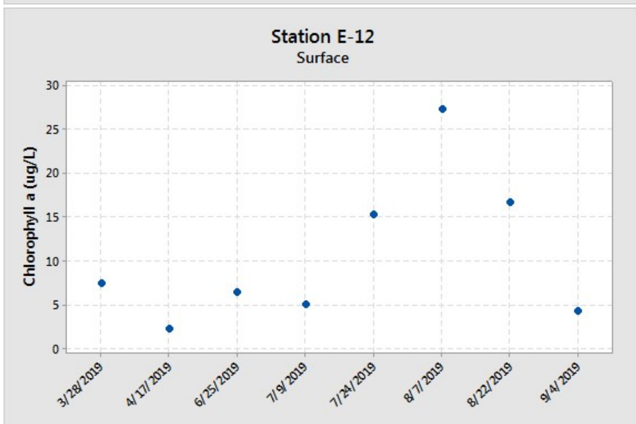

Station I2
Secchi Depth (m)
1/2/2019
3/8/2019
5/6/2019
7/1/2019
7/29/2019
8/27/2019
11/4/2019

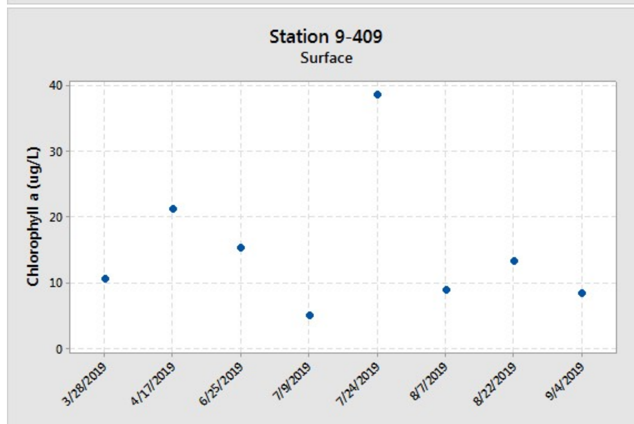
Appendix G – 2019 Year-Round Chlorophyll Data

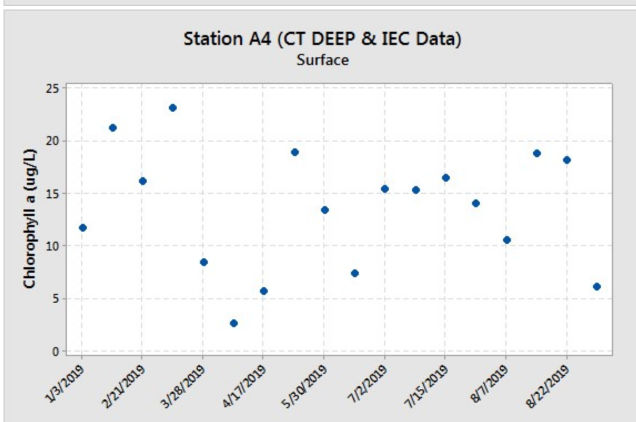
Individual value plots showing each chlorophyll a concentration recorded by the IEC and CT DEEP. CT DEEP data collected between January and September 2019. IEC data collected between March and September 2019. Additional stations are available upon request. See Figure 1 for station locations.

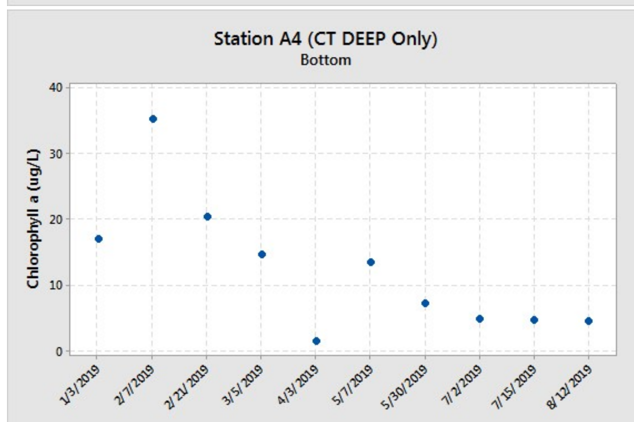


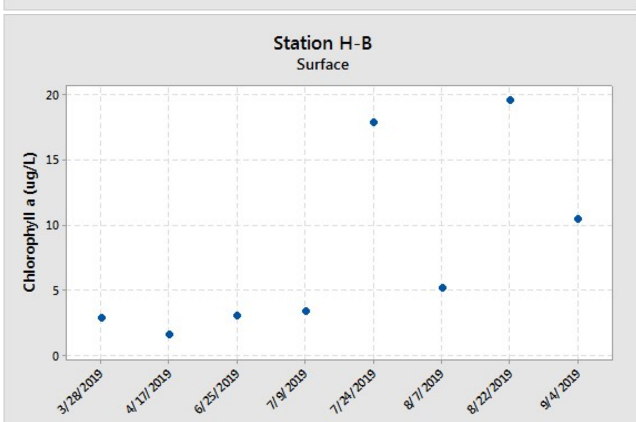


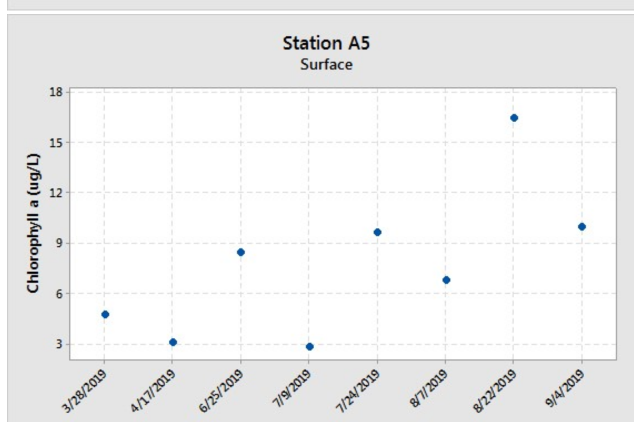


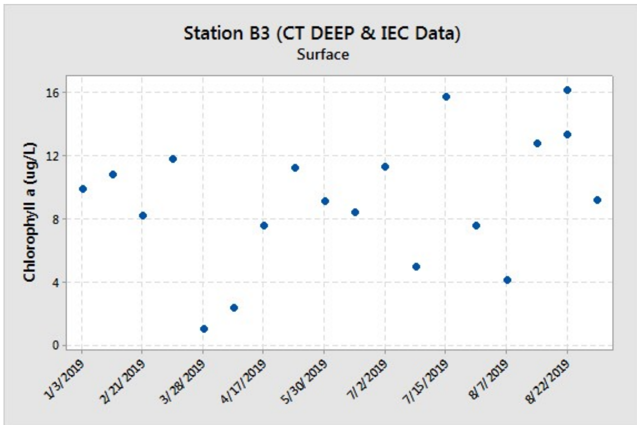


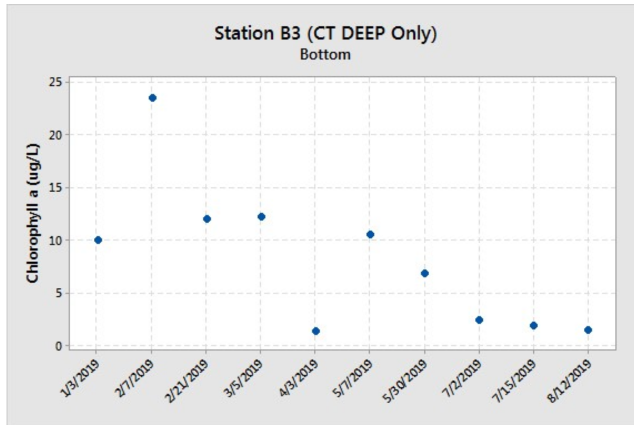


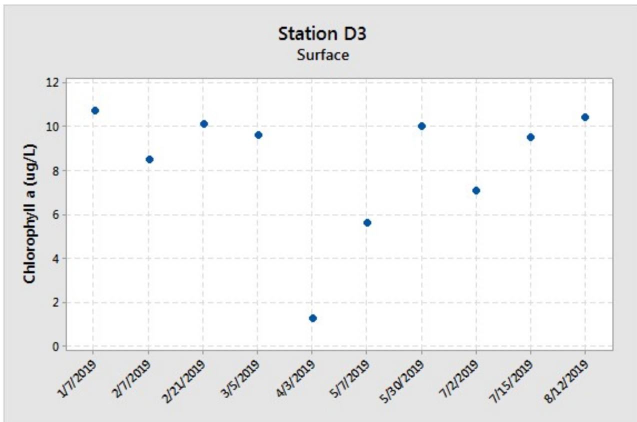


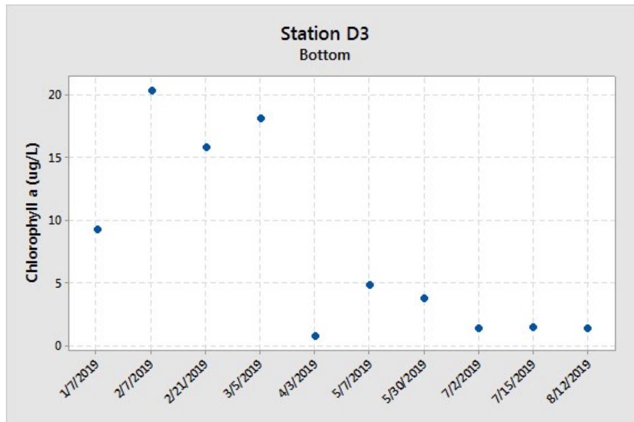


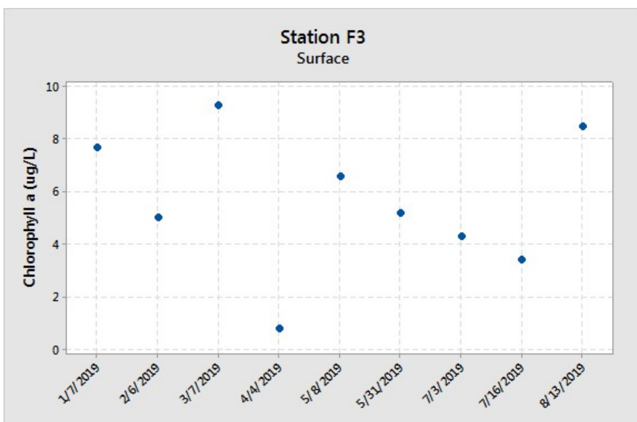


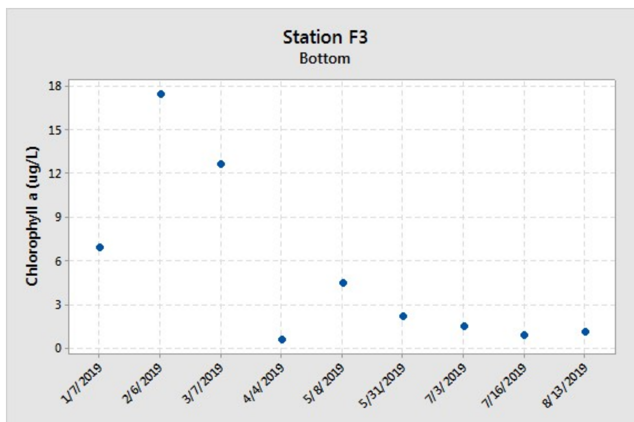

Station B3 (CT DEEP & IEC Data)
Surface
Chlorophyll a (ug/L)

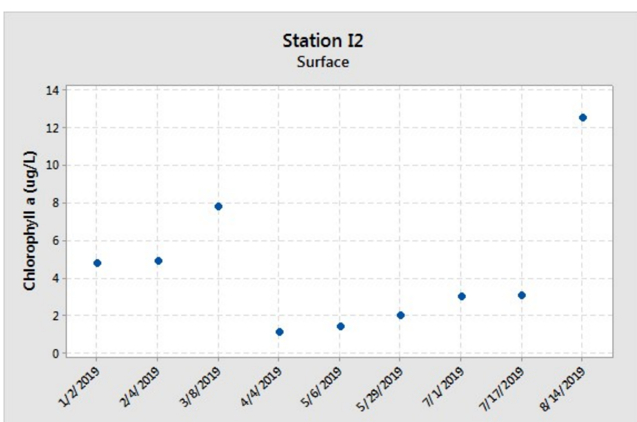

Station B3 (CT DEEP Only)
Bottom
Chlorophyll a (ug/L)

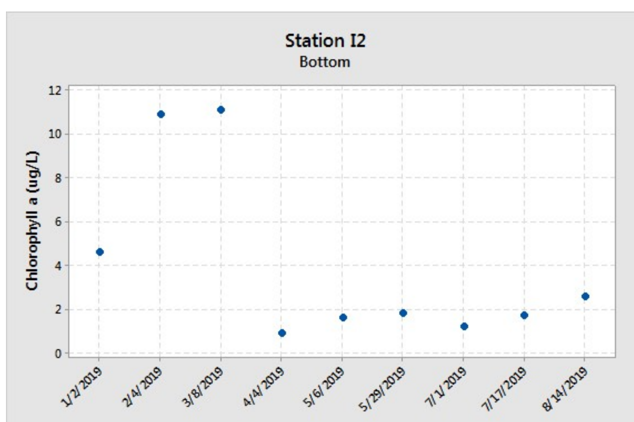

Station D3
Surface
Chlorophyll a (ug/L)


Station D3
Bottom
Chlorophyll a (ug/L)


Station F3
Surface
Chlorophyll a (ug/L)


Station F3
Bottom
Chlorophyll a (ug/L)


Station I2
Surface
Chlorophyll a (ug/L)


Station I2
Bottom
Chlorophyll a (ug/L)

Acknowledgements

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