2022 Long Island Sound Hypoxia Season Review

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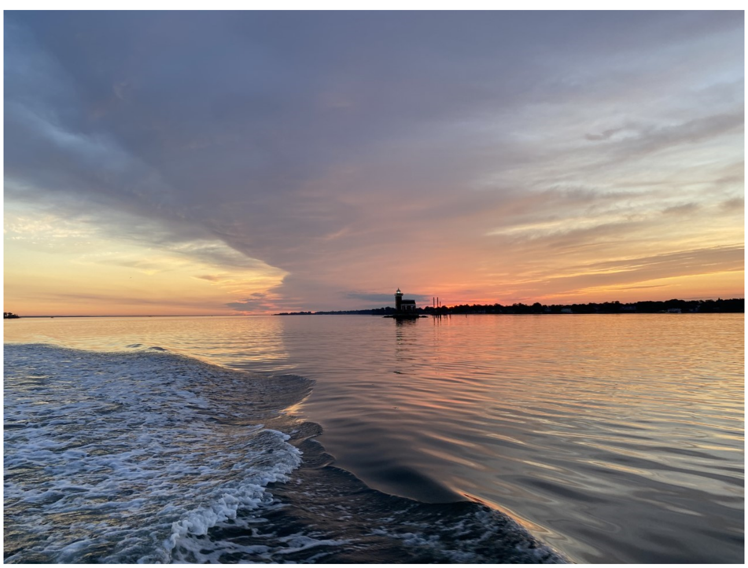
Introduction

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 nutrient loading as a result of urbanization and changes in land use (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 affects 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 2022 hypoxia season.



Methods Overview

Since 1991, CT DEEP has conducted an intensive year-round water quality monitoring program on LIS. Physico-chemical parameters (temperature, salinity, DO, pH, and water clarity), 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](#)).

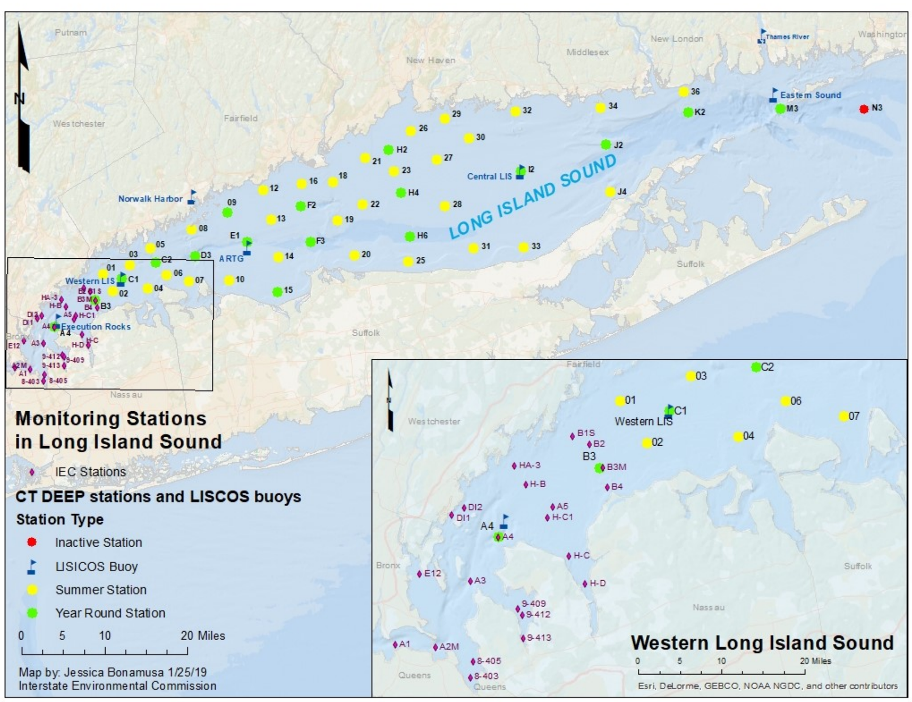
IEC has conducted summer season monitoring in the far Western LIS (WLIS, Figure 1, map inset) and the Upper East River since 1991. Since 2014, IEC's monitoring program has implemented modifications, including the collection of nutrients, to align it with CT DEEP's program. IEC collects physico-chemical 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 a moored buoy 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 and areal estimates that are 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.

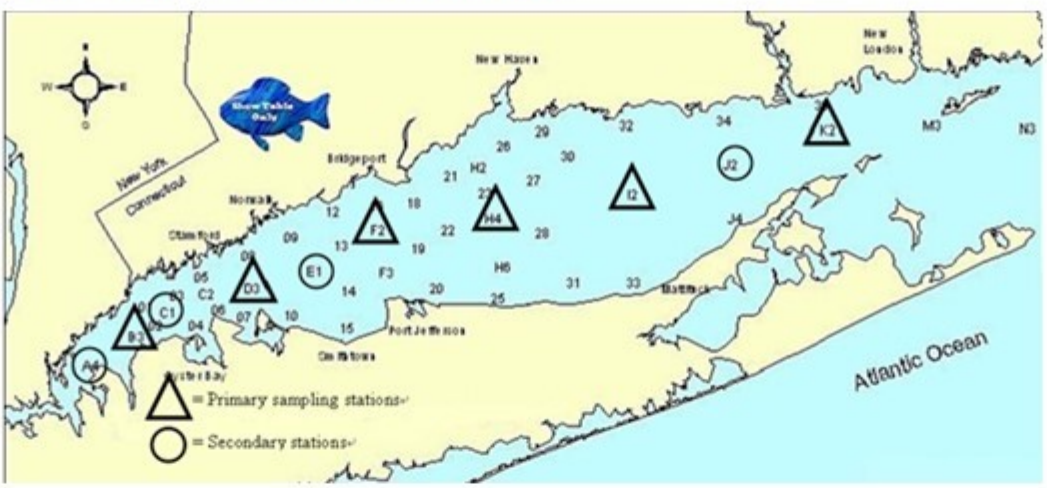


[Figure 1. Hypoxia Monitoring Stations in Long Island Sound](#)

CT DEEP collects monthly surface and bottom water samples from ten stations (triangles and circles, 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). 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 an EPA approved Quality Assurance Project Plan. Results are detailed in a project report submitted to CT DEEP annually. Results from 2022 are not yet available.

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 within the Marine Sciences Department at the University of Connecticut. Collection methods and processing methods are available in an EPA approved Quality Assurance Project Plan. Similarly to the phytoplankton surveys, results from the zooplankton analyses are detailed in a project report submitted to CT DEEP annually. Results from 2022 are not yet available.

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



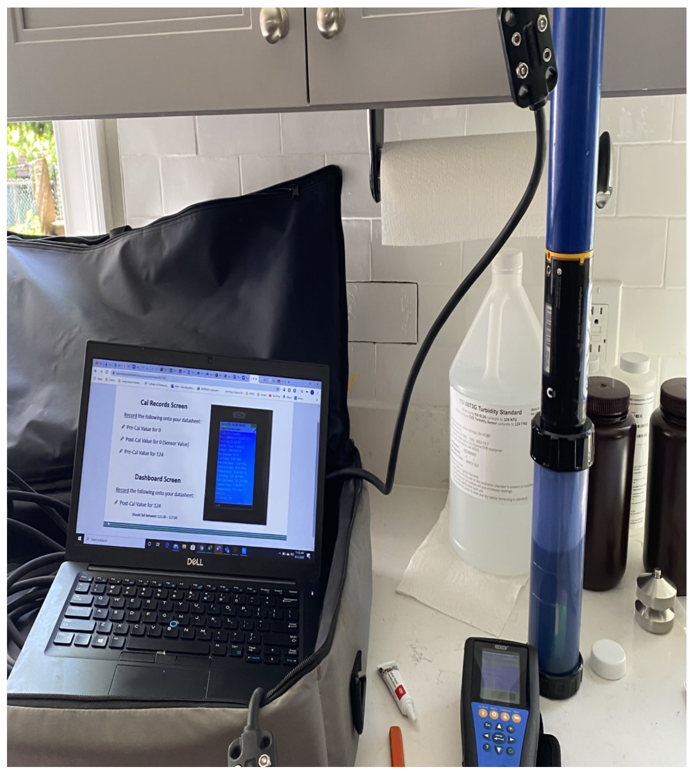
Quality Assurance

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.

Measures of data quality include completeness, representativeness, and comparability.

In 2022, IEC achieved an overall completeness rate of 100%. All 20 runs were completed as scheduled and no stations or sample collections were missed. Some measurements could not be taken at some stations due to issues with equipment. CT DEEP completed 364 station visits in 2021. CT DEEP missed 40 station visits due to the cancellation of the WQJAN21, WQFEB21, and CHFEB21 surveys because of the COVID-19 pandemic, resulting in a 90.1% completeness rate for 2021.

IEC and CT DEEP met their data quality objectives for 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 sample representative temporal conditions. 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 2019.



RESULTS

During the summer of 2022, CT DEEP conducted eight surveys between June 2nd and September 13th while IEC conducted twelve surveys between June 28th and September 15th (Table 1). Hypoxia maps and in situ profiles from stations in WLIS are available in Appendices A-F. All data are available 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

For LIS, DO levels below 3.0 mg/L are considered hypoxic, causing mobile animals to leave 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). This study documented a 4% reduction in finfish biomass when DO levels are 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 is 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, C2, D3, E1, 01, 02, 12, 14, and 15 exhibiting dissolved oxygen concentrations below 3.0 mg/L at some point during the course of the season.

Hypoxic conditions were found during seven IEC surveys. All 13 of IEC's open-water stations exhibited hypoxic conditions at some point over the course of the season.

Timing and Duration

The 2022 hypoxic event lasted an estimated **58 days** beginning on July 10th and ending on September 5th. This is also evident in the continuous data collected by the LISICOS Execution Rocks Buoy. Compared to the previous 35 years, 2022 was slightly above the average of 53 days (Figure 3).

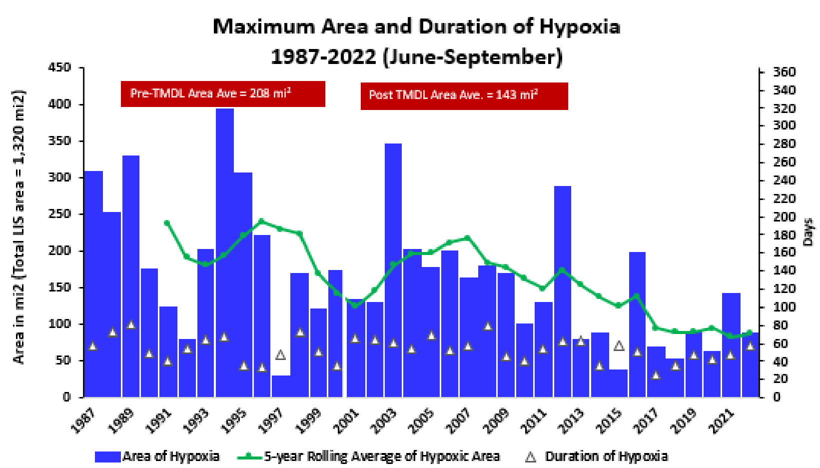


Figure 3. Maximum Area and Duration of Hypoxia. Blue bars represent area, white triangles represent duration, and the green line is the five-year rolling average of hypoxic area. The total area of Long Island Sound is 1,320 mi^2.

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
WQJUN22	6/2/2022	6/6/2022	17	0	0	6.89	B3
HYJUN22	6/14/2022	6/14/2022	23	0	0	5.95	A4
IEC RUN #1	6/28/2022	6/28/2022	22	0	NC		
WQJUL22	7/6/2022	7/8/2022	42	0	0	3.64	A4
IEC RUN #2	7/6/2022	7/6/2022	22	0	NC	7.17	H-D*
IEC RUN #3	7/12/2022	7/12/2022	22	2	NC	1.93	9-413*
HYJUL22	7/18/2022	7/20/2022	40	2	18.76	2.77	A4
IEC RUN #4	7/19/2022	7/19/2022	22	5	NC	2.16	A5
IEC RUN #5	7/26/2022	7/26/2022	22	16	NC	0.55	H-D*
WQAUG22	**8/1/2022**	**8/3/2022**	**42**	**6**	**86.64**	**1.43**	**A4**
IEC RUN #6	**8/2/2022**	**8/2/2022**	**22**	**13**	**NC**	**0.87**	**H-C**
IEC RUN #7	8/12/2022	8/12/2022	22	12	NC	0.98	H-C
IEC RUN #8	8/16/2022	8/16/2022	22	4	NC	2.57	9-413*
HYAUG22	8/17/2022	8/19/2022	40	7	18.76	2.47	14
IEC RUN #9	8/23/2022	8/23/2022	22	13	NC	0.95	9-413*
IEC RUN #10	8/30/2022	8/30/2022	22	10	NC	1.72	H-B
WQSEP22	8/31/2022	9/2/2022	41	6	59.19	1.90	A4
IEC RUN #11	9/9/2022	9/9/2022	22	0	NC	3.28	9-413*
HYSEP22	9/13/2022	9/13/2022	18	0	0	4.51	A4
IEC RUN #12	9/15/2022	9/15/2022	22	0	NC	3.45	A2M

Bold= Maximum Extent of Hypoxia

NC= Not Applicable

* Embayment Station

Area estimates

In order to maintain the continuity and comparability of the long-term data set, areal estimates are based on CT DEEP data only. It is expected that data from 1991-2022 will be re-interpolated using both the CT DEEP and IEC stations at some point in the future. CT DEEP and IEC data are synoptic and provide a snapshot of hypoxic conditions during a specific timeframe over a broad area, while the LISICOS data provide a continuous measurement of hypoxia at specific buoy locations over a more detailed span of time. This often results in disparity between the datasets.

Estimated Maximum Area Between 3.0 and 4.8 mg/L

In 2022, the maximum area of LIS bottom waters between 3.0 and 4.8 mg/L occurred during the WQSEP22 survey (conducted 31 August - 02 September) and was estimated at 369.04 mi^2. From 1991-2022, the yearly area affected by concentrations between 3.0 and 4.8 mg/L averaged 482 mi^2 and varied from 369 to 596 mi^2.

Estimated Maximum Area Below 3.0 mg/L

The 2022 peak hypoxic event occurred during the WQAUG22 cruises between 01 August and 03 August. The maximum area was **86.64 square miles**. Compared to the previous 32-year average (154.2 mi^2), 2022 was below average in area (Figure 3). The lowest dissolved oxygen concentration (0.87 mg/L) documented by IEC during 2022 occurred on 8/02/212 at Station H-C1 (Appendix E). The lowest dissolved oxygen concentration documented by CT DEEP during 2022 at an open water station was 1.43 mg/L and occurred on 8/2/2022 at Station A4 (Appendix D). The Execution Rocks Buoy (Station A4) recorded its lowest reading, 0.12 mg/L, on 8/07/21.

Estimated Maximum Area Below 2.0 mg/L

Based on CT DEEP data, in 2022 the maximum area below 2.0 mg/L was **52.90 square miles**. The average area with concentrations less than 2.0 mg/L, calculated from 1991-2022, is 47.13 mi^2. The IEC documented concentrations below 2.0 mg/L at three of their open-water stations on 26 July, seven of their open-water stations on 2 August, five of their open-water stations on 12 August, and one on 30 August. At the LISICOS Execution Rocks Buoy, there was 32.42 cumulative days below 2.0 mg/L.

Estimated Maximum Area Below 1.0 mg/L

CT DEEP documented 0 stations with a DO concentration below 1 mg/L.. The IEC documented concentrations below 1 mg/L at their open-water stations at Station H-D on 26 July and Station H-C on 2 and 12 August. The LISICOS Execution Rocks Buoy documented a minimum DO of 0.12 mg/L and 10.71 cumulative days of DO concentrations less than 1.0 mg/L. The overall average area affected from 1991-2022 is 10.40 mi^2. The greatest area with DO below 1 mg/L (62 square miles) was during the summer of 2003.

Frequency

Figure 4 shows the frequency of hypoxia occurrence for stations over the 1994-2022 period. The percent of WLIS stations that experience hypoxic conditions continues to be between 90 and 100% (Figure 4).

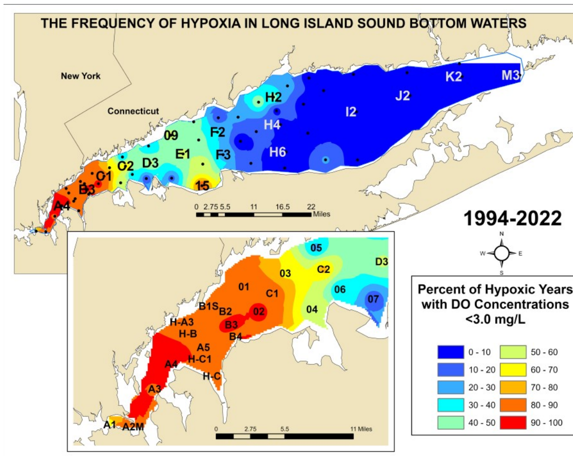


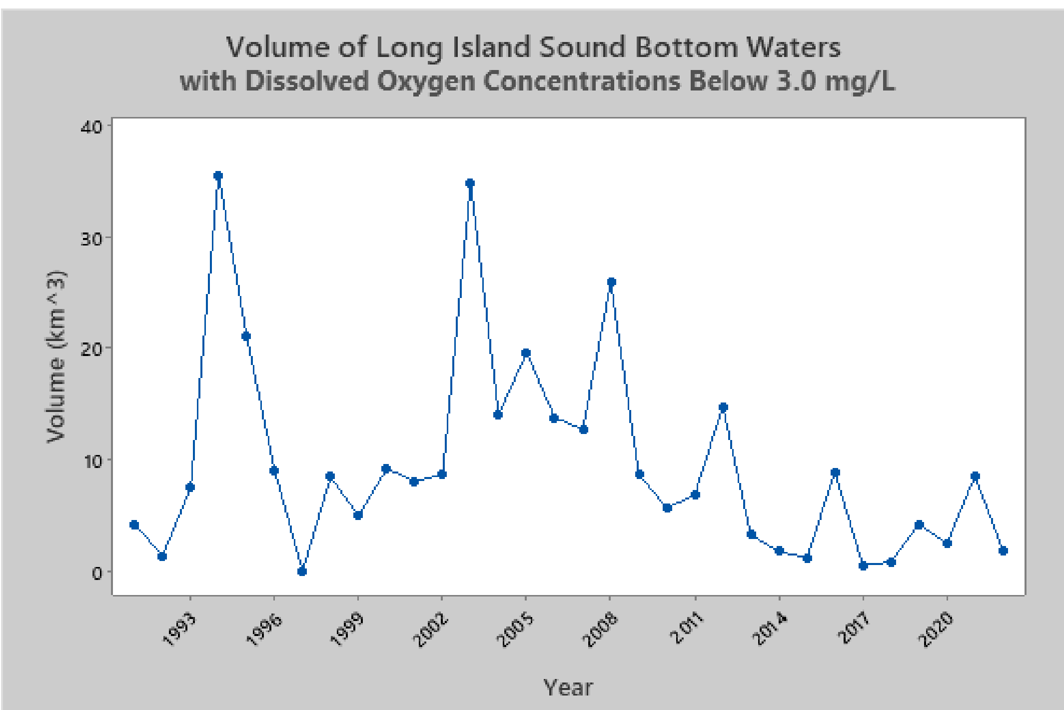
Figure 4. Frequency of Hypoxia in Long Island Sound Bottom Waters

Volume estimates

In 2019, CT DEEP and the O'Donnell lab at UCONN Marine Sciences undertook a project to develop a tool to calculate the hypoxic volume of Long Island Sound. The tool is available to the public and allows users to calculate area and volume estimates on the fly for any survey from 1991-present. The tool utilizes CT DEEP and IEC data. The tool also allows users to create profile graphs of *in situ* data.

The maximum volume of water with concentrations below 3.0 mg/L occurred during the WQAUG22 survey and was 1.82 km^3 (0.44 mi^3).

	Area (km^2)			Volume (km^3)		
CRUISE	2 mg/l	3 mg/l	4.8mg/l	2 mg/l	3 mg/l	4.8 mg/l
WQJUN20	0	0	0	0	0	0
HYJUN20	0	0	0	0	0	0
WQJUL20	0	0	292	0	0	4.77
HYJUL20	12	144	1484	0.1	1.86	57.31
WQAUG20	52	**192**	1496	0.45	**2.46**	53.12
HYAUG20	0	0	1112	0	0	35.3
WQSEP20	0	24	856	0	0.22	22.85
HYSEP20	No Cruise Conducted					
WQJUN21	0	0	0	0	0	0
HYJUN21	0	0	0	0	0	0
WQJUL21	0	0	44	0	0	2.72
HYJUL21	0	0	512	0	0	8.1
WQAUG21	64	204	1408	0.99	2.37	47.97
HYAUG21	108	**360**	1400	0.26	**8.51**	52.96
WQSEP21	20	56	856	0	0.32	22.08
HYSEP21	0	0	284	0	0	5.6
WQJUN22	0	0	0	0	0	0
HYJUN22	0	0	0	0	0	0
WQJUL22	0	0	220	0	0	1.76
HYJUL22	0	0	416	0	0	11.2
WQAUG22	104	200	1104	0.51	1.82	38.05
HYAUG22	0	136	1168	0	1.22	37.6
WQSEP22	44	152	1092	0	0.54	32.29
HYSEP22	0	0	100	0	0	1.7



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.

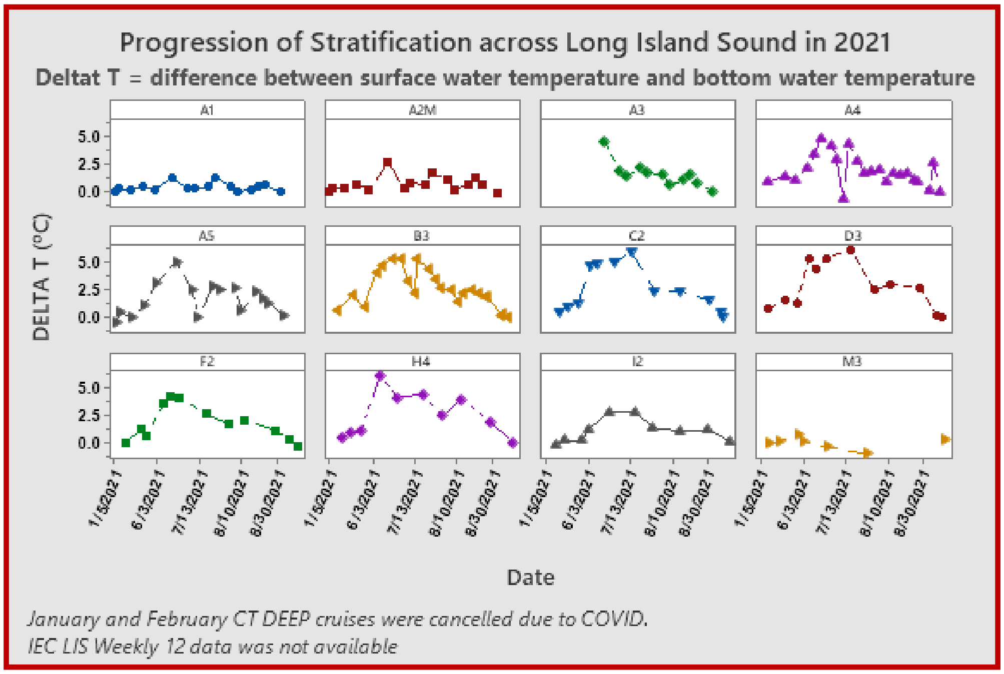


Figure 5. Progression of stratification across Long Island Sound in 2021 where Delta T= surface water temperature minus bottom water temperature.

In 2021, stratification began to set up in April with delta t's (the difference between surface and bottom water temperature) reaching around or above 1.0ºC (Figure 5) . Delta T's peaked at most stations in early-mid July. Destratification (fall turnover) began around mid–August, however station A3 had a delta t of –9.32ºC , which is the largest difference in temperature seen during the entire year. The 2021 maximum surface temperature was 25.25ºC recorded on August 17 at Station 28. The minimum surface temperature was 2.12ºC at Station E1 recorded on March 9. The 2021 maximum bottom temperature was 24.86ºC recorded on August 17 at Station 9-413. The minimum bottom temperature was 2.21ºC at Station 15 recorded on March 9.

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.

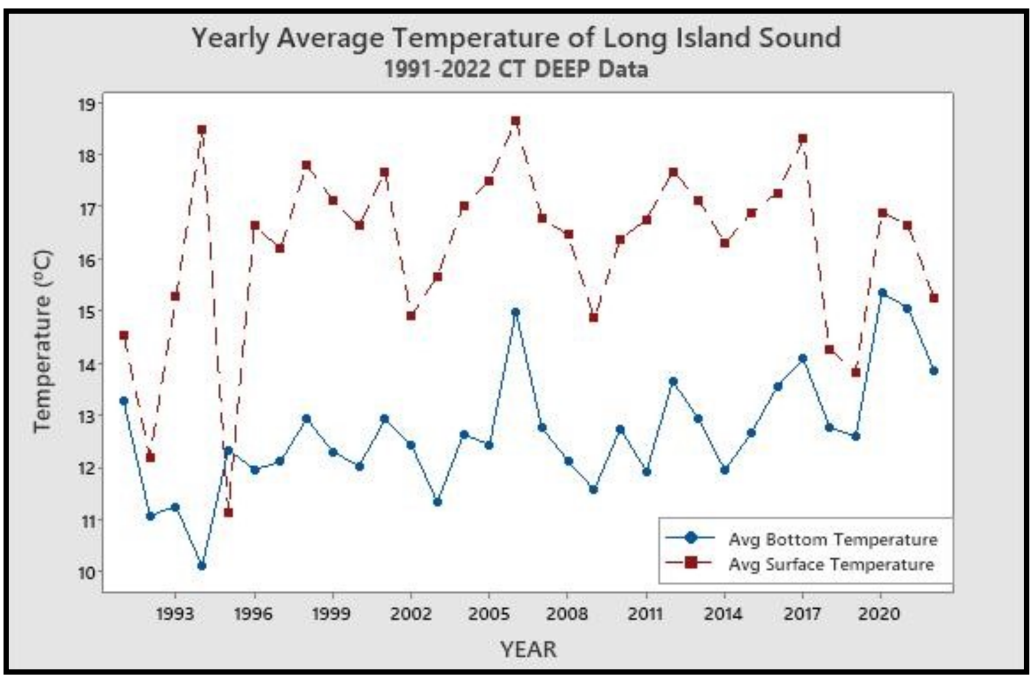


Figure 6. Yearly Average Water Temperatures of Long Island Sound.

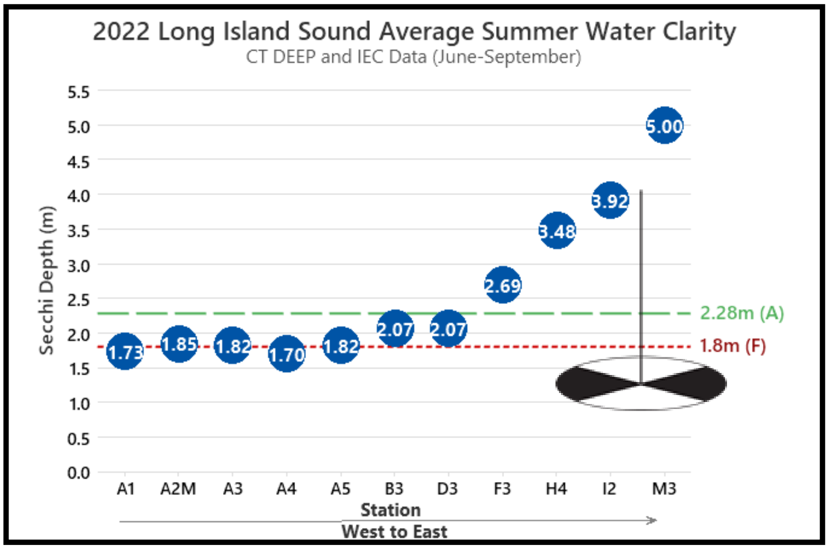
Water Clarity

Water clarity, a measure of how much light penetrates the water column, is an important indicator of the health of seagrass beds, and thus, the ecosystem as a whole (see page 15). 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. 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. The graphs below (Figure 7) highlight this water clarity gradient. In 2022, the western-most axial station (A1 near Whitestone Bridge) had an average Secchi disk depth of 1.7 meters for the summer and 1.7 meters for the year. In both graphs, the average Secchi disk depths gradually increase, reaching a summer average of 2.6 meters and a yearly average of 4.4 meters at the eastern-most axial station (M3 near Fishers Island).

Using average Secchi disk depths, the Long Island Sound Report Card developed by Save the Sound utilizes the following water clarity depth thresholds to "grade" each station: averages <1.8 meters receive an F (<60%), averages 1.8 to <1.95 meters receive a D (60-70%), averages 1.95 to <2.12 meters receive a C (70-80%), averages 2.12 to <2.28 meters receive a B (80-90%), and averages >2.28 meters receive an A (90-100%). Updates to the Report Card are now posted through the Sound Health Explorer.

According to that criteria, Stations A1 and A4 get an F; Stations A2M, A3, and A5 receive a D; Stations B3 and D3 receive a C, and Stations F3, H4, I2 and M3 get an A for the summer of 2022 (Figure 7a).

Some improvements are seen when using the full-year data (Figure 7b), as Stations A4 and A5 go from an F to a B and C, respectively. Stations B3 and D3 go from a C to an A. Station F3 and H4 remain at an A despite slight changes in clarity. However, water clarity at Stations A1 and A2M worsened, the former remaining at an F while the latter goes from a D to an F.



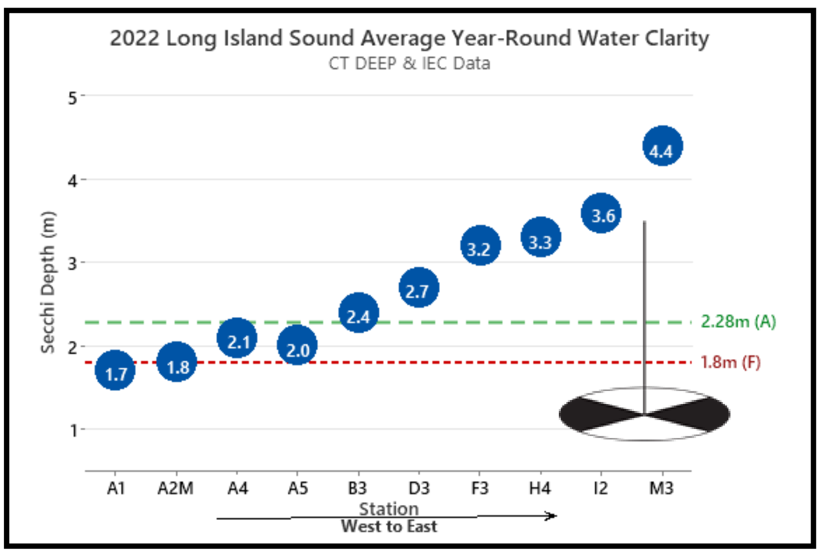


Figure 7. Average water clarity across Long Island Sound in 2022. a) Summer and b) Year-round

Chlorophyll-a

The spring phytoplankton bloom occurs in Long Island Sound between February and April. Historically high levels of chlorophyll-a (chl-a) in the Western Sound during this time have been linked to summertime hypoxia conditions. The 2022 spring bloom began in February. Year-round chlorophyll-a data collected by CT DEEP in 2022 show smaller blooms at the start of the Summer season, however data past June has not been processed and therefore could not be noted. IEC began collecting year round data in the fall of 2018. Some IEC data was not collected or processed in June, some summer runs, and November. The maximum chl-a concentration measured at an axial station was 75.12 ug/L at Station 9-413 on August 2.

Western Sound data collected by IEC between January and December 2022 and CT DEEP data collected between February and June 2022 are available in Appendix H. 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 (SiO_2), and nitrate + nitrite (NO_x), 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 also 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.

pH

In Long Island Sound, eutrophication can contribute to coastal acidification (Wallace et. al., 2014). Excess nutrients fuel algae and phytoplankton growth. 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 released guidelines for measuring changes in pH and carbonate chemistry in eastern coastal waters in 2018 (Pimenta and Grear, 2018). Two of four parameters are needed to describe the seawater carbonate system - pCO2 (partial pressure of carbon dioxide), DIC (dissolved inorganic carbon), alkalinity, and pH, along with temperature and salinity measurements. As of 2018, CT DEEP and IEC only collect one of the four needed parameters - pH. Data from 2021 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 are currently being recalibrated/reconditioned by the manufacturer and will be reinstalled as soon as possible.

Researchers from UCONN began collecting data 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. Due to COVID restrictions, UCONN researchers weren't able to accompany DEEP staff aboard the R/V Dempsey in 2020. However, DEEP staff were able to run the instrumentation to collect the continuous data and collect grab samples which were then processed by UCONN. Preliminary data from 2019 were presented in an On-Demand session of the Restore America's Estuaries Conference held 29 September—1 October 2020. In January of 2021, the first LIS-Respire publication was published, which found that while hypoxic conditions in the Sound are being reduced, further intervention will be needed in order to combat the changes caused by a warming climate. Another manuscript is awaiting publication, while two others are planned to be submitted in 2022.

As part of the National Coastal Condition 2020 sampling (See the NCCA write up for additional details), CT DEEP and EPA Contractors collected surface Total Alkalinity samples from 23 LIS proper stations and 60 embayment stations. The NCCA intensification continued at an additional 60 embayment stations in 2021.

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 2022 was within the top 20 hottest recorded summers for 27 major climate sites, and the hottest on record for Newark, NJ. The beginning of June started with varied average temperatures across New England, with temperatures ranging from 2°F below normal in parts of Maine and New York, to 3°F above normal in parts of New Jersey. Temperatures remained varied for the 2nd half of June, with average temperatures ranging from 3°F cooler than normal in most of northeastern New England to 3°F warmer in western Pennsylvania and West Virginia. Temperature variation continued into the first half of July, with averages roughly matching those of the 2nd half of June. By the 2nd half of July, temperatures in New England were more than 3°F above normal, with 33 of 35 major climate sites reporting a hotter-than-normal July. During this time, New England experienced a heatwave from July 19-25 in which temperature highs were at or above 90°F and lows were at or above 70°F. Temperatures in August ranged from near normal in western Pennsylvania to 6°F above normal along the coastline. Temperatures would continue to remain well above the normal, closing out August as one of the hottest on record for 8 major climate sites, including Hartford, CT and Islip, NY.

Before the beginning of the summer season, parts of New England were experiencing drought conditions. By the end of August, drought conditions had expanded and intensified throughout almost the entirety of New England, with the region surrounding Long Island Sound being in a severe drought. Precipitation in June varied, with rainfall ranging from 25% of normal to more than 200% of normal for New England. In July, precipitation in New England was below average, with areas around Long Island Sound receiving less than 25% of normal rainfall for the first half of the month, and 25-75% of normal rainfall for the second half. In the first half of August, precipitation was once again less than 25% of normal for all of Long Island Sound and most of New England By the 2nd half of August, rainfall varied across the northeast, ranging from 25%-200% of normal. Long Island Sound, however, was still below the normal.

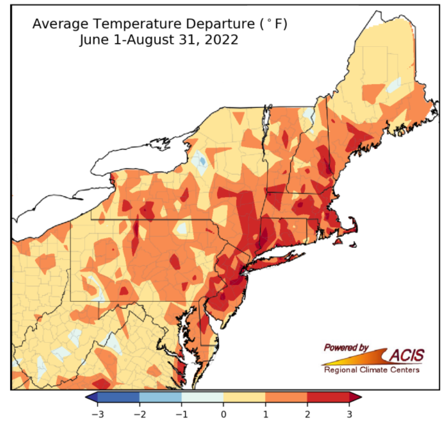


Figure 11. 2022 Northeast Average Summer

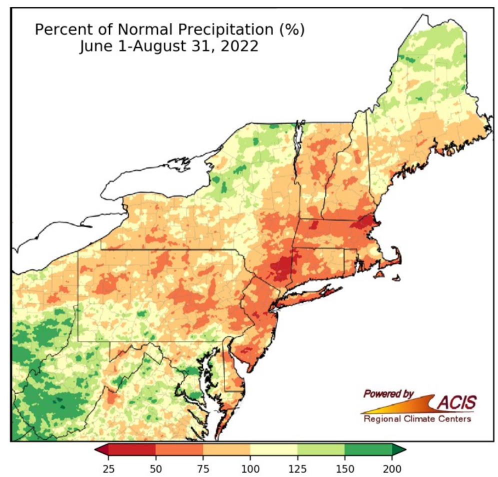


Figure 12. 2022 Northeast Total Summer Precipitation in Inches. From NRCC.

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 2018-2022 five-year running average is 86.6 square miles (Figure 3). This is a 58% reduction from the pre-TMDL baseline. However, further work is needed to achieve water quality standards and meet the CCMP goal. Considerable variability from year to year still exists and the extent is influenced by weather.

While outside the scope of this report, it would be beneficial to examine each station for attainment of water quality standards with respect to the 3.0 mg/L threshold, as well as the 4.8 mg/L threshold. This would be a better measure of the progress towards DO criteria attainment. Additionally, it would be useful to examine the duration of DO in the 3.0 –4.8 mg/L tiers at each station and examine the water column profiles at each station.

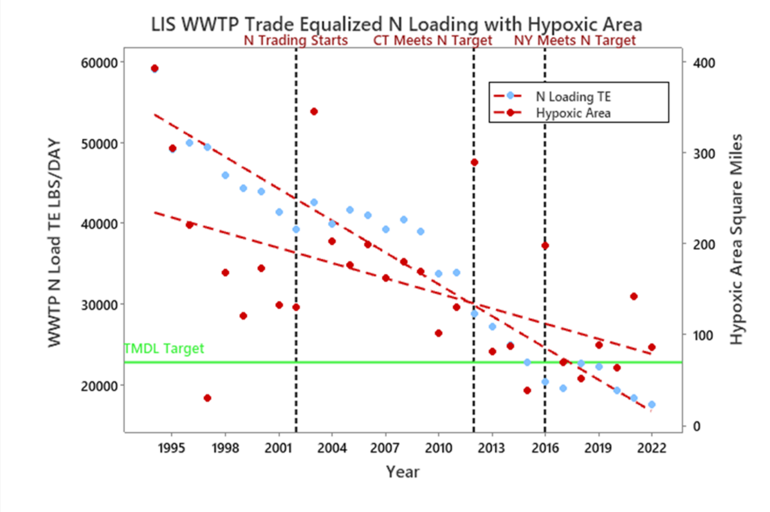


Figure 13. Graph of WWTP Nitrogen Discharge versus Hypoxic Area

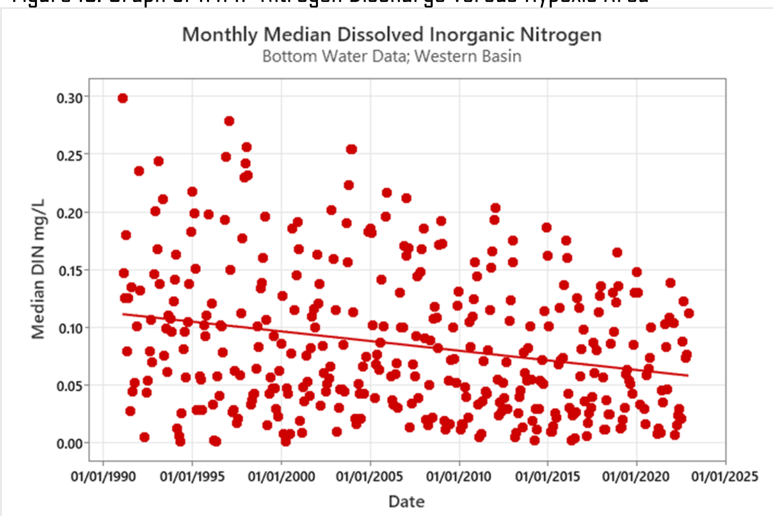


Figure 14. Graph of Monthly Median Bottom Dissolved Inorganic Nitrogen Concentrations from Western Long Island Sound

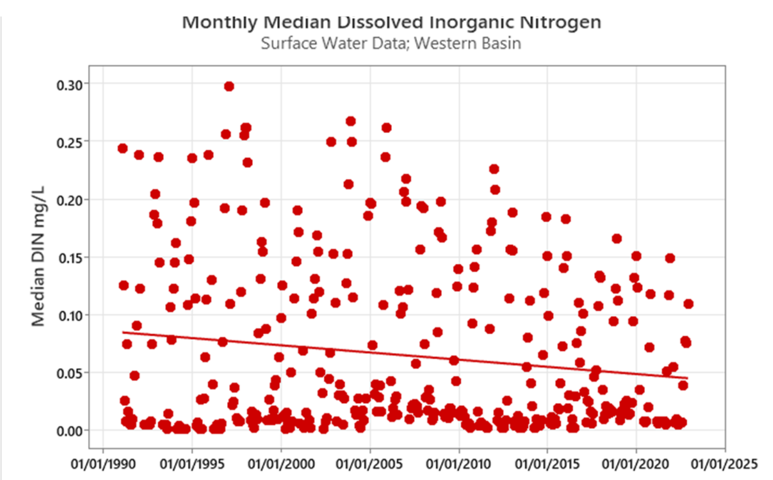


Figure 15. Graph of Monthly Median Surface Dissolved Inorganic Nitrogen Concentrations from Western Long Island Sound

Nitrogen Loading

Another goal of the CCMP relates 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 source 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 13 illustrates the downward movement in hypoxic area as well as a downward trend in nitrogen discharges from both NY and CT WWTPs. 2021 however, did see the highest hypoxic area since 2016. 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.

Since 2018, when nitrogen loading increased for the first time since 2011, loading in the Sound has continued to decrease and is currently sitting below 20,000 TE lbs/day, well beneath the TMDL target

Dissolved Inorganic Nitrogen (nitrate + nitrite + ammonia) is the most bioavailable form of nitrogen used by phytoplankton. Figures 14 and 15 illustrate the monthly median concentration of Dissolved Inorganic Nitrogen measured from the surface and bottom waters of western LIS at CT DEEP stations. The general tendency of the data are in a downward direction.

Water Clarity

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

Water clarity is a measure of how much light penetrates through the water column of Long Island Sound and is important in nearshore waters for the growth of eelgrass. Eelgrass, *Zostera marina,* is a rooted, underwater grass that provides habitat and protection for fish and invertebrates and food for many migratory birds. Healthy eelgrass beds also trap sediment and reduce wave energy during storms, improving water quality and protecting coastal areas from erosion. 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). The depth limitation of seagrass in the Eastern Sound is used as the standard by which water clarity is judged throughout the Sound, including areas which do not currently support seagrass.

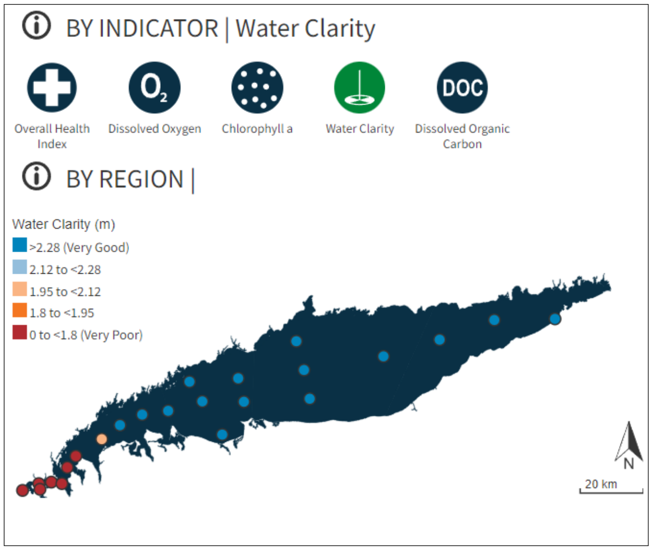


Figure 16. Image from the Long Island Sound Report Card showing station data for the water clarity indicator. Image shows 2018 data.

The CCMP target utilizes 2015 data as the baseline and threshold values developed as part of the [Long Island Sound Report Card](#) to track progress (Figure 16). Generally, eelgrass beds need about 22% of the light at the surface to reach the plant; at 3.65 m of total water depth, this equates to a Secchi depth of ~2.4 m. At 1.1 m of total water depth (almost too shallow for eelgrass), this equates to a Secchi depth of ~0.7 m. These two endpoints were used to develop an equation to relate Secchi depth to a score, where <0.7 m gets a 0% and >2.4m gets a 100%. Annual average Secchi disk depths greater than 2.28 meters are considered very good and receive an A, (90-100%) while depths less than 1.8 meters are considered very poor (an F, <60%).

Generally, with the exception of stations in the Western Narrows, water clarity across LIS is good (Figure 17). Water clarity in the Western Sound is especially impacted by suspended sediments, organic matter, and plankton in the water column.

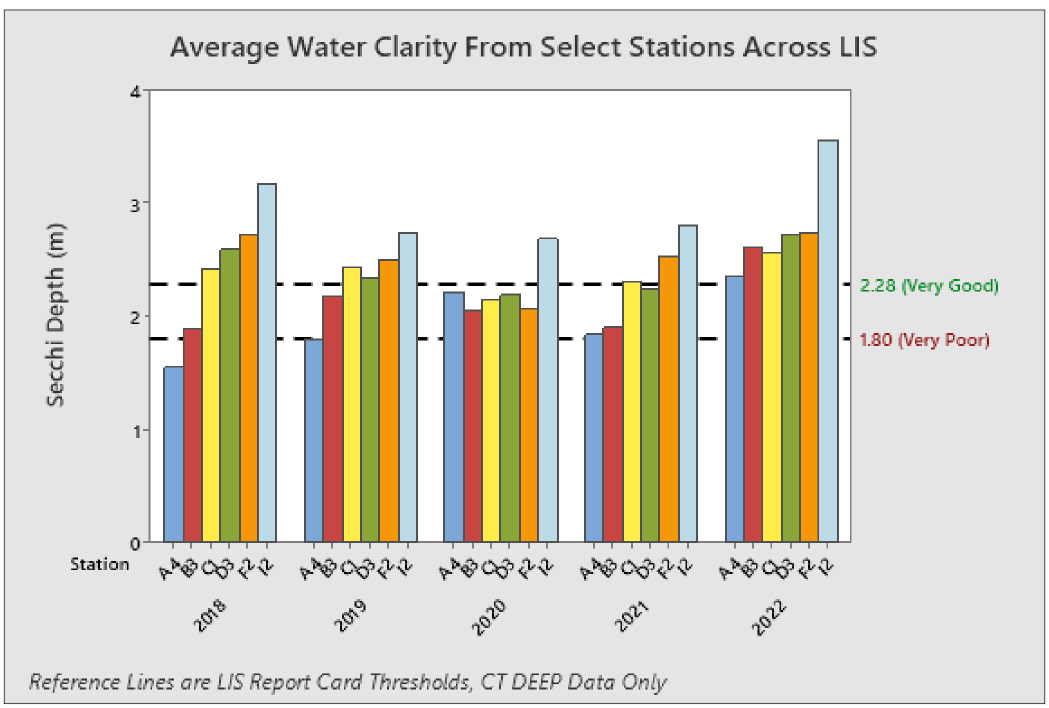


Figure 17. Year round averages of water clarity data from select stations across LIS.

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Simpson, D.G., Gottschall, K., and Johnson, M. 1996. Cooperative interagency resource assessment (Job 5). In: A study of marine recreational fisheries in Connecticut, CT DEP Marine Fisheries Office, PO Box 719, Old Lyme, CT 06371, p. 99-122.

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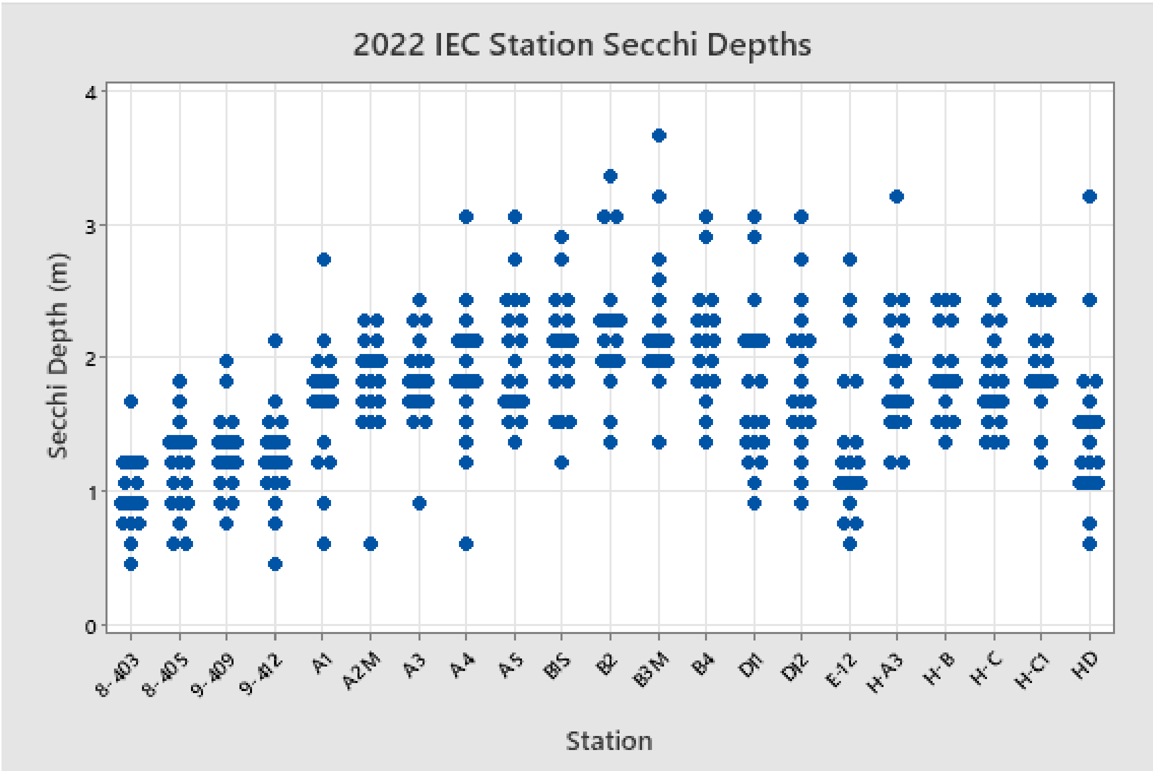
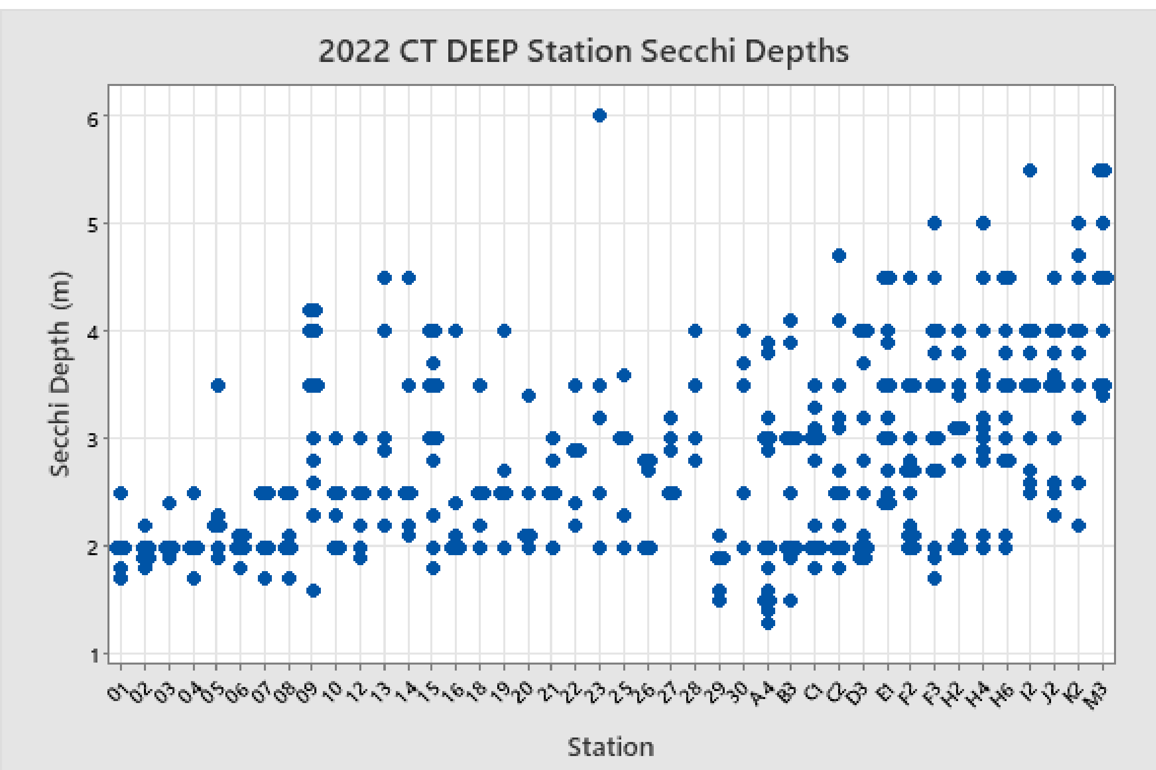
[2022 DEEP Summer (June-September) Profile Data]

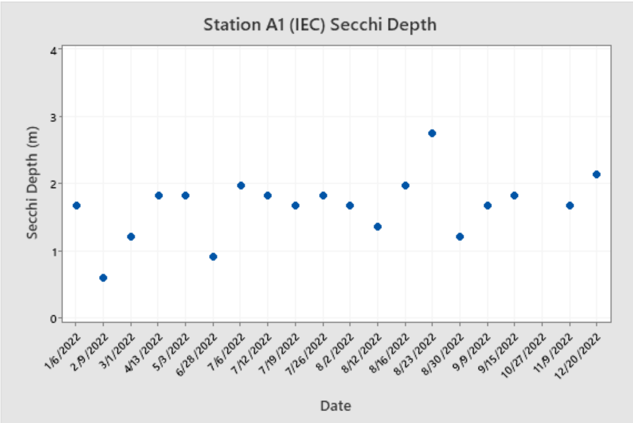
[2022 IEC Data (January-December)]

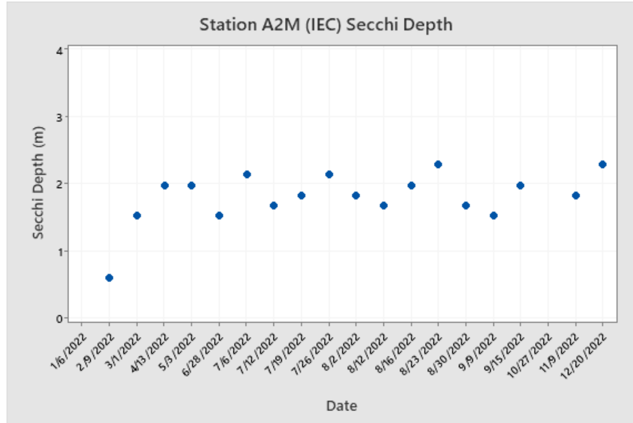
Appendix I – 2022 Year-Round Water Clarity Data

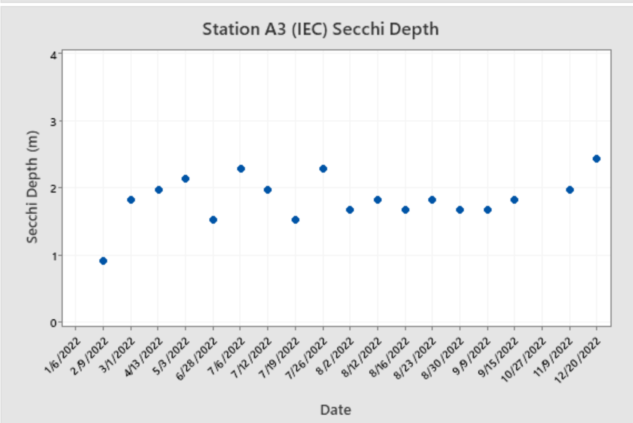
Individual value plots showing each Secchi disk depth recorded by the IEC and CT DEEP in 2022.
Data from select stations are presented temporally on the following pages. See Figure 1 for station locations.

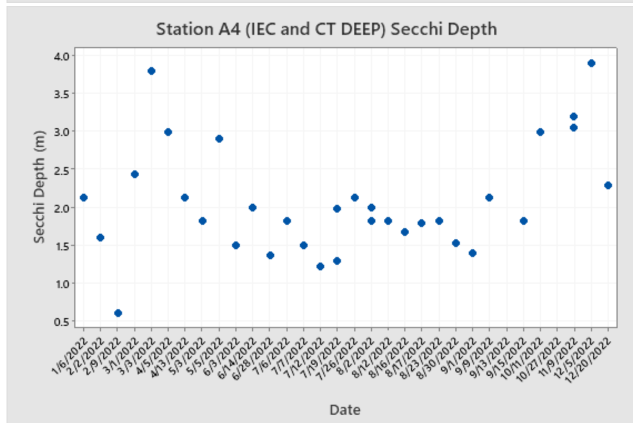


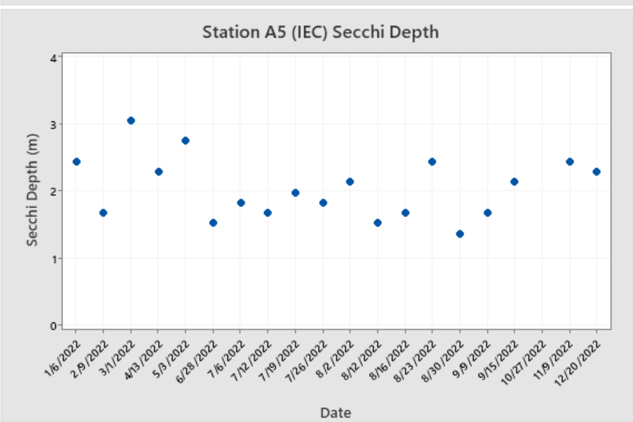


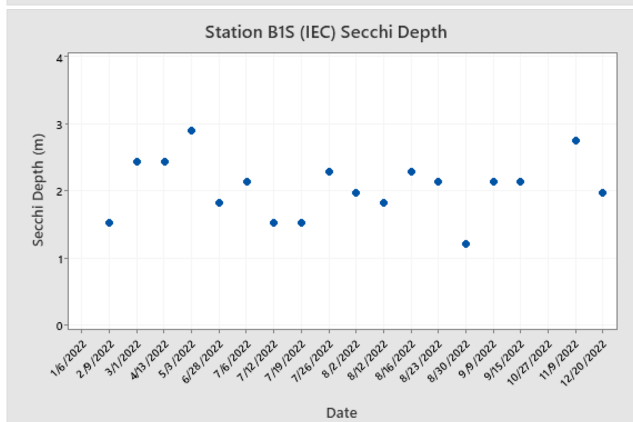

Station A1 (IEC) Secchi Depth
Secchi Depth (m)
Date

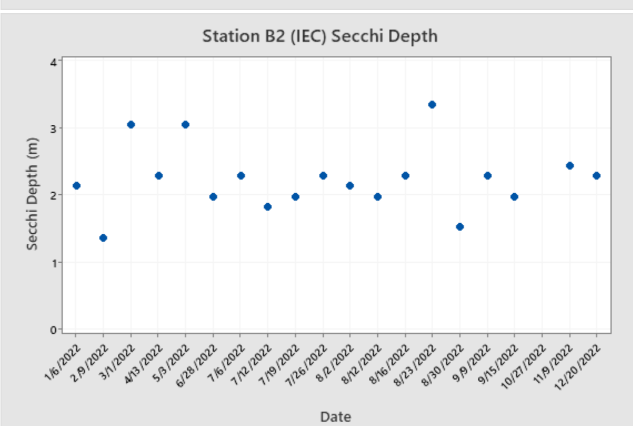

Station A2M (IEC) Secchi Depth
Secchi Depth (m)
Date

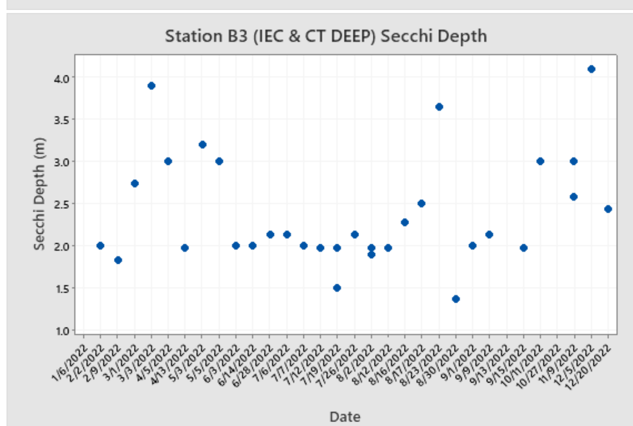

Station A3 (IEC) Secchi Depth
Secchi Depth (m)
Date

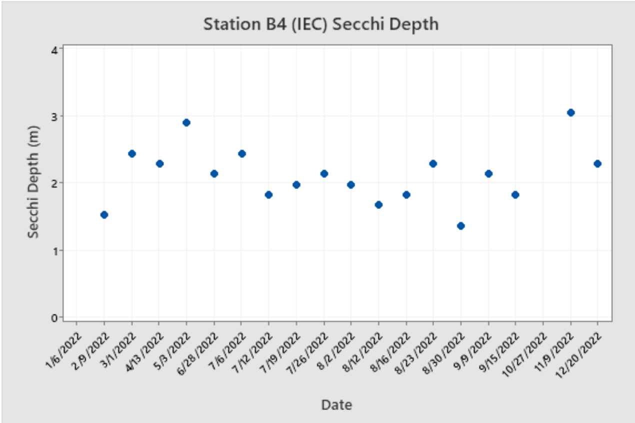

Station A4 (IEC and CT DEEP) Secchi Depth
Secchi Depth (m)
Date

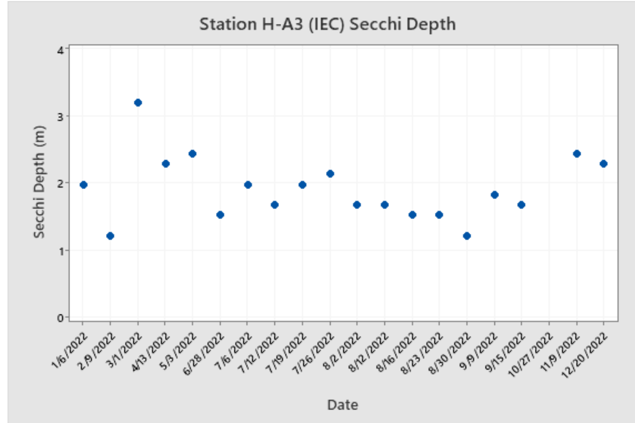

Station A5 (IEC) Secchi Depth
Secchi Depth (m)
Date

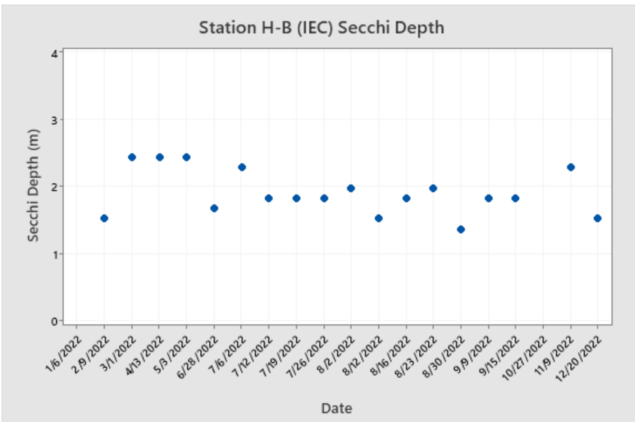

Station B1S (IEC) Secchi Depth
Secchi Depth (m)
Date

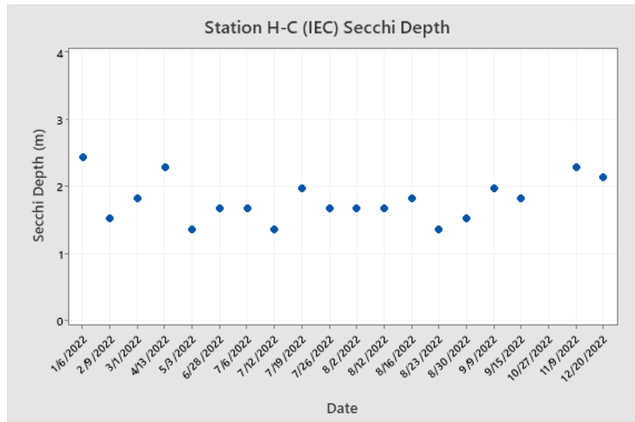

Station B2 (IEC) Secchi Depth
Secchi Depth (m)
Date

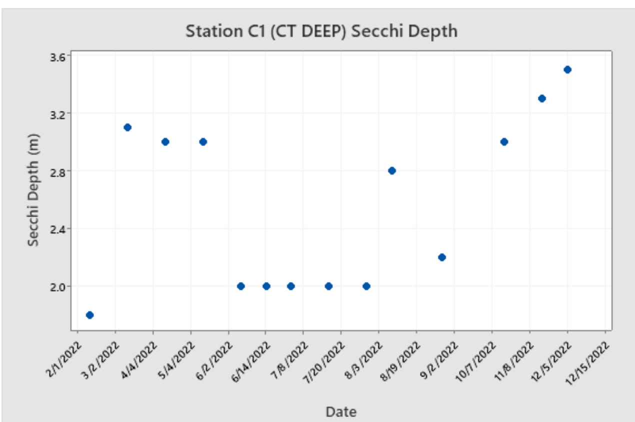

Station B3 (IEC & CT DEEP) Secchi Depth
Secchi Depth (m)
Date

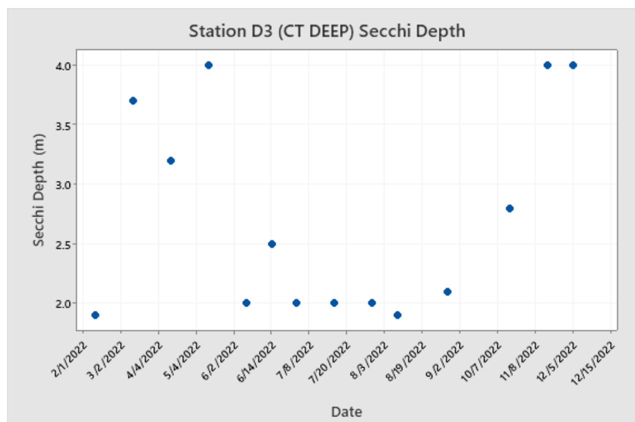

Station B4 (IEC) Secchi Depth
Secchi Depth (m)
Date

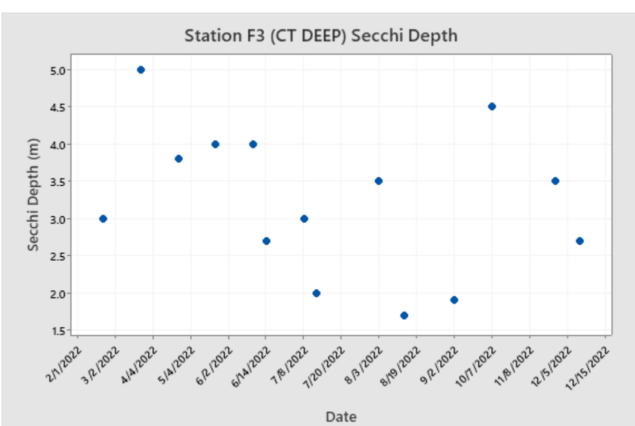

Station H-A3 (IEC) Secchi Depth
Secchi Depth (m)
Date

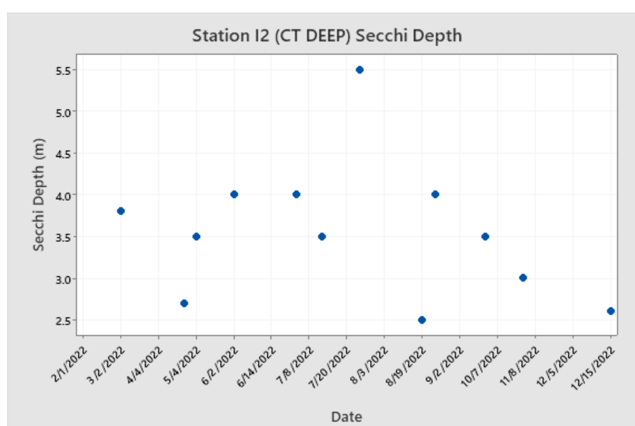

Station H-B (IEC) Secchi Depth
Secchi Depth (m)
Date


Station H-C (IEC) Secchi Depth
Secchi Depth (m)
Date


Station C1 (CT DEEP) Secchi Depth
Secchi Depth (m)
Date

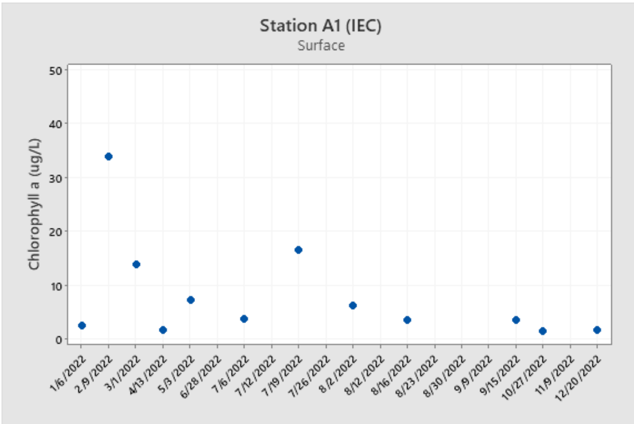

Station D3 (CT DEEP) Secchi Depth
Secchi Depth (m)
Date

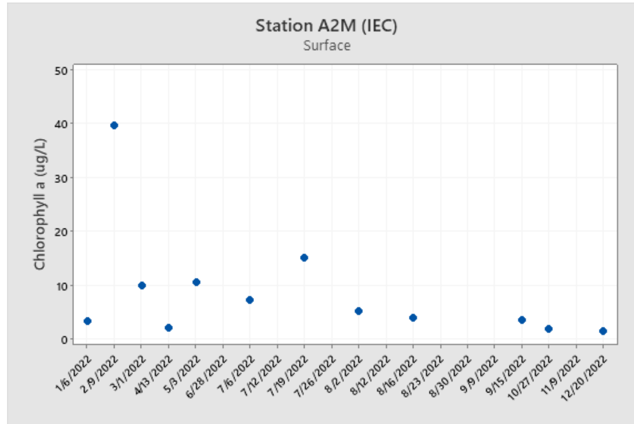

Station F3 (CT DEEP) Secchi Depth
Secchi Depth (m)
Date

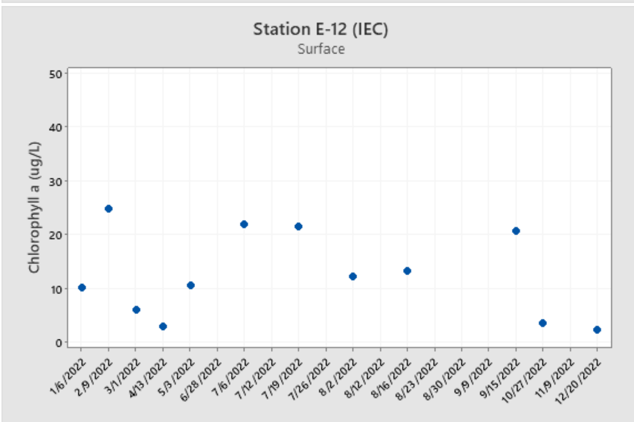

Station I2 (CT DEEP) Secchi Depth
Secchi Depth (m)
Date

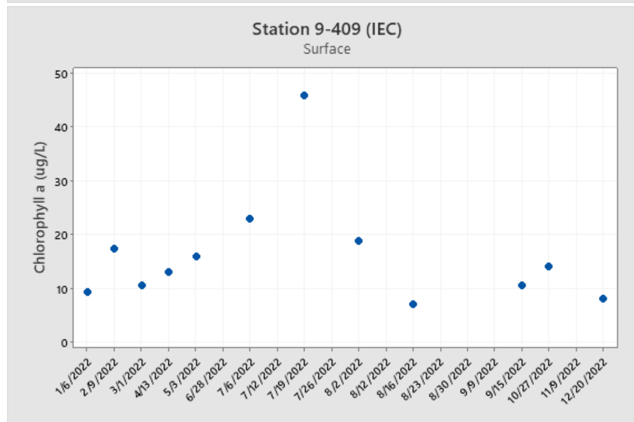
Appendix J – 2022 Year-Round Chlorophyll Data

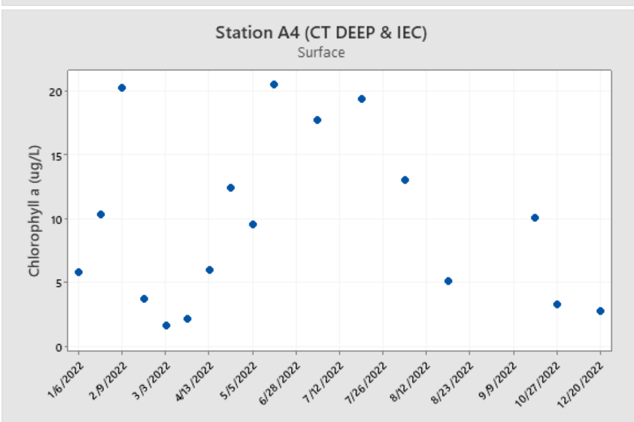
Individual value plots showing each chlorophyll a concentration recorded by the IEC and CT DEEP. CT DEEP data collected between February and June 2022. IEC data collected between January and December 2022. Additional stations are available upon request. See <u>Figure 1</u> for station locations.

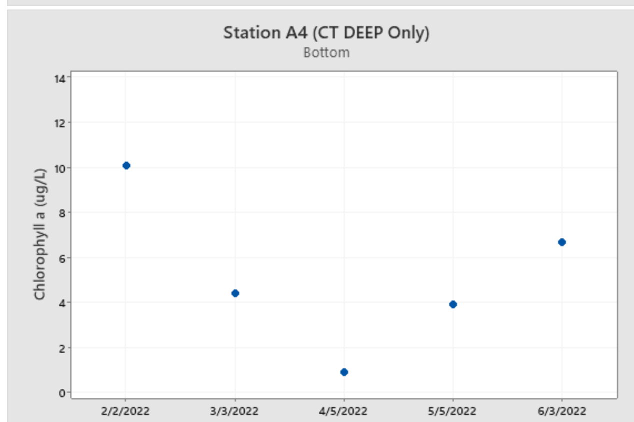


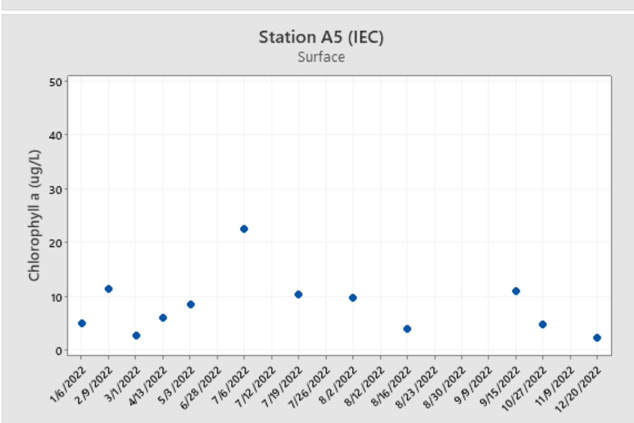


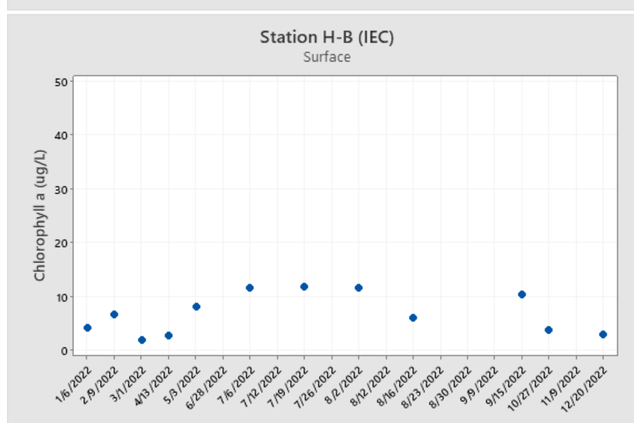


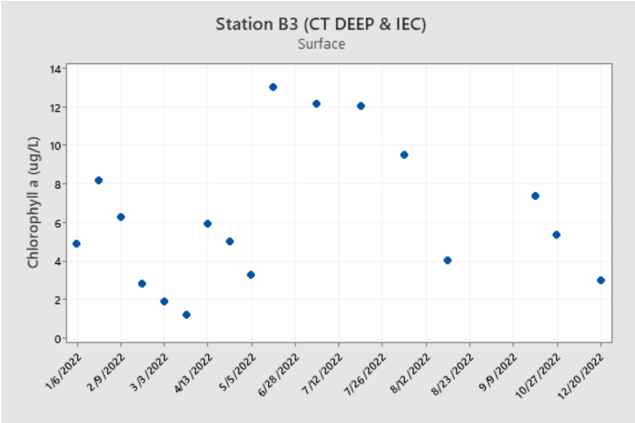











Station B3 (CT DEEP & IEC)
Surface
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
14
1/6/2022
2/9/2022
3/3/2022
4/13/2022
5/5/2022
6/28/2022
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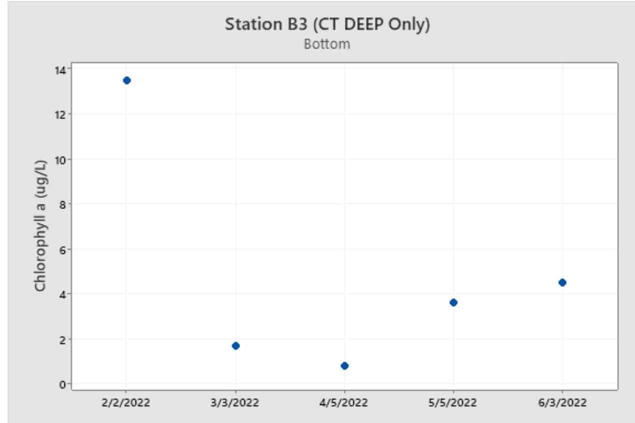
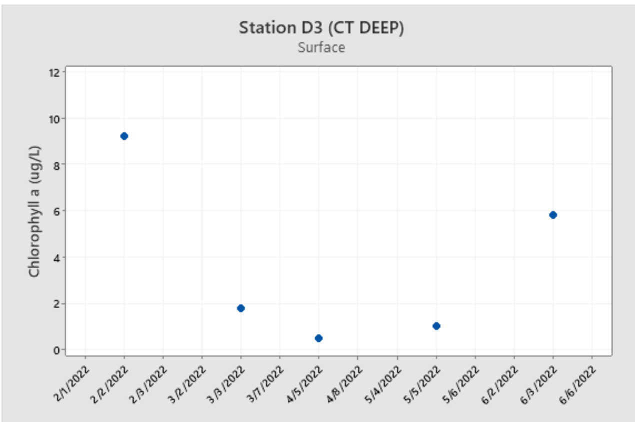
10/27/2022
12/20/2022


Station B3 (CT DEEP Only)
Bottom
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
14
2/2/2022
3/3/2022
4/5/2022
5/5/2022
6/3/2022


Station D3 (CT DEEP)
Surface
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
2/1/2022
2/2/2022
2/3/2022
3/2/2022
3/3/2022
3/7/2022
4/5/2022
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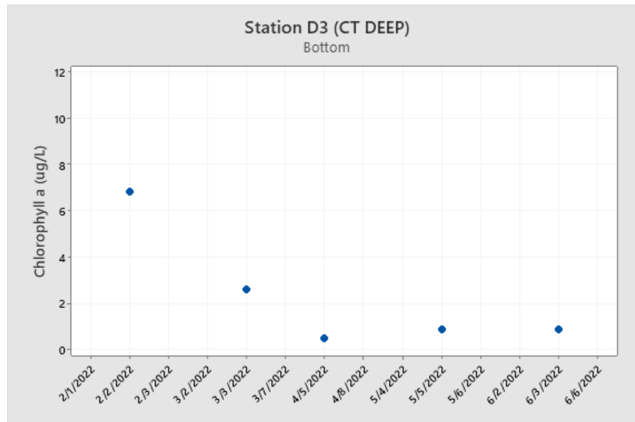
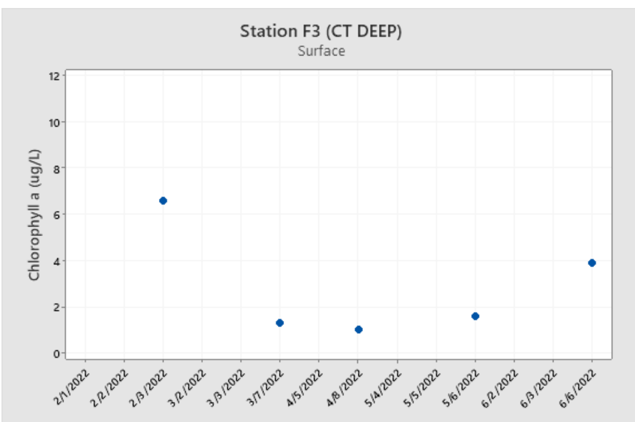
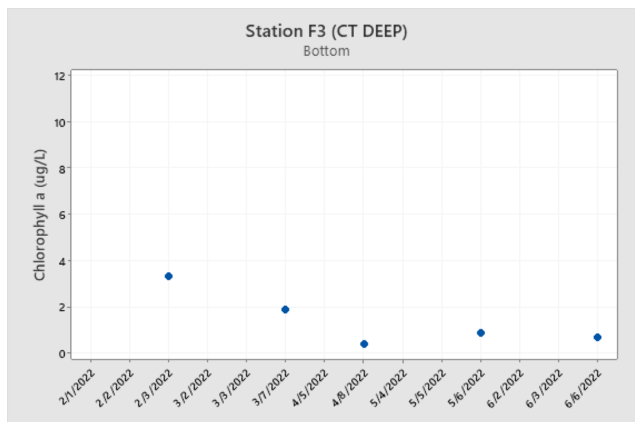
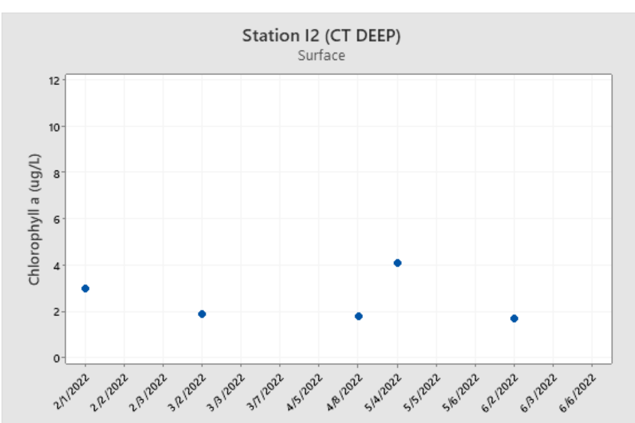
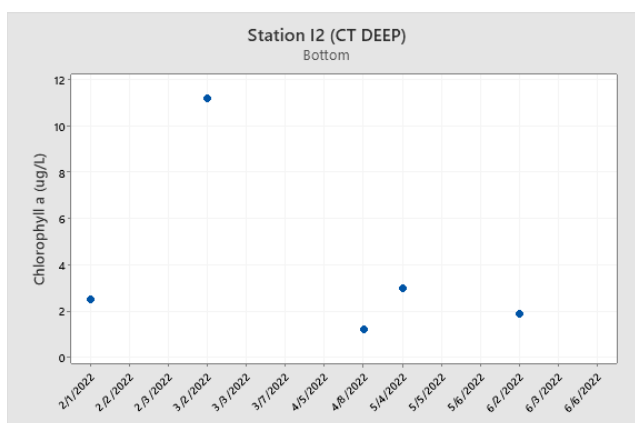
6/3/2022
6/6/2022


Station D3 (CT DEEP)
Bottom
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
2/1/2022
2/2/2022
2/3/2022
3/2/2022
3/3/2022
3/7/2022
4/5/2022
4/8/2022
5/4/2022
5/5/2022
5/6/2022
6/2/2022
6/3/2022
6/6/2022


Station F3 (CT DEEP)
Surface
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
2/1/2022
2/2/2022
2/3/2022
3/2/2022
3/3/2022
3/7/2022
4/5/2022
4/8/2022
5/4/2022
5/5/2022
5/6/2022
6/2/2022
6/3/2022
6/6/2022


Station F3 (CT DEEP)
Bottom
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
2/1/2022
2/2/2022
2/3/2022
3/2/2022
3/3/2022
3/7/2022
4/5/2022
4/8/2022
5/4/2022
5/5/2022
5/6/2022
6/2/2022
6/3/2022
6/6/2022


Station I2 (CT DEEP)
Surface
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
2/1/2022
2/2/2022
2/3/2022
3/2/2022
3/3/2022
3/7/2022
4/5/2022
4/8/2022
5/4/2022
5/5/2022
5/6/2022
6/2/2022
6/3/2022
6/6/2022


Station I2 (CT DEEP)
Bottom
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
2/1/2022
2/2/2022
2/3/2022
3/2/2022
3/3/2022
3/7/2022
4/5/2022
4/8/2022
5/4/2022
5/5/2022
5/6/2022
6/2/2022
6/3/2022
6/6/2022

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