2020 Long Island Sound Hypoxia Season Review

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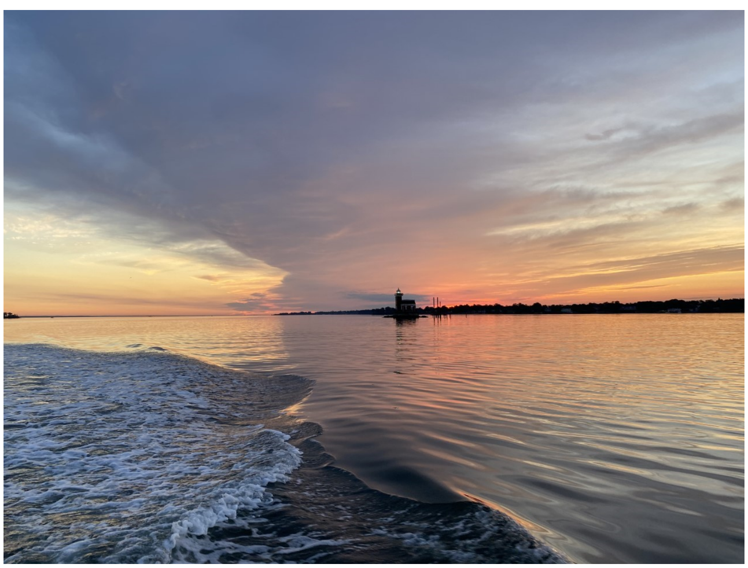
Introduction

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.

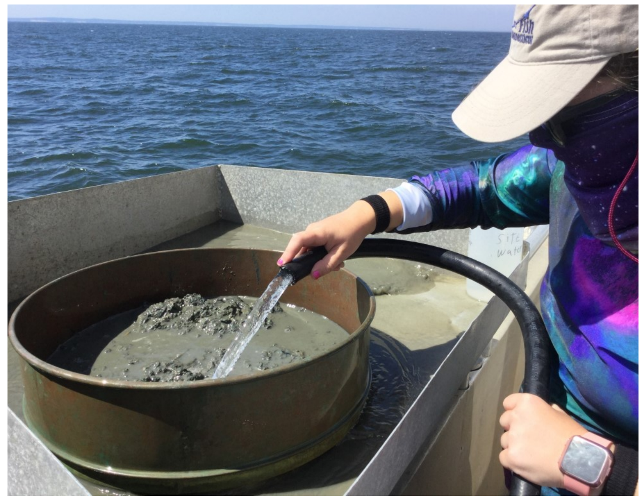
In response to the critical need to document summer hypoxic conditions in Long Island Sound, the Connecticut Department of Energy and Environmental Protection (CT DEEP) and the Interstate Environmental Commission (IEC) have monitored dissolved oxygen, as well as other key water quality parameters relevant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



Science in the time of Covid-19

-Written by CT DEEP Summer Seasonal Staffer Danielle Shubat

The year of 2020 started as any normal year, however in March the state shutdown due to the rise of Covid-19. With the state shutdown, any nonessential worker had to stay home and/or work from home. As one can imagine, this would impact a job in which one has to be on a boat, interacting with others, and carrying out water quality tests in Long Island Sound.



With the shutdown, the April and May Water Quality cruises were fully cancelled. The June Water Quality cruise was able to be carried out, but later on in the month rather than the usually scheduled first or second week of the month. On top of that, the amount of staff allowed to be aboard the boat was severely limited. Only the captain of the boat and one other worker was allowed to be on the vessel. With such a limited amount of people, this also limited the amount of data that could be collected. In the best interest of time and sample collection, this meant that water samples were collected, stored, and processed in the laboratory on a later date. In late June, the seasonal workers were able to begin their training in the laboratory. With training, they also processed the water samples that were collected. To do this, the equipment that is usually used on the boat was brought into the lab and set up with the appropriate 6+ feet away from each other.

After going through a long process of having to be approved by the state, writing guidelines and rules ensuring we would follow Covid-19 guidelines, the Water Quality cruises were allowed to continue in early July. Following the guidelines of having 5 or less people on the boat, wearing masks at all times, and staying 6+ feet away were only some of the guidelines that had to be followed in order for the cruises to continue.

The summer was spent following these guidelines and figuring out the best ways to carry out the work with these guidelines. The team made it work to the best of their abilities. It was hard to wear a mask in direct sunlight on a 90°F day, but the crew toughed it out in order to carry out their jobs. We limited the amount of people that would be in the cabin of the boat which meant that people would carry out their duties in shifts and sit outside when they were done to allow the next person to come in.

Instead of processing data in the lab and working together to come up with graphs and maps, all data entry and analysis was carried out at home. Sometimes this lead to some confusion because of the lack of in person explanation and guidance when one did not understand a task. But again, it was another thing that the team toughed out and tried to accomplish to the best of their ability. For the seasonal workers, time that would have been spent working on learning new things under the teaching and guidance of Katie or Matt, turned into more webinars, zoom meetings, and online classes.

Everything was going as well as it could and the teams was learning new ways of doing things that used to be done in person be, until the months started to get colder and the cases of Covid-19 in Connecticut began to increase. The cold weather meant that the crew would be in the cabin of the boat for most of the Water Quality cruise in order to stay warm. However the increase in cases was worrying and even though the team was small if every person was in the cabin of the boat, it would get crowded. Thinking ahead about how the cruises in the colder months would carry out with the uptick in cases, the team decided it was in their best interest to cancel the December Water Quality cruise.

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.

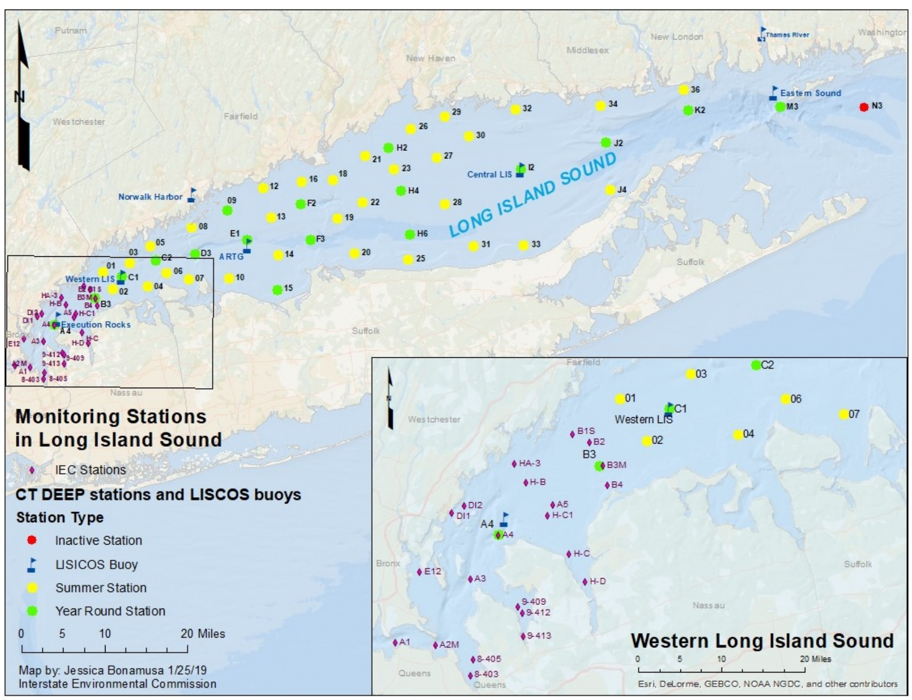
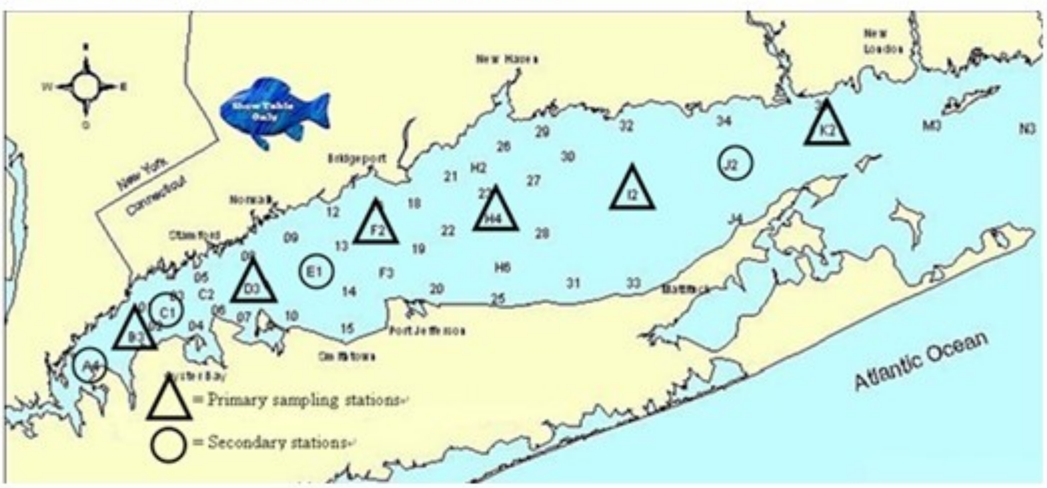


Figure 1. Hypoxia Monitoring Stations in Long Island Sound

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 2019 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 2019 are not yet available.

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



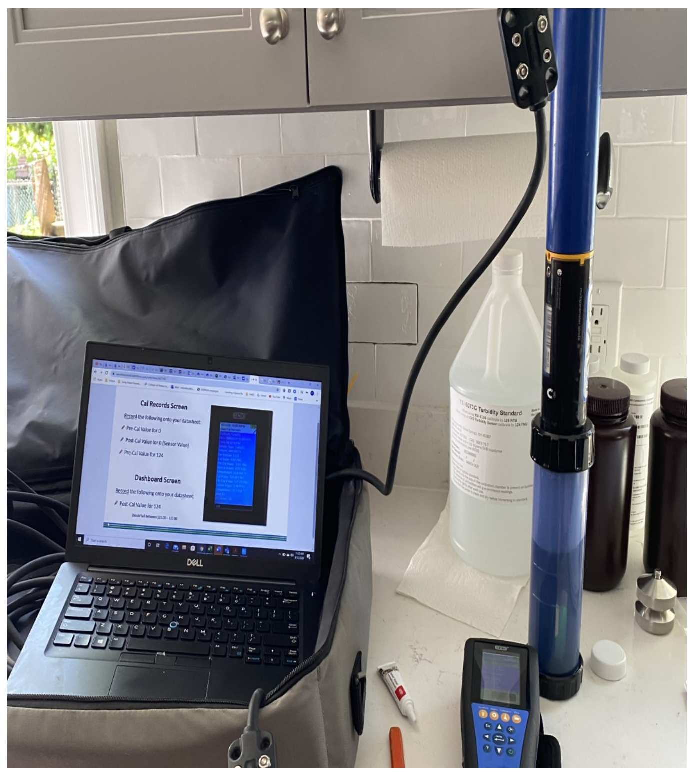
Quality Assurance

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 2018, IEC achieved an overall completeness rate of 95.8%; one run was terminated early due to unsafe weather conditions, resulting in 11 missed station visits. CT DEEP completed 401 station visits in 2018. The mid-March chlorophyll survey was not conducted due to weather, resulting in 6 missed stations visits and a 98.5% completeness rate for 2018. Due to the pandemic, many surveys were cancelled for both organizations. CT DEEP missed 63 station visits due to the cancellation of the CHMAR20, WQAPR20, WQMAY20, and WQDEC20 surveys and combining the WQJUN and HYJUN20 surveys. IEC cancelled XYZ resulting in # missed station visits. .

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



RESULTS

During the summer of 2020, CT DEEP conducted six surveys between June 16th and September 10th while IEC conducted twelve surveys between June 30th and September 15th (Table 1). Hypoxia maps and in situ profiles from stations in WLIS are available in Appendix A. 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, 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 found during nine 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. .

Timing and Duration

The 2020 hypoxic event lasted an estimated **43 days** beginning on July 7th and ending on September 10th. This is also evident in the continuous data collected by the LISICOS Execution Rocks Buoy. Compared to the previous 32 years, 2020 was below the average of 53 days (Figure 3).

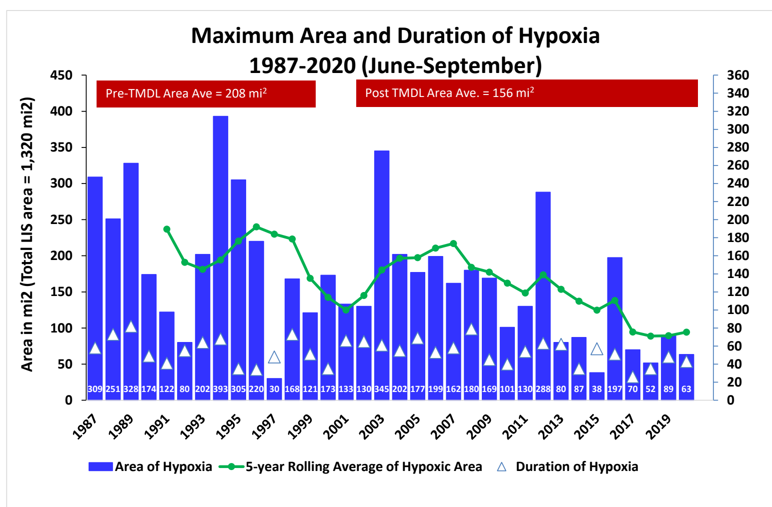


Figure 3. Maximum Area and Duration of Hypoxia. Blue bars represent area, white triangles represent duration, and the green line is the five-year rolling average of hypoxic area. The total area of Long Island Sound is 1,320 mi^2.

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
HY/ WQJUN21	6/3/2021	6/9/2021	17	0	0	6.44	A4
IEC RUN #1	7/1/2021	7/1/2021	23	0	0	3.53	H-C
WQJUL21	7/6/2021	7/12/2021	39	0	0	3.07	A4
IEC RUN #2	7/7/2021	7/7/2021	24	1		2.58	9-413*
IEC RUN #3	7/13/2021	7/13/2021	24	0	0	3.12	B2
HYJUL21	7/19/2021	7/21/2021	39	0	0	3.32	A4
IEC RUN #4	7/22/2021	7/22/2021	24	4		1.78	H-C
IEC RUN #5	7/25/2021	7/25/2021	23	12		2.33	A5
WQAUG20	8/2/2021	8/4/2021	42	7		1.02	A4
IEC RUN #6	8/3/2021	8/3/2021	24	19		0.74	H-C1
IEC RUN #7	8/12/2020	8/12/2020	22	17	NC	1.38	HC-1*
IEC RUN #8	8/18/2020	8/18/2020	22	1	NC	2.16	9-413*
HYAUG21	8/16/2021	8/18/2021	41	12		1.71	B3
IEC RUN #9	8/25/2020	8/25/2020	22	2	NC	N/A	9-413*
IEC RUN #10	8/31/2020	8/31/2020	22	0	NC	3.06	A3*
WQSEP21	8/30/2021	9/1/2021	40	1		1.69	B3
IEC RUN #11	9/8/2020	9/8/2020	22	2	NC	2.67	A5*
IEC RUN #12	9/16/2020	9/16/2020	22	0	NC	4.39	B1S*

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 1991-2019 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 2020, the maximum area of LIS bottom waters between 3.0 and 4.8 mg/L occurred during the HYJUL20 survey conducted (20 - 22 July) and was estimated at 514 mi^2. From 1991-2020, the area affected by concentrations between 3.0 and 4.8 mg/L averaged 577 mi^2 and varied from 409 to 730 mi^2.

Estimated Maximum Area Below 3.0 mg/L

The 2020 peak hypoxic event occurred during the WQAUG20 cruises between 3 August and 12 August. The maximum area was **132.5 square miles**. Compared to the previous 32-year average (175.5 mi^2), 2020 was below average in area (Figure 3). The lowest dissolved oxygen concentration (1.77 mg/L) documented by CT DEEP during 2020 occurred on 8/12/20 at Station A4 (Appendix A, pg. A3). The lowest dissolved oxygen concentration documented by IEC during 2020 at an open water station was 1.14 mg/L and occurred on 7/28/20 at Station A4 (Appendix A). The Execution Rocks Buoy recorded its lowest reading, 0.16 mg/L, on 7/30/20.

Estimated Maximum Area Below 2.0 mg/L

Based on CT DEEP data, in 2020, the maximum area below 2.0 mg/L was **16.8 square miles**. The average area with concentrations less than 2.0 mg/L, calculated from 1991-2020, is 47.10 mi^2. The IEC documented concentrations below 2.0 mg/L at three of their open-water stations on 20 July, seven of their open-water stations on 28 July, and zero of their open-water stations on 6 August. At the LISICOS Execution Rocks buoy, there was 30.77 cumulative days below 2.0 mg/L.

Estimated Maximum Area Below 1.0 mg/L

CT DEEP documented no stations with a DO concentration below 1 mg/L. The IEC documented no concentrations below 1 mg/L at any of their open-water stations. The LISICOS Execution Rocks buoy (Station A4) documented a minimum DO of 0.16 mg/L and 15.03 cumulative days of DO concentrations less than 1.0 mg/L. The overall average area affected from 1991-2020 is 10.82 mi^2. The greatest area with DO below 1 mg/L (62 square miles) was during the summer of 2003.

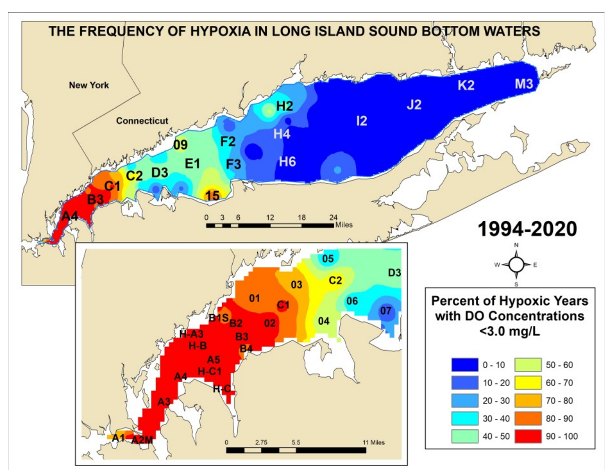


Figure 4. Frequency of Hypoxia in Long Island Sound Bottom Waters

Frequency

Figure 4 shows the frequency of hypoxia occurrence for stations over the 1994 -2019 period. The percent of WLIS stations that experience hypoxic conditions continues to be between 90 and 100% (Figure 4). However, stations C2, D3, E1, 09, and 15 seem to be showing 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.

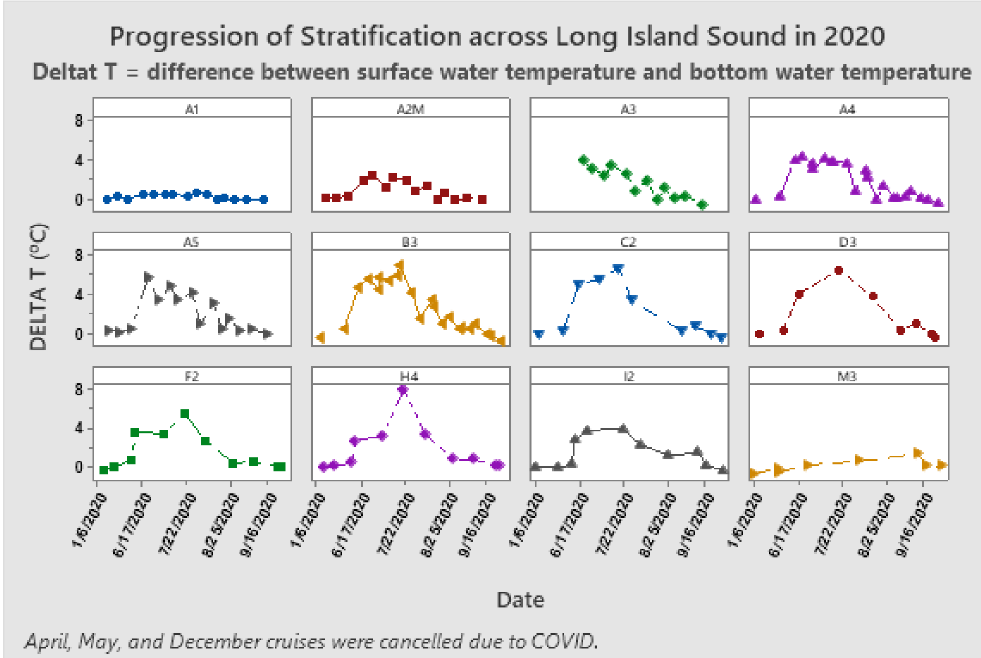


Figure 5. Progression of stratification across Long Island Sound in 2020 where Delta T= surface water temperature minus bottom water temperature.

In 2019, stratification began to set up in May (Figure 5) . Delta T's (the difference between surface and bottom water temperature) peaked in the Western Narrows in early July. 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 at Station 15 recorded on March 7. The 2019 maximum bottom temperature was 22.96ºC recorded on August 13 at Station 15. The minimum bottom temperature was 1.35ºC at Station 15 recorded on March 7.

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.

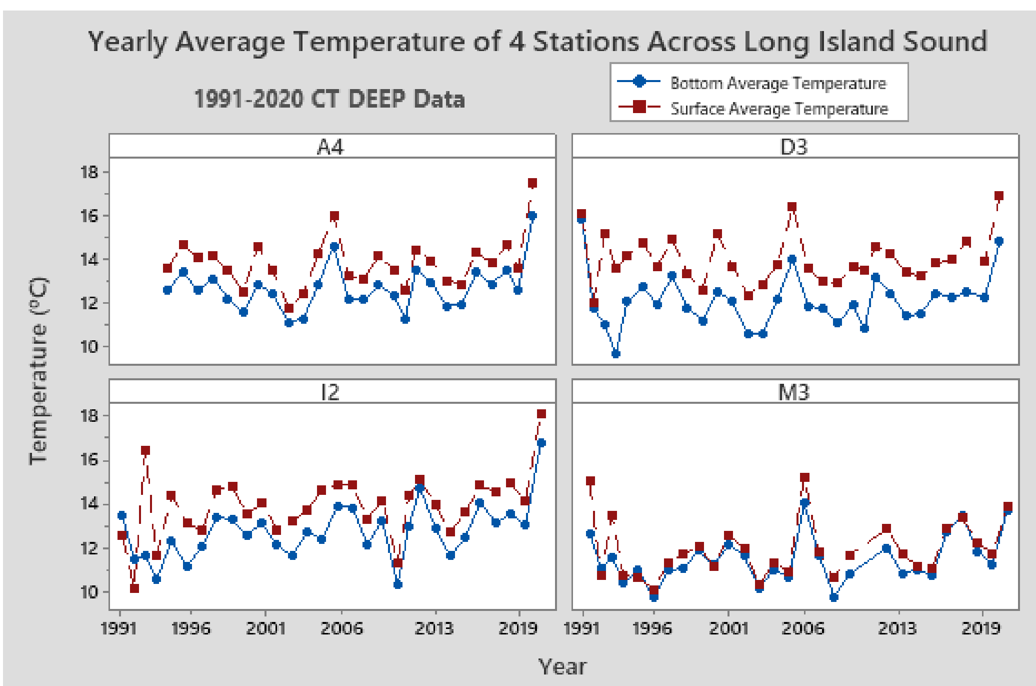


Figure 6. Yearly Average Water Temperatures of Long Island Sound.

Water Clarity

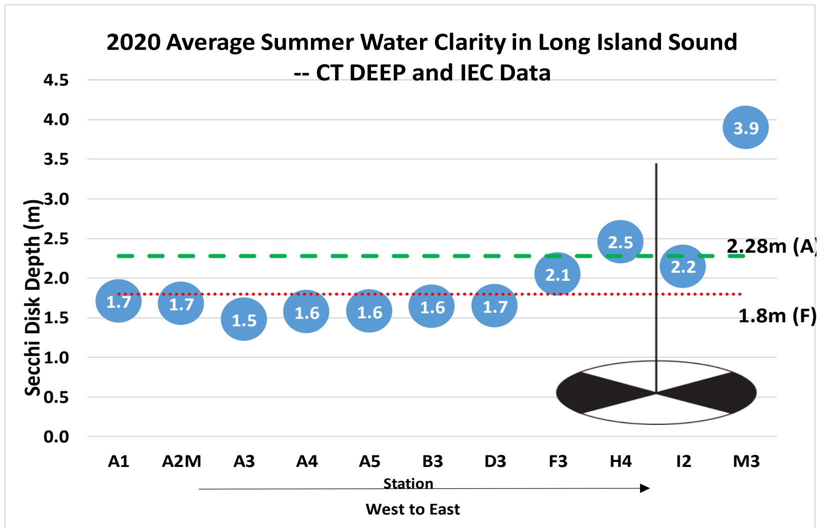
Water clarity, a measure of how much light penetrates the water column, is an important indicator of the health of seagrass beds, and thus, the ecosystem as a whole (see page 16). In Long Island Sound, water clarity improves as you move eastward. The eastern portion of the Sound is a wide and deep channel 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. 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 2020, the western-most axial station (A1 near Whitestone Bridge) had an average Secchi disk depth of 1.7 meters for both the summer and for the year. In both graphs, the average Secchi disk depths gradually increase, reaching a summer average of 3.9 meters and a yearly average of 3.5 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%).

According to that criteria, Stations A1, A2M, A3, A4, A5, B3 and D3 get an F; Stations F3 receive a D; Station I2 receives a B, and Stations H4 and M3 get an A for the summer of 2020 (Figure 7a).

Some improvements are seen when using the full-year data (Figure 7b), as Stations A4, A5, B3, and D3 go from an F to a D, and Stations F3 goes from a D to an A.

Individual station data from 2020 are available in Appendix B.



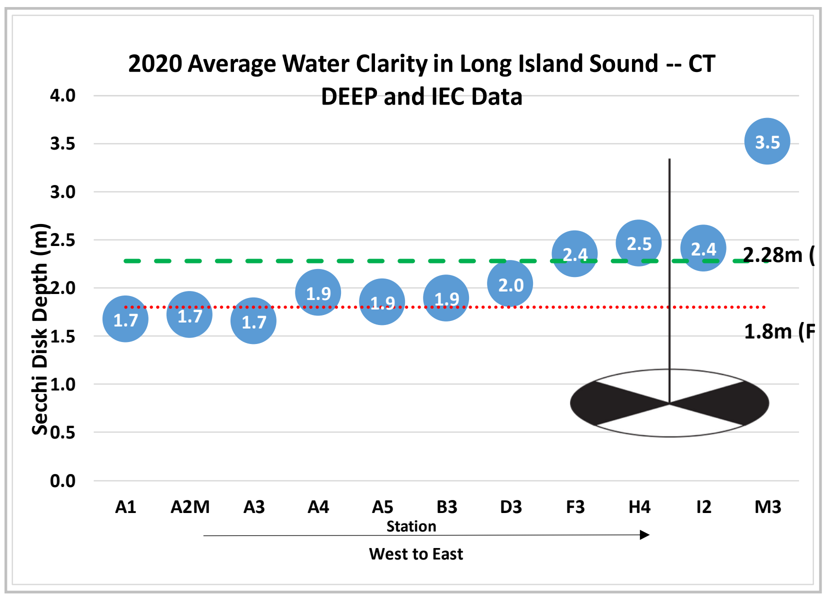


Figure 7. Average water clarity across Long Island Sound in 2020. a) Summer and b) Year-round

Chlorophyll-a

The spring phytoplankton bloom occurs in Long Island Sound between February and April. Historically high levels of chlorophyll-a 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 chl 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 (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 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 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.

As part of the National Coastal Condition 2020 sampling (See NCCA write up on page X for additional details), CT DEEP and EPA Contractors collected surface Total Alkalinity samples from 23 LIS proper stations and 60 embayment stations.

Discussion

Weather

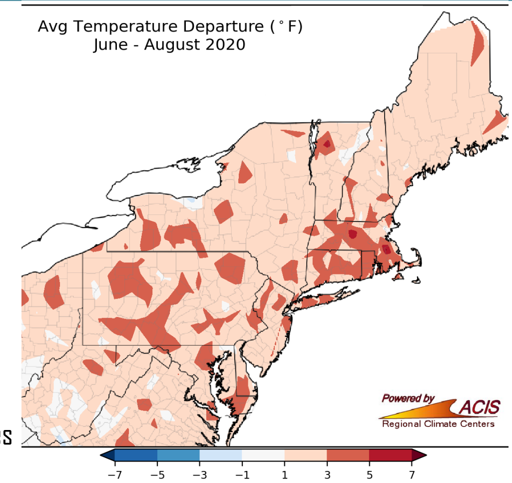


Figure 11. 2020 Northeast Average Summer Temperature Departure in ºF. From NRCC.

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 beginning of June started cold; Hartford reported the coldest June 1st on record. Temperatures rebounded and the second half of June had above normal temperatures with a 90-degree heat wave the weekend of 6/19-6/21. Precipitation was below average across Long Island Sound . Connecticut saw its hottest July on record. Hartford saw its greatest number of days of at least 90ºF ever recorded. On July 27 Hartford, CT reached temperatures of 98ºF, breaking its past record for hottest day in July. The past record for was 96ºF in 1964. Connecticut saw lower than average amounts of rain this month. It was almost the driest July on record, with the driest being in 1986, Water levels in reservoirs in Bridgeport and Greenwich were close to the levels they were during the 2016 drought. The drought in the Northeast Continued through August. The percentage of area in extreme, severe, or moderate drought in New England increased. The Northeast had the 15th hottest August on record. Tropical Storm Isaias produced extreme rainfall, tornados, and damaging winds across the Northeast on August 4. The Northeast droughts continued into September and intensified during this month. Much of New England experienced a warmer than average start to September reaching about 1-3ºF higher than average in most parts. Bridgeport, CT experienced its 14th warmest start of September on record (September 1st to the 15th). Connecticut ended the summer by having the driest summer in Hartford, CT.

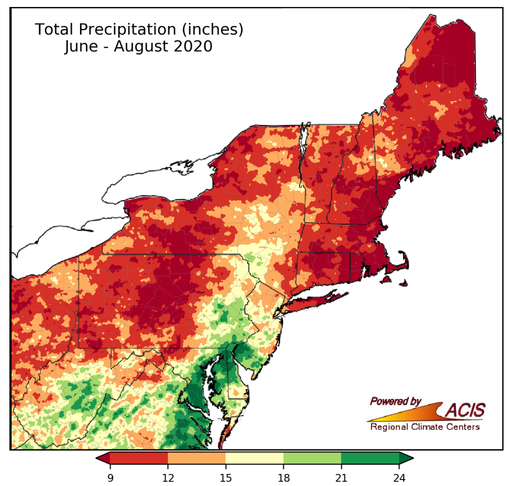


Figure 12. 2020 Northeast Total Summer Precipitation in Inches. From NRCC.

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 2). This is a 57% 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.

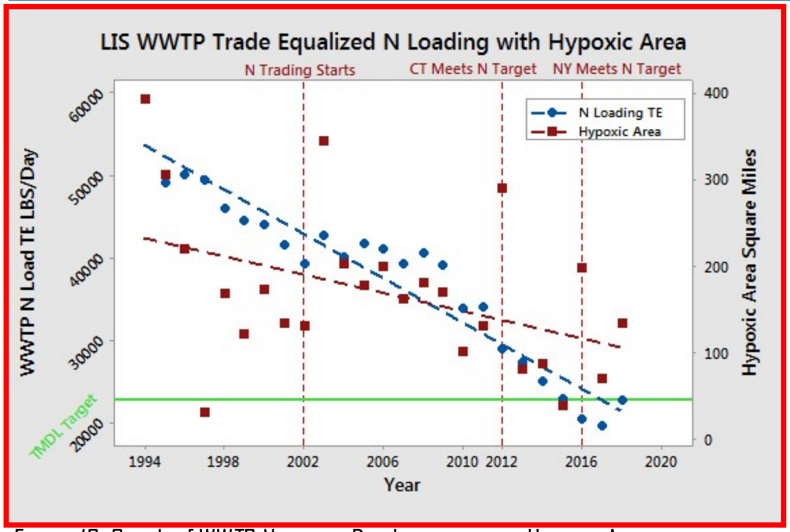


Figure 13. Graph of WWTP Nitrogen Discharge versus Hypoxic Area

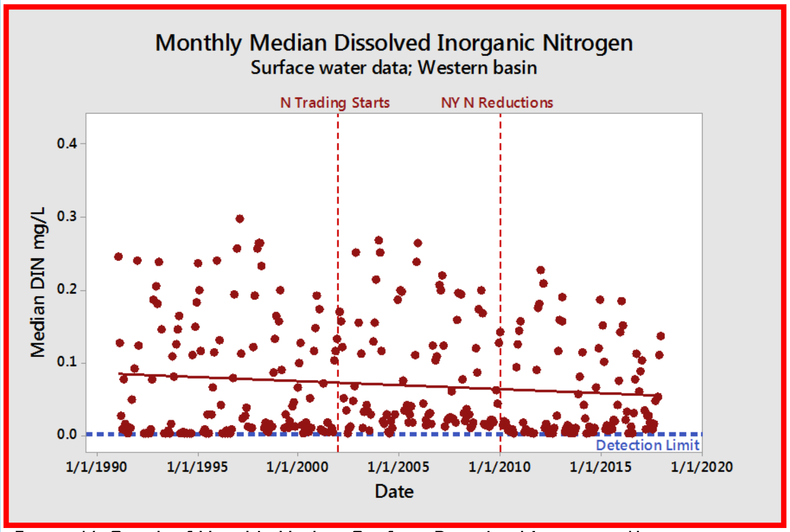


Figure 14. Graph of Monthly Median Surface Dissolved Inorganic Nitrogen Concentrations from Western Long Island Sound

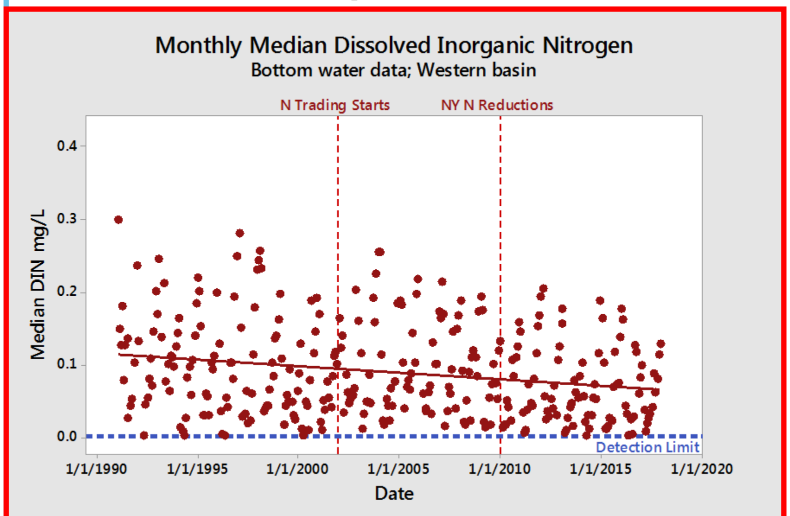


Figure 15. Graph of Monthly Median Surface Dissolved Inorganic Nitrogen Concentrations from Western Long Island Sound

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. 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.

In 2018 the cold, wetter than normal weather decreased the efficiency of nitrogen removal of the treatment systems resulting in an increase in loads to LIS for the first time since 2011. However, the 2018 loading to LIS was still 42 million pounds less than the early 1990s baseline.

Dissolved Inorganic Nitrogen (nitrate + nitrite + ammonia) is the most bioavailable form of nitrogen used by phyto-plankton. 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.

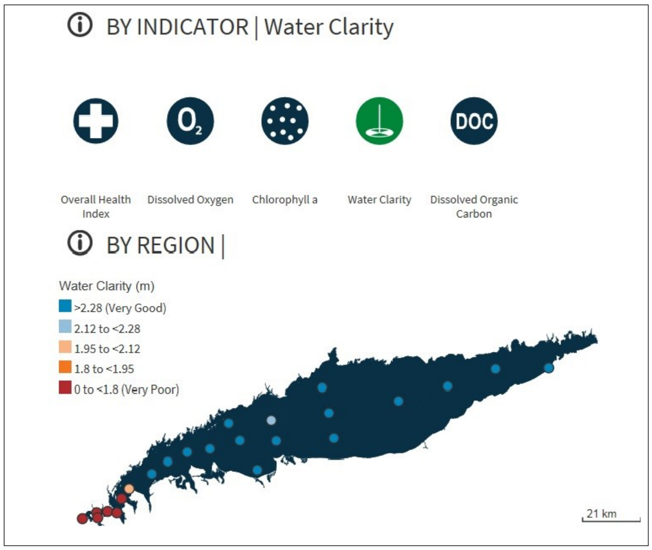


Figure 16. Image from the Long Island Sound Report Card showing station data for the water clarity indicator. Image shows 2017 data.

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.

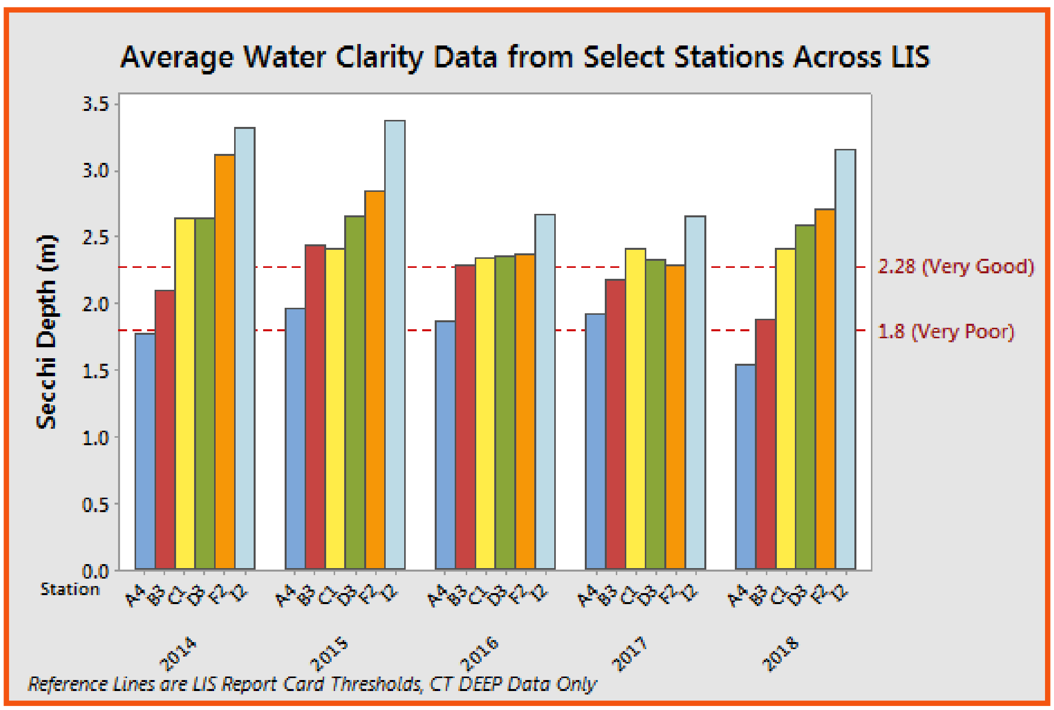


Figure 17. Year round averages of water clarity data from select stations across LIS.

Future Monitoring Recommendations

Flux measurements at East River/Throggs Neck

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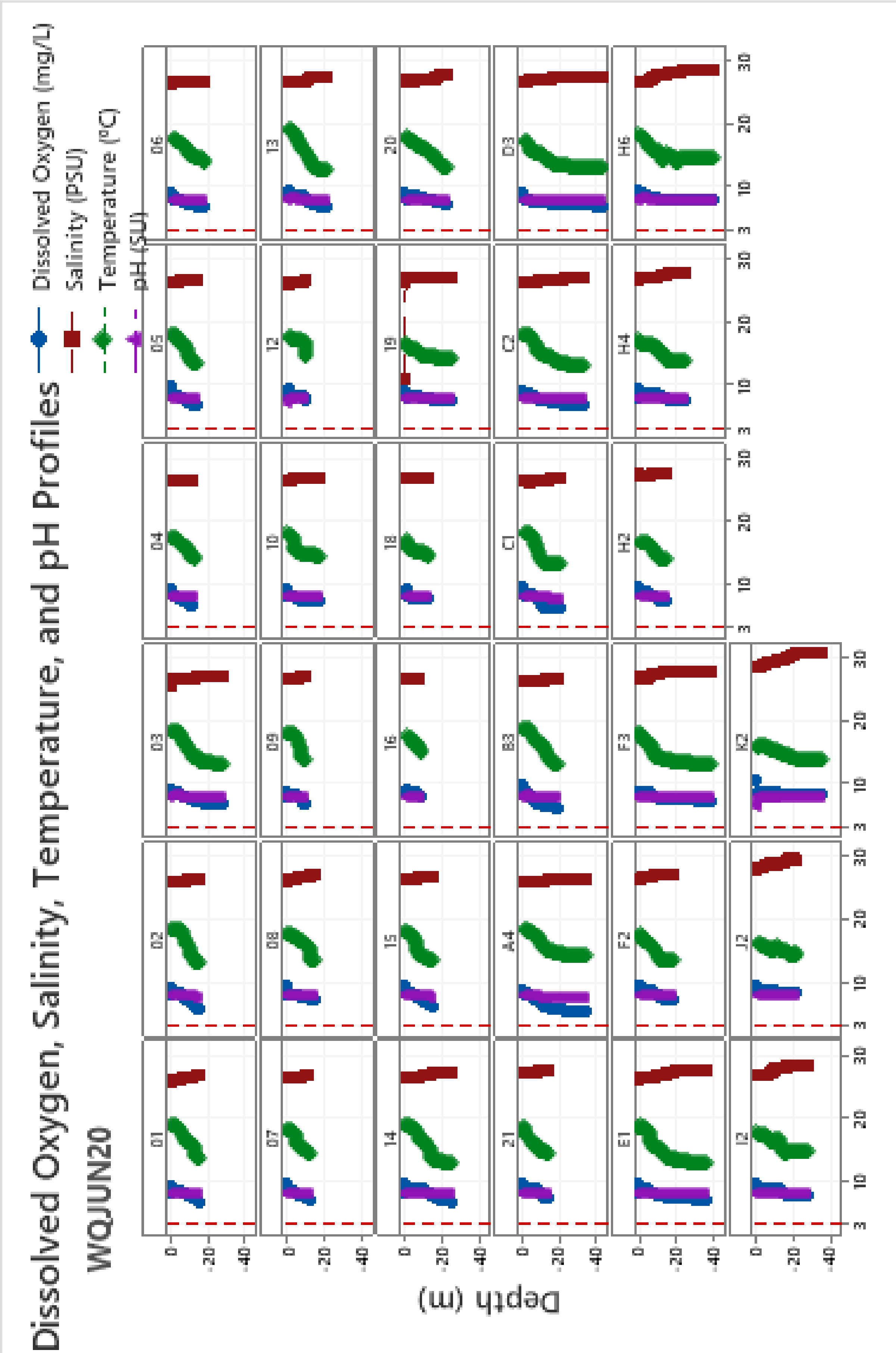
Appendix A – 2020 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP WQJUN20 and IEC Run #1


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
WQJUN20
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)
Depth (m)
01
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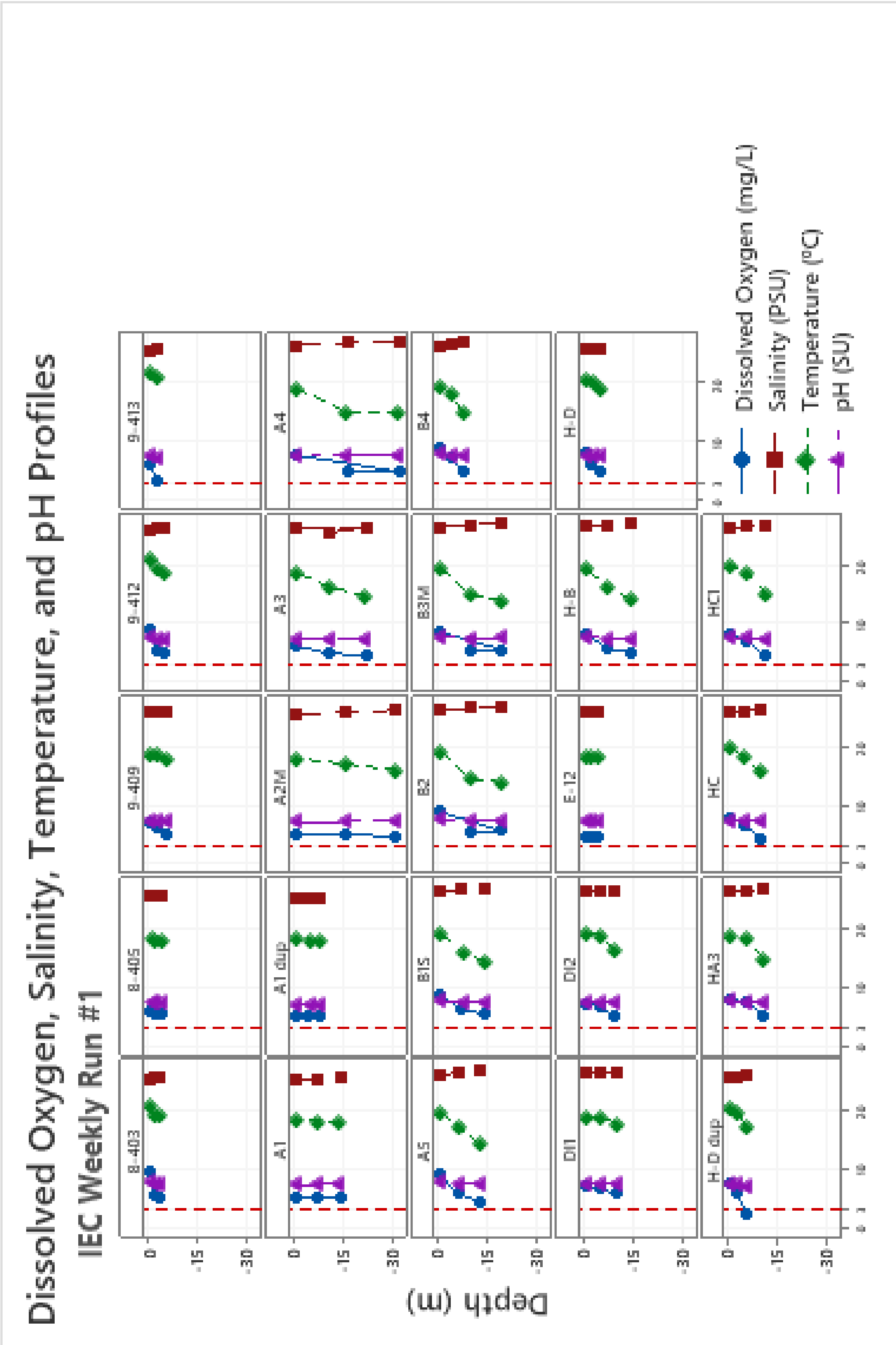
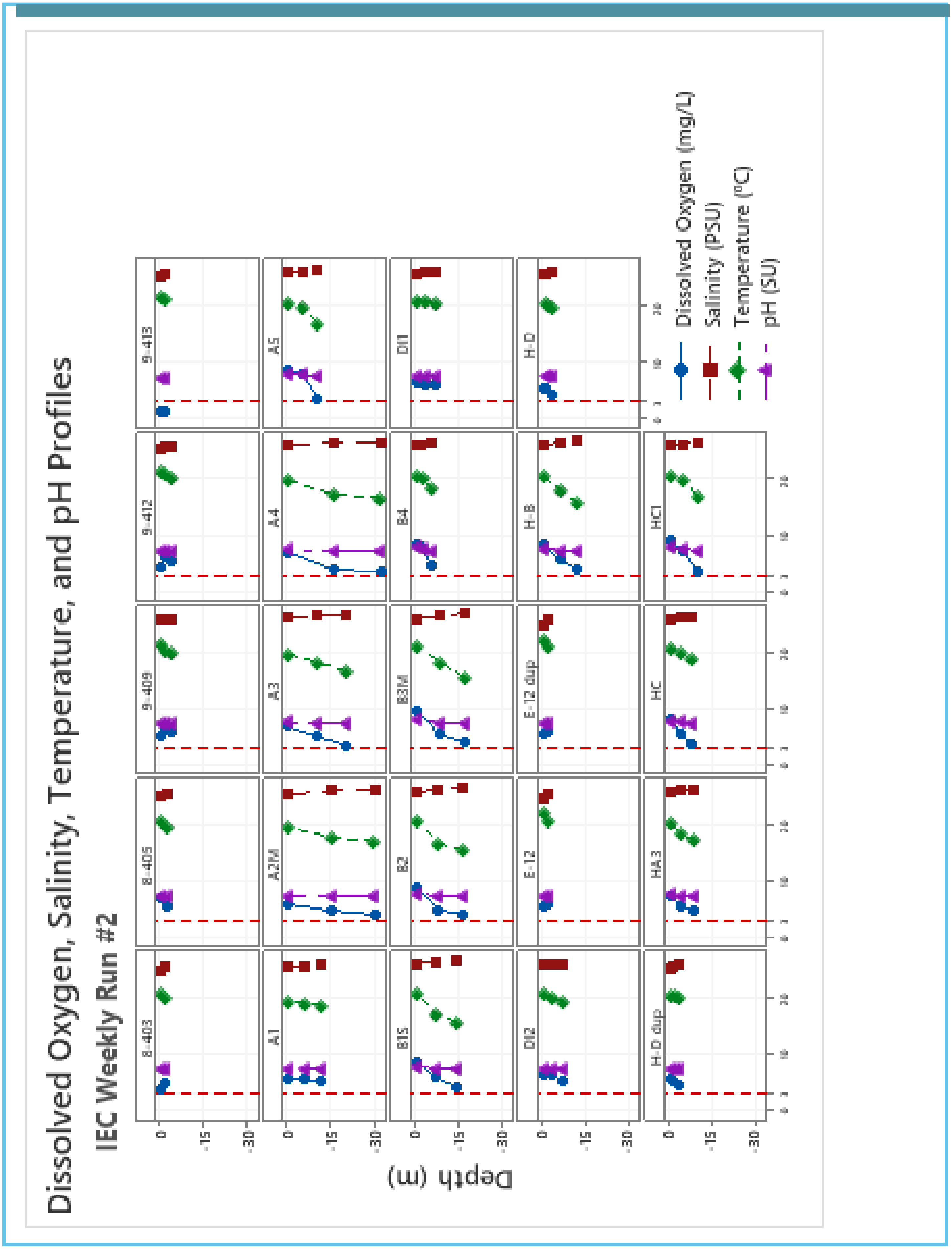
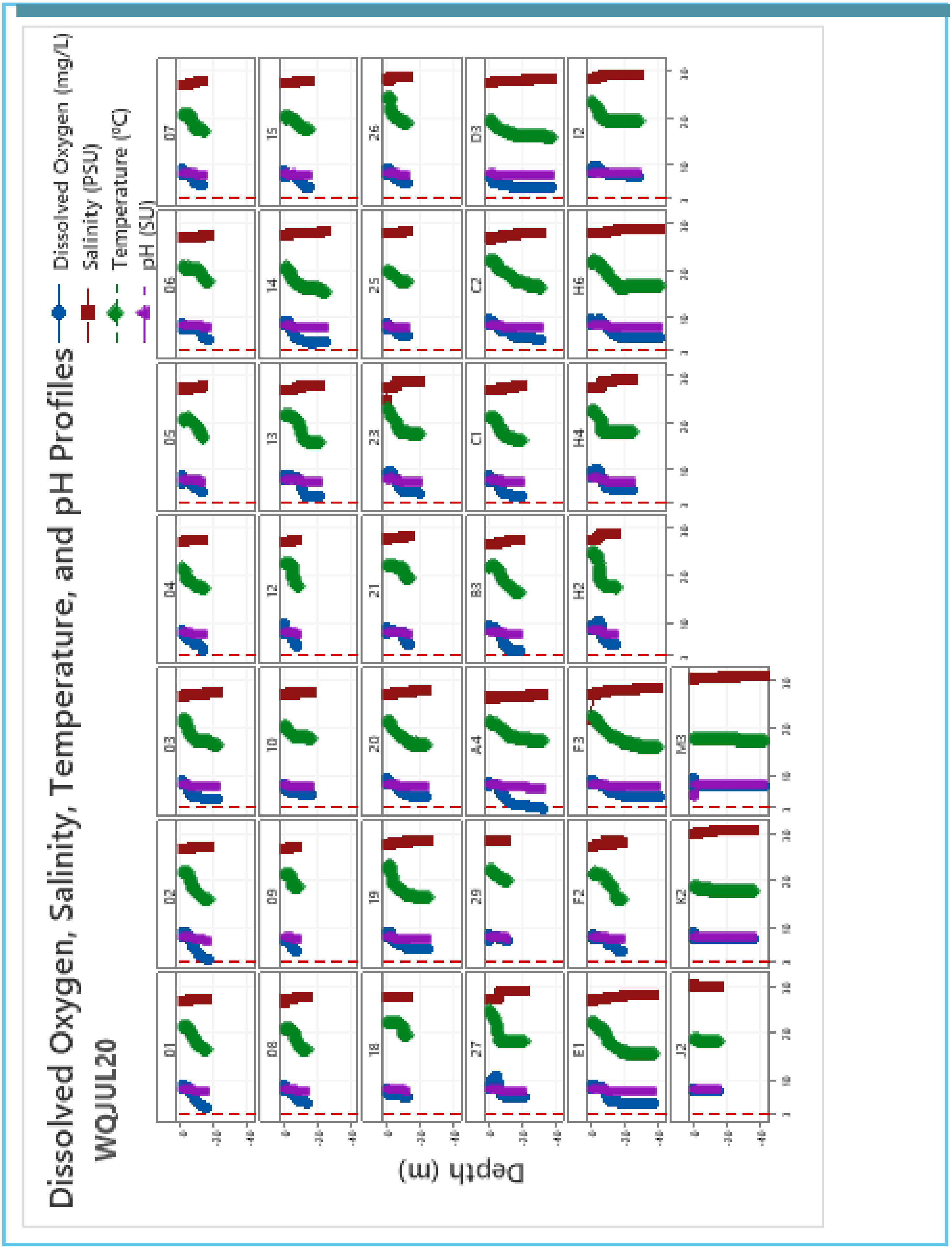
14
15
16
18
19
20
21
A4
B3
C1
C2
D3
E1
F2
F3
H2
H4
H6
I2
J2
K2


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #1
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A1 dup
A2M
A3
A4
A5
B1S
B2
B3M
B4
DI1
DI2
E-12
H-B
H-D
H-D dup
HA3
HC
HCI
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)

Appendix A – 2019 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP WQJUL20 and IEC Run #2


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #2
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
DI1
DI2
E-12
E-12 dup
H-B
H-D
H-D dup
HA3
HC
HC1
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)



Dissolved Oxygen, Salinity, Temperature, and pH Profiles
WQJUL20
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)
Depth (m)
01
02
03
04
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14
15
18
19
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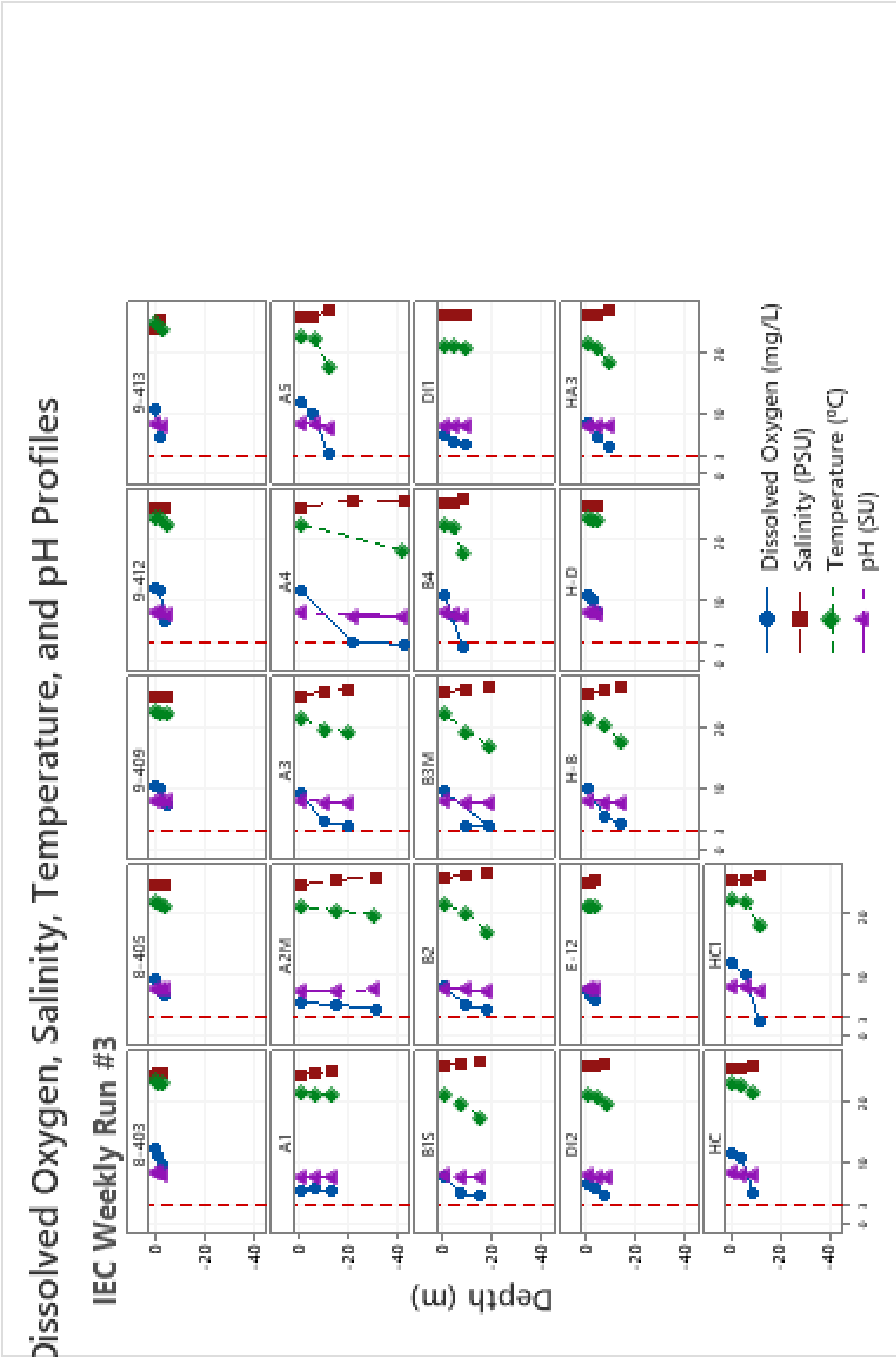
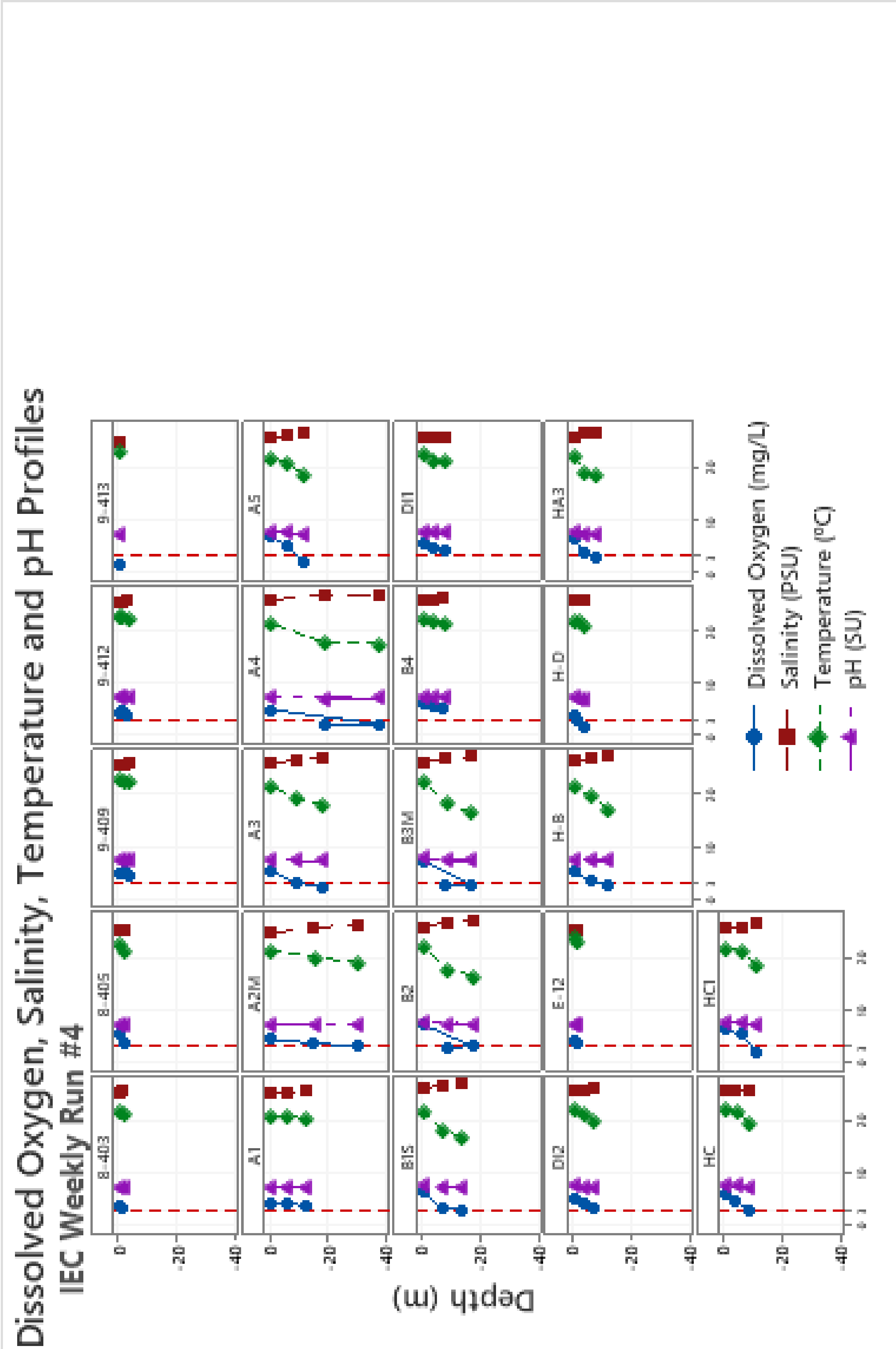
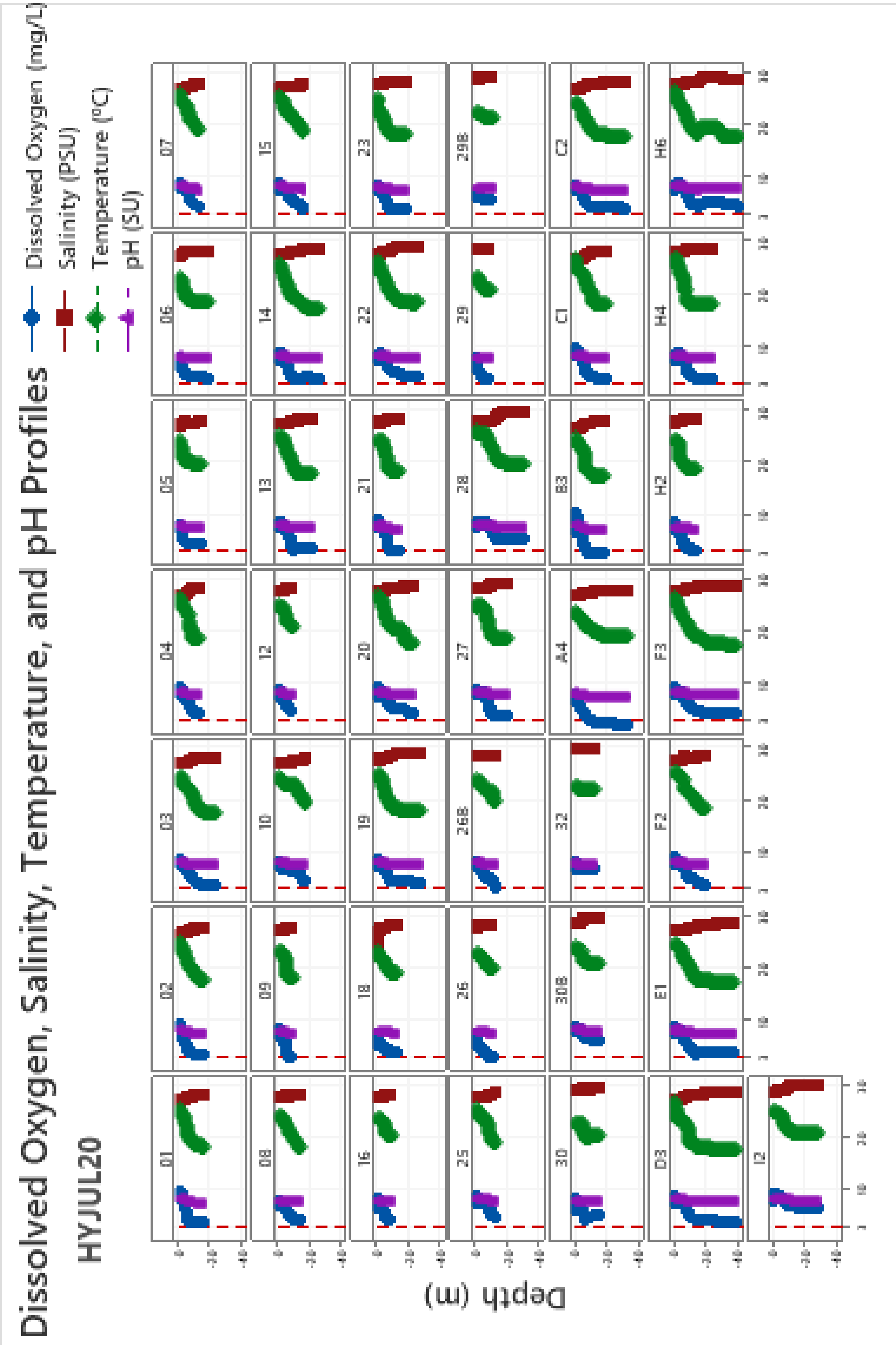
21
23
25
26
27
29
A4
B3
C1
C2
D3
E1
F2
F3
H2
H4
H6
I2
J2
K2
M3


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #3
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
D11
D12
E-12
H-B
H-D
HA3
HC
HC1
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)

Appendix B – 2020 DEEP and IEC Summer
Dissolved Oxygen, Temperature, and Salinity Data by Survey
DEEP HYJUL20 and IEC Run #4


Dissolved Oxygen, Salinity, Temperature and pH Profiles
IEC Weekly Run #4
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
DI1
DI2
E-12
H-B
H-D
HA3
HC
HC1
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)



Dissolved Oxygen, Salinity, Temperature, and pH Profiles
HYJUL20
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)
Depth (m)
01
02
03
04
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21
22
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25
26
26B
27
28
29
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B3
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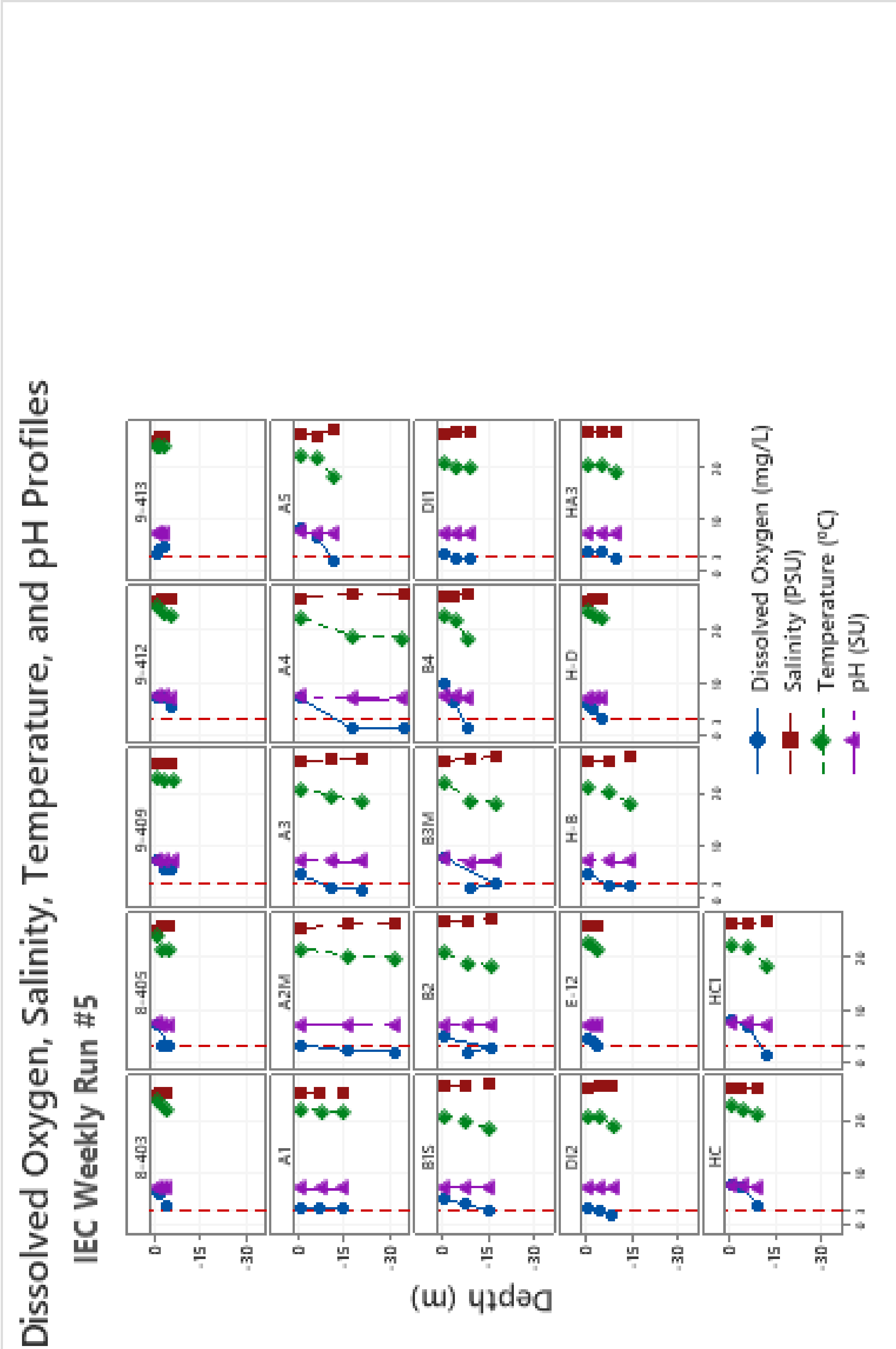
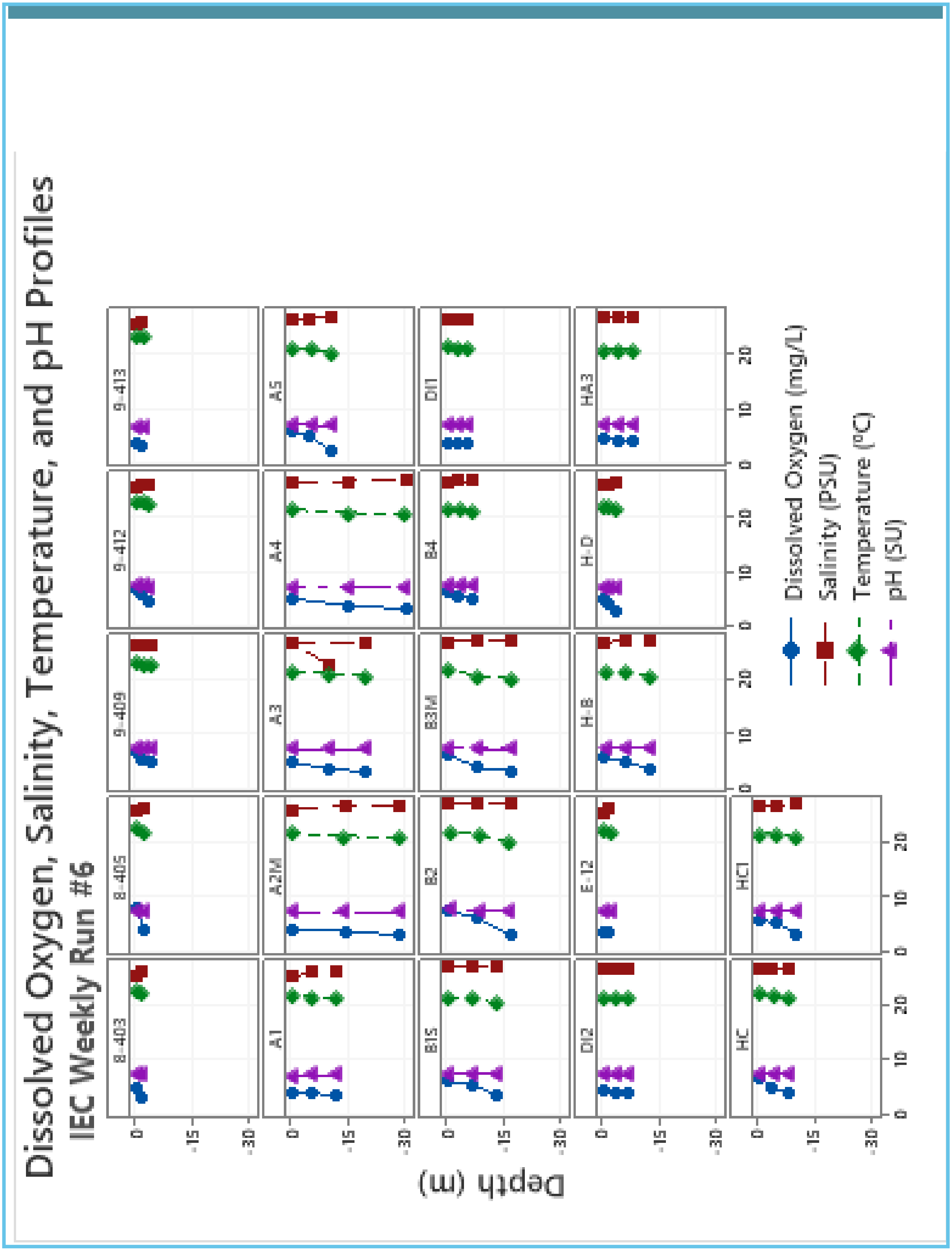
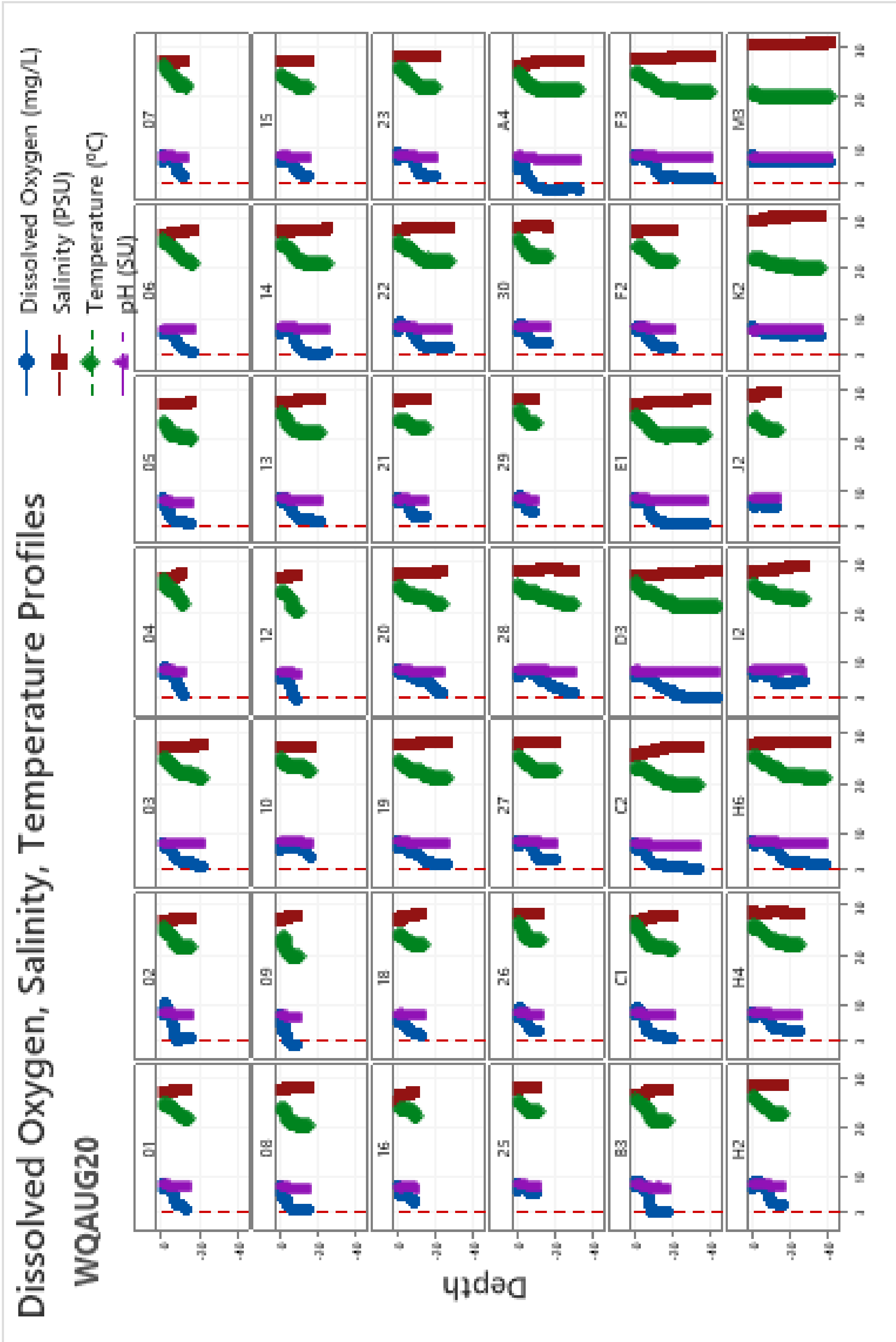
C2
D3
E1
F2
F3
H2
H4
H6
I2


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #5
Depth (m)
0
-15
-30
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
DI1
DI2
E-12
H-B
H-D
HA3
HC
HC1
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)

Appendix C – 2020 DEEP and IEC Summer
Dissolved Oxygen, Temperature, Salinity and pH Data by Survey
DEEP WQAUG20 and IEC Run #6


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #6
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
DI1
DI2
E-12
H-B
H-D
HA3
HC
HC1
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)



Dissolved Oxygen, Salinity, Temperature Profiles
WQAUG20
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)
Depth
01
02
03
04
05
06
07
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09
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12
13
14
15
16
18
19
20
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22
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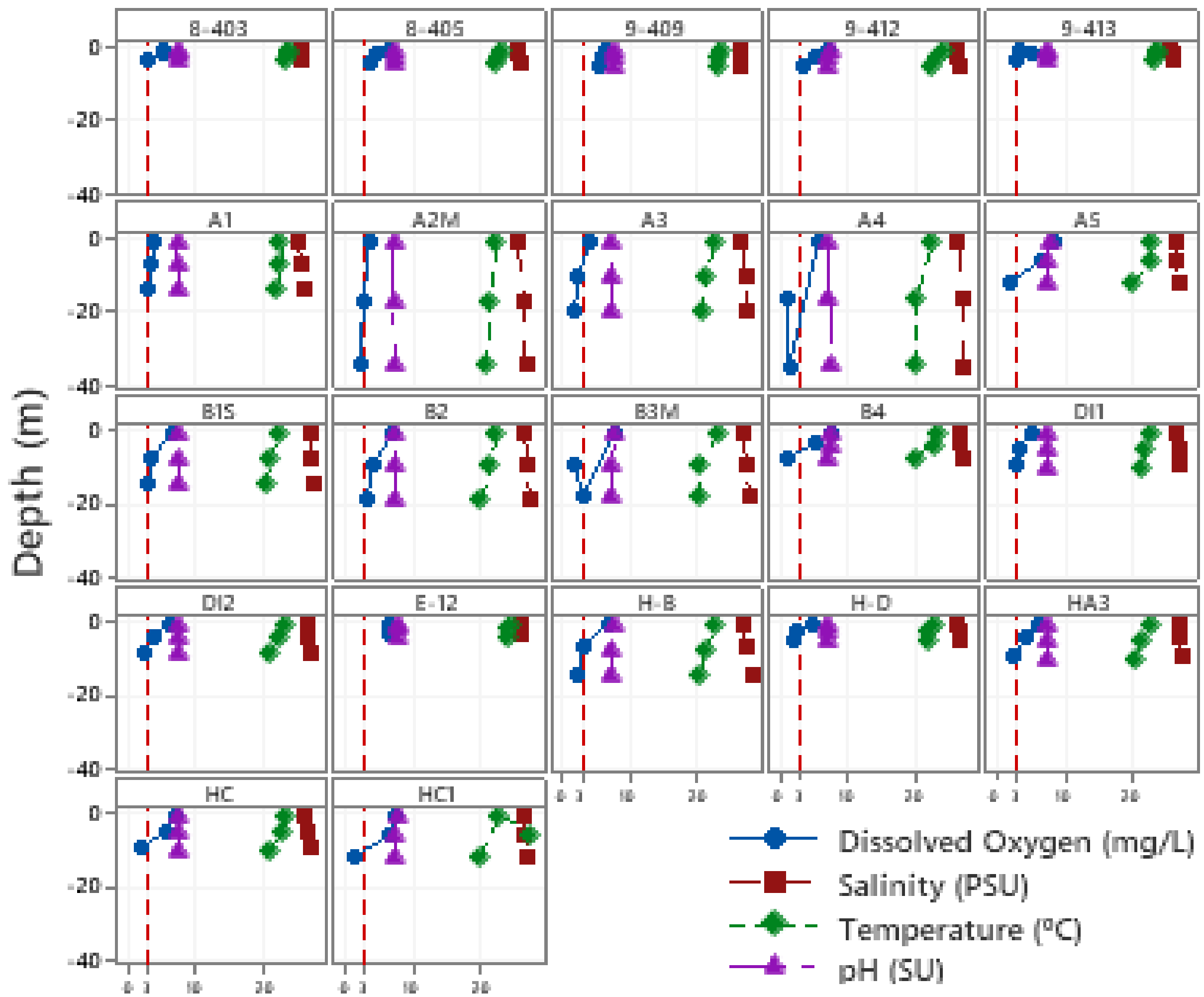
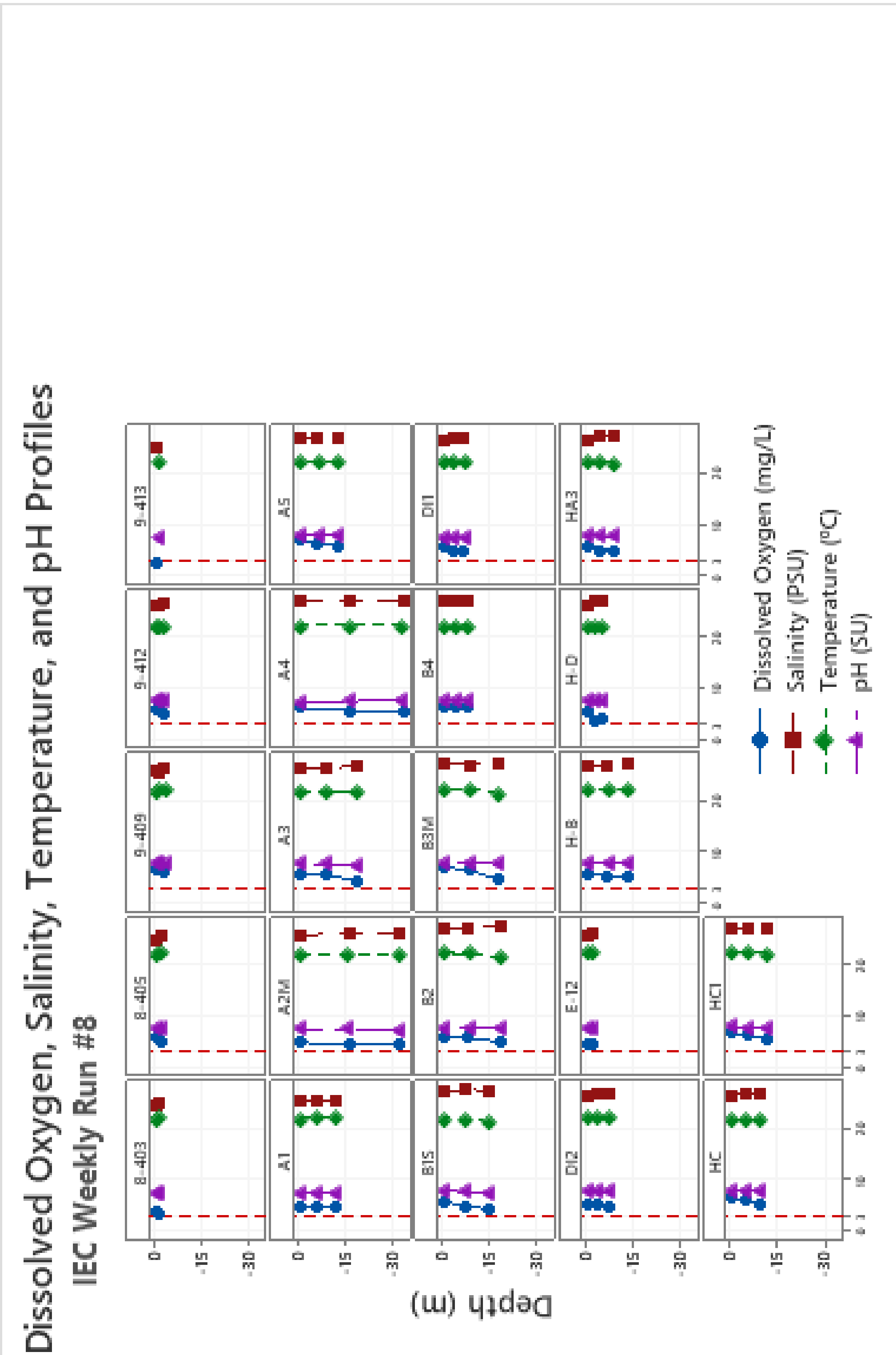
25
26
27
28
29
30
A4
B3
C1
C2
D3
E1
F2
F3
H2
H4
H6
I2
J2
K2
M3

Dissolved Oxygen, Salinity, Temperature, and pH Profiles

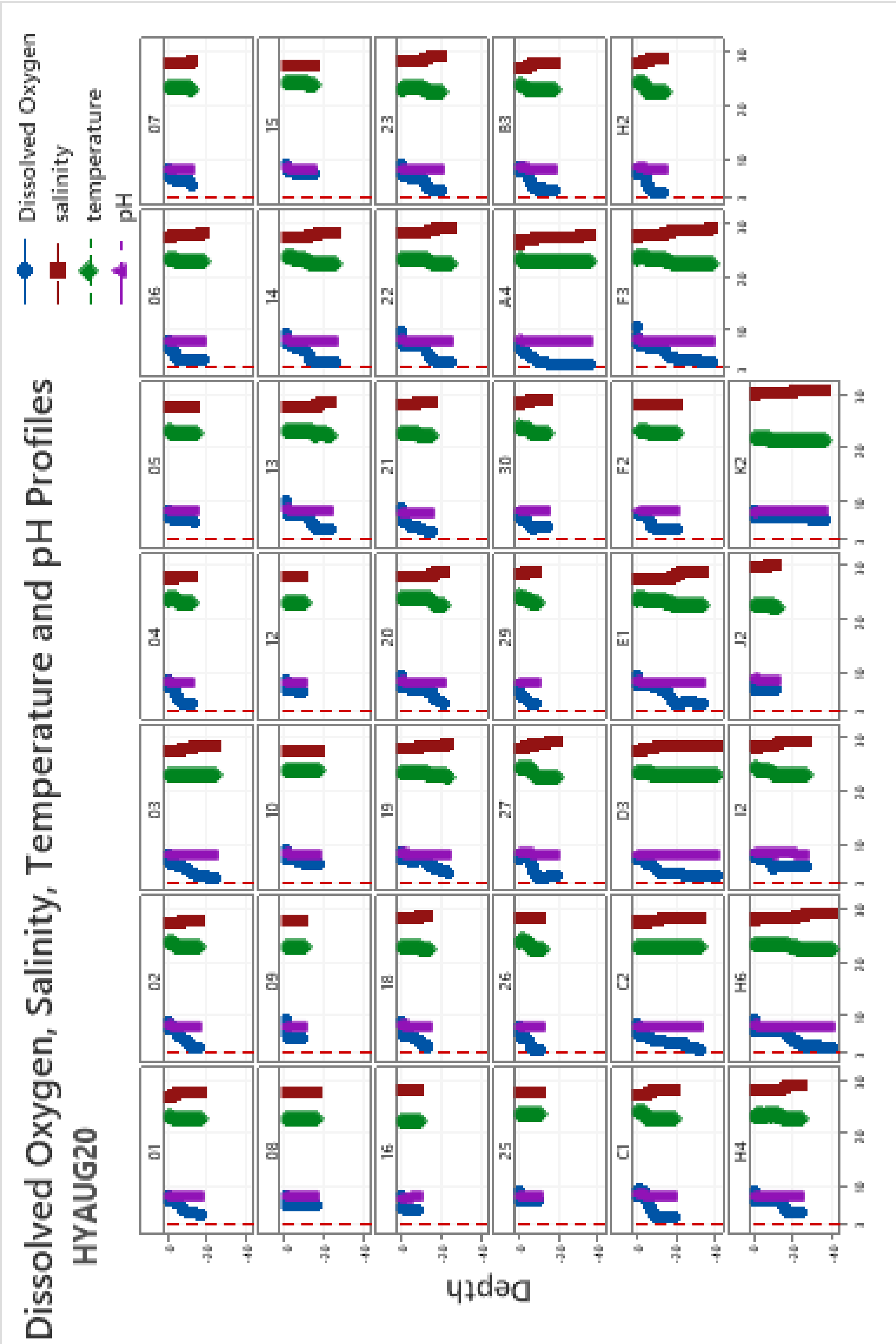
IEC Weekly Run #7



Appendix D – 2020 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP HYAUG20 and IEC Run #8



Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #8
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
D11
D12
E-12
H-B
H-D
HA3
HC
HC1
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)


Dissolved Oxygen, Salinity, Temperature and pH Profiles
HYAUG20
Dissolved Oxygen
salinity
temperature
pH
Depth
01
02
03
04
05
06
07
08
09
10
12
13
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27
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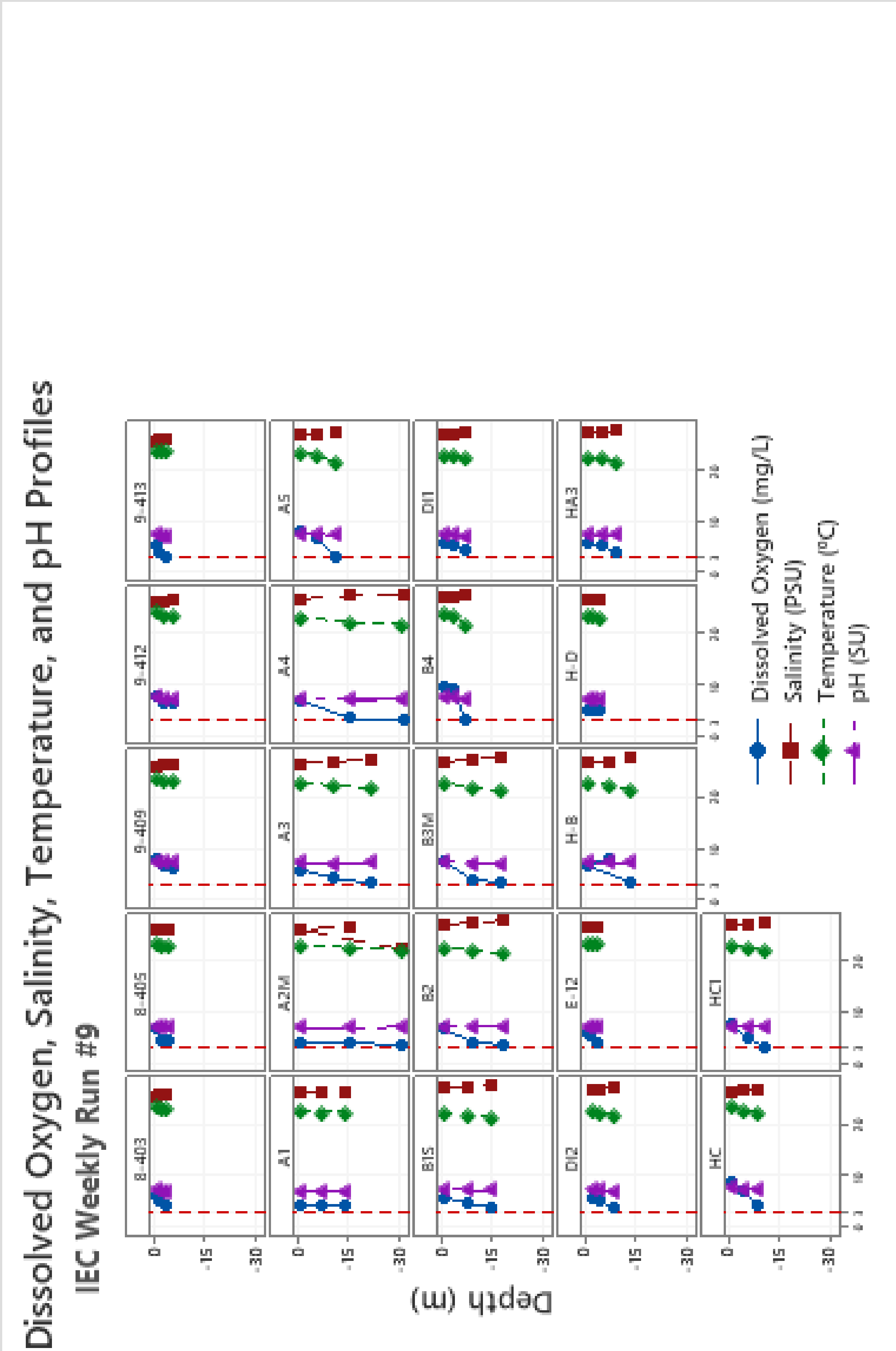
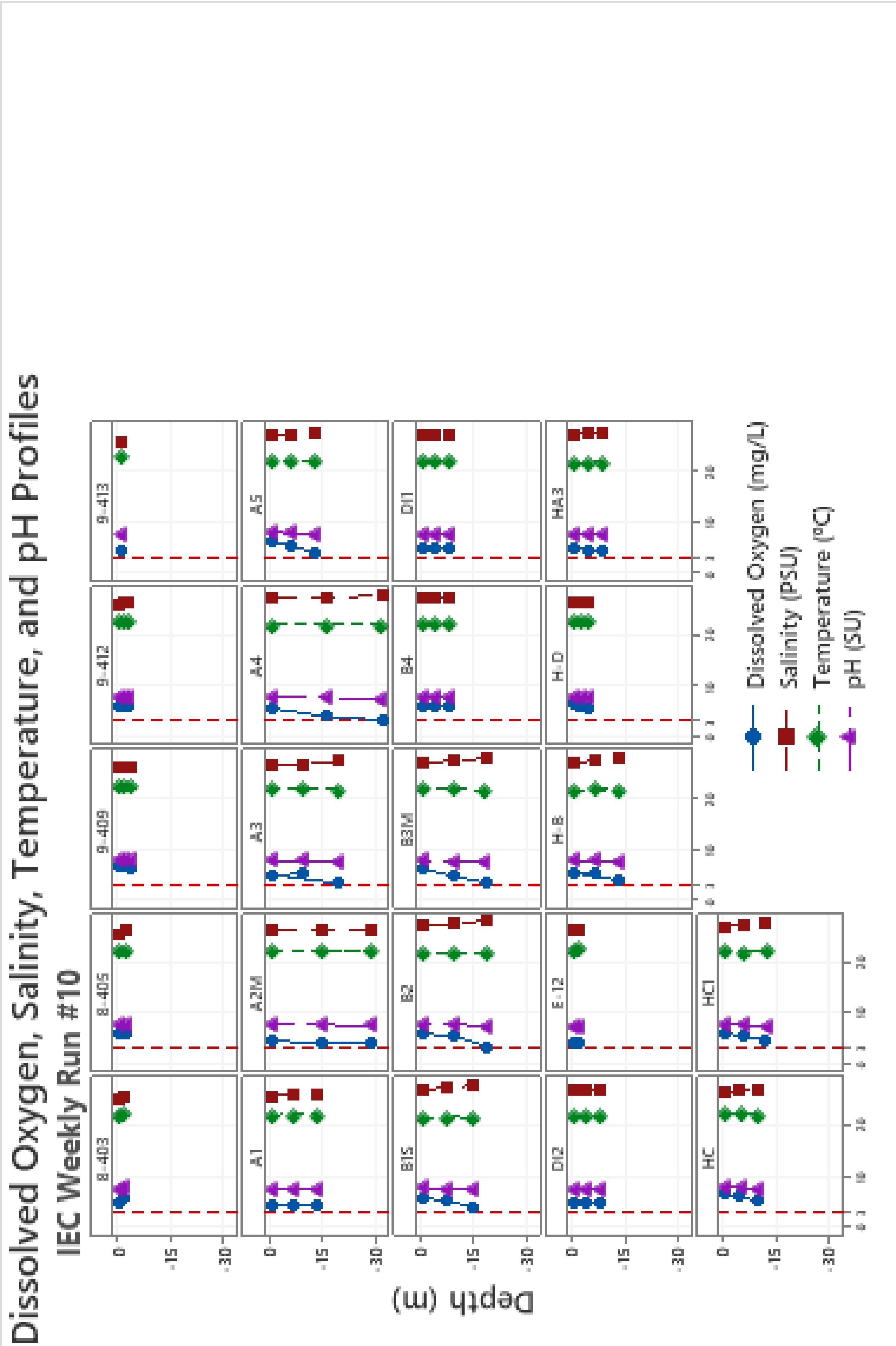
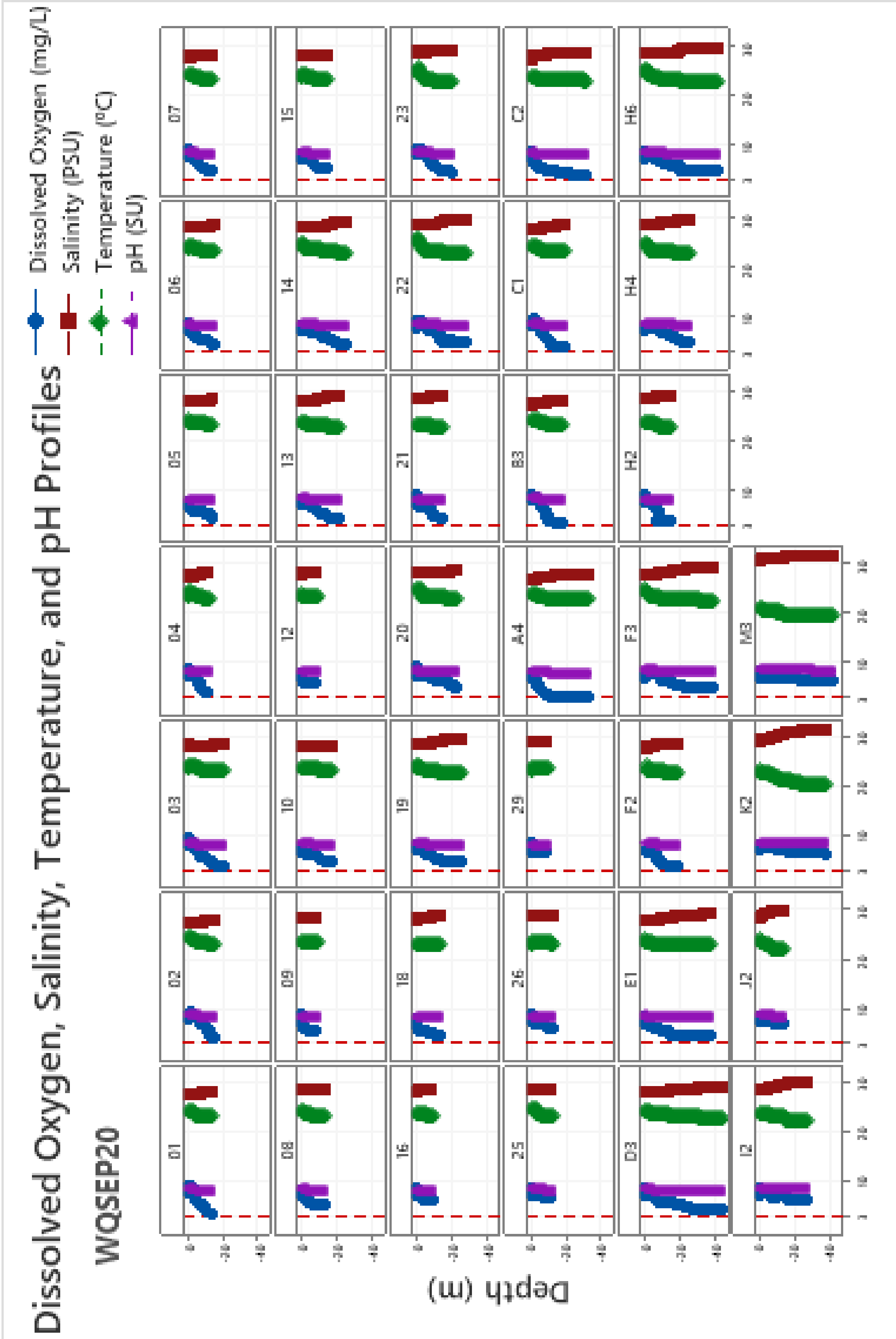
H6
I2
J2
K2


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #9
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
D11
D12
E-12
H-B
H-D
HA3
HC
HC1
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)

Appendix E – 2020 DEEP and IEC Summer Dissolved Oxygen, Temperature, and Salinity Data by Survey DEEP WQSEP20 and IEC Run #10


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #10
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
D11
D12
E-12
H-B
H-D
HA3
HC
HC1
0
-15
-30
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)


Dissolved Oxygen, Salinity, Temperature, and pH Profiles
WQSEP20
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)
Depth (m)
01
02
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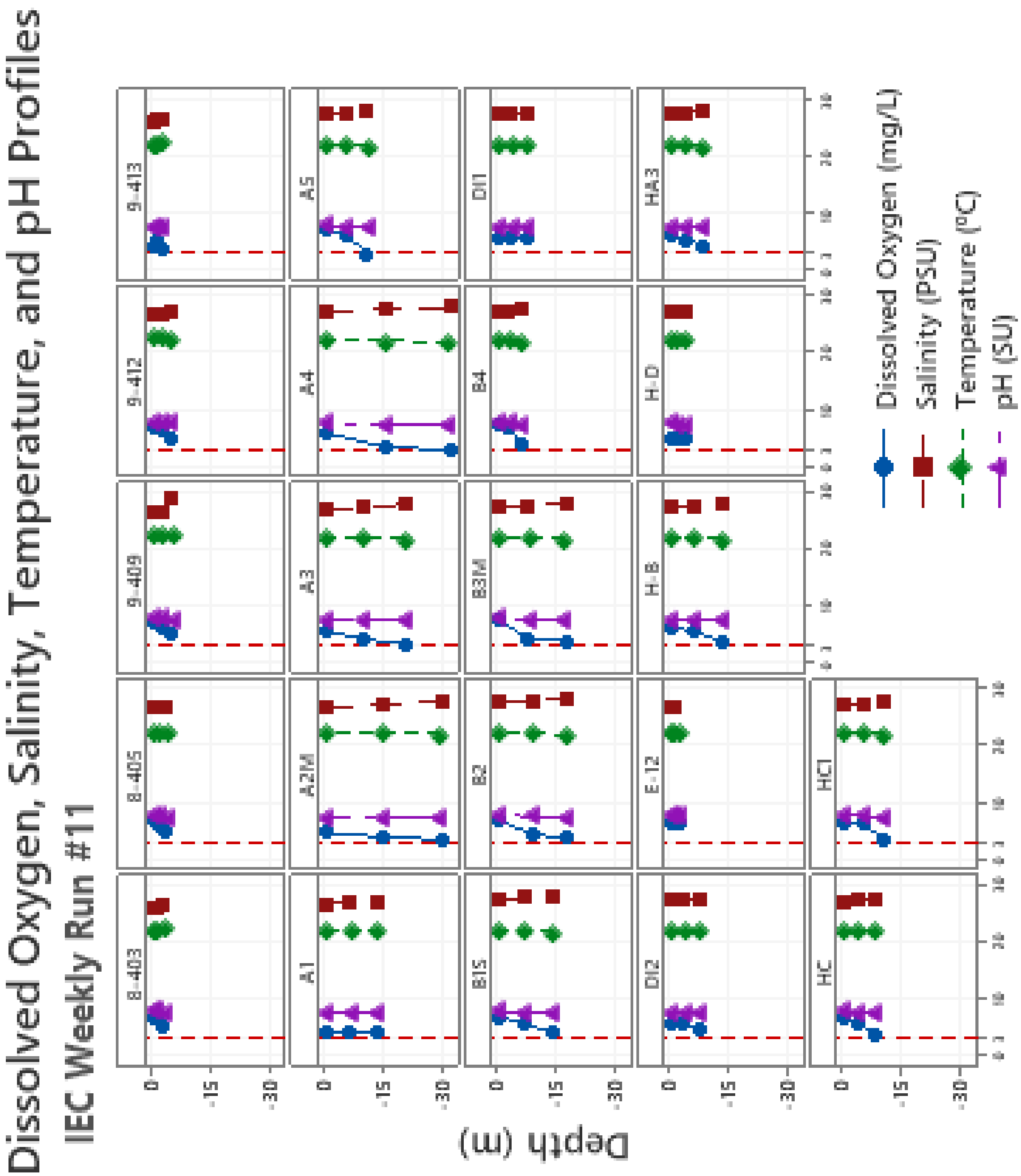
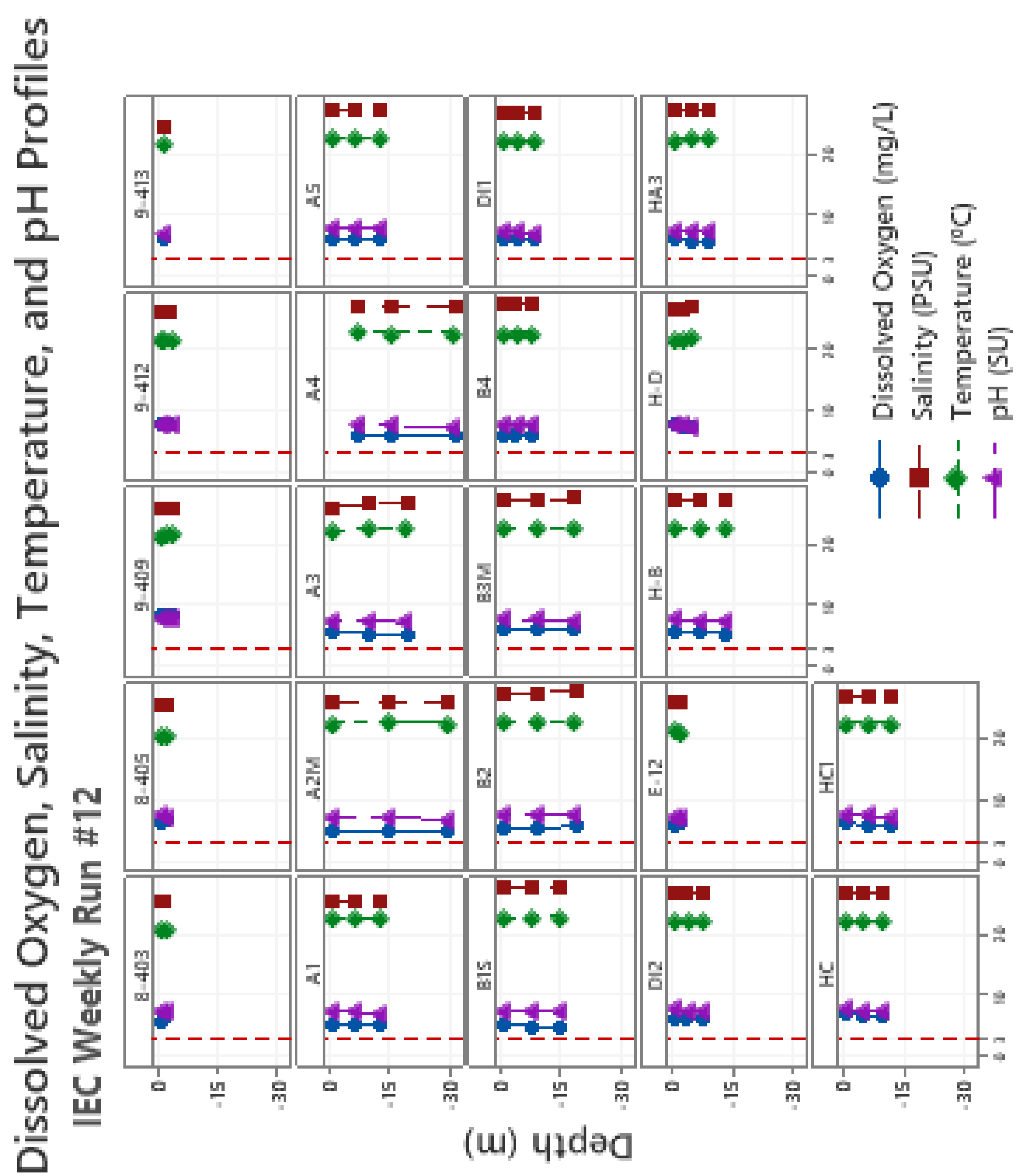
A4
B3
C1
C2
D3
E1
F2
F3
H2
H4
H6
I2
J2
K2
M3



Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #11
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
DI1
DI2
E-12
H-B
H-D
HA3
HC
HC1
0
-15
-30
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (°C)
pH (SU)

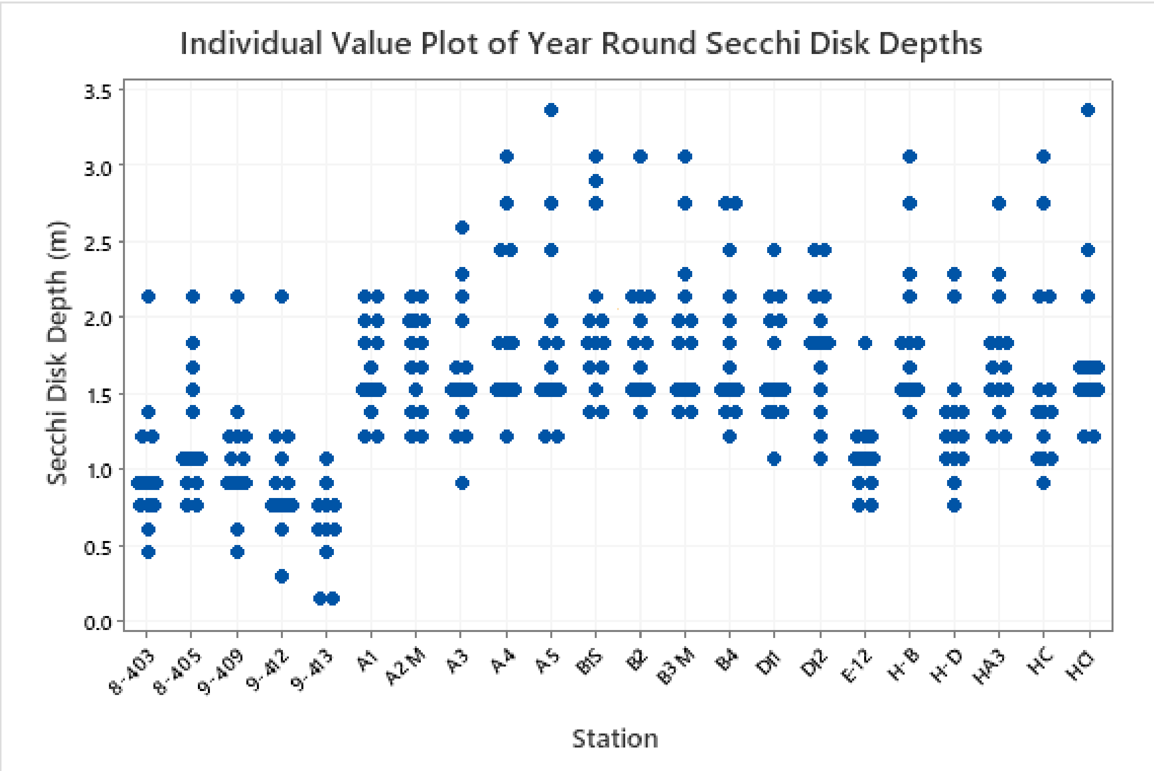

Dissolved Oxygen, Salinity, Temperature, and pH Profiles
IEC Weekly Run #12
Depth (m)
8-403
8-405
9-409
9-412
9-413
A1
A2M
A3
A4
A5
B1S
B2
B3M
B4
DI1
DI2
E-12
H-B
H-D
HA3
HC
HC1
0
-15
-30
Dissolved Oxygen (mg/L)
Salinity (PSU)
Temperature (ºC)
pH (SU)

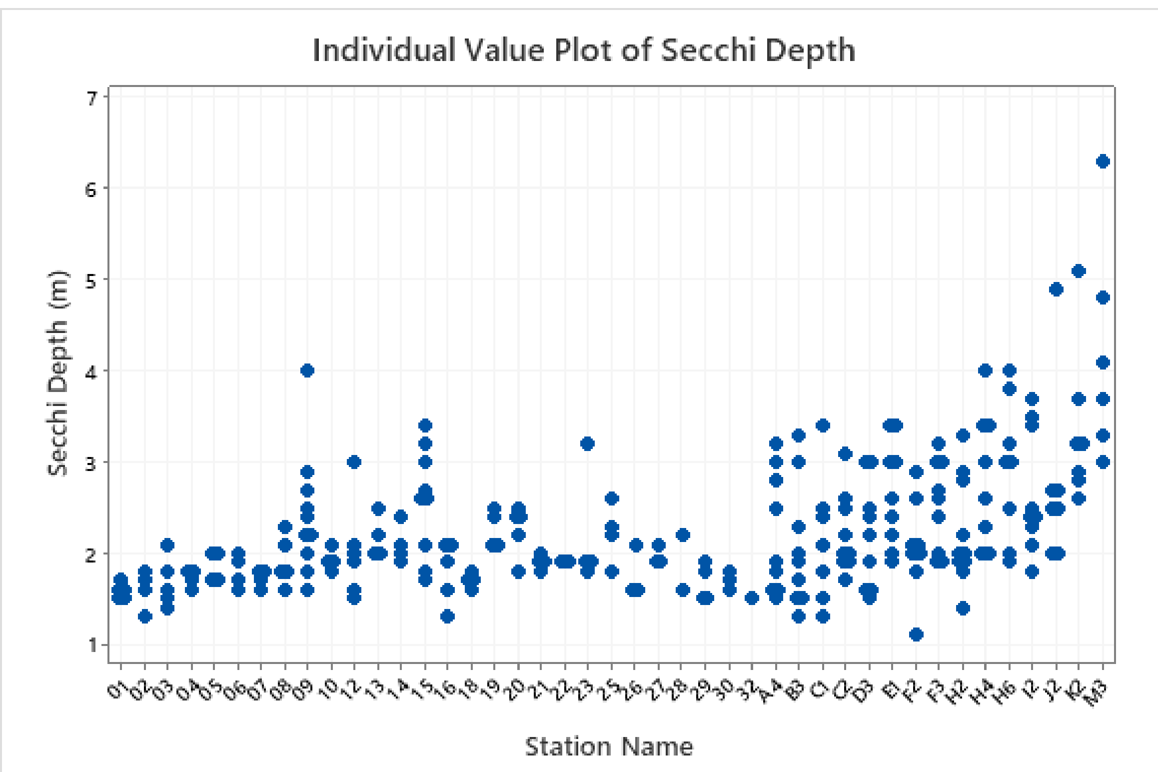
[2020 DEEP Summer (June-September) Profile Data]

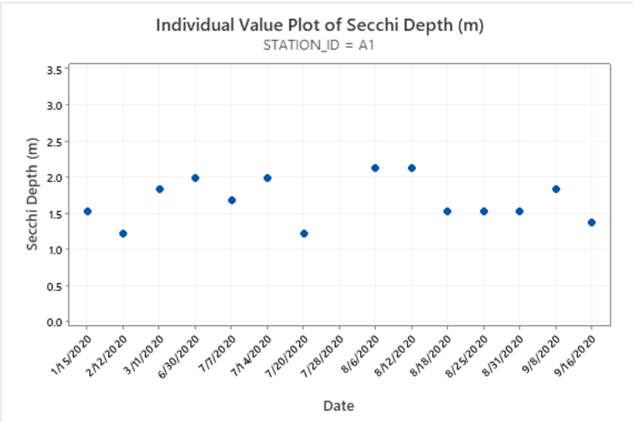
[2020 IEC Data (January-November)]

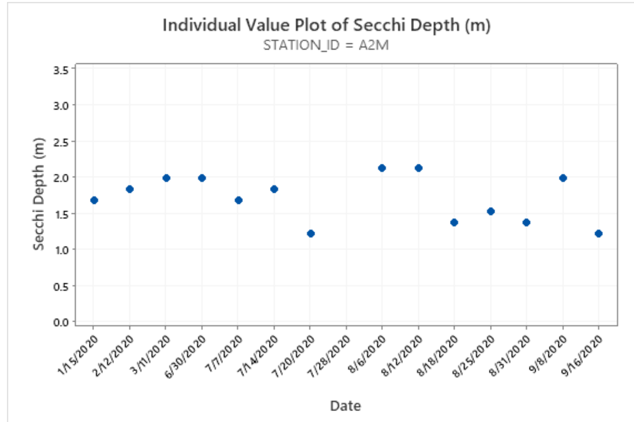
Appendix F – 2020 Year-Round Water Clarity Data

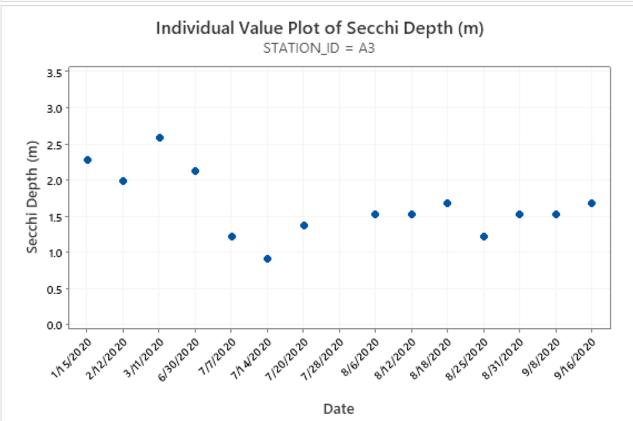
Individual value plots showing each Secchi disk depth recorded by the IEC (Figure F1) and CT DEEP (Figure F2) in 2020. Data from select stations are presented temporally in Figures F3– F16 on the following pages. See Figure 1 for station locations.

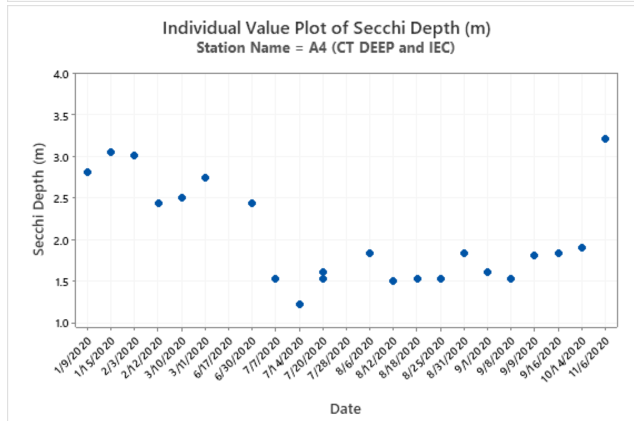


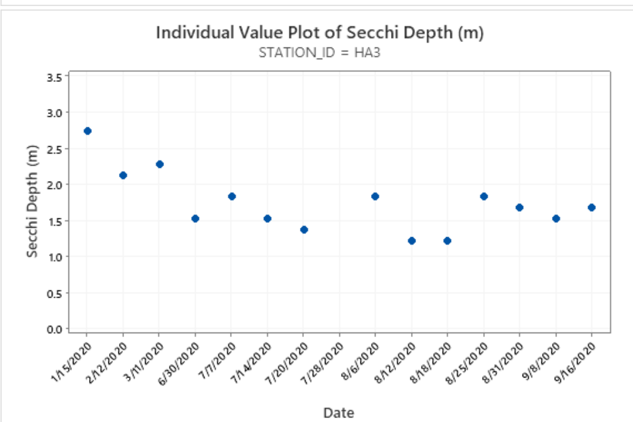


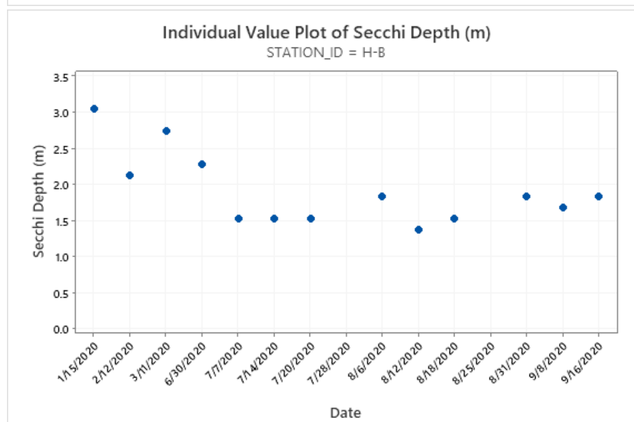

Individual Value Plot of Secchi Depth (m)
STATION_ID = A1
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1/15/2020
2/12/2020
3/11/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/8/2020
9/16/2020
Date

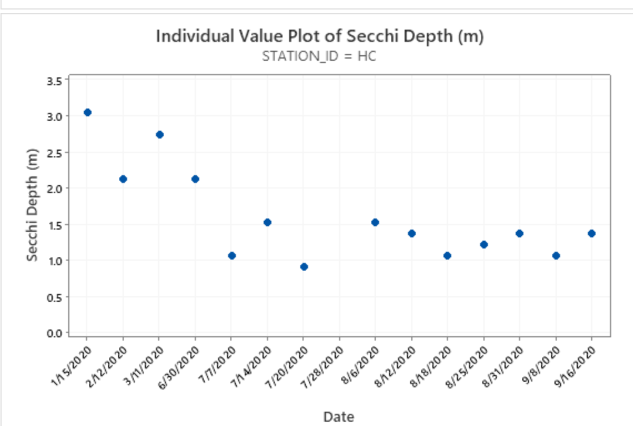

Individual Value Plot of Secchi Depth (m)
STATION_ID = A2M
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1/15/2020
2/12/2020
3/11/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/8/2020
9/16/2020
Date

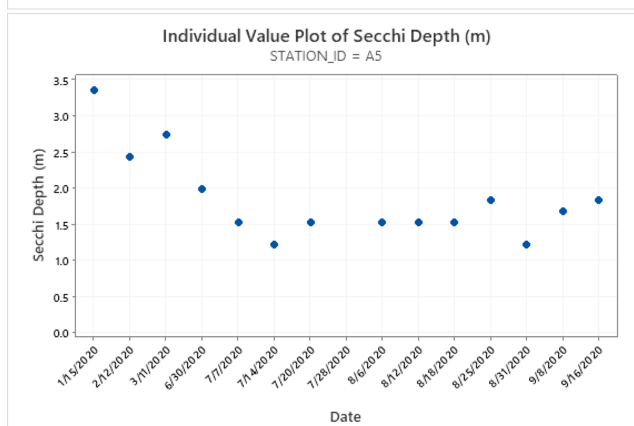

Individual Value Plot of Secchi Depth (m)
STATION_ID = A3
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1/15/2020
2/12/2020
3/11/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/8/2020
9/16/2020
Date

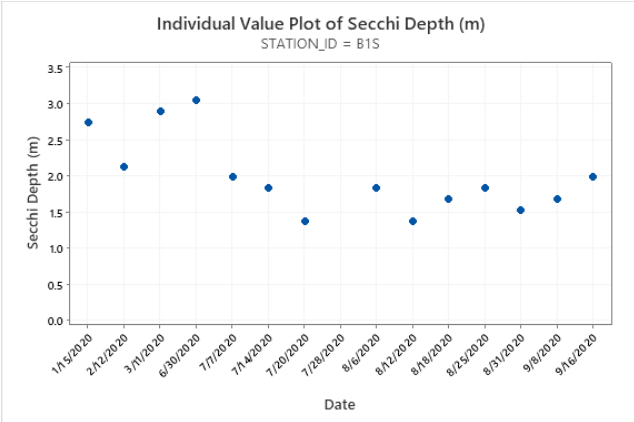

Individual Value Plot of Secchi Depth (m)
Station Name = A4 (CT DEEP and IEC)
Secchi Depth (m)
1.0
1.5
2.0
2.5
3.0
3.5
4.0
1/9/2020
1/15/2020
2/3/2020
2/12/2020
3/10/2020
3/11/2020
6/17/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/1/2020
9/8/2020
9/9/2020
9/16/2020
10/14/2020
11/6/2020
Date

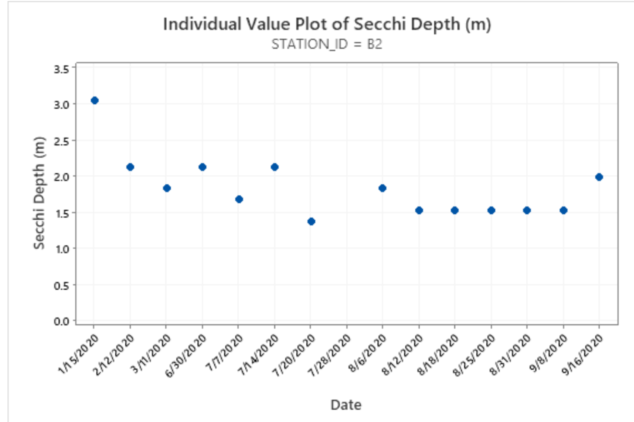

Individual Value Plot of Secchi Depth (m)
STATION_ID = HA3
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1/15/2020
2/12/2020
3/11/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/8/2020
9/16/2020
Date

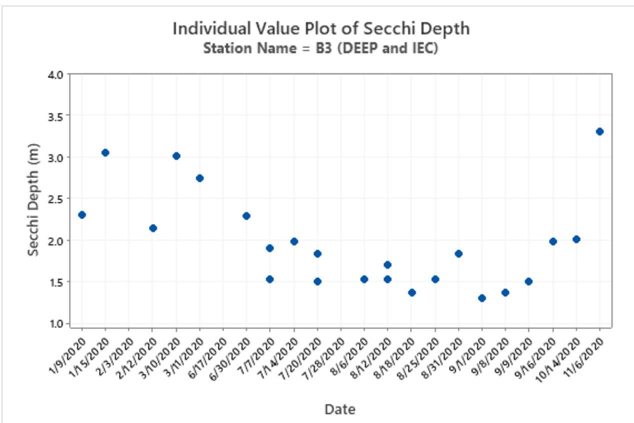

Individual Value Plot of Secchi Depth (m)
STATION_ID = H-B
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1/15/2020
2/12/2020
3/11/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/8/2020
9/16/2020
Date

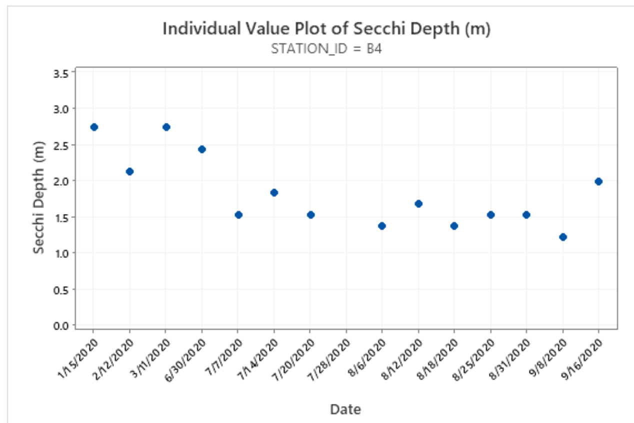

Individual Value Plot of Secchi Depth (m)
STATION_ID = HC
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1/15/2020
2/12/2020
3/11/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/8/2020
9/16/2020
Date

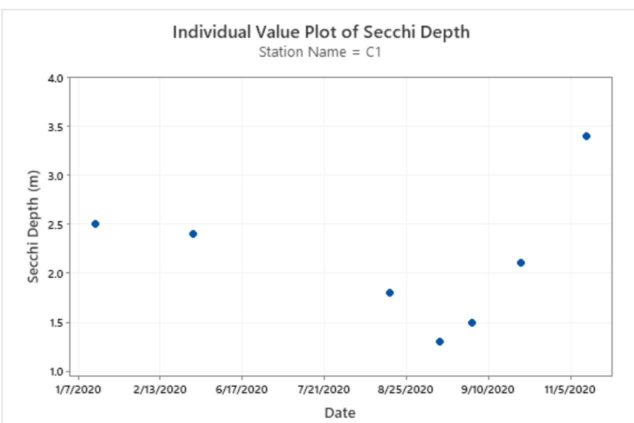

Individual Value Plot of Secchi Depth (m)
STATION_ID = A5
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1/15/2020
2/12/2020
3/11/2020
6/30/2020
7/7/2020
7/14/2020
7/20/2020
7/28/2020
8/6/2020
8/12/2020
8/18/2020
8/25/2020
8/31/2020
9/8/2020
9/16/2020
Date

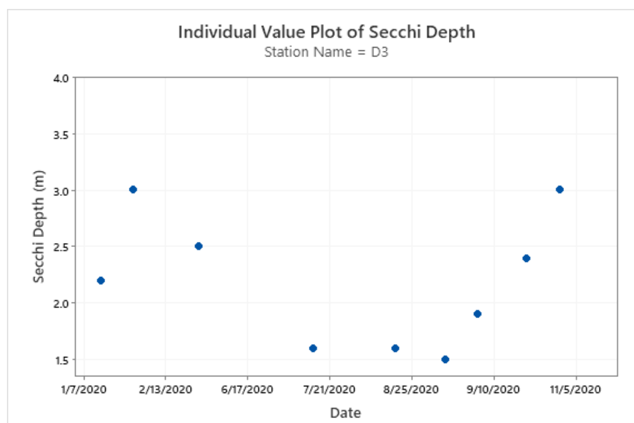

Individual Value Plot of Secchi Depth (m)
STATION_ID = B1S
Secchi Depth (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
1/15/2020 2/12/2020 3/11/2020 6/30/2020 7/7/2020 7/14/2020 7/20/2020 7/28/2020 8/6/2020 8/12/2020 8/18/2020 8/25/2020 8/31/2020 9/8/2020 9/16/2020
Date

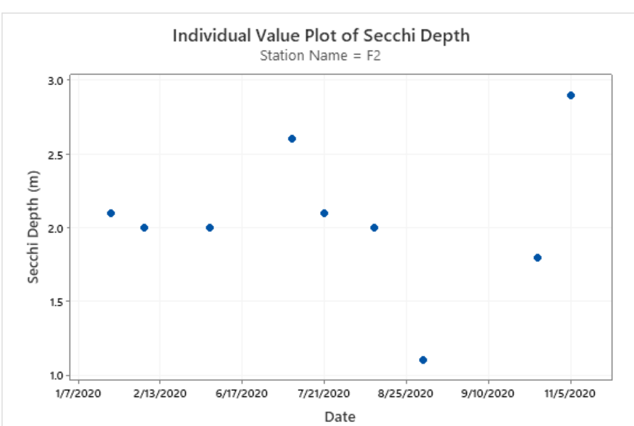

Individual Value Plot of Secchi Depth (m)
STATION_ID = B2
Secchi Depth (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
1/15/2020 2/12/2020 3/11/2020 6/30/2020 7/7/2020 7/14/2020 7/20/2020 7/28/2020 8/6/2020 8/12/2020 8/18/2020 8/25/2020 8/31/2020 9/8/2020 9/16/2020
Date

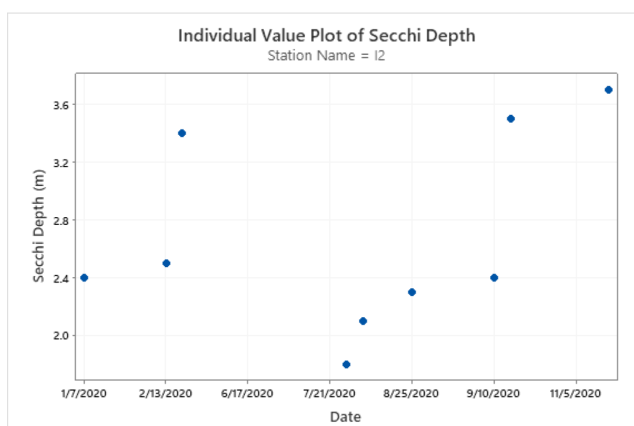

Individual Value Plot of Secchi Depth
Station Name = B3 (DEEP and IEC)
Secchi Depth (m)
1.0 1.5 2.0 2.5 3.0 3.5 4.0
1/9/2020 1/15/2020 2/3/2020 2/12/2020 3/10/2020 3/11/2020 6/17/2020 6/30/2020 7/7/2020 7/14/2020 7/20/2020 7/28/2020 8/6/2020 8/12/2020 8/18/2020 8/25/2020 8/31/2020 9/1/2020 9/8/2020 9/9/2020 9/16/2020 10/14/2020 11/6/2020
Date


Individual Value Plot of Secchi Depth (m)
STATION_ID = B4
Secchi Depth (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
1/15/2020 2/12/2020 3/11/2020 6/30/2020 7/7/2020 7/14/2020 7/20/2020 7/28/2020 8/6/2020 8/12/2020 8/18/2020 8/25/2020 8/31/2020 9/8/2020 9/16/2020
Date


Individual Value Plot of Secchi Depth
Station Name = C1
Secchi Depth (m)
1.0 1.5 2.0 2.5 3.0 3.5 4.0
1/7/2020 2/13/2020 6/17/2020 7/21/2020 8/25/2020 9/10/2020 11/5/2020
Date

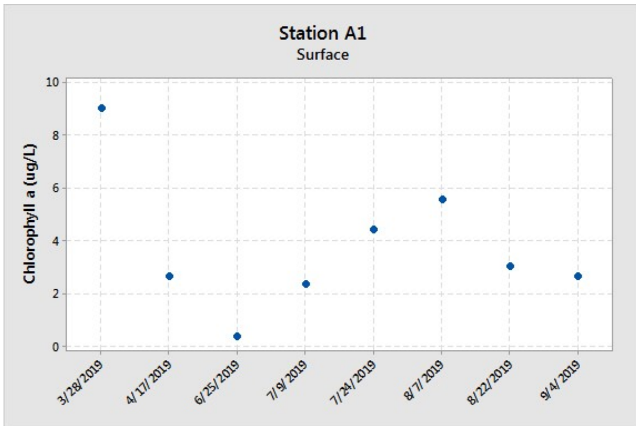

Individual Value Plot of Secchi Depth
Station Name = D3
Secchi Depth (m)
1.5 2.0 2.5 3.0 3.5 4.0
1/7/2020 2/13/2020 6/17/2020 7/21/2020 8/25/2020 9/10/2020 11/5/2020
Date

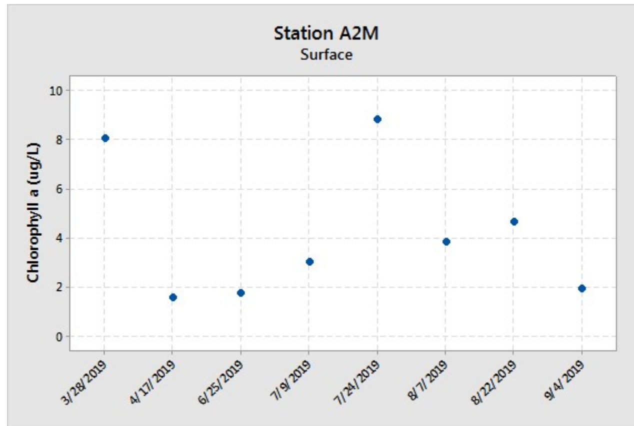

Individual Value Plot of Secchi Depth
Station Name = F2
Secchi Depth (m)
1.0 1.5 2.0 2.5 3.0
1/7/2020 2/13/2020 6/17/2020 7/21/2020 8/25/2020 9/10/2020 11/5/2020
Date

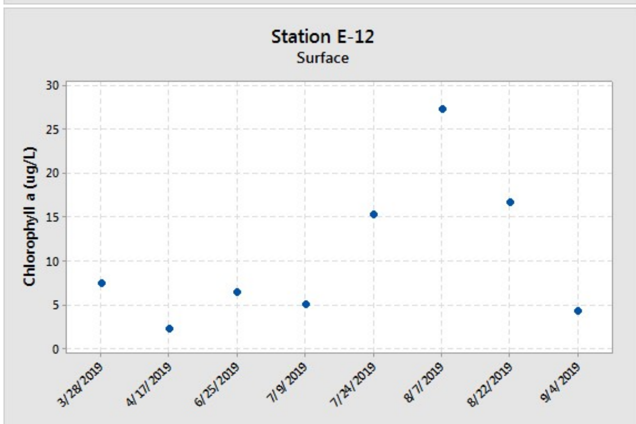

Individual Value Plot of Secchi Depth
Station Name = I2
Secchi Depth (m)
2.0 2.4 2.8 3.2 3.6
1/7/2020 2/13/2020 6/17/2020 7/21/2020 8/25/2020 9/10/2020 11/5/2020
Date

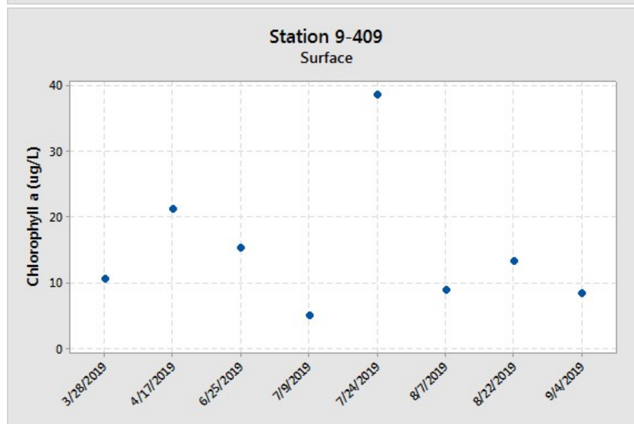
Appendix G – 2019 Year-Round Chlorophyll Data

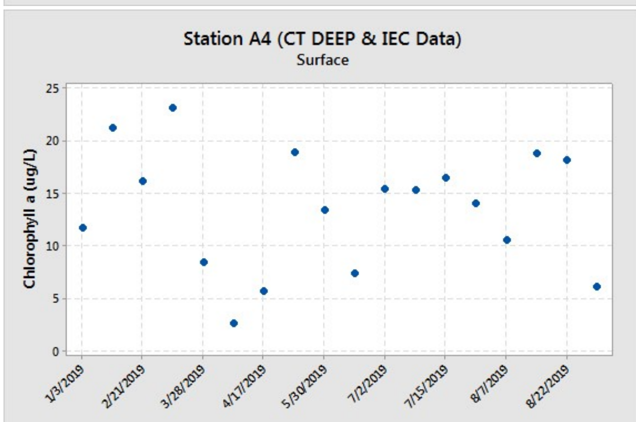
Individual value plots showing each chlorophyll a concentration recorded by the IEC and CT DEEP. CT DEEP data collected between January and September 2019. IEC data collected between March and September 2019. Additional stations are available upon request. See Figure 1 for station locations.

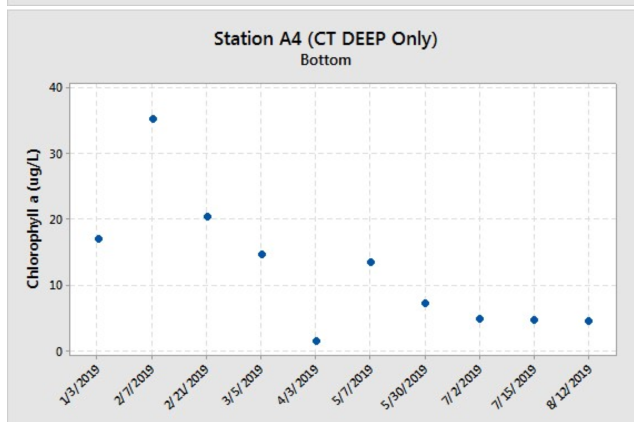


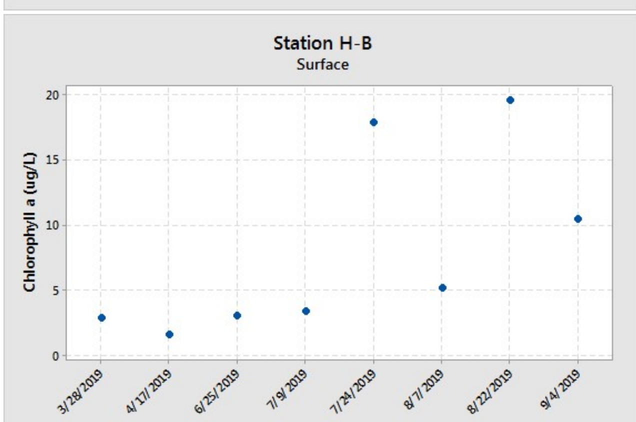


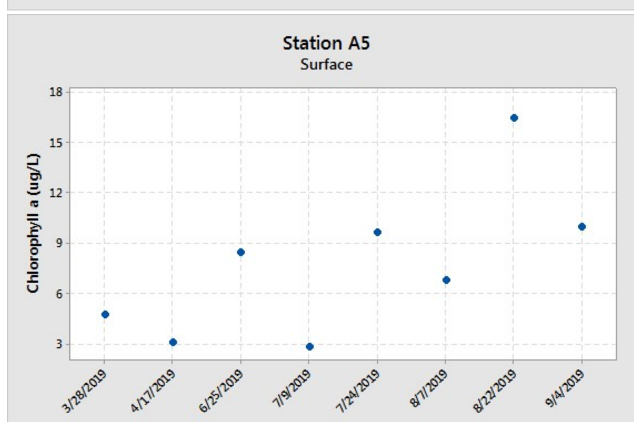


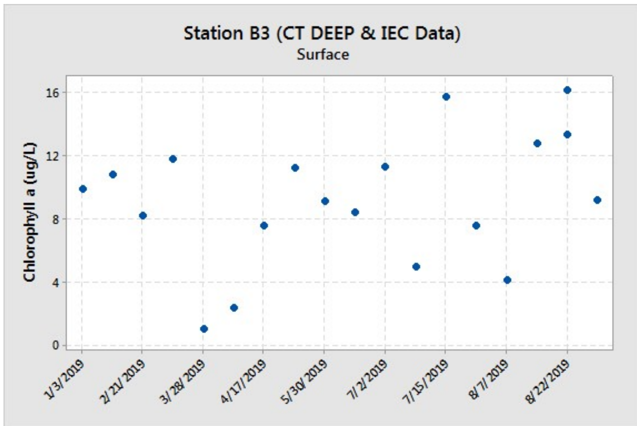


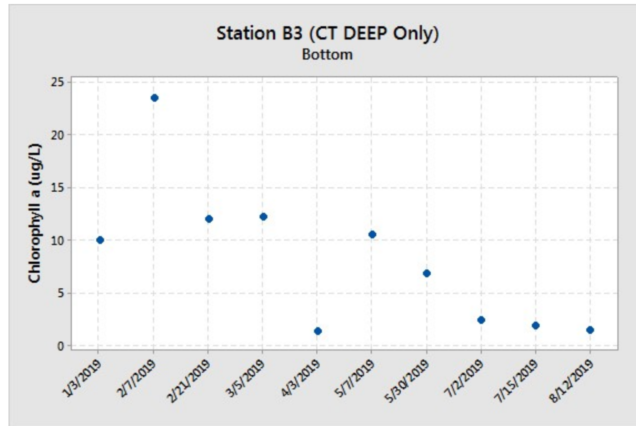


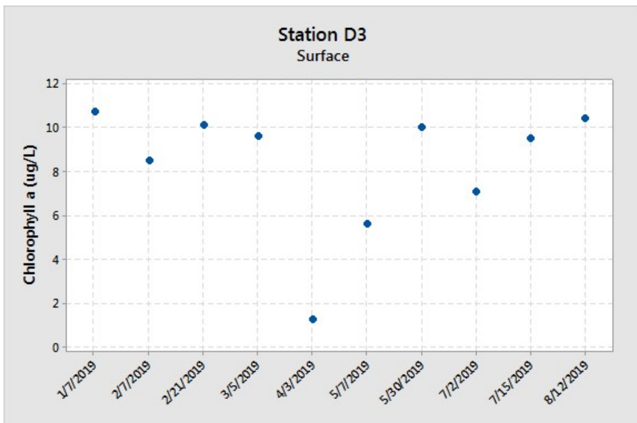


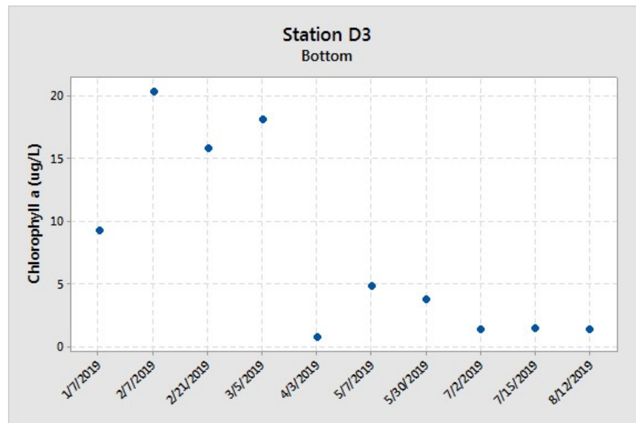


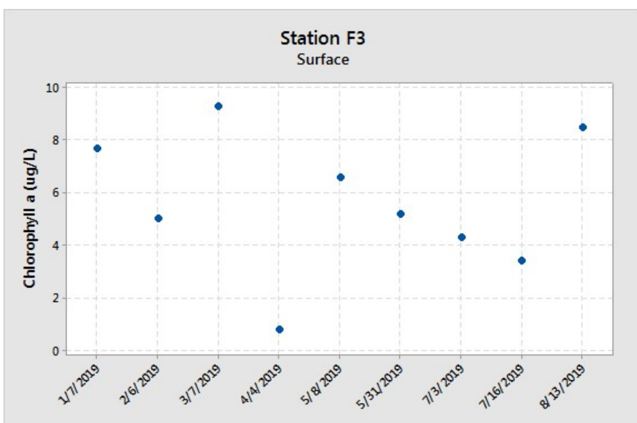


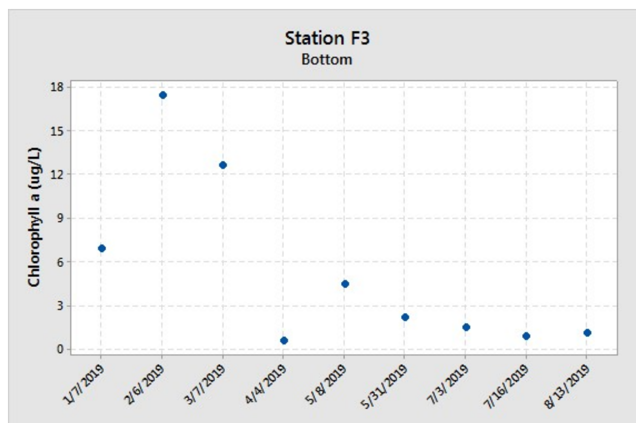

Station B3 (CT DEEP & IEC Data)
Surface
Chlorophyll a (ug/L)
0
4
8
12
16
1/3/2019
2/21/2019
3/28/2019
4/17/2019
5/30/2019
7/2/2019
7/15/2019
8/7/2019
8/22/2019

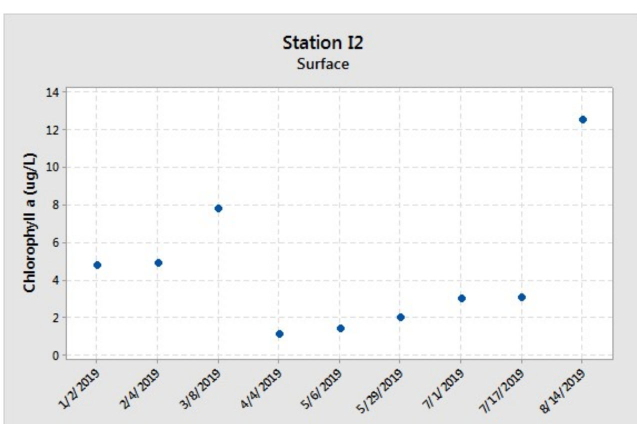

Station B3 (CT DEEP Only)
Bottom
Chlorophyll a (ug/L)
0
5
10
15
20
25
1/3/2019
2/7/2019
2/21/2019
3/5/2019
4/3/2019
5/7/2019
5/30/2019
7/2/2019
7/15/2019
8/12/2019

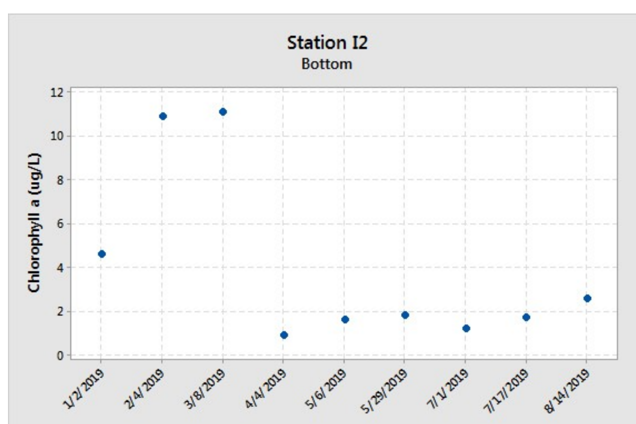

Station D3
Surface
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
1/7/2019
2/7/2019
2/21/2019
3/5/2019
4/3/2019
5/7/2019
5/30/2019
7/2/2019
7/15/2019
8/12/2019


Station D3
Bottom
Chlorophyll a (ug/L)
0
5
10
15
20
1/7/2019
2/7/2019
2/21/2019
3/5/2019
4/3/2019
5/7/2019
5/30/2019
7/2/2019
7/15/2019
8/12/2019


Station F3
Surface
Chlorophyll a (ug/L)
0
2
4
6
8
10
1/7/2019
2/6/2019
3/7/2019
4/4/2019
5/8/2019
5/31/2019
7/3/2019
7/16/2019
8/13/2019


Station F3
Bottom
Chlorophyll a (ug/L)
0
3
6
9
12
15
18
1/7/2019
2/6/2019
3/7/2019
4/4/2019
5/8/2019
5/31/2019
7/3/2019
7/16/2019
8/13/2019


Station I2
Surface
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
14
1/2/2019
2/4/2019
3/8/2019
4/4/2019
5/6/2019
5/29/2019
7/1/2019
7/17/2019
8/14/2019


Station I2
Bottom
Chlorophyll a (ug/L)
0
2
4
6
8
10
12
1/2/2019
2/4/2019
3/8/2019
4/4/2019
5/6/2019
5/29/2019
7/1/2019
7/17/2019
8/14/2019

Acknowledgements

Funding for the CT DEEP Long Island Sound Water Quality Monitoring Program and IEC's Western Long Island Sound monitoring program is provided by the Environmental Protection Agency through the Long Island Sound Study.

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