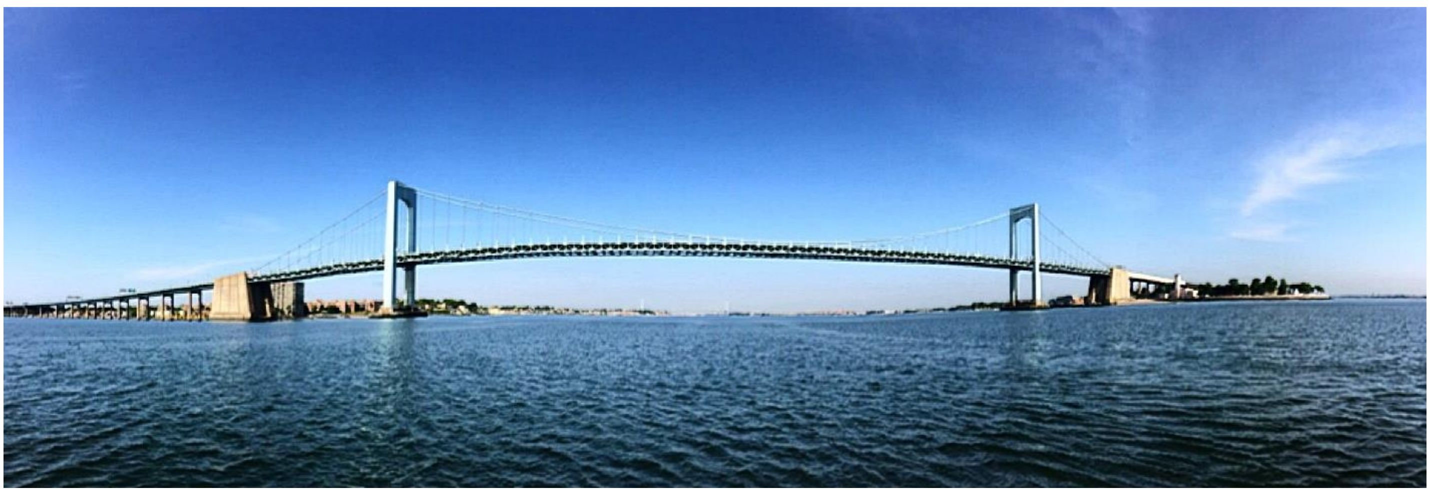
HYPOXIA
IN
FAR WESTERN LONG ISLAND SOUND
AND
UPPER EAST RIVER

2014



NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMMISSION

INTERSTATE ENVIRONMENTAL COMMISSION DISTRICT

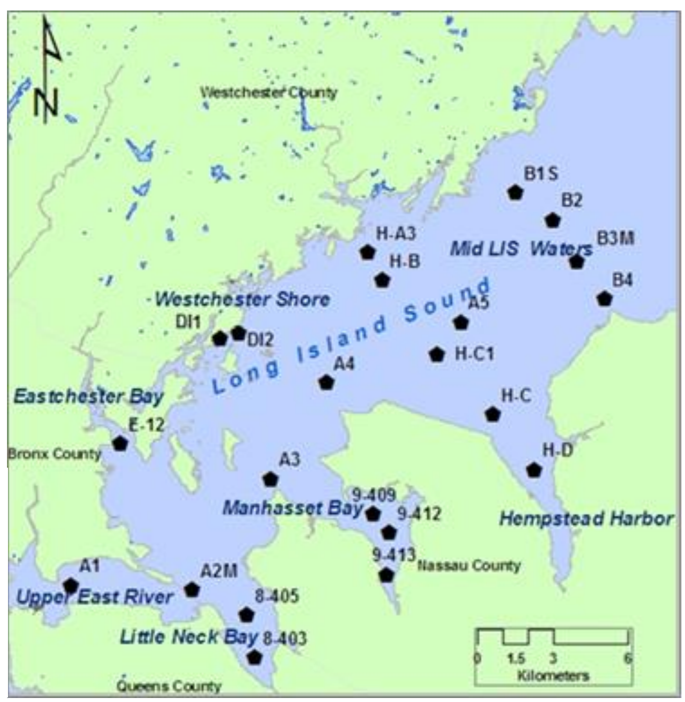
Overview of IEC District's Monitoring Program

The Interstate Environmental Commission District (IEC District) has monitored the westernmost portion of the Western Long Island Sound Basin each year since 1991. Targeted water quality surveys are completed between June and September to document the transition of waters into and out of a state of hypoxia. This collaborative program is performed in support of the National Estuary Program's Long Island Sound Study (LISS; http://longislandsoundstudy.net/).

The map above depicts the three major Long Island Sound basins (Western, Central, and Eastern) and watersheds. The red oval depicts the project study area—"The Narrows"— in the Western Basin of Long Island Sound.

(Credits: Map, by Mapping Specialists and Lucy Reading-Ikkanda; Sound Health 2008)

IEC District's 2014 monitoring program consisted of 7 surveys at 22 stations in Long Island Sound, from the upper East River to the far western Long Island Sound (also known as the Narrows; see maps above and below). *In situ* water quality measurements were recorded and surface samples were collected and analyzed for total suspended solids, chlorophyll *a* (a pigment in photosynthetic organisms used as an indicator of algal abundance), and nutrients (a priority water quality indicator and management concern identified by the Long Island Sound Study).



The map to the right depicts IEC District's 22 sampling stations located in far western Long Island Sound. *In situ* measurements of pH, temperature, salinity, water clarity (Secchi disk depth), and dissolved oxygen were collected at each station during the 2014 survey season.

The project study areas are *Upper East River; Eastchester Bay; Westchester Shore; Mid LIS Waters; inner Little Neck Bay; Manhasset Bay; and Hempstead Harbor.*

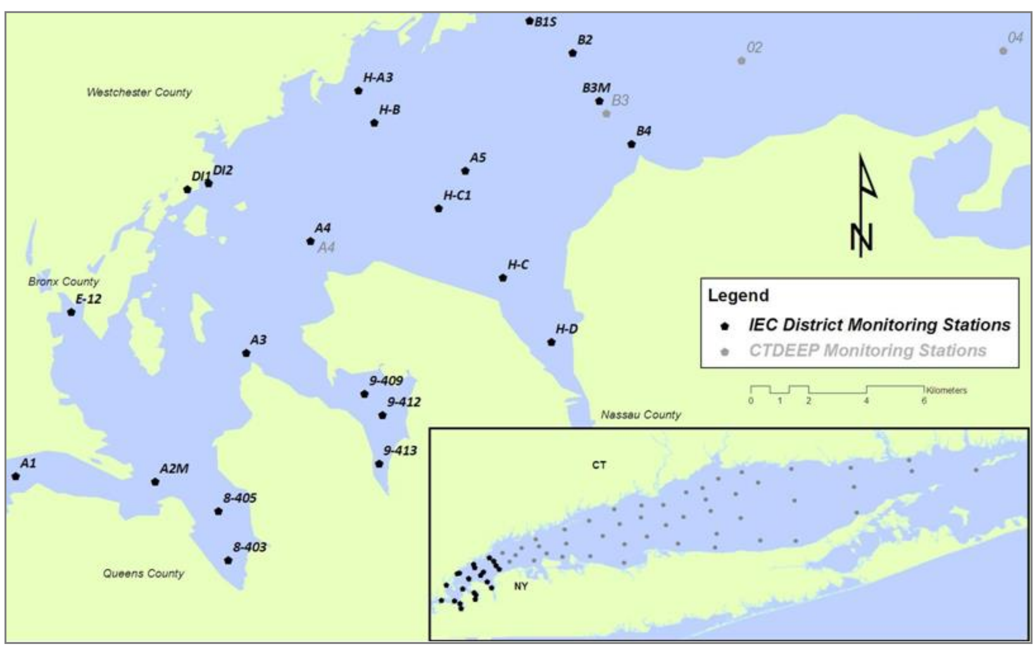
IEC District's Western Long Island Sound Monitoring Program 2014

The overall goal of IEC District's seasonal monitoring program is to effectively measure key water quality indicators identified by the Long Island Sound Study (LISS), such as hypoxia (low dissolved oxygen) and nutrient pollution, which are important for managing priority areas of concern. IEC District worked cooperatively with US EPA's Long Island Sound Office and LISS partners to ensure this season's monitoring project served the needs of the management community of the LISS.

Historically, IEC District's monitoring activities primarily focused on the collection and dissemination of conventional water quality parameters, including dissolved oxygen and chlorophyll *a*. This season, at the request of LISS, a suite of nutrient parameters were incorporated. As part of a multi-agency collaborative effort, the IEC District continued to perform monitoring along with state and local entities such as the Connecticut Department of Energy and Environmental Protection (CT DEEP– http://www.ct.gov/deep), the University of Connecticut Department of Marine Sciences (UCONN– http://lisicos.uconn.edu/index.php), New York City Department of Environmental Protection (NYC DEP– http://nyc.gov/dep), municipal health departments, and citizen science groups. Specific objectives for the 2014 season included enhanced coordination with CTDEEP and other LISS partners to ensure the most efficient monitoring program for the entire Sound.

IEC District's monitoring surveys were conducted between June and September. Documenting water quality conditions during the summer, when dissolved oxygen (DO) concentrations typically reach lowest levels, allows for better characterization of hypoxia and the identification of the most problematic areas in the Sound. Monitoring results will contribute to measuring the effectiveness of management activities and provide information to assess progress of programs implemented under the Comprehensive Conservation and Management Plan (CCMP) for Long Island Sound. IEC District data will also assist to better characterize nutrient concentrations in open waters and embayments of the Sound, which can be used to assess the relationships between dissolved oxygen and nutrient concentrations, as well as assess progress and results of nutrient reduction efforts within the western Long Island Sound watershed.

The purpose of this report is to present the results from the *IEC District Western Long Island Sound Monitoring Program (2014)*. It focuses on hypoxia (low DO) and select water quality parameters by presenting *in situ* data collected by the IEC District during the 2014 season. However, a regional and temporal context is provided via supplementary datasets (*i.e.*, CT DEEP 2014 and IEC 1991-2013).



The map above depicts IEC District's 22 WLIS stations in relation to CT DEEP's stations.

Long Island Sound and Hypoxia

Why is it so important to address hypoxia?

Direct consequences of hypoxia include fish kills, which deplete impact anglers and disrupt ecosystems. Motile species (*e.g.*, non-larval-stage fish) can typically survive a hypoxic event by moving to waters with more oxygen levels. However, less motile and immobile species (*i.e.*, clams or crabs) may die during hypoxic events because they cannot seek out refuge in oxygen-rich waters; others may survive but become susceptible to disease. In turn, this can decrease the amount of life in hypoxic areas (known as dead zones).

Hypoxia also affects the ability of young fish or shellfish to find the necessary food and habitat to become adults. Accordingly, fish and shellfish stocks may be reduced or become less stable because fewer young survive to reproductive age. Species that rely on fish to survive are also impacted when their food supply becomes scarce due to hypoxic conditions.

Long Island Sound, located within one of the most densely populated areas in the nation, is a recognized Estuary of National Significance by the Environmental Protection Agency (EPA) National Estuary Program. Known for its valuable natural resources and beauty, the Long Island Sound provides a diverse array of recreational and commercial opportunities. As an estuary, the Sound is home to numerous species of flora and fauna and provides feeding and breeding habitat for many species of fish, shellfish, waterfowl, and other birds.

Urbanization and changes in land use have resulted in an increase in the amount of pollution entering Long Island Sound. Nutrient pollution from nearby wastewater facilities and runoff; toxic pollution from pesticides, herbicides, and industrial facilities; pathogens from inadequately treated sewage and wastewater effluent; and floatable debris from improper disposal of trash all pose significant threats to the Sound's fragile ecosystem. Excessive nitrogen loading and the resulting hypoxic conditions in the Long Island Sound have been identified as the estuary's most pressing problems.

Hypoxia

Hypoxia—low dissolved oxygen—is primarily a problem for estuaries and coastal waters. Dissolved oxygen concentrations that drop below an organism's threshold to survive could be fatal; persistently low levels of dissolved oxygen may alter seasonal migration routes and render habitat unsuitable. In their early life stages, aquatic organisms are more at risk than free swimming adults due to increased sensitivity and an inability to relocate.

The LISS defines hypoxic waters as those that have dissolved oxygen concentrations of less than 3.0 milligrams per liter (mg/L). While this benchmark is used to identify the onset of hypoxia, in circumstances where DO is below 5.0 mg/L, biological stresses on aquatic organisms have been observed. Dissolved oxygen concentrations at or above 5.0 mg/L are believed to be protective of marine life.

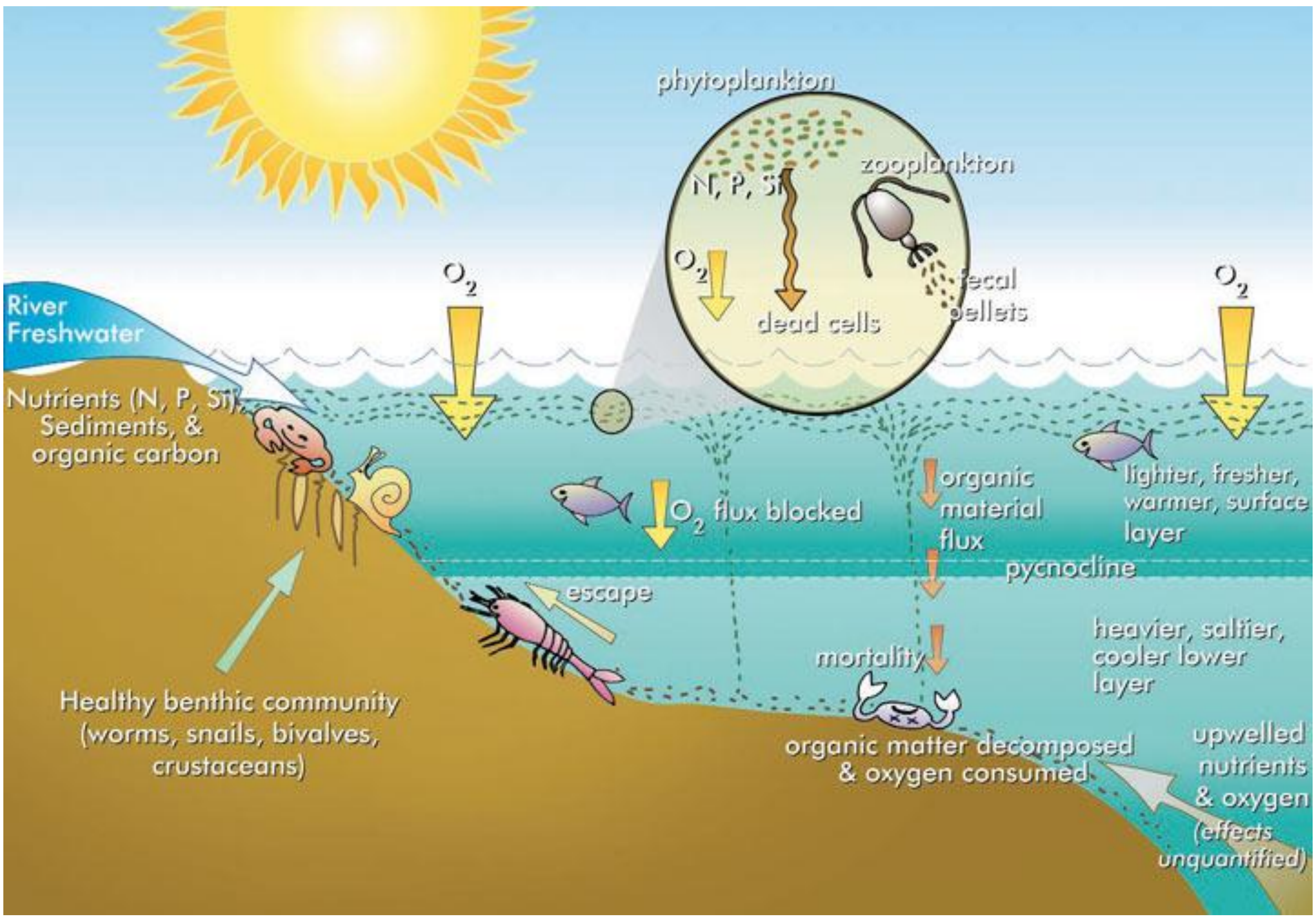
Hypoxia may occur in aquatic environments, particularly shallow coastal and estuarine areas, due to natural chemical and physical factors. However, the occurrence of hypoxic conditions are likely accelerated by human activities. Hypoxia occurs in many places throughout the world; however, some estuaries, including Long Island Sound, experience dissolved oxygen problems every summer.

Hypoxia has been identified as the issue of greatest concern for water quality in the Sound. Hypoxic events result from a variety of factors, including excess nutrients and seasonal stratification (layering) of waters. Stratification can occur in

Long Island Sound waters due to either salinity or temperature gradients. Excess nitrogen loading to the Sound, a primary cause of hypoxia in Long Island Sound, can come from many sources, including:

- Discharges from wastewater treatment plants
- Fertilizers from lawns, agriculture, golf courses
- Erosion of nutrient-rich soil
- Atmospheric nitrogen deposition

Hypoxia can result from increases in nutrient-enhanced primary production (algal blooms) and the resulting decomposition of biomass in the water. The figure below illustrates how excess nutrients promote algal growth; as dead algae decompose, oxygen is consumed in the process, resulting in low oxygen in the water. Stratification prevents the mixing of oxygen-rich surface waters with oxygen-poor bottom waters. In the absence of mixing, the bottom water cannot receive adequate oxygen and the hypoxic conditions persist.



The figure above depicts the process of eutrophication and stratification in an estuary. It illustrates the cycle of nutrient-enhanced primary production, followed by decomposition of organic matter coupled with oxygen consumption, and eventual depletion of oxygen.

Credit EPA. Accessed 10/30/2014 at: http://water.epa.gov/type/watersheds/named/msbasin/images/eutro_big.jpg

Methods

This year marks IEC District's 24th consecutive summer of monitoring in the far western Long Island Sound to identify the occurrence and extent of hypoxic conditions. As requested by the LISS partners, instead of its typical 12 weekly surveys, IEC District's 2014 monitoring program consisted of 7 surveys between June and mid-September. This allowed IEC District to add nutrient analysis to the 2014 project.

During each trip, 22 stations were visited from the upper East River to the mid-western Sound (see table below and map on page 1). This includes embayment and open water locations within the following 7 study areas:

- Upper East River
- Eastchester Bay
- Westchester County Shoreline
- Mid-Long Island Sound Waters
- Little Neck Bay
- Manhasset Bay
- Hempstead Harbor

In situ measurements were recorded for dissolved oxygen, temperature, salinity, pH, and water clarity. In addition, visual observations and basic meteorological data (air temperature, cloud cover percentage, wind direction) were recorded at the beginning of each survey. This information includes precipitation data (accumulation totals) for the 24 and 48 hours periods prior to each survey.

Station	Depth(m)	Description	Study Area
A1	26	East of Whitestone Bridge	**Upper East River**
A2M	35	East of Throgs Neck Bridge	
E-12	4	Eastchester Bay mid-channel at N 6	**Eastchester Bay**
DI1	10	Davids Island north of Nun "10A"	**Westchester County Shoreline**
DI2	6	Davids Island east of Nun "4"	
H-A3	3	Delancy Point south of Can "1"	
H-B	12	0.7 nm southeast of Daymarker Fl R 4 Sec	
A3	12	Hewlett Point south of Fl G 4 Sec "29"	**Mid-Long Island Sound Waters**
A4	35	East of Sands Point, mid-channel	
A5	13	~2.6 nm east of Execution Lighthouse	
H-C1	11	Hempstead Harbor ~2.0 nm east of Sands Point	
B1S	15	Porgy Shoal south of Fl G 4 Sec R "40"	
B2	20	Matinecock Point 1.6 nm north of Gong "21"	
B3M	19	Matinecock Point 0.7 nm north of Gong "21"	
B4	15	Matinecock Point south of Gong "21"	
8-403	3	Little Neck Bay ~0.2 nm west of yellow Nun "B"	**Little Neck Bay**
8-405	3	Little Neck Bay ~0.15 nm north of mid-channel buoy	
9-409	4	Manhasset Bay	**Manhasset Bay**
9-412	4	Manhasset Bay	
9-413	3	Manhasset Bay	
H-D	7	Hempstead Harbor east of Can "9"	**Hempstead Harbor**
H-C	8	Hempstead Harbor east of R Bell "6"	

Monitoring Overview:

Field Measurements[1]:

- Dissolved Oxygen
- Temperature
- Salinity
- pH
- depth
- Water Clarity (Secchi Disk Depth)[1]

Surface Sampling Parameters:

- Chlorophyll *a*[2]
- Total Suspended Solids[2]
- Nutrients[3]

Visual Observations[1]:

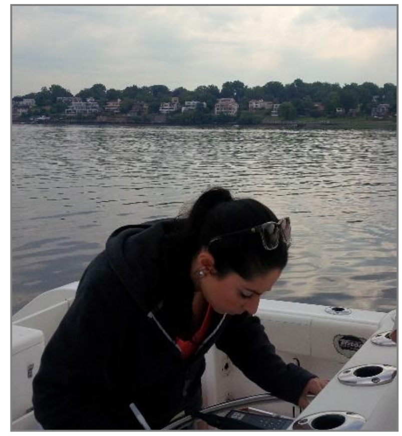
- Percent Cloud Cover
- Sea state
- Weather conditions

[1]Parameter collected in the field

[2]Samples analyzed at the IEC District Laboratory

[3]Samples pre-processed by IEC District (filtered and preserved) and sent to a contractual laboratory—Chesapeake Biological Laboratory—for analysis

IEC District used multi-parameter YSI meters to collect water column data for pH, temperature, salinity, and dissolved oxygen (DO). These parameters were measured at three depths: one meter below the surface (surface), one meter above the sediment substrate (bottom), and a depth midway between the water's surface and the bottom (mid-depth). For stations with a depth of less than 10 meters, only the surface and bottom measurements were taken. Water clarity was measured using a Secchi disk, which was lowered through the water column until the disk was no longer visible and then raised until it reappeared. The depth of these two points were averaged.



IEC District analyst utilizes a YSI multi-parameter meter to measure the *in situ* parameters at station A2M.

Surveys also included the collection surface samples from all 22 stations for chlorophyll *a* and total suspended solids for subsequent analysis in the IEC District Laboratory. From 11 of the 22 stations—selected in coordination with the LISS Water Quality Monitoring Workgroup—samples were collected for analysis of the following nutrients: dissolved and biogenic silica, dissolved organic and particulate carbon, dissolved and particulate nitrogen, ammonia, nitrate and nitrite, total dissolved and particulate phosphorus, and orthophosphate. Nutrient samples were filtered and preserved for storage and transport to and analysis by Chesapeake Biological Laboratories (http://www.umces.edu/cbl).

An overview of the parameters collected and analyzed is provided in the table below. All field work was conducted in accordance with IEC District's EPA approved Quality Assurance Project Plan (QAPP) entitled *Ambient Water Quality Monitoring in the Western Long Island Sound* (approved June 22, 2014). All analyses performed by IEC District were done in accordance with its *Laboratory Quality Control Manual*, EPA-approved QAPP, and NEIWPCC's *Quality Management Plan* (Revision No. 5). To further ensure the quality of collected field data, duplicate measurements were taken at one station per survey.

Field Parameters[1]	**Laboratory Analyses**[2]
Water Depth	Chlorophyll *a* (**Chl *a***): Spectrophotometer
Temperature: Membrane Electrode (YSI Multiparameter Meter)	Total Suspended Solids (**TSS**): Gravimetric
Salinity: Membrane Electrode (YSI Multiparameter Meter)	Ammonia (**NH_3**): Auto analyzer
Dissolved Oxygen (**DO**): Membrane Electrode (YSI Multiparameter Meter)	Nitrate + Nitrite (**NO_3^- + NO_2**): Auto Analyzer
pH: Membrane Electrode (YSI Multiparameter Meter)	Total Dissolved Nitrogen (**TDN**): Persulfate Digestion Auto analyzer
Water Clarity: Secchi disk	Particulate Nitrogen (**PN**): High Temperature Combustion
	Orthophosphate (**PO_4^{3-}**) or (**DIP**): Auto Analyzer
	Total Dissolved Phosphorus (**TDP**): Persulfate Digestion Auto Analyzer
	Particulate Phosphorus (**PP**): HCl Extraction, Auto Analyzer
	Dissolved Organic Carbon (**DOC**): High Temperature Combustion
	Particulate Carbon (**PC**): High Temperature Combustion
	Dissolved Silica (**SiO_2**): Auto Analyzer
	Biogenic Silica (**BioSi**): NaOH Extraction, Auto analyzer

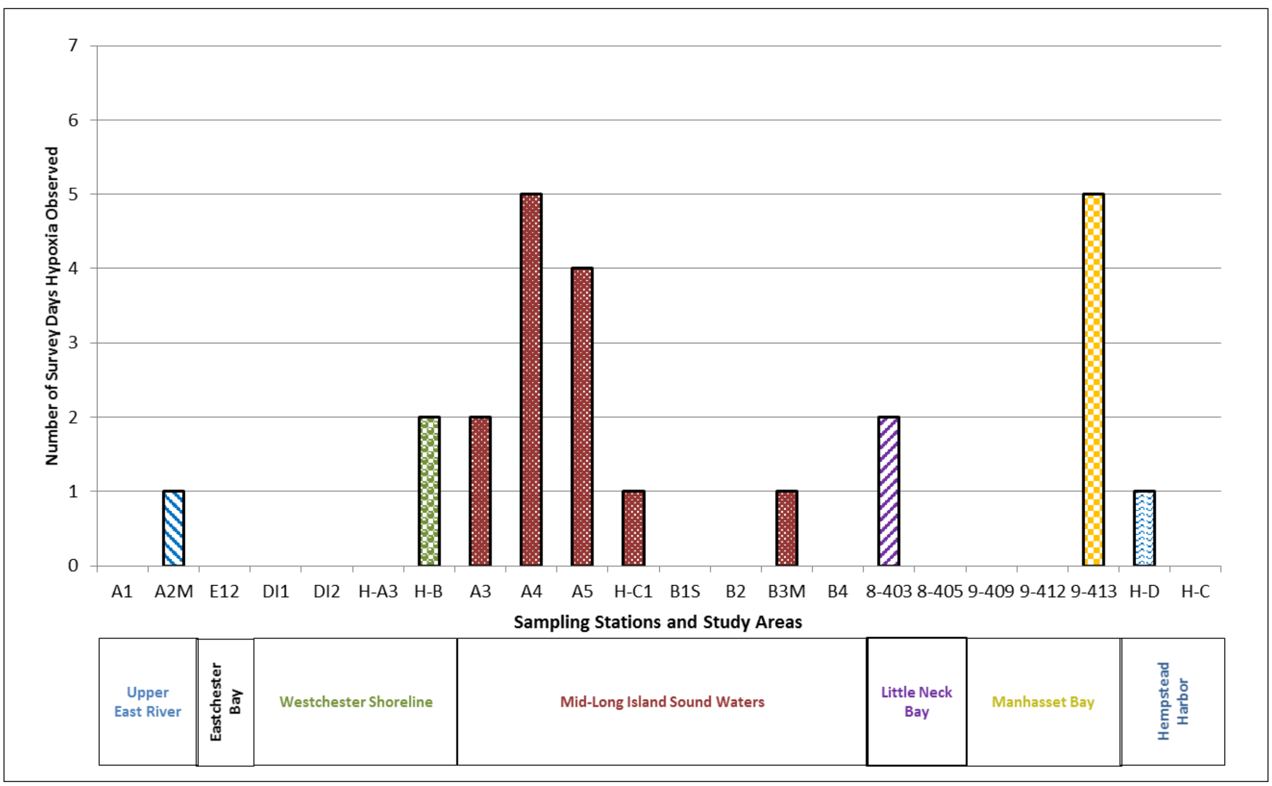
[1]*In situ* parameters measured during monitoring surveys conducted from June 17 to September 17.
[2]Surface samples collected and analyzed during monitoring surveys conducted from June 17 to September 3.

Hypoxia Overview: 2014

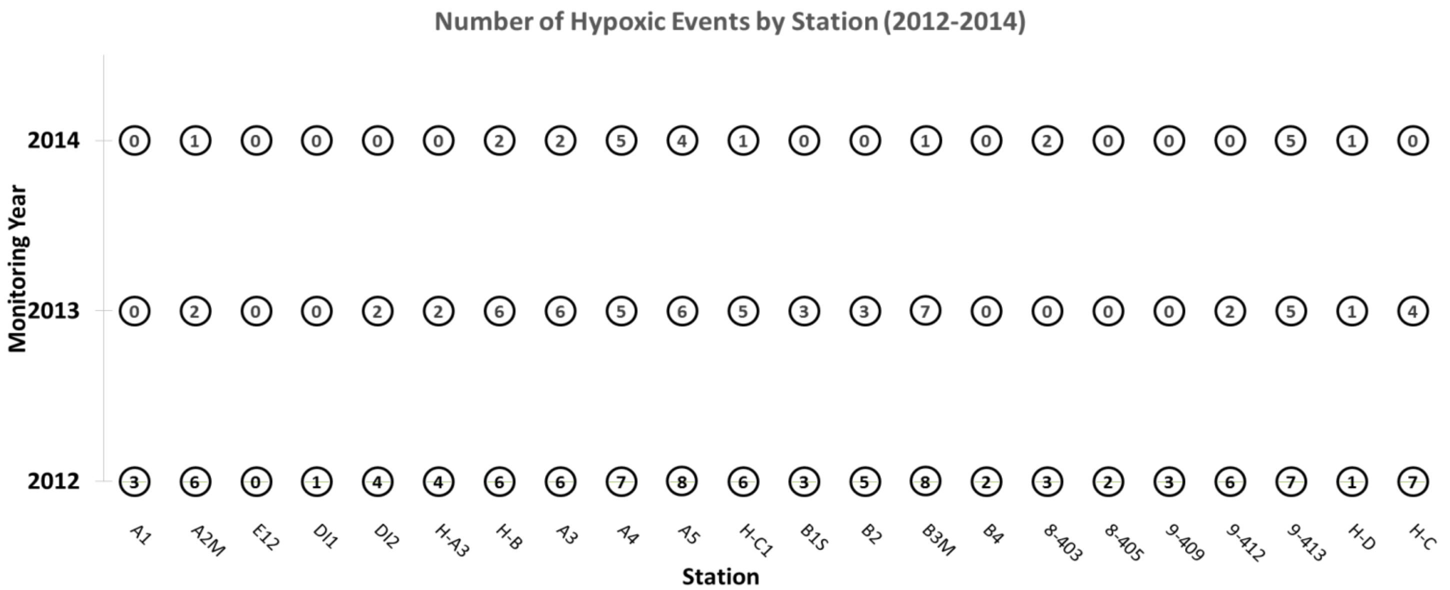
Since 1991, IEC District has conducted monitoring during the summer months in waters extending from the upper East River into western Long Island Sound. Historically, field surveys have focused on documenting hypoxia by estimating the initial onset, observed frequency, and duration. For these purposes, waters are considered to enter a hypoxic state when dissolved oxygen concentrations fall below 3.0 mg/L. However, dissolved oxygen concentrations vary according to the time of day, tidal cycle, depth, and the water's temperature and salinity. Therefore, complementary data are collected to characterize water quality conditions prior to and during the onset, duration, and end of the hypoxic event (See Appendices A through D).

Frequency of Hypoxic Events Observed

The frequency of hypoxic events observed over the 2014 monitoring season was analyzed for each of the seven study areas: the upper East River, Eastchester Bay, Westchester County shoreline, mid-Long Island Sound, and the 3 embayments located on the North Shore Long Island (Little Neck Bay, Manhasset Bay and Hempstead Harbor; see figure below). All study areas have at least two monitoring stations with the exception of Eastchester Bay, which contains only one station. To assess which of the study areas was most impacted by hypoxia, the frequency of hypoxia as well as the number of study sites within each study area was considered.



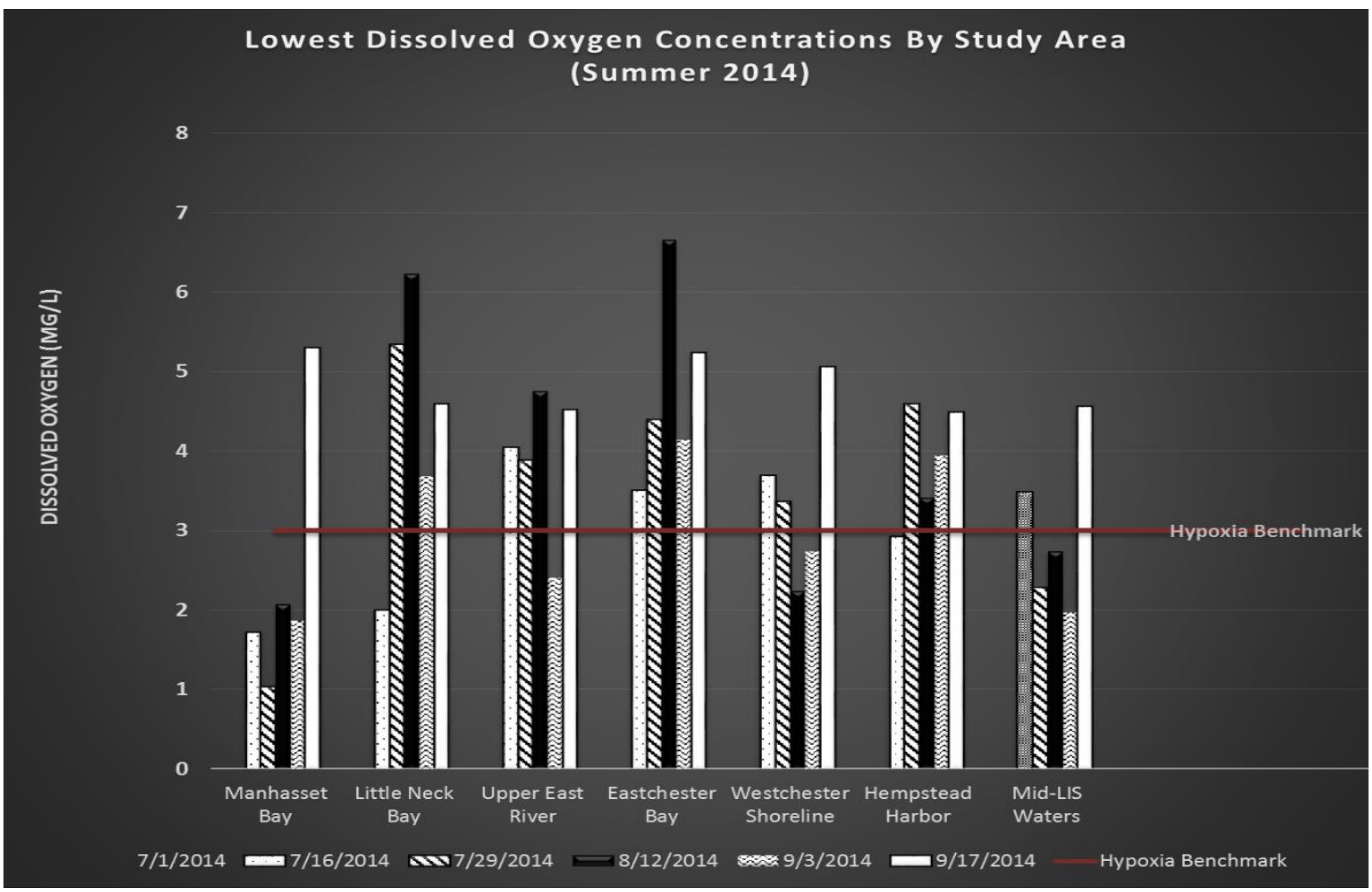
This season, hypoxic conditions appeared to be most prevalent within Manhasset Bay, with DO less than 3.0 mg/L during 4 of the 7 surveys. No hypoxia was observed in Eastchester Bay this season. Station-specific results were comparable to the previous two monitoring seasons, which also showed high number of hypoxic events in mid-WLIS waters and Manhasset Bay (see figure next page).



The figure above illustrates the number of surveys hypoxia was observed at each sampling location during NEIWPCC-IEC District's 2014, 2013, and 2012 monitoring seasons; 7, 11, and 12 seasonal surveys were conducted, respectively.

Onset of Hypoxia

In June, no hypoxia was observed during IEC District's survey. Dissolved oxygen was greater than 8.0 mg/L throughout the study area and all measurements were above saturation at all depths throughout the water column. The first indication of hypoxia was observed in mid-July (7/16). Hypoxic conditions (DO < 3.0 mg/L) were observed at a subset of stations in three embayments (Manhasset Bay, Little Neck Bay, and Hempstead Harbor; see figure below).



The figure above shows the lowest DO during each survey in each study area.

On July 29 and August 12, hypoxia was observed in Manhasset Bay (station 9-413) and two mid-Sound stations (A5 and A4). In addition on August 12, station H-B, located along the Westchester shoreline, was also hypoxic.

On September 3, hypoxia was found at the greatest number of stations (10), and the lowest average bottom DO concentration (3.45 mg/L) of the season was observed. Dissolved oxygen in bottom waters at 8 of the 22 stations were hypoxic. In addition to Manhasset Bay (9-413), hypoxic conditions were observed in the East River (station A2M) and six open-water stations (A3, H-B, B3M, H-C1, A5, and A4). By the final monitoring survey (9/17), no hypoxia was observed throughout the study area (see table below and hypoxia maps on the following pages).

The extent of hypoxia throughout the season was determined by calculating the percentage of hypoxic stations observed during each monitoring survey (see table below). DO measurements recorded during the September 3rd survey showed the highest percent (36%) of hypoxic stations (in either bottom, mid, or surface waters). This is twice the amount observed on August 12, when 18% of stations were hypoxic.

The extent and duration of hypoxia in the Sound varies each year due to various inter-related factors including physical factors, such as the strength of stratification in the water column, and biochemical factors, such as the degree of phytoplankton decay—an effect of the amount of phytoplankton growth—which is related to nitrogen loading and excess nutrients. The observed water quality conditions associated with hypoxia is summarized in the table below.

Survey	Date in 2014	Weather Conditions	% of Hypoxic Stations Observed	Range of Secchi Disk Depths (m)	Mean ΔT (°C)	Mean Bottom DO (mg/L)	Mean Surface DO (mg/L)	Range of DO (mg/L)
1	06/17	23-29°C under cloudy and overcast skies	0%	0.5-1.5	1.23	12.4	12.6	10.5-14.7
2	07/01	24-30°C under partly cloudy skies	*	0.8-2.3	2.39	*	*	*
3	07/16	~0.93 in. rain in previous 48 hrs.; 21-23°C with overcast skies and periods of light rain	14%	0.9-2.1	1.14	3.66	**<u>4.72</u>**	1.7-7.8
4	07/29	~0.26 in. rain w/in prior 48 hrs.; 18-23°C under clear & sunny skies	14%	0.9-2.1	0.88	4.14	5.49	1.04-9.06
5	08/12	24-26°C with overcast skies	18%	0.5-1.8	0.66	4.44	6.40	2.08-8.78
6	09/03	23-27°C under mostly cloudy skies	*<u>36%</u>*	1.1-2.4	0.78	**<u>3.45</u>**	6.14	1.87-9.63
7	09/17	~0.42 in. rain w/in prior 24 hrs; 16-21°C under sunny skies.	0%	1.1-3.1	-0.03	5.41	5.98	4.38-9.63

<u>Bold and underlined values</u> indicate the lowest mean DO in surface and bottom waters among all monitoring surveys. *<u>Italicized and underlined value</u>* indicates the greatest percentage of hypoxic stations observed during a single survey.

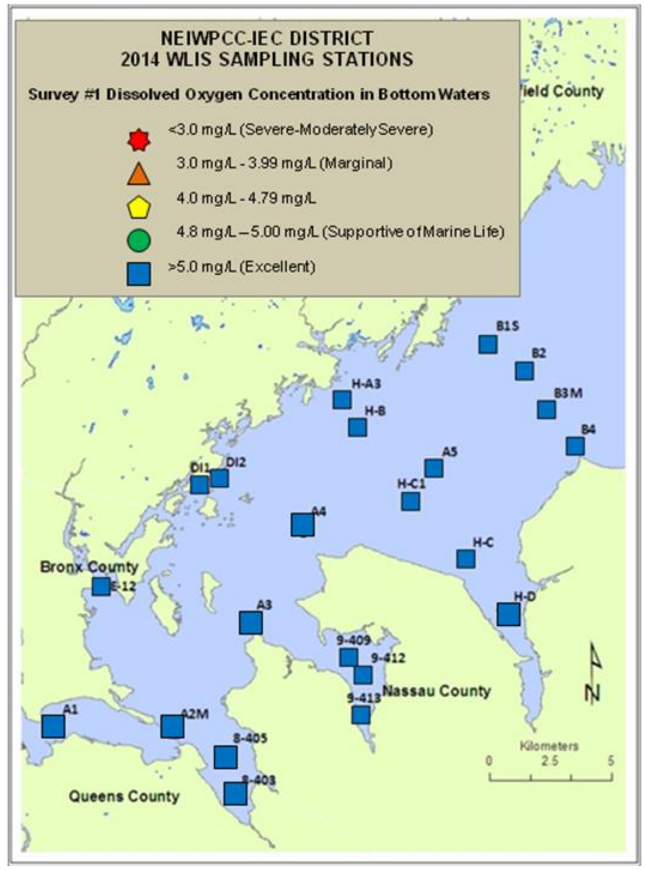
* DO measurements were not recorded due to erratic operation of the probe during the 7/1 survey. This was reported to the QC officer and inspection of the YSI probe confirmed damage to the unit. As a result, the probe was replaced, calibrated, and the YSI unit was determined to be in compliance and placed back in service prior to the 7/16 survey.

Hypoxia Maps

The maps presented on the following pages provide a seasonal overview of the transition into and out of hypoxia in far western LIS waters.

June Survey (6/17/14):

- **No occurrence of hypoxia (DO < 3.00 mg/L) throughout the study area**
- **All DO above 110% saturation**
- **All DO measurements greater than 8.0 mg/L**

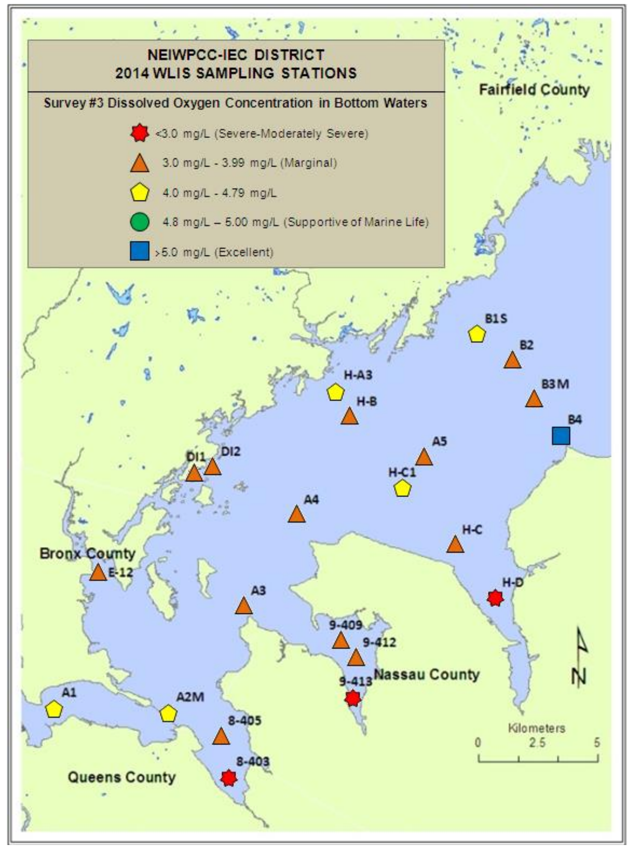


Late June-Early July Survey (7/1/14):

- **No dissolved oxygen and salinity measurements were recorded**
  - DO and salinity measurements were not recorded due to erratic operation of the probe during the 7/1 survey. This was reported to the QC officer and inspection of the YSI probe confirmed damage to the unit. As a result, the probe was replaced, calibrated, and the YSI unit was determined to be in compliance and placed back in service prior to the 7/16 survey.
- **Average water column ΔT = 2.39 °C**

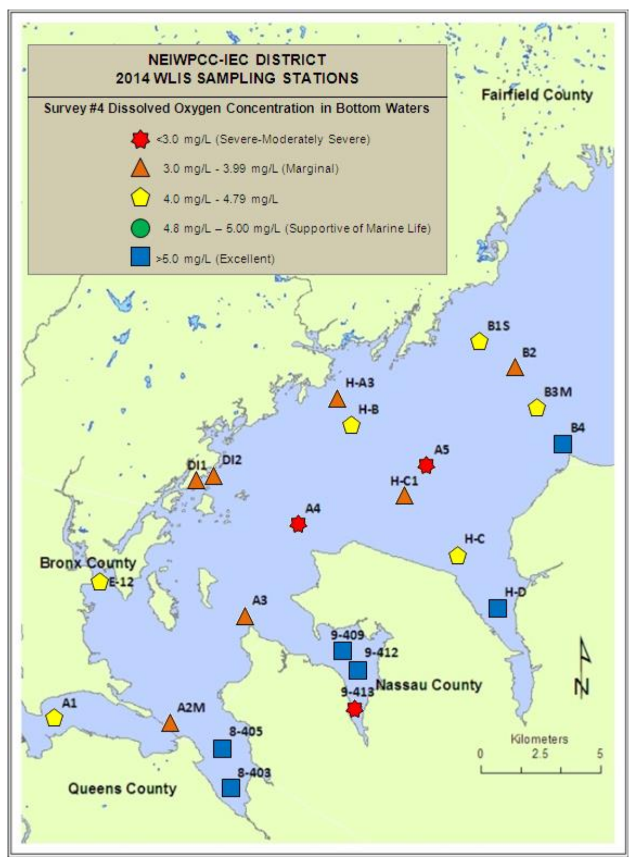
Mid-July Survey (7/16/14):

- **The lowest observed DO: 1.73 mg/L at 20.6 °C (~22% saturation) and was observed at Manhasset Bay site 9-413 at a depth of 1 meter.**
- **The highest observed DO: 7.77mg/L at 20.8 °C in surface water of mid-Sound location B3M (~101% saturation).**
- **Average surface DO concentration = 4.72 mg/L**
- **Average bottom DO concentration = 3.66 mg/L**
- **Average water column ΔT = 1.14 °C**



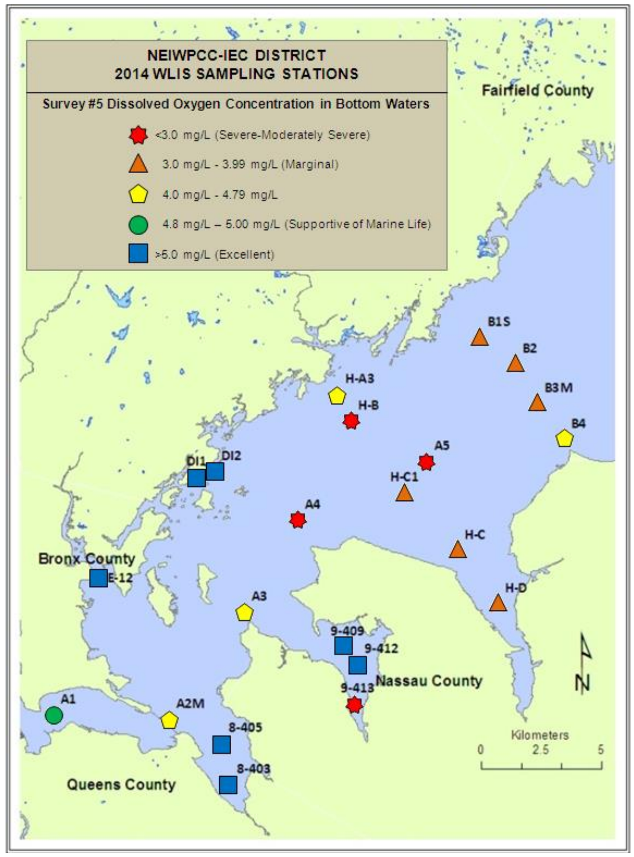
Late-July Survey (7/29/14):

- **Hypoxia (DO < 3.00 mg/L) observed at one embayment station and two open-water stations:**
  - Manhasset Bay (9-413) – 1.48 mg/L at 22.5 °C at 1 meter; 1.04 mg/L at 22.7 °C at 1.2m (bottom depth measurement).
  - A5 (Mid-channel east of Execution Lighthouse) – 2.29 mg/L at 19.2 °C at 11.6m (bottom depth measurement)
  - A4 (Mid-channel east of Sands Point) – 2.68 mg/L at 19.4 °C at 15.2 meters; 2.70 mg/L at 19.3 °C at 30.5m (bottom depth measurement)
- **Manhasset Bay station 9-413 exhibited the lowest DO of the season (1.04 mg/L)**
- **The highest observed DO: 9.06 mg/L at 22.9 °C in surface water of Hempstead Harbor station H-D**
- **Mean surface DO concentration = 5.49 mg/L**
- **Mean bottom DO concentration = 4.14 mg/L**
- **Mean water column ΔT = 0.88 °C**



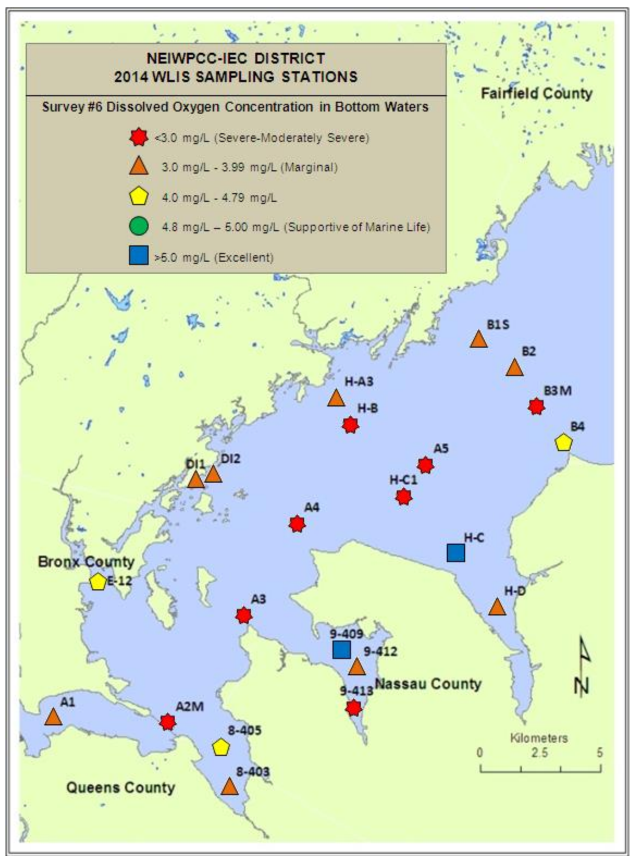
August Survey (8/12/14):

- **Hypoxia (DO < 3.00 mg/L) observed at one embayment station and three open-water stations:**
  - 9-413 (Manhasset Bay) – 2.08 mg/L at 23.7 °C at 0.6m (bottom depth measurement) *2.08 mg/L is the lowest observed DO for Survey #5.
  - H-B (Westchester Shoreline) – 2.24 mg/L at 21.1 °C at 12.8m (bottom depth measurement)
  - A5 (Mid-channel east of Execution Lighthouse) – 2.96 mg/L at 21.5 °C at 6.1m; 2.74 mg/L at 21.4 °C at 12.5m (bottom depth measurement)
  - A4 (Mid-channel east of Sands Point) –2.74 mg/L at 21.6 °C at 30.5m (bottom depth measurement)
- **The highest observed DO: 8.78 mg/L at 23.1 °C in surface water of Mid-LIS station B1S (~119% saturation).**
- **Average surface DO concentration = 6.40 mg/L (highest since survey #1 on 6/17/14)**
- **Average bottom DO concentration = 4.44 mg/L (highest since survey #1 on 6/17/14)**
- **Average water column ΔT = 0.66 °C**



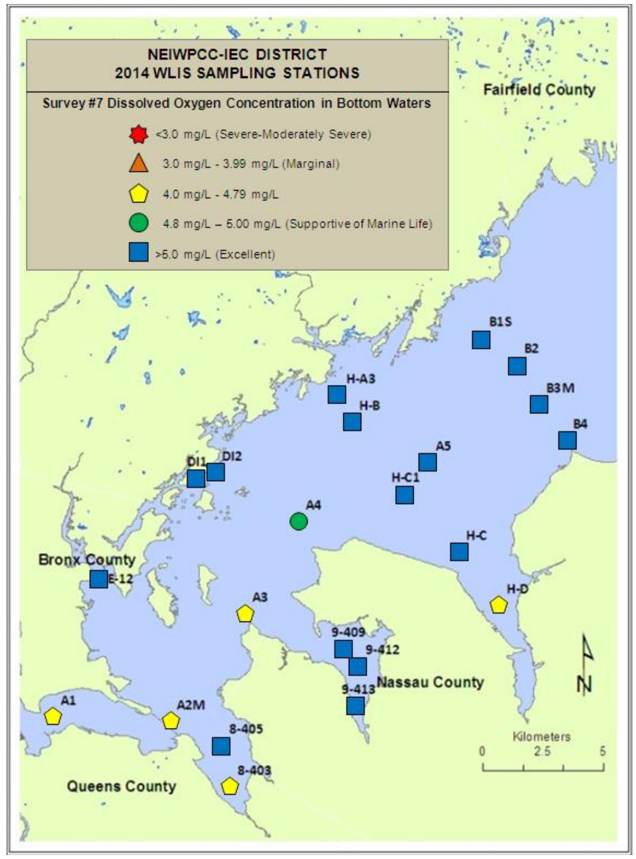
Early September Survey (9/3/14):

- **Bottom measurements at 8 of 22 monitoring stations were indicative of hypoxia (DO < 3.00 mg/L):**
  - 9-413 (Manhasset Bay) – 1.87 mg/L at 24.0 °C at 2.7m
  - A3 (Hewlett Point) – 2.53 mg/L at 22.7 °C at 11.3 meters; 2.34 mg/L at 22.5 °C at 22.3m
  - A2M (East of Throgs Neck Bridge) – 2.41 mg/L at 22.6 °C at 29.3m
  - H-B (Westchester Shoreline) – 2.74 mg/L at 22.3 °C at 12.5m
  - B3M (Matinecock Point) – 2.94 mg/L at 22.2 °C at 16.8m
  - H-C1 (Hempstead Harbor) – 2.45 mg/L at 22.9 °C at 9.8m
  - A5 (Mid-channel east of Execution Lighthouse) – 1.97 mg/L at 22.6 °C at 10.1m
  - A4 (Mid-channel east of Sands Point) –2.91 mg/L at 22.8 °C at 15.2 meters; 2.42 mg/L at 22.5 °C at 30.5m
- **The lowest observed DO: 1.87 mg/L at 24.0 °C in bottom water of Manhasset Bay station 9-413 (~26% saturation).**
- **The highest observed DO: 9.63 mg/L at 24.6 °C in surface water of Mid-LIS station B4**
- **Average surface DO concentration = 6.14 mg/L**
- **Average bottom DO concentration = 3.45 mg/L (lowest of the monitoring season)**
- **Average water column ΔT = 0.78 °C**



Mid-September Survey (9/17/14):

- **No hypoxic conditions (DO < 3.00 mg/L) observed**
- **Highest observed DO: 9.63 mg/L at 20.7 °C in surface water of Manhasset Bay location 9-412**
- **Lowest observed DO: 4.38 mg/L at 21.1 °C in bottom water of Hempstead Harbor location H-D**
- **Average surface DO concentration = 5.98 mg/L.**
- **Average bottom DO concentration = 5.41 mg/L.**
- **Average water column ΔT = -0.03 °C**

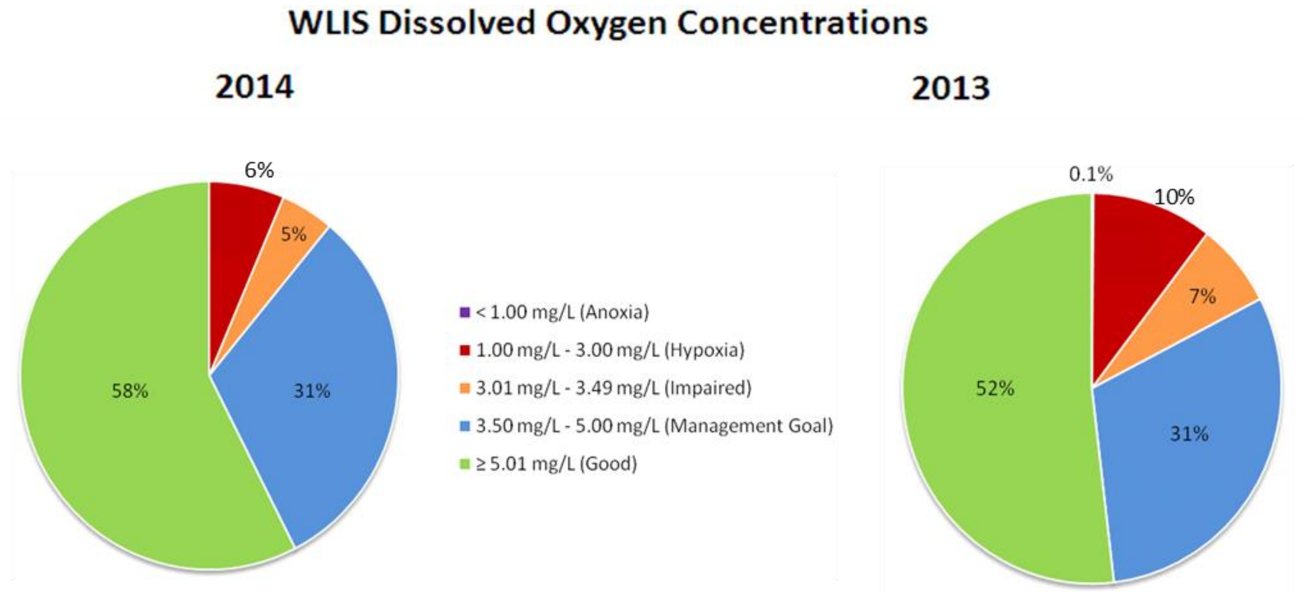


Comparison with LISS Dissolved Oxygen Management Targets

The Long Island Sound Study defines hypoxia as DO concentrations less than 3.0 mg/L and anoxia as concentrations below 1.0 mg/L. However, organisms may be adversely affected above this level, depending upon the length of exposure. Current research indicates that the most severe effects (such as mortality) may occur when dissolved oxygen levels fall below 3.5 mg/L in the short-term (*i.e.*, 4 days) and below 1.5 mg/L at any time. However, there may be mild effects of hypoxia when dissolved oxygen levels fall below 5.0 mg/L.

The quality of Long Island Sound waters can be characterized by comparing the measurements of DO to the LISS interim dissolved oxygen targets, which have been established to minimize the adverse impacts of hypoxia. Goals include increasing short-term average dissolved oxygen in bottom waters to 3.5 mg/L (in areas where conditions currently fall below this level) and ensuring concentrations do not fall below 1.5 mg/L at any time.

This year, 89% of all DO measurements either met or exceeded 3.5 mg/L. The figure below shows a slight improvement from last summer when 83% of measurements met or exceeded this target. This season, only 0.3% of all measurements failed to meet the 1.5 mg/L benchmark, comparatively, 0.9% of all measurements fell below this target in 2013.



Dissolved oxygen concentrations from 2014 (7 surveys) and 2013 (12 surveys). Blue and green sections represent the percentage of samples where dissolved oxygen concentrations met the interim target of 3.5 mg/L or better. Red sections represent the percentage of samples that

Severity of Observed Conditions

This season, 24 measurements (or 6%) were hypoxic (see figure next page). The majority of hypoxic conditions (17 out of 24) were observed in bottom waters (one meter above the sediment). In only three instances were hypoxic conditions observed in surface waters (one meter below the water surface): once in Little Neck Bay (station 8-403) on July 16 and twice in Manhasset Bay (station 9-413) on July 16 and July 29. There were no anoxic conditions (DO below 1.0 mg/L) observed this season. The lowest observed DO concentration for the season was 1.04 mg/L, which was in bottom waters of Manhasset Bay (station 9-413) on July 29.

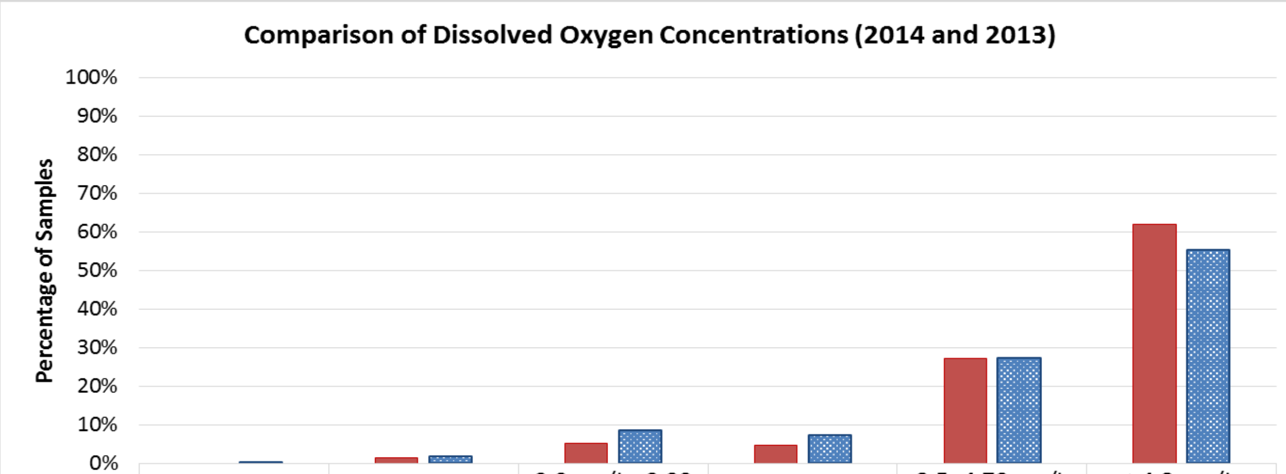
2014:

- **0% of DO measurements in 2014 were less than 1.0 mg/L (anoxic)**
- **1.3% of DO measurements in 2014 were less than 2.0 mg/L (severely hypoxic)**
- **38% of DO measurements in 2014 were less than 4.8 mg/L**

2013:

- **0.1% of DO measurements in 2013 were less than 1.0 mg/L (anoxic)**
- **1.8% of DO measurements in 2013 were less than 2.0 mg/L (severely hypoxic)**
- **45% of DO measurements in 2013 were less than 4.8 mg/L**

All DO measurements from 2014 and 2013 are grouped by concentration range to show the degree of severity (percentage of samples) in the figure below[1]. Dissolved oxygen of 4.8 mg/L or greater meets the chronic criterion for growth and protection (regardless of the duration). Relative to 2013, 62% of all measurements recorded this season meet this threshold.



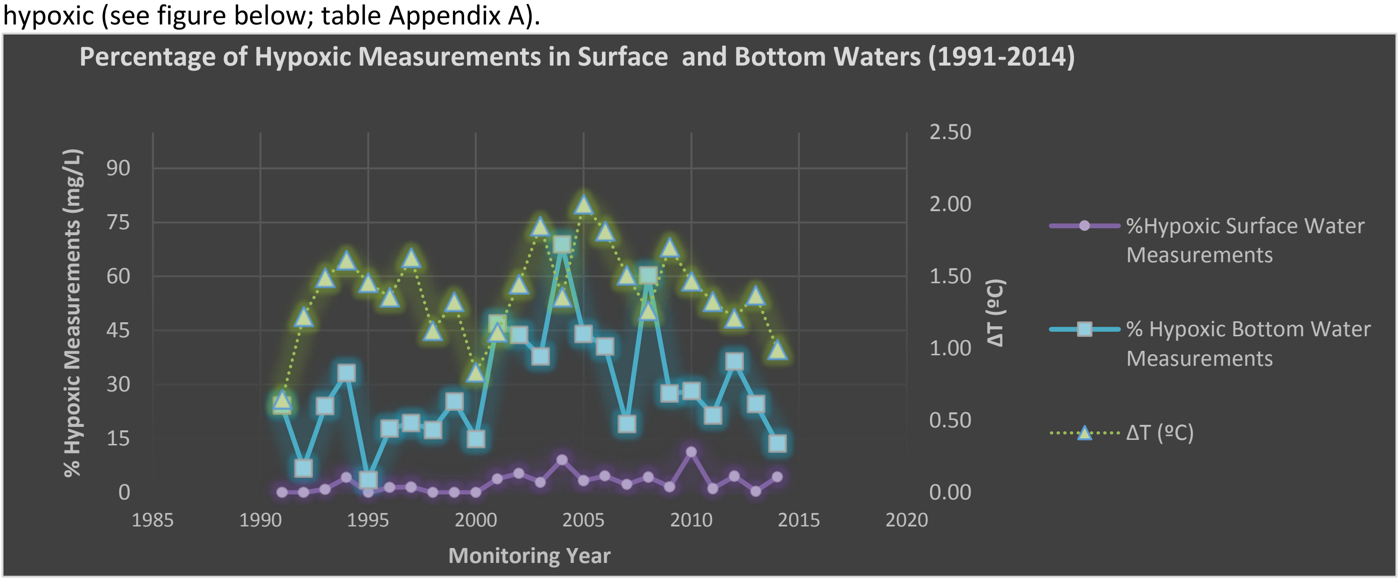
	< 1.0 mg/L (Anoxia)	1.0 mg/L - 1.99 mg/L (Severe Hypoxia)	2.0 mg/L - 2.99 mg/L (Moderate Hypoxia)	3.0 -3.49 mg/L (Marginal)	3.5 -4.79 mg/L (Interim Management Goal)	≥4.8 mg/L (Excellent- Supportive of Marine Life)
2014	0.0%	1.3%	5.1%	4.6%	27.2%	61.8%
2013	0.1%	1.7%	8.4%	7.1%	27.3%	55.3%

The graph above illustrates all DO measurements - grouped by concentration range and respective degree of severity - from the 2014 and 2013 monitoring seasons.

[1]Severe hypoxia benchmark (DO < 2.0 mg/L) is derived from *EPA's Report on the Environment:* <u>http://www.epa.gov/roe/</u>

Historical Comparison

The figure below contains 24 seasons of IEC District's DO measurements from surface and bottom waters and illustrates the historical variation of the percentage of those readings that were hypoxic (< 3 mg/L). In 2004, 69%—the most of all the 24 seasons—of DO measurements in bottom waters were hypoxic. This year, 25% of bottom-water measurements were hypoxic. This is a considerable improvement from last year, when 36% of bottom-water measurements were hypoxic (see figure below; table Appendix A).



The figure above shows the summer (June-September) delta T (ΔT or difference in surface and bottom water temperature) and percent hypoxic measurements in surface and bottom waters from 1991-2014.

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APPENDICES

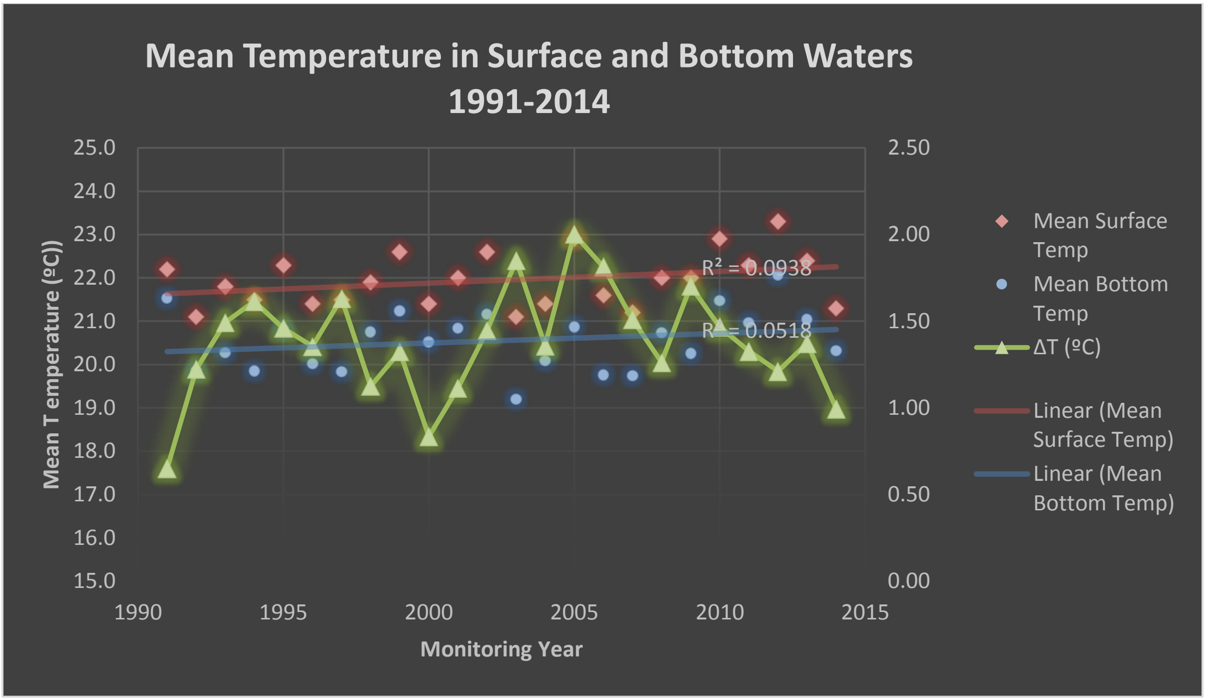
Appendix A:

Dissolved Oxygen and Temperature

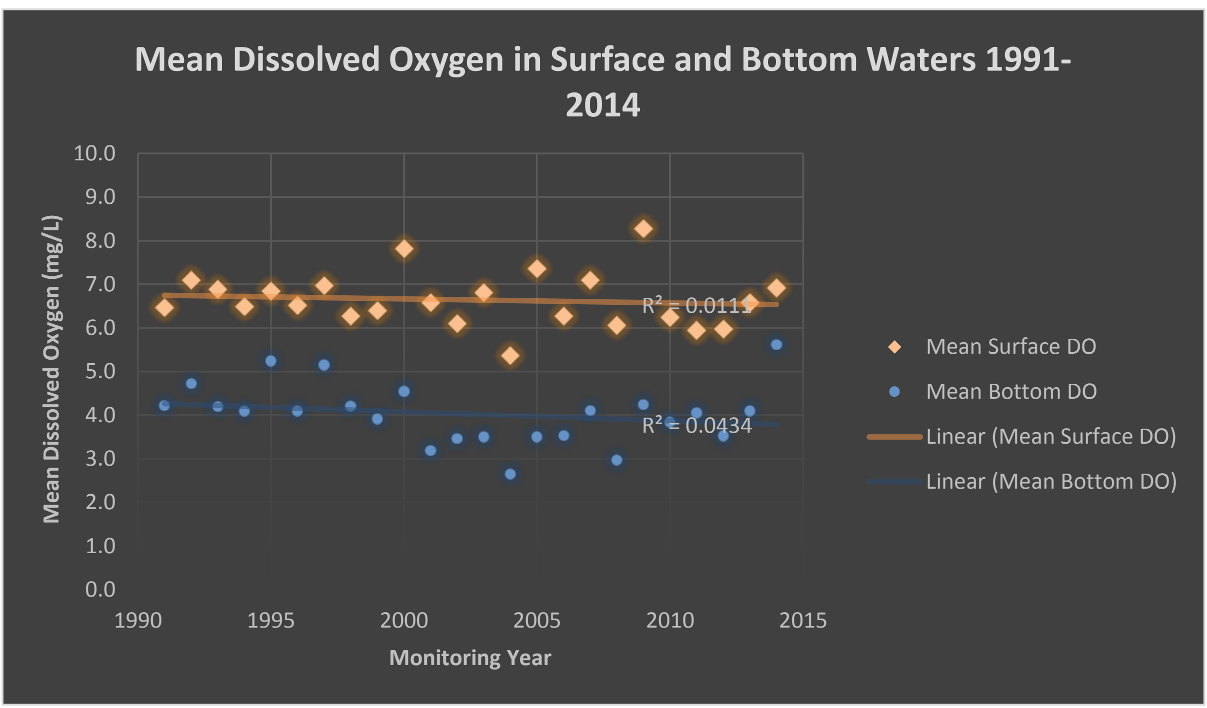
The table below summarizes the highest, lowest, and mean summer (June through September) temperatures; the mean temperature change (Delta T); and percentage of hypoxic surface and bottom waters since 1991 in the far western Long Island Sound.

Year (Summer Season)	Mean Summer Temp. (ºC)		ΔT (ºC)	Mean Summer DO (mg/L)		% Hypoxic Measurements (DO<3.0 mg/L)	
	Surface	Bottom		Surface	Bottom	Surface	Bottom
1991	22.2	21.5	*0.65*	6.47	4.21	0	24.2
1992	21.1	19.9	1.22	7.1	4.72	0	6.8
1993	21.8	20.3	1.49	6.88	4.19	0.93	24.1
1994	21.5	19.8	1.62	6.49	4.09	4.17	33.3
1995	22.3	20.8	1.46	6.85	5.24	0	***3.5***
1996	21.4	20.0	1.36	6.52	4.09	1.44	17.8
1997	21.5	19.8	1.63	6.97	5.15	1.55	19.3
1998	21.9	20.7	1.13	6.27	4.21	0	17.5
1999	22.6	21.2	1.32	6.4	3.91	0	25.4
2000	21.4	20.5	0.84	7.82	4.55	0	15.0
2001	22.0	20.8	1.12	6.59	3.19	3.83	47.0
2002	22.6	21.2	1.45	6.1	3.46	5.33	43.8
2003	21.1	19.2	1.85	6.81	3.5	2.89	37.8
2004	21.4	20.1	1.36	5.37	2.65	9.13	**68.9**
2005	22.9	20.9	**2.00**	7.36	3.5	3.31	44.1
2006	21.6	19.8	1.81	6.27	3.53	4.62	40.7
2007	21.2	19.7	1.51	7.1	4.1	2.23	19.1
2008	22.0	20.7	1.26	6.07	2.97	4.31	60.4
2009	22.0	20.3	1.70	**8.28**	4.25	1.59	27.5
2010	22.9	21.5	1.47	6.25	3.84	**11.3**	28.2
2011	22.3	21.0	1.33	5.95	4.05	1.14	21.5
2012	**23.3**	**22.1**	1.21	5.98	3.53	4.53	36.4
2013	22.4	21.0	1.37	6.58	4.10	0.40	24.7
2014	21.3	20.3	0.99	6.92	**5.62**	4.35	13.6

Since IEC District began monitoring these waters in 1991, the warmest waters (**bold underlined** values) were observed in 2012. The greatest temperature change was found in 2005 and hypoxia was most prevalent in 2004 (also see figures below).



The figure above shows the summer (June-September) mean temperature and change in temperature (ΔT) in both surface and bottom waters from 1991-2014.

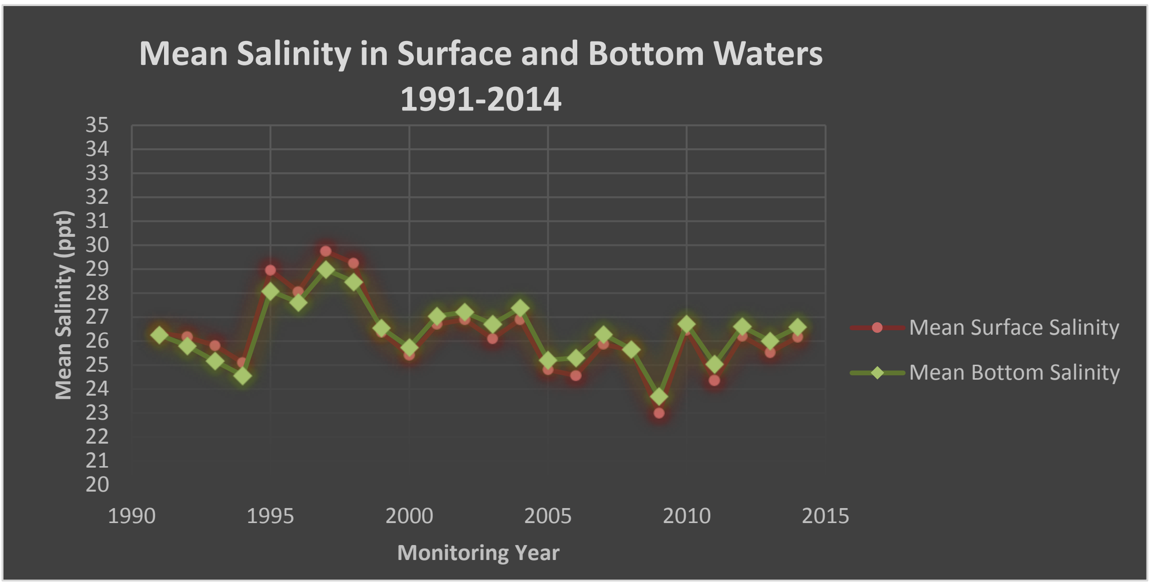


The figure above shows the summer (June-September) mean DO concentration in surface and bottom waters from 1991-2014.

Appendix B:

Salinity

Salinity, measured in parts per thousand (ppt), quantifies the salt content in water. It is an important water quality parameter for interpreting observed dissolved oxygen concentrations; salinity can also affect algal growth. In addition, most aquatic species have preferred salinity ranges. Freshwater inputs (from rivers or runoff) to Long Island Sound reduce salinity. In addition, runoff can deliver associated pollutants and solids. The figure and table below provide a context for summer salinity concentrations in surface and bottom waters from 1991-2014.



The figure above shows the summer (June-September) mean salinity measured in surface and bottom waters from 1991-2014.

Year (Summer Season)	Salinity (ppt)							
	Surface Waters				Bottom Waters			
	Count (n=)	High	Low	Mean	Count (n=)	High	Low	Mean
1991	157	31.0	20.0	26.3	155	30.0	20.0	26.3
1992	192	28.0	23.0	26.2	192	28.0	22.0	25.8
1993	216	28.0	24.0	25.8	216	29.0	23.0	25.2
1994	216	28.0	22.0	25.1	216	27.0	21.0	24.6
1995	173	32.0	25.0	29.0	173	32.0	20.5	28.1
1996	172	32.0	23.0	28.0	171	32.0	22.0	27.6
1997	193	34.0	26.5	**<u>29.7</u>**	193	33.0	25.0	**<u>29.0</u>**
1998	202	35.0	23.0	29.2	201	35.0	23.0	28.5
1999	236	27.6	24.6	26.4	236	27.8	22.5	26.5
2000	231	28.6	22.7	25.4	231	28.9	22.4	25.7
2001	235	29.9	23.6	26.7	235	30.1	24.4	27.0
2002	230	28.3	16.7	26.9	232	29.3	23.3	27.2
2003	242	28.3	23.3	26.1	242	28.5	24.2	26.7
2004	252	28.3	23.6	26.9	252	28.9	23.6	27.4
2005	242	26.3	22.8	24.8	242	26.7	23.0	25.2
2006	238	26.1	20.4	24.6	238	26.7	21.0	25.3
2007	224	27.6	24.1	25.9	223	28.1	24.2	26.3
2008	255	27.7	22.7	25.6	255	27.2	21.0	25.7
2009	247	30.0	20.3	23.0	248	29.5	21.5	23.7
2010	240	28.8	22.8	26.5	234	29.0	22.8	26.7
2011	263	36.5	20.0	24.4	258	27.2	21.8	25.0
2012	265	27.6	23.4	26.2	261	28.0	24.9	26.6
2013	248	26.9	21.6	25.5	245	27.2	23.3	26.0
2014	137	28.6	23.3	26.2	136	29.2	24.3	26.6

The table above summarizes the range (lowest and highest) and mean salinity concentrations in surface and bottom waters since monitoring began in 1991. The greatest salinity (<u>bold underlined</u> values) was observed in 1997.

Appendix C:

Water Clarity

The depth to which light penetrates water is known as water clarity. It is an indirect measure of suspended solids, also referred to as transparency. Water clarity can be affected by various biological, chemical, and physical factors. It is greater at lower temperatures because particles do not stay in suspension as well as in higher temperatures. Filter feeders can also positively affect water clarity via physical or biological removal of particles. Water clarity can be negatively affected by the following:

- Runoff and erosion induced by anthropogenic or natural causes
- Biological and chemical factors in the water column (*i.e.*, algal blooms due to excess nutrients and subsequent die offs)
- Physical dynamics, including tidal height, wind and currents, can stir up bottom sediments and keep particles in suspension

IEC District analyst measures water clarity (transparency)

Water clarity is an important parameter because:

- Suspended solids may result in low dissolved oxygen
- Suspended solids can settle out and harm delicate habitats and species (can interfere with feeding)
- Suspended solids block sunlight, limiting phytoplankton and aquatic vegetation
- Suspended solids may indicate runoff which may have other negative effects

Secchi Disk Depth:

Secchi disk depths greater than 1.5m indicate clear water; readings less than 1m may be associated with degraded water quality. The table below shows survey-specific and seasonal water clarity results. All surveys reflected median Secchi disk depths greater than 1m; only 5 (of 7) were greater or equal to 1.5m. As expected, the range of depths varied spatially and temporally, among monitoring stations and surveys (see table below).

	Sample Count (n)	Secchi Depth (m)					
		Mean	High	Low	Median	Variance	Standard Deviation
2014 Season	159	1.6	3.1	0.5	1.5	0.71	0.47
06/17/14	23	1.1	1.5	0.5	1.2	0.22	0.26
07/01/14	23	1.5	2.3	0.8	1.5	0.66	0.45
07/16/14	23	1.6	2.1	0.9	1.7	0.28	0.29
07/29/14	23	1.5	2.1	0.9	1.5	0.44	0.36
08/12/14	22	1.4	2.0	0.6	1.4	0.37	0.34
09/03/14	23	1.7	2.4	1.1	1.7	0.45	0.37
09/17/14	23	2.1	3.1	1.1	2.1	0.87	0.52

Table above provides summary statistics for 2014 Secchi disk depth data.

The lowest clarity (depth of 0.5m) of the 2014 season was observed during the first survey (6/17). Westchester shoreline and Manhasset Bay stations (DI2 and 9-413) exhibited the greatest and least water clarity, respectively, during 3 (of 7) monitoring surveys. For all surveys, the least clarity was observed within two embayments: Manhasset Bay (stations 9-

413, 9-412, and 9-419) and Hempstead Harbor (H-D). Such conditions are indicative of light-limiting conditions, which in turn affect primary productivity and nutrient cycling.

The final survey (9/17) showed the greatest range of water clarity measurements (1.0- 3.1m). In addition, the greatest clarity of the 2014 season was recorded at open water station A3. Altogether, water clarity in the far western Long Island Sound indicated improvement over the summer 2014 season (see graph below).

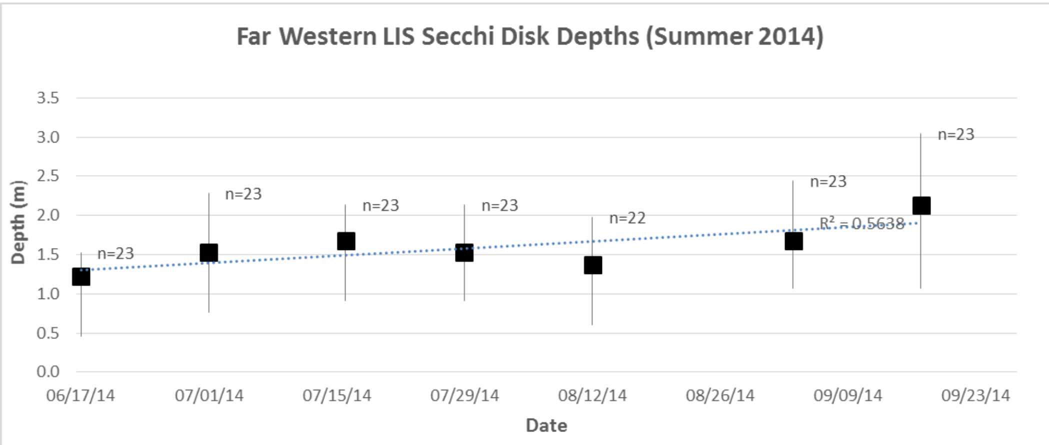
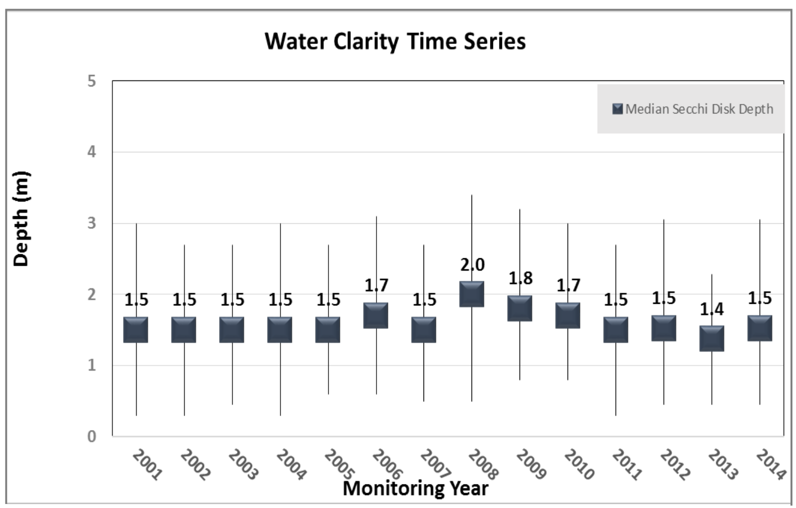


Figure to the left shows the median and range (high and low) of Secchi disk depth measurements in each monitoring survey. The dotted line represents the linear trendline using median values.

The graph below depicts the median and range of water clarity values (lowest-highest Secchi disk depth in meters) for each monitoring season (2001-2014). The median value determined for 2014 (1.5m) showed slight improvement relative to last year (1.4m). Comparatively, 2013 exhibited the lowest value since 2001, when IEC began collecting Secchi disk depth measurements to characterize water clarity. It is important to note that the 2014 monitoring season incorporates *in situ* data from seven surveys (number of samples = 159) compared to the eleven surveys conducted in 2013 (number of samples = 248; see table below).

Year	Secchi Depth (m)				
	Count (n=)	High	Low	Mean	Median
2001	109	3.0	0.3	1.5	1.5
2002	244	2.7	0.3	1.6	1.5
2003	242	2.7	0.5	1.4	1.5
2004	252	3.0	0.3	1.5	1.5
2005	241	2.7	0.6	1.5	1.5
2006	238	3.1	0.6	1.7	1.7
2007	203	2.7	0.5	1.6	1.5
2008	256	3.4	0.5	1.9	**2.0**
2009	251	3.2	0.8	1.7	1.8
2010	240	3.0	0.8	1.7	1.7
2011	261	2.7	0.3	1.5	1.5
2012	263	3.0	0.5	1.5	1.5
2013	248	2.3	0.5	1.4	1.4
2014	159	3.1	0.5	1.6	1.5

The table above provides summary statistics for Secchi disk depth data (2001-2014).



The graph above illustrates median and range of Secchi disk depth values (low to high) recorded since the parameter was first incorporated into IEC monitoring surveys in 2001.

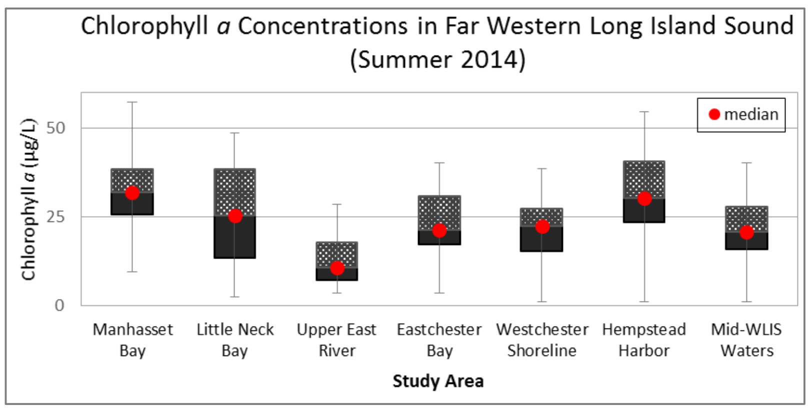
Appendix D:

Chlorophyll *a*

IEC District Environmental Analyst collects a sample to be analyzed for chlorophyll *a*. This pigment—found in aquatic plants and algae—serves as an indicator of algal production and is used to assess the overall health of Long Island Sound.

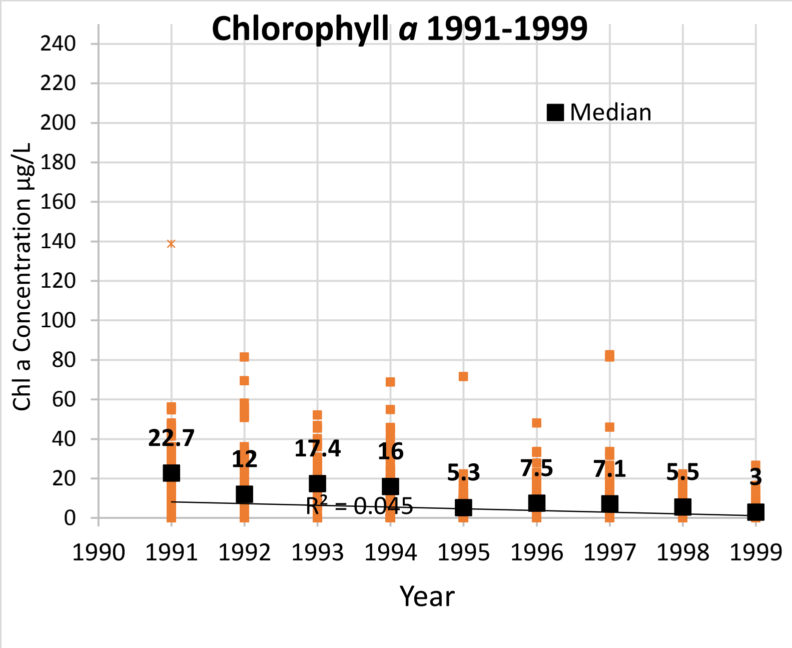
The concentration of chlorophyll *a* is a common indicator of the amount of phytoplankton in a given water sample. The amount of chlorophyll *a* varied by study area. The highest concentrations of chlorophyll *a* were observed in embayment areas, including Hempstead Harbor and Manhasset Bay, which may have caused the poor water clarity conditions described in the previous section. Station-specific chlorophyll *a* results from the surveys conducted in 2014 were analyzed by study area to depict spatial variations across the western Long Island Sound (see figure below).

The figure to the right depicts the variability of chlorophyll *a* concentrations within and between study areas. Median chlorophyll *a* concentrations determined for the 2014 summer monitoring season (June-September) are displayed by study area. The boxplots are used to depict the data values within the 1st quartile (shaded) and 3rd quartile (patterned); whiskers show the range of values (highest and lowest).

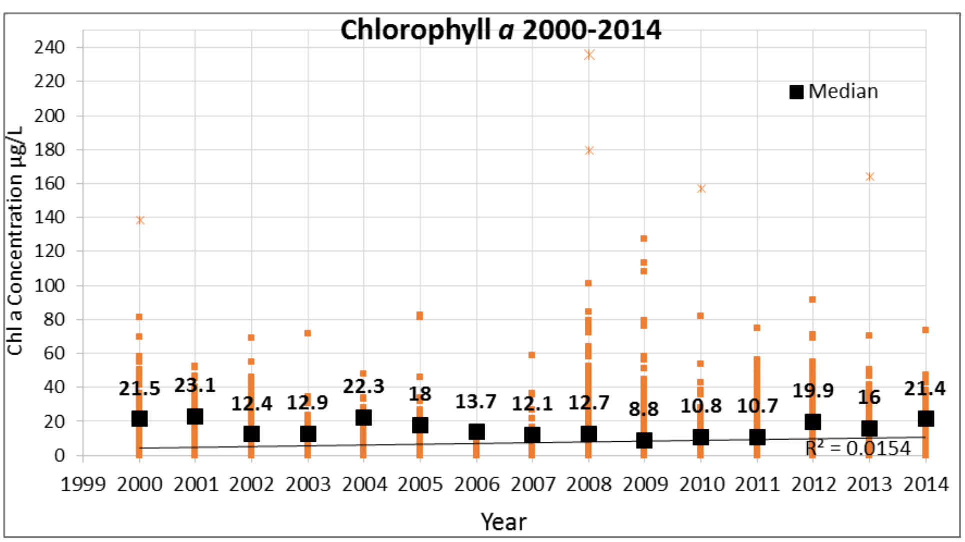


The median chlorophyll *a* value observed this summer (21.4 µg/L) was the highest concentration observed in a decade (22.3 µg/L in 2004; see figure below).

Mean and median chlorophyll *a* concentrations from this season were comparable to those from 1991 and the years of most abundance on record (see figure below). There is uncertainty about the specific cause for the temporal variation of chlorophyll *a* in the western Sound, however, the Long Island Sound Study suggests it may be linked to changes in temperature, sunlight, or predator (zooplankton) abundance.



The figure above depicts median and range of chlorophyll *a* concentrations for each summer monitoring season (June-September). The median surface concentrations from all monitoring stations and surveys are depicted graphically for each year (1991-1999). Median values are displayed numerically. Outliers are indicated with an asterisk (*).



The figure to the left depicts median and range of chlorophyll *a* concentrations for each summer monitoring season (June - September). The median surface concentrations from all monitoring stations and surveys are depicted graphically for each year (2000-2014). Median values are displayed numerically. Outliers are indicated with an asterisk (*).