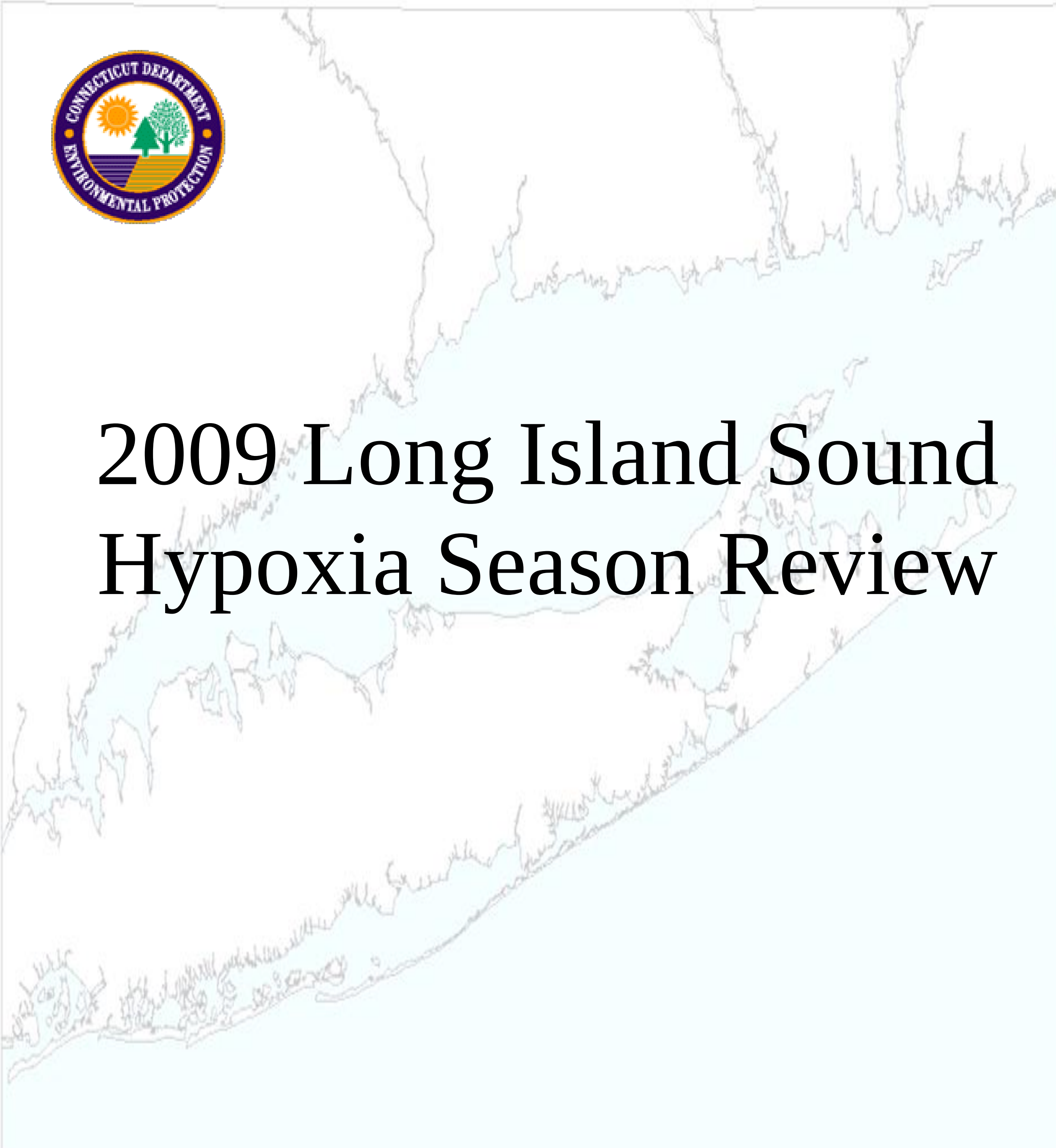
2009 Long Island Sound Hypoxia Season Review



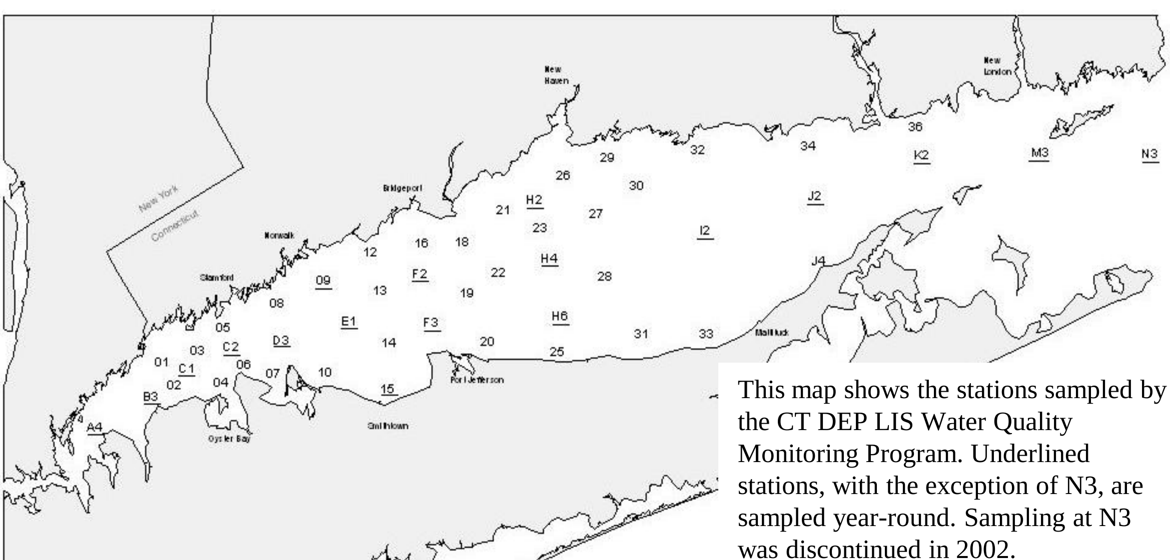
CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION
79 ELM STREET, HARTFORD, CT 06106
AMEY MARRELLA, COMMISSIONER

MONITORING LONG ISLAND SOUND 2009

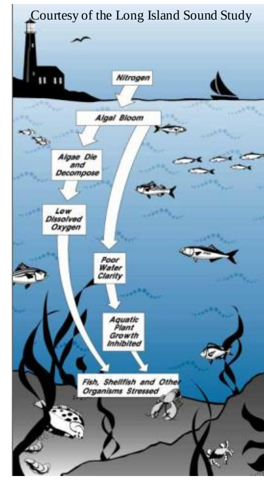
Program Overview

R/V John Dempsey

Since 1991, the Connecticut Department of Environmental Protection (CTDEP) has conducted an intensive year-round water quality monitoring program on Long Island Sound. Water quality is monitored at up to forty-eight (48) sites by staff aboard the Department's Research Vessel *John Dempsey*. These data are used to quantify and identify annual trends and differences in water quality parameters relevant to hypoxia, especially nutrients, temperature, and chlorophyll. These data are also used to evaluate the effectiveness of the management program to reduce nitrogen concentrations. During the summer (June - September) CT DEP conducts additional summer hypoxia surveys at bi-weekly intervals to better define the areal extent and duration of hypoxia.

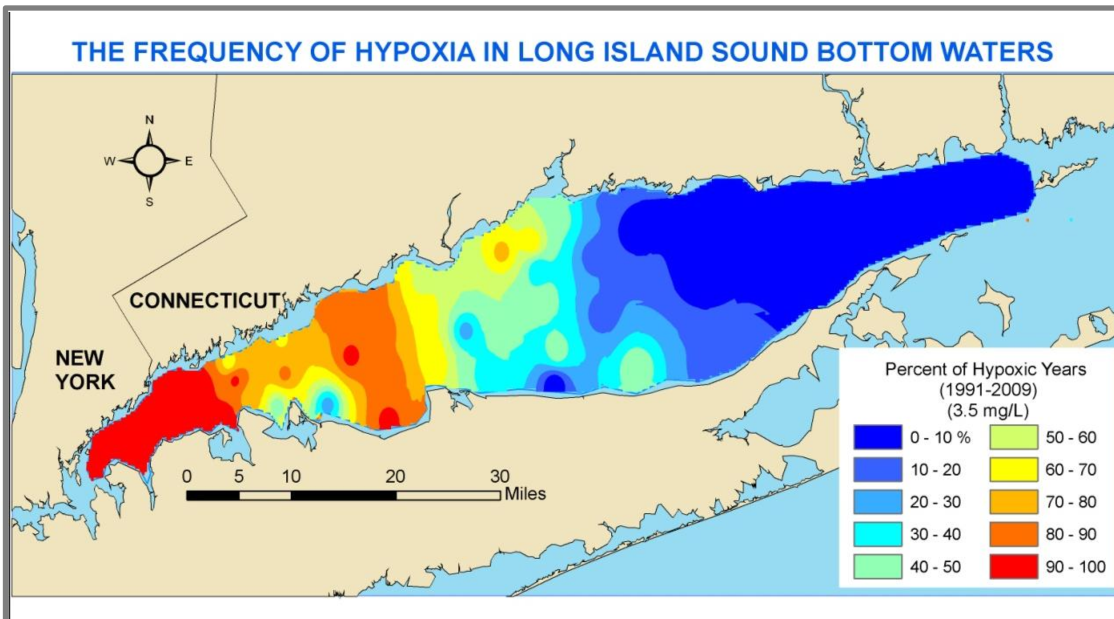


This map shows the stations sampled by the CT DEP LIS Water Quality Monitoring Program. Underlined stations, with the exception of N3, are sampled year-round. Sampling at N3 was discontinued in 2002.



What is Hypoxia?

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, 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, depending upon the length of exposure. In 2002, Connecticut adopted revised water quality criteria for dissolved oxygen. These criteria, designed to protect the state's waters from degradation, define hypoxia as DO concentrations below 3.5 mg/L. Low oxygen levels can occur naturally in estuaries during the summer, when calm weather conditions prevent the mixing of the water column that replenishes bottom water oxygen during the rest of the year. However, studies of the limited historical data base for the Sound suggest that summer oxygen depletion in Western Long Island Sound has grown worse since the 1950s.



How Seriously Does Low Oxygen Impact the Sound?

Each summer low oxygen levels render hundreds of square kilometers of bottom water unhealthy for aquatic life. DO levels follow seasonal patterns with a decrease in bottom water DO over the course of the summer. Hypoxic conditions during the summer are mainly confined to the Narrows and Western Basin of Long Island Sound. Those areas comprise the section of the Sound west of a line from Stratford, CT to Port Jefferson, NY. The maximum extent of the hypoxic condition typically occurs in early August.

2009 Important Facts

CT DEP conducted six cruises during the summer of 2009 between 23 June and 8 September. A total of 225 site visits were completed in 2009, with 26 stations affected by hypoxia throughout the season.

The peak event occurred during the HYAUG09 cruise between 18 and 19 August. The lowest dissolved oxygen concentration (1.49 mg/L) was also documented during this cruise at Station A4.

The hypoxia area maps for 2009 appear on pages 6, 7, and 8.

	CT Water Quality Standards 3.5 mg/L	LISS 3.0 mg/L
Estimated Start Date	7/12/2009	7/19/2009
Estimated End Date	9/3/2009	9/1/2009
Duration (days)	54	45
Maximum Area (mi^2)	369.6	169.1

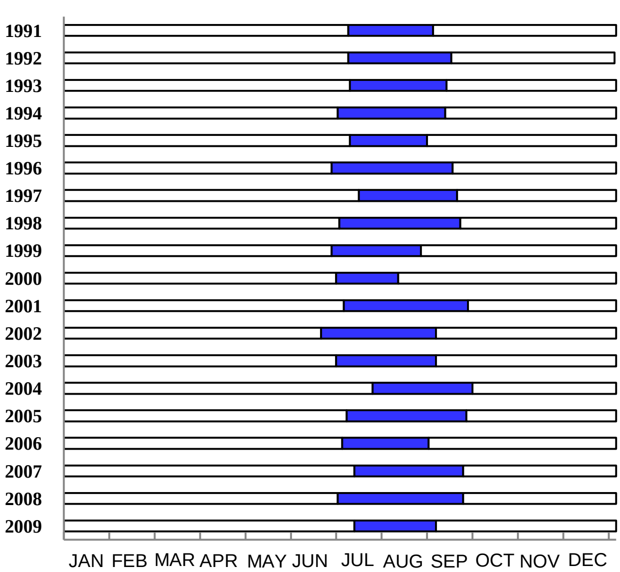
The Long Island Sound Study has defined hypoxia as dissolved oxygen concentrations below 3.0 mg/L. In December of 2002, the State of Connecticut adopted new water quality standards which state that the concentration of dissolved oxygen in offshore waters below the seasonal pycnocline shall not be less than 3.5 mg/L at anytime. As a result CT DEP began reporting on the area of Long Island Sound bottom water affected by DO concentrations less than 3.5 mg/L. Prior to that, CT DEP used the 3.0 mg/L standard. To maintain the long-term dataset and to compare to previous years, the maximum area, start date, end date, and duration based on the 3.0 mg/L standard are also presented.

Timing and Duration of Hypoxia, 1991 - 2009

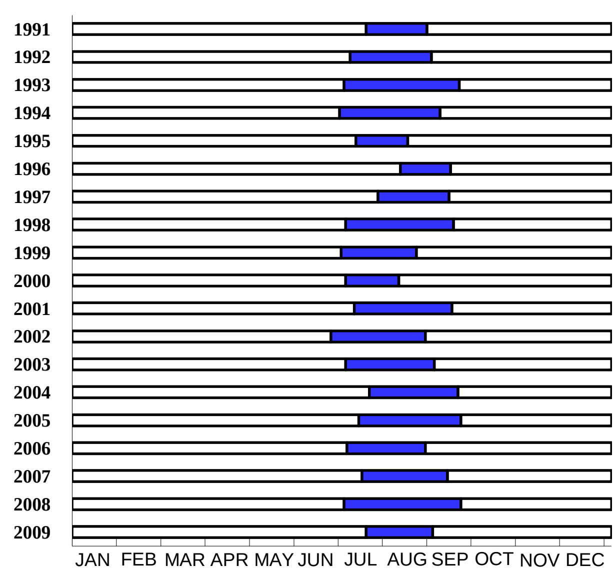
The figures and tables below displays the onset, duration, and end of the hypoxia events from 1991 through 2009based on both the CT 3.5 mg/L standard. And the LISS 3.0 mg/L standard Based on the CT standard of 3.5 mg/L, the average date of onset was July 4 (± 8 days), the average end date was September 10 (± 13 days), and the average duration was 68 days (± 12 days). The earliest onset of hypoxia (red text) occurred on 20 June 2002 and the latest end date (green text) occurred on 26 September 2004. The maximum area of hypoxia (blue text) occurred in 1994. The longest hypoxic event occurred in 2008 (magenta text) and lasted 83 days.

CT Water Quality Standards 3.5 mg/L				
Year	Estimated Start Date	Estimated End Date	Maximum Area (mi^2)	Duration (days)
1991	July 8	Sept 1	263.2	56
1992	July 7	Sept 12	194.5	68
1993	July 5	Sept 12	335.9	70
1994	July1	Sept 16	513.7	71
1995	July 9	Aug 28	415.6	51
1996	June 26	Sept 13	340.4	80
1997	July 15	Sept 17	51	65
1998	July 2	Sept19	286.1	80
1999	June 27	Aug 24	229.4	59
2000	June 29	Aug 8	260.2	41
2001	July 5	Sept 24	215.7	82
2002	June 20	Sept 4	193.9	76
2003	June 30	Sept 3	430.6	66
2004	July 23	Sept26	257.5	66
2005	July 7	Sept 23	300.2	79
2006	July 4	Aug 29	346.1	57
2007	July 12	Sept 21	354	72
2008	June 30	Sept 20	359.9	83
2009	July 12	Sept 3	369.6	54
Average	July 4	Sept10	301	68
Deviation	± 8 days	± 13 days	± 104 mi^2	± 12 days

LISS 3.0 mg/L				
Year	Estimated Start Date	Estimated End Date	Maximum Area (mi^2)	Duration (days)
1991	July 19	Aug 28	122	41
1992	July 7	Aug 30	80	55
1993	July 9	Sept 10	202	64
1994	July 1	Sept 6	393	68
1995	July 12	Aug 15	305	35
1996	Aug 10	Sept 12	220	34
1997	July 27	Sept 12	30	48
1998	July 5	Sept 15	168	73
1999	July 2	Aug 21	121	51
2000	July 2	Aug 6	173	35
2001	July 10	Sept 14	133	66
2002	June 25	Aug 28	130	65
2003	July 5	Sept 3	345	61
2004	July 20	Sept 12	202	55
2005	July 14	Sept 20	177	69
2006	July 6	Aug 27	199	53
2007	July 16	Sept 11	162	58
2008	July 3	Sept 19	180.1	79
2009	July 19	Sept 1	169.1	45
Average	July 11	Sept 5	185	56
Deviation	±11 days	± 5 days	± 87 mi^2	± 14 days



Timing and Duration of Hypoxia based on 3.5 mg/L

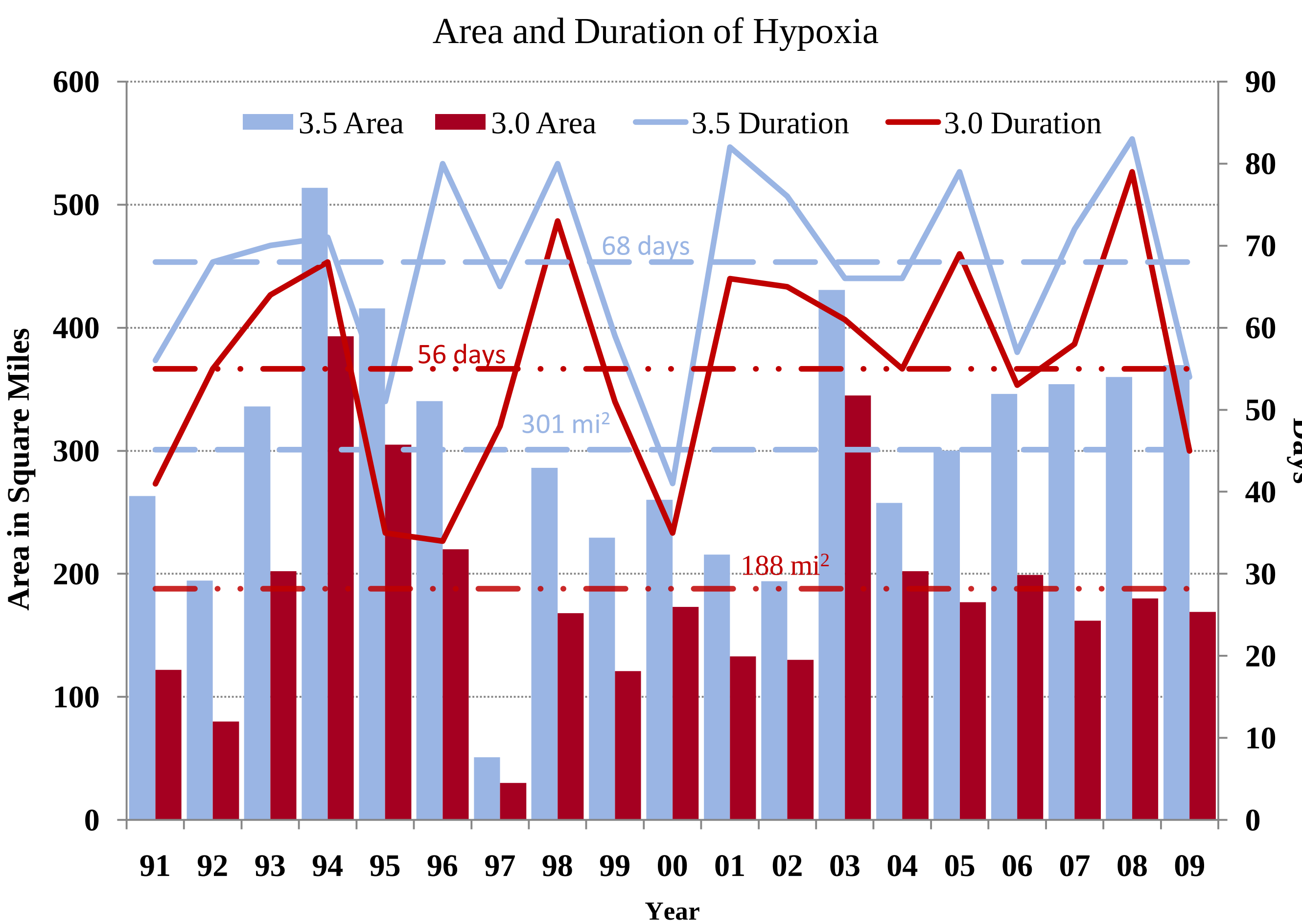


Timing and Duration of Hypoxia based on 3.0 mg/L

Yearly Comparison of Maximum Areal Extent and Duration of Hypoxia

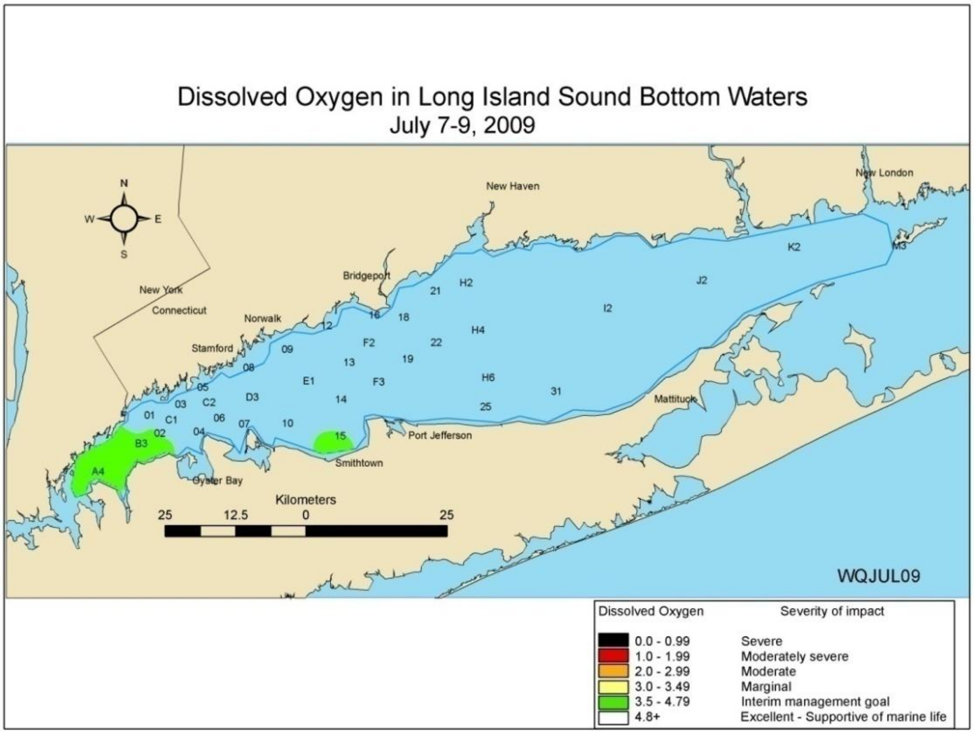
This graph utilizes the data presented on the previous page to illustrate the year-to-year differences in the maximum areal extent of hypoxic conditions. The blue color corresponds to the CT 3.5 mg/L standard while the red color corresponds to the LISS 3.0 mg/L standard.

Based on the 3.5 mg/L standard the average areal extent from 1991-2009 was 301 mi^2 and the average duration was 68 days . Based on the 3.0 mg/L standard the average areal extent was 188 mi^2 and the average duration was 56 days.

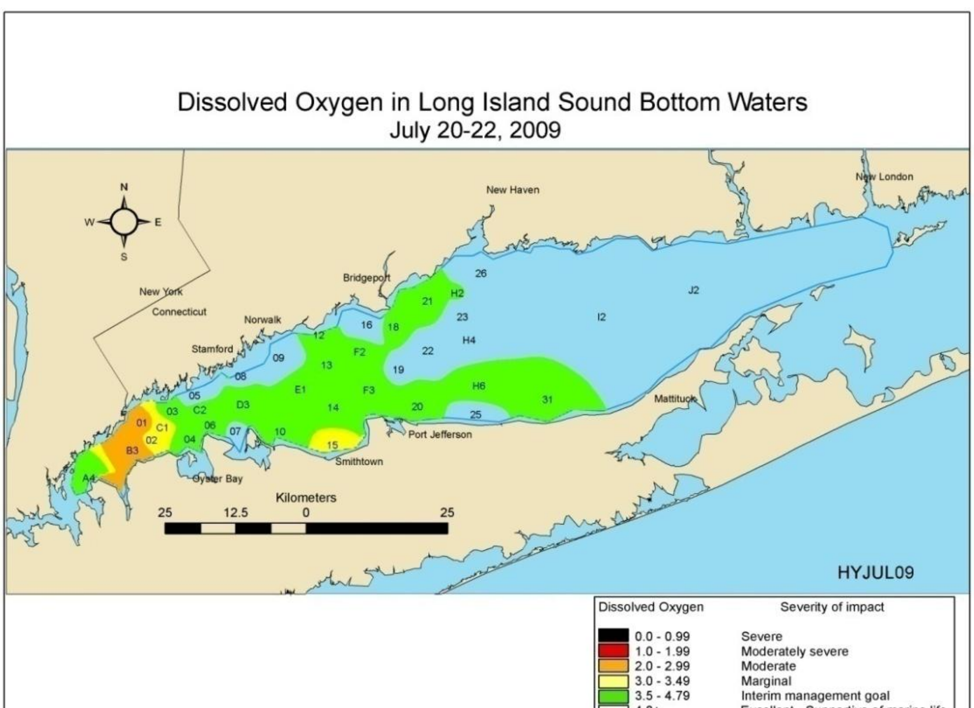


Hypoxia Maps

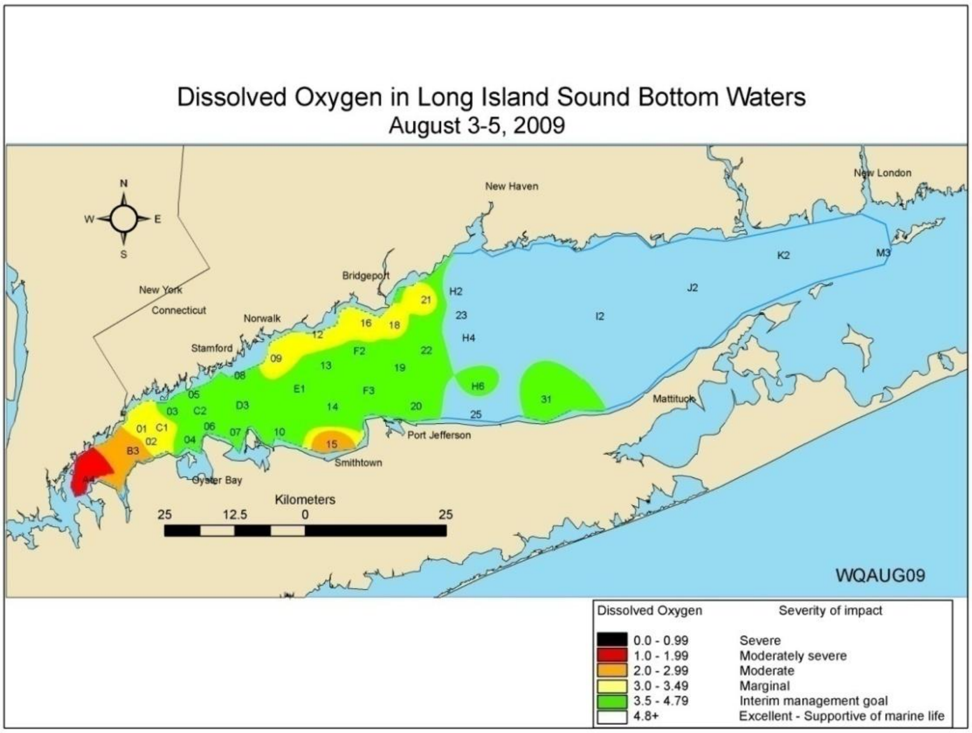
The following maps depict the development of hypoxia through the 2009 season, beginning with the WQJUL09 survey. During this survey DO concentrations were less than 4.8 mg/L at three stations. Data for all surveys are available upon request.



During the HYJUL09 survey, DO concentrations continued to decrease below 4.8 mg/L in the Narrows and Western Basin with Stations 02, C1, and 15 measuring between 3.0 and 3.49 mg/L and Stations B3 and 01 measuring between 2 and 2.99 mg/L.

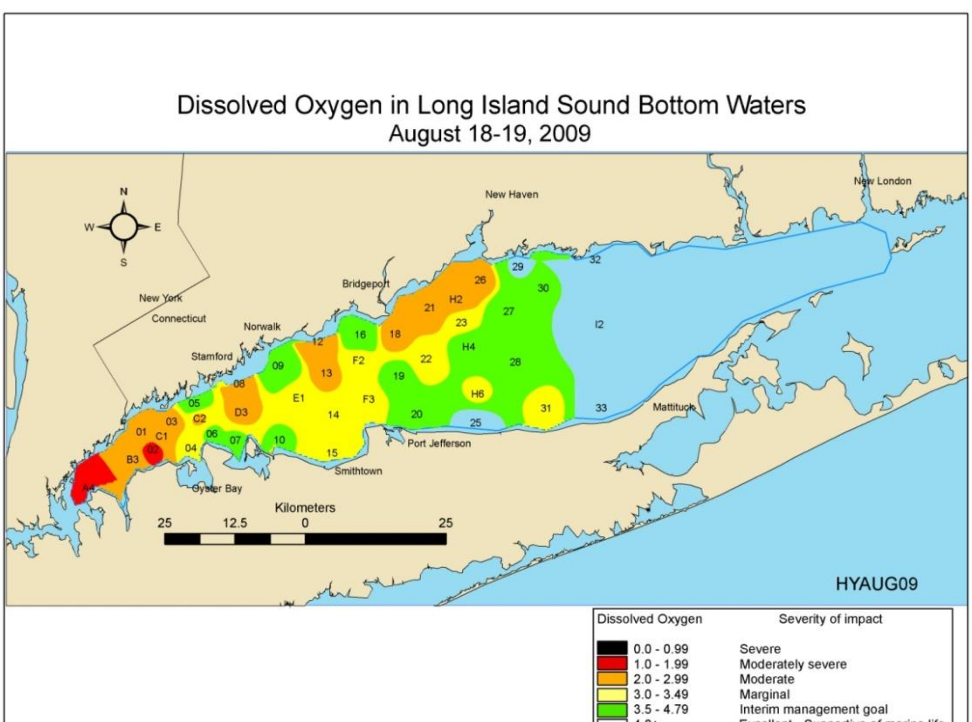


During the WQAUG09 survey, DO concentrations dropped below 3.5 mg/L at 11stations; two of those stations fell below 3 mg/L, and one station was below 2 mg/L.



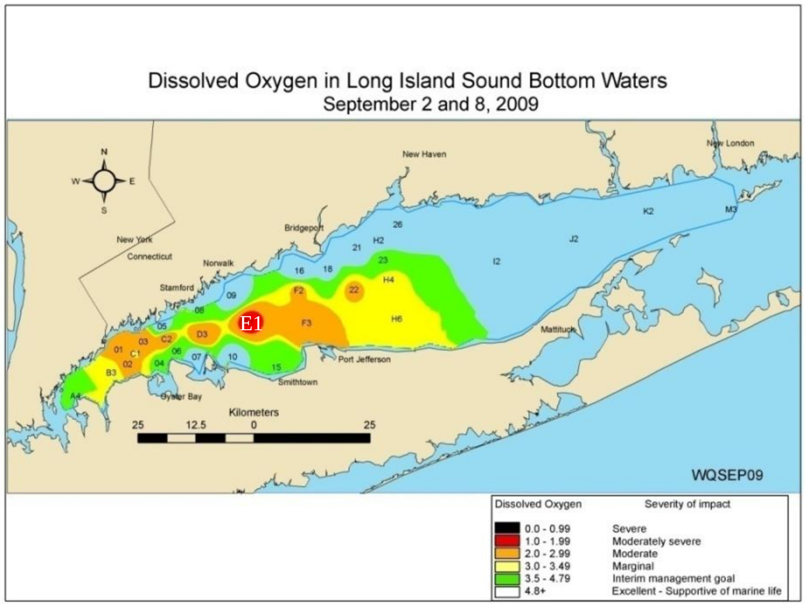
Maximum Areal Extent (369.1 mi^2) of Hypoxia

During the HYAUG09 survey, DO concentrations dropped below 3.5 mg/L at 25 stations; 13 of those stations fell below 3 mg/L, and two stations were below 2 mg/L. The map illustrates the dissolved oxygen concentrations in the bottom waters of Long Island Sound during the height of the hypoxic event.

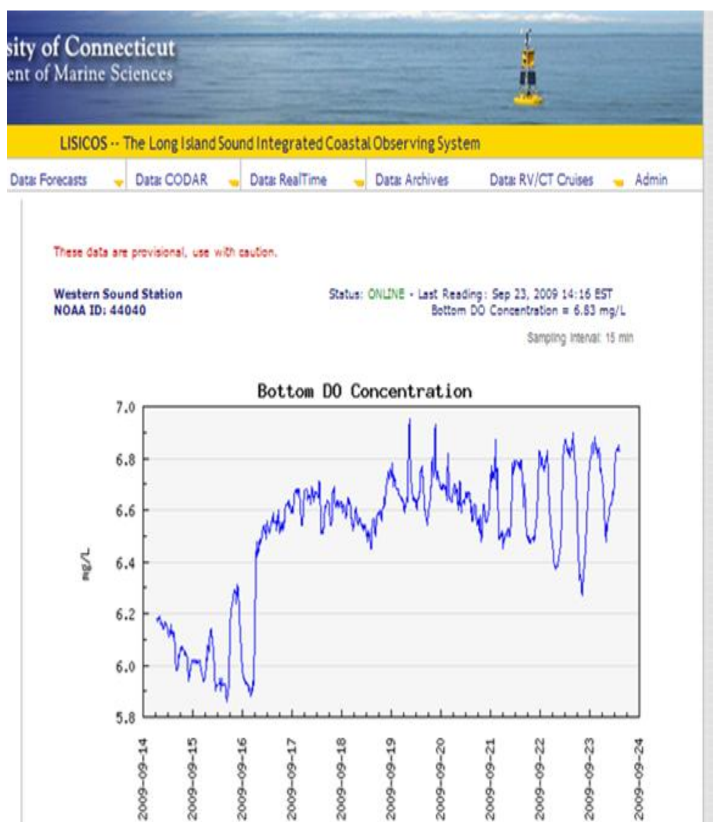


Concentrations began to improve during the WQSEP09 survey in the far western Narrows, where concentrations at A4 and B3 increased above 3.0 mg/L.

Hypoxic conditions persisted in the Eastern Narrows and Western Basin, with concentrations at E1 measuring less than 1.99 mg/L. Some important things to note are that stations in the central and western basins were sampled on 9/2/09 while the remainder were sampled on 9/8, six days later. The dissolved oxygen profiles from 9/2/09 show the turnover in the surface waters had begun, but had not reached the bottom waters at the deepest stations such as E1. Weather conditions following the sampling were favorable for continuing the turnover. Daily maximum temperatures ranged from 21.7 to 27.2ºC while low temperatures ranged from 12.2-19.4ºC. There was no precipitation recorded at Bridgeport from 9/2-9/8. Average wind speeds ranged from 4.6-11.0 mph with gusts ranging from 14-23 mph. Winds began out of the southeast, switched to the North and Northeast, and back to the southeast.



The LISICOS buoy at Station C1 was examined following the 9/2/09 data collection and indicated DO concentrations increasing above standards. Data from 9/14 through 9/24 indicate concentrations above 5 mg/L.



The Interstate Environmental Commission sampled Stations A4 and B3 on 9/8/09. Bottom DO concentrations had improved to 6.1 mg/L at A4 and 5.4 mg/L at B3. IEC also conducted sampling on 9/14 with concentrations at A4 measuring 6.4 mg/L and 7.0 mg/L at B3.

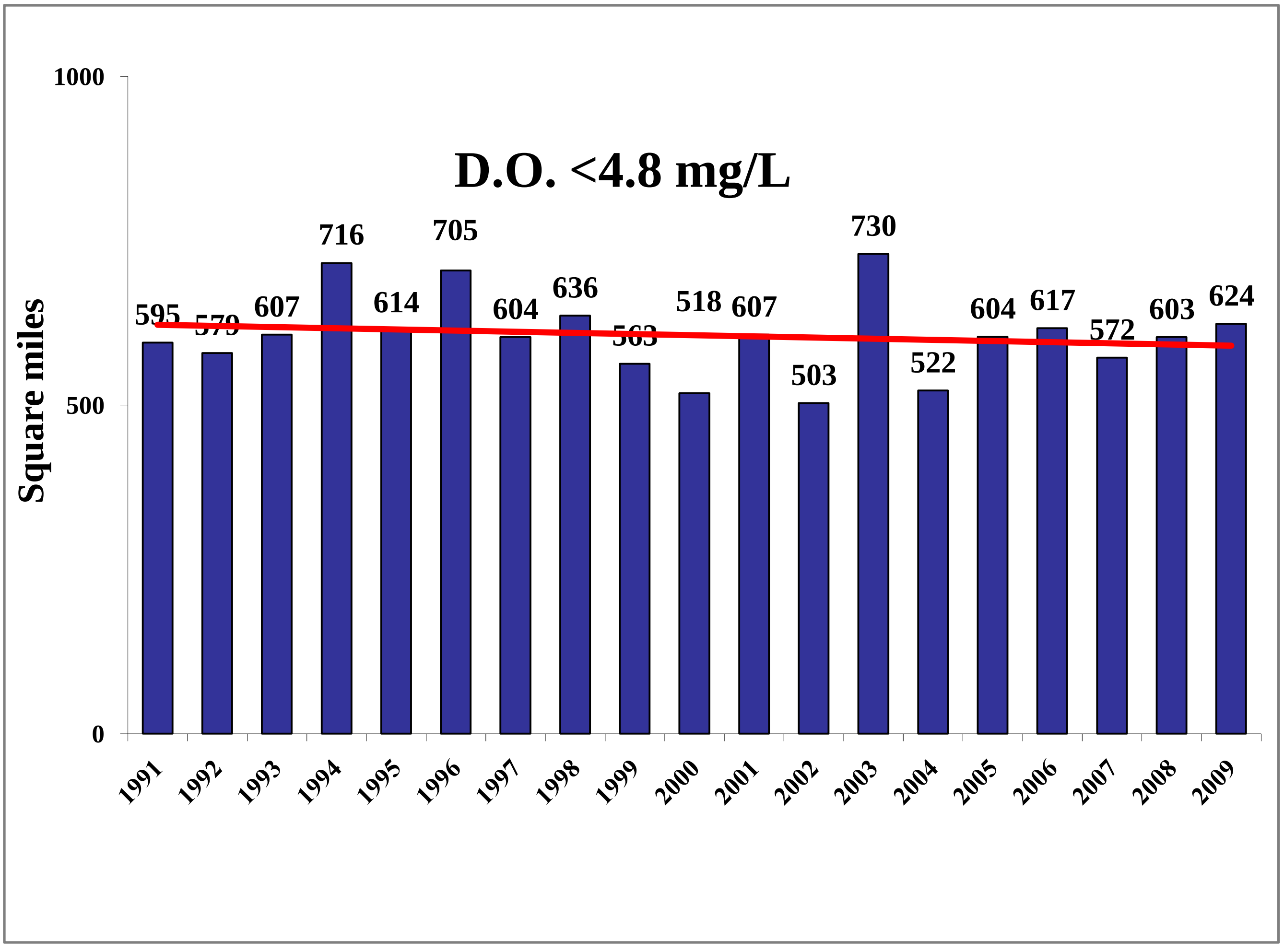
Based on these factors we are confident that the hypoxic event concluded on or about 9/3.

Area of Dissolved Oxygen Below the Chronic Criterion for Growth and Protection of Aquatic Life for LIS

Aquatic organisms are harmed based on a combination of minimum oxygen concentration and duration of the low DO excursion. A DO concentration of 4.8 mg/L meets the chronic criterion for growth and protection of aquatic life regardless of the duration.

This chart illustrates the maximum area of bottom waters within Long Island Sound with DO concentrations less than 4.8 mg/L. In 2009, the maximum area occurred during the HYAUG09 survey. This area was the highest since 2003. The area affected by concentrations less than 4.8 mg/L averages 606.2 square miles and varies slightly from 503 to 730 square miles.

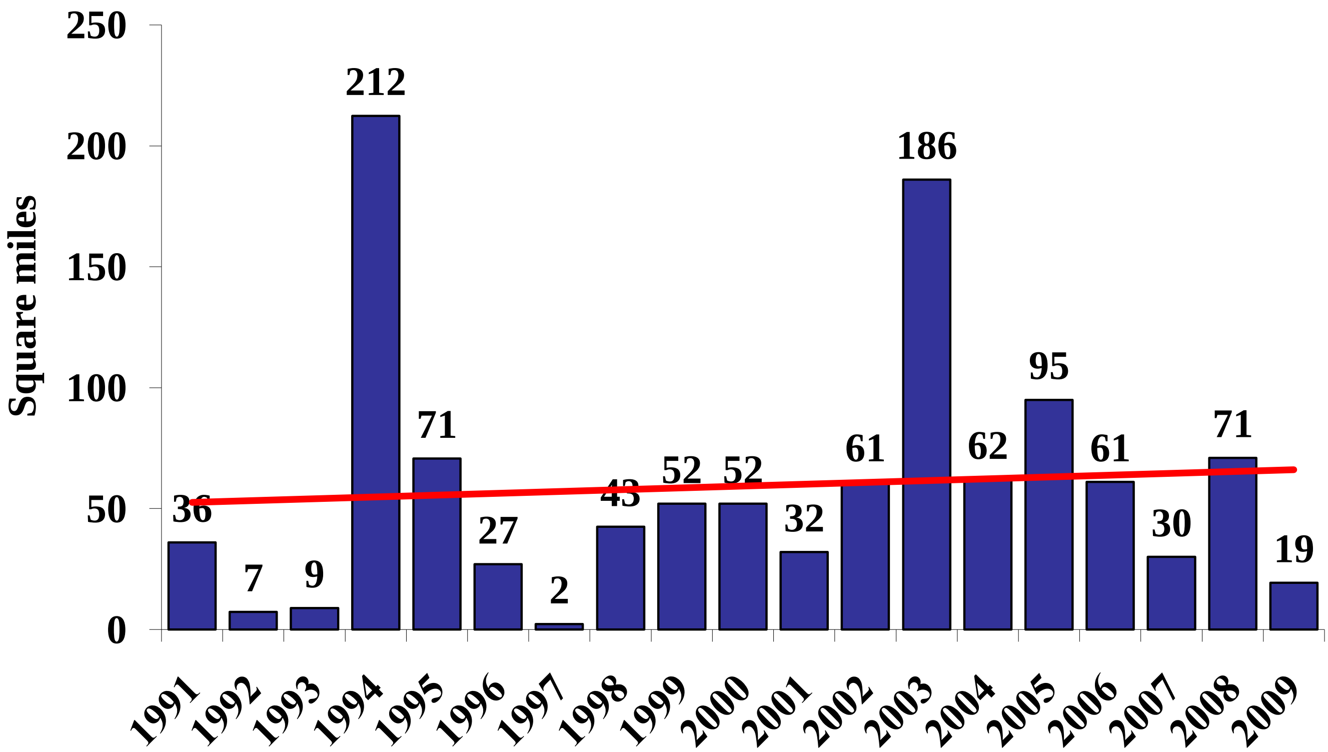
The trend in area affected seems to be decreasing.



Severe Hypoxia

D.O. <2 mg/L

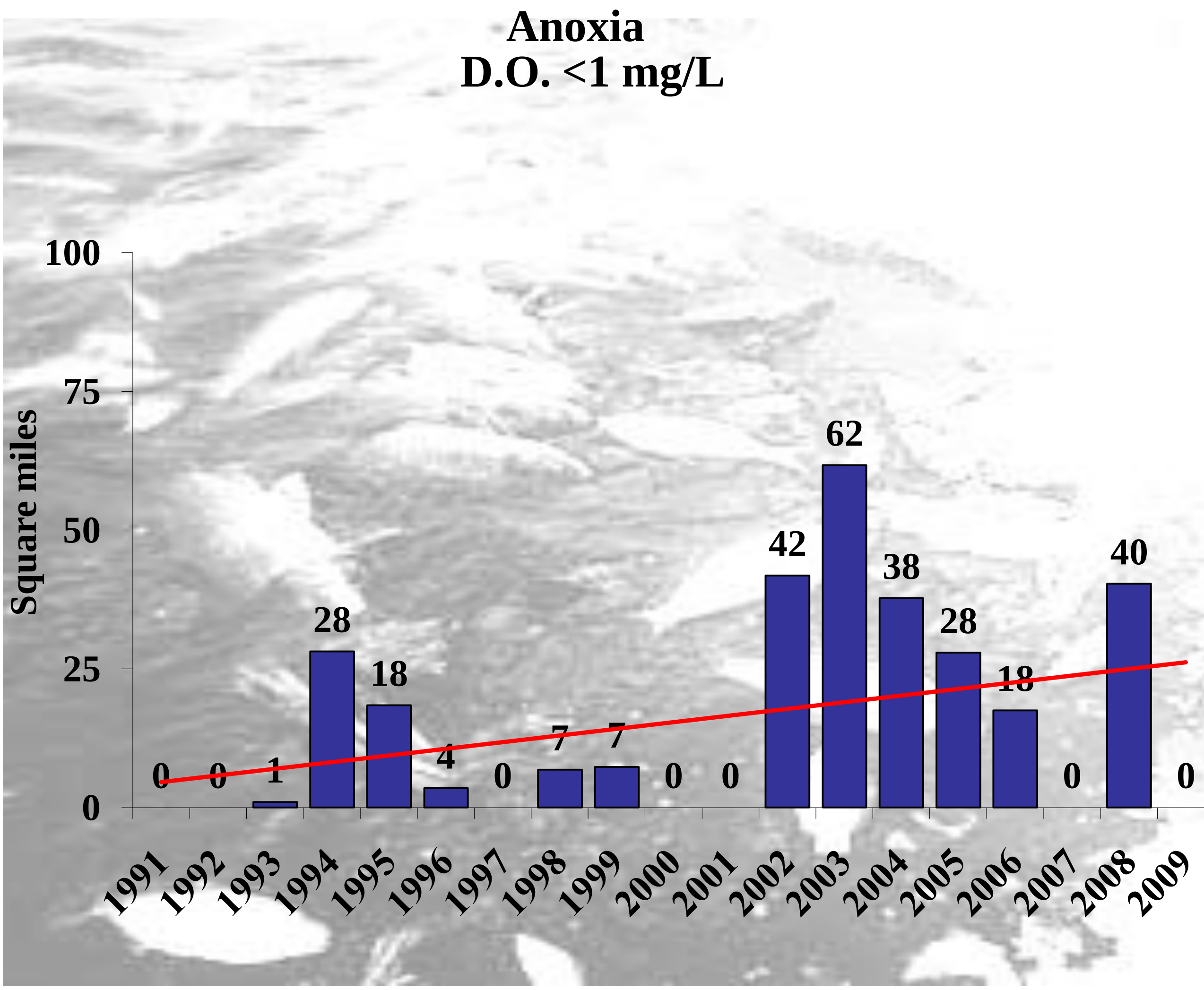
This chart illustrates the area of bottom waters of Long Island Sound with concentrations less than 2 mg/L.



The Gulf of Mexico is another water body that exhibits severe hypoxia, although the standard is determined at the 2.0 mg/L level. The average size of the hypoxic zone in the northern Gulf of Mexico from 2004-2008 is roughly 6563.7 mi^2 (http://www.gulfhypoxia.net/Overview/). For comparison, the average area of LIS with DO concentration less than 2.0 mg/L between 2004 and 2008 is 63.8 mi^2.

In 2009 the maximum area of LIS affected by severe hypoxia was 19 mi^2, the lowest since 1997. The average area, calculated from 1991-2009, is 59.4 mi^2. It seems that there is an increasing trend towards severe hypoxia in LIS (i.e., hypoxia area at 2.0 mg/L seems to be getting worse).

1994 and 2003 appear to be especially bad years for concentrations less than 2 mg/L. 1994 had cold winter bottom water temperatures and an unusually warm June which led to the establishment of strong stratification. The highest average Delta T in July 1994 was 8.54 ºC. 2003 was the second hottest summer since 1895 and the 28th wettest which also led to the Sound being very strongly stratified. Strong stratification (Delta T greater than 4) lasted for four months in 1994 (May-August) and only one month (July) in 2003.

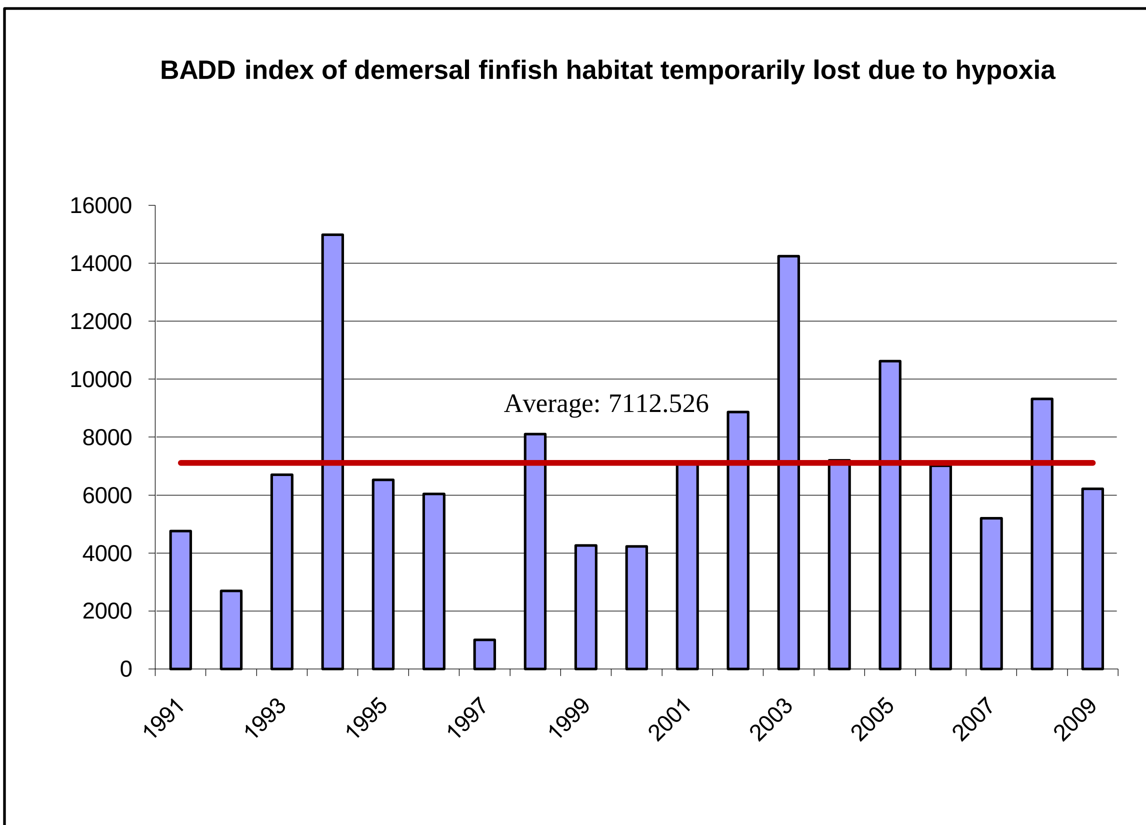


For management purposes the Long Island Sound Study defines anoxia as DO concentrations less than 1 mg/L. Over the last 5 years, Long Island Sound has seen an increase in the area of bottom waters affected by anoxia. The greatest area with D.O. below 1 mg/L observed in LIS, based on ~biweekly sampling by CT DEP, was during the summer of 2003. Prior to 2002, the average area of bottom waters affected by anoxia was 5.92 mi^2. From 2002-2009 the average area affected was 28.4 mi^2. The overall average area affected from 1991-2009 is 15.4 mi^2. A consistent decline was observed from 2003-2007. During the summer of 2008 three stations (A4, B3, and 02) were observed to have gone anoxic. In 2009, CT DEP did not document any stations with DO < 1 mg/L. However, the Interstate Environmental Commission documented two stations that were anoxic on 31 August, Stations B3 (same as CT DEP) and B2 (northwest of B3).

HABITAT IMPAIRMENT ASSOCIATED WITH HYPOXIA

Simpson *et al*, (1995) identified low oxygen tolerance thresholds for 16 individual species of finfish and lobster, and six aggregate species indices. For the most sensitive species (scup, striped sea robin) dissolved oxygen becomes limiting at over 4.0 mg/l, whereas more highly tolerant species (Atlantic herring and butterfish) did not decline in abundance until oxygen levels were below 2.0 mg/l. Both demersal species biomass and demersal species richness begin to decline when dissolved oxygen levels fall below about 3.5 mg/l. No finfish or macroinvertebrates were observed when dissolved oxygen fell below 1.0 mg/l.

An index of habitat impairment (Biomass Area-Day Depletion, BADD) was developed based on the percent reduction in demersal finfish biomass associated with each 1 mg/L interval below 3.5 mg/L. Based on Simpson *et al* (1996), demersal finfish biomass is reduced 100% (total avoidance) in waters with DO<1.0 mg/L. From 1.0-1.9 mg/L biomass is reduced 82%, while a 41% reduction occurs at 2.0-2.9 mg/L, and a 4% reduction occurs at 3.0-3.9 mg/L dissolved oxygen. These rates are applied to the area-days within each DO interval calculated during each survey and summed over the hypoxia season defined here as July 12– September 3 (54 d). The index is then expressed as a percentage of the available area-days (sample area 2,723 km^2 x 54 d, or 147,042 area-days).

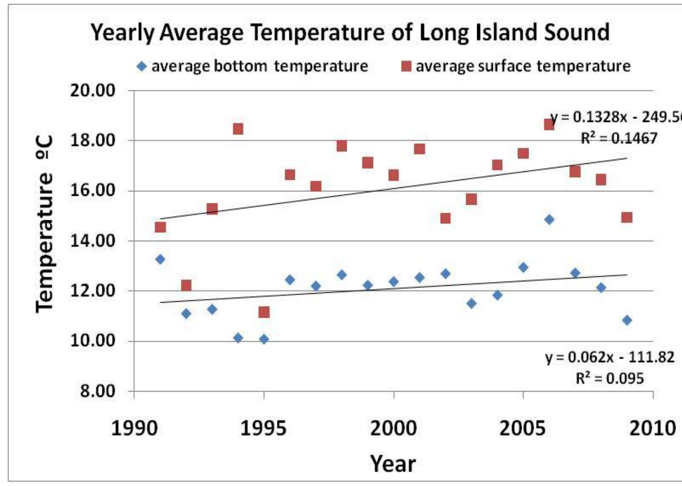


WATER TEMPERATURE

In LIS, water temperature plays a major role in the ecology of the Sound especially in the timing and severity of the Summer hypoxia event. CT DEP's monitoring program records water temperatures and salinity year round, but data collected during the hypoxia monitoring cruises are used to help estimate the extent of favorable conditions for the onset, extent, and end of the hypoxic event. In LIS, there are two key contributors to hypoxia: nutrient enrichment and stratification. Nutrients, especially nitrogen, flow into the Sound from numerous sources including point sources like wastewater treatment plants and nonpoint sources such as stormwater runoff. This enrichment leads to excessive growth of phytoplankton, particularly in the spring. As the plankton die, they begin to decay and settle to the bottom. Bacterial decomposition breaks down the organic material from the algae, using up oxygen in the process.

Delta T

The temperature difference between the bottom waters and the surface waters is known as "delta T". This delta T, along with salinity differences, creates a density difference, or "density gradient" resulting in a separation or "stratification" of water layers that hinders the oxygenated surface waters from circulating downward and mixing with the oxygen starved bottom waters. The pycnocline, or zone where water density increases rapidly with depth due to the changes in temperatures and salinity (see image on next page), inhibits oxygenated surface waters from mixing with oxygen deplete bottom waters exacerbating the hypoxia. The pycnocline typically develops in LIS in late spring/early summer when rapid surface water warming exceeds the rate of warming in the bottom waters and persists

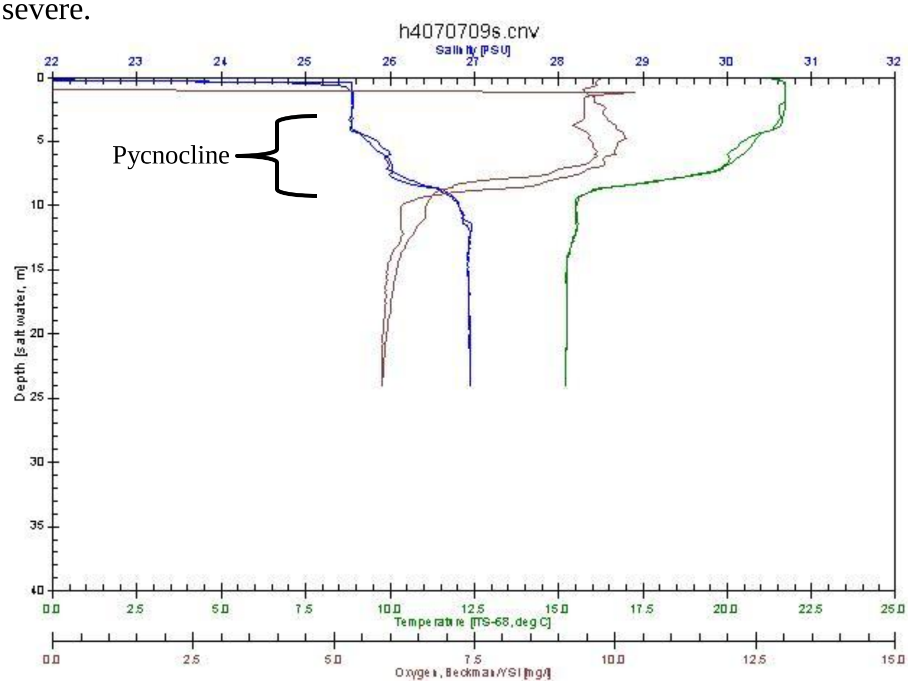


The Sound is coldest during February and March and warmest during August and September. The yearly average surface and bottom temperature of the Sound appear to be increasing.

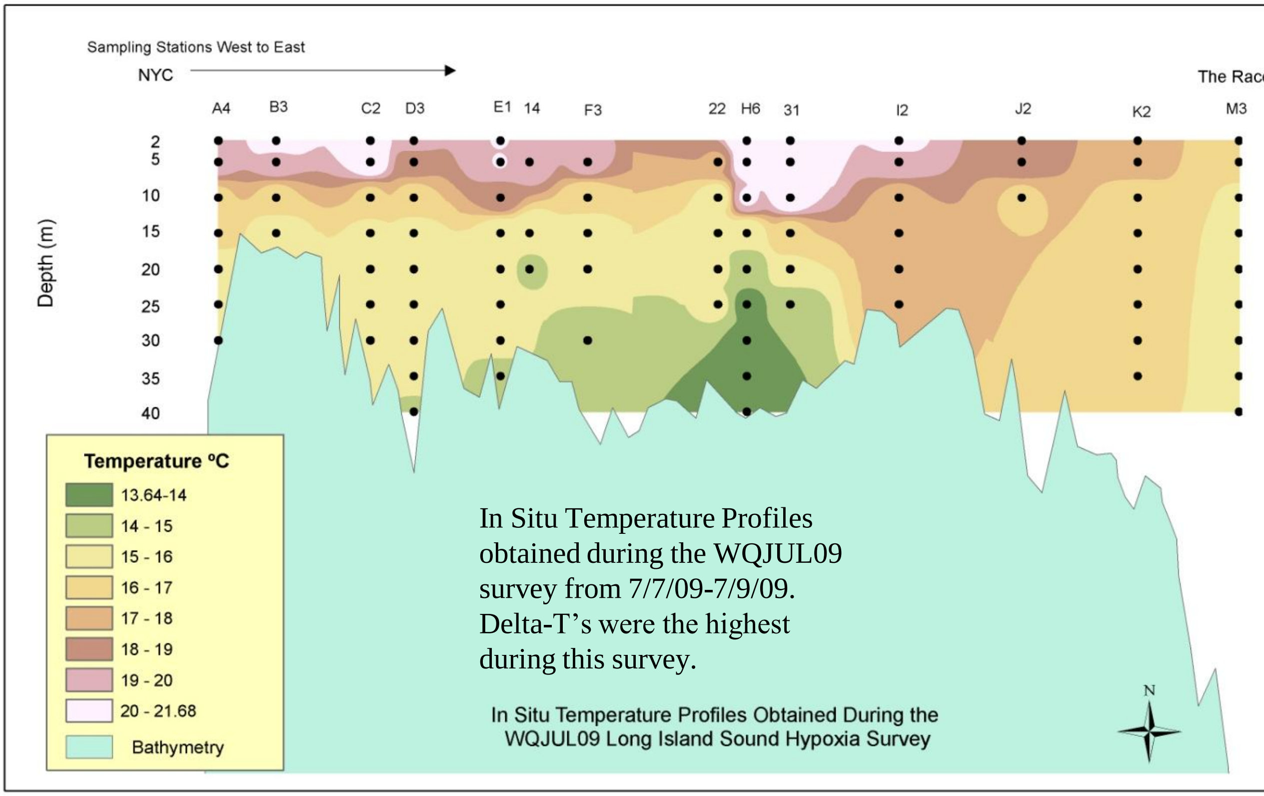
2009 maximum, minimum, and average temperatures (ºC) across Long Island Sound by cruise based upon CT DEP CTD profile data

Cruise	Max	Min	Avg
WQJAN09	4.68	1.70	3.13
WQFEB09	3.34	0.13	1.37
CHFEB09	1.83	1.16	1.32
WQMAR09	2.82	0.81	1.61
CHMAR09	3.24	2.32	2.71
WQAPR09	5.72	3.00	4.06
WQMAY09	11.76	6.15	8.14
WQJUN09	17.16	10.73	13.08
HYJUN09	18.65	12.81	16.03
WQJUL09	22.02	13.65	16.89
HYJUL09	22.37	15.04	18.38
WQAUG09	25.36	17.30	19.76
HYAUG09	25.40	19.03	21.15
WQSEP09	22.97	19.79	21.42

into early fall when it is disrupted by strong winds associated with storms which lead to mixing or cooling air temperatures. With the dissolution of the pycnocline, hypoxic conditions are alleviated/eliminated. The smallest Delta-Ts occur during the winter when the water column is well mixed. The largest Delta T's occur during the early summer. The greater the delta T the greater is the potential for hypoxia to be more severe.



The temperature graphs on page 15 show computer interpolations along the west-east axis of LIS generated from profile data collected during two CT DEP surveys. During the WQJUL09 survey, surface water temperatures were rapidly warming up to 21ºC while the bottom water remained cooler around 13ºC. This set up the largest differences in temperatures between the surface and bottom waters. The second graph shows how the water column was thermally stratified during the HYAUG09 survey when hypoxic conditions were at their worst. The graphs on page 16 show how the Delta T's varied over the course of the summer sampling season. Delta T's increased from the WQMAY09 survey through the WQJUL09 survey, setting up the stratification and leading to the maximum extent of hypoxia in August. By the September survey Delta T's decreased to less than 0.5 ºC over much of the Sound allowing the oxygenated surface waters to mix through to the bottom, leading to the end of the hypoxic event. The graphs also show how the Delta T varies spatially. The western Sound has higher Delta T's due to the limited flushing capacity, topology, and geology. In the east where cooler, oxygen rich, off- shore ocean water mixes with the Sound water, Delta T's are much lower and hypoxia rarely occurs.



Sampling Stations West to East
NYC
The Race
A4 B3 C2 D3 E1 14 F3 22 H6 31 I2 J2 K2 M3
Depth (m)
2 5 10 15 20 25 30 35 40
Temperature ºC
13.64-14
14 - 15
15 - 16
16 - 17
17 - 18
18 - 19
19 - 20
20 - 21.68
Bathymetry
In Situ Temperature Profiles obtained during the WQJUL09 survey from 7/7/09-7/9/09. Delta-T's were the highest during this survey.
In Situ Temperature Profiles Obtained During the WQJUL09 Long Island Sound Hypoxia Survey
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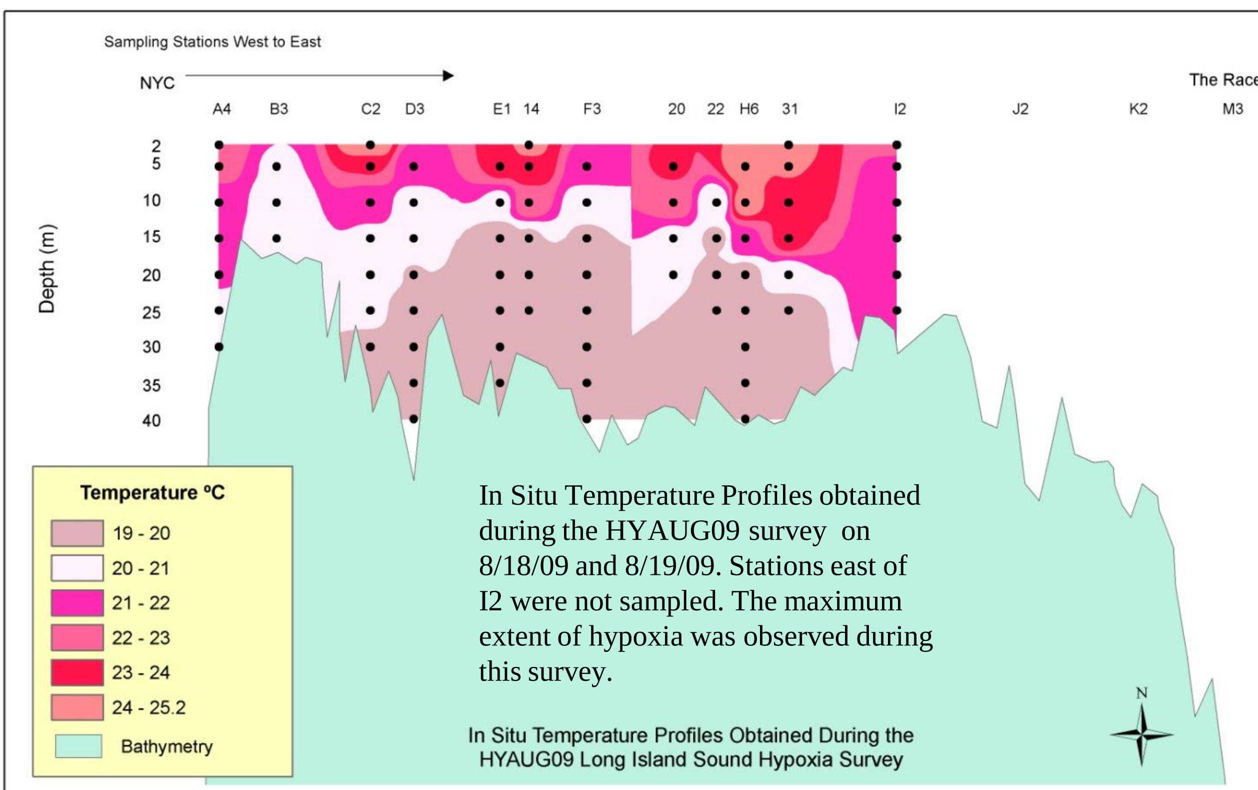

Sampling Stations West to East
NYC
The Race
A4 B3 C2 D3 E1 14 F3 20 22 H6 31 I2 J2 K2 M3
Depth (m)
2 5 10 15 20 25 30 35 40
Temperature ºC
19 - 20
20 - 21
21 - 22
22 - 23
23 - 24
24 - 25.2
Bathymetry
In Situ Temperature Profiles obtained during the HYAUG09 survey on 8/18/09 and 8/19/09. Stations east of I2 were not sampled. The maximum extent of hypoxia was observed during this survey.
In Situ Temperature Profiles Obtained During the HYAUG09 Long Island Sound Hypoxia Survey
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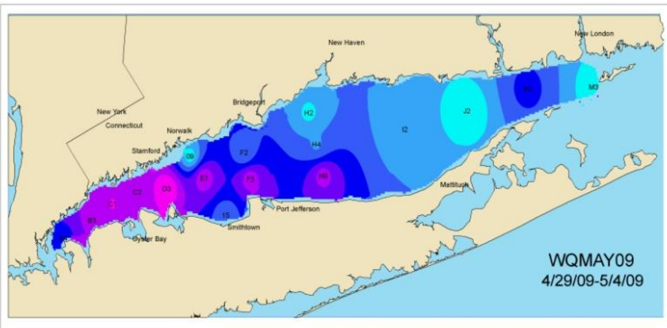
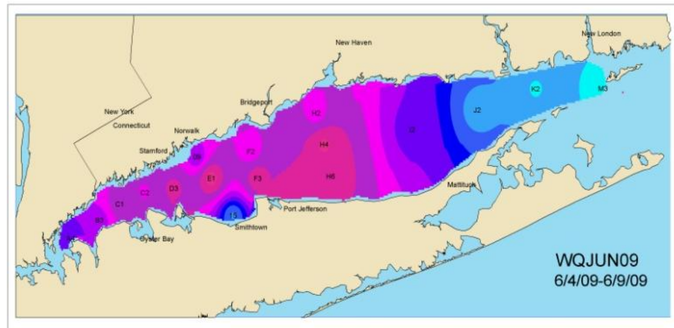
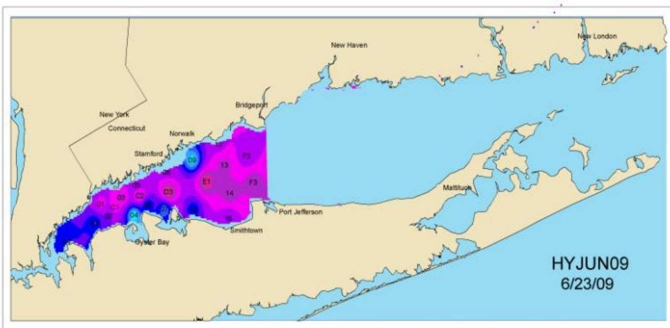
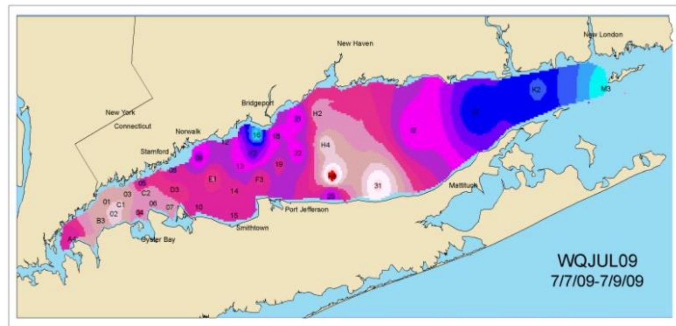
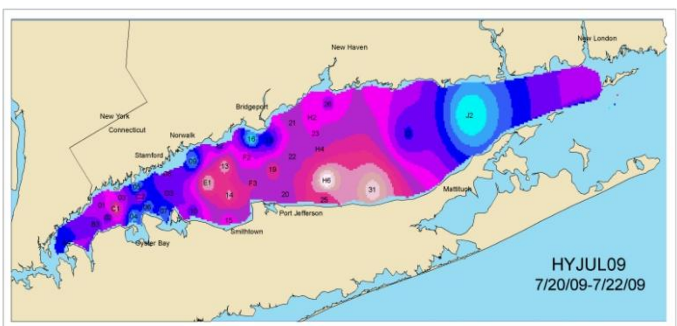
2009 Delta-T Maps

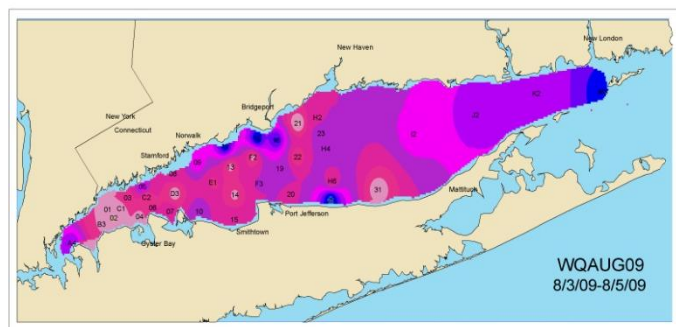


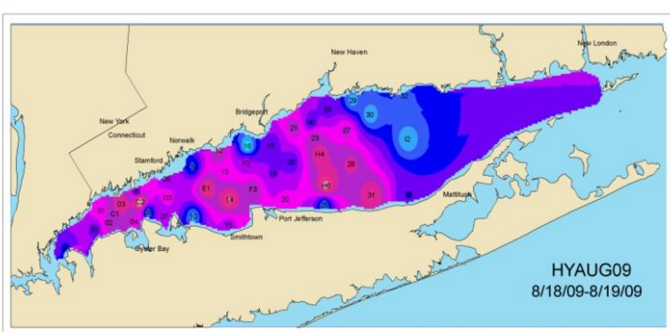


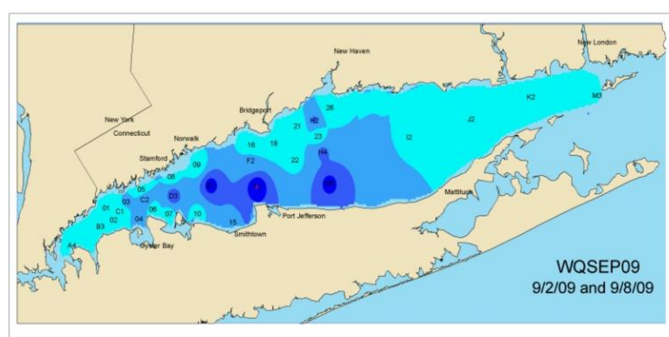












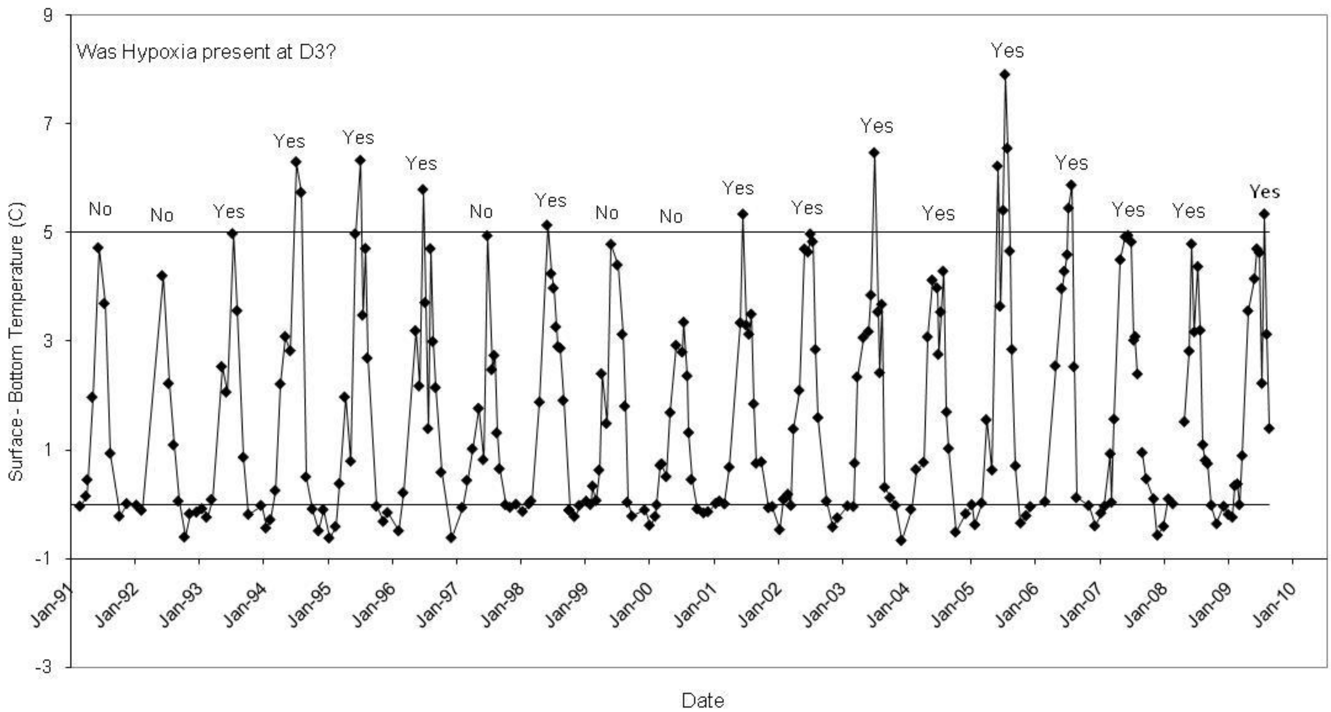
- 0 - 0.5
- >0.5 - 1
- >1 - 1.5
- >1.5 - 2
- .2 - 2.5
- >2.5 - 3
- >3 - 3.5
- .3.5 - 4
- >4- 4.5
- >4.5 - 5
- >5 - 5.5
- >5.5 - 6
- >6 - 6.5
- >6.5 - 7
- >7 - 7.5
- >7.5 - 8

Delta-T ºC

2

This table summarizes the minimum winter temperatures (January, February, and March), the maximum summer temperatures (June, July, August, and September), the maximum delta T, and maximum hypoxic area at Station D3. Station D3 is located in the eastern-most and deepest portion of the Narrows (see map on page 1). The CT DEP 1991-1998 Data Review report (Kaputa and Olsen, CT DEP 2000) found a positive correlation between the maximum delta T observed at D3 and the maximum area of hypoxia in the same year. Delta T was not correlated to the duration of hypoxia. 2004 had the lowest water temperature recorded, 2006 had the highest, 2005 had the highest ΔT_{max}, and 1994 had the largest area of hypoxia.

Year	Minimum Winter Temp (ºC)	Maximum Summer Temp (ºC)	Maximum ΔT (ºC)	Maximum Area of Hypoxia (mi^2) DO<3.0 mg/L	Maximum Area of Hypoxia (mi^2) DO<3.5 mg/L
1991	2.69	22.23	4.75	122	263.2
1992	1.86	20.89	4.83	80	194.5
1993	1.06	22.68	5.33	202	335.9
1994	-0.68	24.08	6.33	**393**	**513.7**
1995	0.95	23.78	6.33	305	415.6
1996	-0.19	23.78	5.91	220	340.4
1997	1.87	21.81	4.96	30	51
1998	3.40	23.20	5.22	168	286.1
1999	2.67	23.41	5.51	121	229.4
2000	0.57	21.99	6.02	173	260.2
2001	1.67	23.20	5.38	133	215.7
2002	4.03	23.47	5.52	130	193.9
2003	-0.52	22.88	6.74	345	430.6
2004	**-0.93**	23.09	4.33	202	257.5
2005	0.53	25.10	**8.19**	177	300.2
2006	2.17	**25.11**	6.72	199	346.1
2007	0.83	23.03	5.12	162	354
2008	2.45	22.47	4.91	180.1	359.9
2009	0.72	24.31	5.90	169.1	369.6



Time series of ΔT (surface water temperature - bottom water temperature) at station D3, 1991 through 2009.

Generally, when Station D3 became hypoxic the observed maximum delta-T was greater than 5ºC and the observed values were largest. 2004, 2007, and 2008 seem to be exceptions.

Salinity

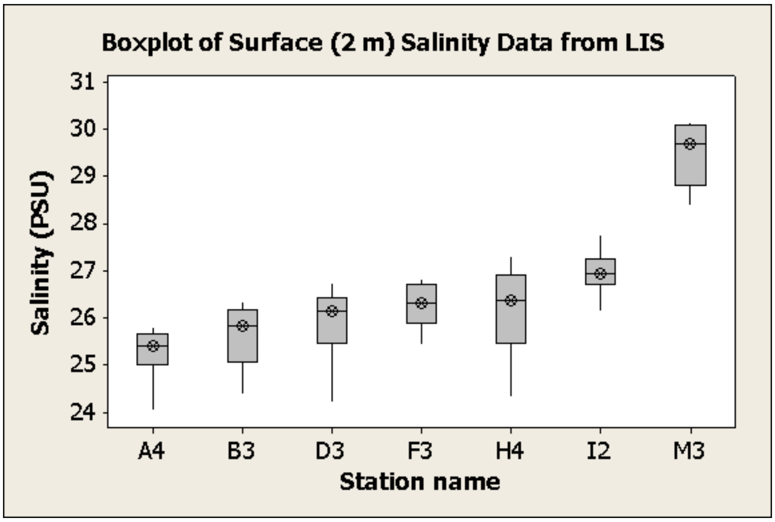
Salinity is a measure of the dissolved salts content of seawater. It is usually expressed in practical salinity units (PSU). Salinity levels across Long Island Sound vary from 23 PSU in the Western Sound at Station A4 to 35 PSU in the eastern Sound at Station M3. The Thames, Connecticut, and Housatonic rivers are the major sources of freshwater entering the Sound. Summary statistics for salinity data collected from seven stations across the Sound from1991-2009 are presented in the tables below. Data collected this year are also presented separately.

		1991-2009 Bottom Water Statistics						
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard Deviation	Variance
A4	224	23.955	28.727	26.348	26.335	0.0625	0.923	0.852
B3	267	24.259	28.926	26.642	26.674	0.0580	0.927	0.860
D3	262	24.912	29.215	27.265	27.376	0.0557	0.874	0.763
F3	254	25.153	29.432	27.607	27.659	0.0564	0.857	0.735
H4	201	25.508	29.700	27.755	27.777	0.0616	0.852	0.726
I2	236	25.762	29.985	28.093	28.221	0.0566	0.839	0.704
M3	206	28.608	32.622	30.584	30.569	0.0519	0.720	0.518

		2009 Bottom Water Statistics						
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard Deviation	Variance
A4	14	24.834	26.313	25.828	25.897	0.104	0.391	0.153
B3	14	24.495	26.583	26.081	26.191	0.136	0.508	0.258
D3	13	26.486	27.026	26.728	26.742	0.0468	0.169	0.0285
F3	12	26.733	27.628	27.057	26.982	0.0714	0.247	0.0611
H4	11	26.869	27.775	27.190	27.192	0.0768	0.255	0.0649
I2	10	26.828	27.973	27.626	27.626	0.100	0.317	0.101
M3	7	29.430	30.556	30.116	30.225	0.148	0.391	0.153

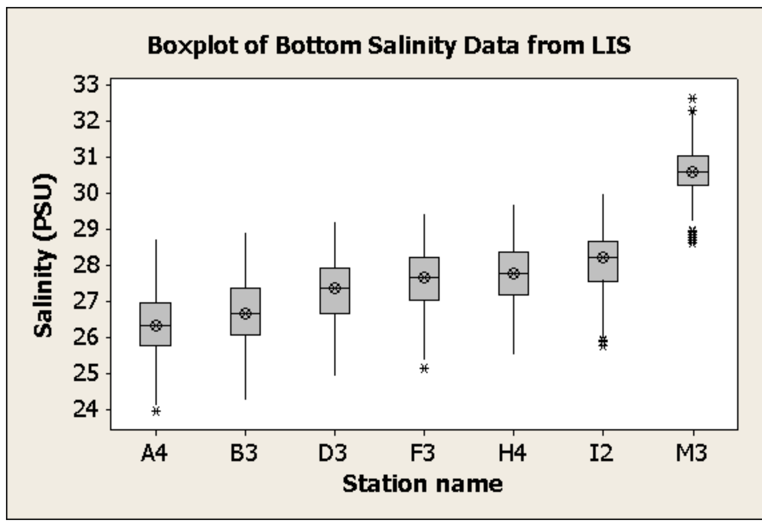
		1991-2009 Surface Statistics						
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard Deviation	Variance
A4	231	22.833	28.278	25.674	25.650	0.0688	1.002	1.003
B3	276	23.898	28.840	26.116	26.178	0.0665	1.034	1.069
D3	275	24.195	29.146	26.696	26.677	0.0674	1.027	1.054
F3	260	24.246	29.307	26.852	26.854	0.0724	1.064	1.133
H4	209	24.315	29.262	27.068	27.146	0.0808	1.072	1.149
I2	240	25.117	29.909	27.520	27.587	0.0727	1.013	1.026
M3	208	25.958	31.758	29.987	30.028	0.0745	0.921	0.848

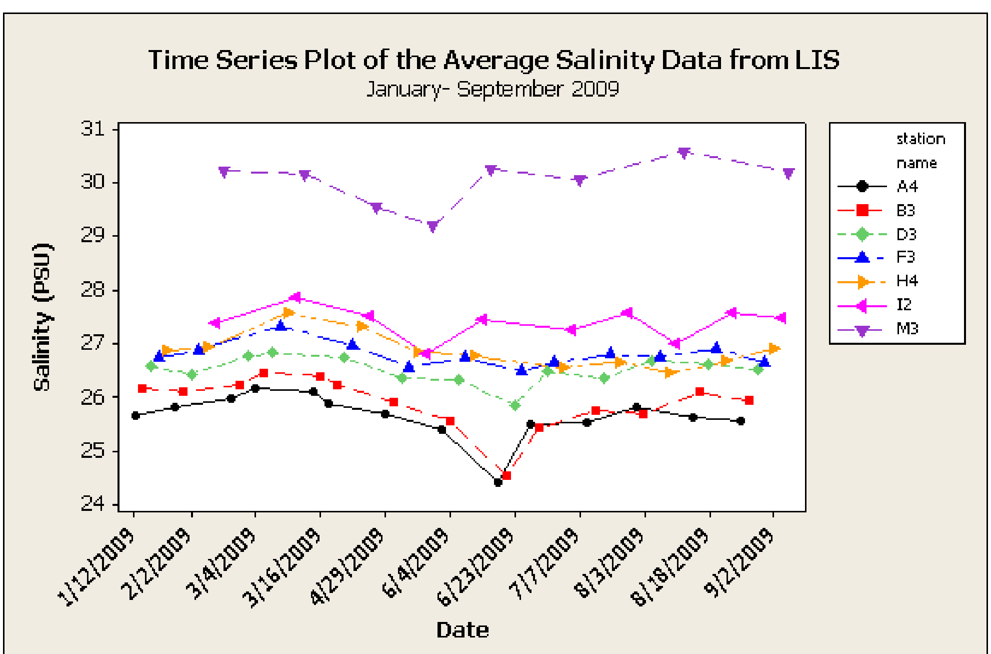
		2009 Surface Statistics						
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard Deviation	Variance
A4	14	24.035	25.814	25.228	25.407	0.157	0.566	0.320
B3	14	24.369	26.339	25.646	25.820	0.182	0.630	0.397
D3	13	24.195	26.730	25.905	26.138	0.218	0.724	0.524
F3	12	25.441	26.837	26.283	26.600	0.148	0.468	0.219
H4	11	24.315	27.296	26.202	26.383	0.291	0.920	0.847
I2	10	26.15	27.767	26.963	26.941	0.149	0.470	0.221
M3	8	28.396	30.157	29.544	29.714	0.244	0.689	0.475



This box plot, based upon data collected from 1991-September 2009, shows the median surface salinity, range, interquartile range, and outliers by station. Surface in this case refers to data collected two (2) meters below the air/water interface. Salinity increases from west to east across the Sound.

This box plot, based upon data collected from 1991-September 2009, shows the median bottom salinity, range, interquartile range, and outliers by station. Bottom in this case refers to data collected five (5) meters above the sediment/water interface. The bottom waters are generally saltier than the surface waters.

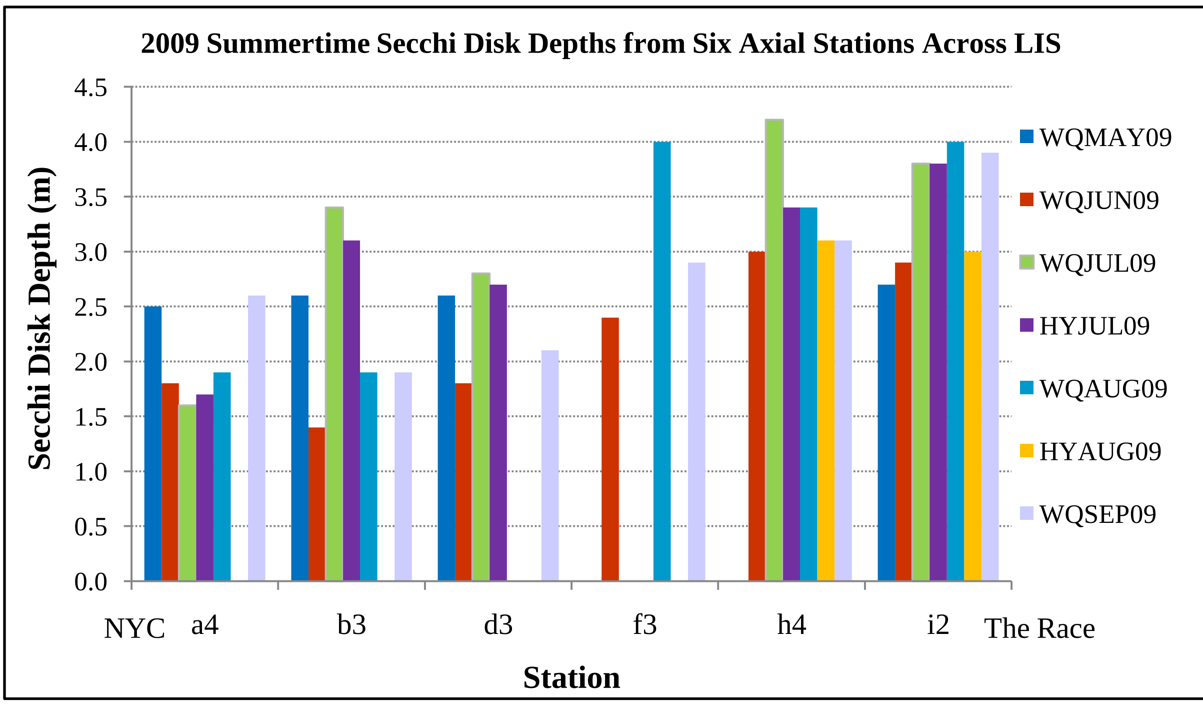




This time series plot illustrates the temporal variability of the mean salinity values by station from January-September 2009.

Water Clarity

Water clarity is measured by lowering a Secchi disk into LIS by a measured line until it disappears. It is then raised until it reappears. The depth where the disk vanishes and reappears is the Secchi disk depth. The depth to disappearance is related to the transparency of the water. Transparency may be reduced by both absorption and scattering of light. Water absorbs light, but absorption is greatly increased by the presence of organic acids that stain the water a brown "tea" color and by particles. Scattering is largely due to turbidity, which can be attributable to both inorganic silt or clay particles, or due to organic particles such as detritus or planktonic algae suspended in the water. CT DEP began taking Secchi Disk measurements in June 2000. Since then, 1780 measurements have been entered into our database; of those 1010 are from the 17 stations sampled annually. The 2000-2009 average Secchi depth is 2.37 m with a minimum depth of 0.3 m (WQMAR04, station D3) and a maximum depth of 6.2 m (WQNOV00 Station K2). Below is a graph depicting Secchi disk depths from six of the axial stations sampled by CT DEP LISS Water Quality Monitoring Program between May and September 2009.

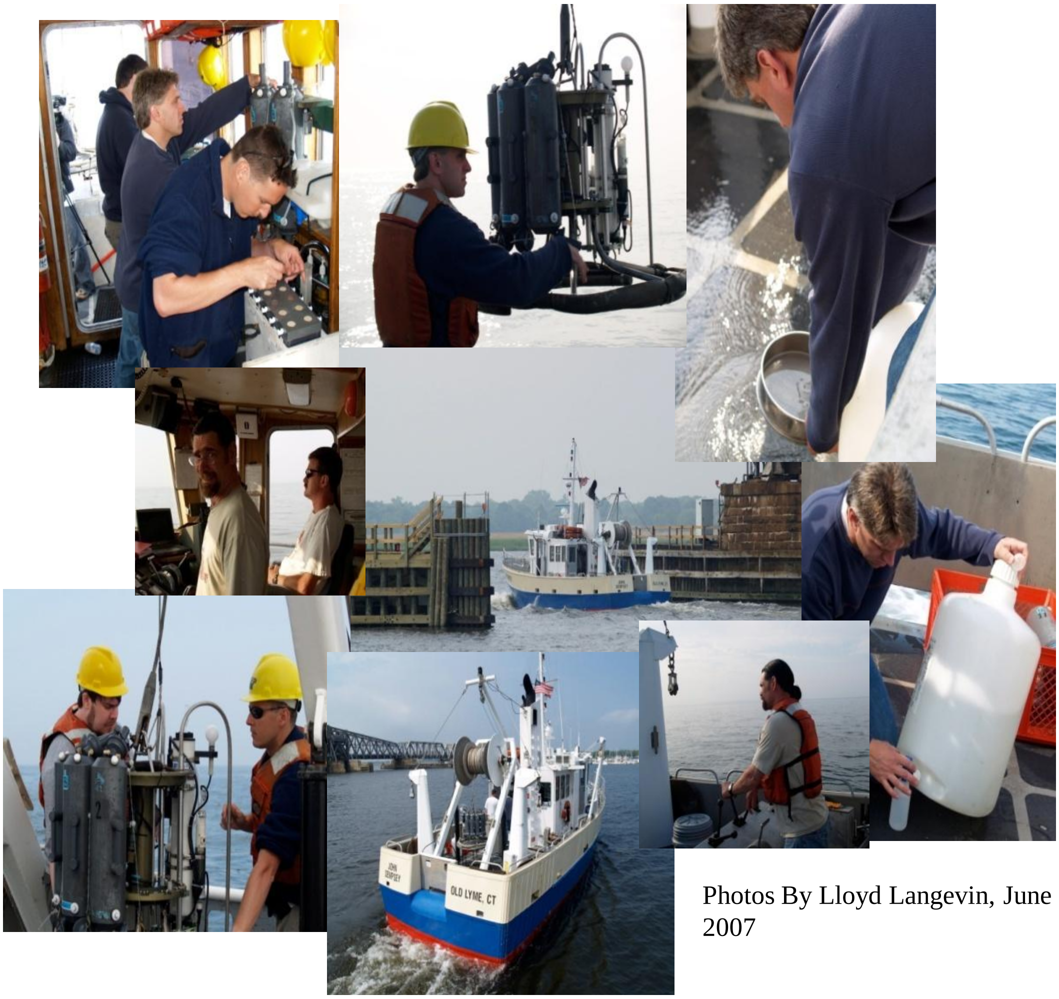


2009 data

- **Average Secchi Disk Depth: 2.94 m (n=166)**
- **Minimum Secchi Disk Depth: 1.4 m at Station B3 during the WQJUN09 cruise**
- **Maximum Secchi Disk Depth: 4.2 m at Station H4 during the WQJUL09 cruise**

2008 data

- **Average Secchi Disk Depth: 2.43 m (n=210)**
- **Minimum Secchi Disk Depth: 1.1 m at Station 29 during the HYAUG08 cruise**
- **Maximum Secchi Disk Depth: 5.0 m at Station 15 during the WQMAR08 cruise and Station 23 during the WQJUL08 cruise**



Photos By Lloyd Langevin, June 2007

Acknowledgements

Funding for the CT DEP Long Island Sound Water Quality Monitoring Program is provided through a grant from the EPA through the Long Island Sound Study.