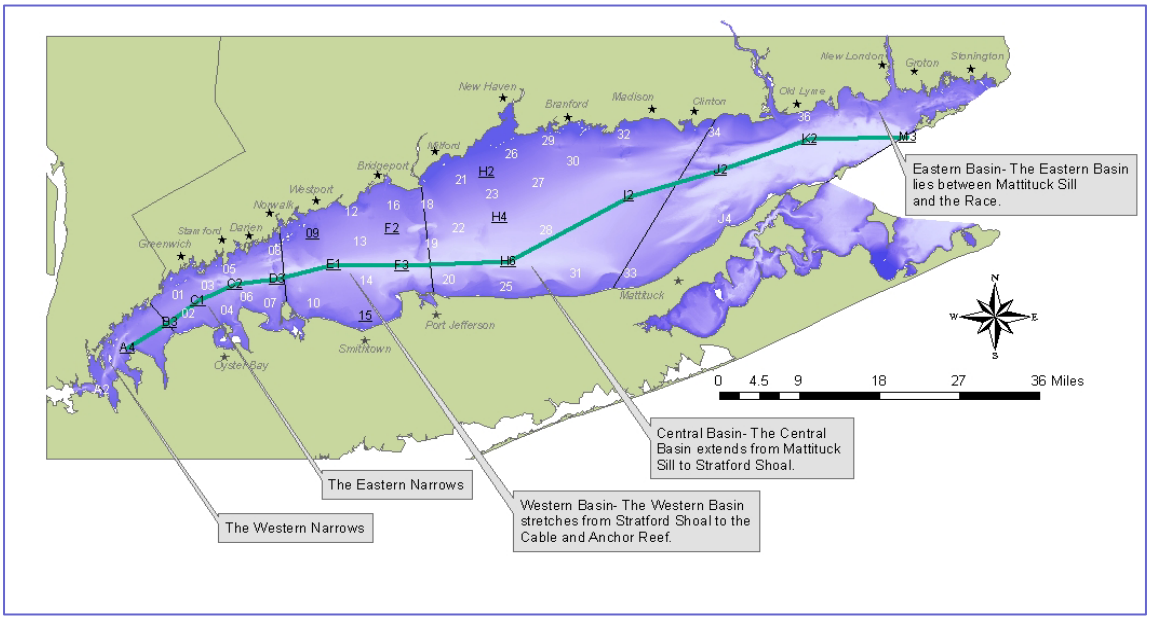
CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION
79 Elm Street, Hartford, CT 06106
Gina McCarthy, Commissioner

MONITORING LONG ISLAND SOUND 2008

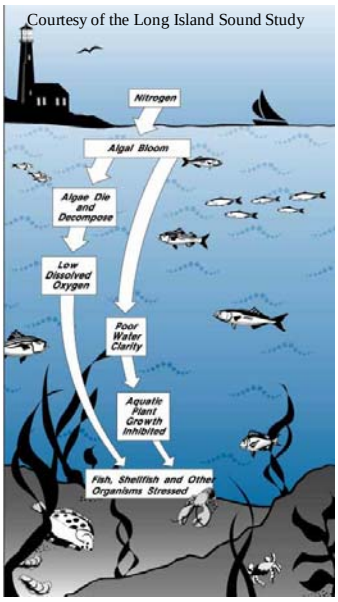
Program Overview

R/V John Dempsey

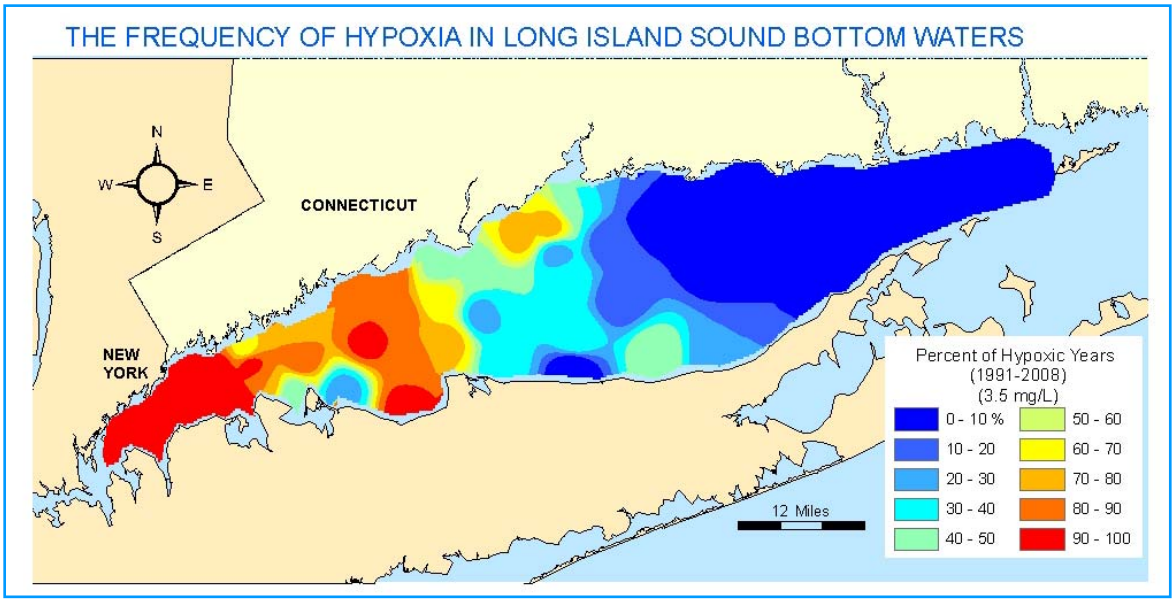
Since 1991, the Connecticut Department of Environmental Protection (CTDEP) has conducted an intensive year-round water quality monitoring program on Long Island Sound. Water quality is monitored at up to forty-eight (48) sites by staff aboard the Department's Research Vessel *John Dempsey*. These data 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.



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. 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 still 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 and affects 297 square miles (770km^2; 1 km^2 is approximately 0.4 square miles) on average.

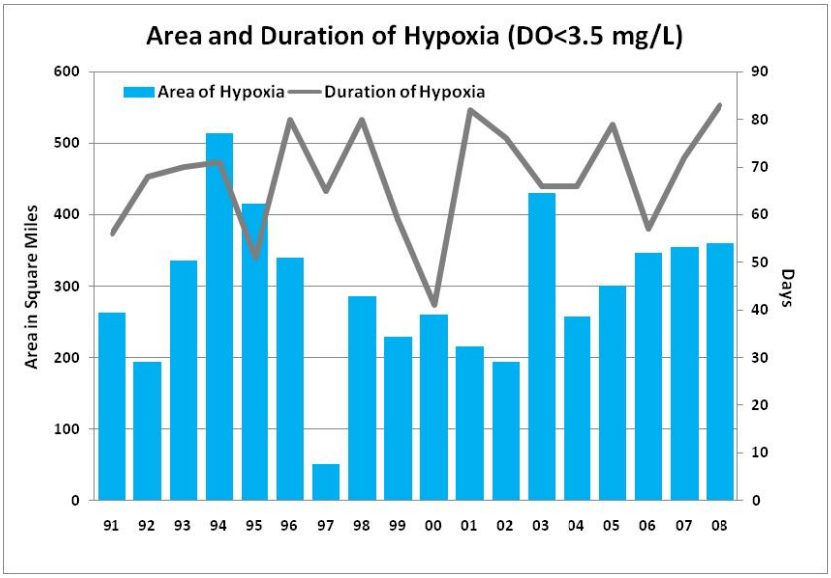
How Severe was Hypoxia in 2008?

During the summer of 2008, seven cruises were conducted, beginning in early June and ending by mid-September. A total of 218 site visits were completed in 2008, with 19 stations affected by hypoxia throughout the season. The number of site visits decreased from 2007 due to the fact that the R/V John Dempsey was unavailable for most of the summer due to mechanical problems. The number of stations affected by hypoxia was also down from 26 stations last year.

In 2008, hypoxic conditions (DO <3.5 mg/L) were estimated to have begun on 30 June and ended on 20 September, approximately 83 days. The peak event occurred in mid-August. The maximum area with bottom water DO less than 3.5 mg/L was 359.9 square miles (932.3 km^2).

In 2008 the area less than 3.5 mg/L was larger than the 2004– 2007 seasons and the duration was the longest on record. The 2008 maximum area was also greater than the 1991-2007 (17-year) average maximum area of 293 mi^2 (760 km^2). The earliest onset of hypoxia occurred on 20 June 2002 and the latest end date occurred on 26 September 2004.

The hypoxia area maps for 2008 appear on the next two pages.



Comparison to Long Island Sound Study Hypoxia Criteria

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 any time. 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 presented below.

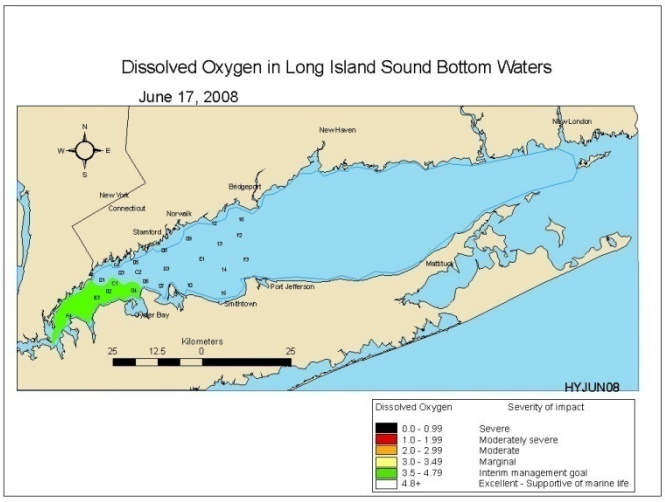
Start Date: 7-3-2008

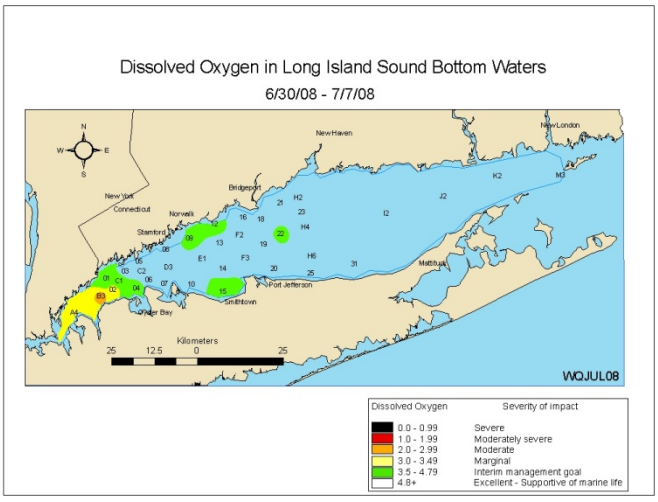
End Date: 9-19-2008

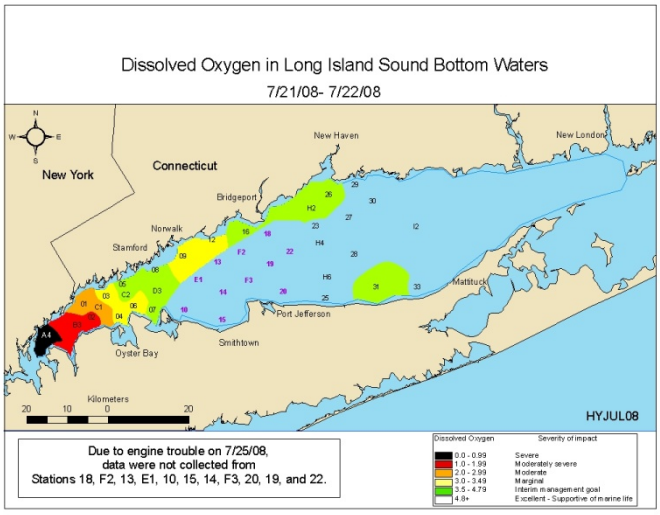
Duration: 79 days

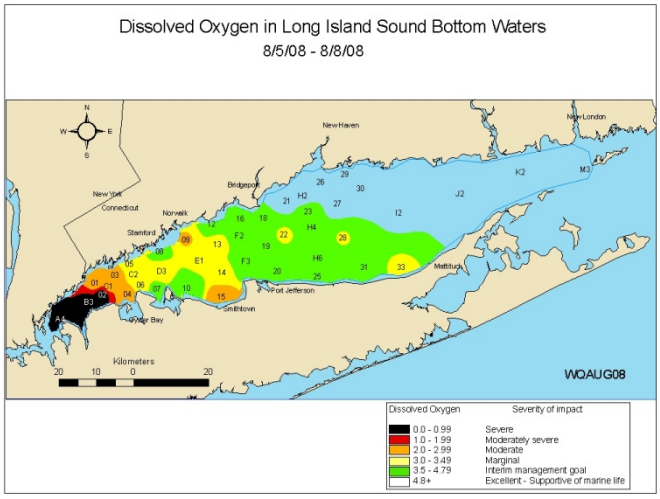
Maximum Area: 466.5 km^2 (180.1 mi^2) during HYAUG08 survey (8/20-8/22/08)

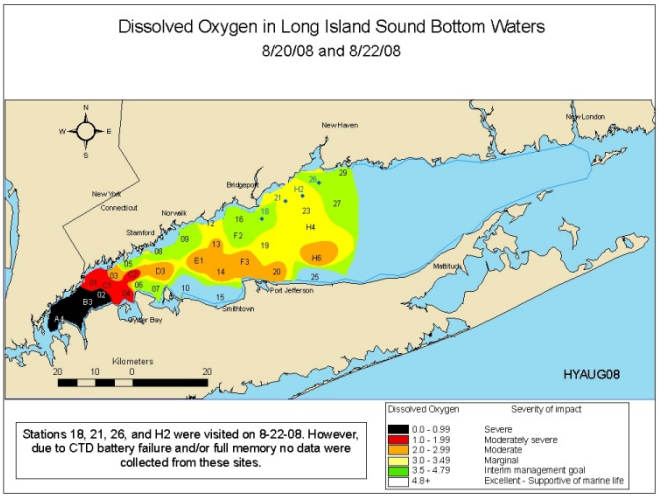
The average date of onset from 1991-2007 based on the 3.0 mg/L standard was July 11 (± 11 days), the average end date was September 3 (± 13 days), and the average duration was 57 days (± 14 days).

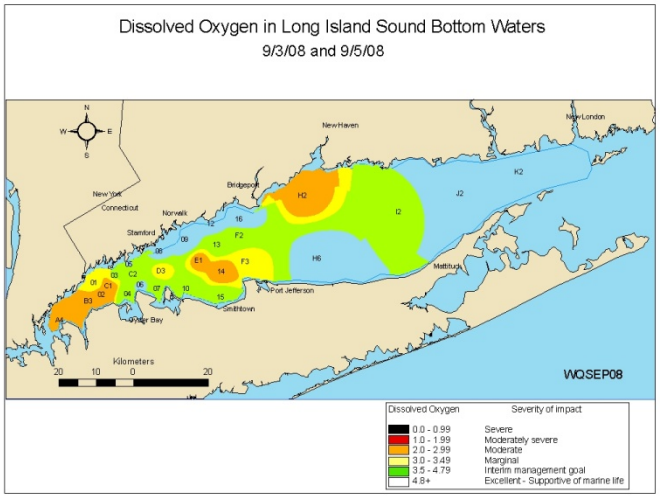




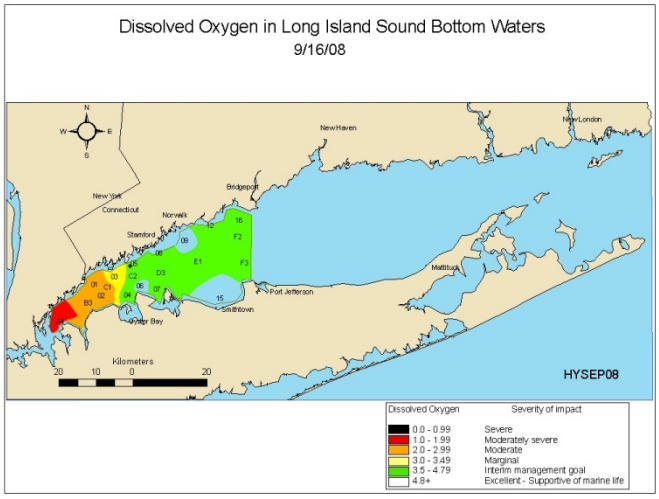








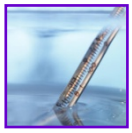
2008 Hypoxia Graphs

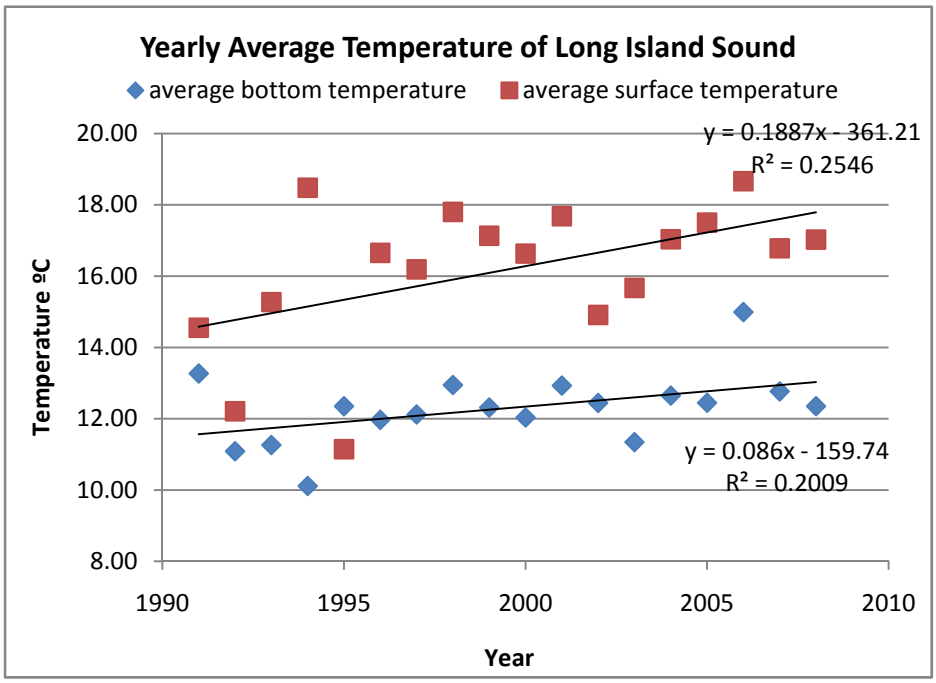


2008 Hypoxia Graphs (continued)

Temperature

Temperature, according to Merriam Webster's online dictionary (accessed 10/15/08) is the degree of hotness or coldness measured on a definite scale. There are three scales used to measure temperature- Fahrenheit, Celsius, and Kelvin. Temperature plays an important role in nature. 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. The yearly average surface and bottom temperature of the Sound appear to be increasing. The Sound is coldest during February and March and warmest during August and September.





18 year (1991-2008) maximum, minimum, and average temperatures across Long Island Sound by survey

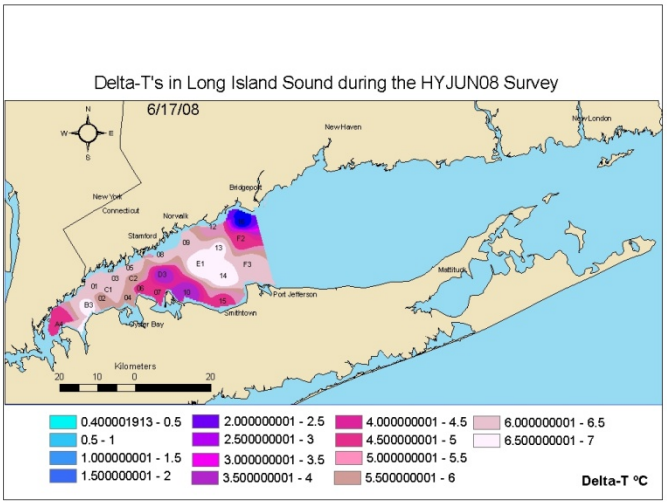
Year	Average Surface Temperature	Average Bottom Temperature
1991	14.55	13.27
1992	12.21	11.08
1993	15.27	11.26
1994	18.48	10.11
1995	11.14	12.35
1996	16.65	11.97
1997	16.19	12.12
1998	17.80	12.94
1999	17.13	12.31
2000	16.63	12.03
2001	17.68	12.93
2002	14.91	12.44
2003	15.67	11.34
2004	17.04	12.65
2005	17.50	12.44
2006	18.67	14.99
2007	16.78	12.76
2008	17.03	12.35
1991-2008	16.76	12.45

Cruise	Max	Min	Avg	n
WQJAN	8.8934	0.5	4.621113	16
WQFEB	6.1632	-1.3248	2.079027	17
CHFEB	4.3282	0.941	2.702303	6
WQMAR	5.6172	-0.7832	2.267428	17
CHMAR	5.7273	0.1129	3.326577	7
WQAPR	10.0724	1.309	4.732279	16
WQMAY	13.8142	5.0543	8.529318	17
WQJUN	19.8157	8.2394	12.6154	18
HYJUN	22.4584	11.1161	15.72328	15
WQJUL	25.1234	11.6385	17.29898	18
HYJUL	26.1107	15.2477	19.20883	15
WQAUG	27.0669	14.0176	20.35486	18
HYAUG	24.9602	18.6776	21.54753	15
WQSEP	25.0314	16.3903	21.52768	18
HYSEP	26.8542	19.5328	21.5397	7
WQOCT	21.5708	15.22	19.05099	18
WQNOV	16.6007	10.4665	13.81996	15
WQDEC	12.1572	4.6549	8.931977	16

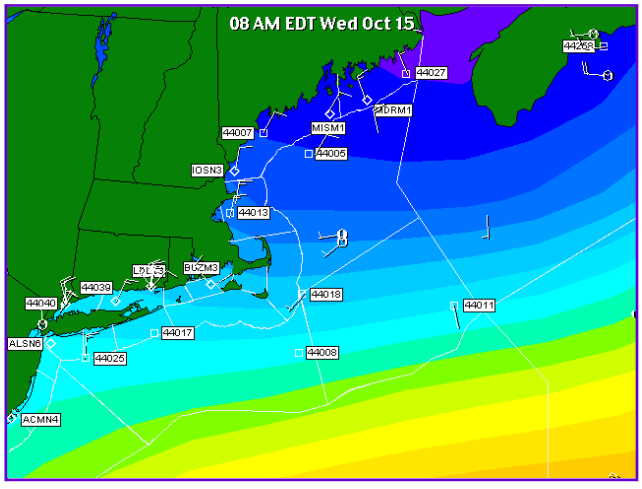
The temperature difference between the bottom waters and the surface waters is known as "delta T". This delta T, along with salinity differences, creates a density difference, or "density gradient" resulting in a separation or "stratification" of water layers that hinders the oxygenated surface waters from circulating downward and mixing with the oxygen starved bottom waters. The greater the delta T the greater is the potential for hypoxia to be more severe.

2008 maximum, minimum, and average temperatures across Long Island Sound by cruise

Cruise	Max	Min	Avg
WQJAN	5.56	4.02	4.89
WQFEB	4.42	2.83	3.34
CHFEB	2.89	2.19	2.71
WQMAR	4.76	2.16	2.99
CHMAR	4.62	3.73	4.11
WQAPR	6.64	4.56	5.40
WQMAY	13.81	7.42	9.91
WQJUN	17.35	10.40	12.38
HYJUN	20.15	12.21	15.29
WQJUL	22.53	14.05	16.63
HYJUL	23.54	16.68	19.41
WQAUG	24.87	18.19	20.91
HYAUG	23.14	19.74	21.51
WQSEP	25.03	19.37	21.90
HYSEP	22.44	21.04	21.87
WQOCT	19.72	17.63	18.91



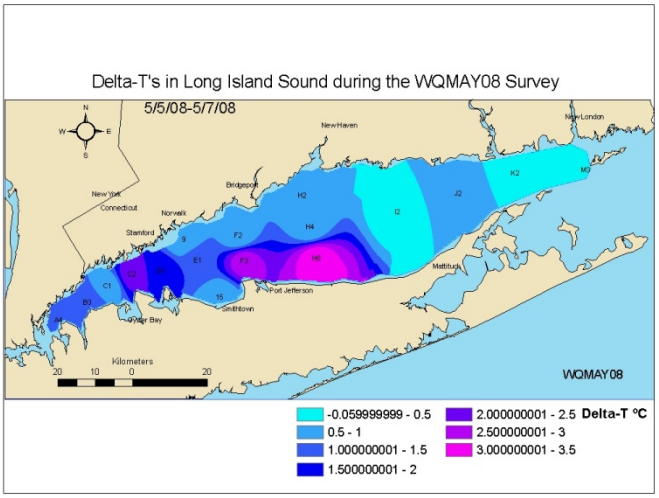
In 2008, the maximum delta T (7.06ºC) was observed during the HYJUN08 survey at Station E1.

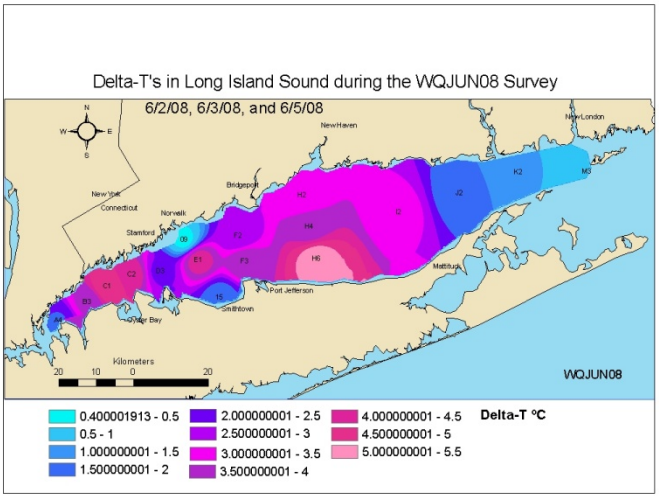


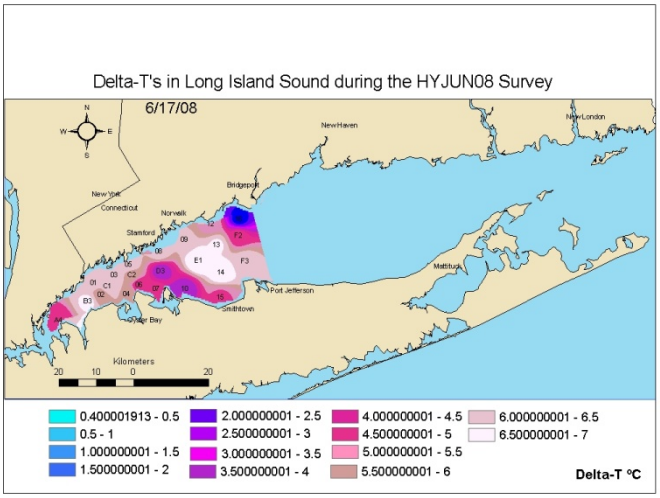
From: Weather Underground marine forecast page
http://www.wunderground.com/MAR/AN/330.html
accessed 10/15/08

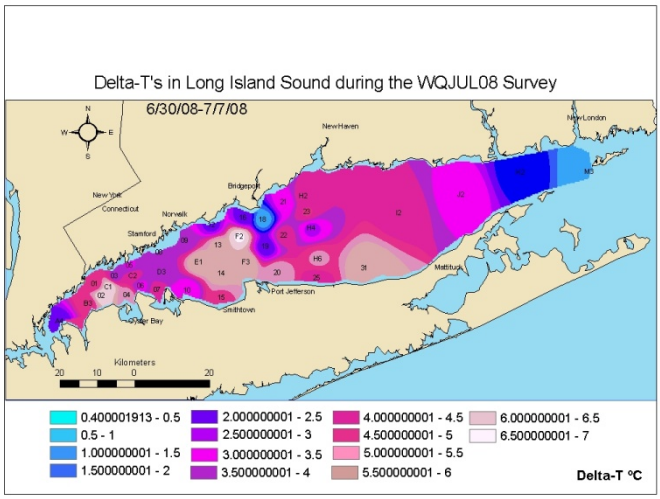
Sea surface temperature, or SST, is important to climate change. As SST increases, the polar ice caps decrease (melt), changing ecosystems around the world. The Long Island Sound Integrated Coastal Observing System (LISICOS) submits data to the National Data Buoy Center including temperature data. The data may be used to generate numerous products including sea surface temperature maps like the one pictured here. Usually, however, sea surface temperature images are obtained from an Advanced Very High Resolution radiometer sensor attached to a National Oceanic and Atmospheric Administration (NOAA) satellite.

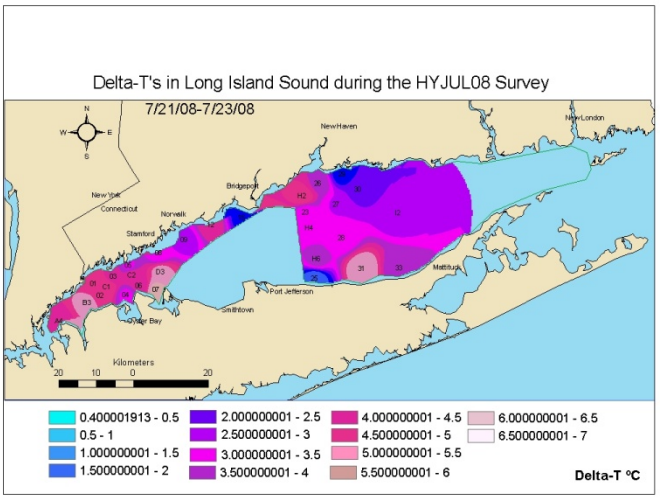
Delta T maps for the 2008 hypoxia season

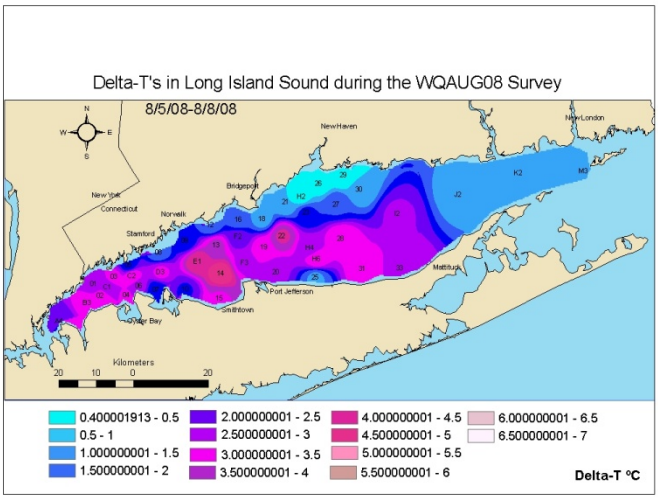


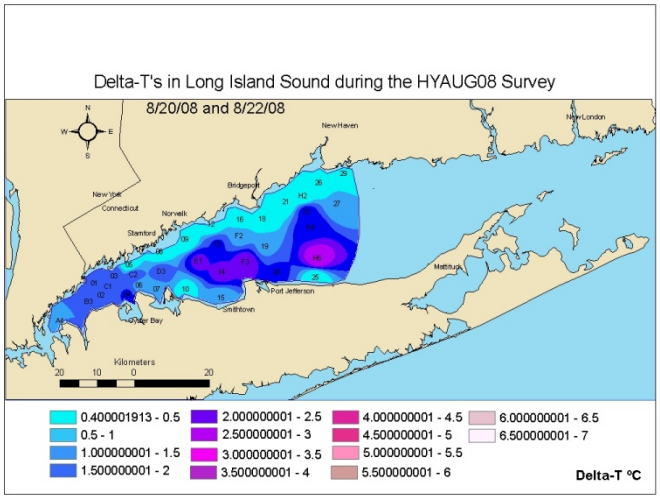


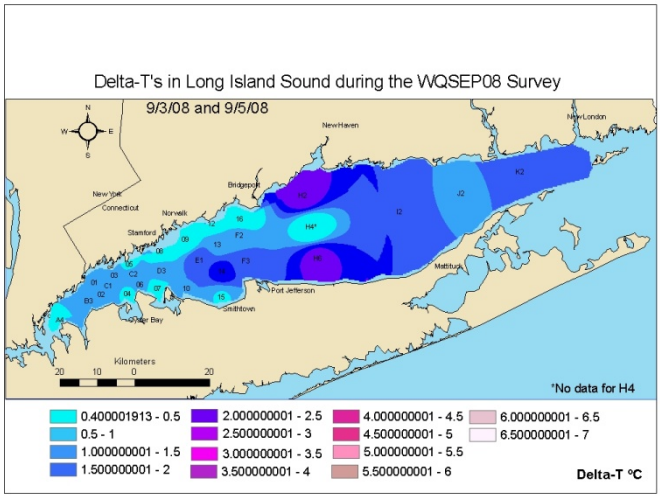


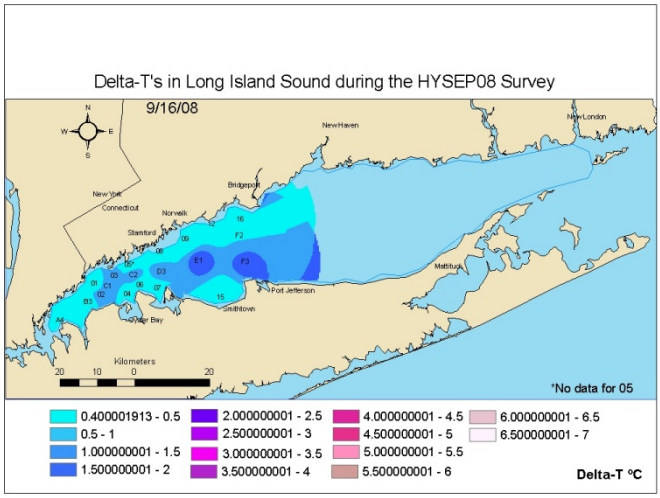










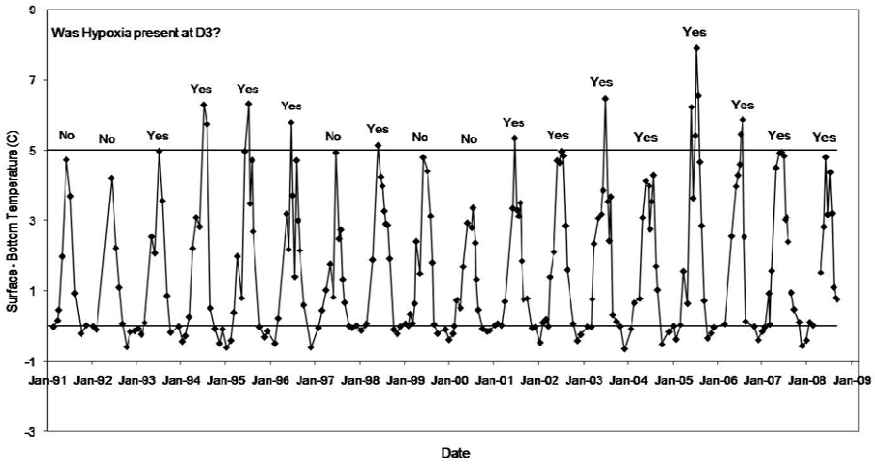


2008 Delta T maps (Cont.)

Year	Minimum Winter Temp (ºC)	Maximum Summer Temp (ºC)	Maximum ΔT (ºC)	Maximum Area of Hypoxia (km^2) DO<3.0 mg/L	Maximum Area of Hypoxia (km^2) DO<3.5 mg/L
1991	2.69	22.23	4.75	330	682
1992	1.86	20.89	4.83	224	504
1993	1.06	22.68	5.33	518	870
1994	-0.68	24.08	6.33	**1022**	**1330**
1995	0.95	23.78	6.33	790	1077
1996	-0.19	23.78	5.91	569	882
1997	1.87	21.81	4.96	77	132
1998	3.40	23.20	5.22	436	741
1999	2.67	23.41	5.51	314	594
2000	0.57	21.99	6.02	447	674
2001	1.67	23.20	5.38	344	559
2002	4.03	23.47	5.52	337	502
2003	-0.52	22.88	6.74	893	1115
2004	**-0.93**	23.09	4.33	523	667
2005	0.53	25.10	**8.19**	459	778
2006	2.17	**25.11**	6.72	515	896
2007	0.83	23.03	5.12	419	917
2008	2.45	22.47	4.91	467	932

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. 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 ΔTmax, and 1994 had the largest area of hypoxia.

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.



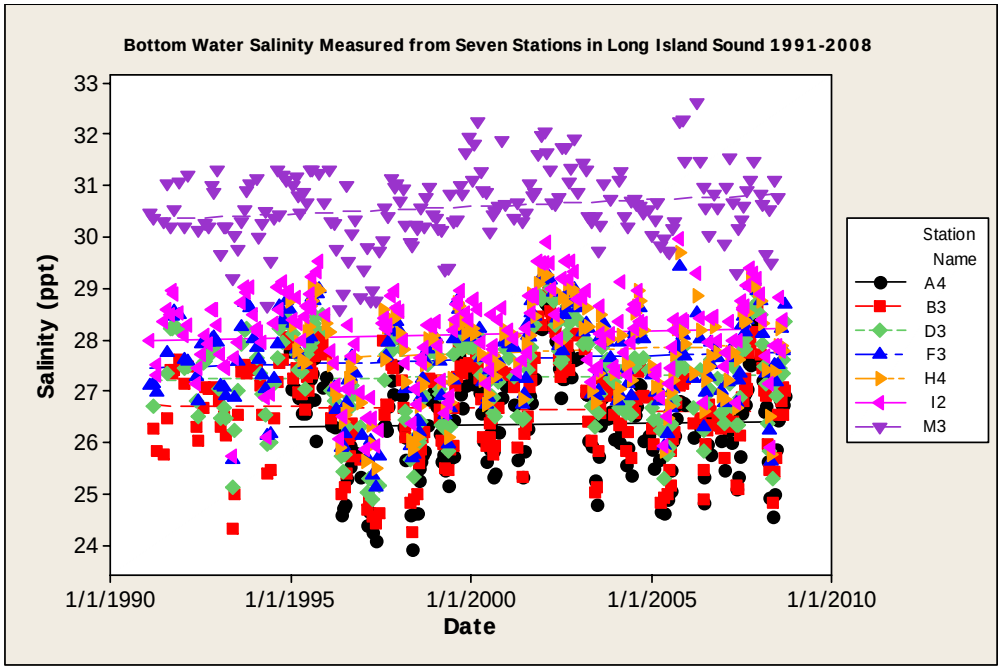
Time series of ΔT (surface water temperature - bottom water temperature) at station D3, 1991 through 2008.

Salinity

Salinity is a measure of the dissolved salts content of seawater. It is usually expressed in parts per thousand (ppt). Salinity levels across Long Island Sound vary from 23 ppt in the Western Sound at Station A4 to 35 ppt 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 from 1991-2008 are presented in the tables below. Data collected this year are also presented separately.

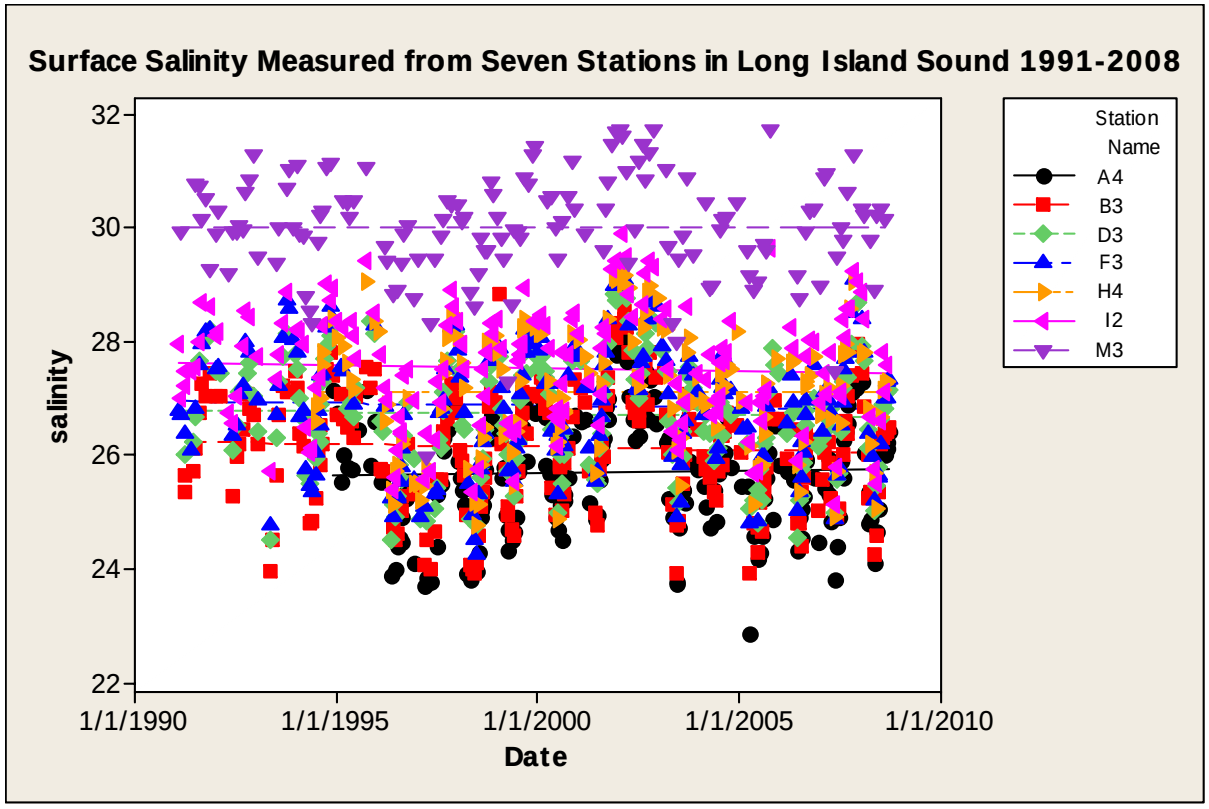
	1991-2008 Bottom Water Statistics							
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard deviation	Variance
A4	207	23.955	28.727	26.38	26.424	0.0666	0.945	0.893
B3	250	24.259	28.926	26.672	26.691	0.0609	0.942	0.887
D3	246	24.912	29.215	27.294	27.437	0.0589	0.893	0.797
F3	239	25.153	29.432	27.637	27.732	0.0595	0.875	0.765
H4	187	25.508	29.7	27.79	27.915	0.0655	0.871	0.758
I2	223	25.762	29.985	28.116	28.29	0.0595	0.856	0.733
M3	195	28.608	32.622	30.604	30.6	0.0541	0.729	0.532

	2008 Bottom Water Statistics							
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard deviation	Variance
A4	15	24.593	27.707	26.34	26.742	0.235	0.911	0.83
B3	15	24.83	27.746	26.512	26.84	0.216	0.835	0.698
D3	15	25.308	28.519	27.229	27.379	0.222	0.86	0.74
F3	12	25.642	28.772	27.585	27.672	0.264	0.916	0.839
H4	10	25.785	28.721	27.611	27.845	0.281	0.888	0.789
I2	10	25.913	28.899	27.898	27.909	0.277	0.877	0.77
M3	7	29.503	31.118	30.456	30.646	0.232	0.613	0.375



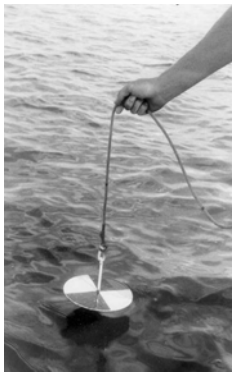
	2008 Surface Water Statistics							
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard deviation	Variance
A4	214	22.833	28.278	25.696	25.696	0.0731	1.023	1.047
B3	259	23.898	28.84	26.133	26.185	0.0697	1.05	1.102
D3	259	24.505	29.146	26.728	26.71	0.0697	1.029	1.06
F3	245	24.246	29.307	26.871	26.942	0.076	1.083	1.173
H4	195	24.747	29.262	27.112	27.207	0.0836	1.067	1.139
I2	227	25.117	29.909	27.542	27.65	0.0768	1.033	1.067
M3	197	25.958	31.758	30.011	30.03	0.0776	0.931	0.867

	2008 Surface Water Statistics							
Station Name	Count	Minimum	Maximum	Mean	Median	SE Mean	Standard deviation	Variance
A4	15	24.099	27.282	25.665	26.033	0.232	0.87	0.757
B3	15	24.246	27.453	25.95	26.251	0.236	0.885	0.782
D3	15	25.01	27.904	26.631	26.829	0.233	0.84	0.706
F3	12	25.186	28.381	26.65	26.69	0.282	0.976	0.952
H4	10	25.056	27.793	26.771	26.984	0.282	0.893	0.798
I2	10	25.486	28.88	27.144	27.099	0.38	1.14	1.3
M3	8	28.909	30.355	30.003	30.221	0.196	0.52	0.27



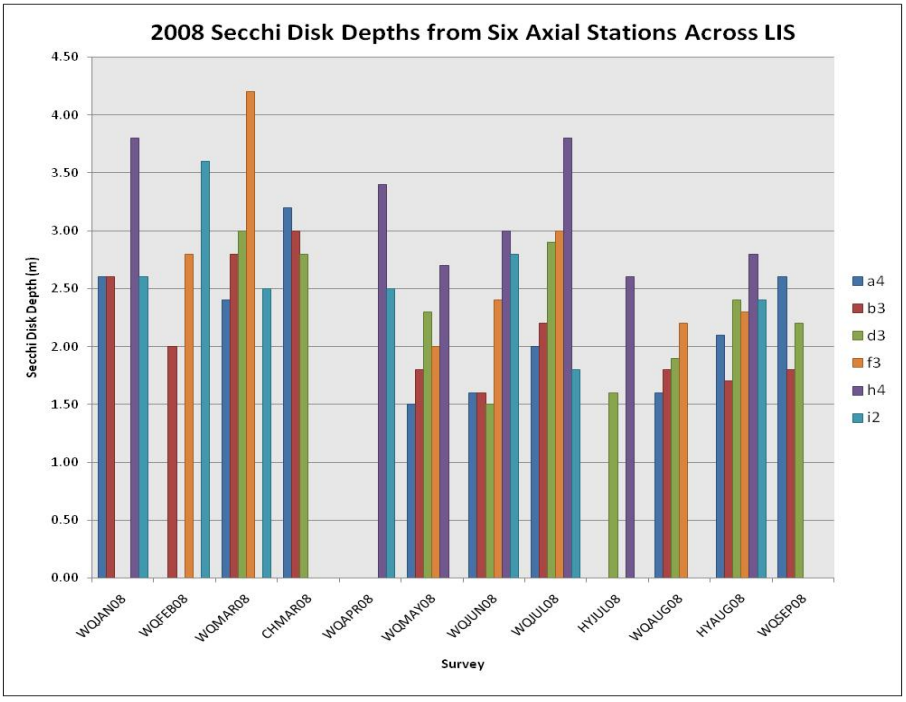
Water Clarity

A quick internet search revealed no readily accepted standard for Secchi disk depths in coastal waters. CT DEP has adopted criteria for Secchi disk depths in lakes during the summer growing season, but no standards for estuarine waters. The lakes criteria are dependent upon the trophic status of the lake and vary from 6 meters in oligotrophic lakes to 0-1 meters in highly eutrophic lakes.



CT DEP began taking Secchi Disk measurements in June 2000. Since then, 1560 measurements have been entered into our database; of those 888 are from the 17 stations sampled annually. The 2000-2007 average Secchi depth is 2.18 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 January and September 2008.



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: 5.0m at Station 15 during the WQMAR08 cruise and Station 23 during the WQJUL08 cruise**

Interesting Facts

⇒ Secchi disk depths were less than or equal to **1 meter** on 17 occasions, with the exception of WQMAR04, all occurred during the summer months (HYJUN00, WQAUG00, WQSEP00, WQJUN01, WQAUG01, WQSEP01, WQMAR04, HYAUG04, HYJUL05, WQAUG05, WQSEP05).

⇒ 793 of the 1560 measurements were less than or equal to **2 meters**

⇒ 922 measurements were between 2 and 6 meters

⇒ Only 1 measurement was greater than **6 meters**

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.

Additional information may be found on the CT DEP website at:
http://www.ct.gov/dep/lis