

US EPA ARCHIVE DOCUMENT

A Temporal and Spatial View of Intermittent Hypoxia in Narragansett Bay



By

Heather Stoffel & Susan Kiernan



Rhode Island Department of Environmental Management -Office of Water Resources

University of Rhode Island- Graduate School of Oceanography

Rhode Island, USA

March 19, 2009

Narragansett Bay Fixed-Site Water Quality Monitoring Network

• **Agencies:** RIDEM-OWR, URI/GSO, NBC, NBNERR, & NBEP

• **13 Site Locations:**

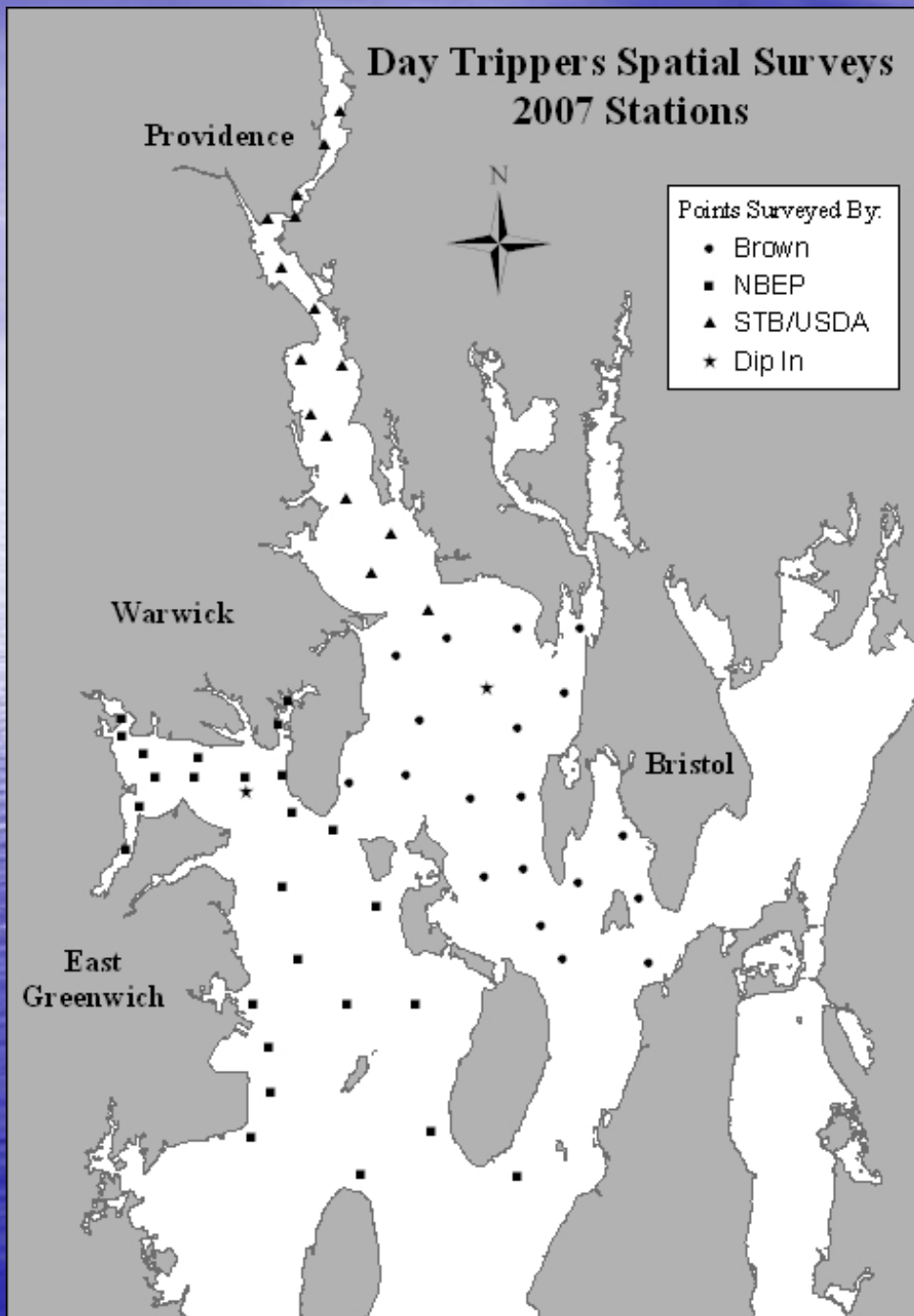
- West Passage (NP, MV, QP, GSO)
- East Passage (PP, PC, TW)
- Providence River (BR, CP)
- Seekonk River (PD)
- West Greenwich Bay (GB, SR)
- Mt. Hope Bay (MH)

• **Monitoring Season:** buoy stations (May-Oct) & land-based stations (year round)

• **Funding:** NOAA Bay Window Program, EPA Clean Water Act (sections 319 & 106), & NBC



Day Trippers



- Season of the spatial DO surveys associated with the CHRP project.
- These surveys target neap tide intervals during the summer months (June-September) to provide snapshots of water column properties (T,S, density, DO, chlorophyll, and turbidity).
- Sample profiles at more than 70 stations using Sea-Bird SBE 19 Plus SEACAT at High resolution (sample rate= 0.25 sec/m)
- Three boats and three instruments are used for these surveys.

Data Collection



Day Trippers

Temperature
Salinity
Dissolved Oxygen
pH (NBFSMN Only)
Chlorophyll



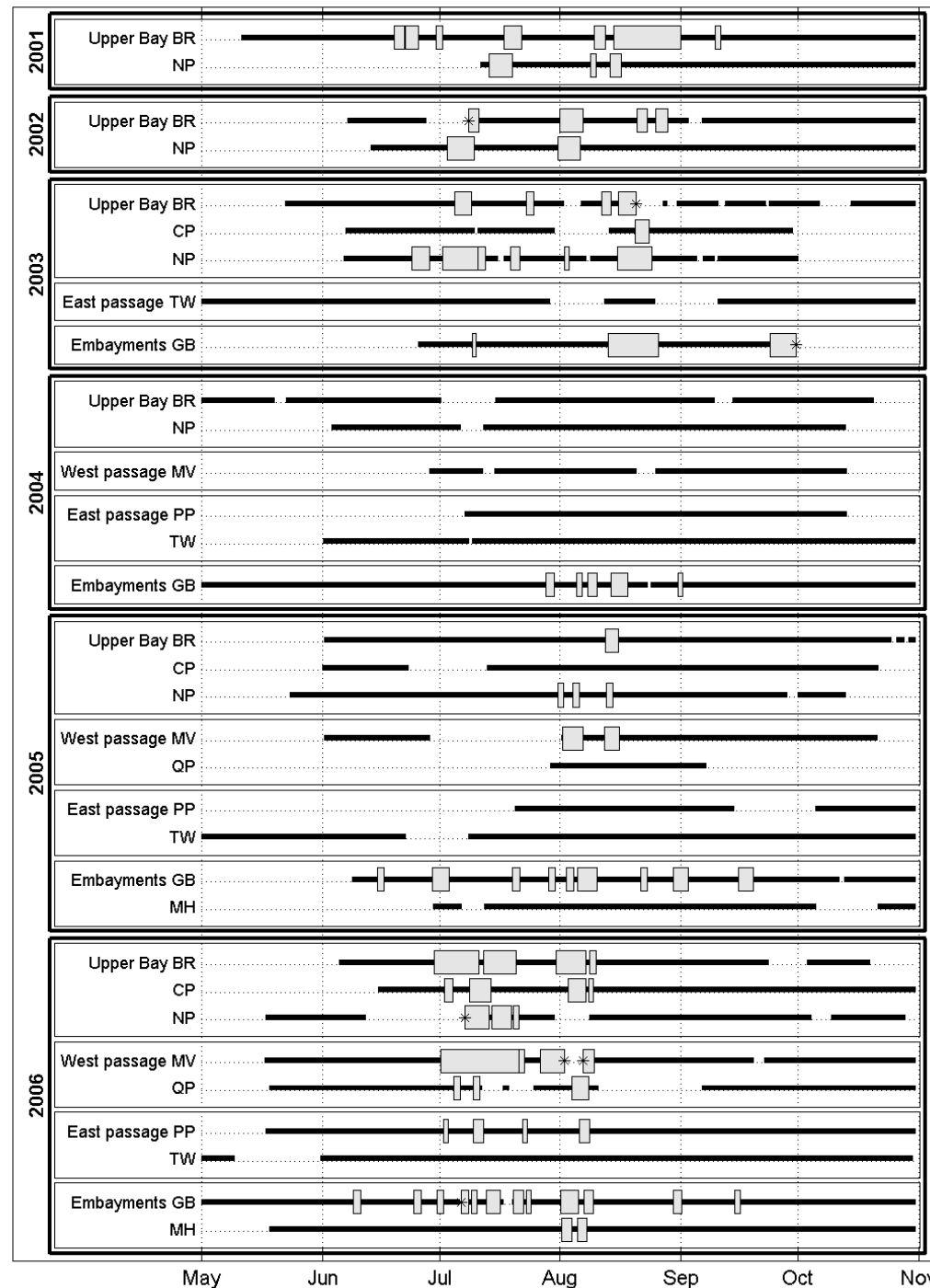
NBFSMN



Event Finder* Results:

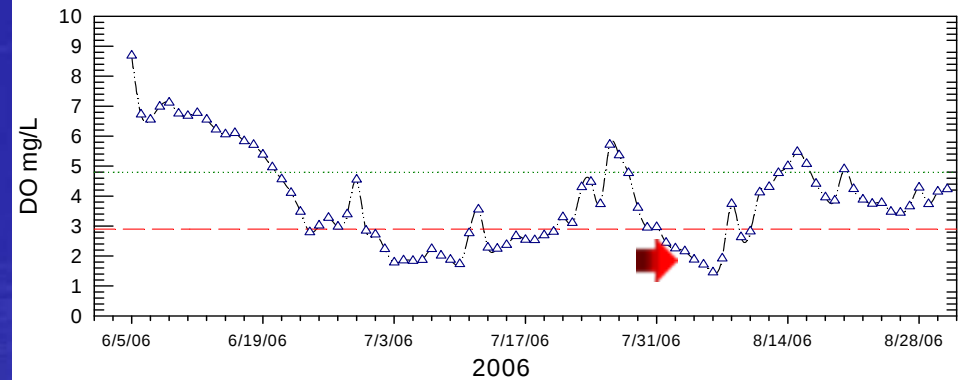
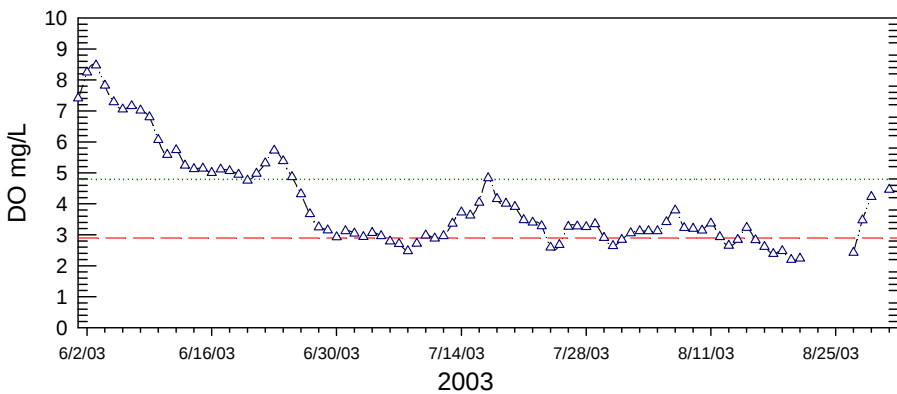
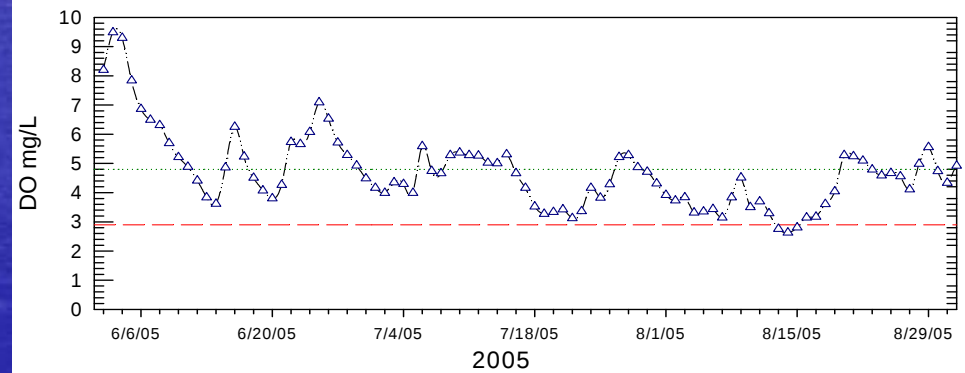
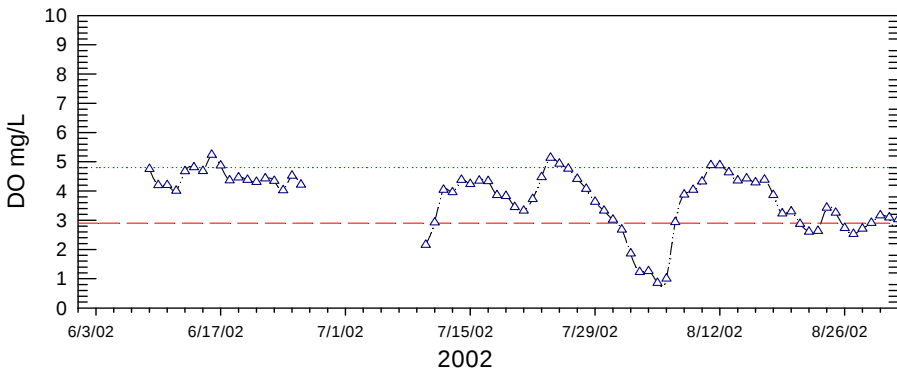
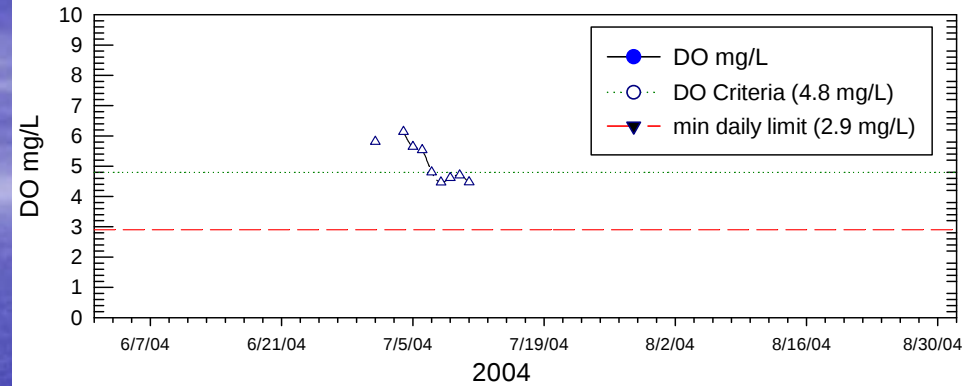
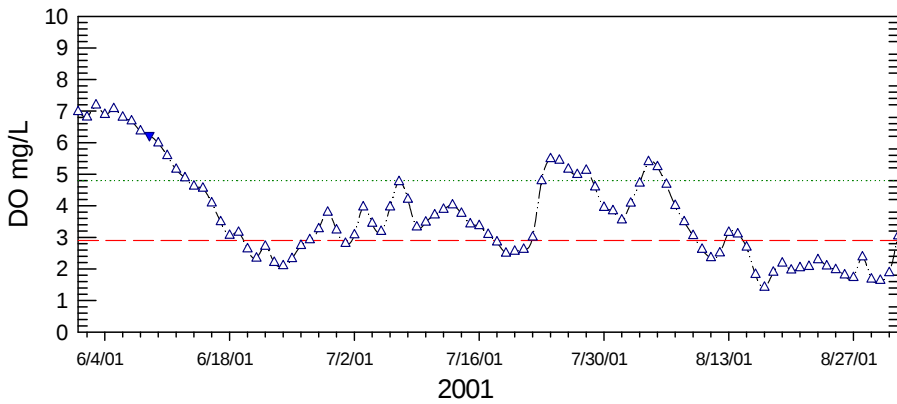
1. Providence River, Upper Bay, Upper East & West Passages experience hypoxia 0-7 events annually. Events are not always bay wide. Individual event durations range from 1-10 days.

2. Greenwich Bay is experiencing more variability (intensity & duration) Experiencing hypoxia during low risk years.

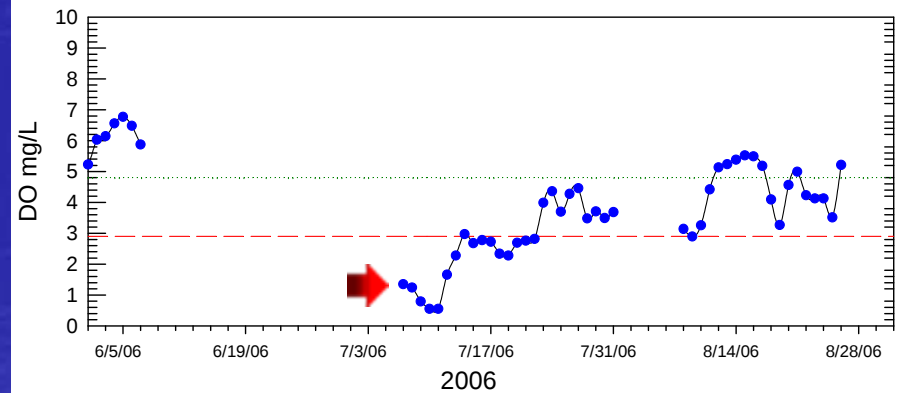
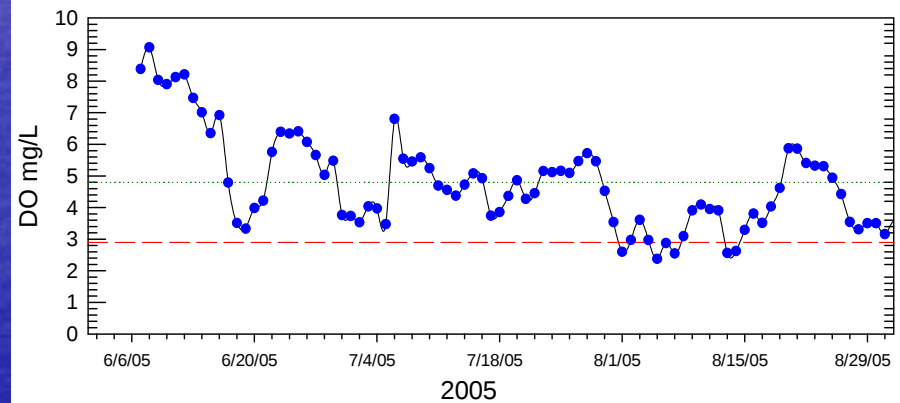
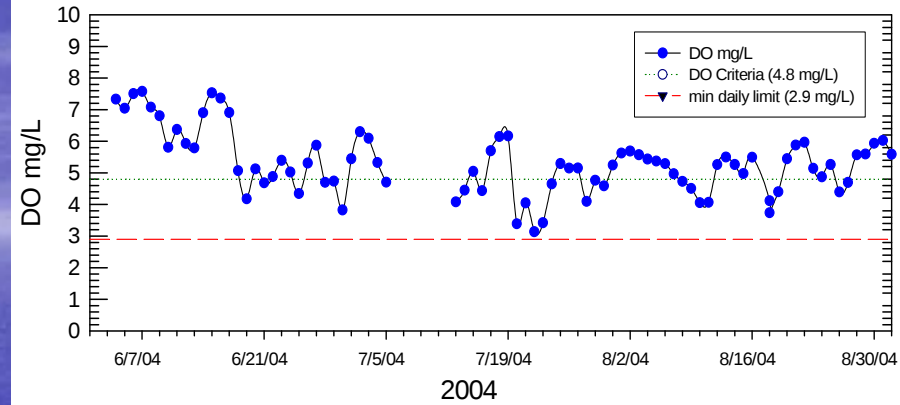
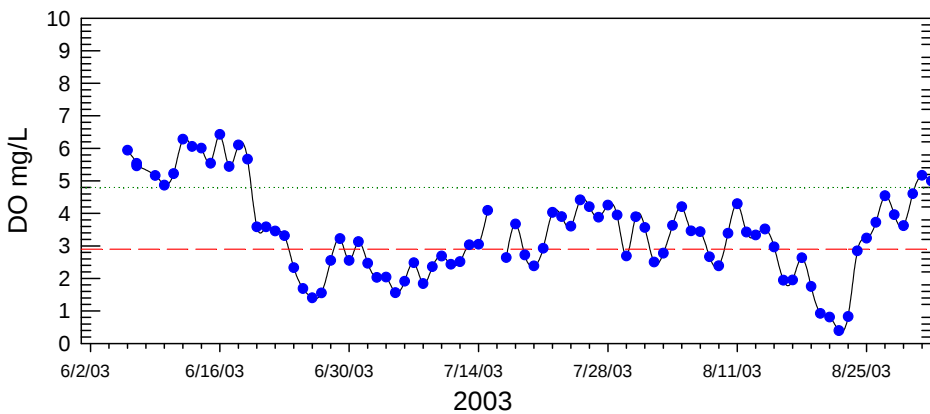
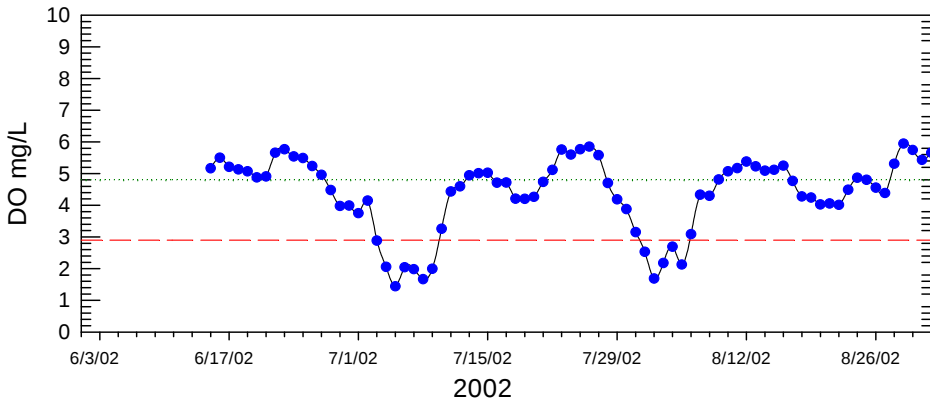
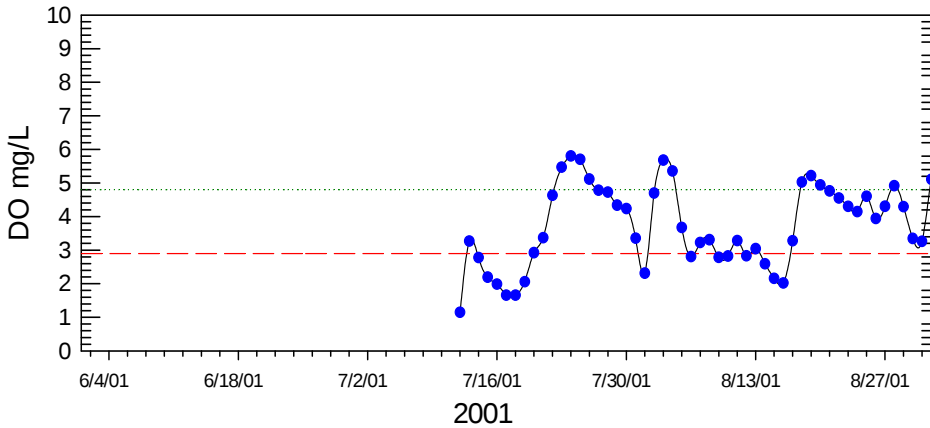


* (Codiga, D., 2008)

Bullock Reach Bottom Oxygen Levels: 2001-2006

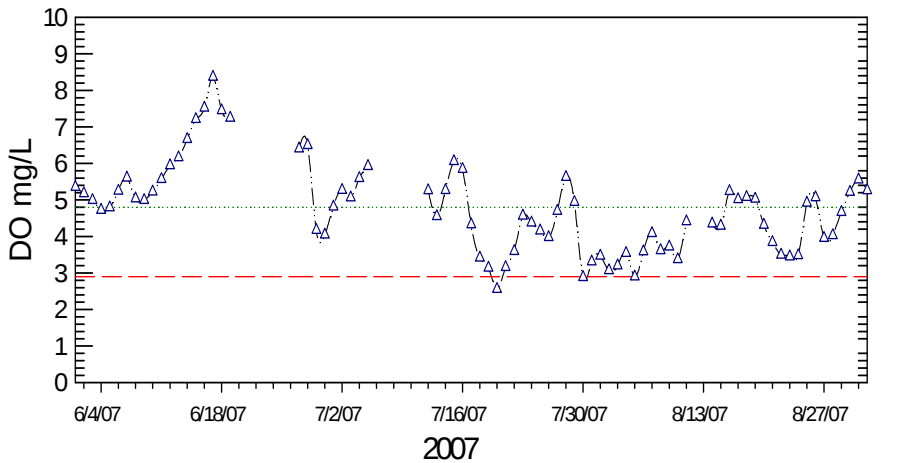


North Prudence Bottom Oxygen Levels: 2001-2006

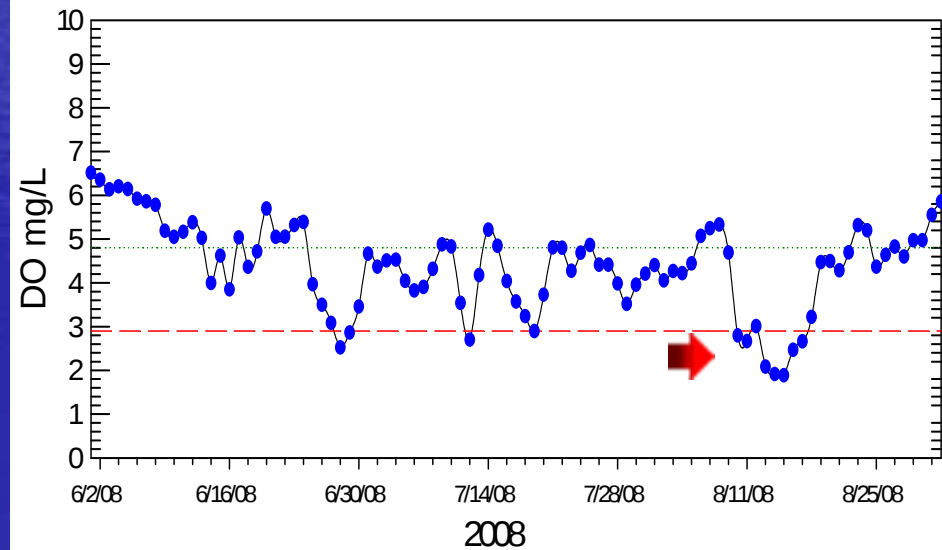
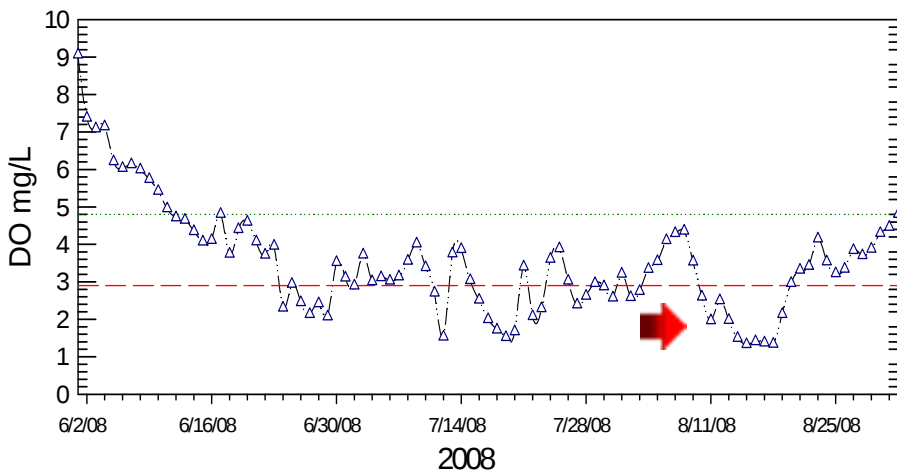
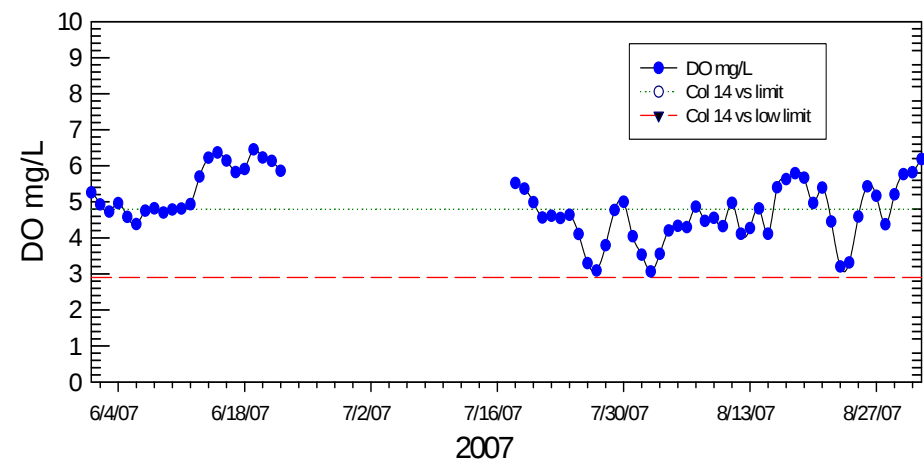


Bullock Reach & North Prudence: 2007-2008

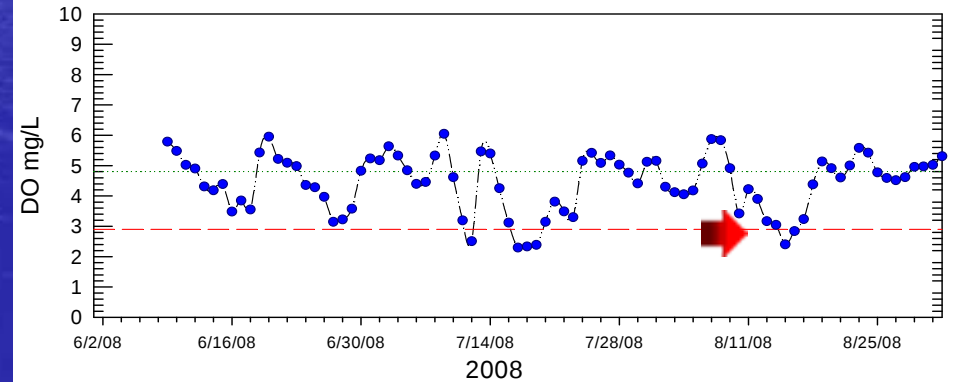
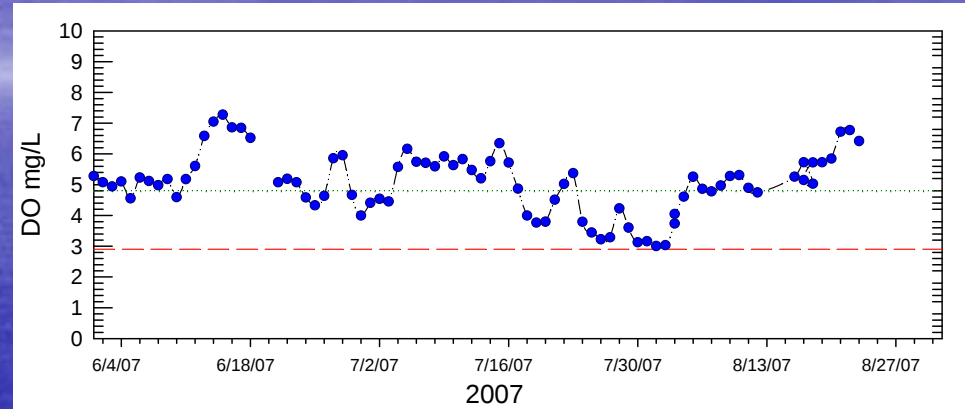
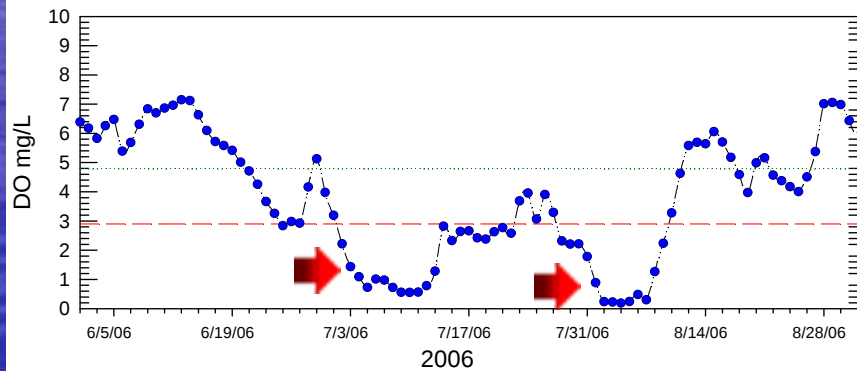
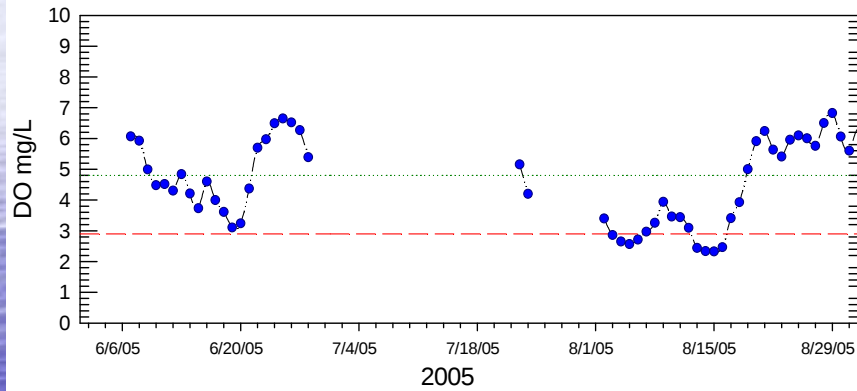
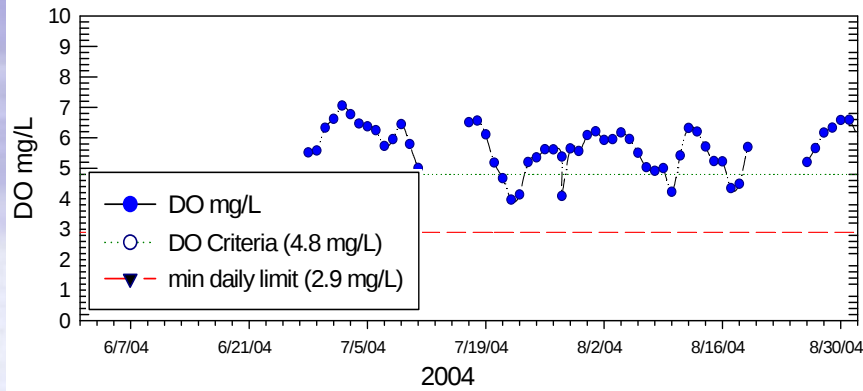
Dissolved Oxygen at Bullock Reach Bottom: 2007-2008



Dissolved Oxygen at North Prudence Bottom 2007-2008

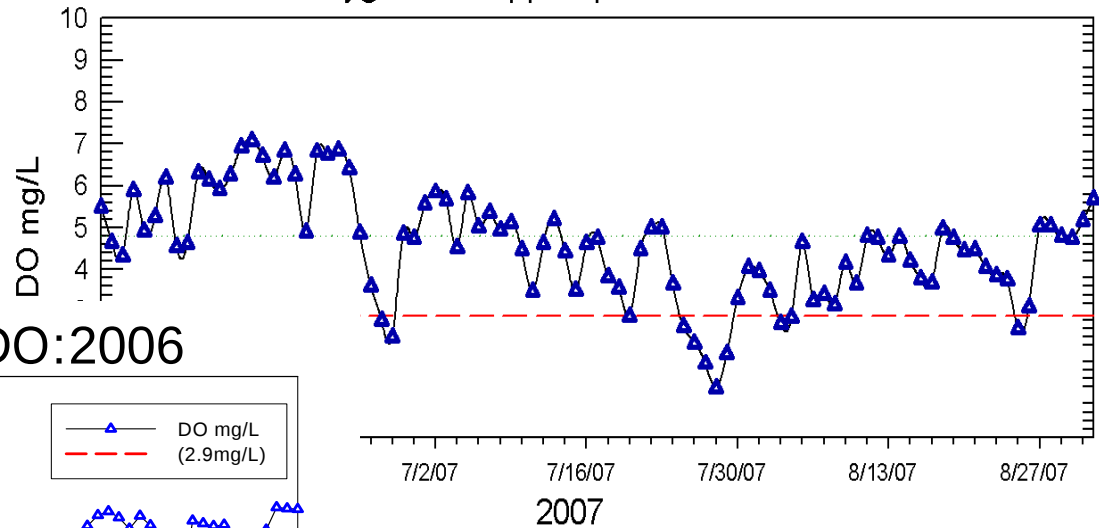


Mt. View Bottom Oxygen Levels: 2004 –2008

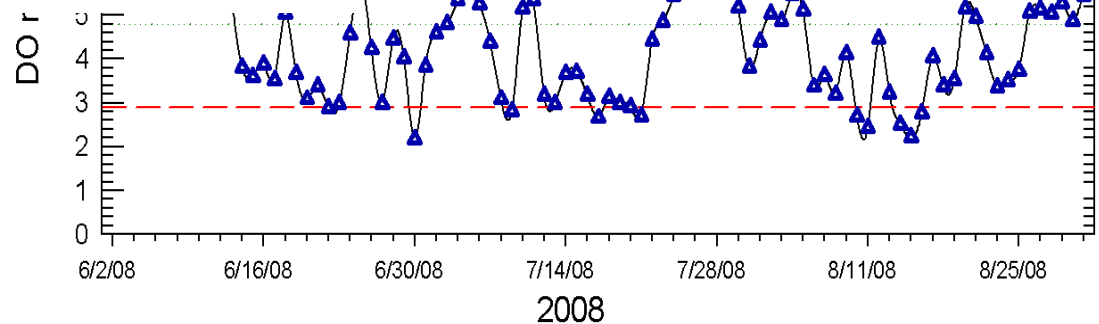
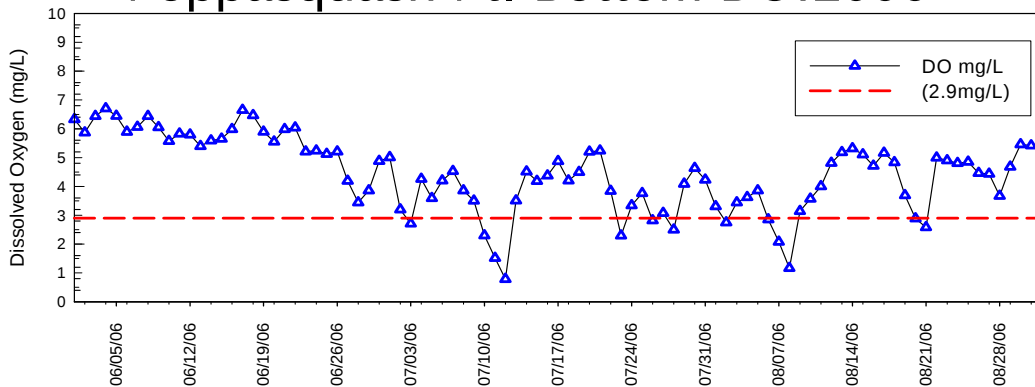


Poppasquash Pt. Bottom Oxygen Levels

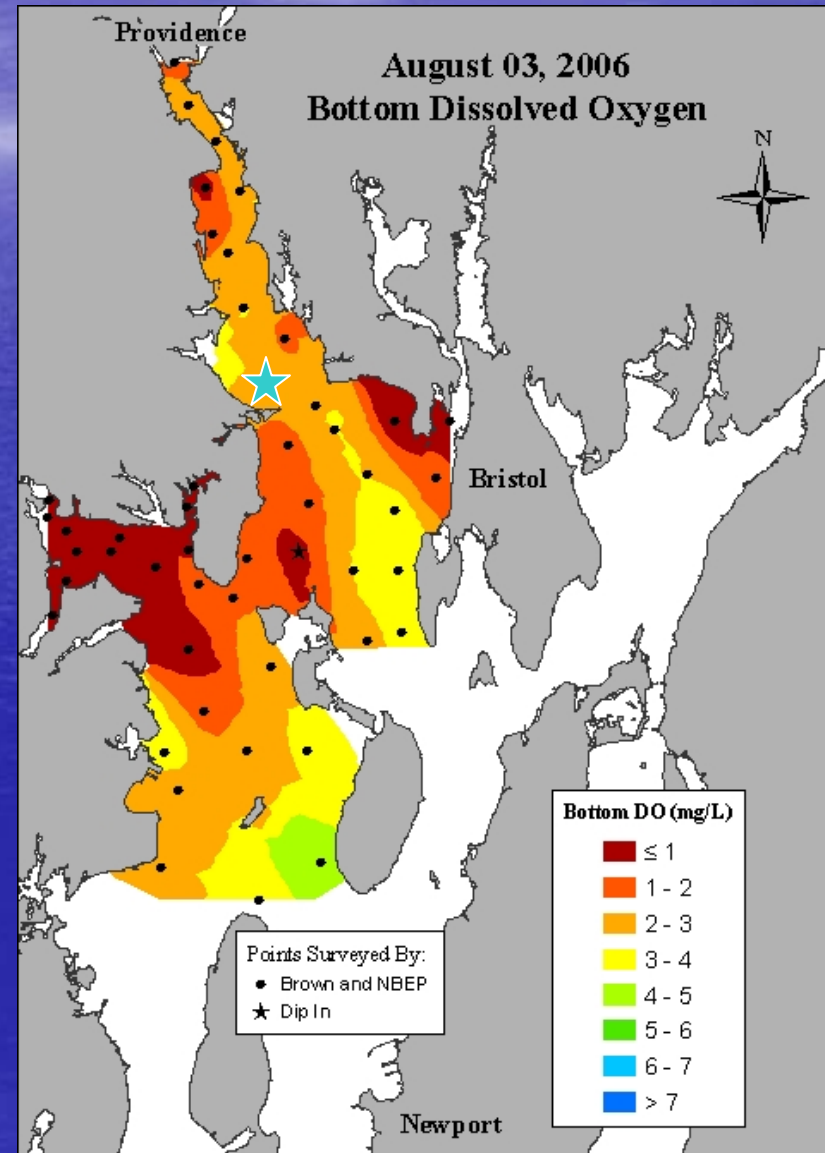
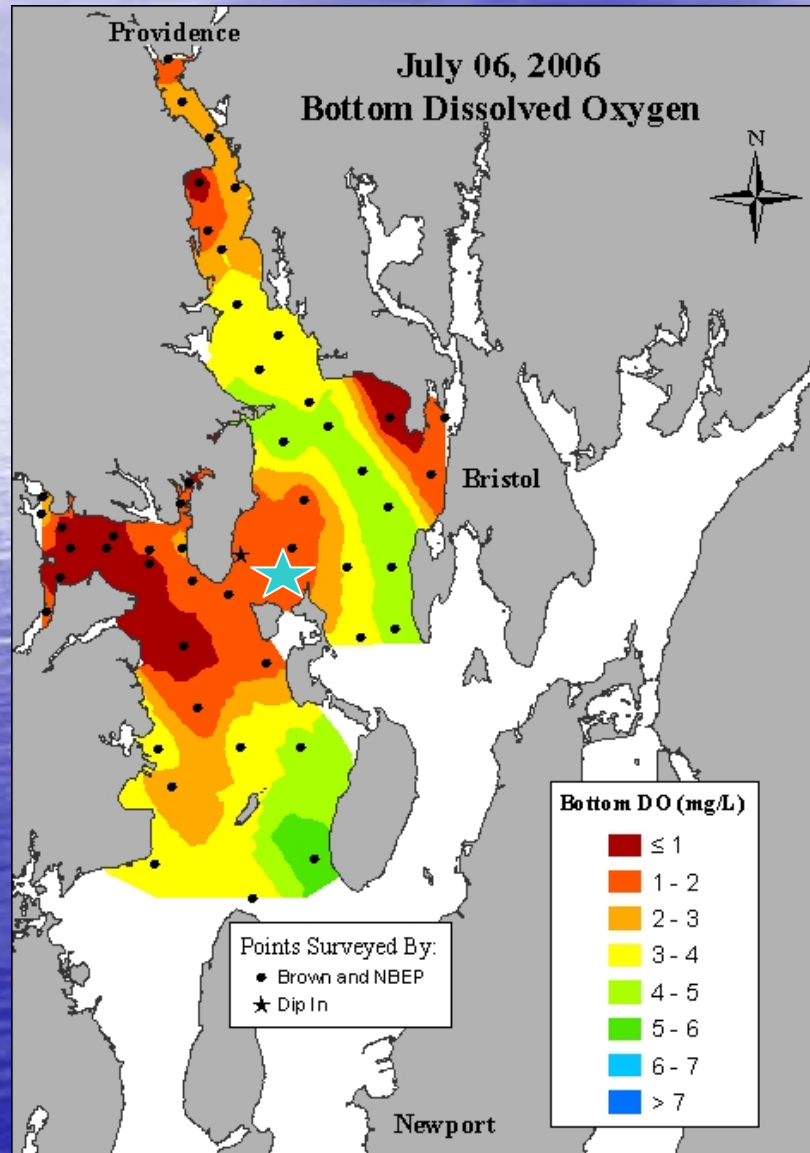
Dissolved Oxygen at Poppasquash Pt. Bottom: 2007-2008



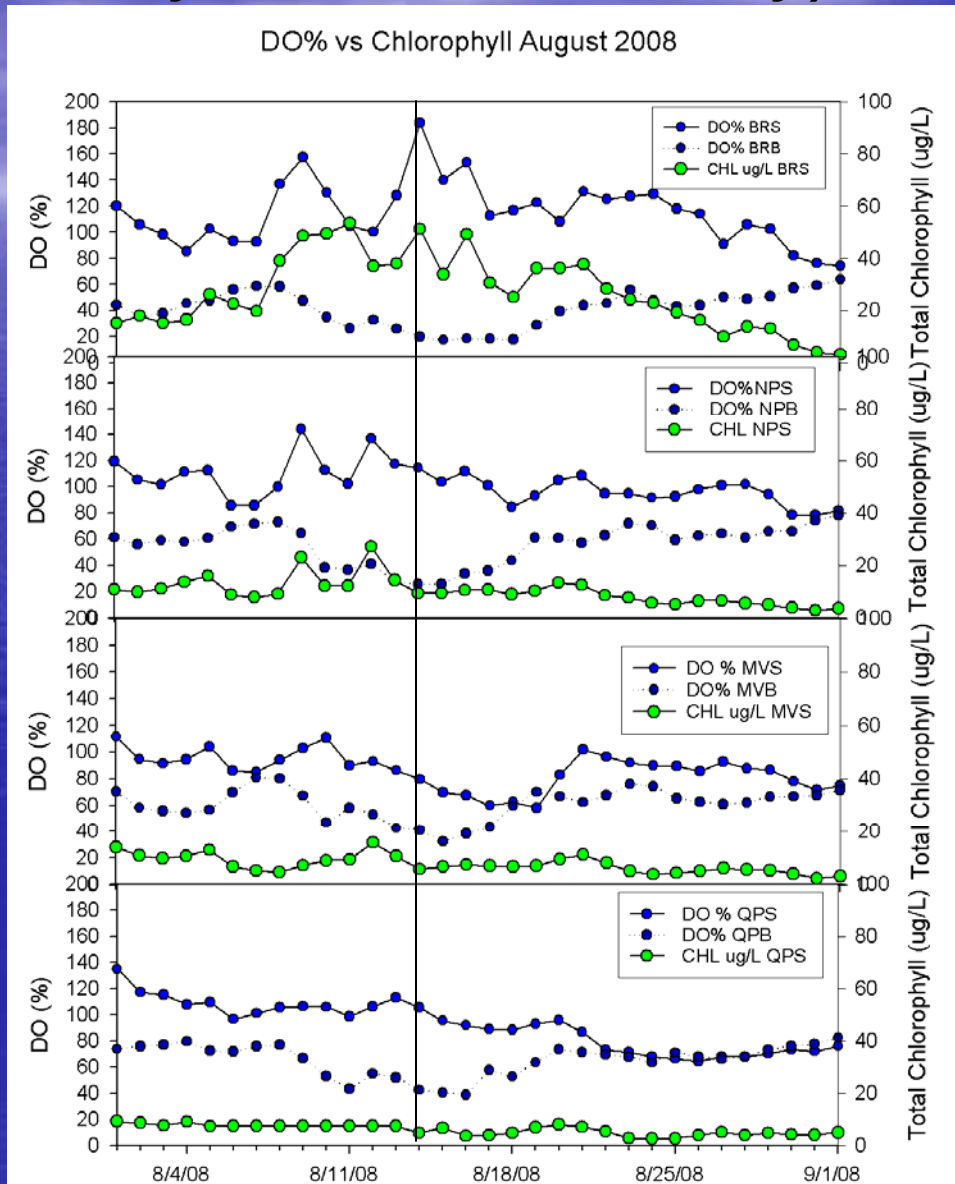
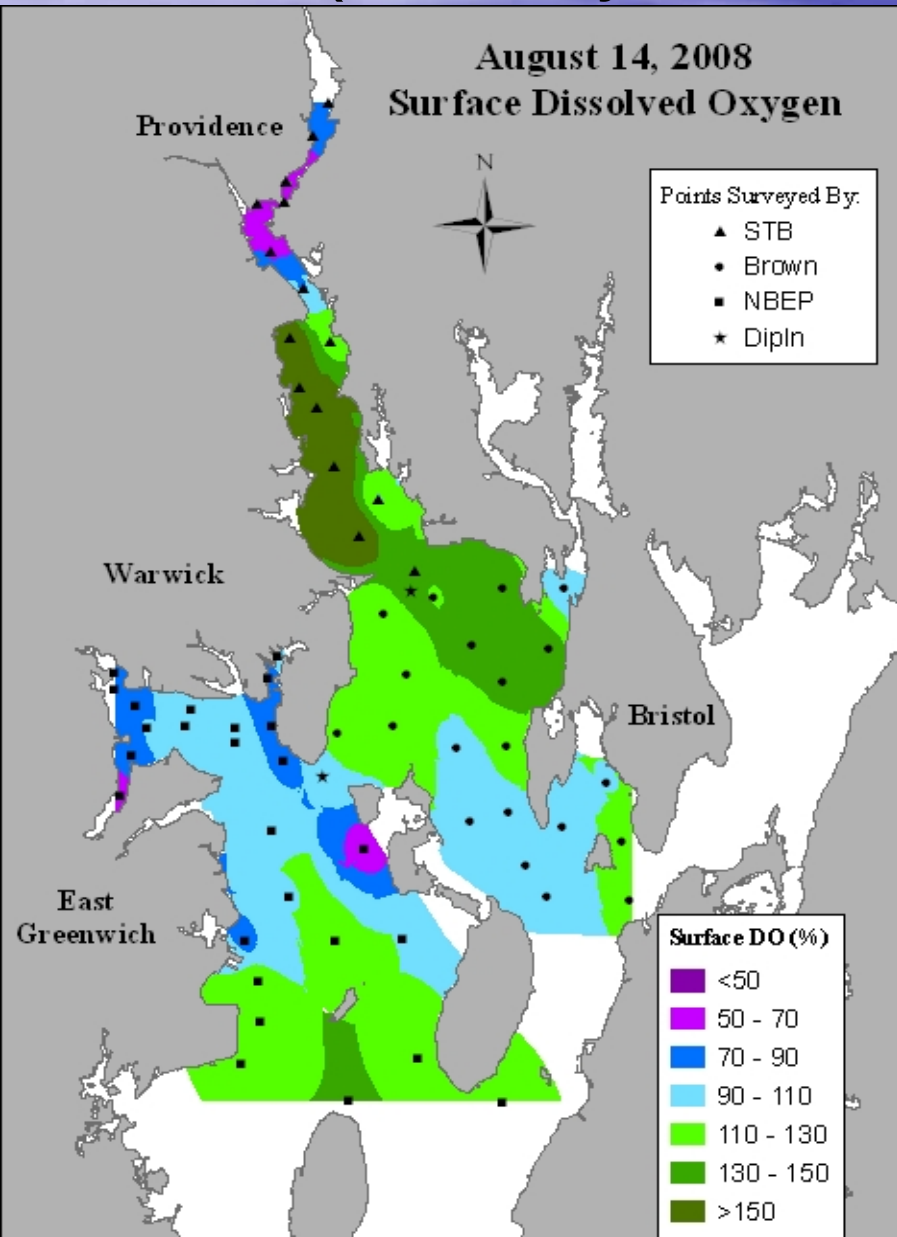
Poppasquash Pt. Bottom DO:2006



Spatial Extent of Hypoxia through Day Tripper Surveys: 2006

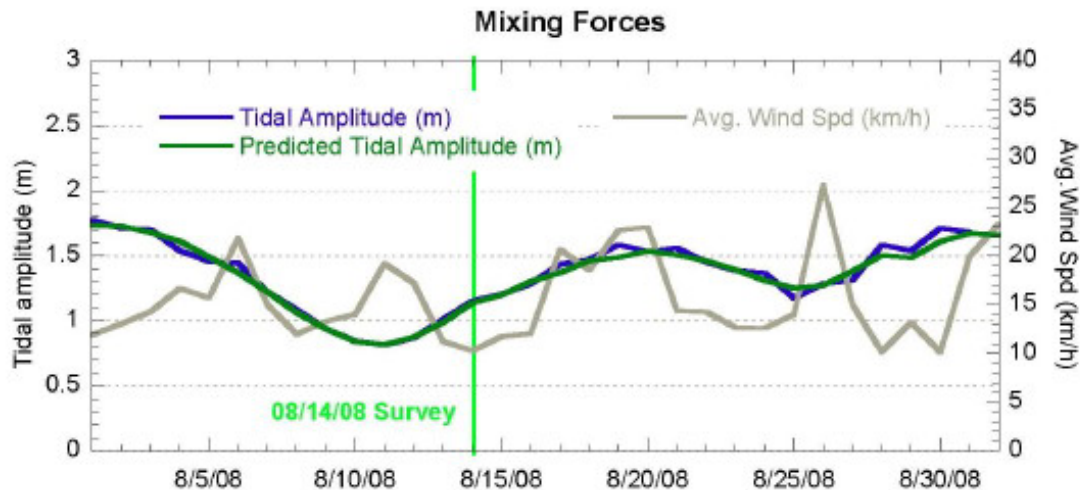
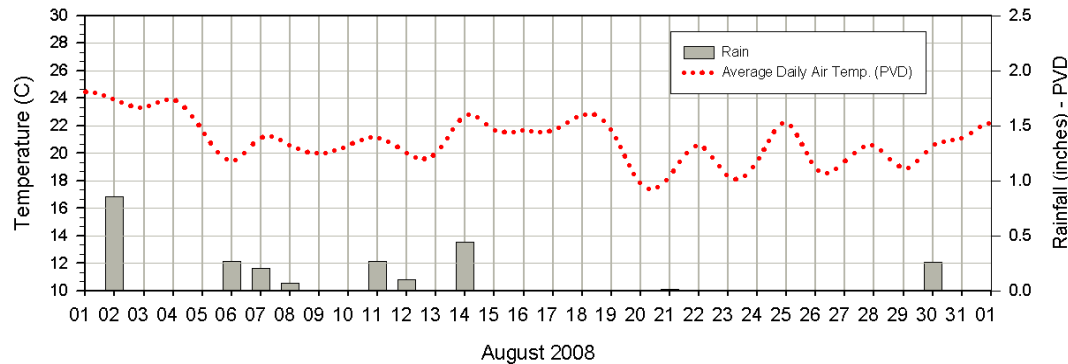


Spatial Extent of Hypoxia through Day Tripper Surveys: 2008 (Courtesy of Dave Murray, Brown University)



August 2008 Bottom Dissolved Oxygen (Bullock's Reach) and Mixing Forces

Air Temperature & Rainfall Data August 2008



Forcing Factors on Hypoxia

Stratification

- river flow
- temperature

Winds

- low winds=low mixing

Tidal Amplitude

- low tidal range= higher hypoxia risk

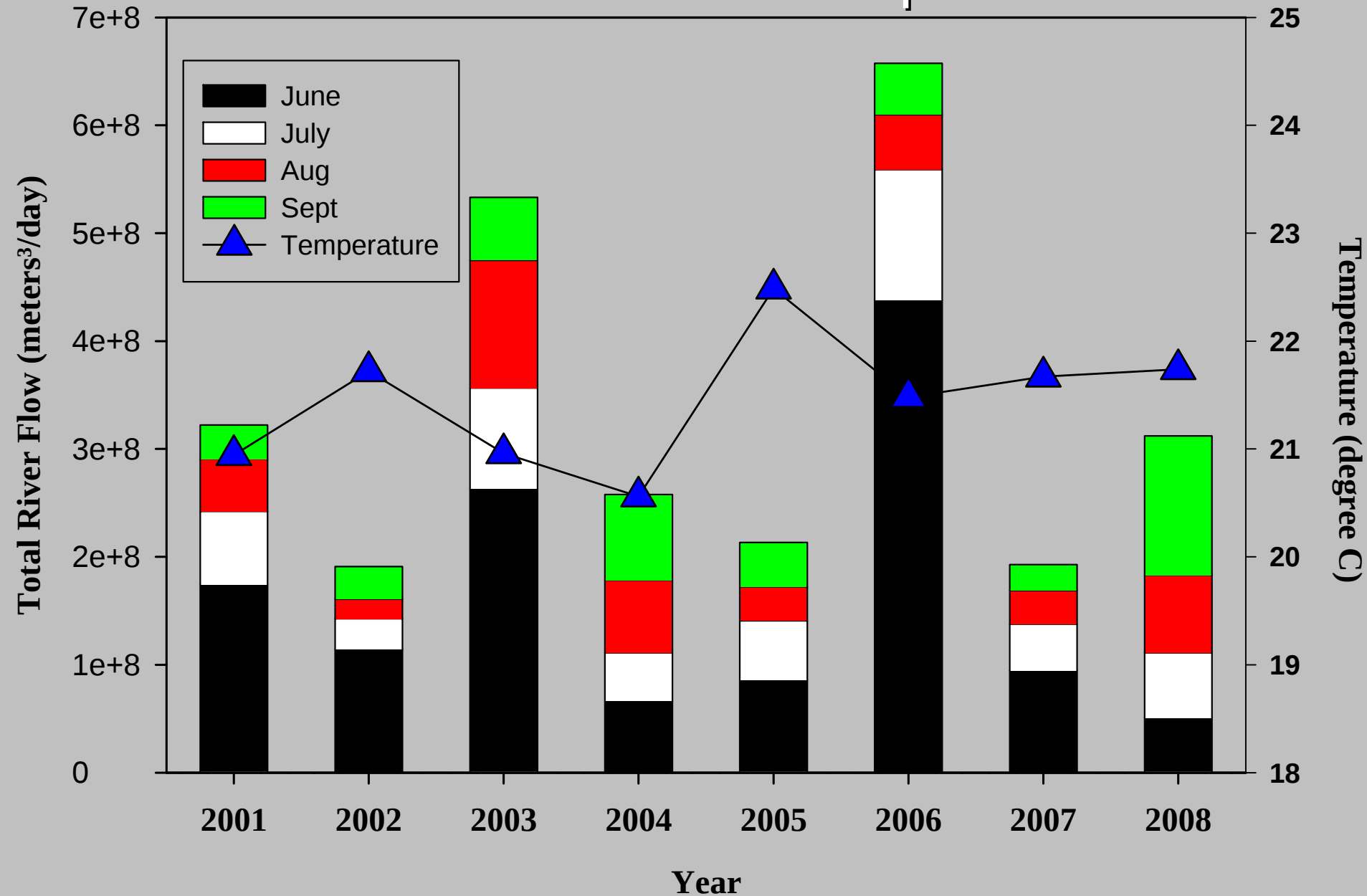
Chlorophyll Levels

- bloom events

Summary of low DO throughout the Upper Bay using Hypoxia event Finder Method on Temporal Data

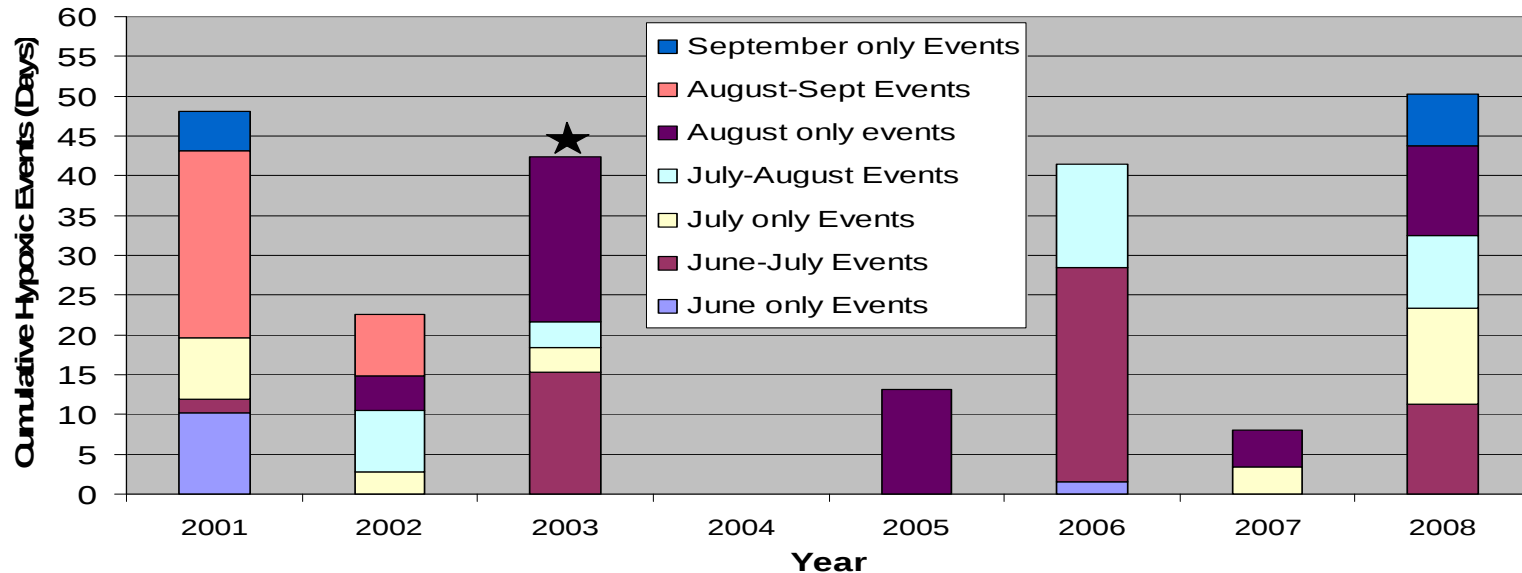
1. Hypoxia has been documented primarily in the Upper Bay, from the Seekonk River to Quonset Pt in the West Passage, and to Poppasquash Point in the East Passage. Greenwich Bay experiences severe and highly variable seasonal hypoxia.
2. Late spring/early summer river flows strongly influence stratification intensity throughout Upper Bay.
3. Inter-annual variability in hypoxia is linked to inter-annual variability in flow and temperature. High flow and/or warm years produce longer durations during hypoxic events.

Seasonal Flow & Temperature

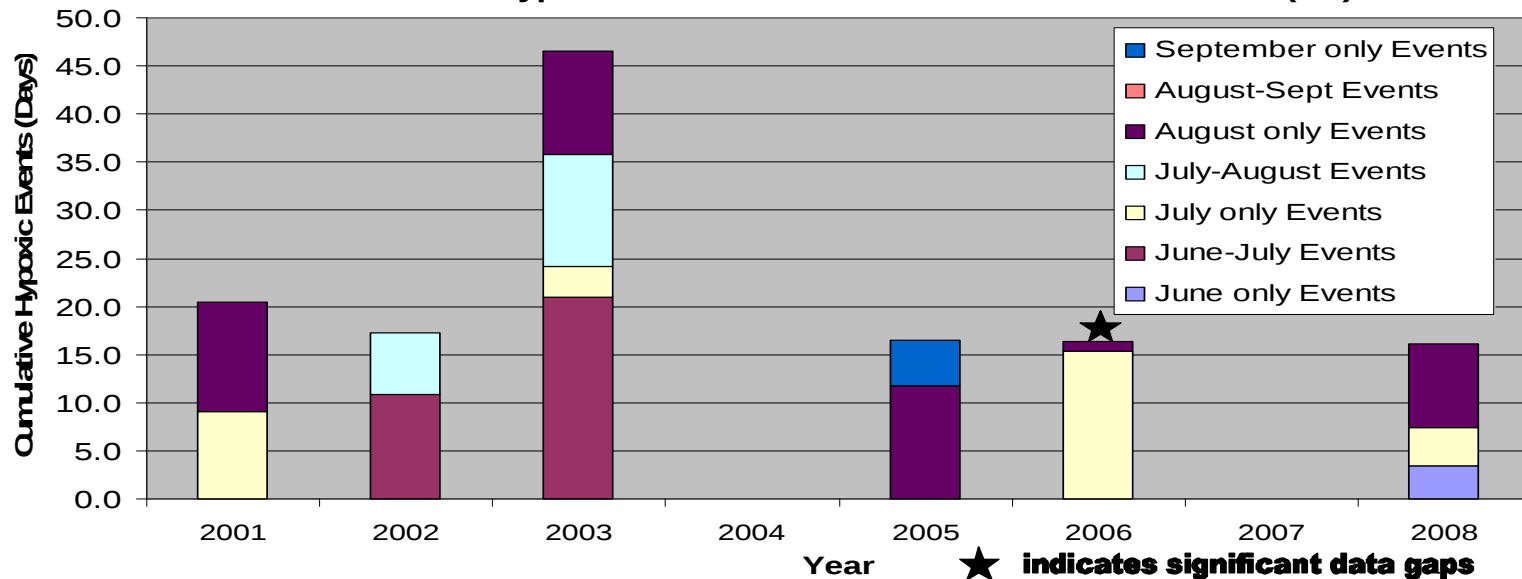


Ranked Hypoxia Seasons

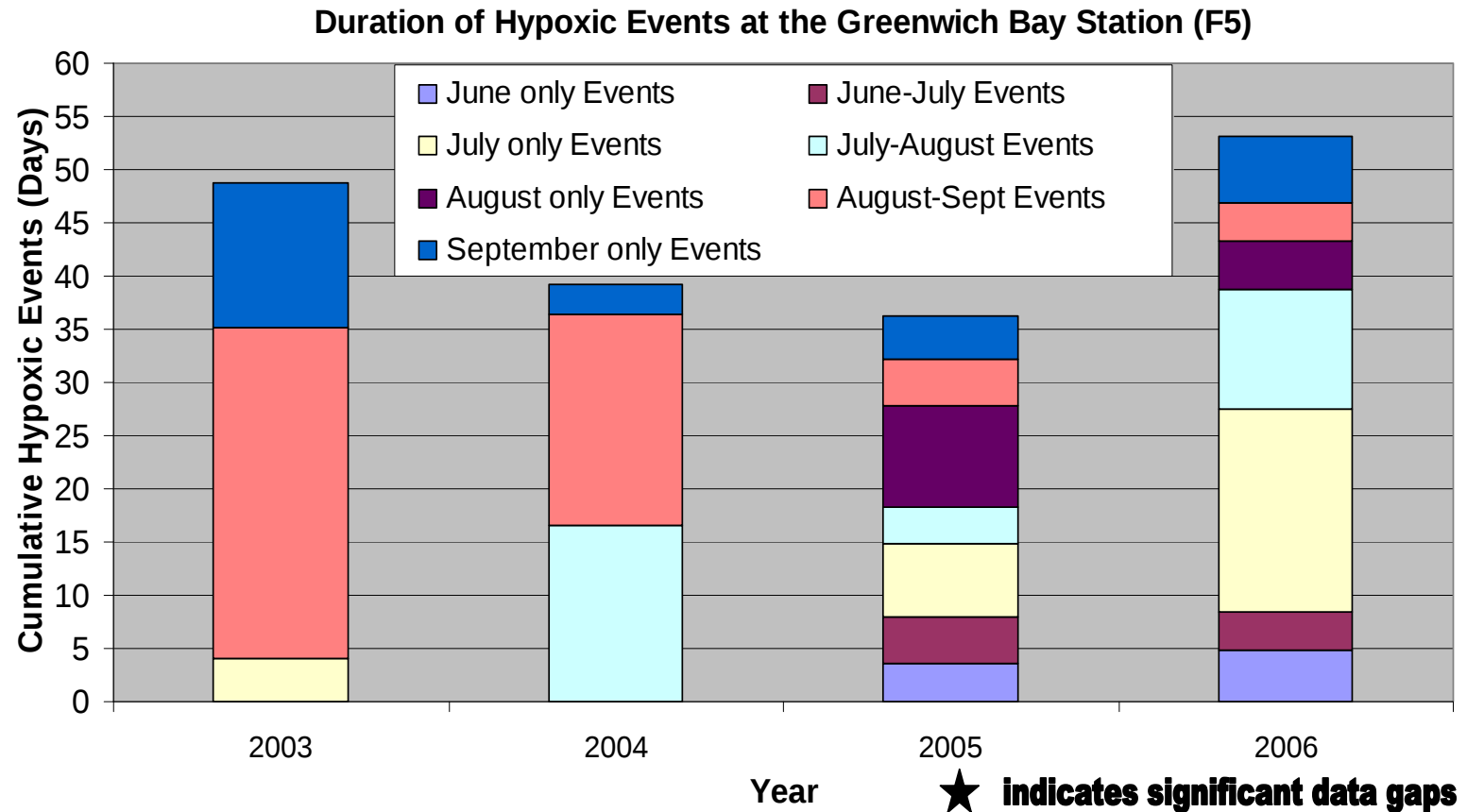
Duration of Hypoxic Events at the Bullock Reach Station (B4)



Duration of Hypoxic Events at the North Prudence Station (B2)



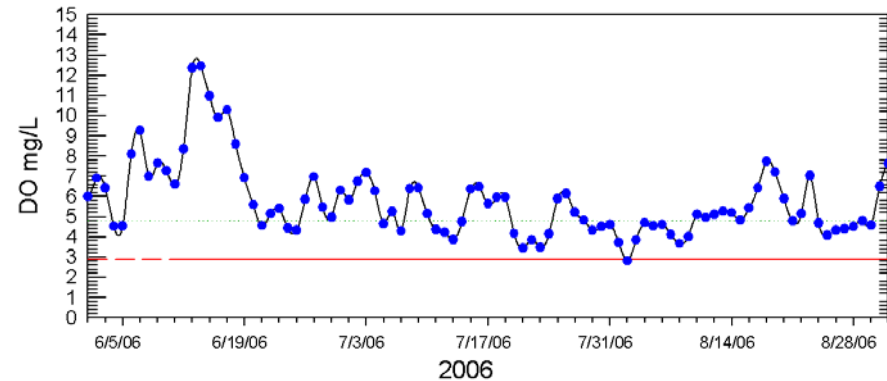
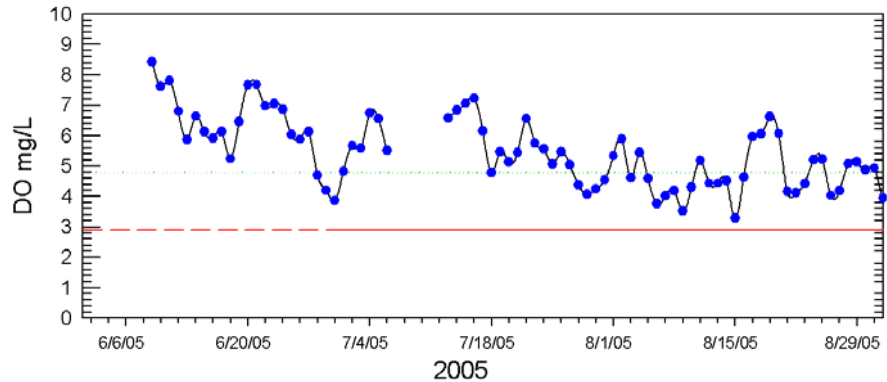
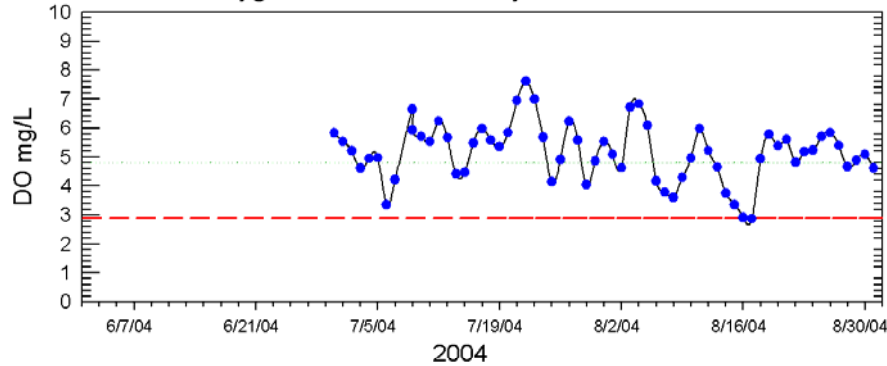
Greenwich Bay Annual Hypoxia



Greenwich Bay Dissolved Oxygen Data: 2004-2006

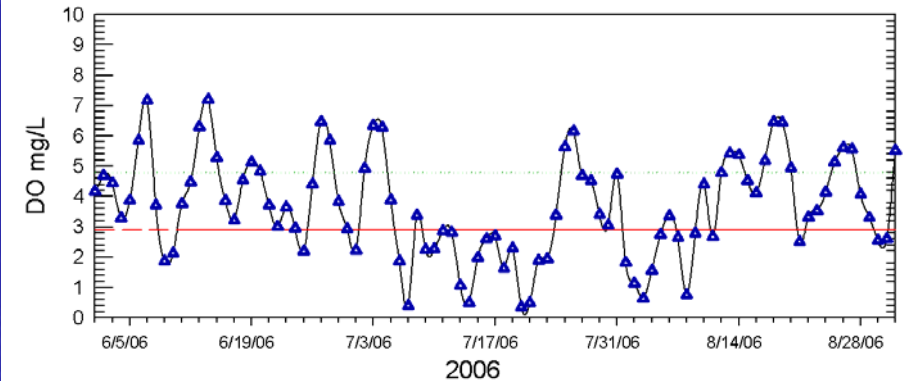
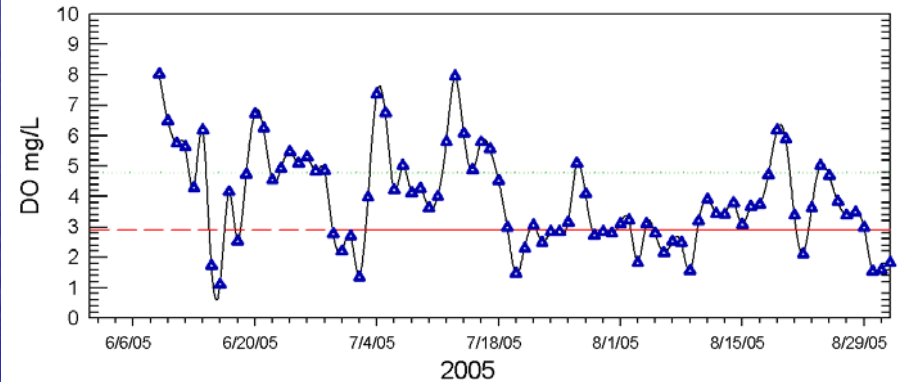
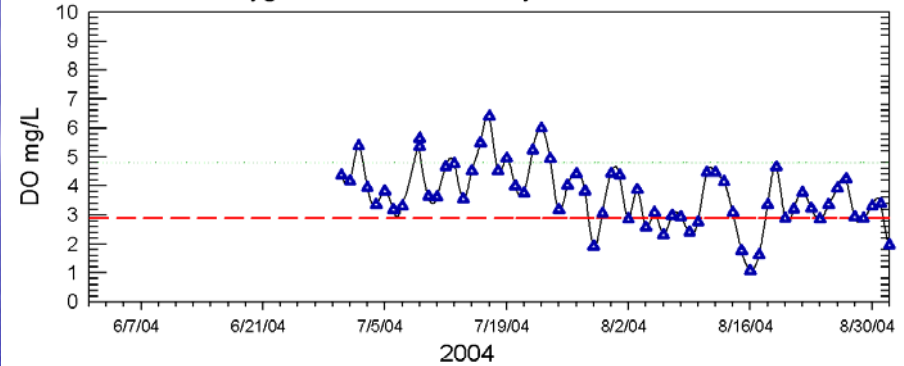
Surface

Dissolved Oxygen at Greenwich Bay Marina Surface: 2004-2006



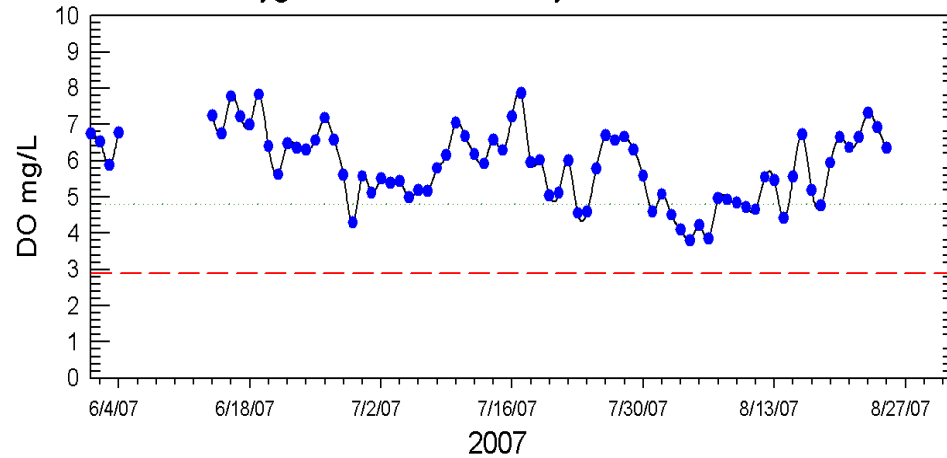
Bottom

Dissolved Oxygen at Greenwich Bay Marina Bottom: 2004-2006

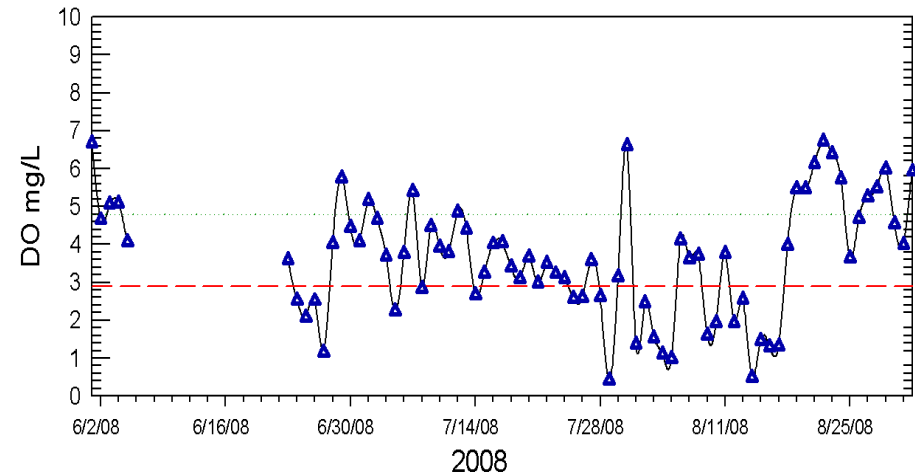
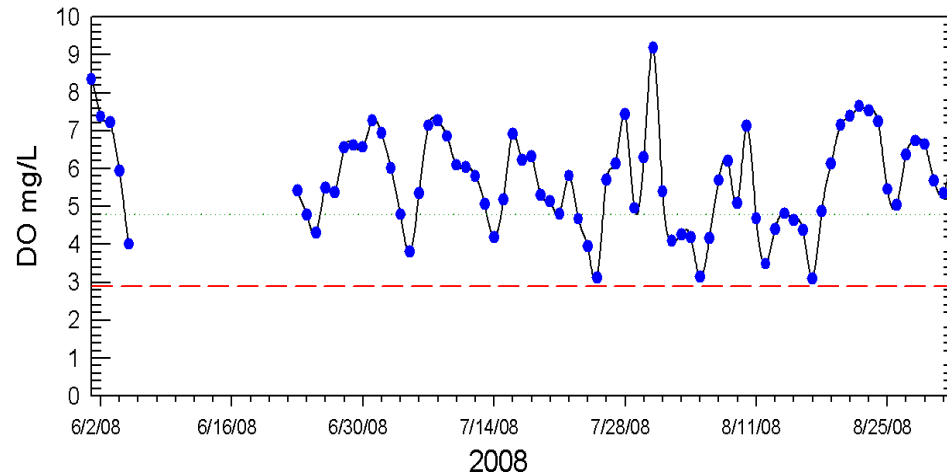
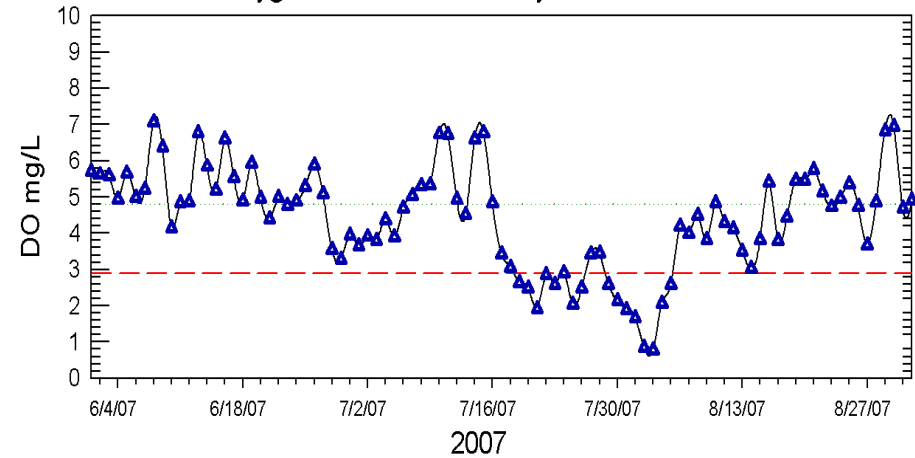


Greenwich Bay Oxygen Levels: 2007-2008

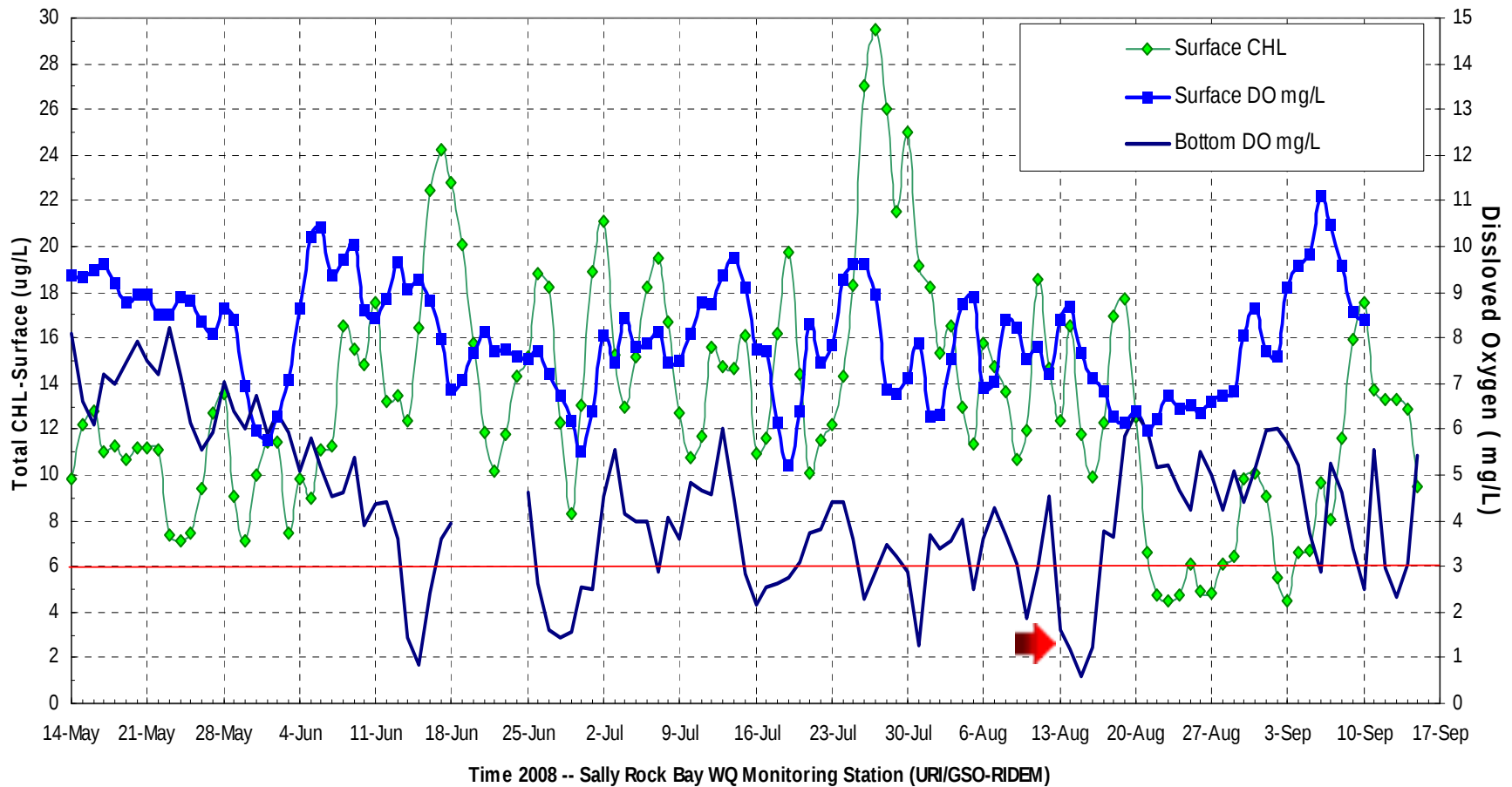
Dissolved Oxygen at Greenwich Bay Marina Surface: 2007-2008



Dissolved Oxygen at Greenwich Bay Marina Bottom: 2007-2008



Sally Rock Oxygen & Chlorophyll Levels: 2008



Dissolved Oxygen Criteria For Rhode Island Waters with a Pycnocline (Bottom Waters)

Waters with a DO concentration above an instantaneous value of 4.8 mg/l shall be considered protective of Aquatic Life Uses. When instantaneous DO values fall below 4.8 mg/l, the waters shall not be:

1. Less than 2.9 mg/l for more than 24 consecutive hours during the recruitment season; nor
2. Less than 1.4 mg/l for more than 1 hour more than twice during the recruitment season; nor
3. Shall they exceed the cumulative DO exposure presented in Table 3.A.

Allowable Number of Days without Exceeding a 5% Reduction in Seasonal Larval Recruitment

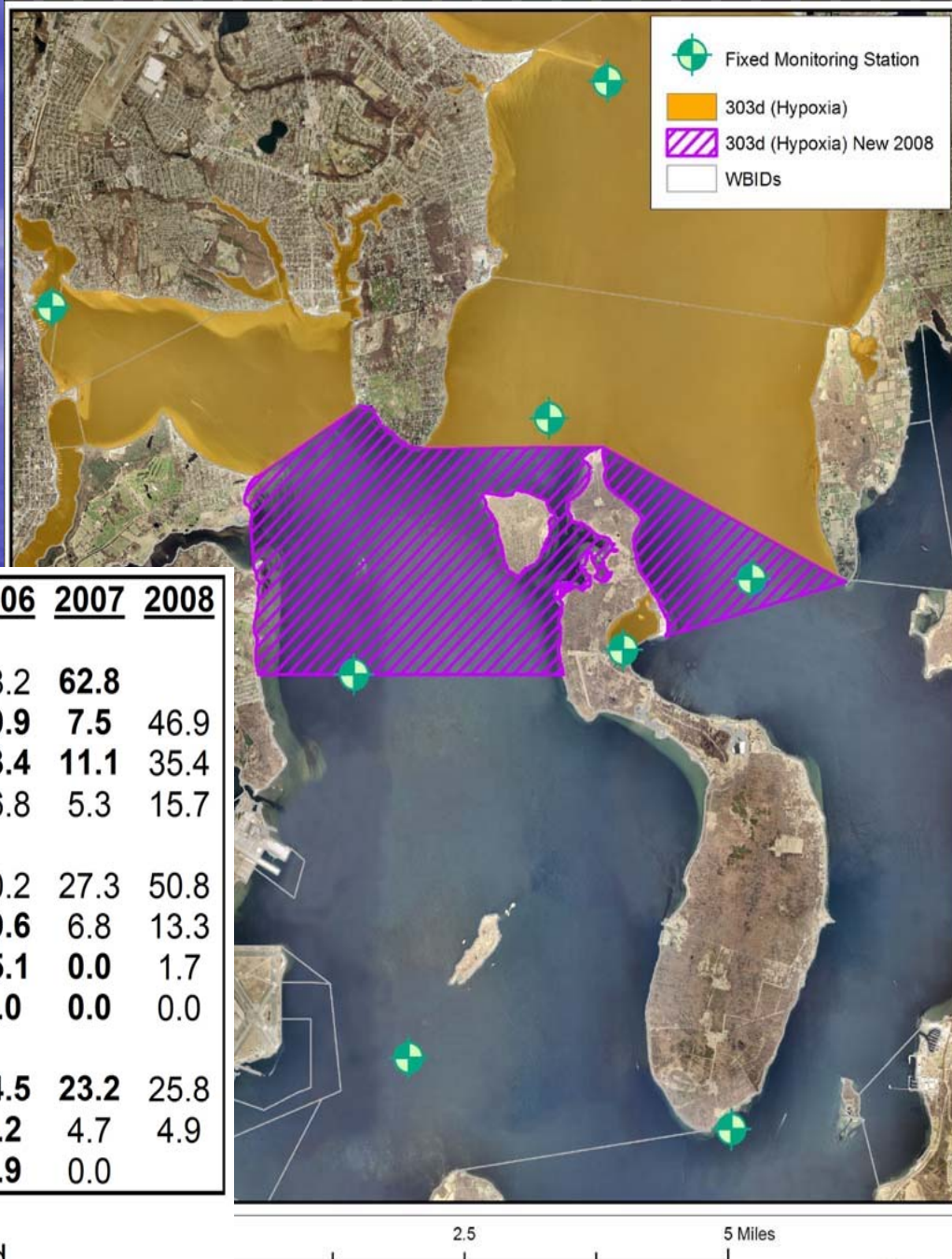
Table 3.A.
Saltwater DO Criteria For Waters Below the Seasonal Pycnocline

24 Hour (Daily) DO Exposure Concentration (mg/L)	Daily Percent Larval Mortality (%)	Allowable Number of Days Without Exceeding a 5% Reduction in Seasonal Larval Recruitment
4.6	4.96	42
4.5	6.05	30
4.4	7.36	24
4.3	8.93	20
4.2	10.79	18
4.1	12.98	16
4	15.55	14
3.9	18.51	12
3.8	21.88	10
3.7	25.69	9
3.6	29.89	8
3.5	34.47	7
3.4	39.36	6
3.3	44.46	5
3.2	49.69	4
3.1	54.92	3
3	60.05	2
2.9	64.97	1

RIDOCS Software Assessment Tool

- Software tool developed by EPA and applied to Rhode Island State Water Quality Criteria
- Runs the time-series data against the criteria & identifies cumulative exceedence.
- Allows for larval protection derived from the EPA criteria for dissolved oxygen for saltwater
- Violations of the criteria are not to occur more than once every 3 years.

Translating the RIDOCS Results into Impairment Listings for Oxygen in Narragansett Bay



Station Name	2001	2002	2003	2004	2005	2006	2007	2008
Upper Bay:								
Phillipsdale				67.2	58.2	58.2	62.8	
Bullock Reach	49.1	29.6	28.6	6.0	12.4	39.9	7.5	46.9
Conimicut Pt			18.2		12.8	23.4	11.1	35.4
North Prudence	19.4	14.8	39.1	1.7	12.3	16.8	5.3	15.7
West Passage:								
Greenwich Bay			57.5	59.7	51.9	60.2	27.3	50.8
Mt. View				0.3	13.5	39.6	6.8	13.3
Quonset Pt					0.0	15.1	0.0	1.7
GSO Dock	0.0	0.0		0.0	0.0	0.0	0.0	0.0
East Passage:								
Popposquash Pt				2.6	2.3	24.5	23.2	25.8
Mt. Hope Bay					0.0	9.2	4.7	4.9
T-Wharf				0.0	0.0	1.9	0.0	

-Blanks indicate no data available for analysis

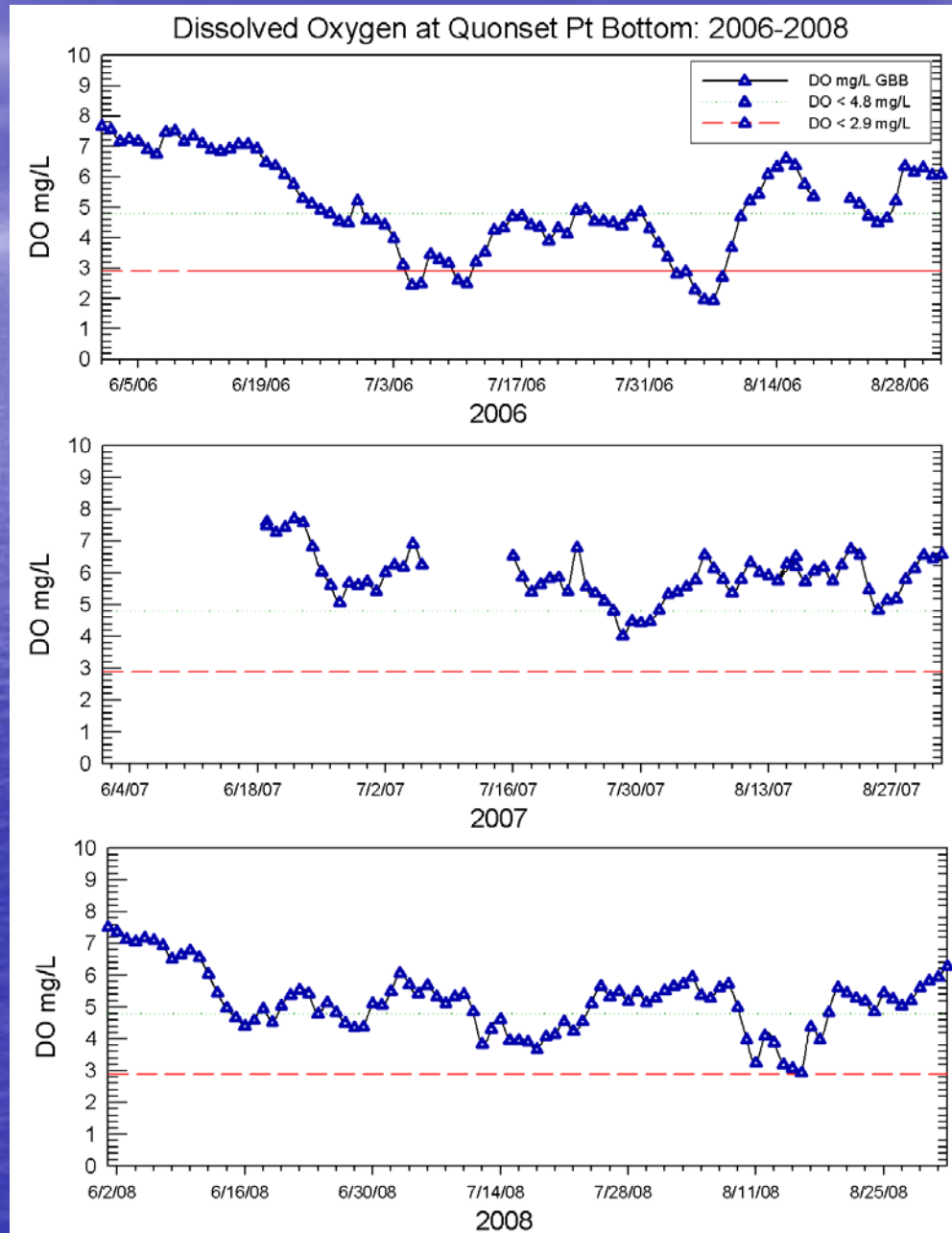
-Non-Bold indicates data missing during critical period

Date:	2/09
Drawn by:	paj

This map was created by RIDEM for informational, planning and guidance use only. It is a general reference, not a legally authoritative source for the location of natural or manmade features. Proper interpretation of this map may require the assistance of appropriate professional services. The cartographic representations depicted have not been verified by a RI Registered Professional Land Surveyor and are not intended to be used in place of a survey. RIDEM makes no warranty, express or implied, related to the accuracy, reliability, completeness, or currentness of this map.



Quonset Pt Bottom DO data: 2006-2008



Conclusions & Implications for Management

- **Previously listed waters remain listed**
 - Providence River, Upper Bay, & Greenwich Bay
 - A portion of the Upper West & East Passages was added to the 303 (d) list based on temporal & spatial datasets
- **Greenwich Bay**
 - Experiencing high variability in duration & intensity
 - Hypoxic annually, independent of river flow
 - Upgrades to WWTF on-line in 2006
 - Increased monitoring based on hydrodynamics of the bay in 2008
- **West Passage**
 - Area of concern: Mt. View to Quonset Point
 - Management Strategies for Providence River & Greenwich Bay effect this area

Recent Publications:

- Bergondo, D., Kester, D.R., Stoffel, H.E., Woods, W.L., (2005). Time series observations during the low sub-surface oxygen events in Narragansett Bay during summer 2001, *Marine Chemistry*, 97: 90-103.
- [Deacutis, C.F., Murray, D., Prell, W., Saarman, E., and Korhun, L., 2006, Hypoxia in the Upper Half of Narragansett Bay, RI, During August 2001 and 2002](#), in Natural and Anthropogenic Influences on the Mount Hope Bay Ecosystem, *Northeastern Naturalist* 13(Special Issue 4):173-198.
- Saarman, E., Prell, W., Murray, D.W., Deacutis, C., 2008. Chapter 11: Summer bottom water dissolved oxygen in Upper Narragansett Bay. In: Science for Ecosystem-based Estuarine Management: Narragansett Bay in the 21st Century, Desbonnet & Costa-Pierce (eds.), Springer Series In Environmental Management, 325-347.

Special Thanks

- A Special Thanks to All, Especially:

- Candace Oviatt, Taylor Crockford, Ed Requentina, Dan Newman, Chris Deacutis, Dave Murray, BROWN, NBNEP, MERL, NBC, Cathy Walker and Dan Codiga
- Funding: EPA, RIDEM-OWR, Bay Window

- References & Data Links:

- Codiga, D.L., 2008. A Moving Window Trigger Algorithm to Identify and Characterize Hypoxic Events Using Time Series Observations, with Application to Narragansett Bay. Technical Report 2008-01. Graduate School of Oceanography, University of Rhode Island, Narragansett, RI. 101pp.
- www.narrabay.org
- www.dem.ri.gov/bart.htm
- www.geo.brown.edu/georesearch/insomniacs/index.html
- www.narrabay.com/empact/