2007 Memorial Day Weekend Diatom Bloom - After Action Review

Dactyliosolen fragilissimus
Formerly *Rhizosolenia fragilissima*

6/26/07 Monmouth County Health Dept.

Diatom blooms occurred 8 out of 11 years from 1985-1995

Gastrich, 2000)

Table 1. Listing of documented algae blooms from 1957-1995 in the New York Harbor and New York Bight (Cosper and Cerami, 1996)

Year	Species	Max Density	Area	Time Frame	Severity	Extent	Impact	References
1985	Dinoflagellates; others	1.00E+07	RB, SHB, JCN	June	1	2	2	Olsen, NJDEP
1986	K. rotundatum	1.00E+07	RB, SHB, JCN	June - July	3	3	9	Olsen, NJDEP
1986	N. atomus	5.00E+08	JC	July - Sept	1	3	3	Olsen, NJDEP
1987	P. triestinum		WLIS	July - Sept	3	3	9	Mahoney, 1989
1987	N. atomus	1.00E+08	RB, SHB, JCN	July - Sept	1	3	3	Olsen, NJDEP
1987	Diatoms; C. pelagica, Thalassiosira, Cyclotella	1.00E+07	RB, SHB, JCN	May - Sept	1	3	3	Olsen, NJDEP
1988	Phytoflagellates; O. luteus, K. rotundatum, E. lanowii	2.50E+07	RB, SHB	May - Aug	3	3	9	Olsen & NOAA
1988	C. pelagica	2.00E+07	JCN, RB	May - June	1	3	3	NJDEP
1989	Diatoms; S. costatum, C. closterium	1.00E+08	RB, SHB, JCN	July - Sept	1	3	3	Olsen, NJDEP
1989	Phytoflagellates; K. rotundatum	5.00E+07	RB, UH, JCN	June - July	1	3	3	Olsen, NJDEP
1989	Phytoflagellates; O. luteus, K. rotundatum, E. lanowii	5.00E+07	JCN, JCM	Oct	1	2	2	Olsen, NJDEP
1990	N. atomus	1.00E+08	RB, SHB	June - Sept	1	3	3	Olsen, NJDEP
1990	Diatoms; many common	1.00E+08	RB, SHB, JCN	July - Sept	1	3	3	Olsen, NJDEP
1990	K. rotundatum	1.00E+07	RB, SHB	Late June	1	2	2	Olsen, NJDEP
1990	O. luteus	1.00E+07	SHB	June - July	1	2	2	Olsen, NJDEP
1991	Diatoms; S. costatum, many common	5.00E+07	RB, SHB, JCN	May - Sept	1	3	3	Olsen, NJDEP
1991	P. minimum	2.50E+07	RB, SHB	May - June	1	2	2	Olsen, NJDEP
1992	K. rotundatum	3.00E+07	RB, SHB	July	3	2	6	Olsen, NJDEP
1992	Diatoms; S. costatum, other common	6.00E+07	RB, SHB, JCN	May - Aug	1	3	3	Olsen, NJDEP
1993	Red Tides; species diverse	1.00E+07	RB, SHB, JCN	May - Sept	1	3	3	Olsen, NJDEP
1993	Diatoms; S. costatum, sp. diverse	2.00E+08	RB, SHB	May - Sept	1	3	3	Olsen, NJDEP
1994	Diatoms; many common	2.50E+07	RB, SHB, JCN	May - Sept	1	3	3	Olsen, NJDEP
1994	E. lanowii	2.50E+07	RB, SHB	June - July	1	3	3	Olsen, NJDEP
1995	Diatoms; many common	3.00E+07	RB, SHB, JCN	May - Sept	1	3	3	Olsen, NJDEP
1995	Phytoflagellates; O. luteus, K. rotundatum, E. lanowii	2.40E+07	RB, SHB, JCN	July	3	2	6	Olsen, NJDEP
1995	N. atomus	1.00E+08	RB, SHB	July	1	2	2	Olsen, NJDEP

Phytoplankton Chronology Since 1996 (draft)

1998, May 22: Diatom bloom on Memorial Day weekend from Sandy Hook to Barnegat Inlet (Murray, 1998); "from 1996-1998, flagellate red tides were overshadowed by … diatoms" (*Skeletonema costatum and Thlassiosira spp*.) (Gastrich, 2000).

1999: 6/7/99 and 6/18/99 – brownish water in Sandy Hook Bay, diatom cell counts of 15,000 to 20,000 per mL of ***Rhizosolenia***, *Asterionella, and Skeletonema spp*. and in mid June, *Thalassiosira sp*. 7/28/99 – moderate bloom dinoflagellates *Katodinium and Prorocentrum sp*., mixed with diatoms and chlorophytes (Gastrich, 2000).

2000: 6/21/00 - *Katodinium sp. and Eutreptia sp*. (MCHD Lab).

2003: 7/19/03 – *Olisthodiscus luteus*, 21, 282 cells/mL at Spring Lake (MCHD Lab). DEP reported moderate bloom (<= 5000 cells/mL) of *O. luteus* on 7/20/03, with "exceptionally high" chlorophyll a levels from 34-151 ug/L (Connell, R. 7/21/03. Email).

SEASONAL PHYTOPLANKTON PATTERNS BY THE HR ESTUARY

SPRING - Diatoms: *Skeletonema costatum, Rhizosolenia sp, Nitzschia sp*

SUMMER/FALL

Flagellates: "red tides" - *Olisthodiscus luteus, Prorocentrum micans, and Katodinium rotundatum* (the last 2 occur almost every year); and *Peridinium, Ceratium* sp.

Chlorophytes: *Nannochloris atomus* (Draxler et al., 1984; SAIC, 1986)

2007 DIATOM BLOOM CHRONOLOGY

A typical, progressive dinoflagellate bloom (Prorocentrum sp.) started in the Navesink and Shrewsbury Rivers around May 2nd.

"Chlorophyll a values reported in bloom concentrations in Navesink and Shrewsbury Rivers. Dominant species appears to be Prorocentrum sp." (Heddendorf, W. **5/2/07**. Email. DEP).

MONMOUTH COUNTY DEPARTMENT OF HEALTH
ENVIRONMENTAL LABORATORY

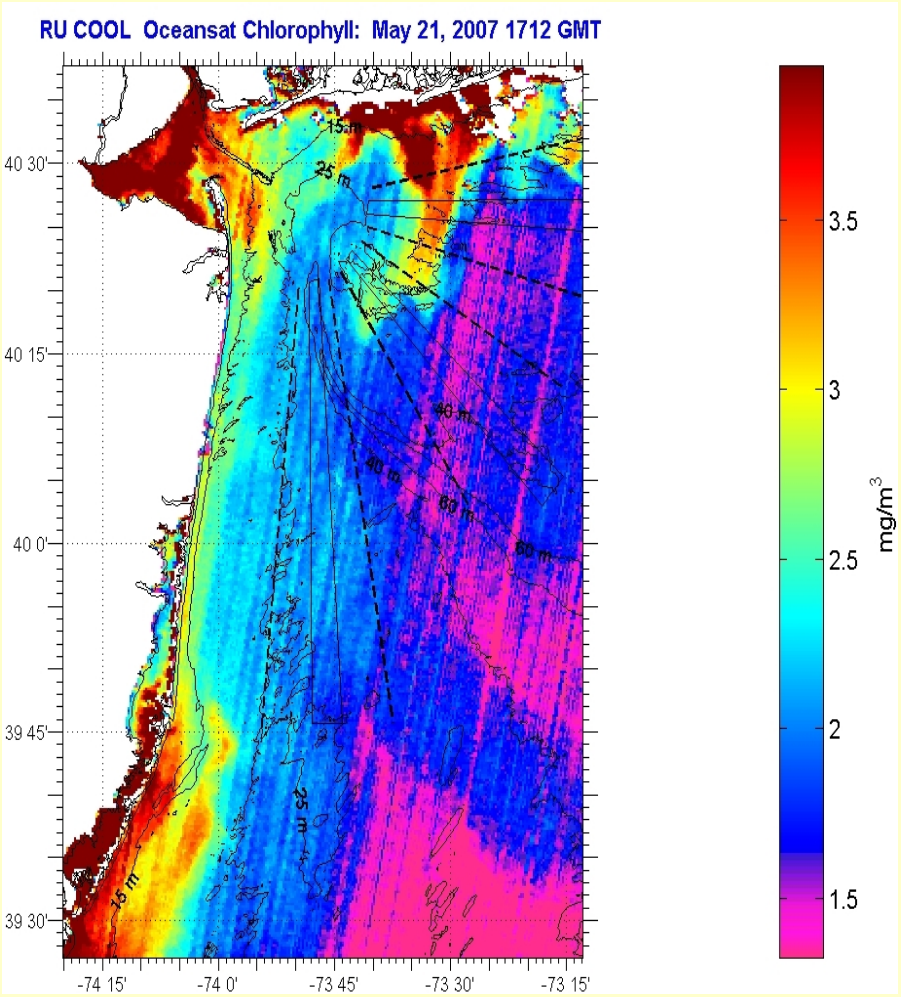
05/18/07 River Rd., Fair Haven (Nav R): Prorocentrum minimum (6,120 cells/ml)
05/19/07 Wharfside Condos, Ocean Av, Mon Bch (Shrews R): Prorocentrum minimum (7,440 cells/ml); Miller St., Highlands: Prorocentrum minimum (5,240 cells/ml)
05/21/07 Wharfside Condos, Ocean Av, Mon Bch: Prorocentrum minimum (7,440 cells/ml)
05/22/07 Two Rivers Water Rec Auth: Prorocentrum minimum (15,000 cells/ml);
Breezy Point by Gooseneck Bridge, Oport: Prorocentrum minimum (8,360 cells/ml);
Beachway and Raritan, Keansburg: (mixed flagellates, **Diatom D. fragillisima**, and high detritus); Sandy Hook Light (SH Bay) (P. minimum and **diatom D. fragillisima** but not really high counts); Miller St Highlands P. minimum (5,240 cells/ml); Wharfside Condos, Ocean Ave. Monmouth Beach P. minimum (7440 cells/ml).
05/24/07 GSP Milemarker 119.1 (Matawan Ck): Diatom Skeletonema sp. (<1,000cells/ml) and dinoflagellate Prorocentrum minimum (<1,000 cells/ml)

Less than 48 hours later, the dominant species had changed to a diatom, and the DEP Hotline began getting calls about water quality on Saturday May 26 .

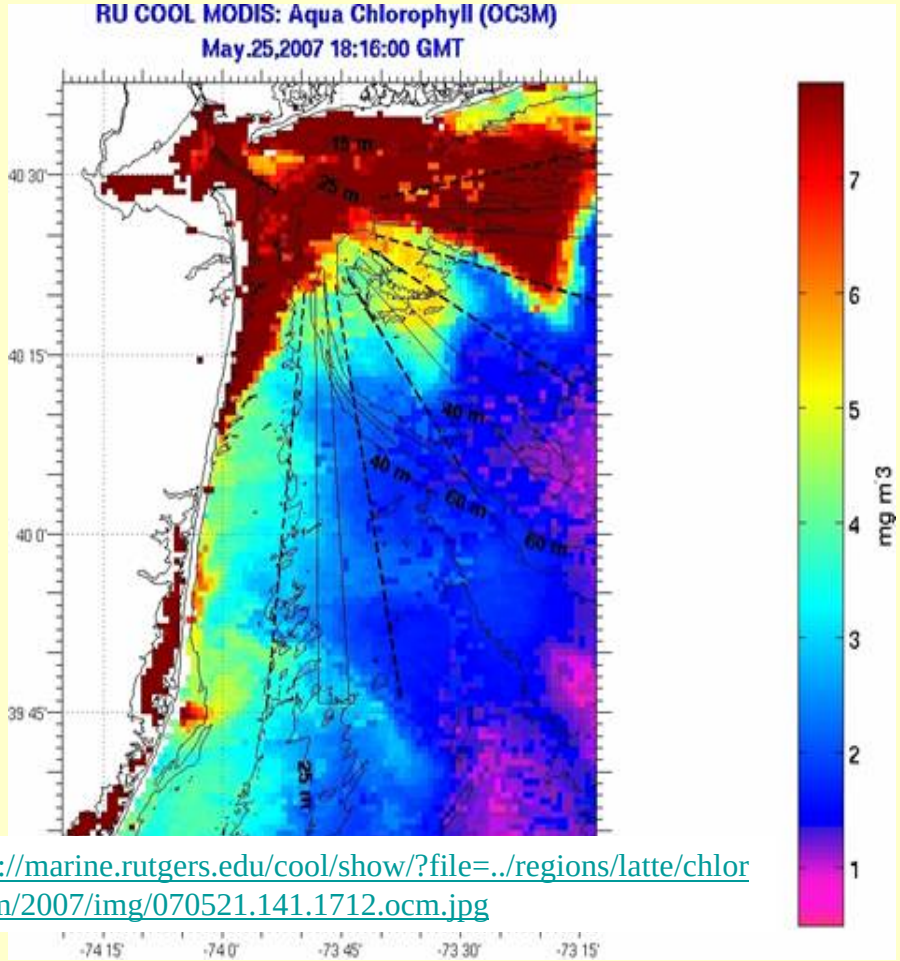
5/29/07 The first Memorial Day weekend diatom bloom documented since 1998.

Cedar Ave. Allenhurst 05/29/2007@09:00
A75T0066
Diatom ***Dactyliosolen fragilissimus*(5,0000 cells/ml)**. Few dinoflagellates. Copepods(Crustaceans) are numerous. In addition small flies seem to have been attracted to the copepods(?)
Deal Casino. Deal 05/29/2007@09:10
A75T0067
Diatom ***Dactyliosolen fragilissimus*(13,560 cells/ml)** and dinoflagellate *Prorocentrum minimum*(1,200 cells/ml), *Gyrodinium estuaralie*(160 cells/ml). Numerous Copepods(Crustaceans) on surface.
Monmouth Beach 05/29/2007@08:17
A75T0064
Diatom ***Dactyliosolen fragilissimus*(15,680 cells/ml)** and dinoflagellate *Prorocentrum minimum*(600 cells/ml).
Spermacetti Cove. Sandy Hook 05/29/2007@09:15
A75T0068
Diatom ***Dactyliosolen fragilissimus*(22,080 cells/ml)** and dinoflagellate *Prorocentrum minimum*(1,800 cells/ml), Gyrodinium estuaralie(160 cells/ml), Few *Heterocapsa triquetra* and unided flagellates.
Thompson Ave. Leonardo 05/29/2007@08:52
A75T0065
Predominately Diatom ***Dactyliosolen fragilissimus*(17,360 cells/ml)** and *Skeletonema costatum*(2,080 cells/ml) and dinoflagellate *Prorocentrum minimum*(160 cells/ml), *Heterocapsa triquetra, Gyrodinium estuaralie*(160 cells/ml). Detritus heavy.

By Wednesday 5/30/07 the bloom had dissipated.



Monday, May 21, 2007: Chair, Env Comm Monmouth Beach, calls about soap suds in Navesink & Shrewsbury Rivers in MC. All algae contain highly unsaturated fatty acids, (HUFA) which foam during decomposition and agitation (Cloern and Dufford, 2005; IDEM, 2007).



DEP guidelines for bloom conditions: Ocean: >12 ug/l. Raritan Sandy/Hook Bay and the Rivers: >20 ug/l. (Schuster, R. 6/16/07. Email. DEP.) (1 mg/m3 = 1 ug/l)

Note the doubling in scale on Friday May 25th, 1 day before the hotline calls.

http://marine.rutgers.edu/cool/show/?file=../regions/latte/chlor/ocm/2007/img/070521.141.1712.ocm.jpg

DIATOM ECOLOGY – Runoff, Sunlight, Heat

Diatoms grow very rapidly and have short lifetimes. Blooms "seed" in shallower waters (Eilersten et al. 1995). Spring and fall blooms are dependent on fluxes of N, P and, unlike dinoflagellates, require **dissolved silica**. Diatoms use dissolved silica in approximately a 1 to1 ratio with nitrogen (Officer and Ryther, 1980). **Silicon is found in quartz, sand, silt, clay, and glauconite, which is an iron-silicate mineral.**

"In temperate latitudes, silicon in the form of dissolved silicate is usually supplied in plentiful amounts through **land weathering** to the estuarine and coastal zones." (Officer and Ryther, 1980).

In other words, runoff. For example, sediment cores of hypoxic zones in the Gulf of Mexico indicate that algal production, deposition, and oxygen stress were much lower in the earlier 20th century, with an increase in biogenic silica (a measure of diatom abundance) and organic carbon beginning in the 1950's. (Glauconite abundance (associated with upwellings and hypoxia) also increased dramatically in the 1940's and 1950's in these marine sediments) (NOAA, 2007).

Following the initial diatom bloom, crash, and sinking to the sediments, N and P in fecal pellets from grazing copepods recycle back to the water column faster than diatom "tests" (siliceous shell) – setting up conditions for summer dinoflagellate blooms. In Chesapeake Bay, dissolved Si is almost entirely removed during the spring diatom bloom (Conley and Malone, 1992).

Mass sedimentation of diatom blooms is a survival strategy in turbid estuaries, until seasonal mixing brings nutrient-rich bottom waters back to the surface; spring storms re-entrain resting diatom spores and tests from the sediment (Eilersten et al. 1995; Cloern and Dufford, 2005; Officer and Ryther, 1980).

Many diatoms survive low temperatures and diatom (and other phytoplankton) biomass is often high near the bottom during blooms (Malone and Chervin, 1979).

ANTECEDENT CONDITIONS

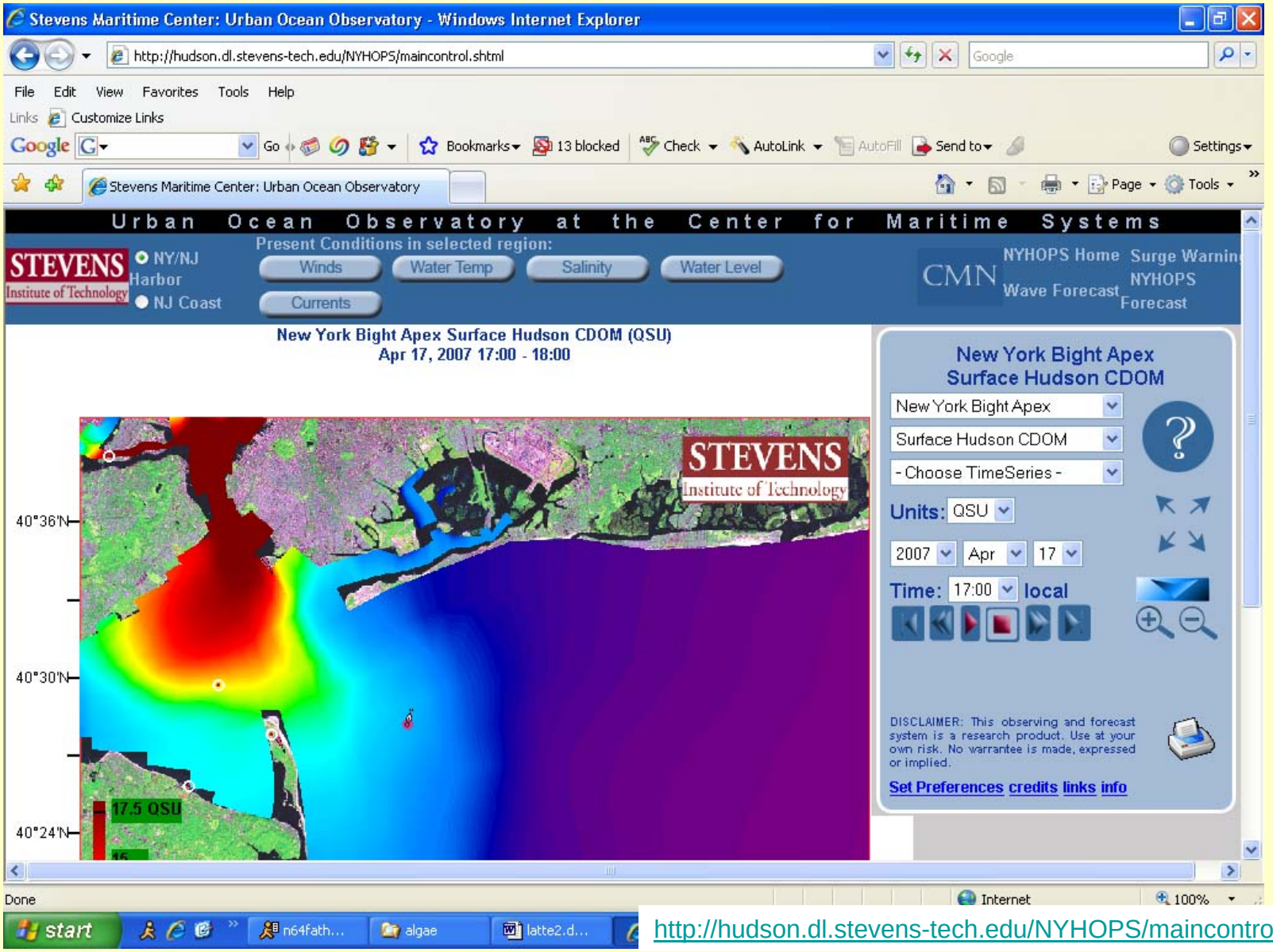
High river flow:

April 2007 will go into the record book as New Jersey's **wettest** fourth month of the year in 113 years of statewide records. The 9.03" of precipitation is well above the monthly average of 3.93". Only 1983, with 8.91", rivals this past month for the top spot. The third wettest, April 1973 with 6.64", sits far behind.

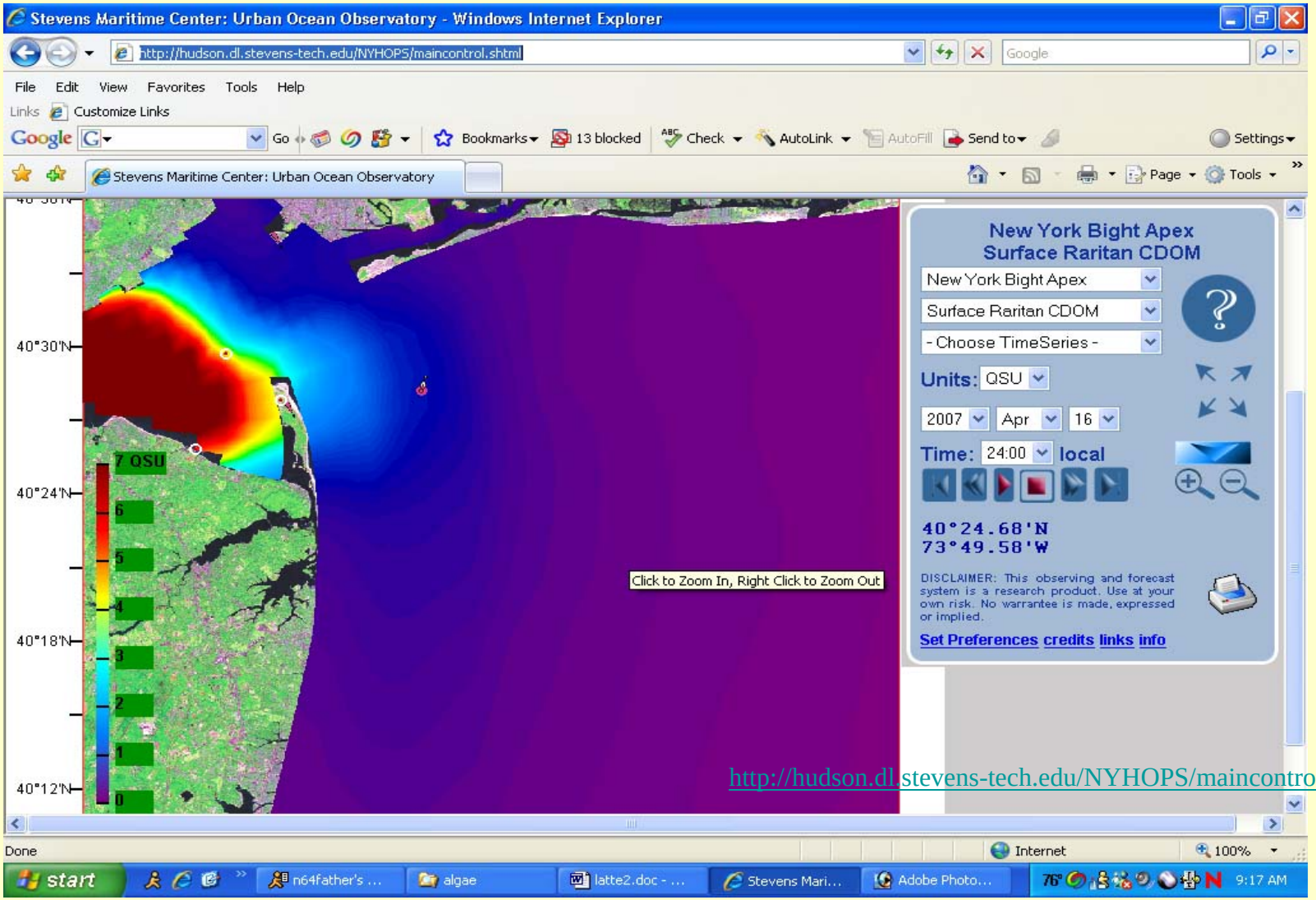
Low river flow:

May 2007. The record wet conditions of April were only a memory this past May. **Dry** weather enveloped the Garden State, where, on average, only 1.55" of precipitation fell. This totals some 2.75" below the 4.30" average. May 2007 went into the record books as the 11th driest since 1895, and the most parched since 1993. (Robinson, 2007). http://climate.rutgers.edu/stateclim/?section=menu&%20target=april07

CHROMOPHORIC DISSOLVED ORGANIC MATTER

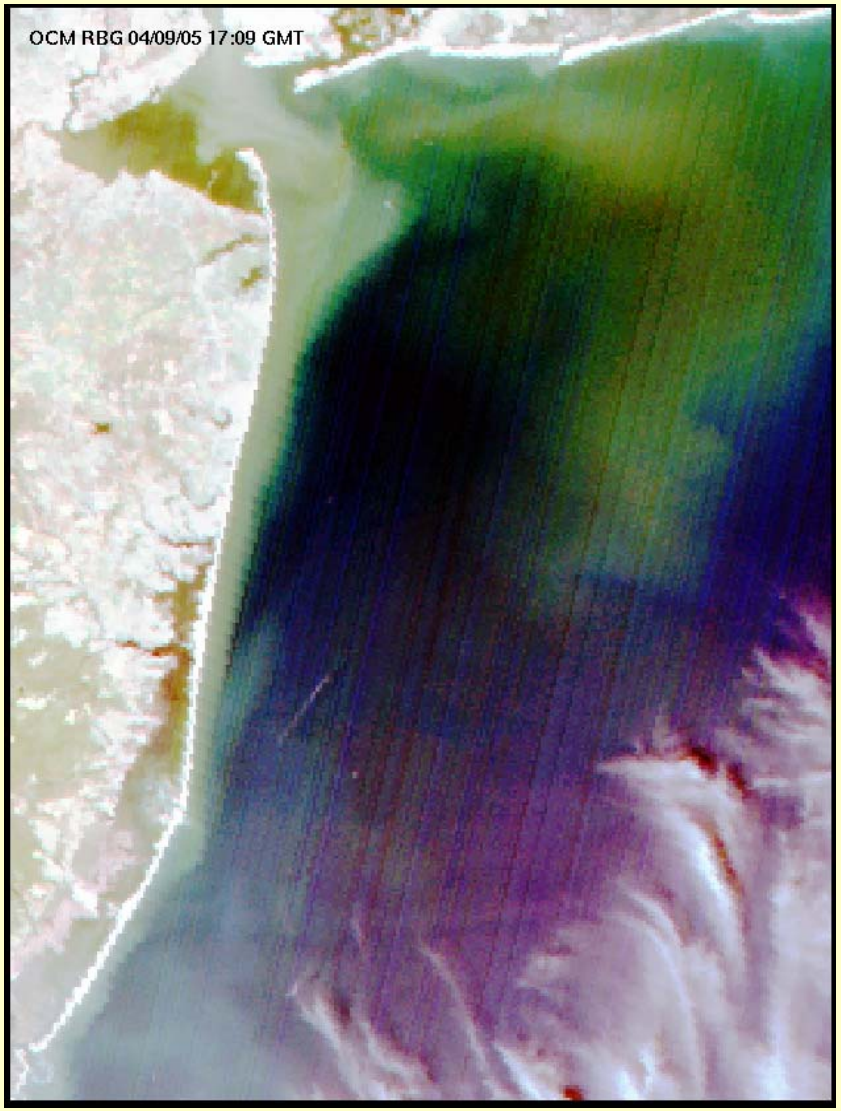


http://hudson.dl.stevens-tech.edu/NYHOPS/maincontrol.shtml



http://hudson.dl.stevens-tech.edu/NYHOPS/maincontrol.shtml

"Riverine inputs" contributed to more than half of the dissolved silicate in Chesapeake Bay, controlling the magnitude of the spring diatom bloom (Conley and Malone, 1992).



WHICH RIVER IS MUDDIEST?

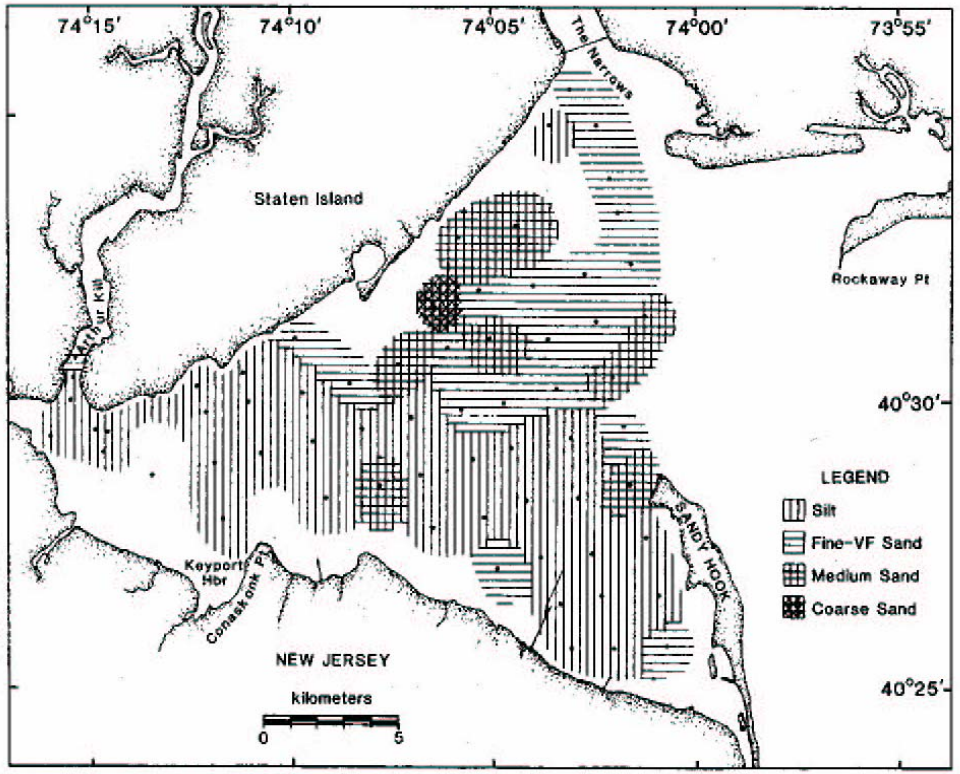
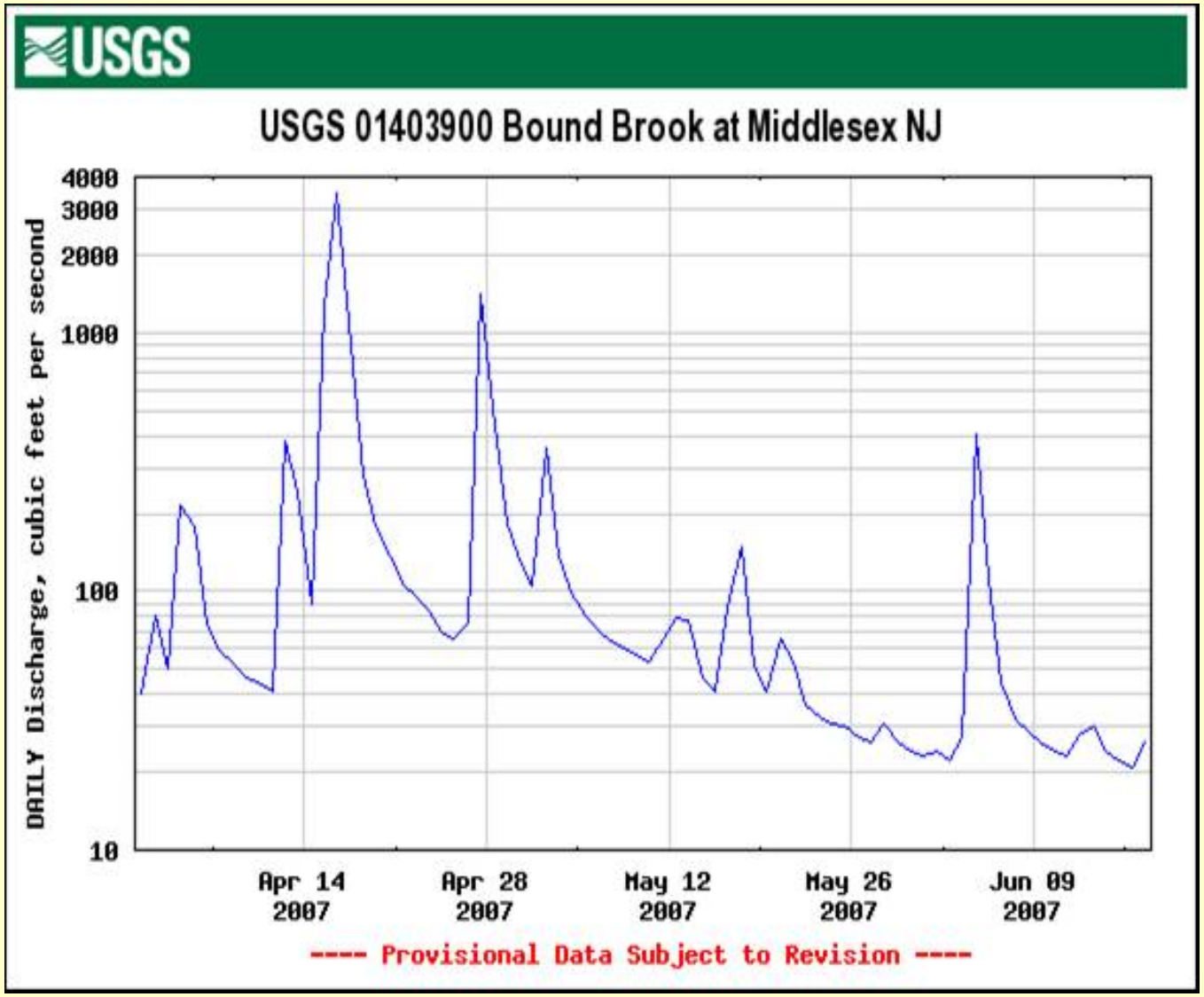


Fig. 2. Mean grain size of Raritan estuary sediments, based on 1973 data; blank areas indicate 1973 data not available.

The NJ Bayshore's muddy shoreline is predominantly shaped by runoff from the Raritan River, not the Hudson River, which is silica-poor (Officer and Ryther, 1980; Steimle et al., 1989). The Raritan is also the major source of nitrate (Jeffries, 1962).

Bob Chant (Rutgers), Scott Glenn (Rutgers), Bob Houghton (Lamont), Bernie Gardner (U. Mass), John Wilkin (Rutgers), John Reindfelder (Rutgers), Bob Chen (U.Mass). 2005. An Interdisciplinary Process Study of the Hudson River Plume in an Operational Research Observatory. Lagrangian Transport & Transformation Experiment. Powerpoint. Rutgers.



Note spike during nor'easter; and more moderate storms just before start of bloom.

http://waterdata.usgs.gov/nwis/dv/?dd_cd=05_00060_00003&format=img_default&site_no=01403900&set_logscale_y=1&begin_date=20070401&end_date=20070617

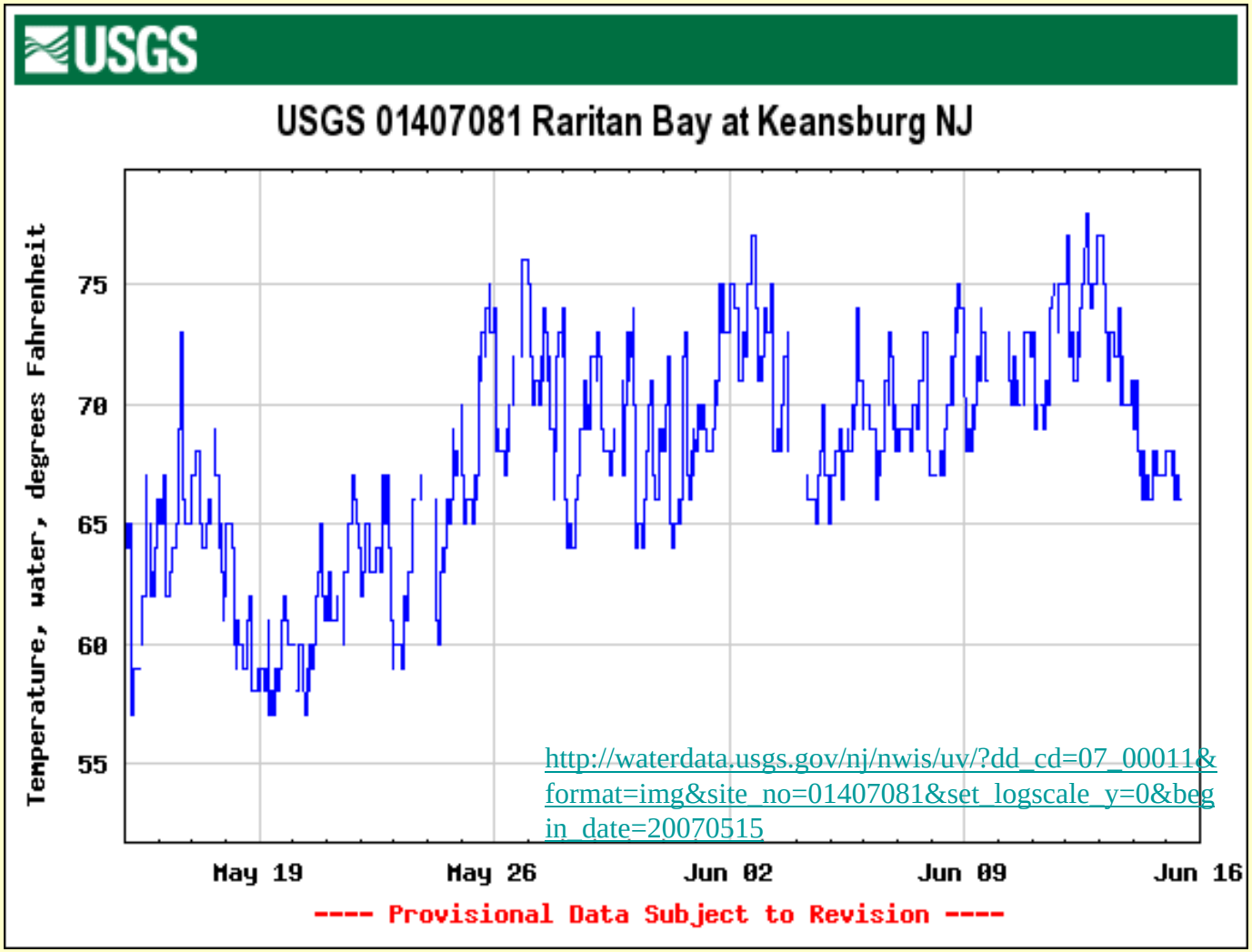
SELECTIVE RETENTION OF DIATOMS IN THE ESTUARY DURING MODERATE RIVER FLOWS

In the San Francisco Bay Estuary (10 m channel in the upper reach, 1.5 m channels in the shallows), diatom blooms and suspended sediment maxima were both associated with moderate flow conditions that retained these particles of similar density in the estuary. The moderate flow conditions in combination with increasing light resulted in blooms.

When river flow is too **high** during floods, suspended particulates including diatoms are swept out of the bay, and the residence time for diatoms in the shoals is too short to seed a bloom.

When the flow is too **low** during summer drought, the particles sink to the bottom and are not advected up, since horizontal and vertical flow velocities have decreased.

When river discharge falls within a critical range resulting in **moderate** flows, suspended particulates maxima, including silica-based diatoms, are positioned by shallow bays. The landward flowing bottom current converges with the seaward river current, and these opposing flows in the surface and bottom layers create an upward advection. As sediments and diatoms sink to the bottom, this advection carries them upward, preventing them from settling in the sediment, and suspending them in the water column, while lighter microflagellates are carried seaward, and these more dense particles are carried landward, trapping the diatoms in the nearby shoals, and allowing a bloom to seed (Cloern et al., 1983).



Sunny days make a nutrient more available to diatoms, but not flagellates

20F rise in water temperature in 1 week - starting 1 day before the first complaint.

Like growth processes in higher plants, diatom blooms are dependent on **longer photoperiods** (longer sun lit days) (Eilersten et al. 1995). Diatoms respond rapidly to episodic high-light, high nutrient pulses (Cloern and Dufford, 2005). The solubility of silica increases with decreasing pressure and **increasing heat** (AODP, 2007). Mean doubling times for phytoplankton productivity ranged from 8 days during December-March, to **1 day during June-July** (Malone and Chervin, 1979).

We now have the tools to learn how to make algae sampling proactive, not just reactive.

LINKS FOR BLOOM 'FORECASTING'

PRIMARY

USGS RARITAN BAY AT KEANSBURG (WATER TEMP ETC)
http://waterdata.usgs.gov/nj/nwis/uv?cb_00011=on&format=gif&period=7&site_no=01407081
RUTGERS – CHLORAPHYLL A
http://marine.rutgers.edu/cool/sat_data/?product=chlor&region=latte&nothumbs=0
NJDEP – CHLORAPHYLL A
http://www.nj.gov/dep/bmw/remotesensing.htm
STEVENS - CDOM
http://hudson.dl.stevens-tech.edu/NYHOPS/
EPA – UV INDEX
http://epa.gov/sunwise/uvindex.html

SECONDARY

USGS RARITAN RIVER AT RAHWAY (closest to Raritan Bay)
http://waterdata.usgs.gov/nj/nwis/uv/?site_no=01395000&PARAmeter_cd=00065,00060
USGS RARITAN RIVER AT BOUNDBROOK (closest to Raritan Bay without tidal influence)
http://waterdata.usgs.gov/nj/nwis/uv/?site_no=01403900&PARAmeter_cd=00065,00060
RUTGERS LATTE - CODAR
http://marine.rutgers.edu/cool/sat_data/?product=sst_codar&region=latte&nothumbs=0

Phytoplankton taxonomy performed by MCHD Water Pollution Laboratory. Bloom pictures by Virginia Loftin of the DEP and Joe Reynolds of the Atlantic Highlands Herald. *Dactyliosolen fragilissimus* picture by MCHD Lab.

REFERENCES

Australian Ocean Drilling Program. Accessed 6/14/07. Ocean sediments. http://www.odp.usyd.edu.au/odp_CD/oceplat/opindex.html

Cloern, J., Alpine, A., Cole, B., Wong, R., Arthur, J. and Ball, M. 1983. River discharge controls phytoplankton dynamics in the northern San Francisco Bay Estuary. Estuarine, Coastal and Shelf Science. Vol. 16. pps. 415-429. http://sfbay.wr.usgs.gov/publications/pdf/cloern_1983_phytoplankton.pdf

Cloern, J. and Dufford, R. 2005. Phytoplankton community ecology: principles applied in San Francisco Bay. Marine Ecology Progress Series. Vol. 285: 11-28. http://sfbay.wr.usgs.gov/publications/pdf/cloern_2005_phytoplankton_ecology.pdf

Conley, D. and Malone, T. 1992. Annual cycle of dissolved silicate in Chesapeake Bay: implications for the production and fate of phytoplankton biomass. Marine Ecology Progress Series. Vol 81:121-128. http://www.int-res.com/articles/meps/81/m081p121.pdf

Cosgrove, E. Voting contest and photo of D. fragillissimus. Laboratory Supervisor, MCHD.

Draxler, A., Waldhauer, R., Matte, A. and Mahoney, J. 1984. Nutrients, hydrography, and their relationship to phytoflagellates in the Hudson-Raritan Estuary. Bulletin NJ Acad Sci. Vol. 29, No.2 pp. 97-120

Eilertsen, H., Sandberg, S. and Toileisen, H. 1995. Photoperiodic control of diatom spore growth: a theory to explain the onset of phytoplankton blooms. Marine Ecology Progress Series. Vol 116; 303-307. http://www.int-res.com/articles/meps/116/m116p303.pdf

Gastrich, M. 2000. Harmful algal blooms in coastal waters of NJ. NJDEP. DSRT. http://www.state.nj.us/dep/dsr/coastal/hab2.PDF

Indiana Dept. of Environmental Management. Accessed 6/19/07. Foam fact sheet: what causes foam to appear on Indiana lakes, rivers and streams? Office of Water Quality Assessment. http://www.in.gov/idem/programs/water/quality/surveys/025surfacefoam.pdf

Jeffries, H. 1962. Environmental Characteristics of Raritan Bay, A Polluted Estuary." Narragansett Marine Laboratory. No. 35. Rhode Island.

Loftin, V. 2007. Flyover picture of Sandy Hook Bay. DEP.

Malone, T. and Chervin, M. 1979. The production and fate of phytoplankton size fractions in the plume of the Hudson River, NY Bight. Limnol. Oceanogr., 24(4), 683-696 http://www.aslo.org/lo/toc/vol_24/issue_4/0683.pdf

Murray, B. 5/22/1998. Algae bloom deemed harmless. Star Ledger. Page 31.

NOAA. Accessed 6/19/07. The causes of hypoxia in the Northern Gulf of Mexico. National Ocean Service. http://oceanservice.noaa.gov/products/hypox_finalcauses.pdf

Officer, C. and Ryther, J. 1980. The possible importance of silicon in marine eutrophication. Marine Ecology Progress Series. Vol 3; 83-91. http://www.int-res.com/articles/meps/3/m003p083.pdf .

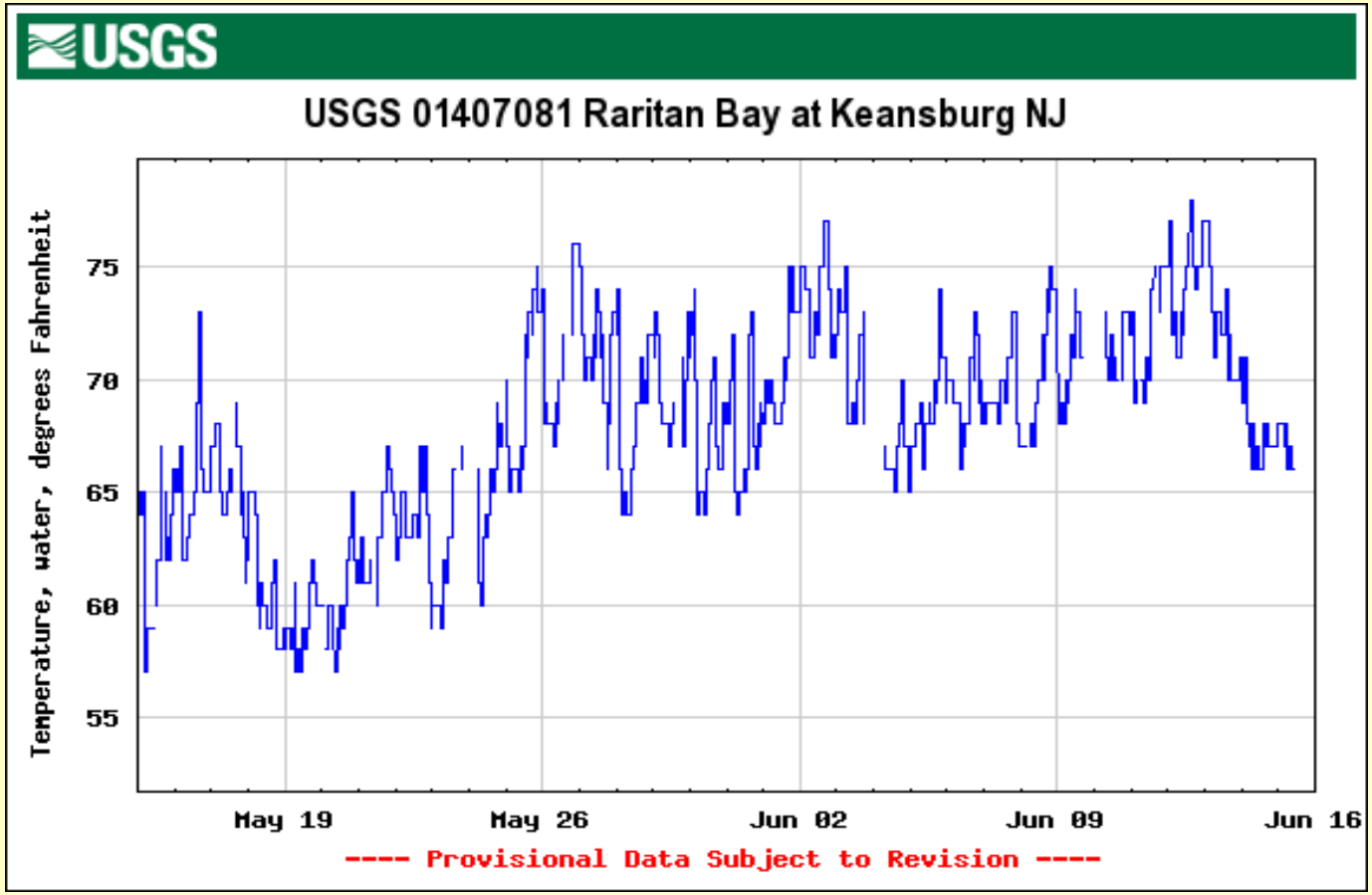
Reynolds, J. 5/28/07. Yucky brown tide in Sandy Hook Bay. Old Oak Trail column, Atlantic Highlands Herald. http://www.ahherald.com/content/view/1884/27/

Robinson, D. Accessed 6/18/07. April and May 2007 Climate Summary. New Jersey State Climatologist Center for Environmental Prediction, Cook College/NJAES, Rutgers University.http://climate.rutgers.edu/stateclim/?section=menu&%20target=april07.

Science Applications International Corporation. 1986. An environmental inventory of the New Jersey coast/New York Bight relevant to green tide occurrence. Prepared for EPA under contract to Battelle Memorial Institute.

Steimle, F. and Caracciolo-Ward, J. 1989. A reassessment of the status of the benthic macrofauna of the Raritan Estuary. Estuaries. Vol112, No. 3, p. 145-156. http://estuariesandcoasts.org/cdrom/ESTU1989_12_3_145_156.pdf

This tide gage and 24 others will be shutdown on July 1, 2007, due to lack of funding. In past years, these tide gages have been funded by New Jersey Dept. Of Transportation and USGS.



Funding, solely by USGS and NJDOT, will continue temporarily for 1 year.

This needs permanent funding.

This tide gage and 24 others may be shutdown on October 1, 2007, due to lack of funding. In past years, these tide gages have been funded by New Jersey Dept. Of Transportation and USGS.