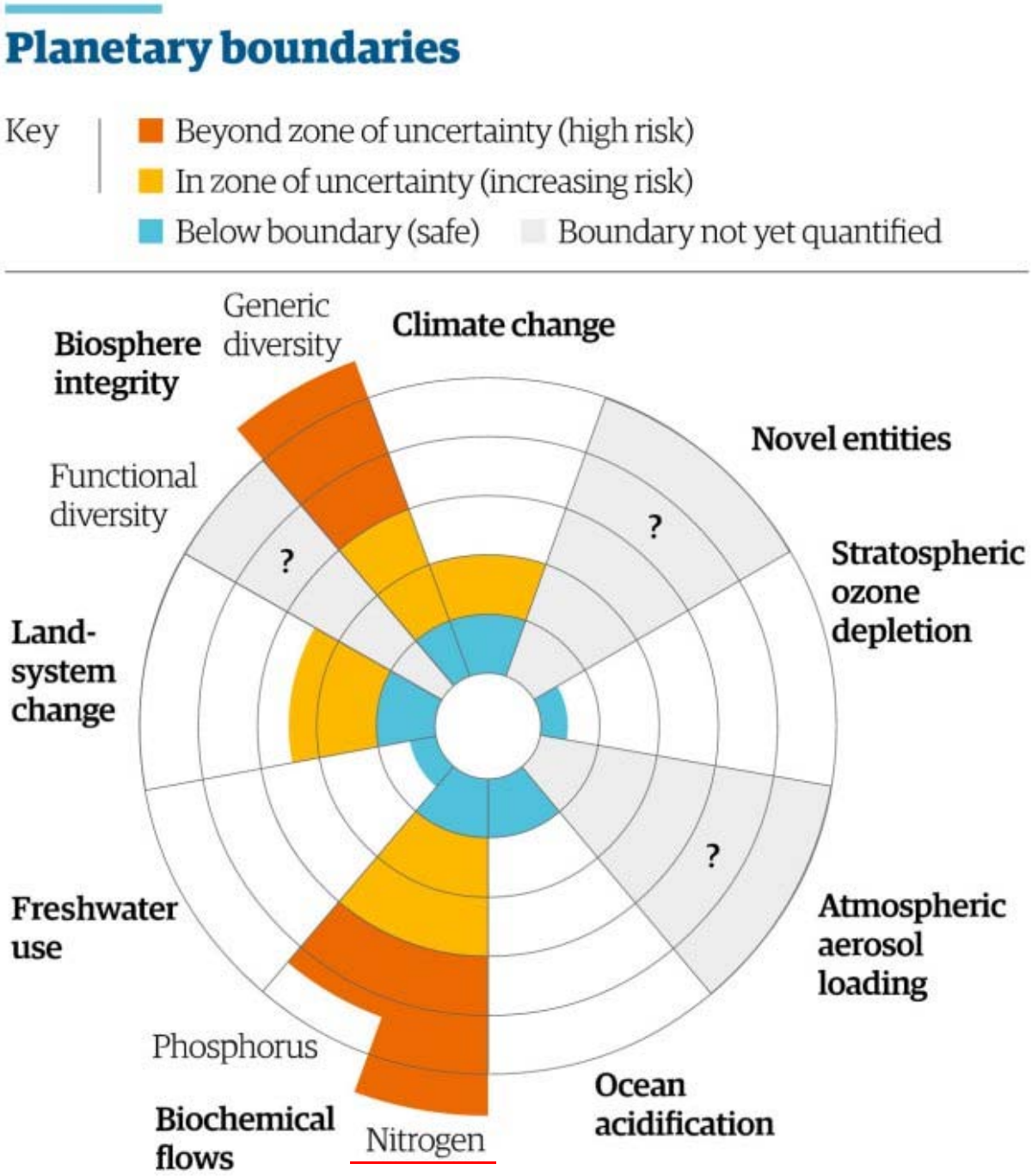
Status and trends in nitrogen-based eutrophication in NY marine coastal waters

Stony Brook University

Christopher J. Gobler

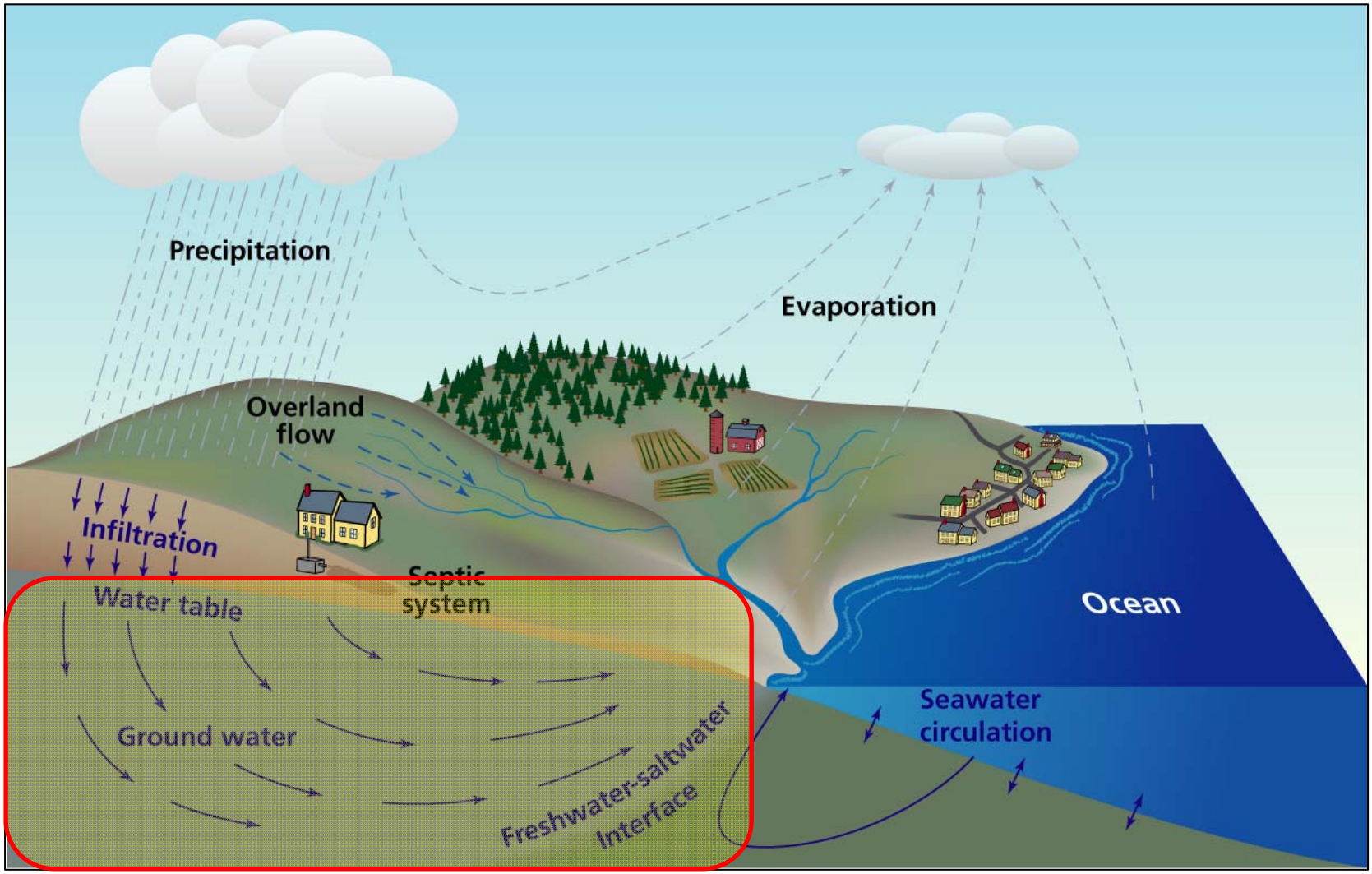
Planetary boundaries: Guiding human development on a changing planet

Steffen et al 2015, Science

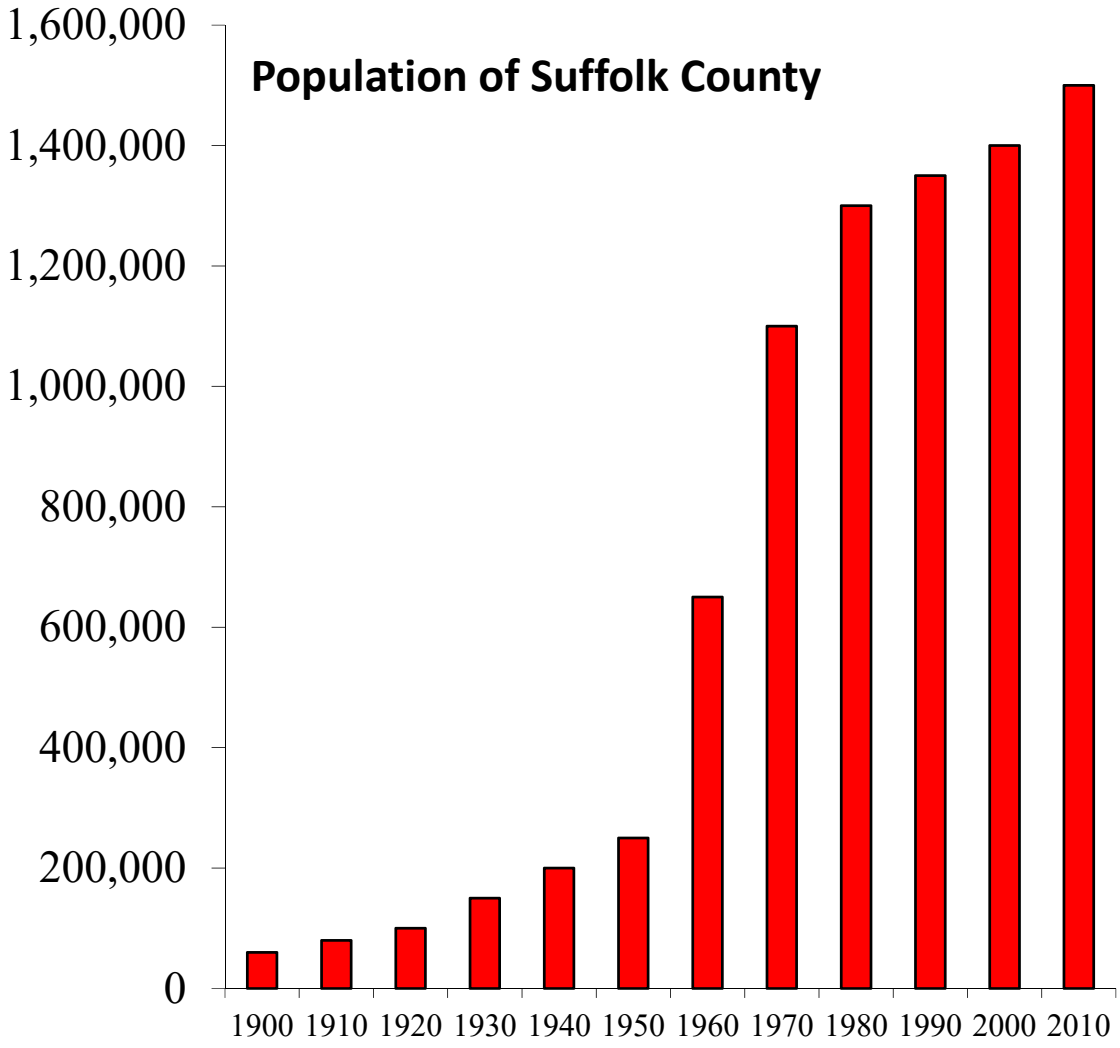


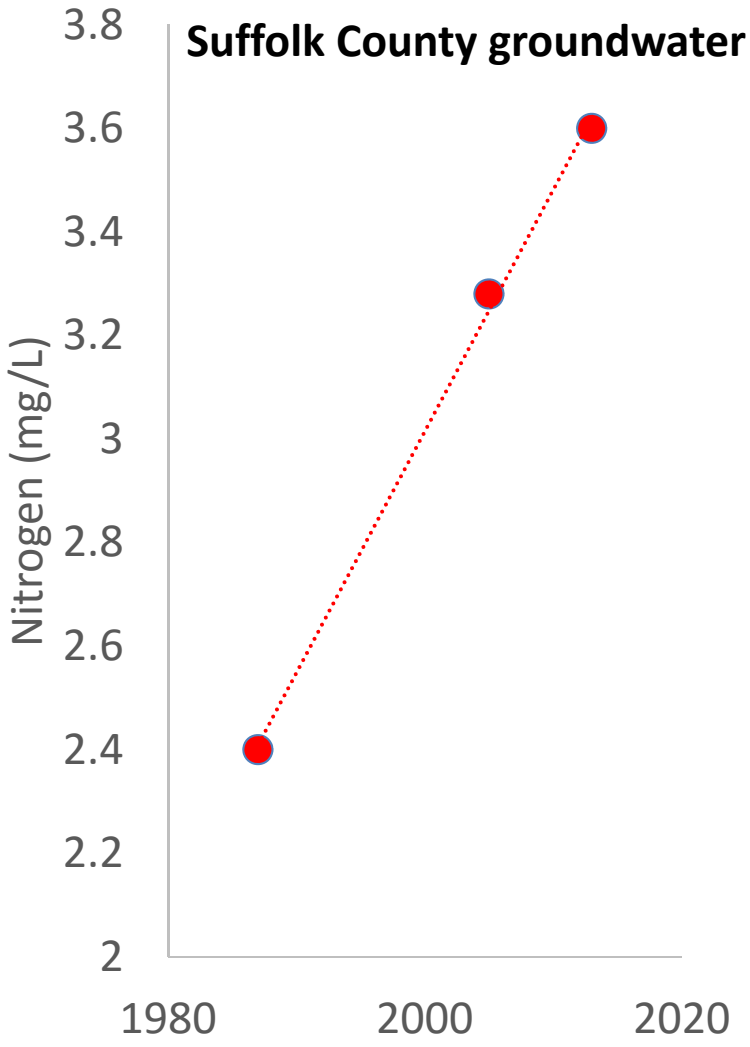
All of Long Island is a watershed -

Materials on land eventually enter our groundwater and surface water.

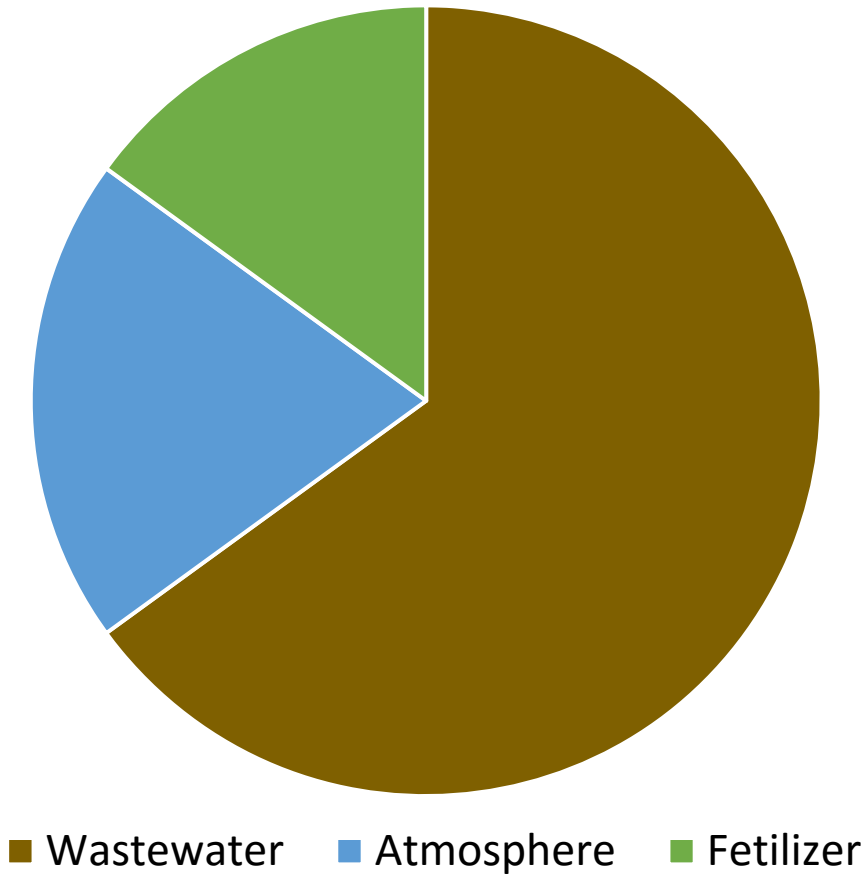


Expanding population, nitrogen levels





Where is the nitrogen coming from?



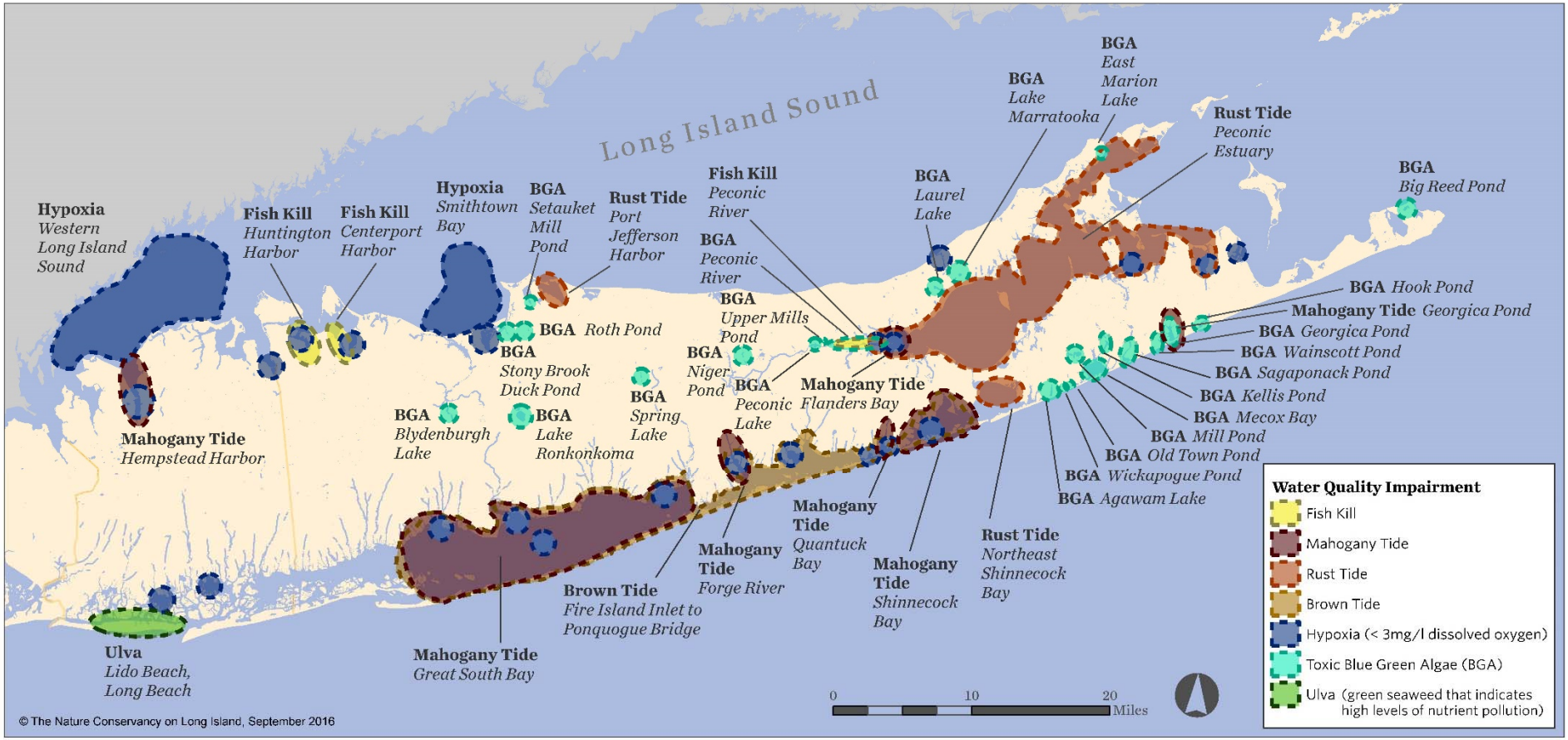
Great South Bay, Moriches Bay, Shinnecock Bay, Peconic Bay, North shore harbors of Nassau and Suffolk County, Kinney and Valiela, 2011; Stinnette, 2014, Lloyd, 2014, 2016

Stony Brook University
School of Marine and Atmospheric Sciences

LICCRA

Long Island Water Quality Impairments, Summer 2016

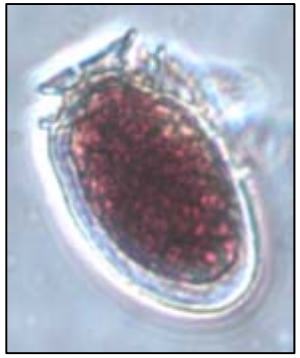
The Nature Conservancy
Protecting nature. Preserving life.



Harmful algal blooms across Long Island

PSP

Toxic blue green algae



DSP

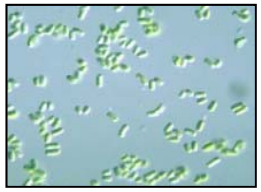
Brown tide

Seaweeds

Rust Tide

History of Harmful Algae on Long Island

1951 – 1954, Green tides, Chlorophytes



1951 **Closure of Moriches Inlet, duck farms common**

1954 **Moriches Inlet opened, green tides end**

1954 – 1985, 30-yr HAB free

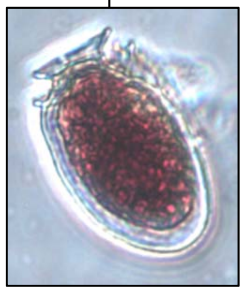
1985 - First brown tide caused by *Aureococcus*

2003- First toxic blue green algae bloom

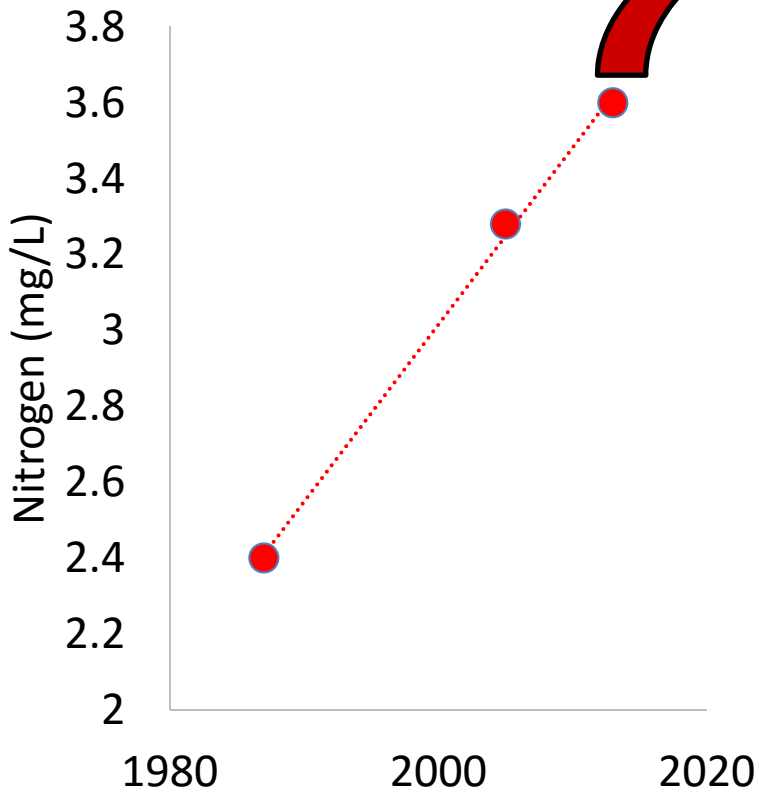
2004 - First rust tide caused by *Cochlodinium*

2006- First PSP event caused by *Alexandrium*

2008 - First DSP caused by *Dinophysis*

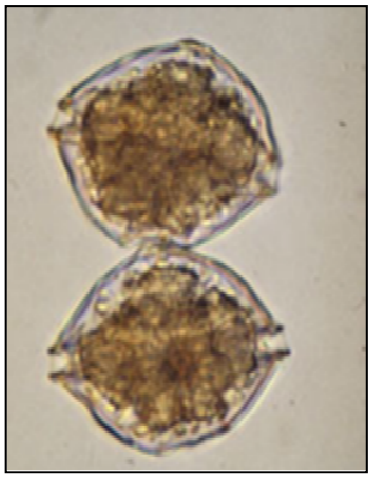


More nitrogen makes harmful algae on Long Island grow faster and/or more toxic

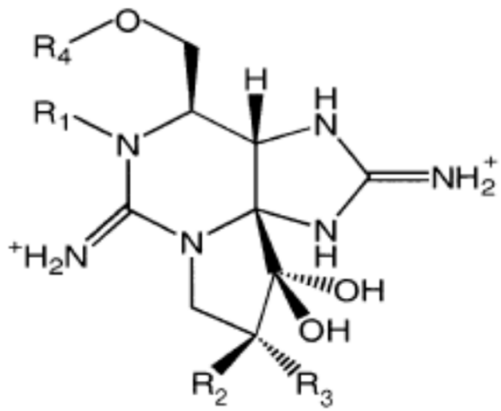


Studies: Hattenrath et al 2010; Gobler et al 2011, 2012; Gobler and Sunda 2012; Harke and Gobler 2013, 2015 Hattenrath-Lehmann et al 2015A&B; Gobler et el 2016; Harke et al 2016.

Alexandrium red tides and paralytic shellfish poisoning (PSP) on Long Island in 2015

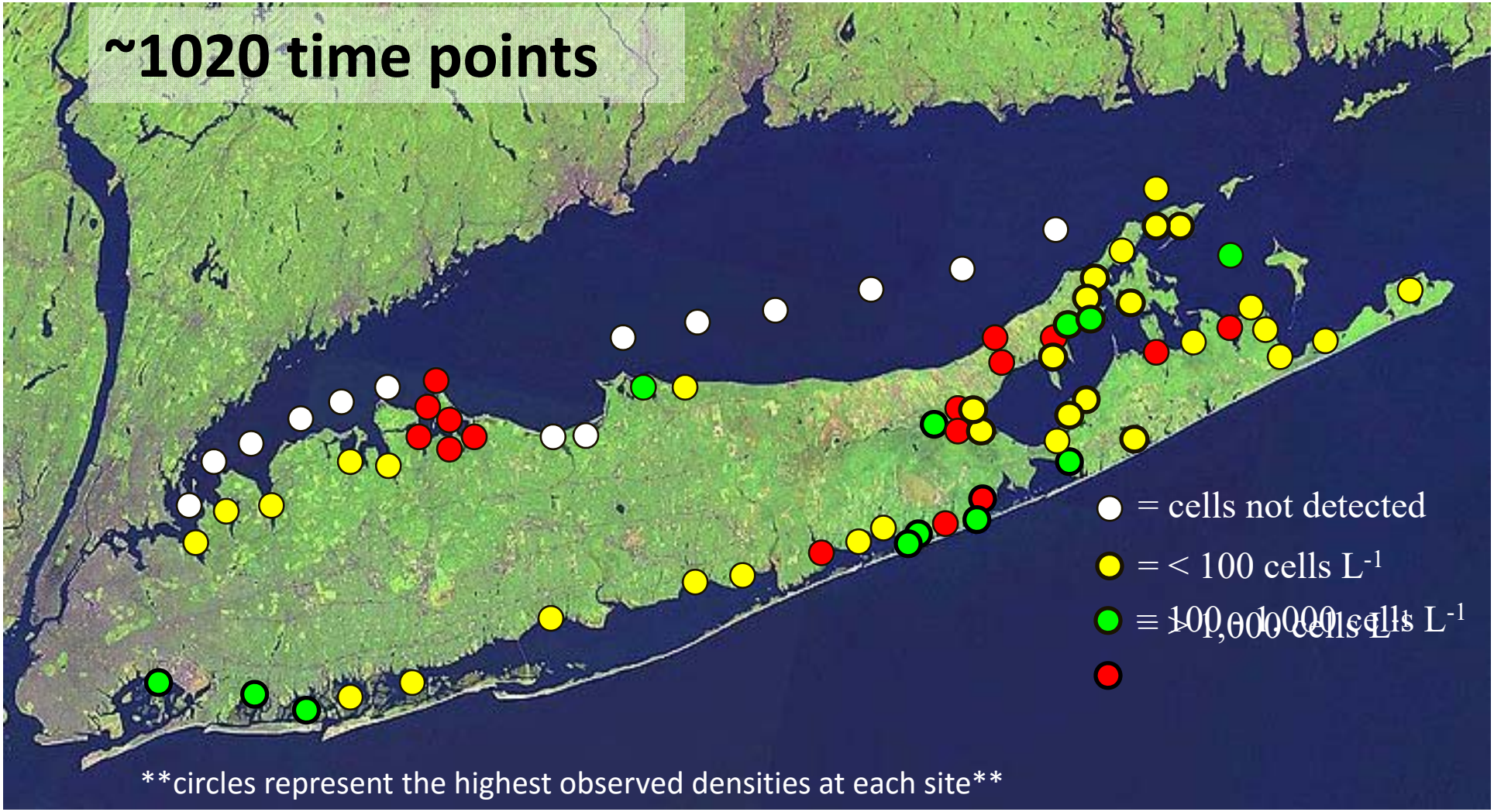


Alexandrium



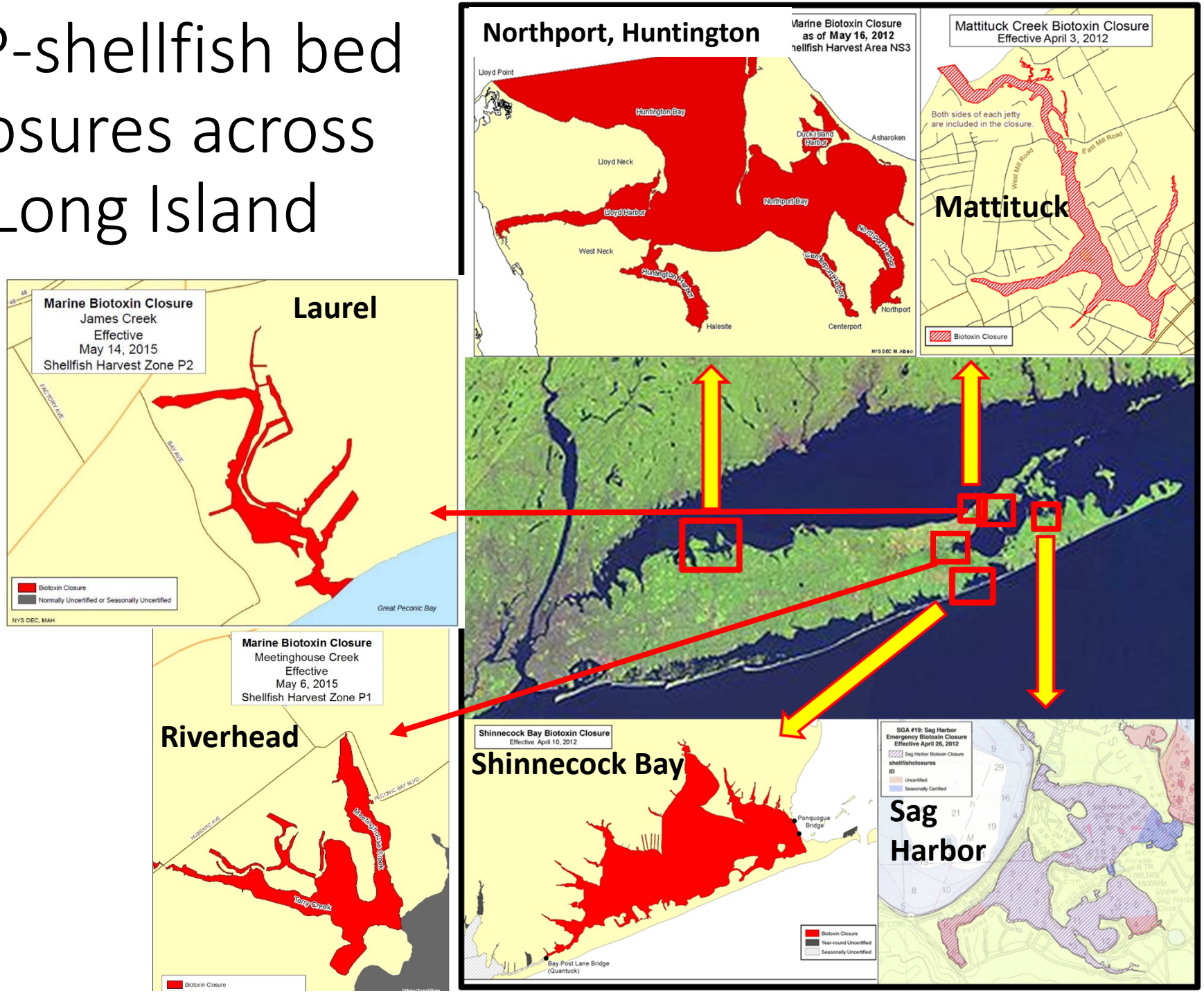
Saxitoxin

Presence of PSP-producing *Alexandrium* in LI: 2007-2015



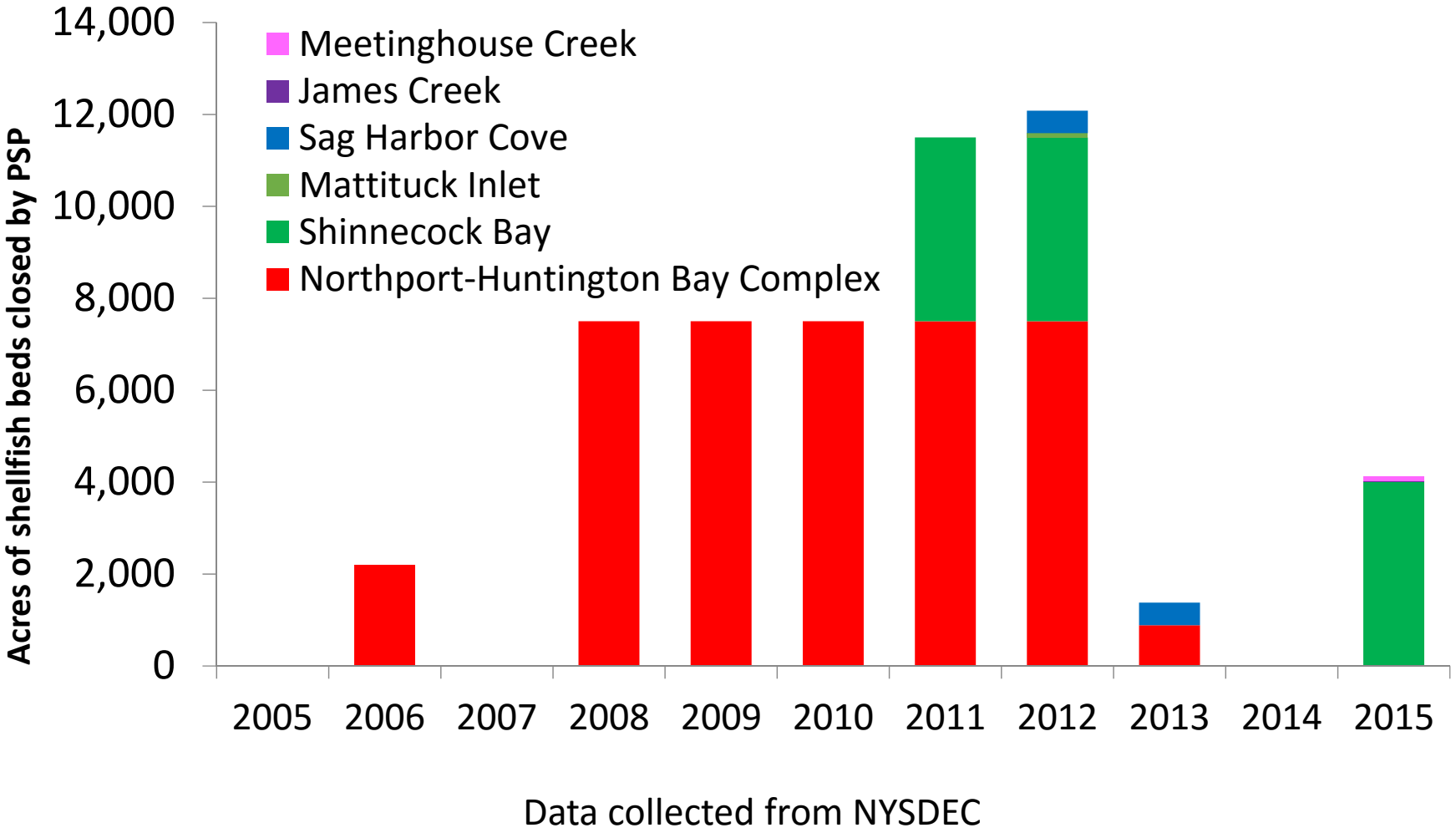
- *Alexandrium* found at 62 of 76 sites sampled (82%)

PSP-shellfish bed closures across Long Island



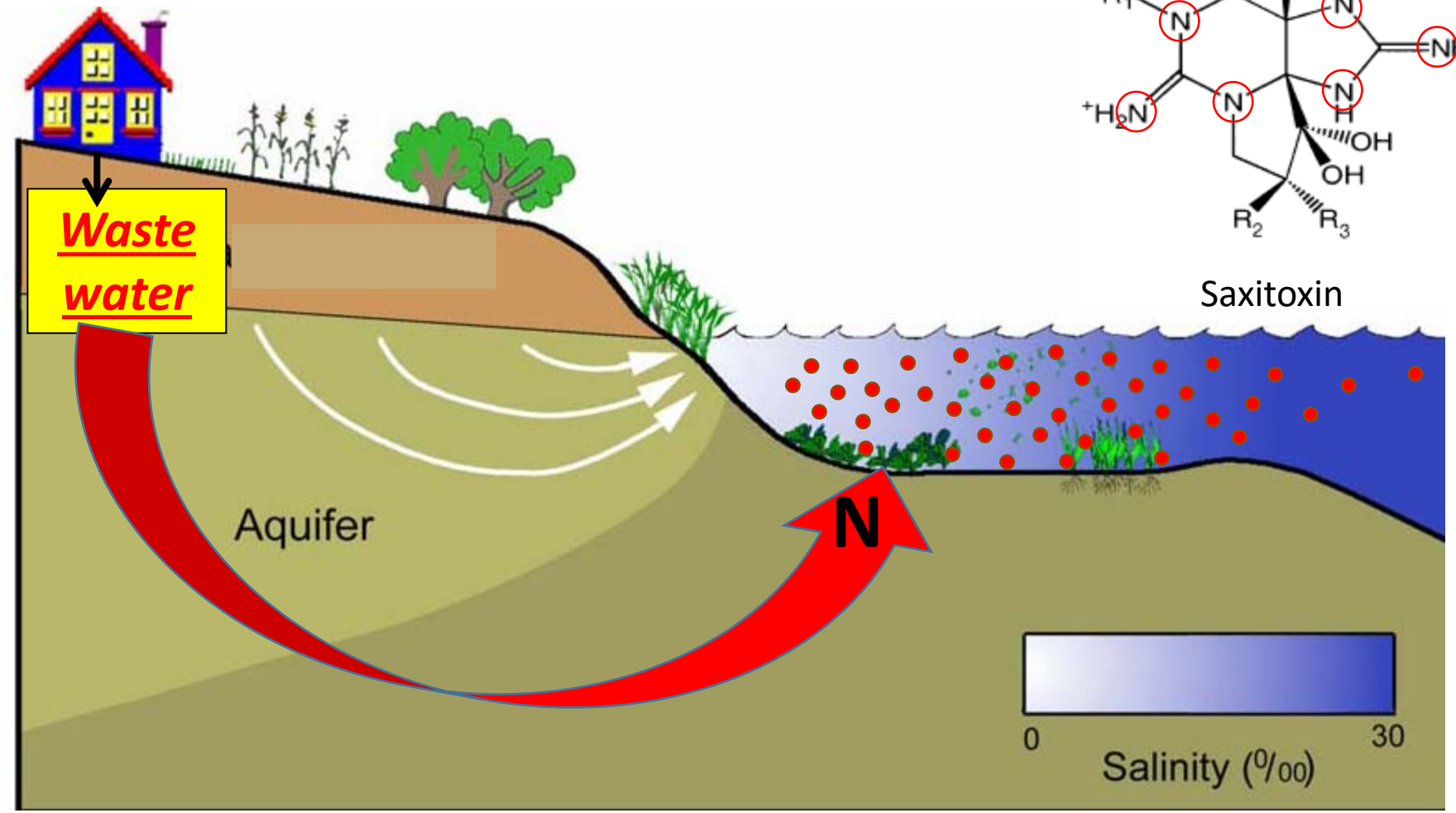
Expansion of PSP-induced shellfish bed closures on Long Island, 2005 – 2015

Prior to 2006, Long Island had never experienced a PSP event, 15 since



Wastewater-derived nitrogen loading promotes PSP on Long Island.

-Hattenrath et al 2010, 2015



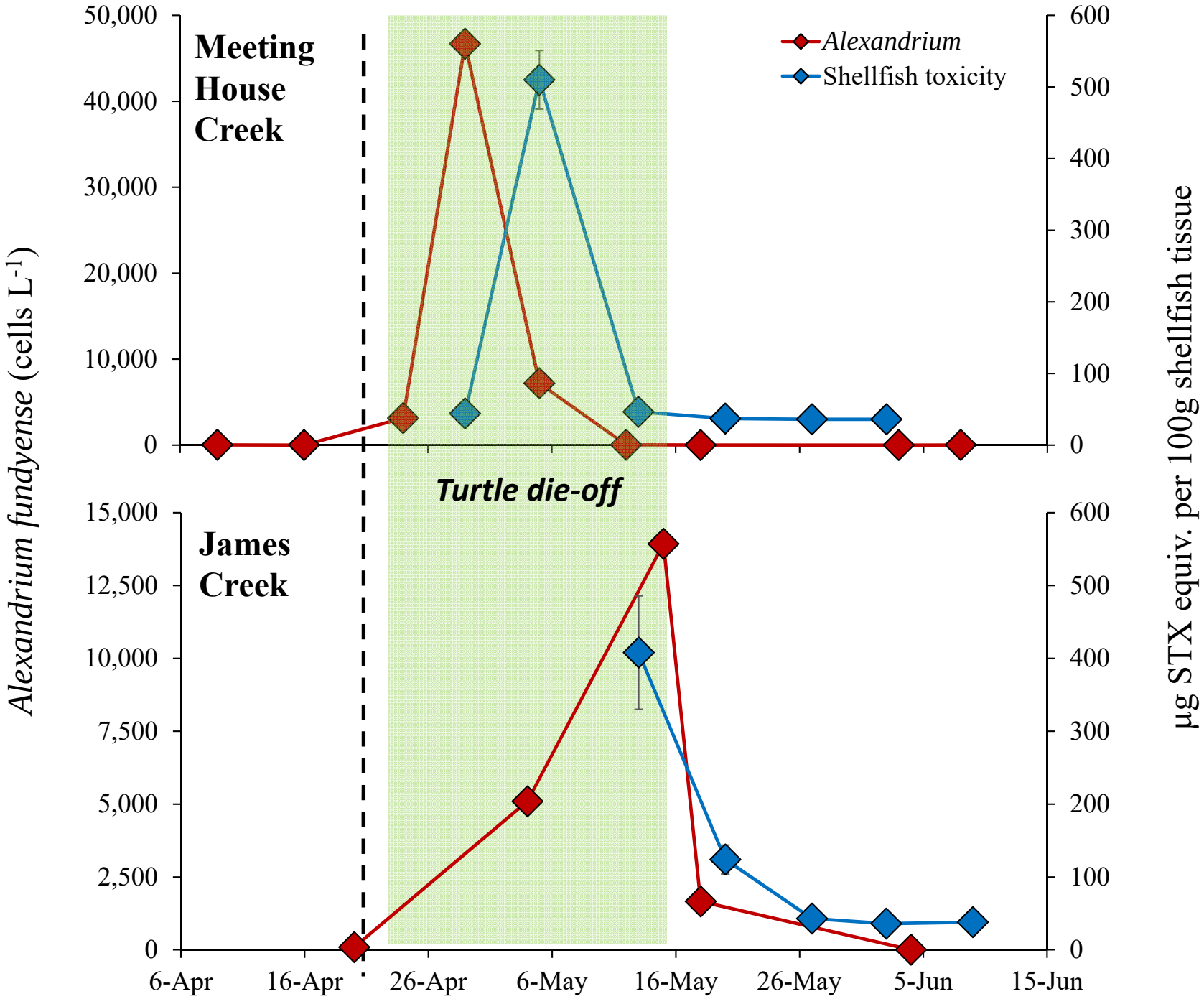
Saxitoxin

Newsday

Suffolk LONG ISLAND

Massive diamondback turtle die-off threatens local population

Updated May 18, 2015 10:08 PM


Meeting House Creek
James Creek
Alexandrium
Shellfish toxicity
Turtle die-off
Alexandrium fundyense (cells L-1)
µg STX equiv. per 100g shellfish tissue
50,000
40,000
30,000
20,000
10,000
0
15,000
12,500
10,000
7,500
5,000
2,500
600
500
400
300
200
100
6-Apr
16-Apr
26-Apr
6-May
16-May
26-May
5-Jun
15-Jun

Alexandrium and PSP, 1986-2016

Year	Maximum *Alexandrium* densities (cells L^{-1})	Maximum shellfish toxicity (µg STX eq $100g^{-1}$ shellfish tissue)
1986	14,000 (20-May)[a]	190[a*]
1987	500 (20-April)[a]	50[a]
1988	1,600 (9-April)[a]	60[a]
1989	5,700 (30-March)[a]	60[a]
1989	480 (4-May)[b]	<40[b]
1989	1000 (4-May)[c]	58[c]
2008	4,733 (29-Apr)	n.m.
2009	19,868 (23-Apr)	<40
2010	1,982 (15-Apr)	57
2011	1,166 (5-May)	48
2012	17,206 (11-Apr)	380*
2013	1,058 (10-Apr)	40
2014	7,480 (8-May)	53
2015	**46,690 (29-April)**	**540**
2016	550 (16-May)	<40

Potential lethal dose of mussels to turtles

With lethal dose of 10ug/kg

Sex	average weight (kg)	lethal dose (ug)	Amount (g) of mussel required for a lethal dose	# of mussels* for lethal dose
Male	0.226	2.26	0.418518519	<1
Female	0.68	6.8	1.259259259	<1

With lethal dose of 100ug/kg

Sex	average weight (kg)	lethal dose (ug)	Amount (g) of mussel required for a lethal dose	# of mussels* for lethal dose
Male	0.226	22.6	4.185185185	~1
Female	0.68	68	12.59259259	~3

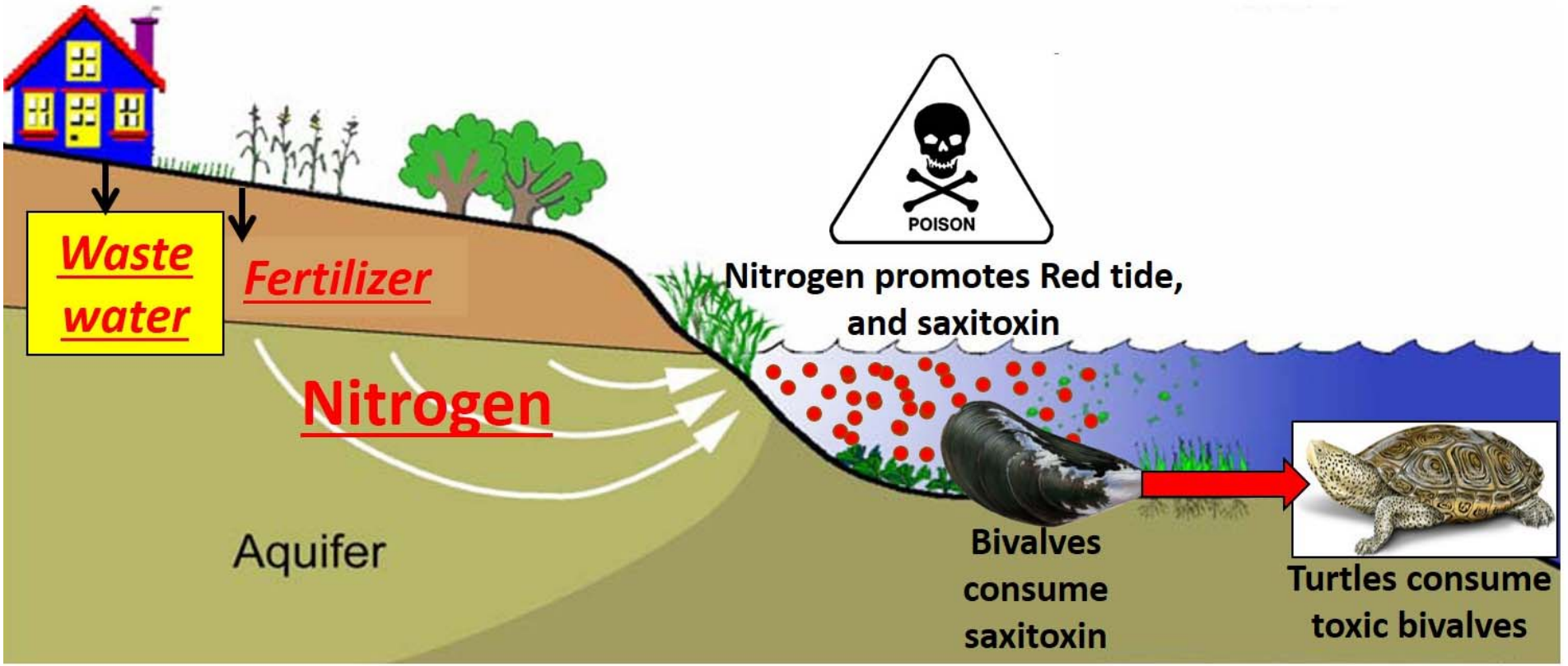
The consumption of more mussels would have been tolerable earlier in the bloom.

Saxitoxin in turtles

DNA sequencing of gut content reveals presences of ribbed mussel DNA in digestive tracts of all turtles.

SB1	Late (5/15)	0	1.2	0	0
CU1	Early (4/24)	1	0	1.2	n/a
CU2	Early (4/24)	0	12.5	0	n/a
NY10383.11	Middle (4/28-5/3)	n/a	n/a	n/a	0.2
NY10383.12	Middle (4/28-5/3)	n/a	n/a	n/a	0.3

Linking land-derived nitrogen to turtle deaths

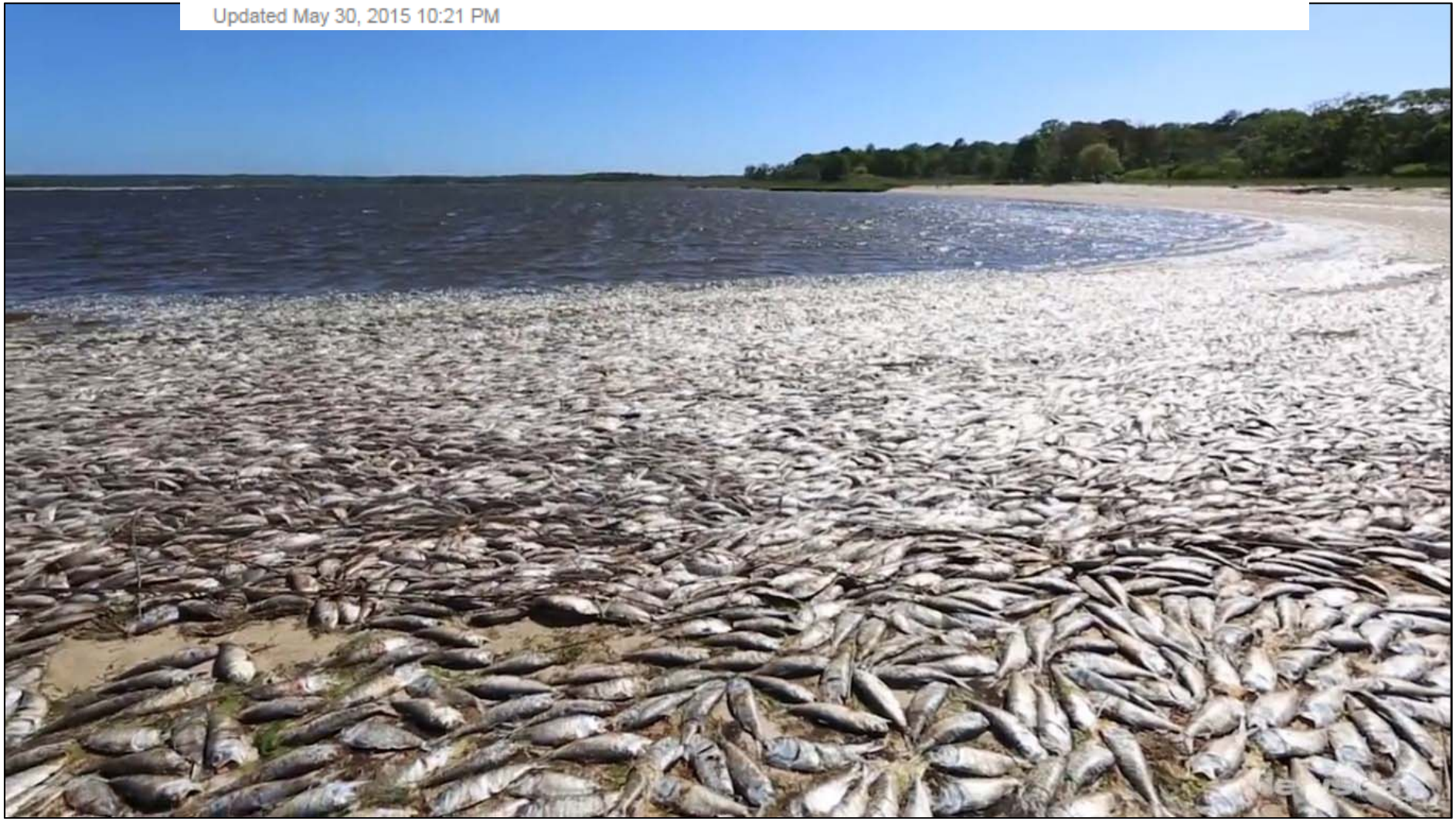


Newsday

Suffolk LONG ISLAND

Massive fish kill reported in Riverhead, Southampton towns

Updated May 30, 2015 10:21 PM



400,000 dead fish

Investigation of Fish Kills Occurring in the Peconic River - Riverhead, N.Y. Spring 2015

Suffolk County Department of Health Services
James L. Tomarken, M.D., M.P.H., M.B.A., M.S.W.
Commissioner

New York State Dept. of Environmental Conservation
Marc Gerstman, Acting Commissioner

Stony Brook University
School of Marine and Atmospheric Sciences
Christopher J. Gobler, Ph.D., Associate Dean for Research, Professor

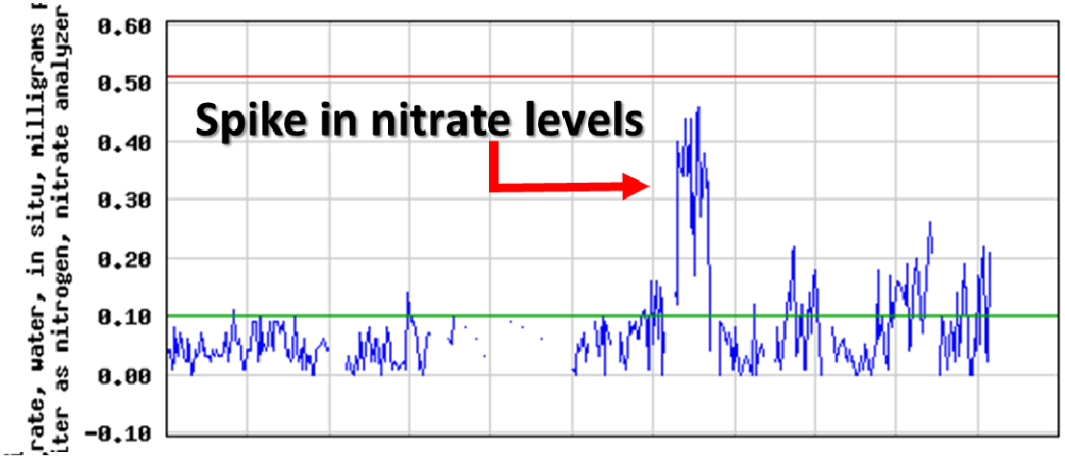
January, 2016

2015 fish kill official causes of death

- **Low oxygen** conditions promoted by algal blooms and rising temperatures.
- **Nitrogen**-promoted **algal blooms causing gill damage.**
- Larger than normal numbers of fish in a confined region.

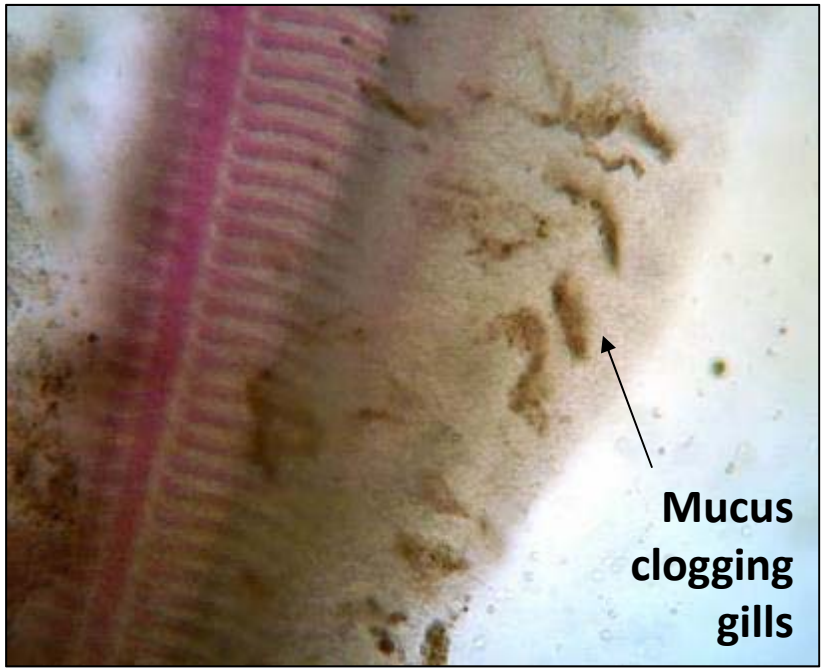
How does this happen?

Widespread fish kill May 29-30



Gymnodinium instriatum

Gill damage caused by *Gymnodinium instriatum*



Weather

The Long Island Water Quality Index

By The Gobler Laboratory at Stony Brook University

The Long Island Water Quality Index is provided weekly by The Gobler Laboratory at Stony Brook University to inform about the quality of the water around Long Island. Click on the dots on the map below to obtain more information on the specific reading for that area. More information here

Long Island Water Quality Index ranking system

Feature	Good	Fair	Poor	Sources for ranking

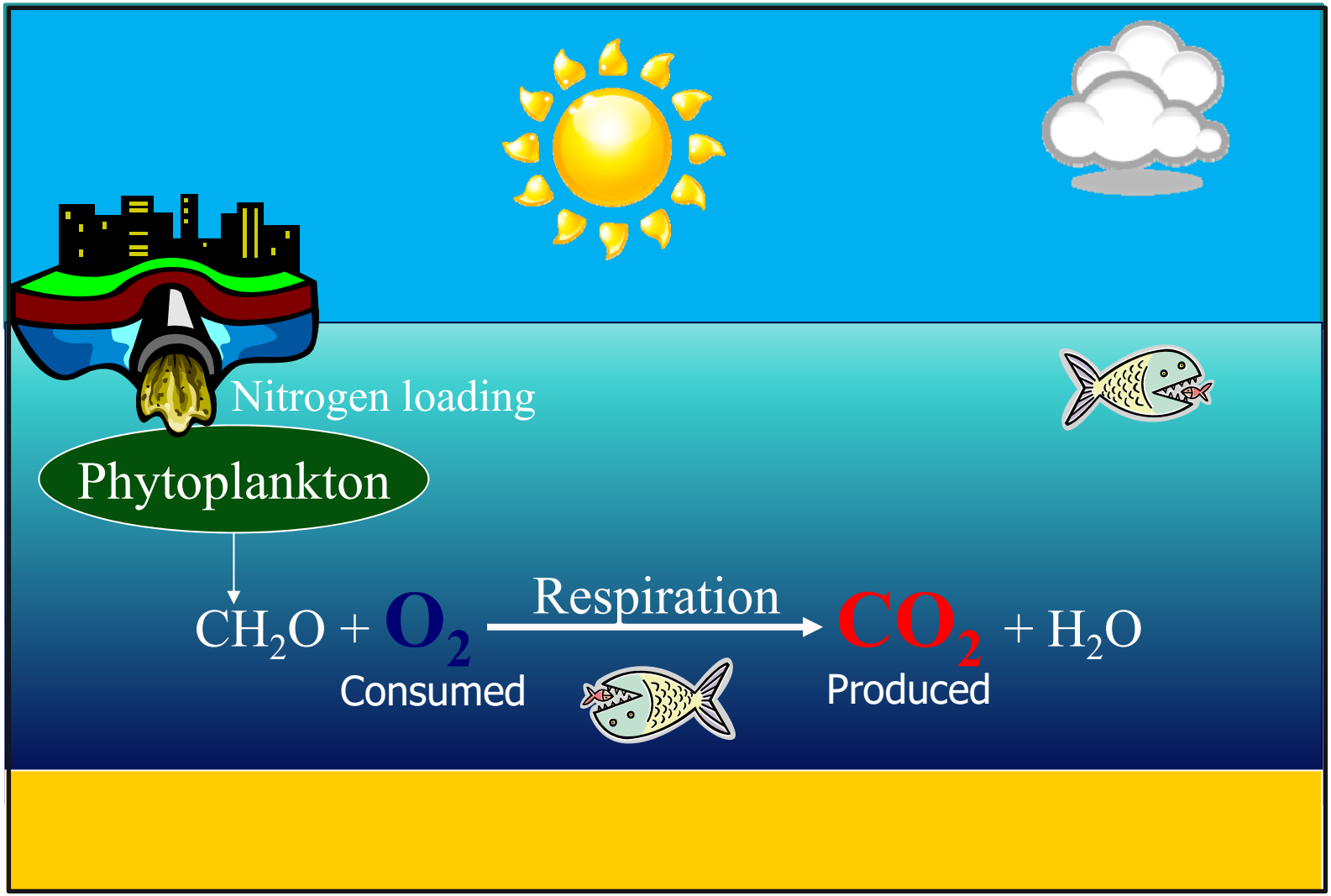
Thursday evening weather forecasts, May – September 2014 - 2016

Quantitative water quality assessment

Feature	Good	Fair	Poor	Sources for ranking
Chlorophyll a (µg/L)	<5	5-20	>20	USEPA, NOAA, NYSDOH
Dissolved oxygen (mg/L)	>5	3-5	<3	NYSDEC, USEPA
Water clarity	>2m	1-2m	<1m	USEPA, NYSDOH
Fecal coliform (colonies per 100m	<14	14-2,000	>2,000	NYSDEC, NYSDOH
Harmful algal blooms	None, low	Minor impact	Major impact	NOAA, Scientific literature
Temperature (°C)	<25	25-28	>28	Scientific literature
Score	3	2	1	

Site	Minimum oxygen (mg/L)	Average temp (°C)	Water Clarity (m)	Fecal Coliform (per 100 mL)	Chlorophyll (ug/L)	Harmful Algae	SCORE	Class	Impairment
Hempstead Harbor	3.83	22.55	1	110	23.37	None	2	Fair	Oxygen, algae, fecal bacteria
Oyster Bay Harbor	4	23	2.1	<10	8.7	None	2.66667	Good	
Cold Spring Harbor	0	23.2	1.7	<10	13.57	None	2.33333	Fair	Oxygen, water clarity, harmful algae
Huntington Harbor	4.98	23.6	1.5	10	15.94667	None	2.5	Good	
Northport Harbor	0	24.2	1	<10	26.1	Prorocentrum>1,000/mL	1.66667	Poor	Oxygen, water clarity, algae

Excessive nitrogen loading leads to **low oxygen**



"More algae and warm temperatures during summer make bacteria **hyperventilate**"

New York State Department of Environmental Conservation
Division of Water, 4th Floor
625 Broadway, Albany, New York 12233-3500
Phone: (518) 402-8233 • **FAX:** (518) 402-8230
Website: www.dec.ny.gov

Alexander B. Grannis
Commissioner

Dissolved oxygen standard for NYS

NOV 0 4 2008

MEMORANDUM

TO: Bureau Directors, Division Directors,
Regional Directors, and Regional Water Engineers

FROM: James DeZolt, Director, Division of Water

SUBJECT: Division of Water Technical and Operational Guidance Series (TOGS) 1.1.6,
Interpretation Guidance for Marine Dissolved Oxygen Standard

The ambient water quality standards for DO for Class SA, SB and SC waters are 4.8 mg/L, with allowable excursions to not less than 3.0 mg/L for certain periods of time. The standards can be found at 6 NYCRR 703.3. and are repeated below for the convenience of the reader. This standard is continuously applicable throughout the year.

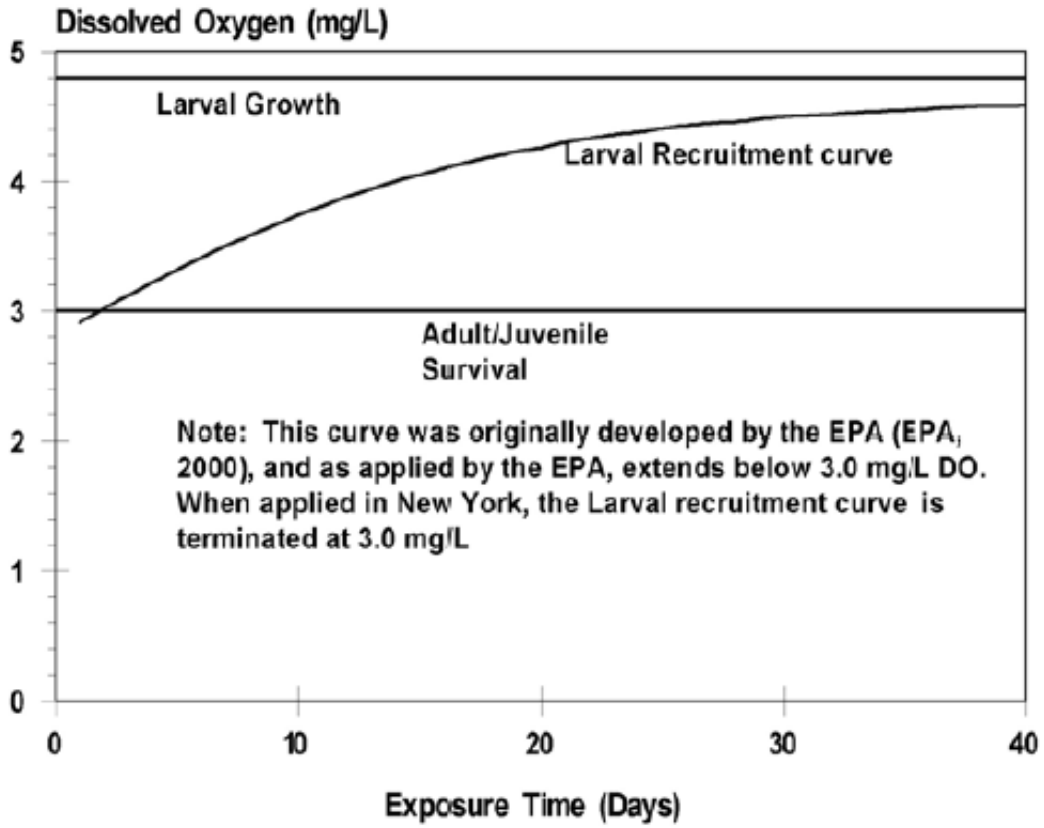
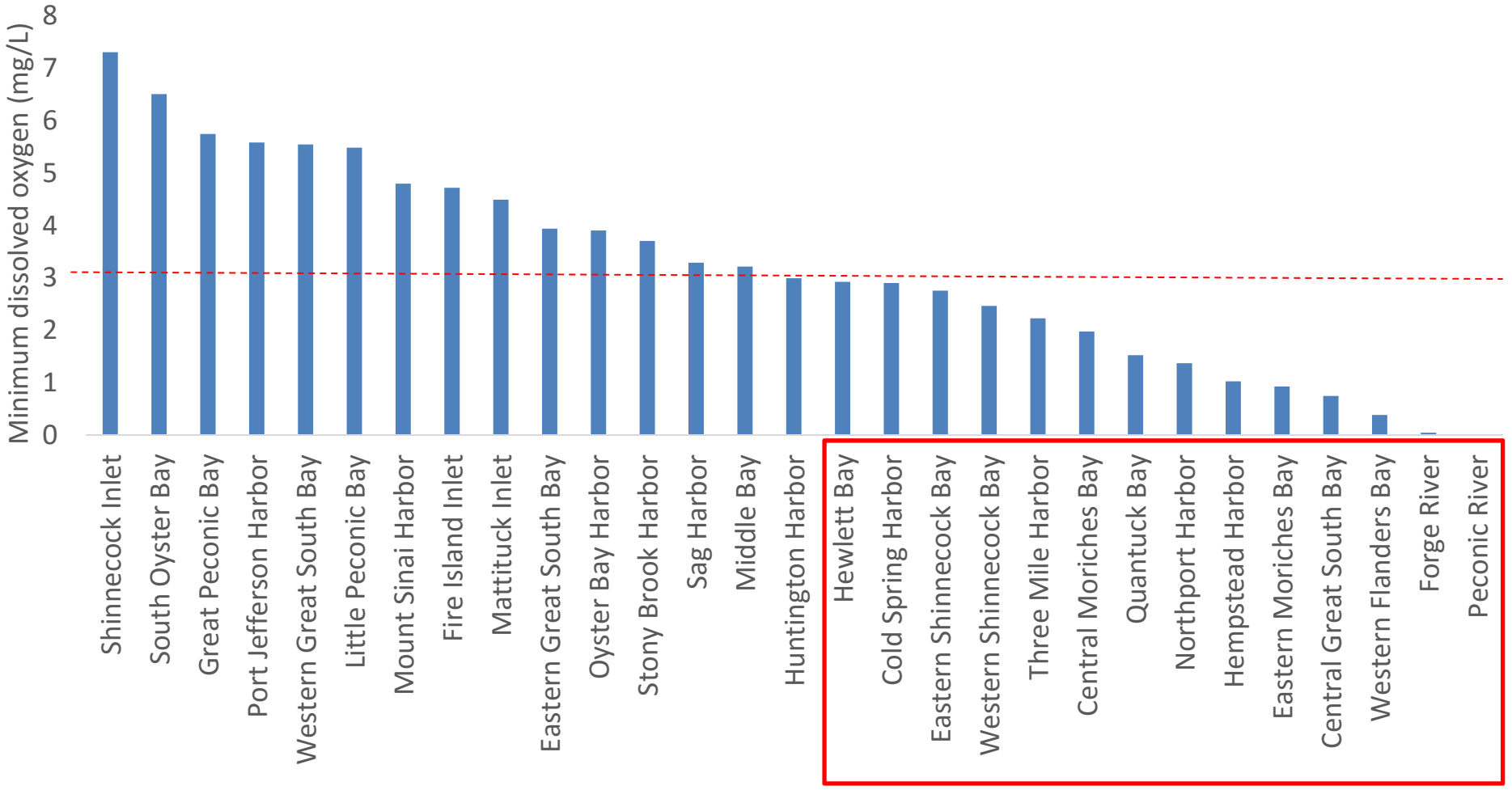
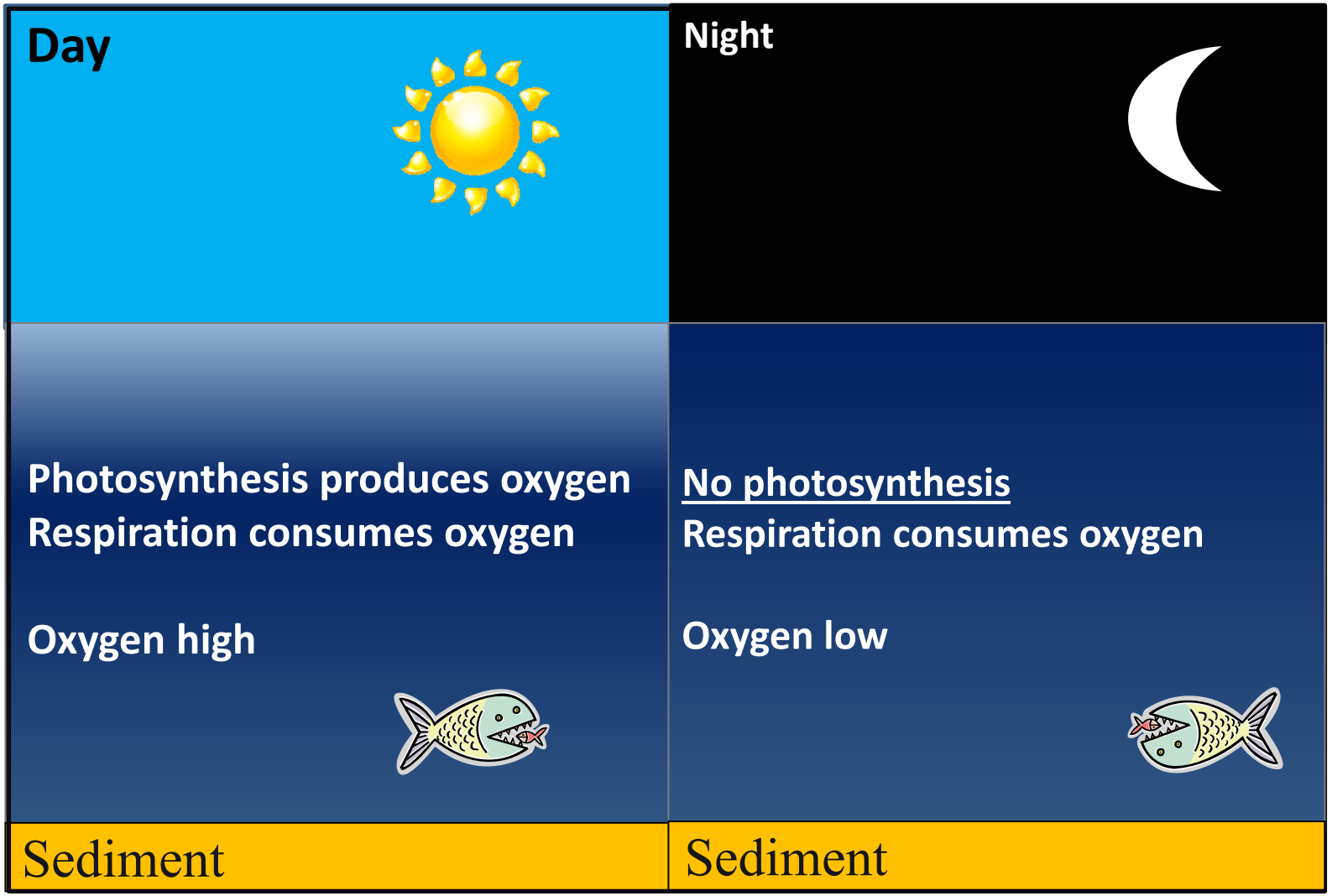


Figure 1. Graphic depiction of water quality standards for dissolved oxygen in saltwater. Shown are the saltwater chronic water quality standard (4.8 mg/L DO based on larval growth); the larval recruitment curve produced by equation 1; and the saltwater acute water quality standard (3.0 mg/L DO based on adult/juvenile survival).

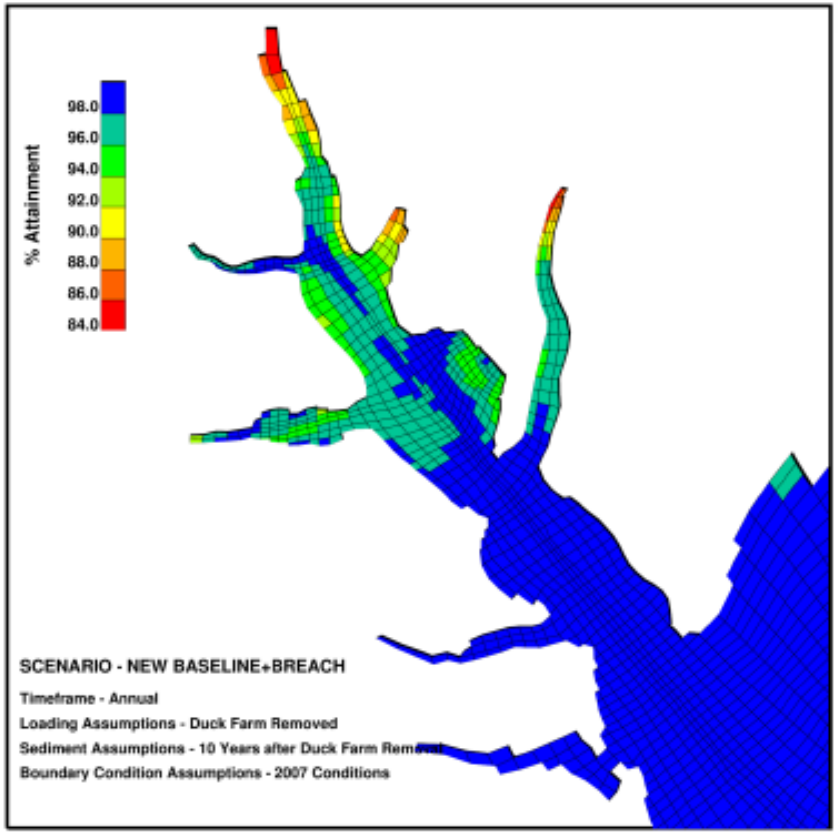
Dissolved oxygen, 2016



Excessive nitrogen loading leads to hypoxia or low oxygen

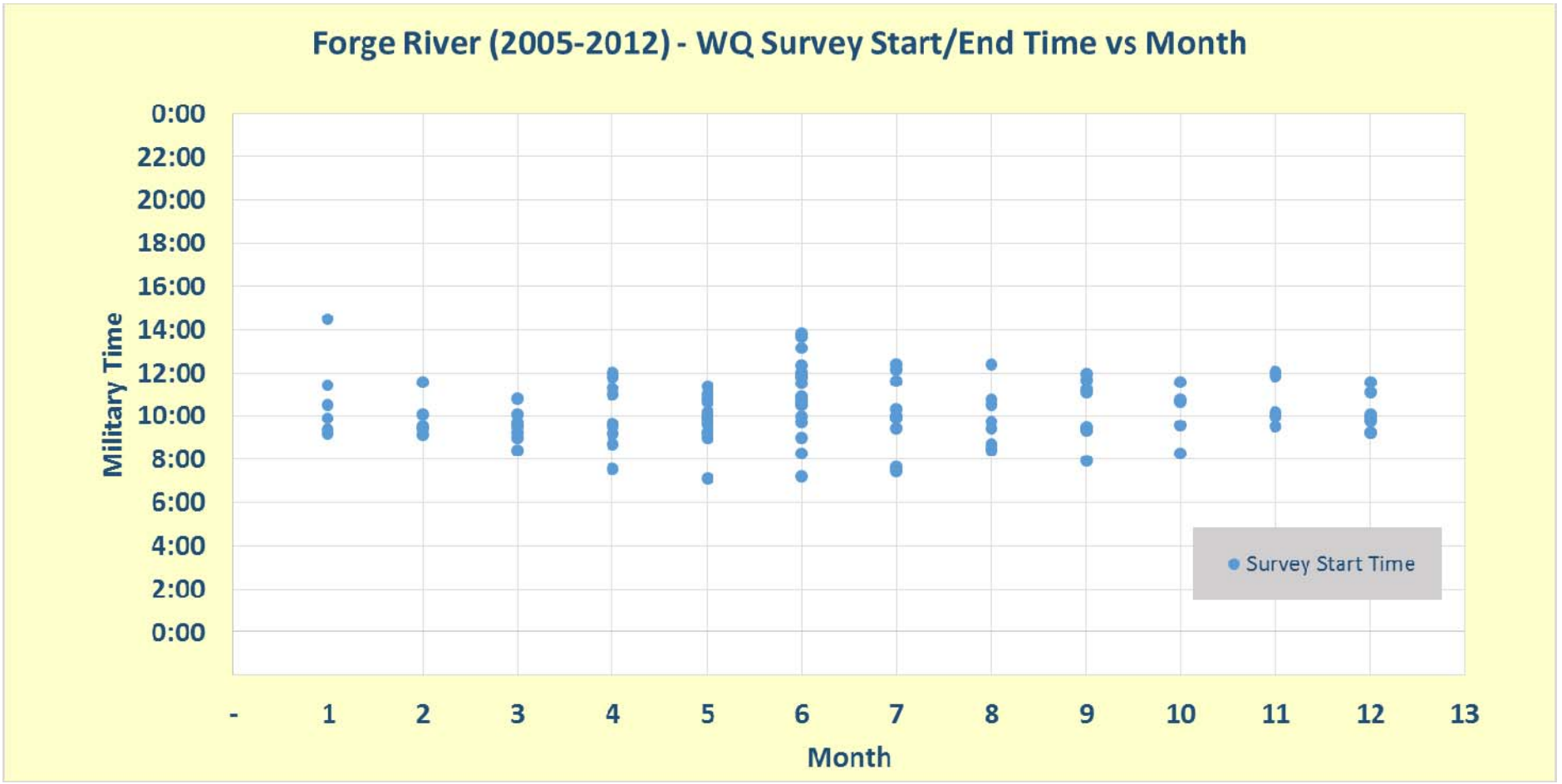


Example of low oxygen: Forge River, NY



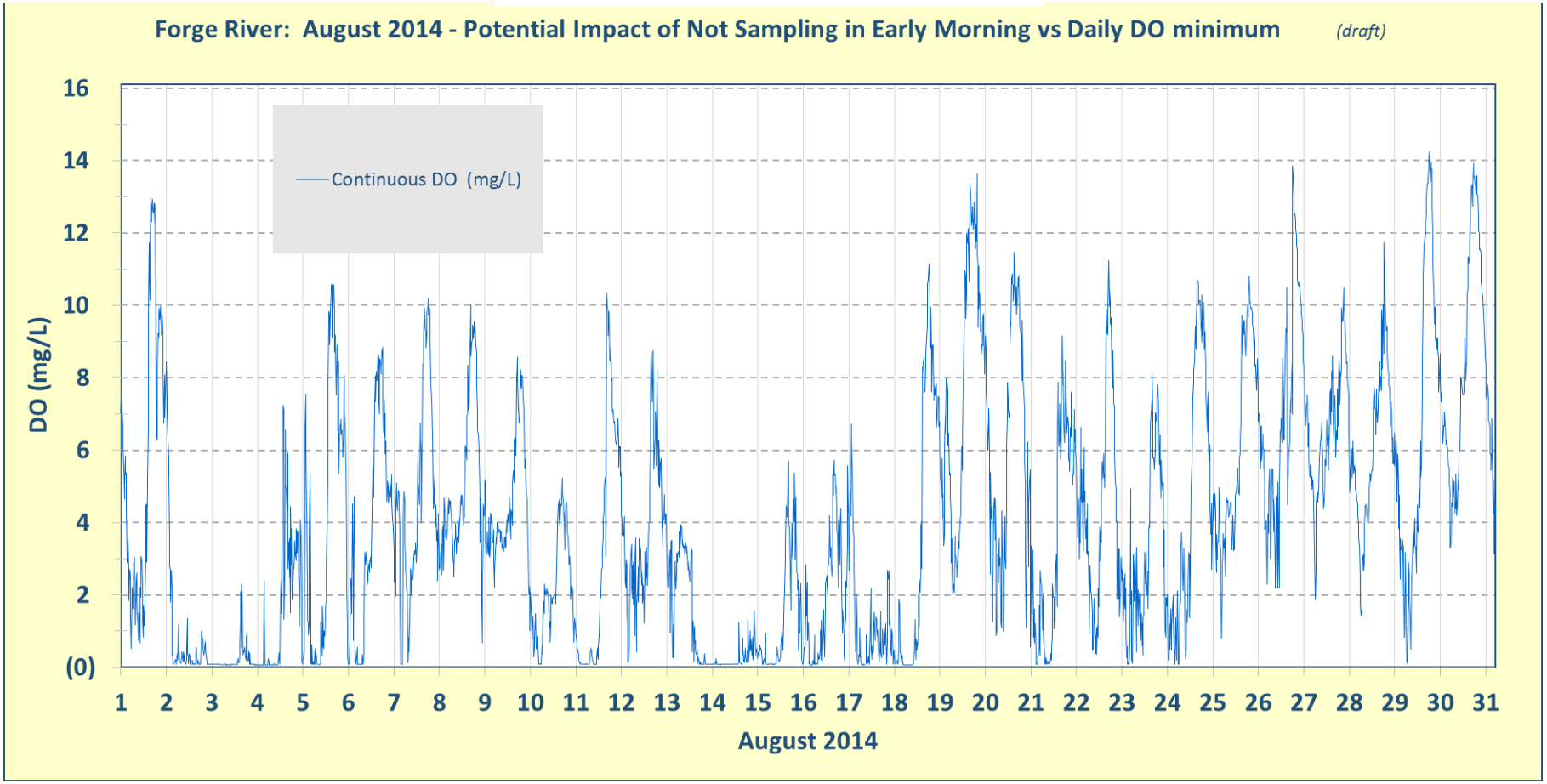
PERCENT OF ANNUAL VOLUME WITH DAYS HAVING DO CONCENTRATION >= 3.0 mg/L

igure 6 – Annual Percent Attainment of Acute DO Criterion on a Volumetric Basis- Updated Baseline Conditions



Richard Winfield, US EPA

Continuous measurements



Richard Winfield, US EPA

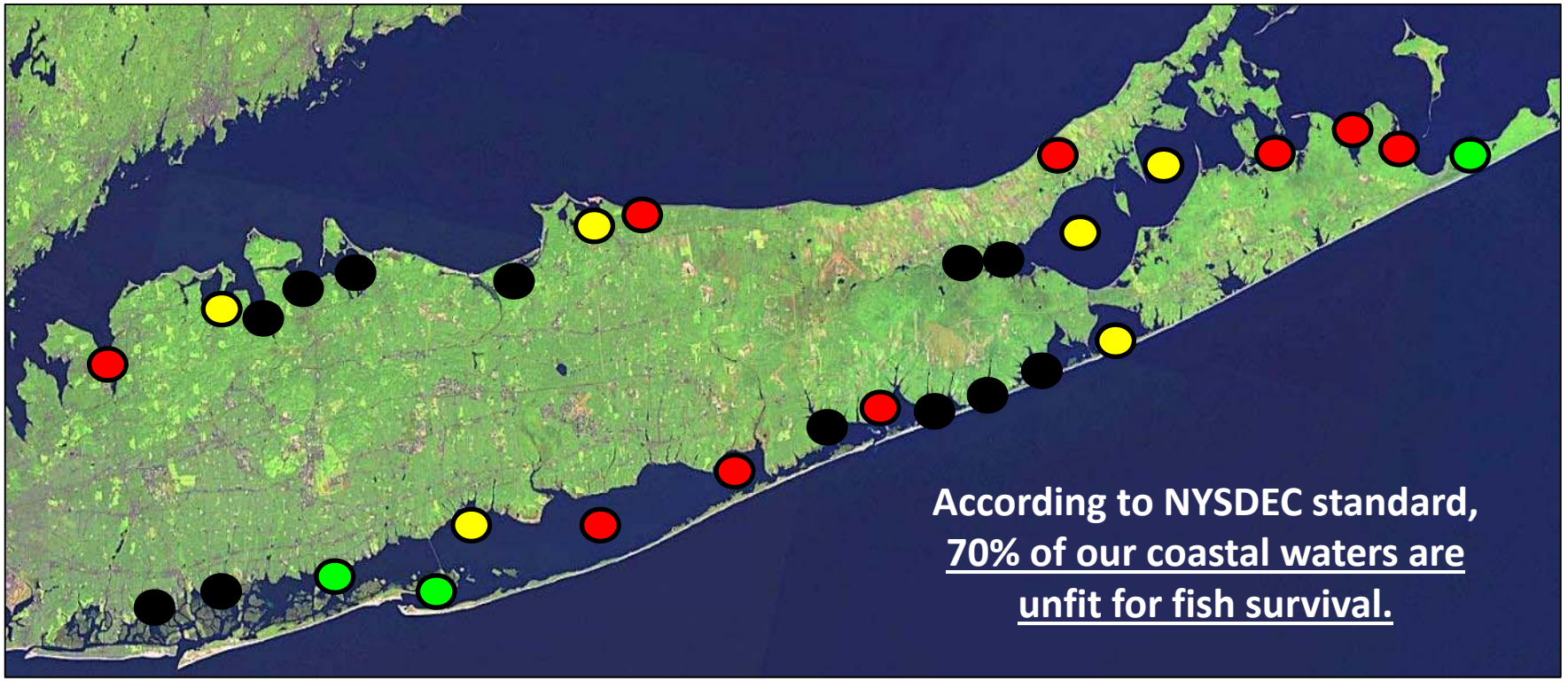
August 2014 Forge River

% of Time in compliance with > 3 mg/L standard

Based on Continuous Monitor	3%
Based on 8 am measurement	39%
Based on 11 am measurement	75%

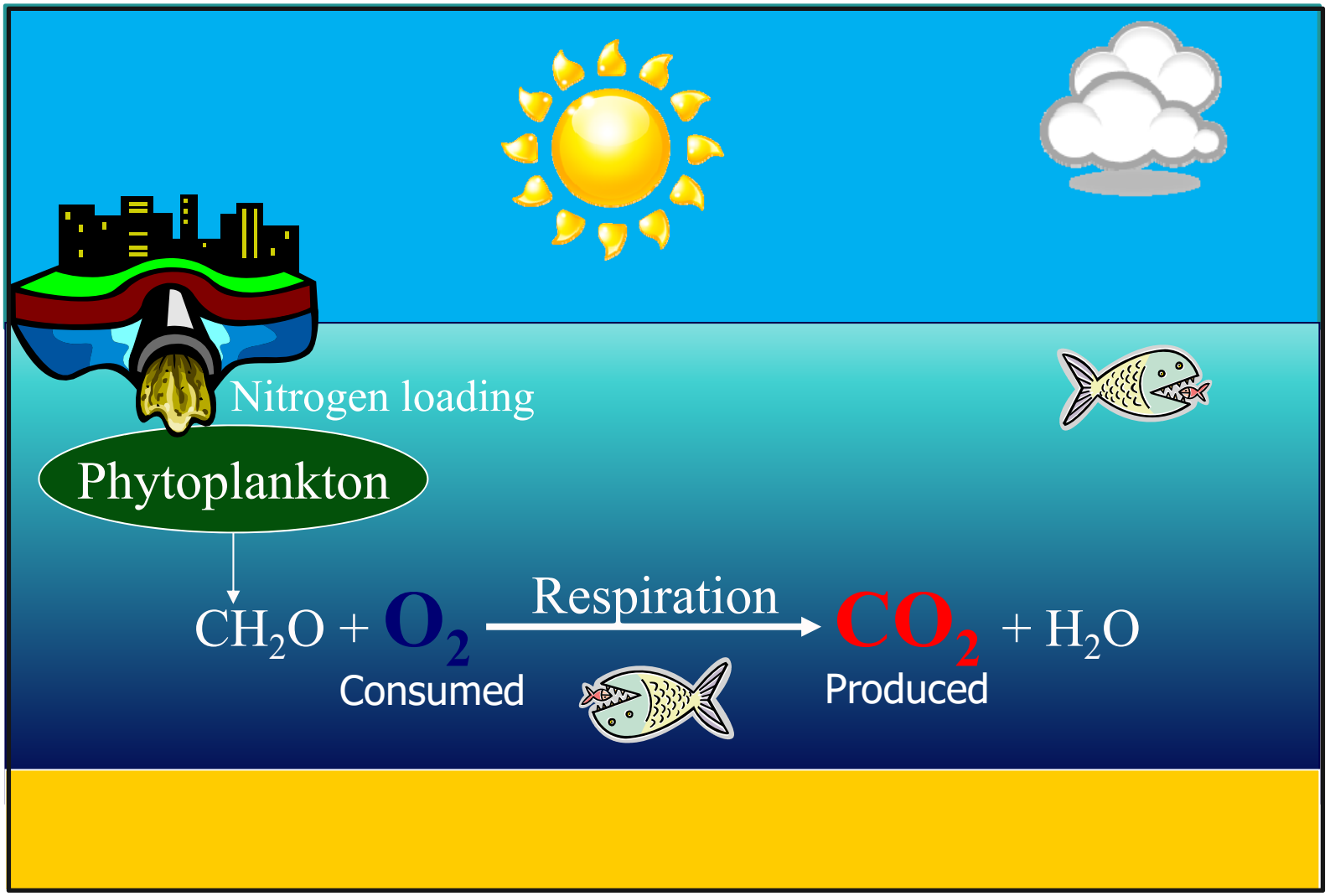
Richard Winfield, US EPA

Dissolved oxygen minimums across Long Island, July & August 2016



- > 5 mg/L, need for fish propagation; Good; 10% of sites
- 3 - 5 mg/L, need for fish survival; Fair; 20% of sites
- 0.1 - 3 mg/L, not suitable for fish survival; Poor; 30% of sites
- < 0.1 mg/L, not suitable for fish survival; Lethal; 40% of sites

Excessive N loading leads to low oxygen **and high CO_2**



"More algae and warm temperatures during summer make bacteria **hyperventilate**"

Estuarine, Coastal and Shelf Science 148 (2014) 1–13

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Invited feature

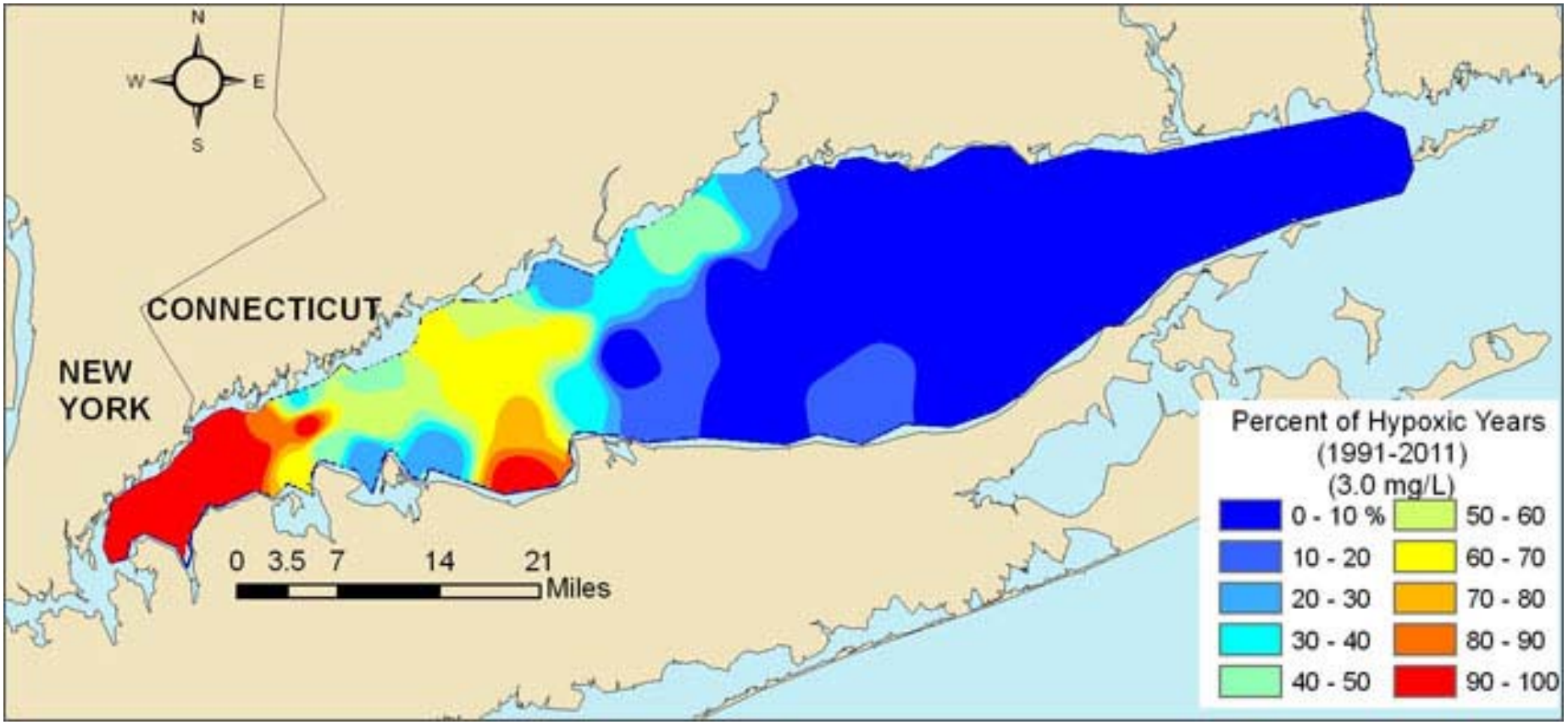
Coastal ocean acidification: The other eutrophication problem

Ryan B. Wallace [a], Hannes Baumann [a], Jason S. Grear [b], Robert C. Aller [a], Christopher J. Gobler [a, *]

[a] Stony Brook University, School of Marine and Atmospheric Sciences, 239 Montauk Hwy, Southampton, NY 11968, USA
[b] US Environmental Protection Agency, Atlantic Ecology Division, National Health and Environmental Effects Research Laboratory, Office of Research and Development, 27 Tarzwell Dr, Narragansett, RI 02882, USA

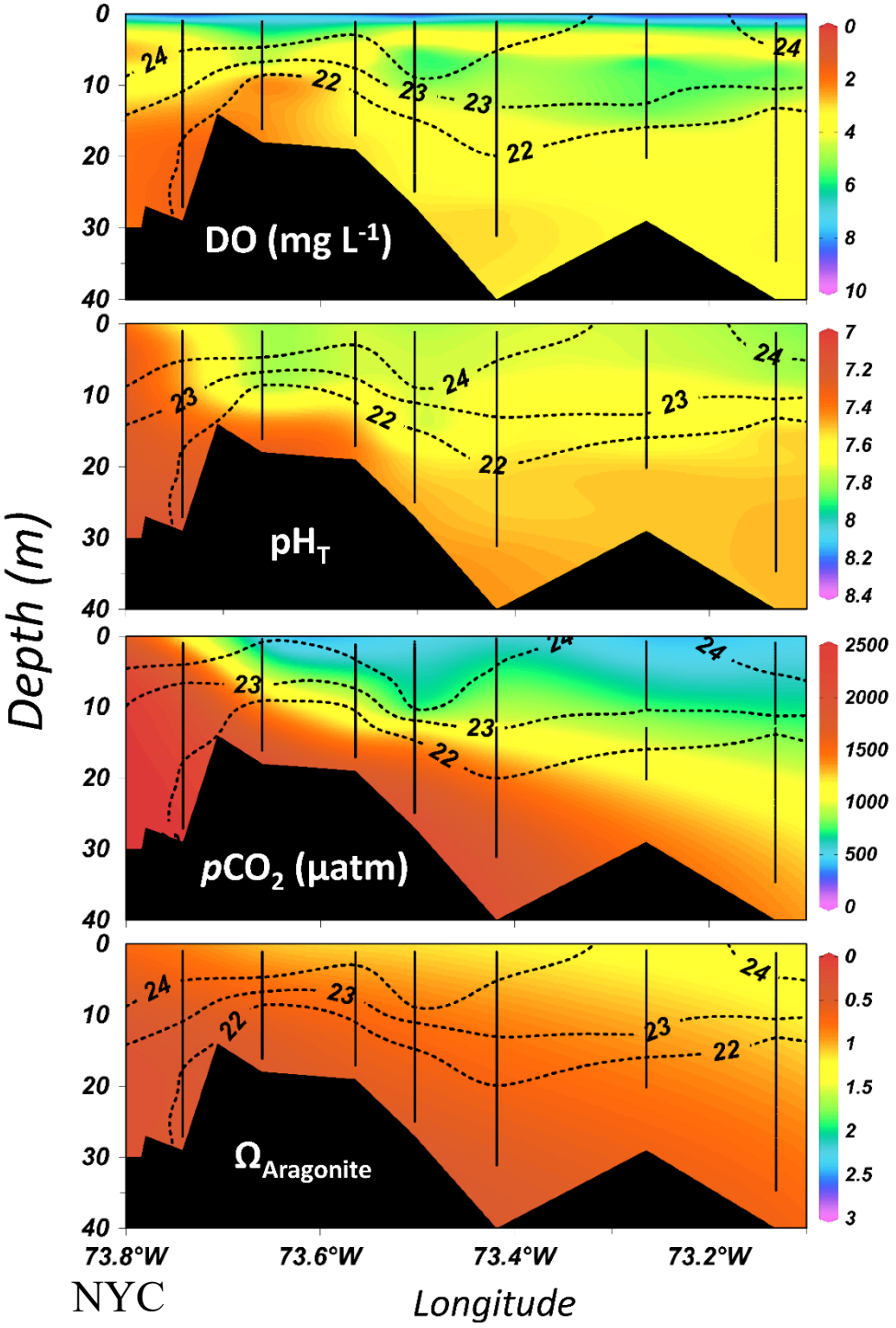
Nutrient discharge into coastal zone → **Nutrients stimulate algal blooms** → **Decay of algae = ↑CO_2, ↓ pH, ↓ DO**

The annual occurrence of hypoxia and acidification in Long Island Sound



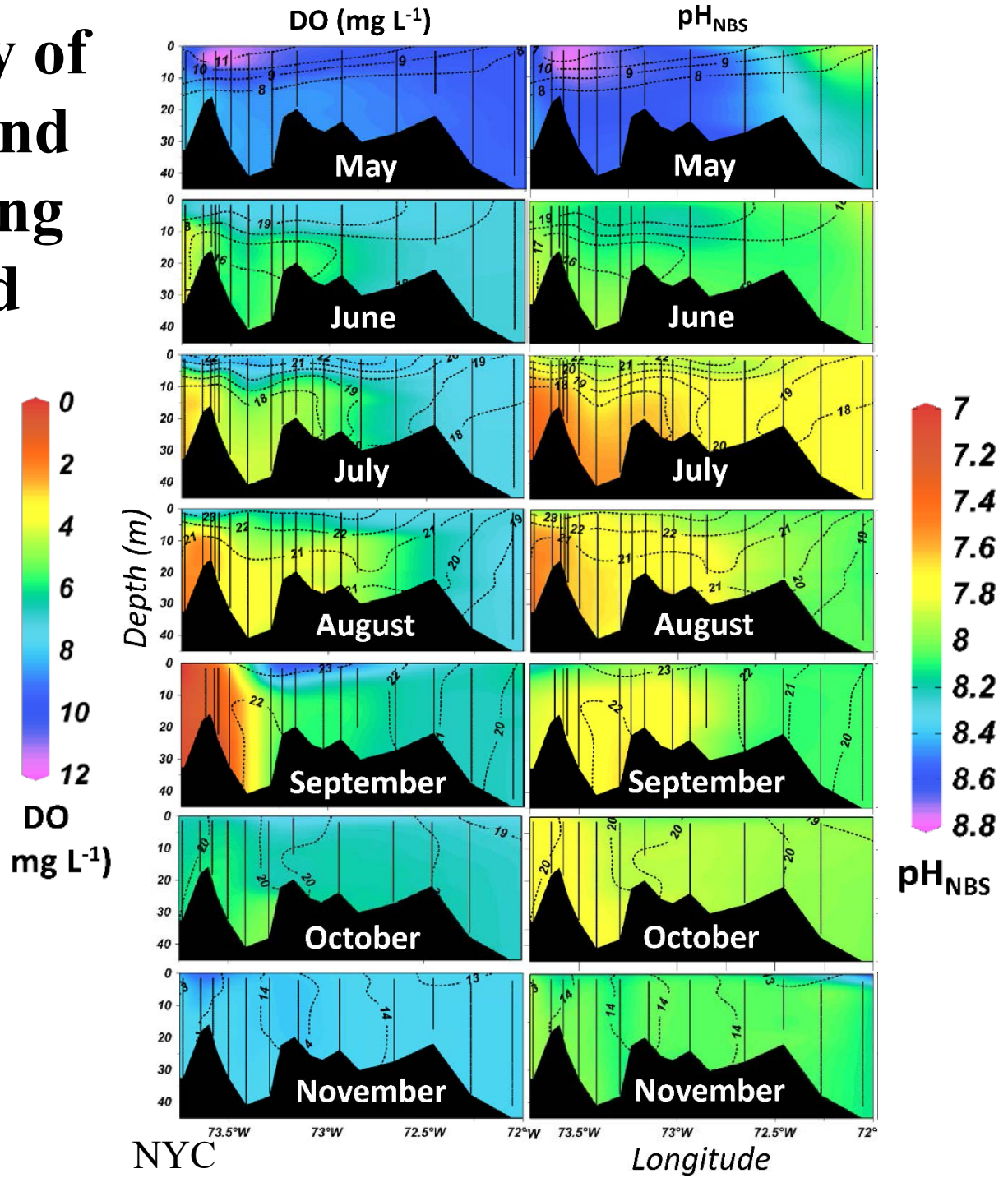
Co-occurrence of low oxygen and acidification in Long Island Sound

The intensity of acidification in Long Island Sound during summer exceeds levels project for the open ocean in 2100.



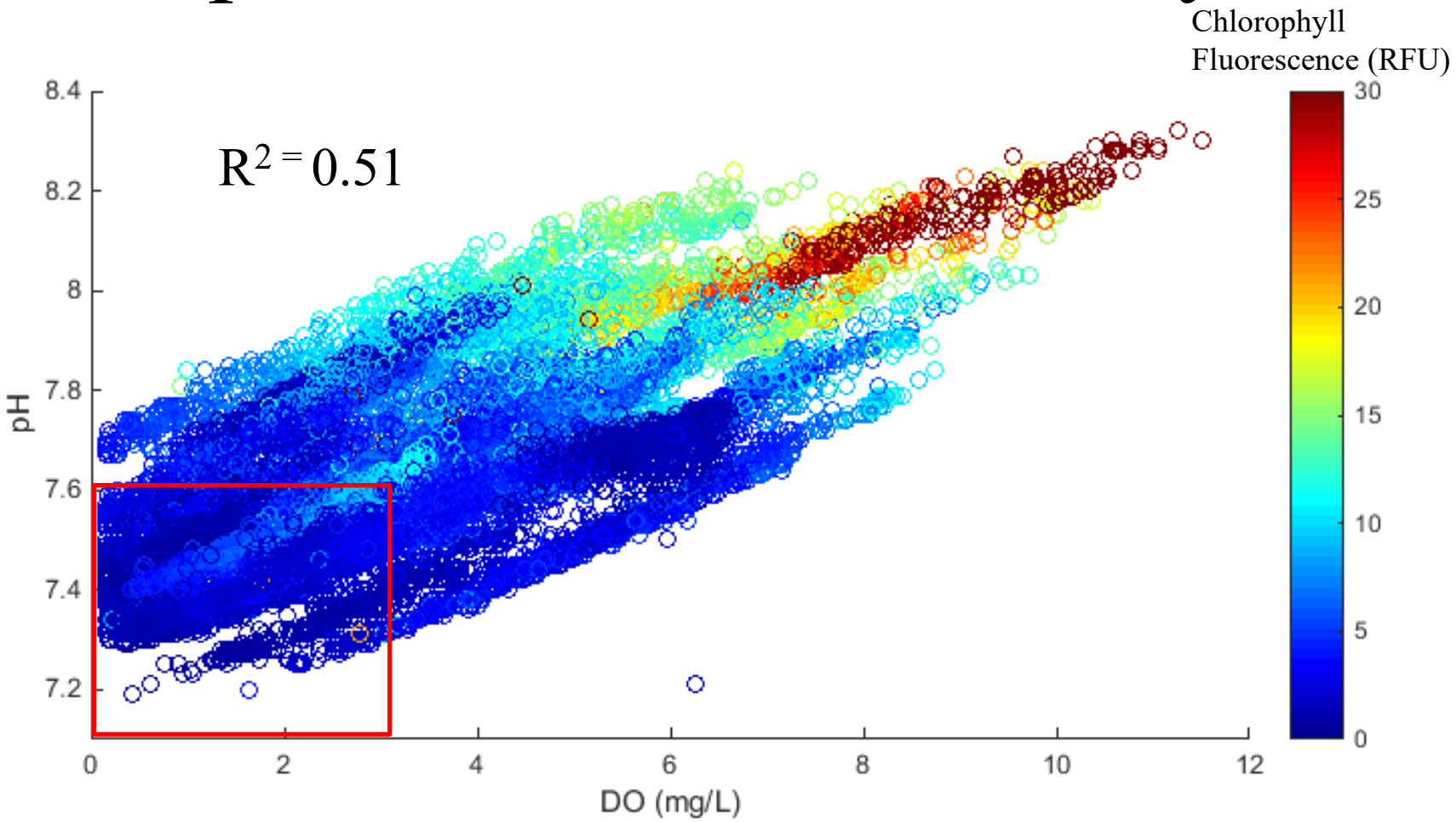
Wallace et al, 2014, ECCS

The seasonality of acidification and hypoxia in Long Island Sound



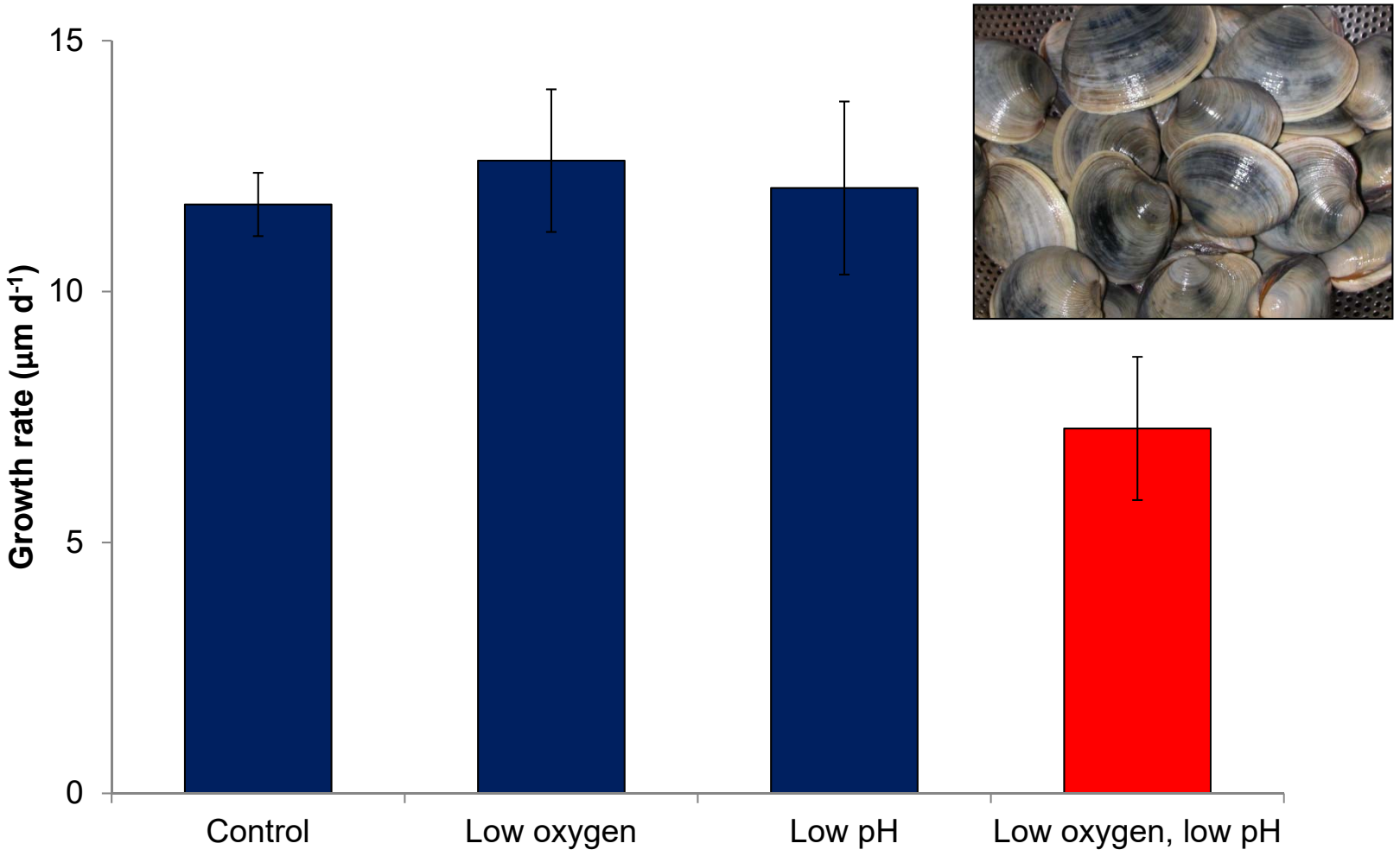
Wallace et al, 2014, ECCS;
CTDEEP data set

pH and DO, Jamaica Bay



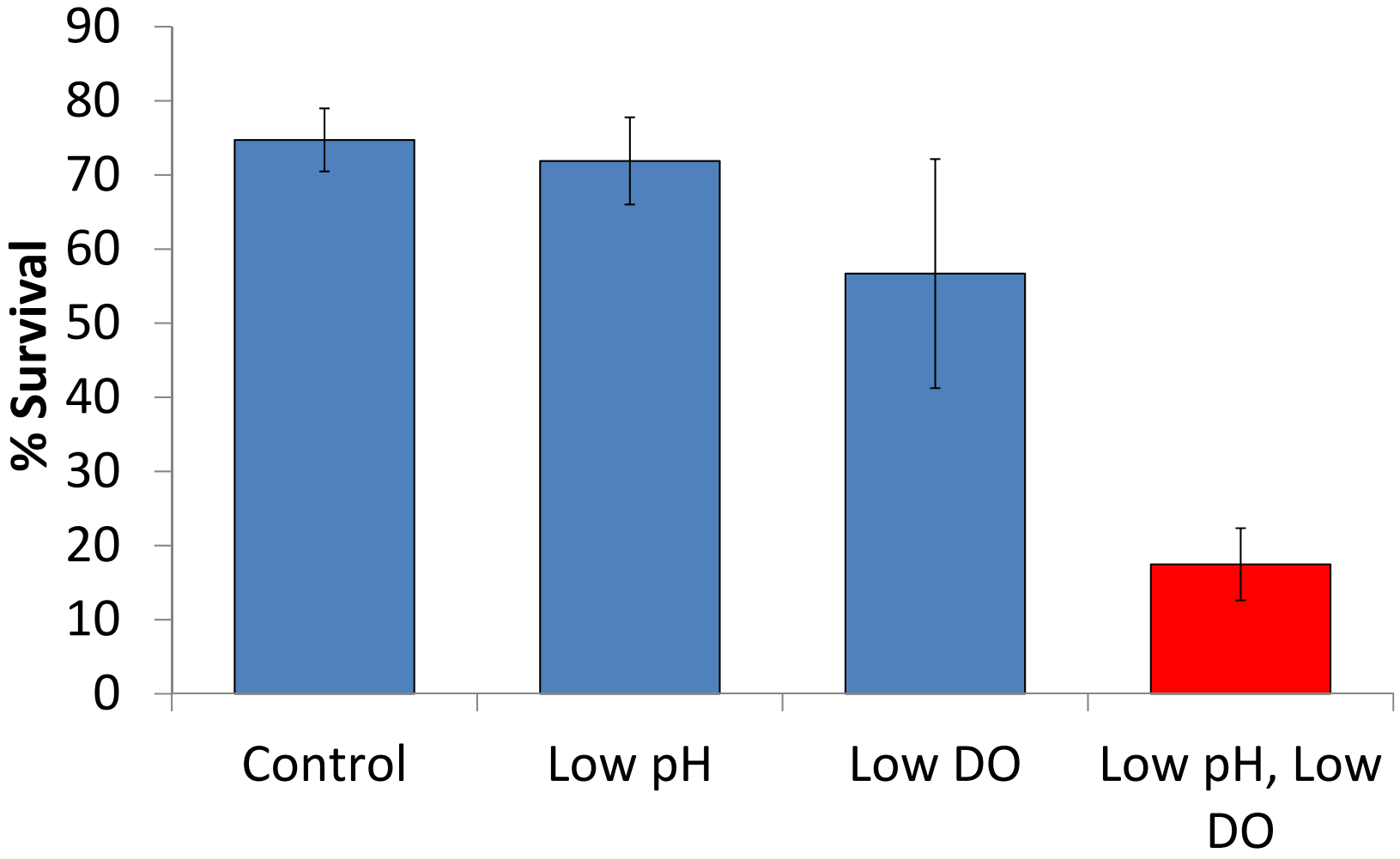

How does acidification and low oxygen effect marine life?
Credit: Travis Dove Photography

Growth of juvenile hard clams (4 months old) exposed to low oxygen and acidification



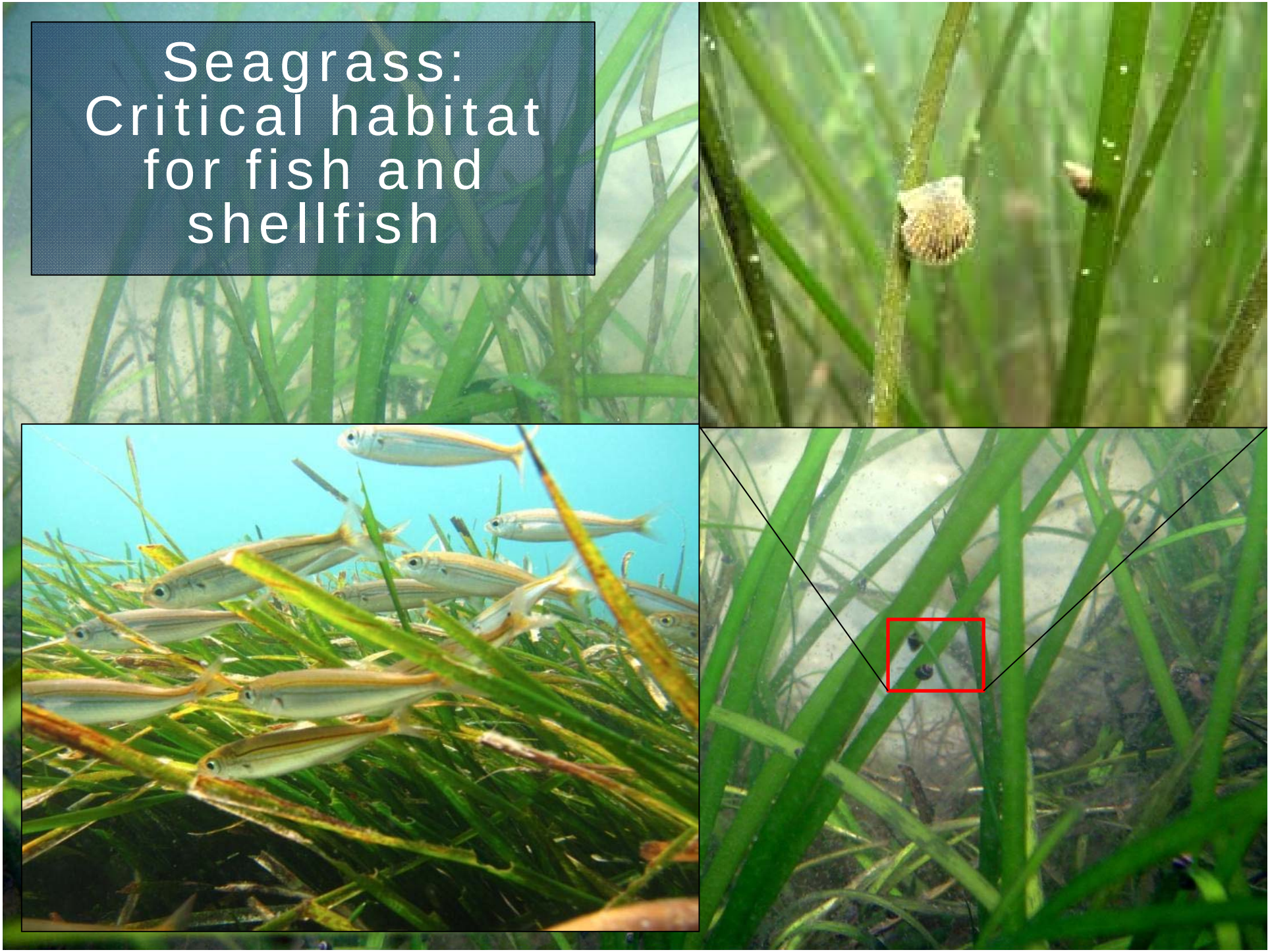
Gobler et al 2014, PLOS One

Menidia menidia

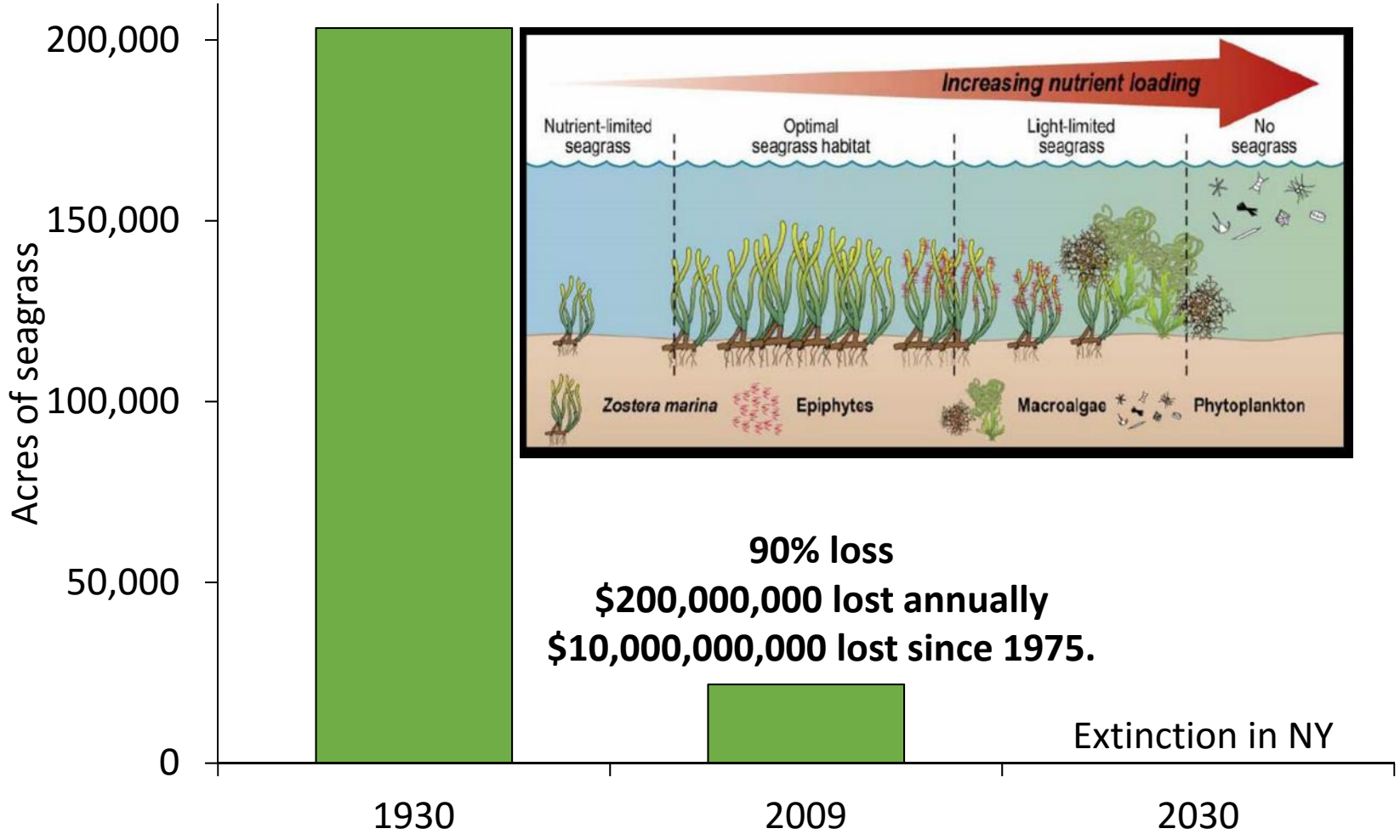


Depasquale et al,2015, MEPS

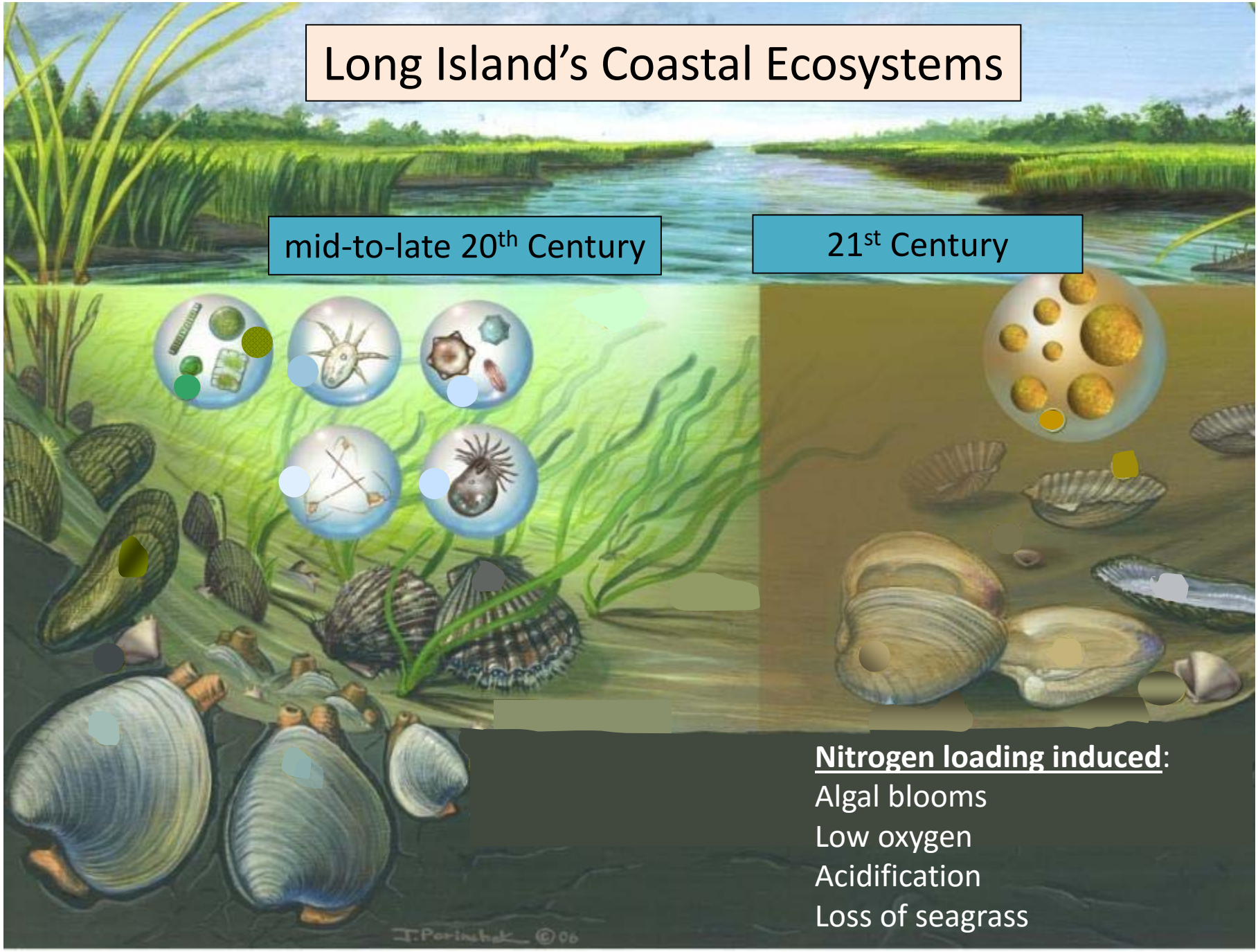
Seagrass: Critical habitat for fish and shellfish



NYS seagrass, 1930 - 2030



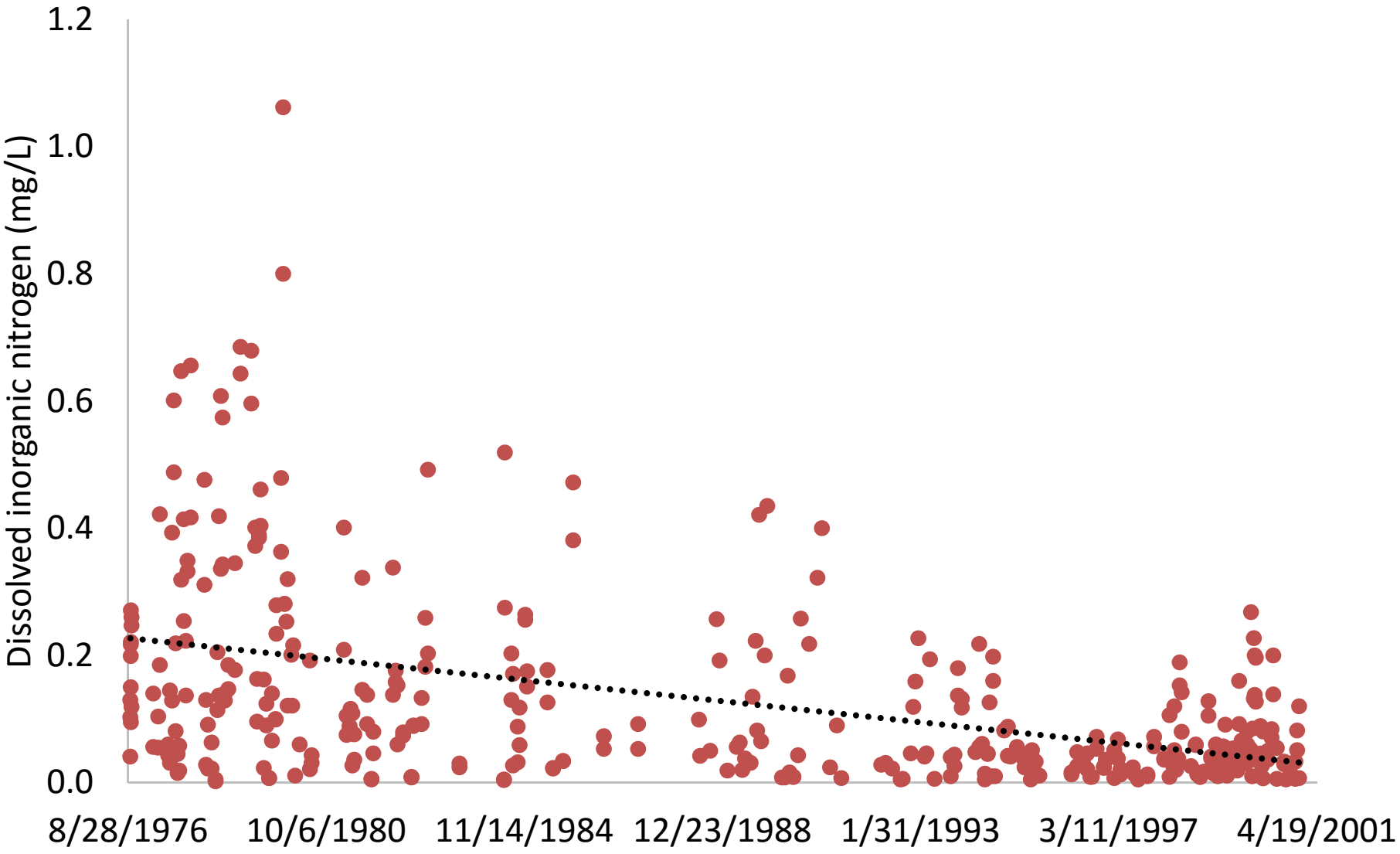
NYSDEC Seagrass Taskforce Final Report, 2010; Suffolk County assessment, 2014


Long Island's Coastal Ecosystems
mid-to-late 20th Century
21st Century
Nitrogen loading induced:
Algal blooms
Low oxygen
Acidification
Loss of seagrass

Can eutrophication induced impairments be reversed in NY coastal waters?

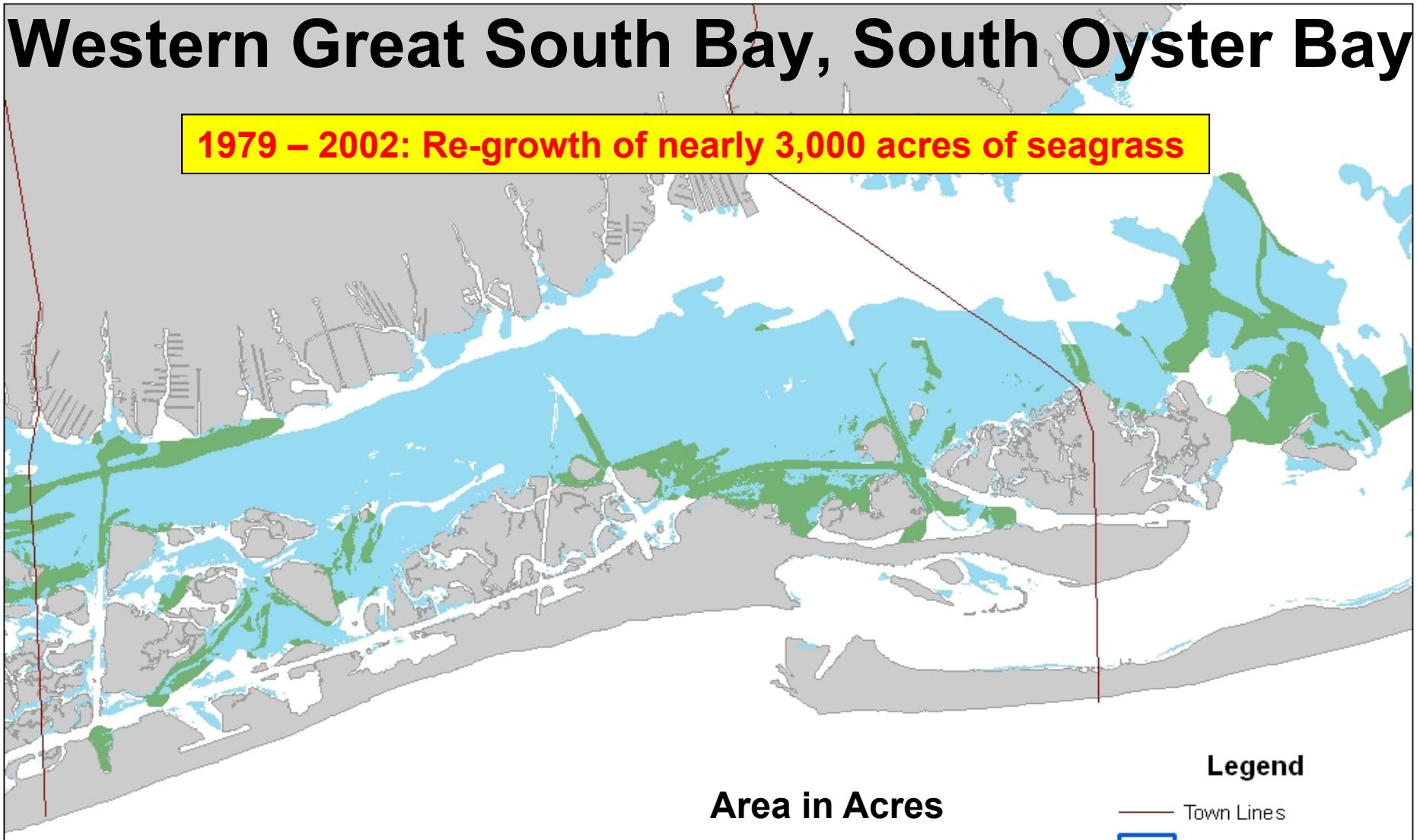
Bergen Point Sewage Treatment Plant

Before and after ocean outfall



Western Great South Bay, South Oyster Bay

1979 – 2002: Re-growth of nearly 3,000 acres of seagrass



Area in Acres

2002	**6096**
1979	**3913**
Change	**2813**

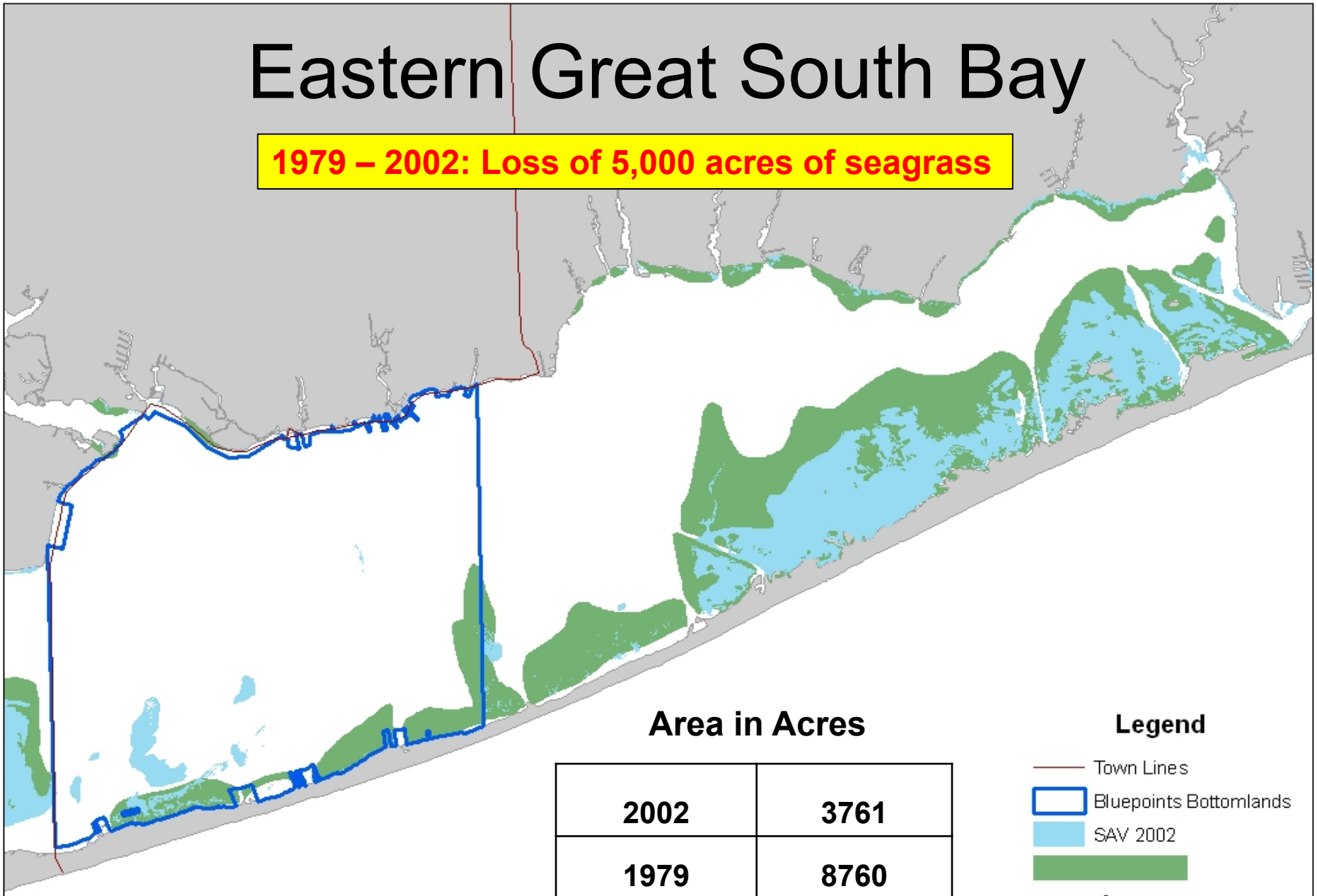
Legend

- Town Lines
- Bluepoints Bottomlands
- SAV 2002
- SAV 1979

Source data; NOAA, NYS DOS, Jones and Schubel 1979

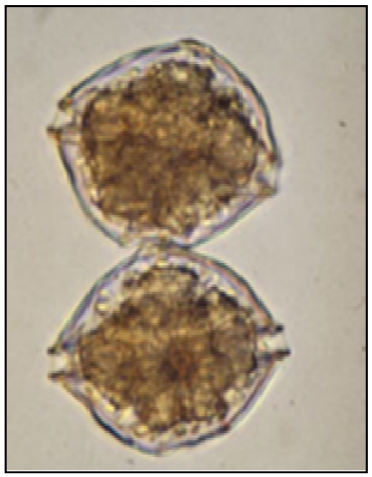
Eastern Great South Bay

1979 – 2002: Loss of 5,000 acres of seagrass

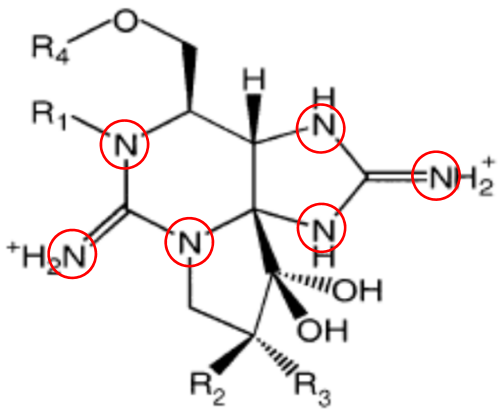


Source data; NOAA, NYS DOS, Jones and Schubel 1979

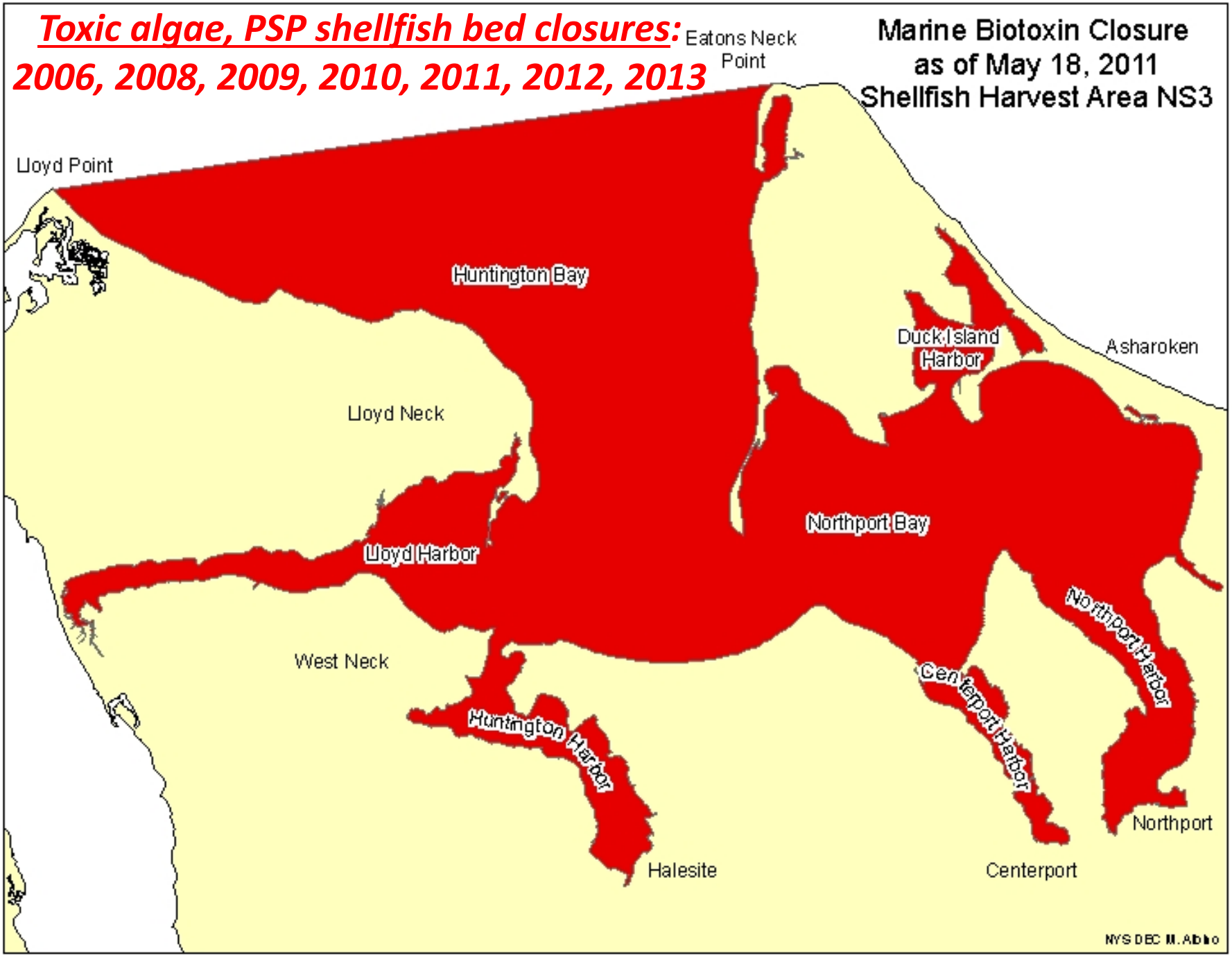
Alexandrium red tides and paralytic shellfish poisoning (PSP) on Long Island



Alexandrium

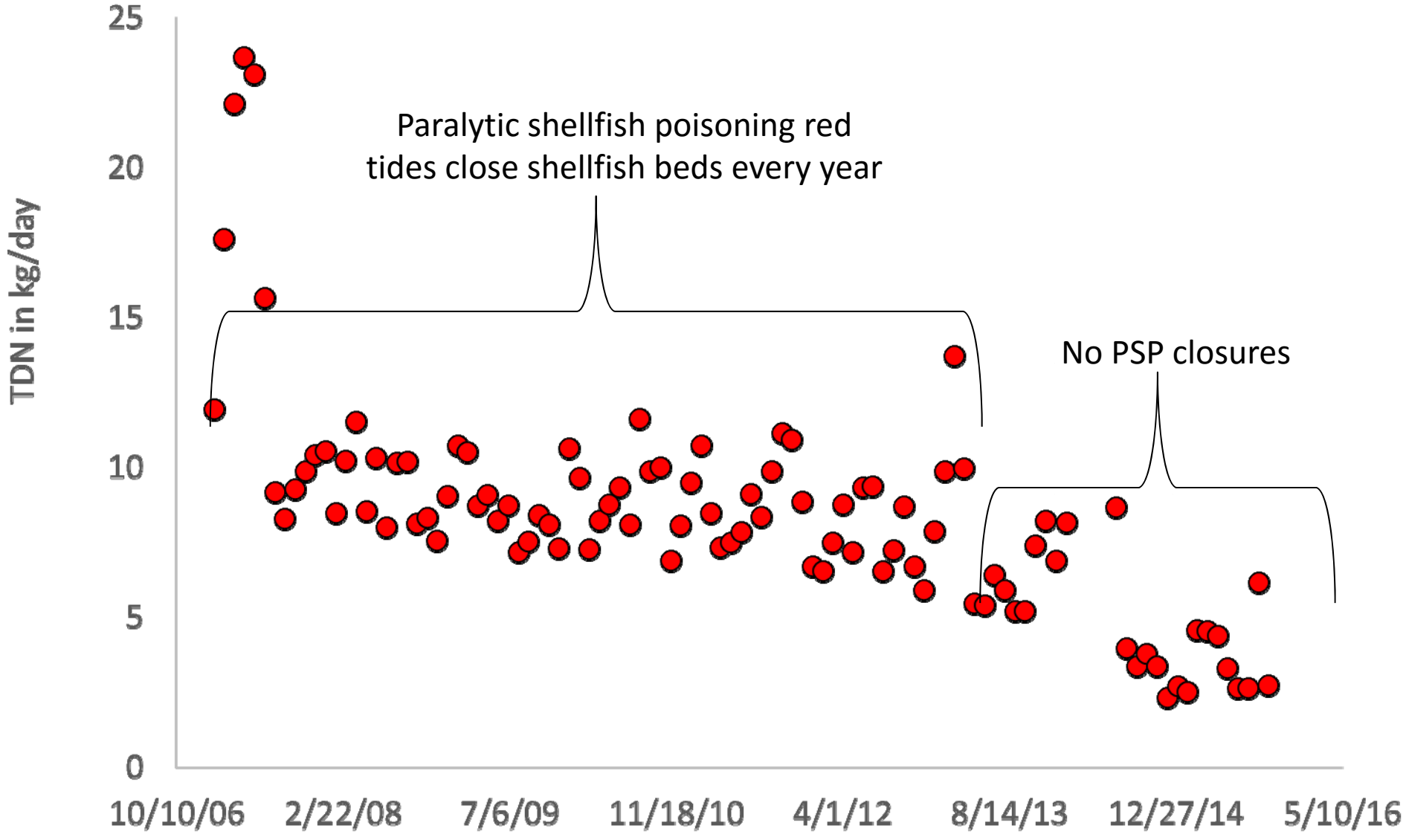


Saxitoxin

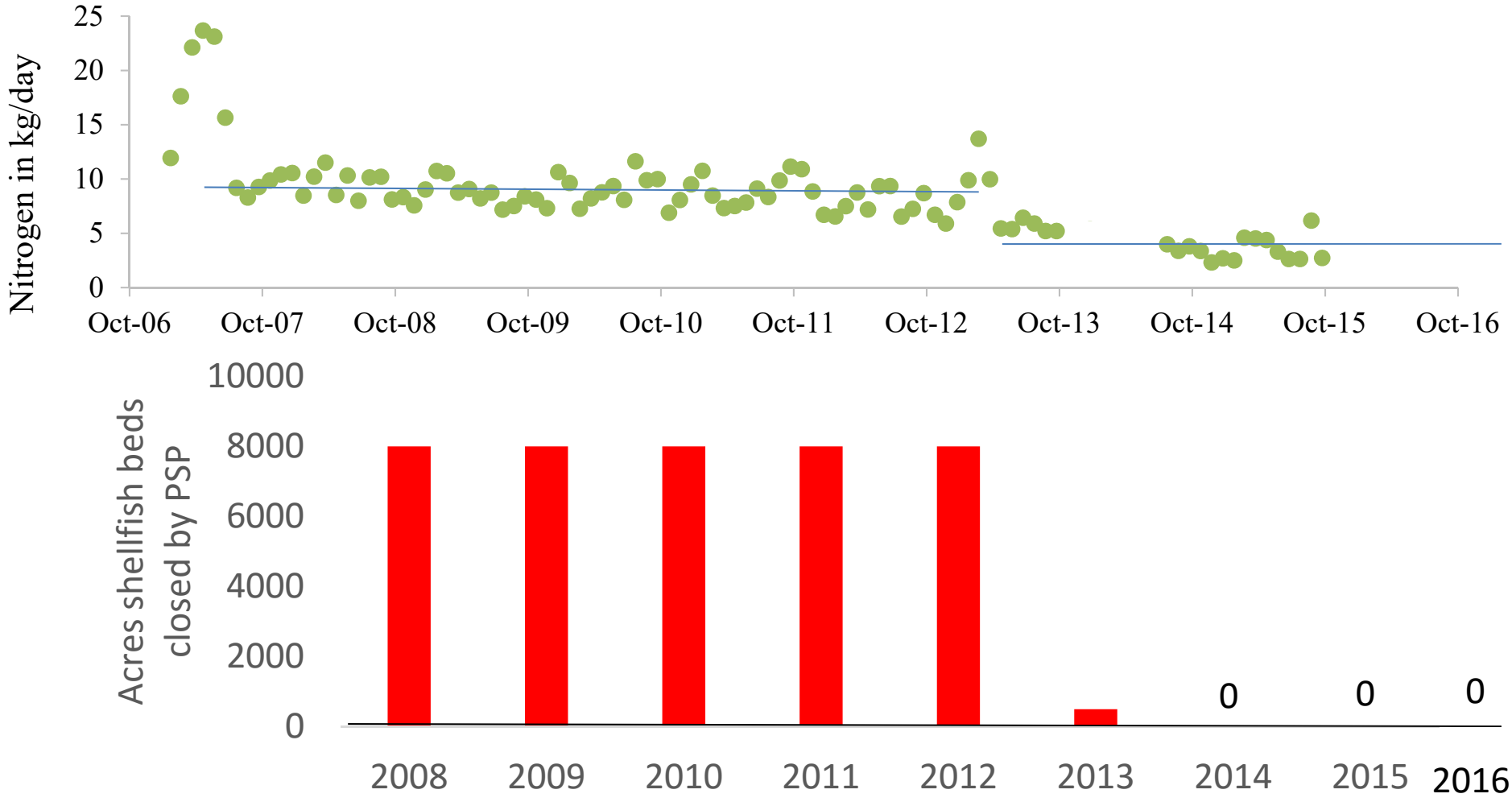

Toxic algae, PSP shellfish bed closures:
2006, 2008, 2009, 2010, 2011, 2012, 2013
Marine Biotoxin Closure
as of May 18, 2011
Shellfish Harvest Area NS3
Eatons Neck Point
Lloyd Point
Huntington Bay
Duck Island Harbor
Asharoken
Lloyd Neck
Northport Bay
Lloyd Harbor
Northport Harbor
West Neck
Centerport Harbor
Huntington Harbor
Northport
Halesite
Centerport
NYS DEC M. Abbo

Upgrade of the Northport Sewage Treatment Plant

Northport STP nitrogen discharge

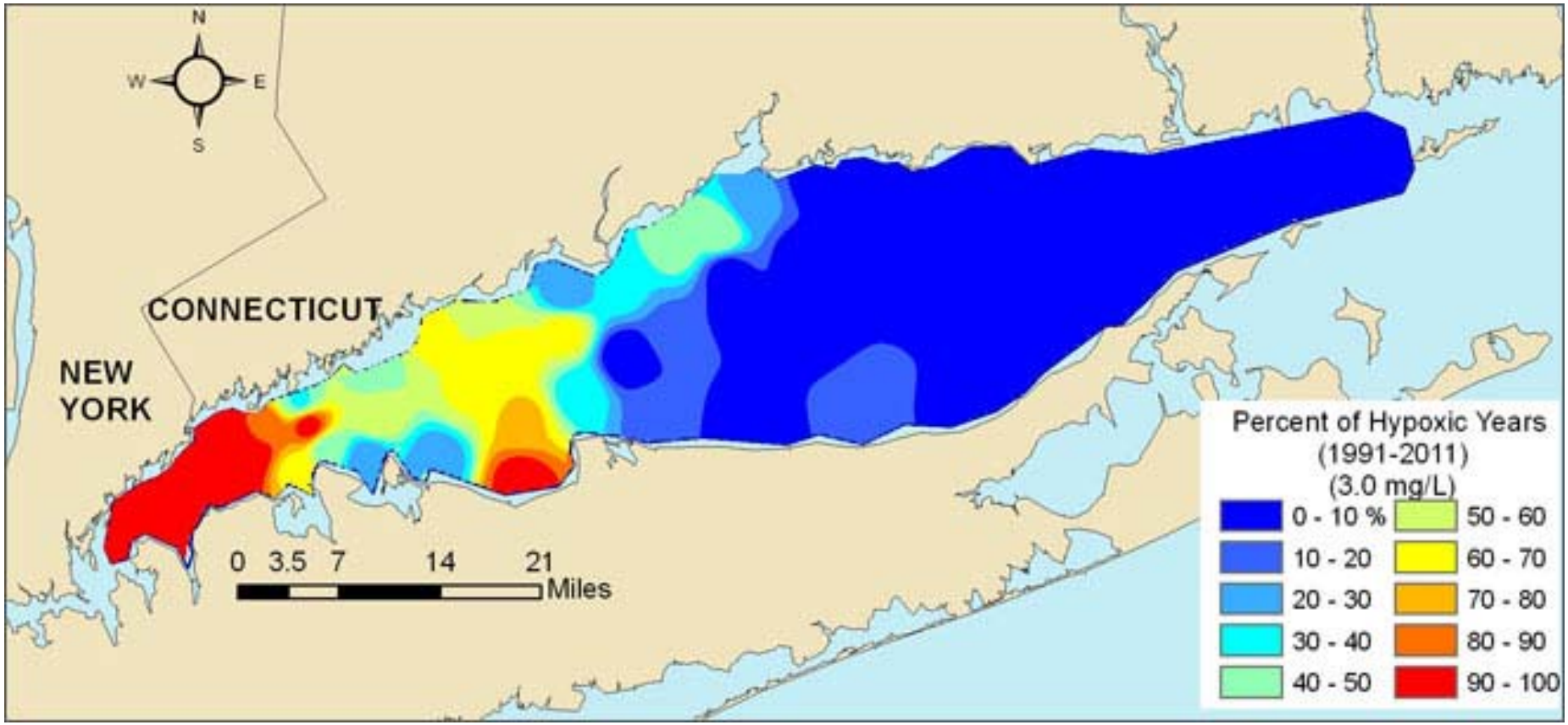


Acres of shellfish beds closed by PSP

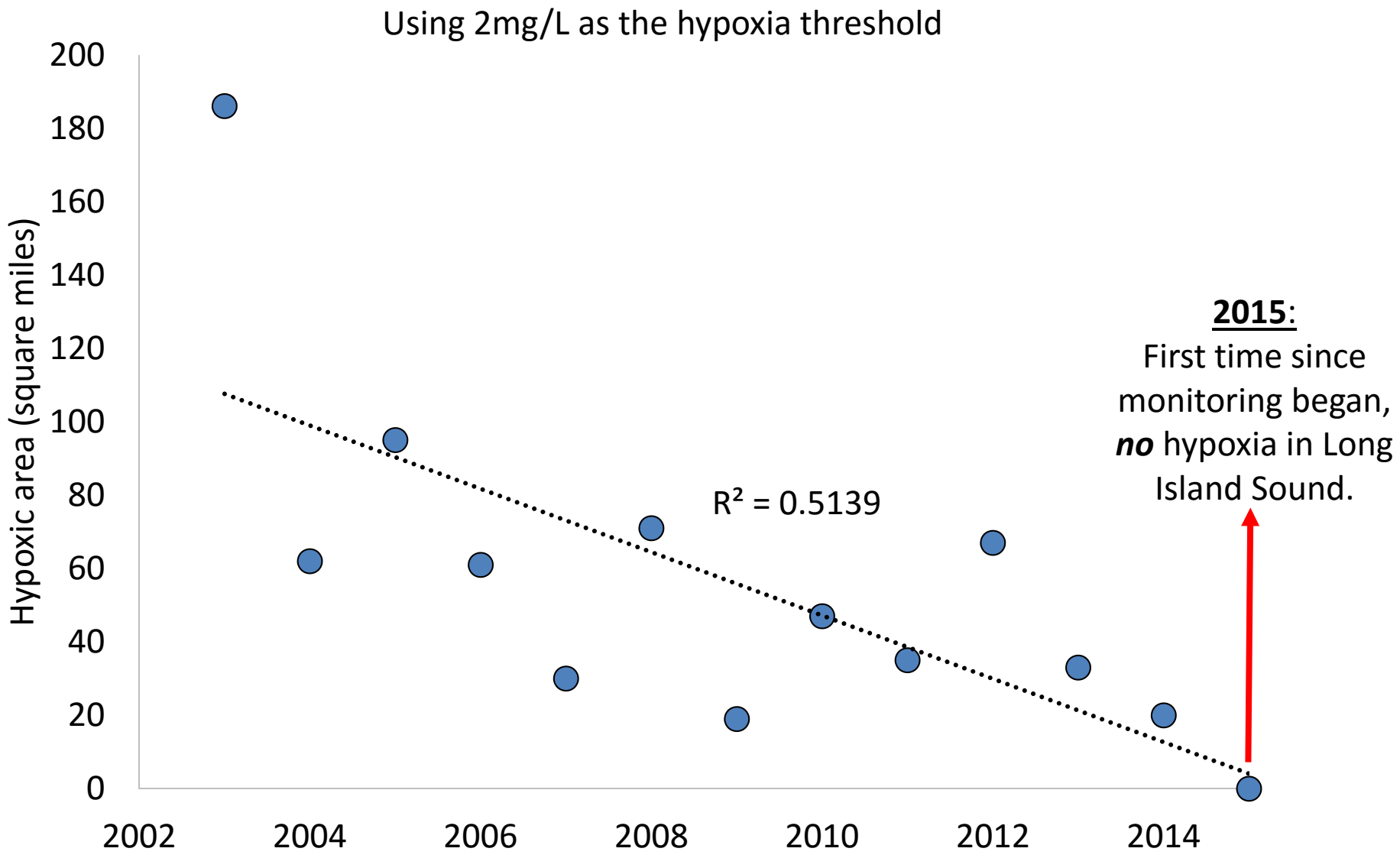


Has nitrogen mitigation helped hypoxia in Long Island Sound?

- Long Island Sound Study: 58.5% N reduction
- Ecosystem response?



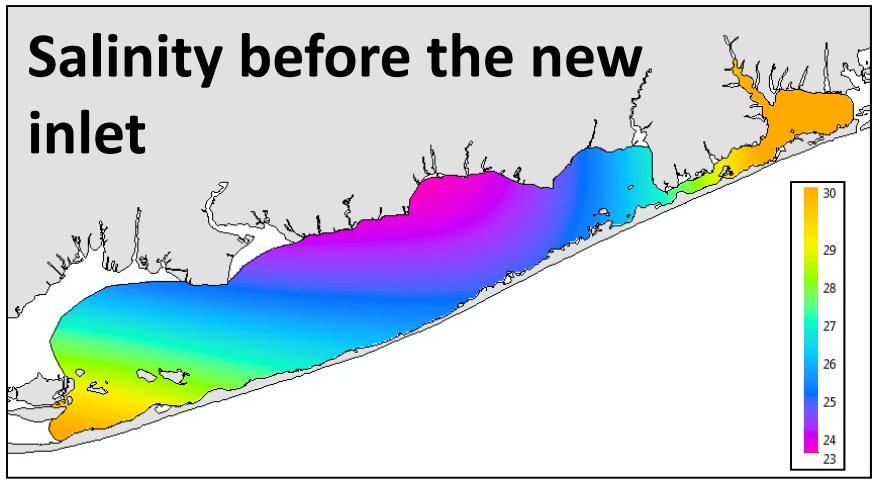
Long Island Sound, 13-year trend in hypoxic area

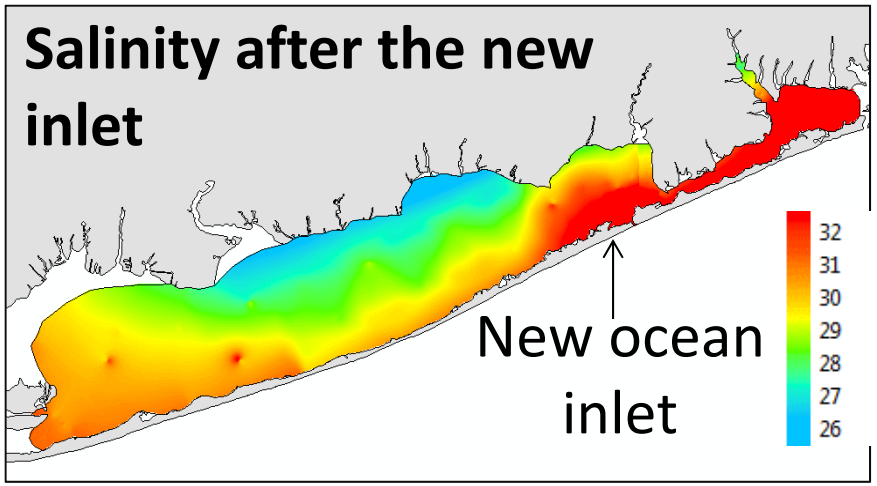


CTDEEP monitoring data

New inlet and ocean flushing

New inlet in Great South Bay following Hurricane Sandy

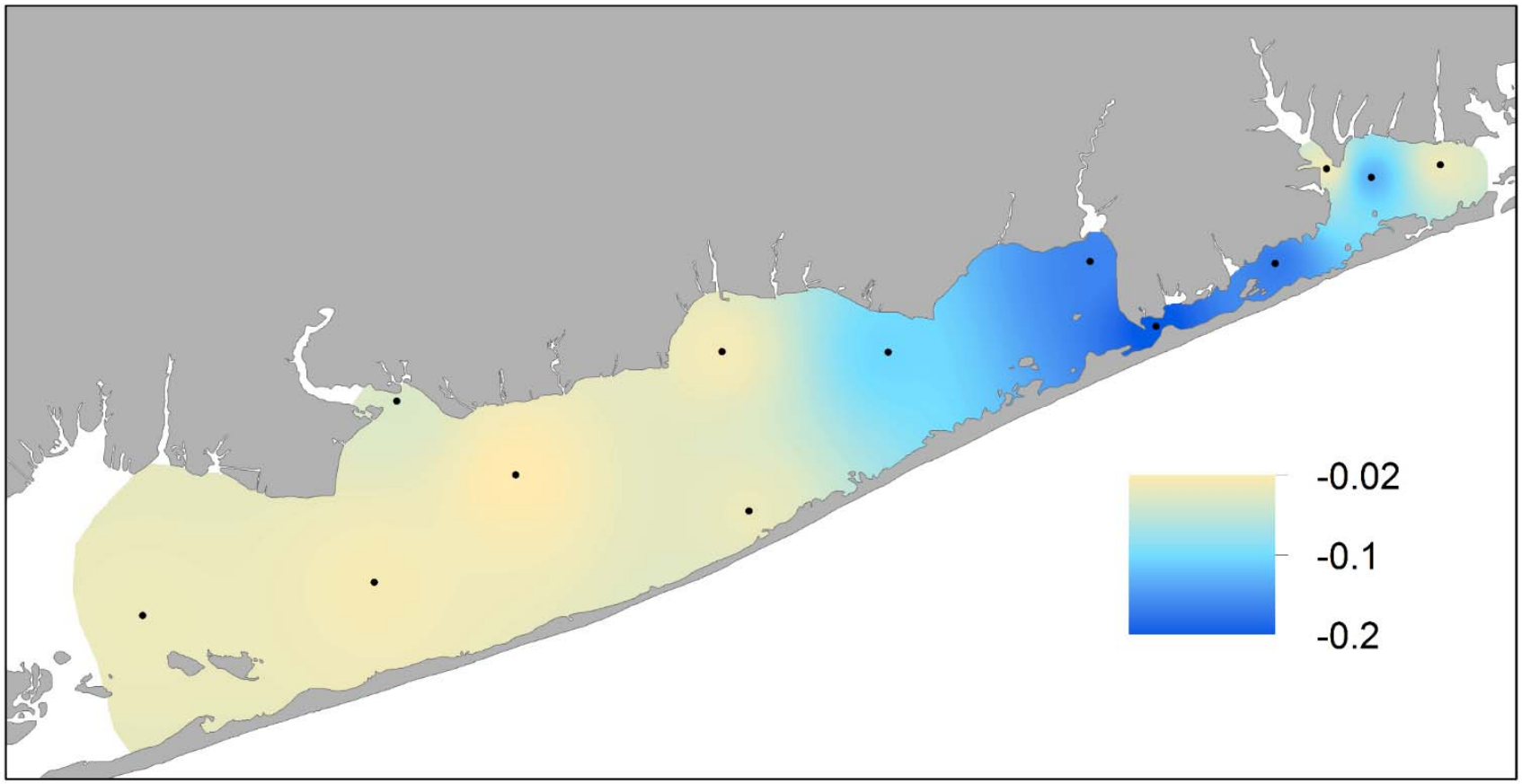




Light in the darkness: New Inlet in Great South Bay

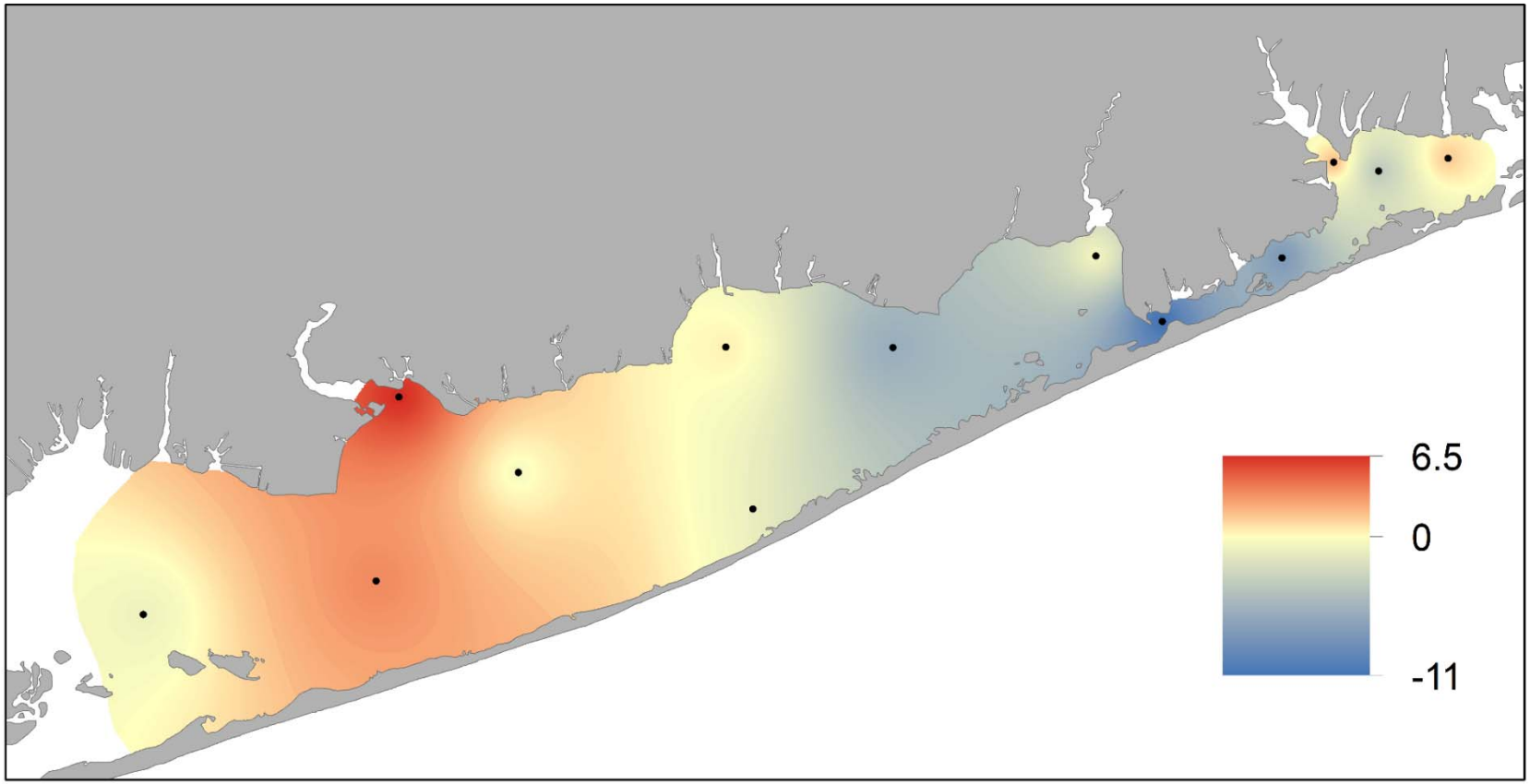
New Inlet spits out brown tide, fall 2014

Decrease in total nitrogen (mg/L)



Post- and pre-New Inlet

Changes in algae (µg/L)



Post- and pre-New Inlet

Conclusions

- Excessive nitrogen loading has promoted numerous water quality and marine habitat impairments in NYS.
- Nitrogen reductions have led to significant water quality and habitat improvements in some regions of NY.