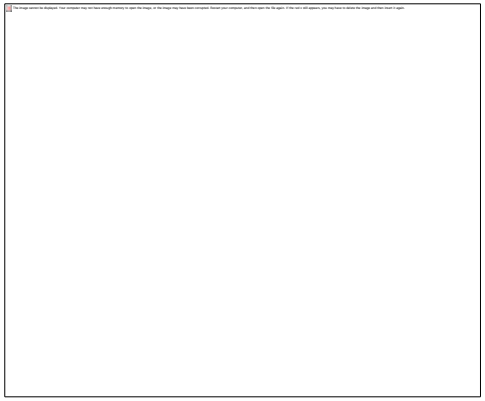
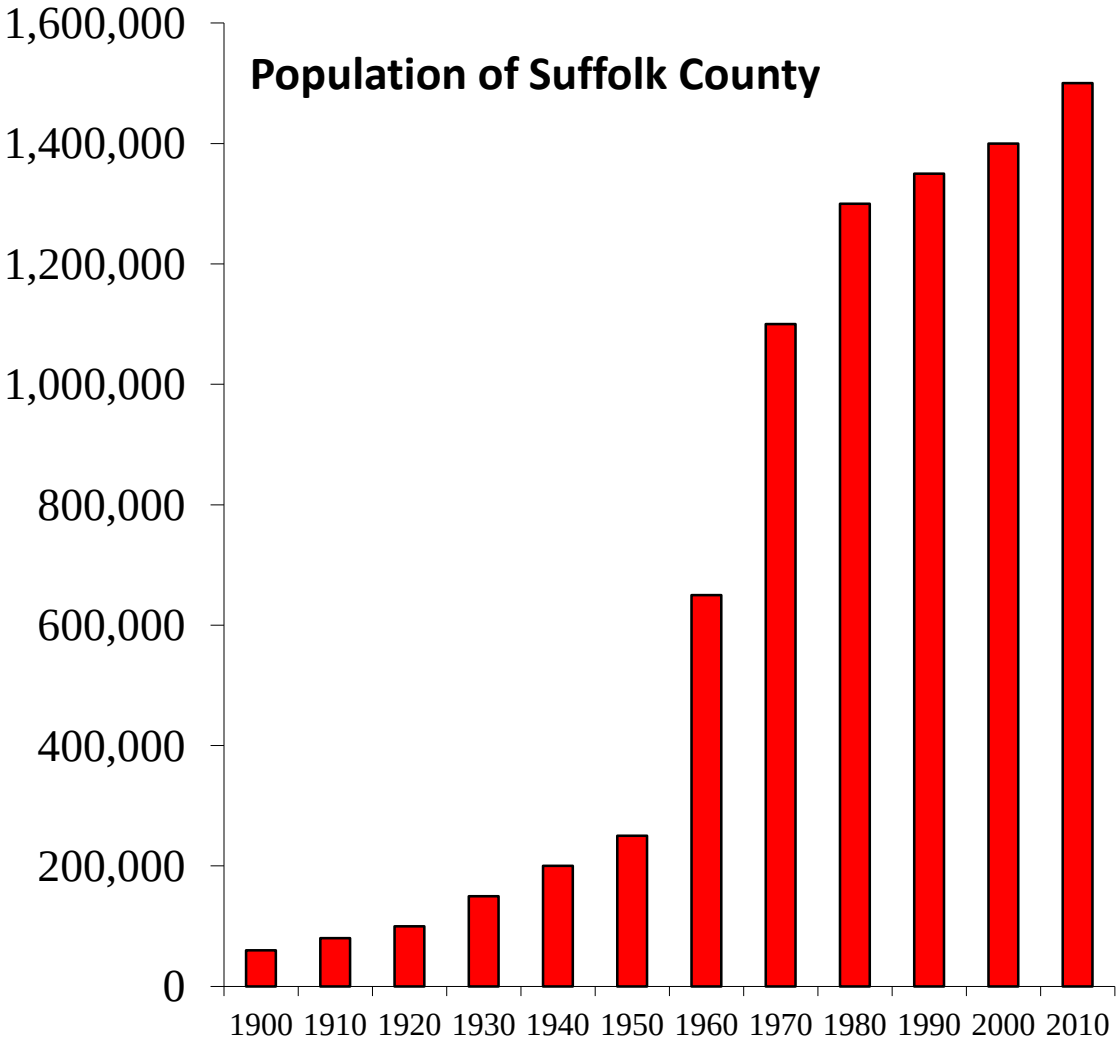
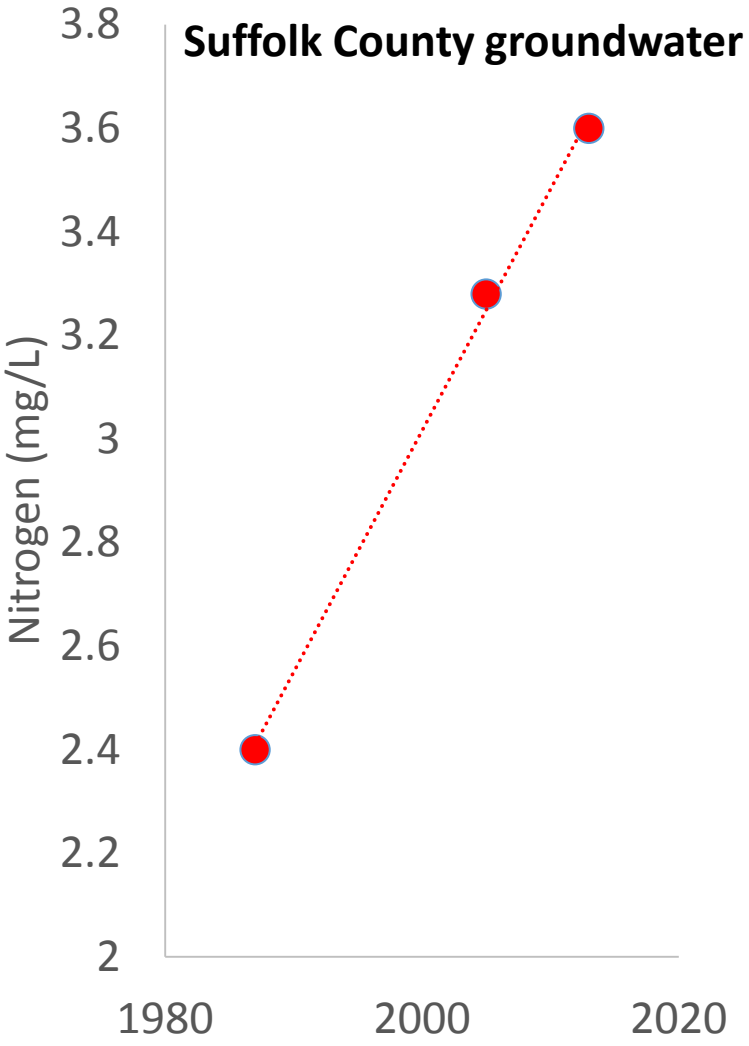
How much is too much? Developing models to determine nitrogen reductions needed to improve water quality in Southampton Town waters



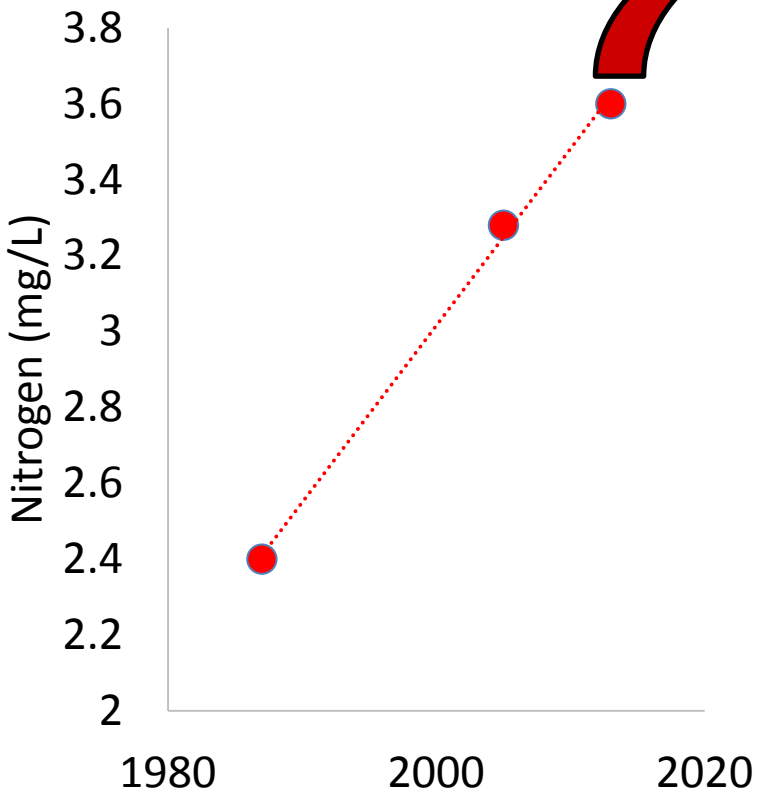
Christopher J. Gobler

Expanding population, nitrogen levels



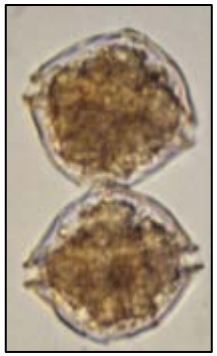


More nitrogen makes harmful algae on Long Island grow faster and/or more toxic.



Studies: Davis et al., 2009, 2010; Hattenrath et al 2010; Gobler et al 2011, 2012; Gobler and Sunda 2012; Harke and Gobler 2013, 2015 Hattenrath-Lehmann et al 2015

Harmful algal blooms across Long Island



PSP

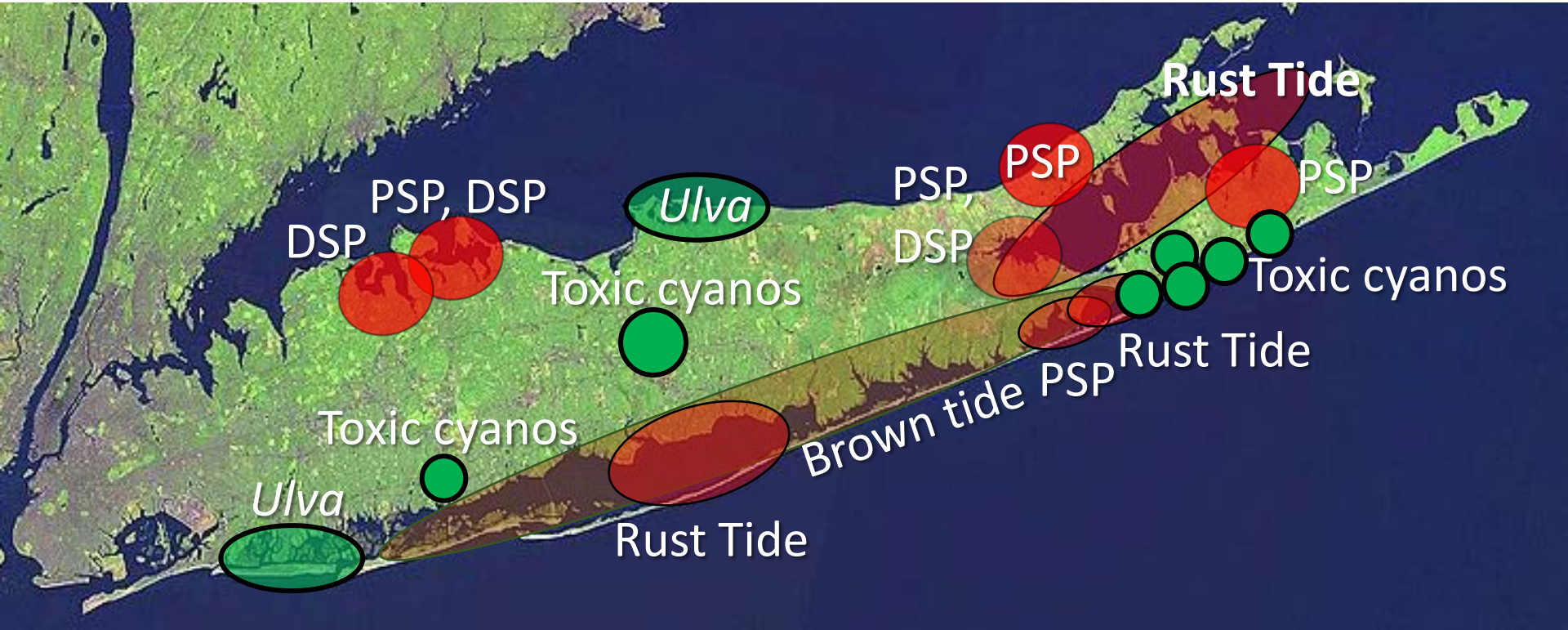
Toxic blue green algae

DSP

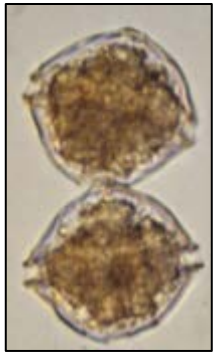
Brown tide

Seaweeds

Rust Tide



Harmful algal blooms across Long Island



PSP

Toxic blue green algae

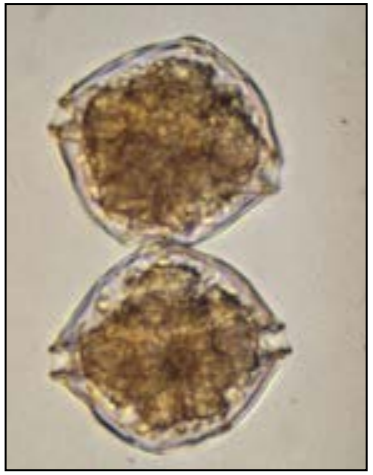
DSP

Brown tide

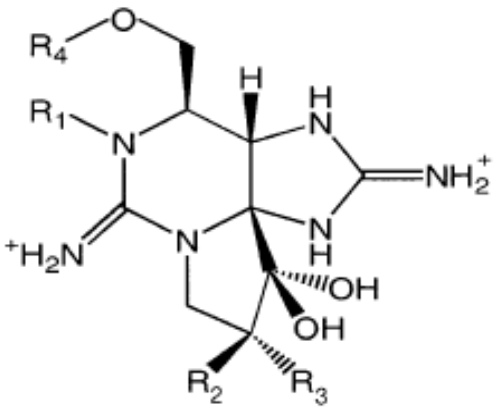
Seaweeds

Rust Tide

Alexandrium red tides and paralytic shellfish poisoning (PSP)



Alexandrium

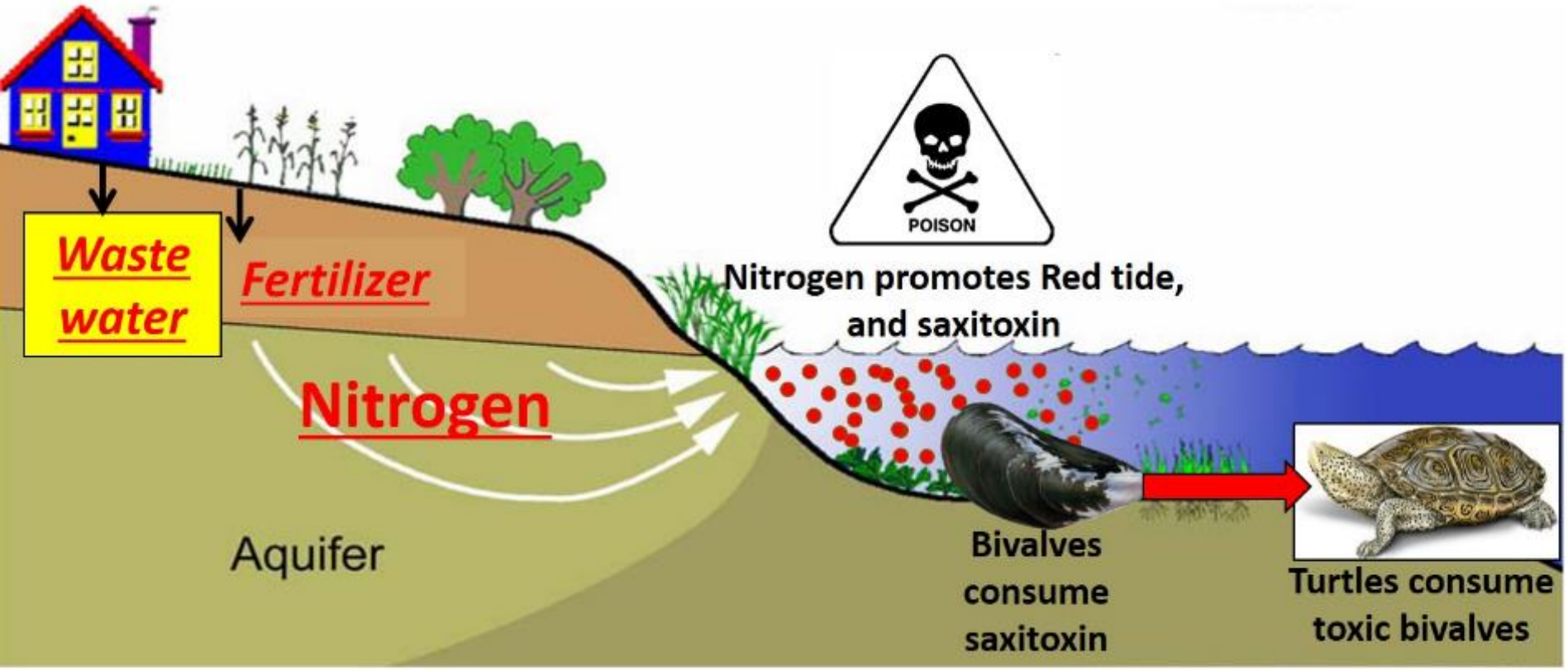


Saxitoxin

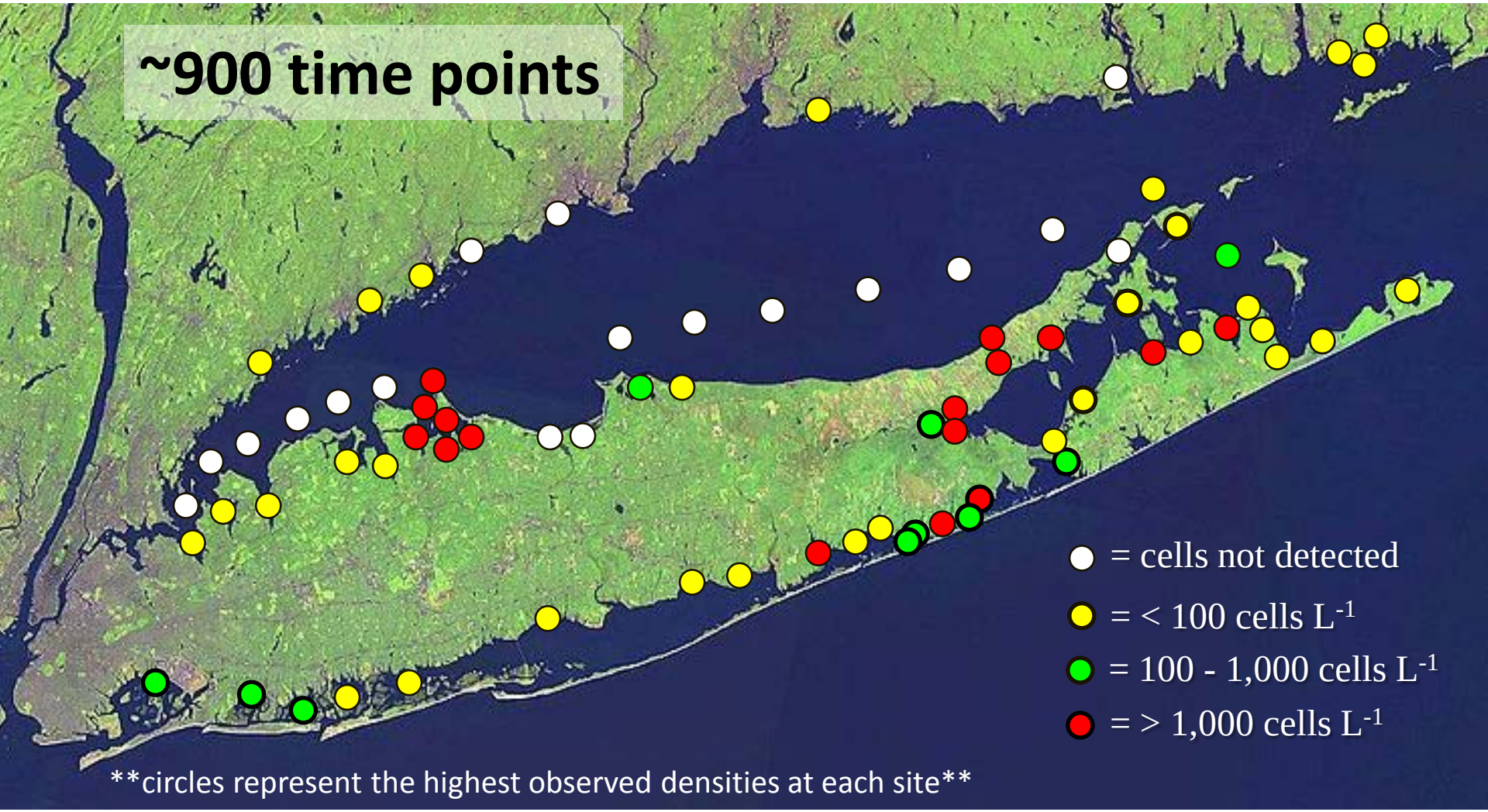
RiverheadLOCAL

riverheadlocal.com
https://www.riverheadlocal.com/2015/05/13/massive-die-off-of-turtles-dozens-of-dead-diamondback-terrapins-wash-up-along-flanders-bay-beaches/

'Massive' die-off of turtles: Dozens of dead diamondback terrapins wash up along Flanders Bay beaches



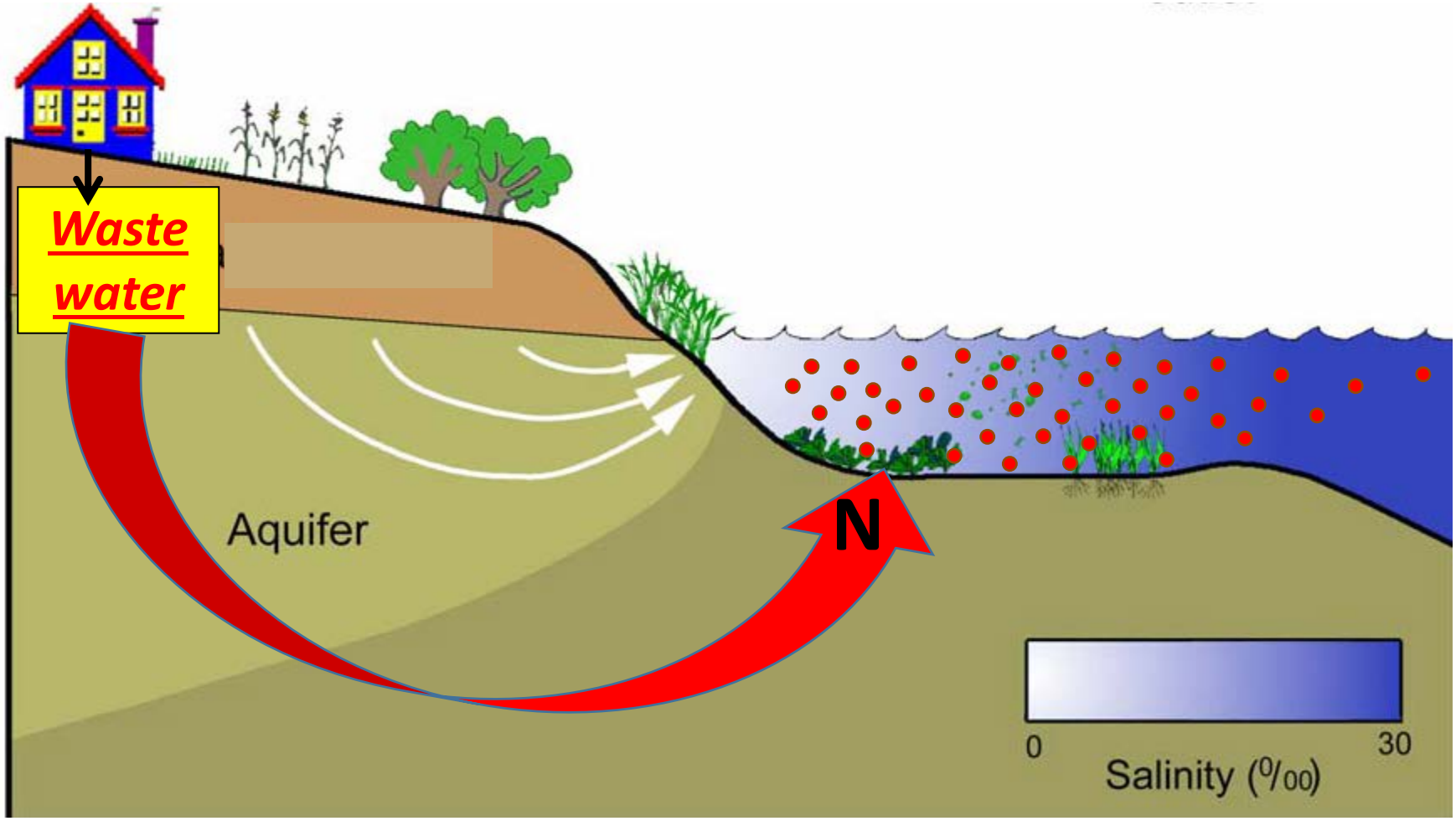
Presence of PSP-producing *Alexandrium* in LI and CT: 2007-2014



- *Alexandrium* found at 49 of 65 sites samples (75%)

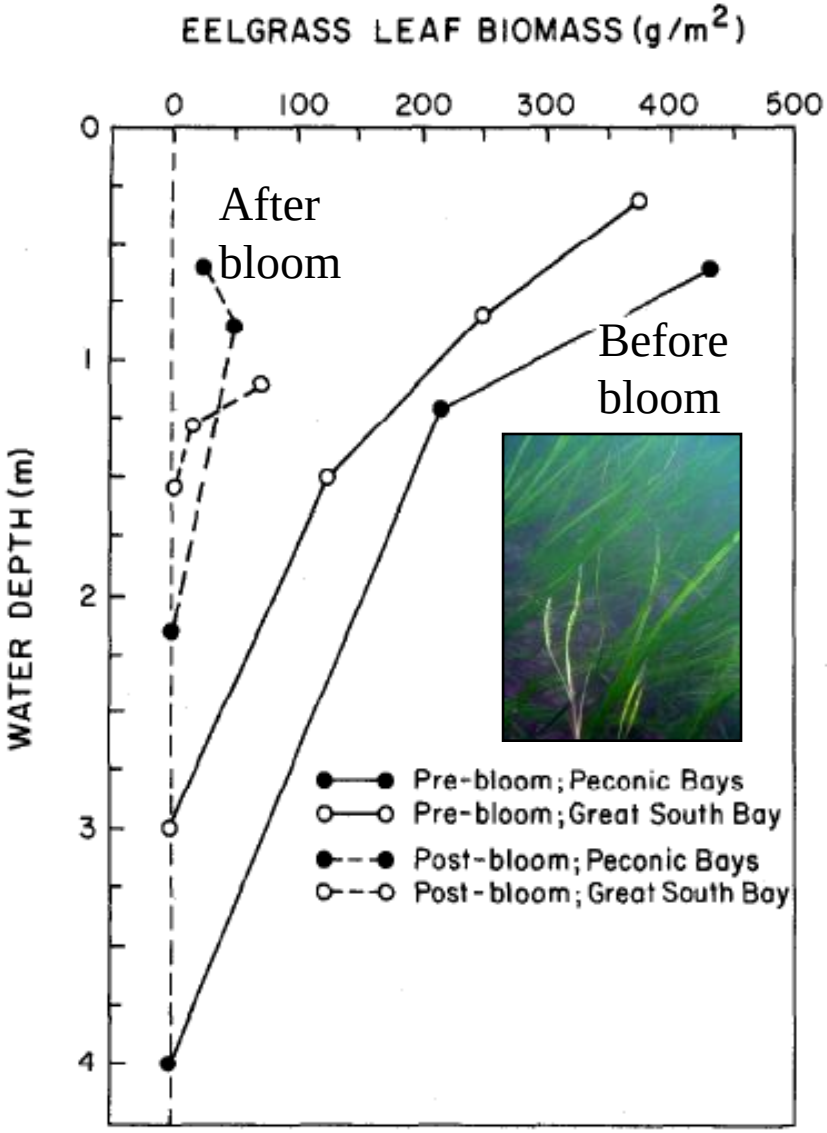
Wastewater-derived nitrogen loading promotes PSP in Long Island Sound.

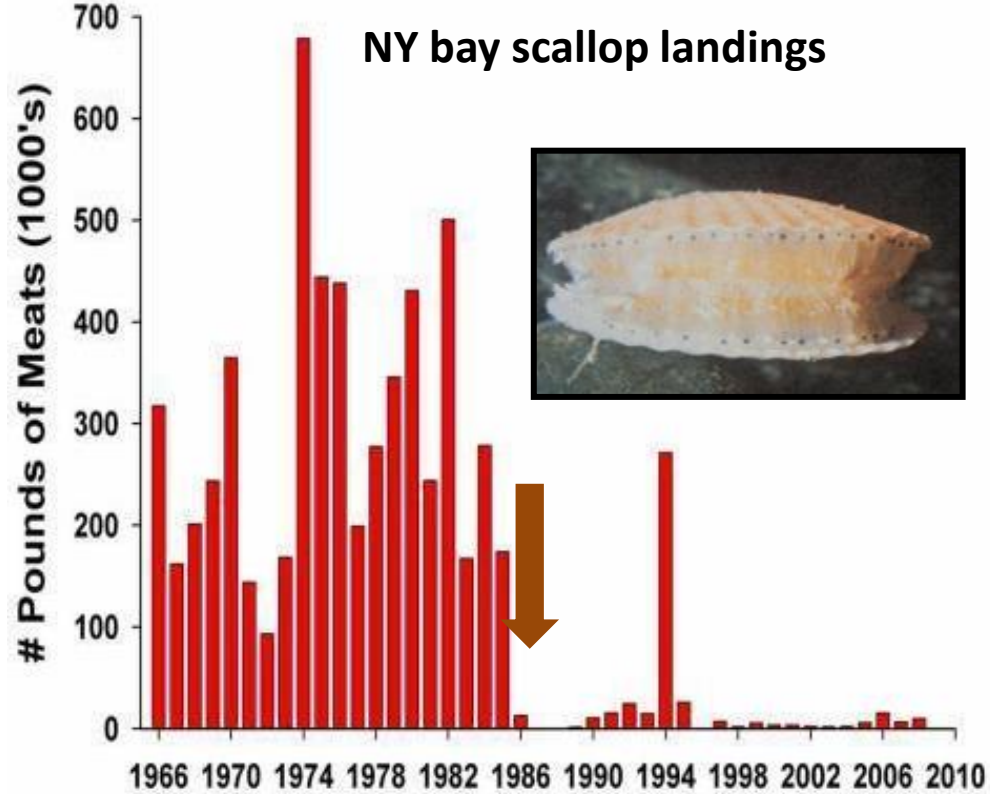
-Hattenrath et al 2010, Harmful Algae

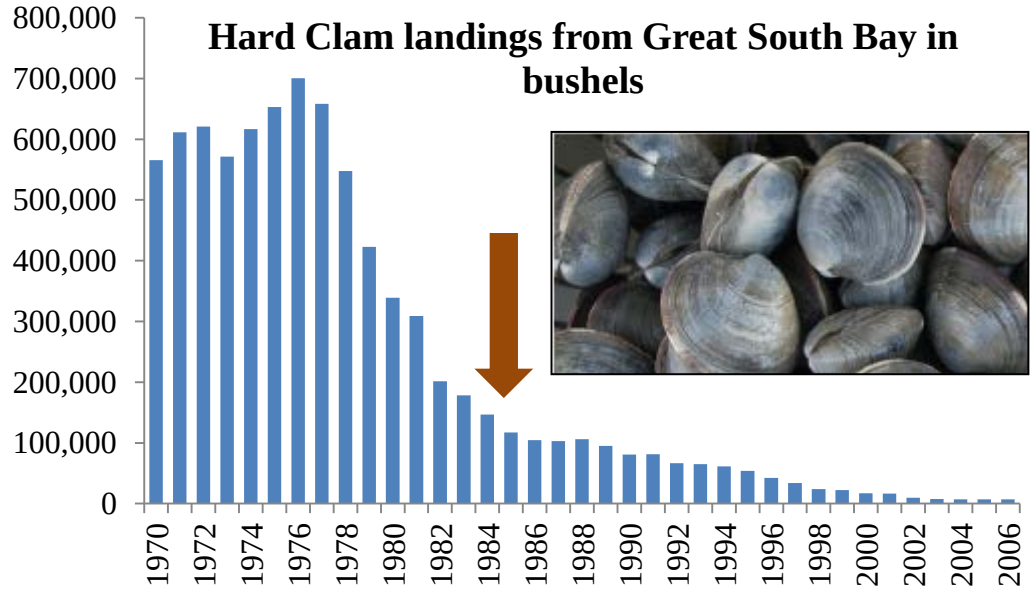


Brown tides
>1,000,000,000
cells per liter

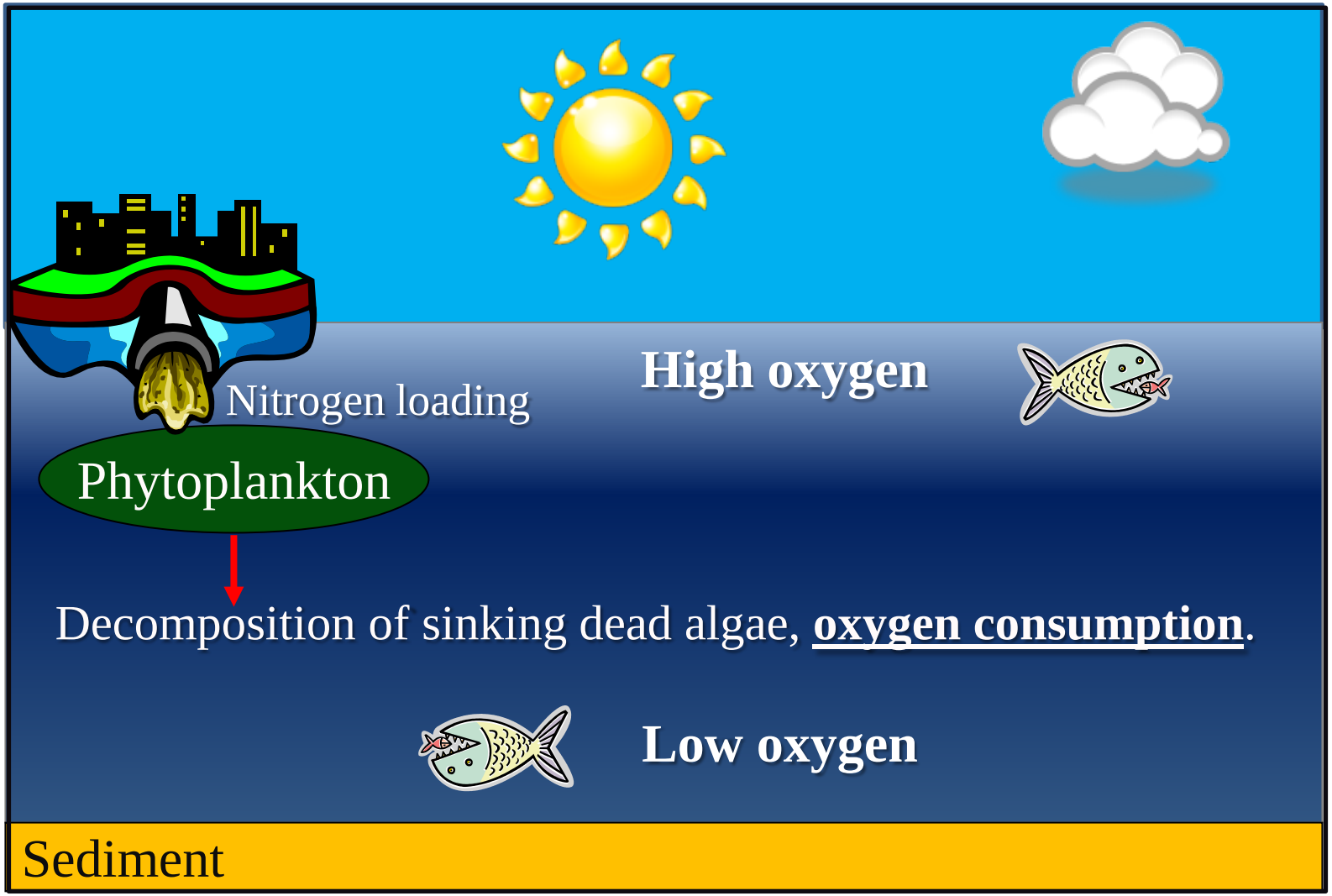
Impacts of brown tides in New York



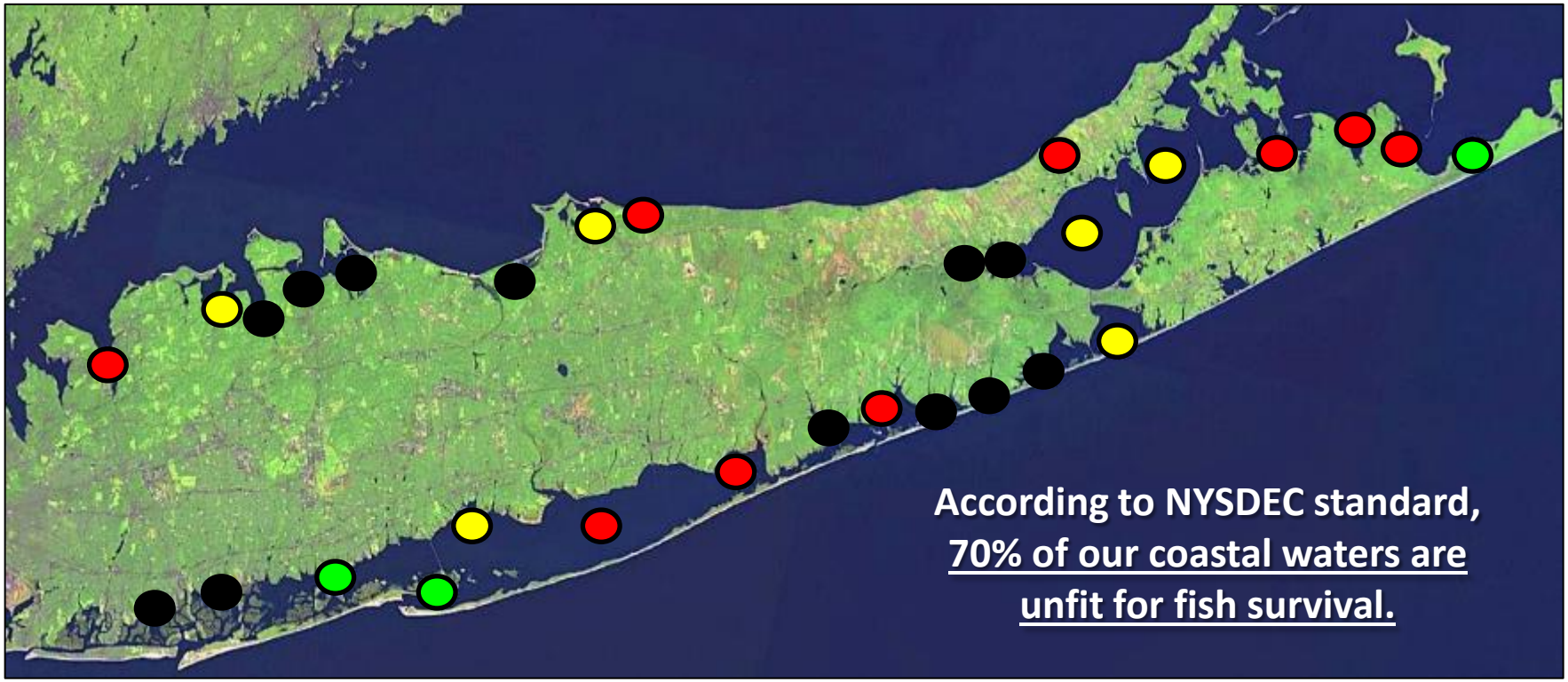




Excessive nitrogen loading leads to hypoxia or low oxygen



Dissolved oxygen minimums across Long Island, July & August 2014



- > 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

Newsday

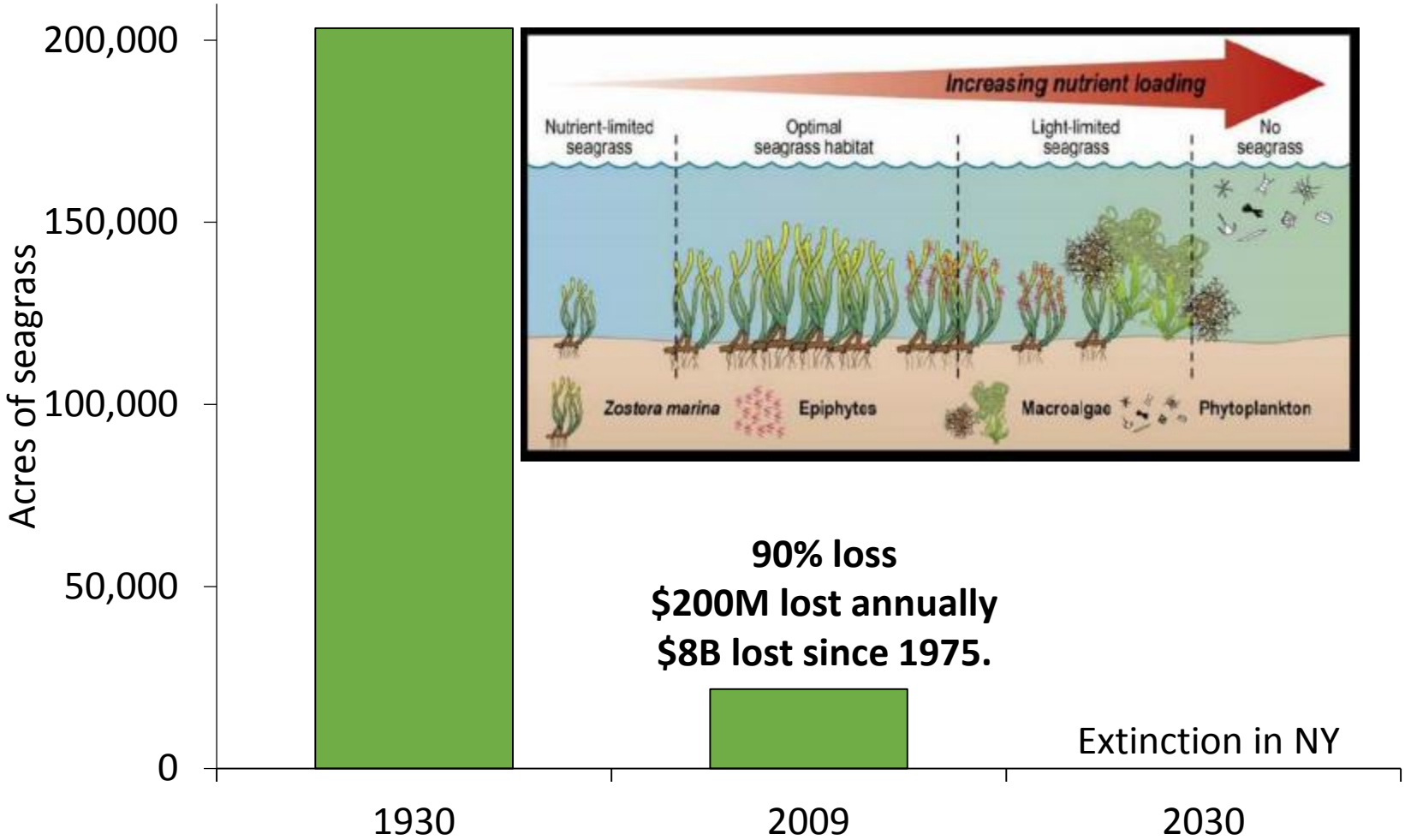
Suffolk LONG ISLAND

Massive fish kill reported in Riverhead, Southampton towns

Updated May 30, 2015 10:21 PM

Seagrass: Critical habitat for fish and shellfish

NYS seagrass, 1930 - 2030



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

Nitrogen Loading to the South Shore, Eastern Bays, NY: Sources, Impacts, and Management Options

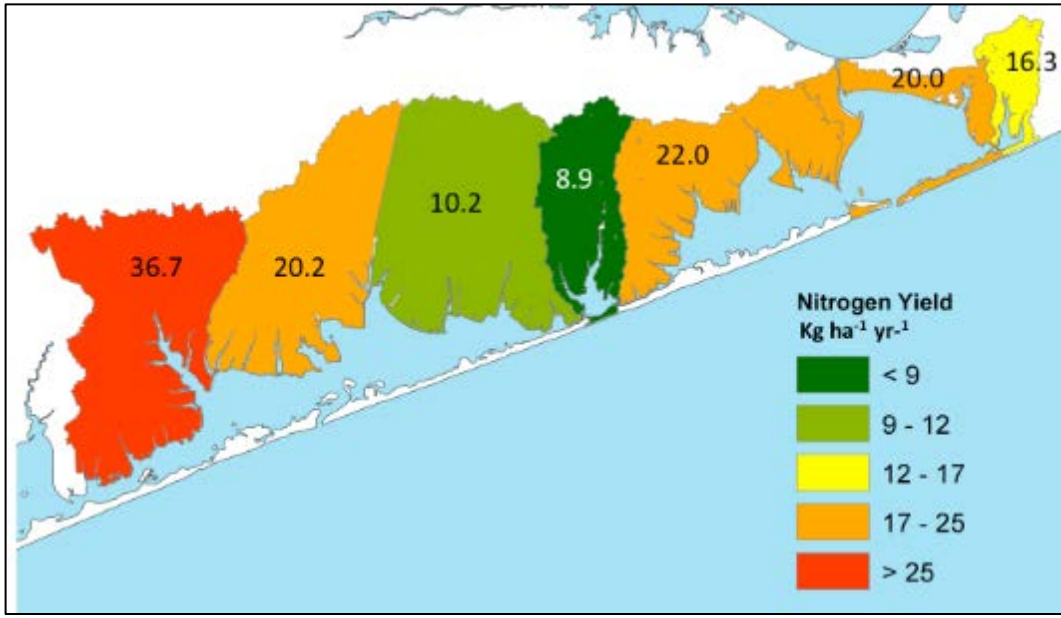
Supported by NYSDOS

Nitrogen loads by watershed

NLM (kg N yr^{-1})

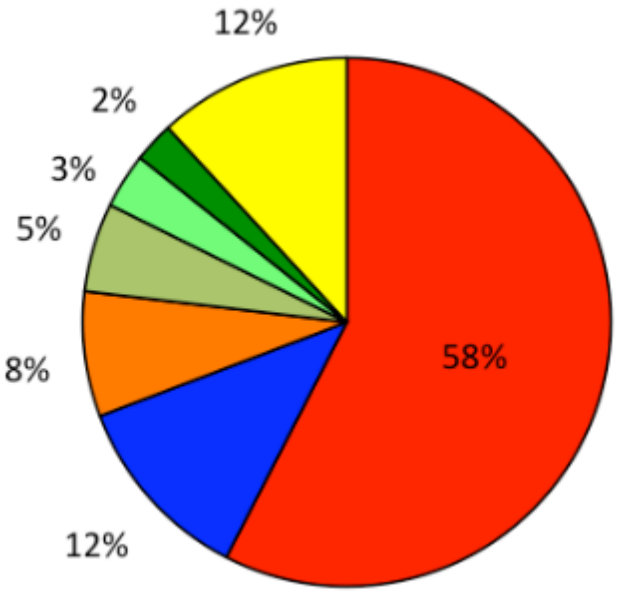
Subwatershed	
Moriches West	211,000
Middle Moriches	96,400
Moriches East	58,800
Quantuck Bay	20,600
Shinnecock Bay West	88,900
Shinnecock Bay East	26,500
Heady Taylor Creek	16,400

N load yields (kg per hectare

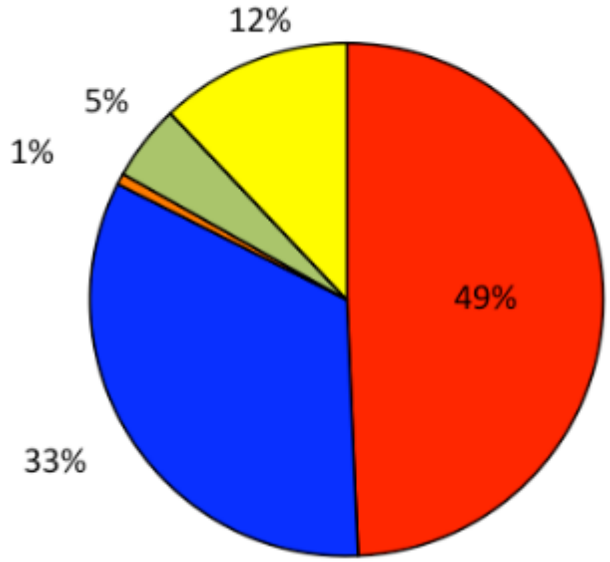


Determined via two independent N loading models, NLM and VLM

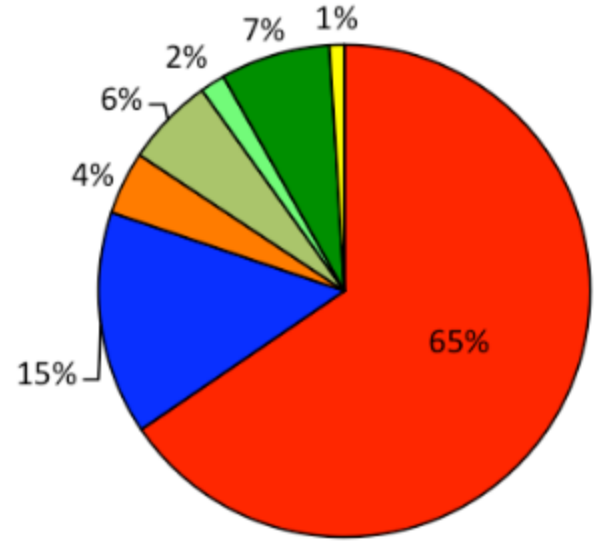
N load sources by bay



Moriches Bay



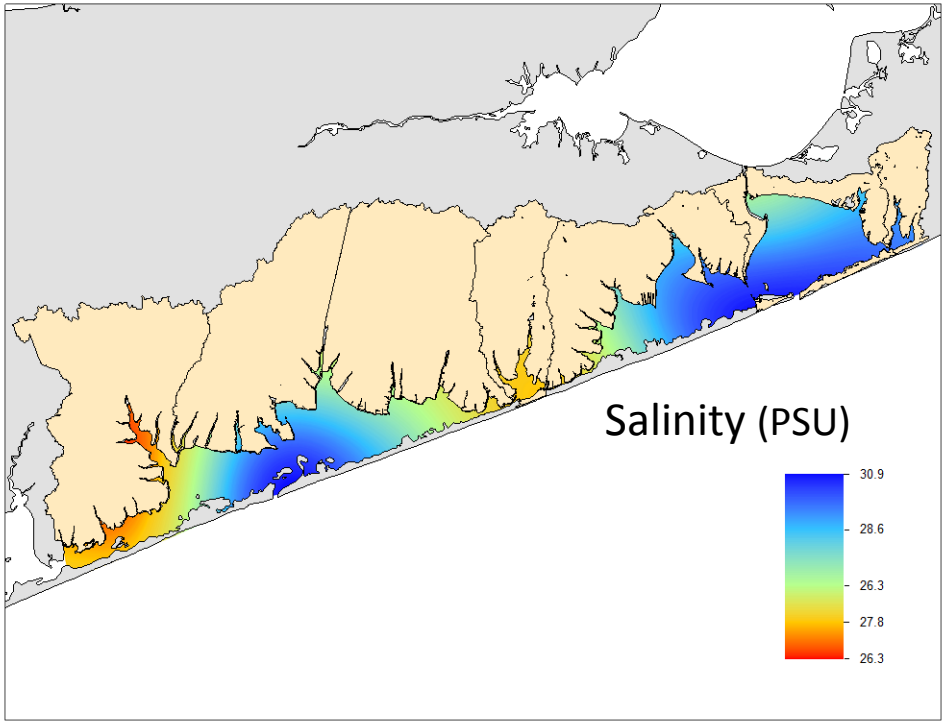
Quantuck Bay

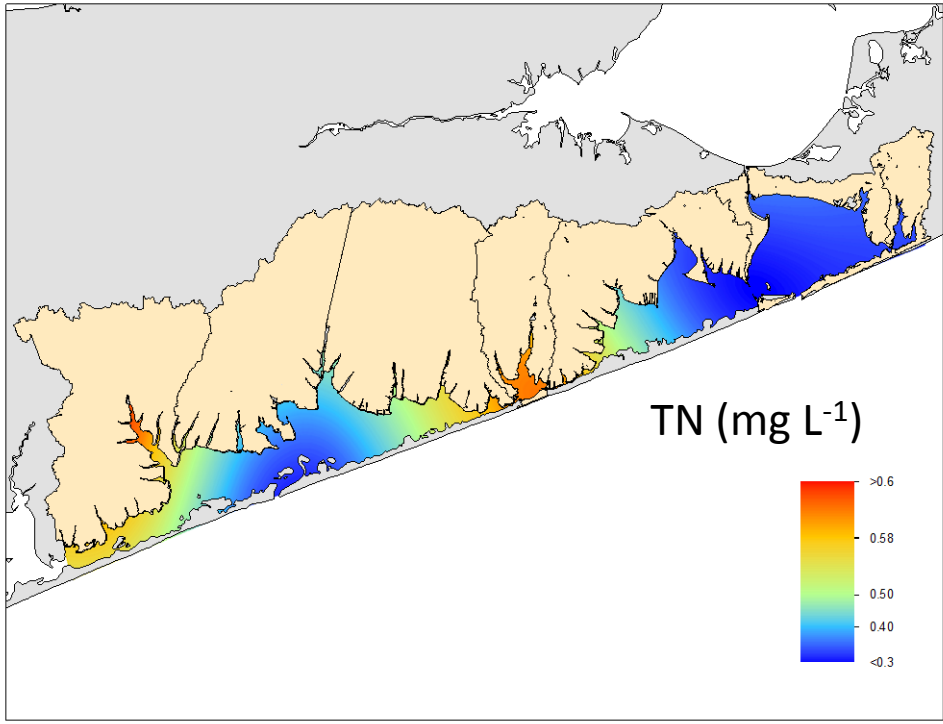


Shinnecock Bay

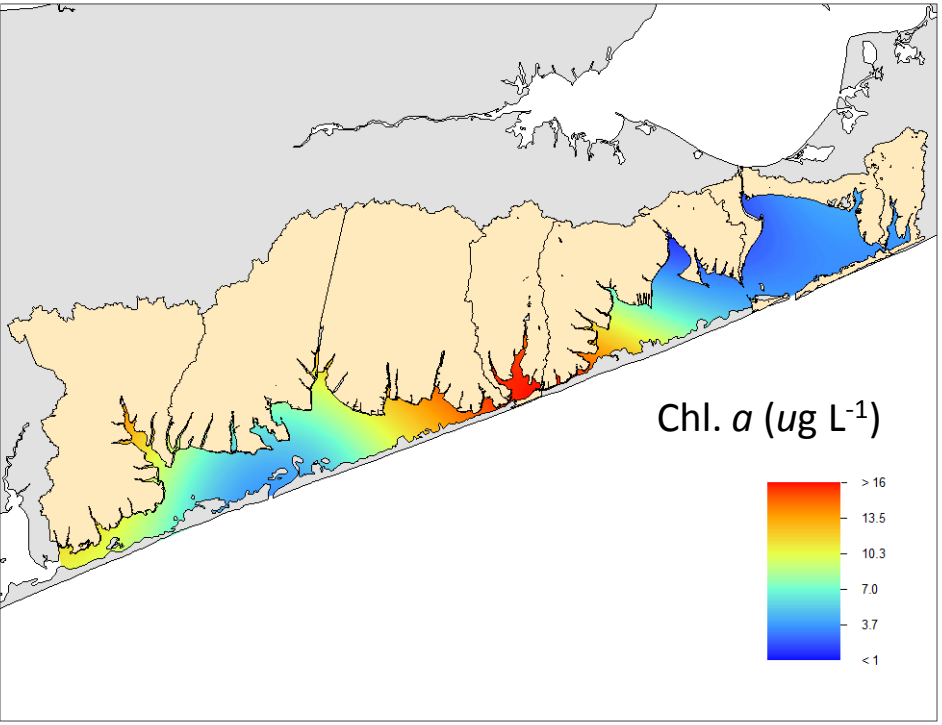
- Waste Water
- Atmospheric Deposition
- Agriculture
- Lawns
- Golf Courses
- Parks and Athletic Fields
- Private WW Treatment

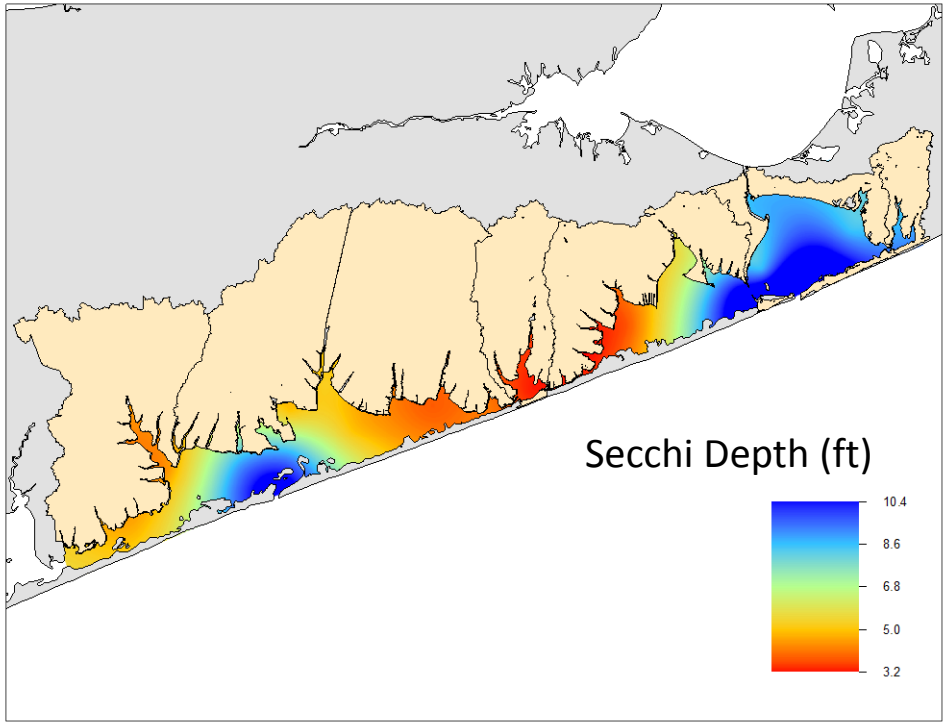
Marine Data Assessment



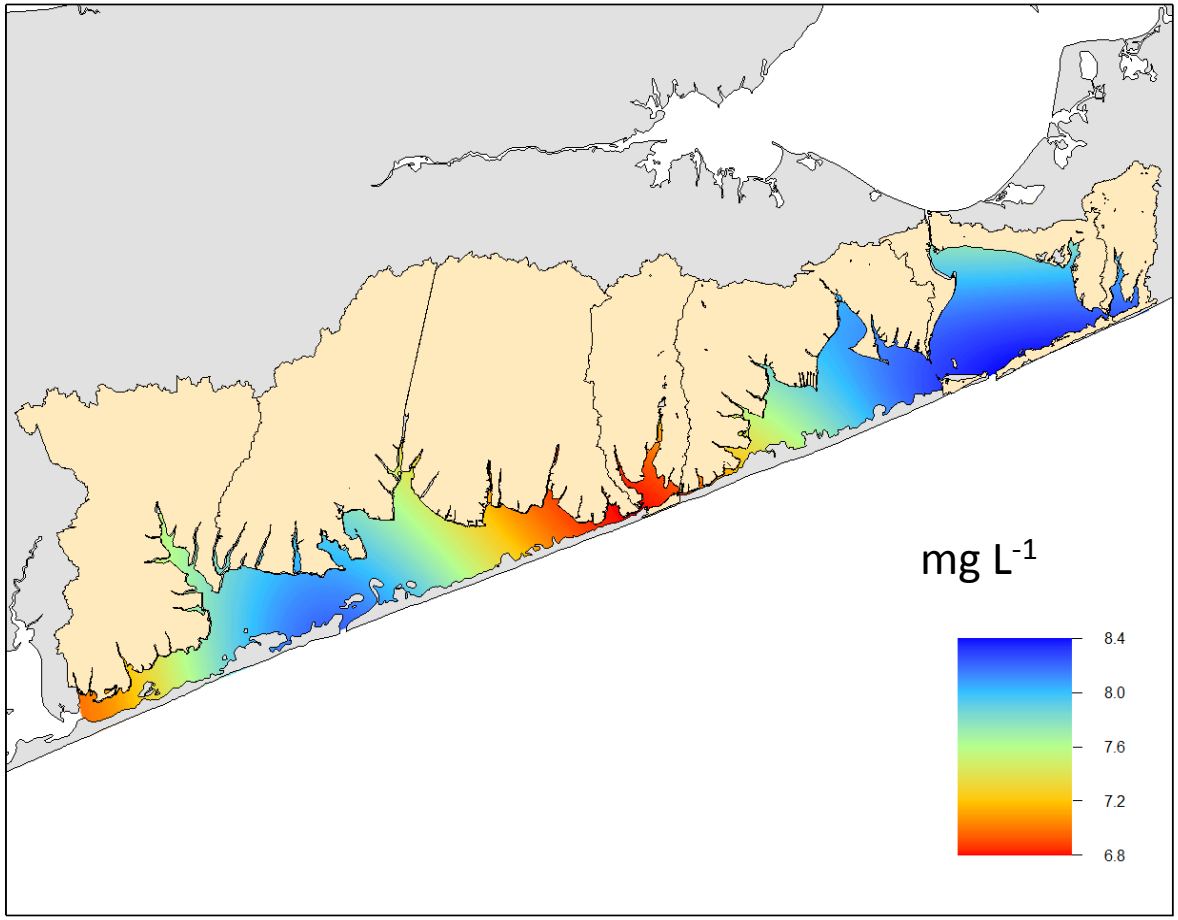


Chlorophyll a and Secchi Depth

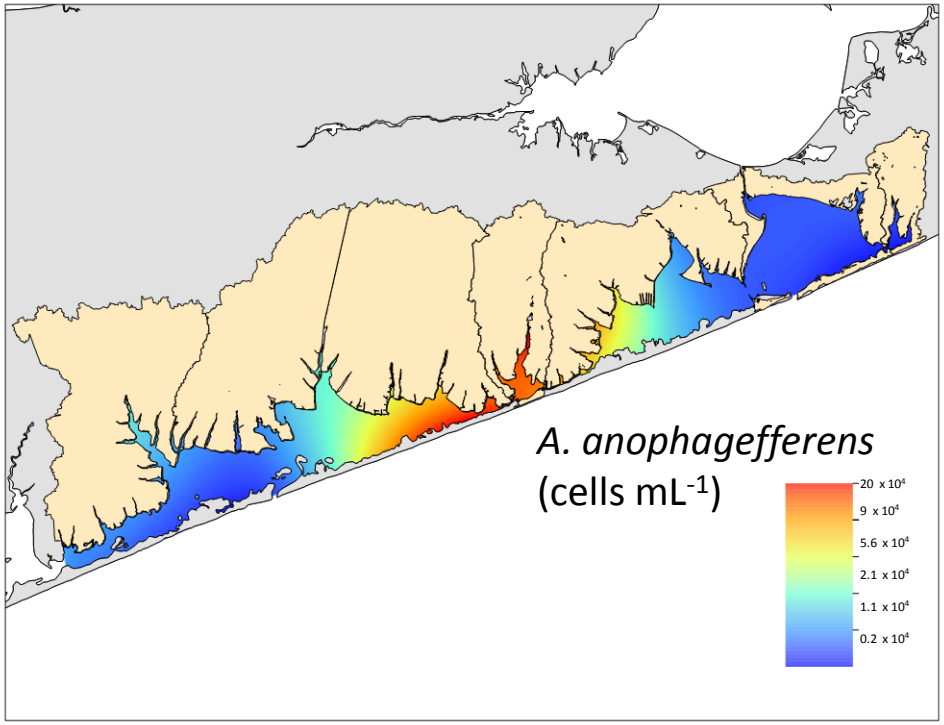


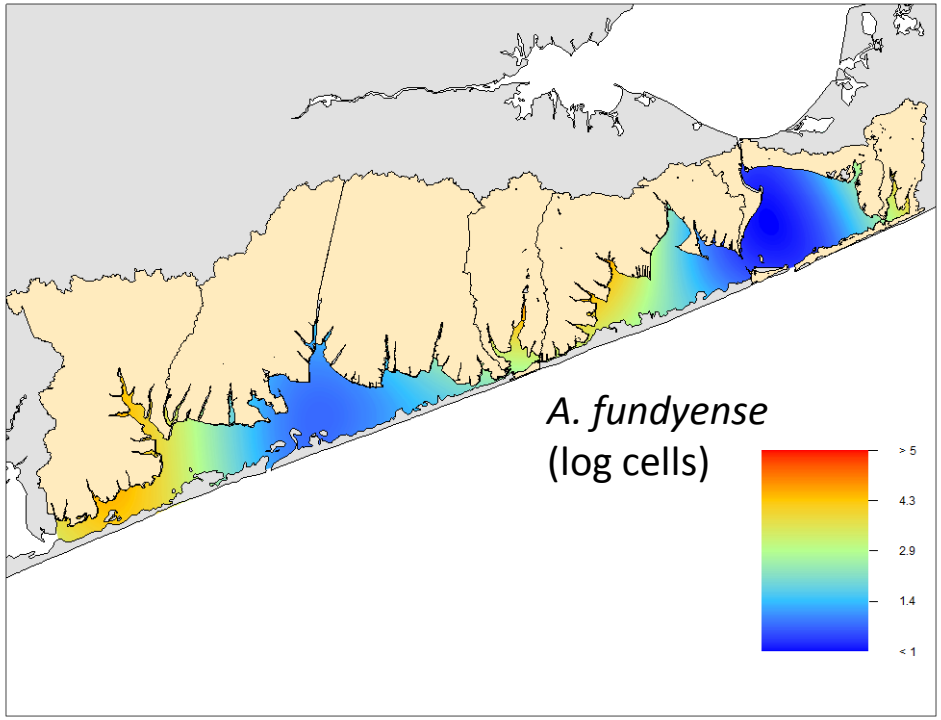


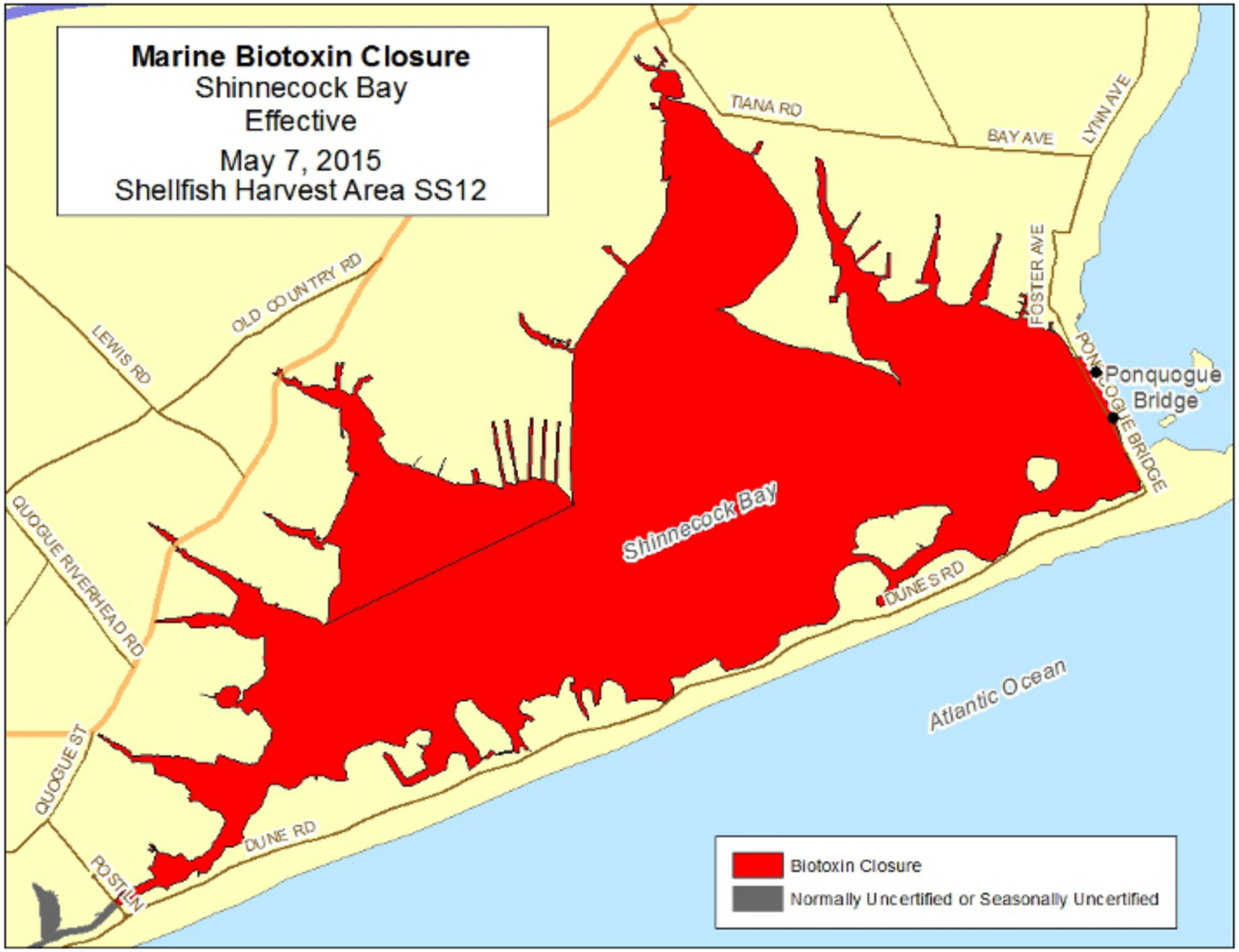
Bottom Dissolved Oxygen



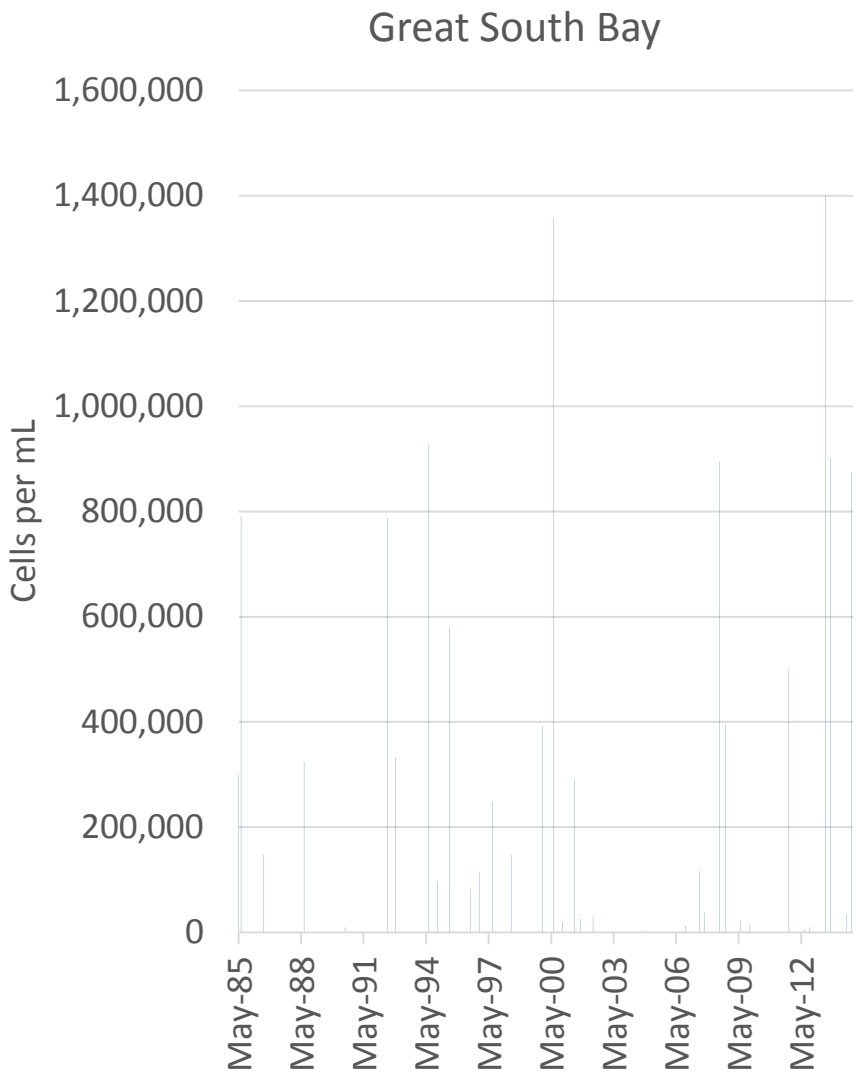
Harmful Algal Blooms

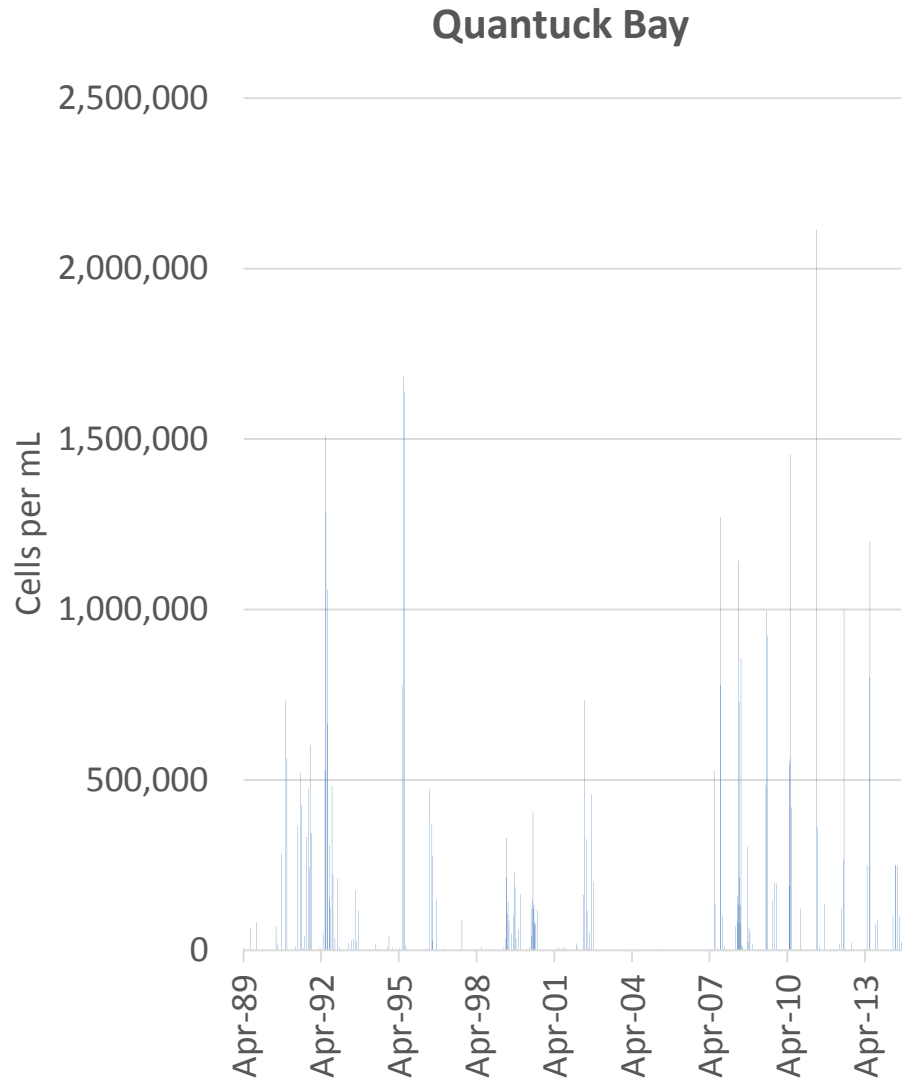




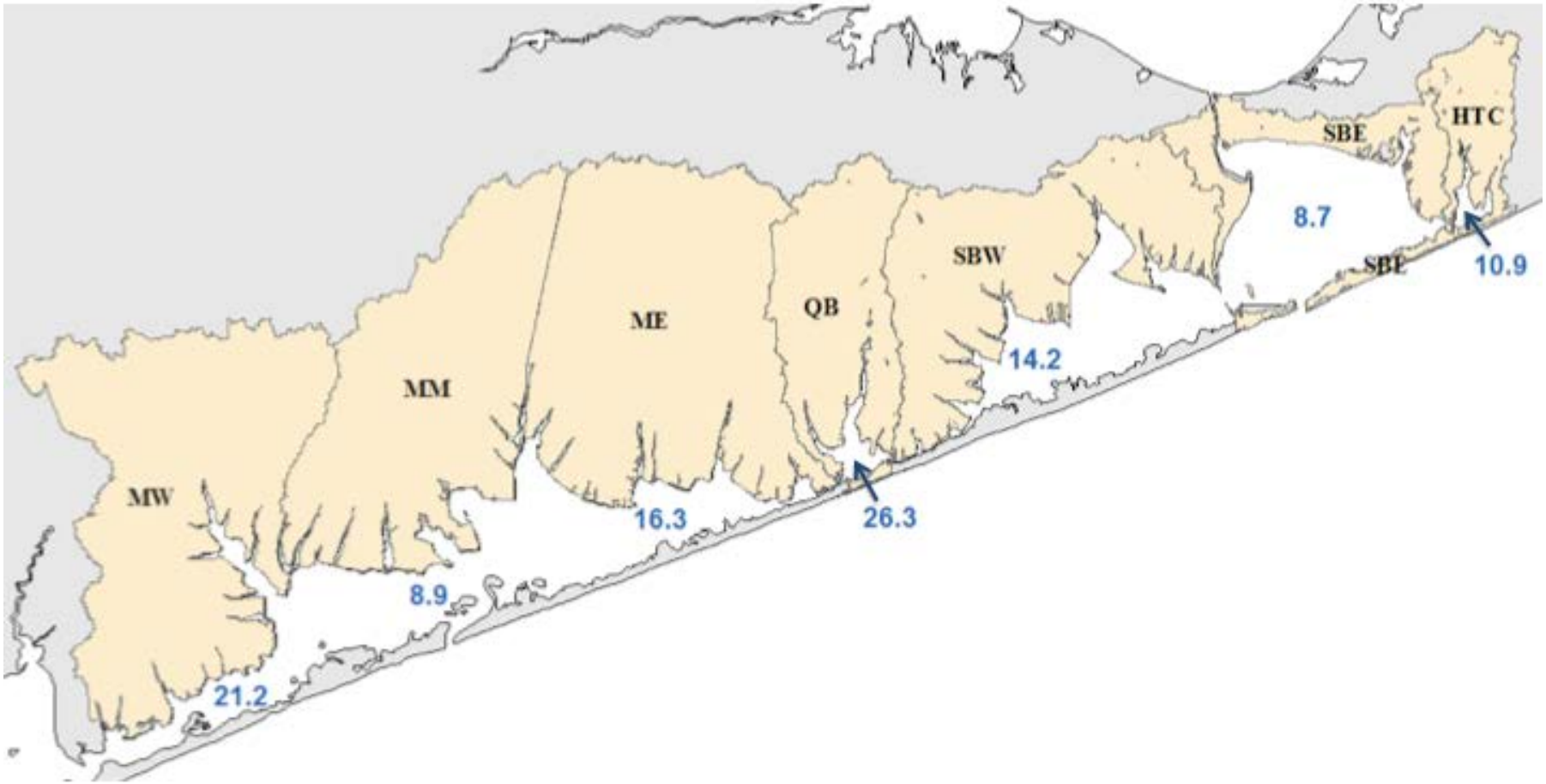

Marine Biotoxin Closure
Shinnecock Bay
Effective
May 7, 2015
Shellfish Harvest Area SS12
TIANA RD
BAY AVE
LYNN AVE
FOSTER AVE
OLD COUNTRY RD
LEWIS RD
Ponquogue Bridge
PONQUOGUE BRIDGE
Shinnecock Bay
QUOGUE RIVERHEAD RD
DUNES RD
Atlantic Ocean
QUOGUE ST
DUNE RD
POSTON
Biotoxin Closure
Normally Uncertified or Seasonally Uncertified

Thirty years of brown tide on Long Island, 1985-2015

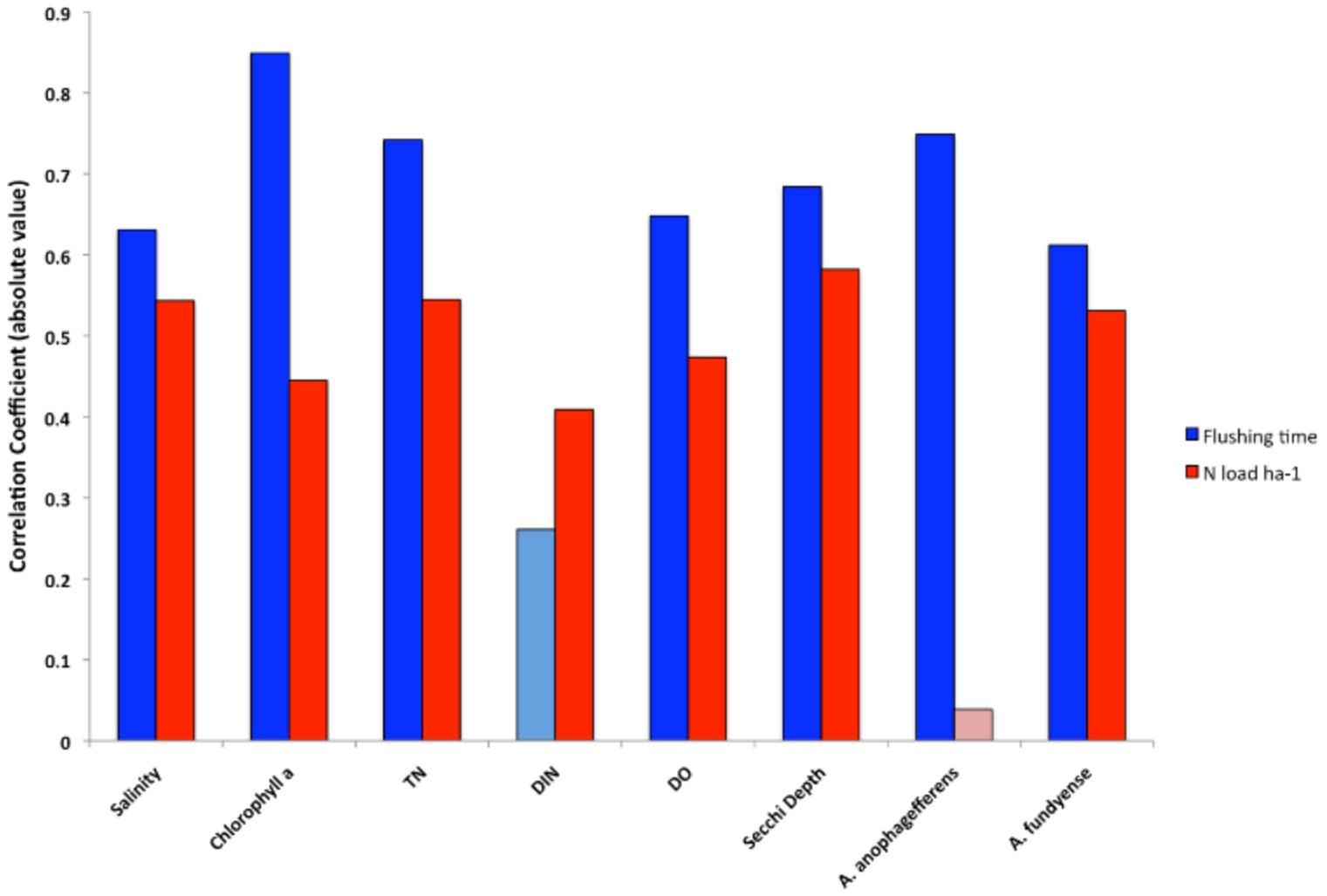




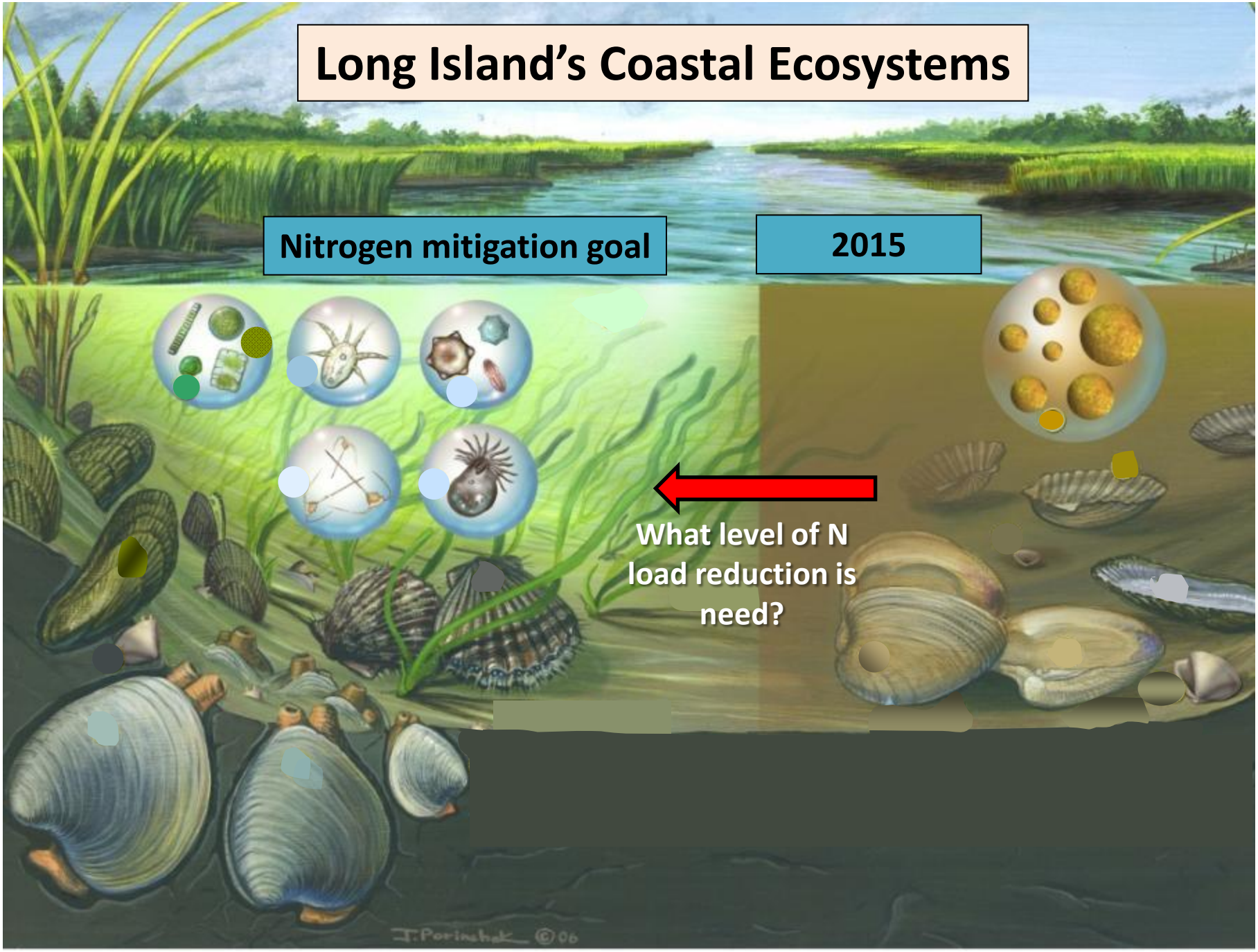
Flushing Time (days)



Statistically significant correlations with N load and flushing time



Long Island's Coastal Ecosystems



Eastern Bays Nitrogen Modeling

Presented by
Anchor QEA, LLC

July 20, 2015

Context

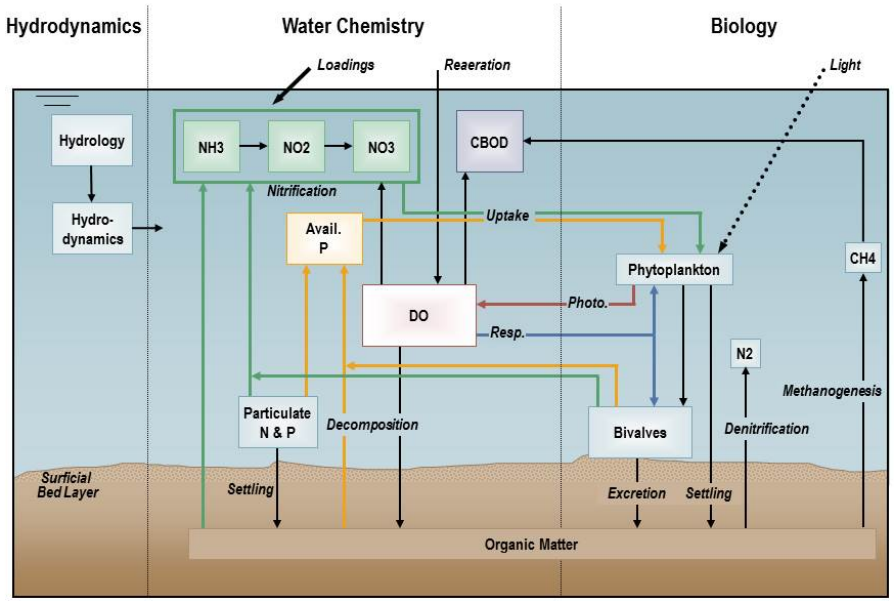
- Ongoing efforts
- Need for a model to integrate the findings from ongoing studies quantifying nitrogen loading and water quality
- Our work is directed to using existing information to develop a model to quantify the relationship between nitrogen loadings and algal blooms and a means to assess how reductions in loading with improve water quality

Specific Objectives

- Provide a tool to relate nitrogen loading, algal blooms, and water quality in Quantuck and Shinnecock Bays
- Support nitrogen reduction planning for the Town of Southampton

Approach

- Develop model of nitrogen cycling, consisting of:
  - Hydrodynamic model
    - Water movement
    - Residence time
  - Water quality model
    - Fate and transport of nitrogen
    - Nitrogen dependent growth rates of algal blooms: *Aureococcus*, *Alexandrium*, general.



Model Development and Preliminary Results

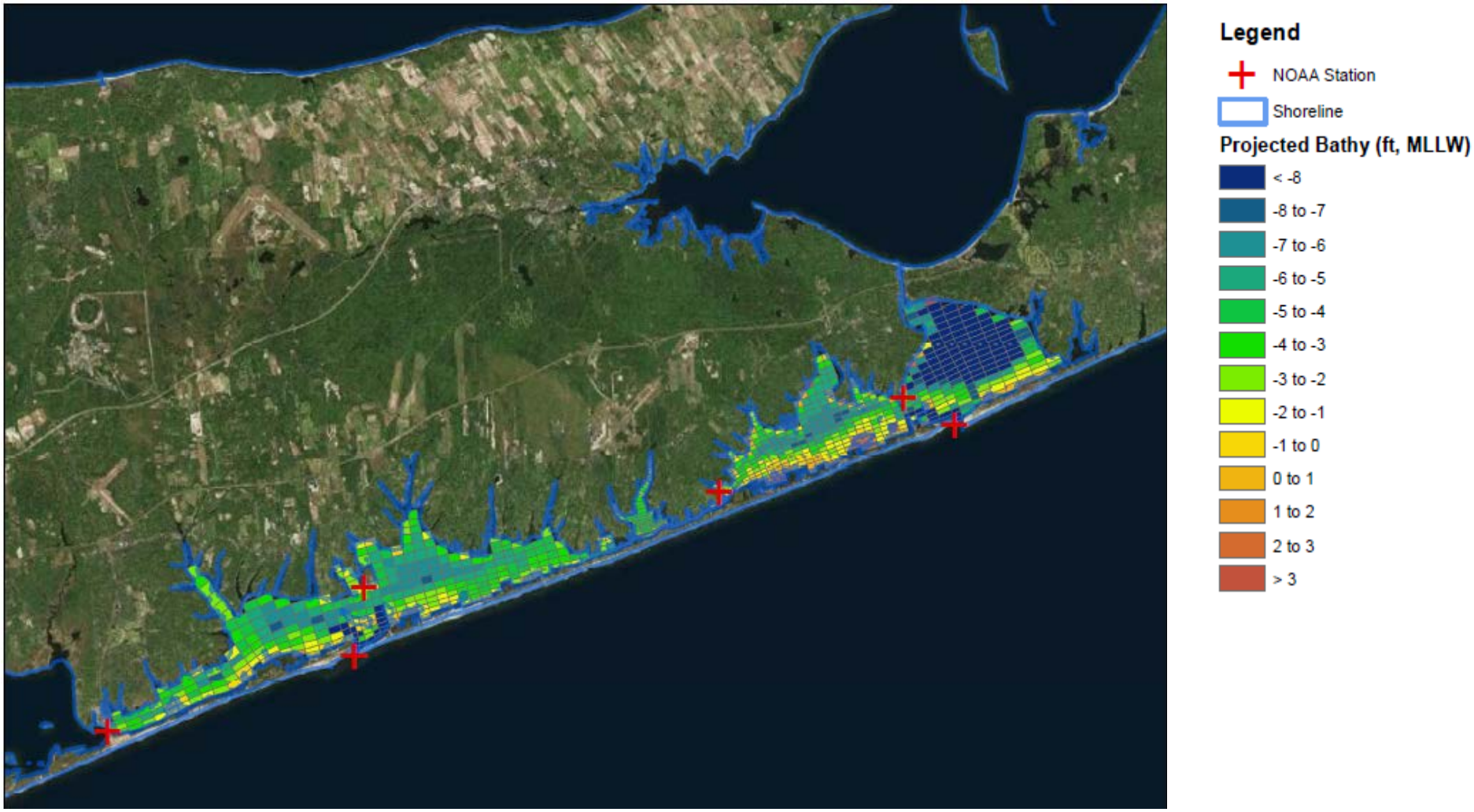
Hydrodynamic Model

- Environmental Fluid Dynamics Code (EFDC)
  - well-tested and widely used three-dimensional (3-D) hydrodynamic modeling framework
  - Approved and supported by the U.S. Environmental Protection Agency (USEPA)
  - Modified and enhanced by Anchor QEA (AQ-EFDC)
- Capable of simulating circulation in coastal and riverine environment with complex geometry
  - Boundary-fitted, curvilinear numerical grid
- Applied in a variety of aquatic systems
  - e.g., Chesapeake Bay, Lower Duwamish Waterway, Hudson River

Hydrodynamic Model Development

- Depth-averaged curvilinear numerical grid
  - Covers Shinnecock, Quantuck, and Moriches Bays
- Model inputs
  - Bathymetry
  - Flow and water surface elevations at model boundaries

Model Grid

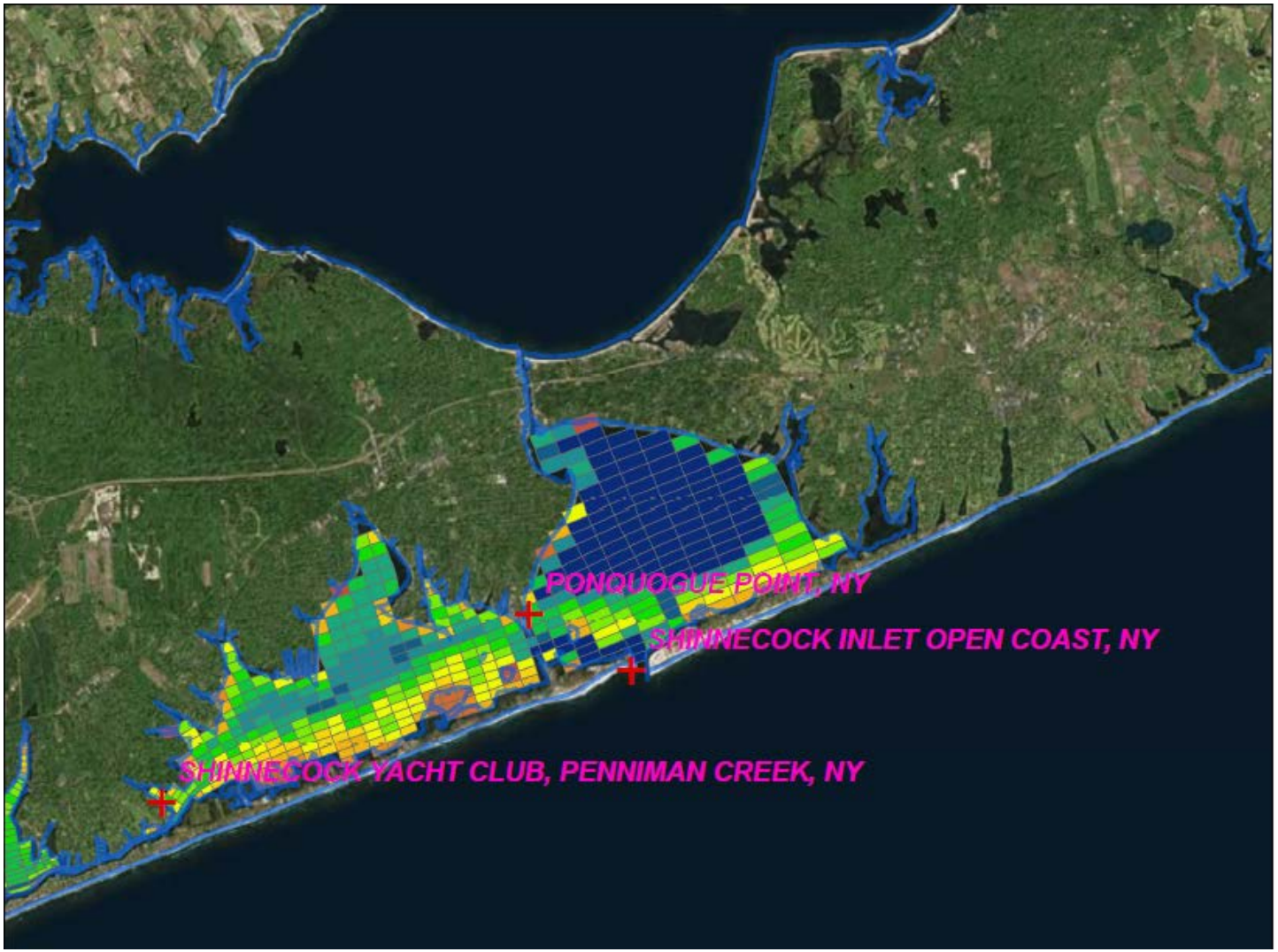


40,000 m (25 miles) in E-W dir. and 5,000 m (3 miles) in N-S dir.
Total 900 cells, average size in E-W dir. = 370 m, average size in N-S dir. = 200 m

Model Grid – Quantuck Bay

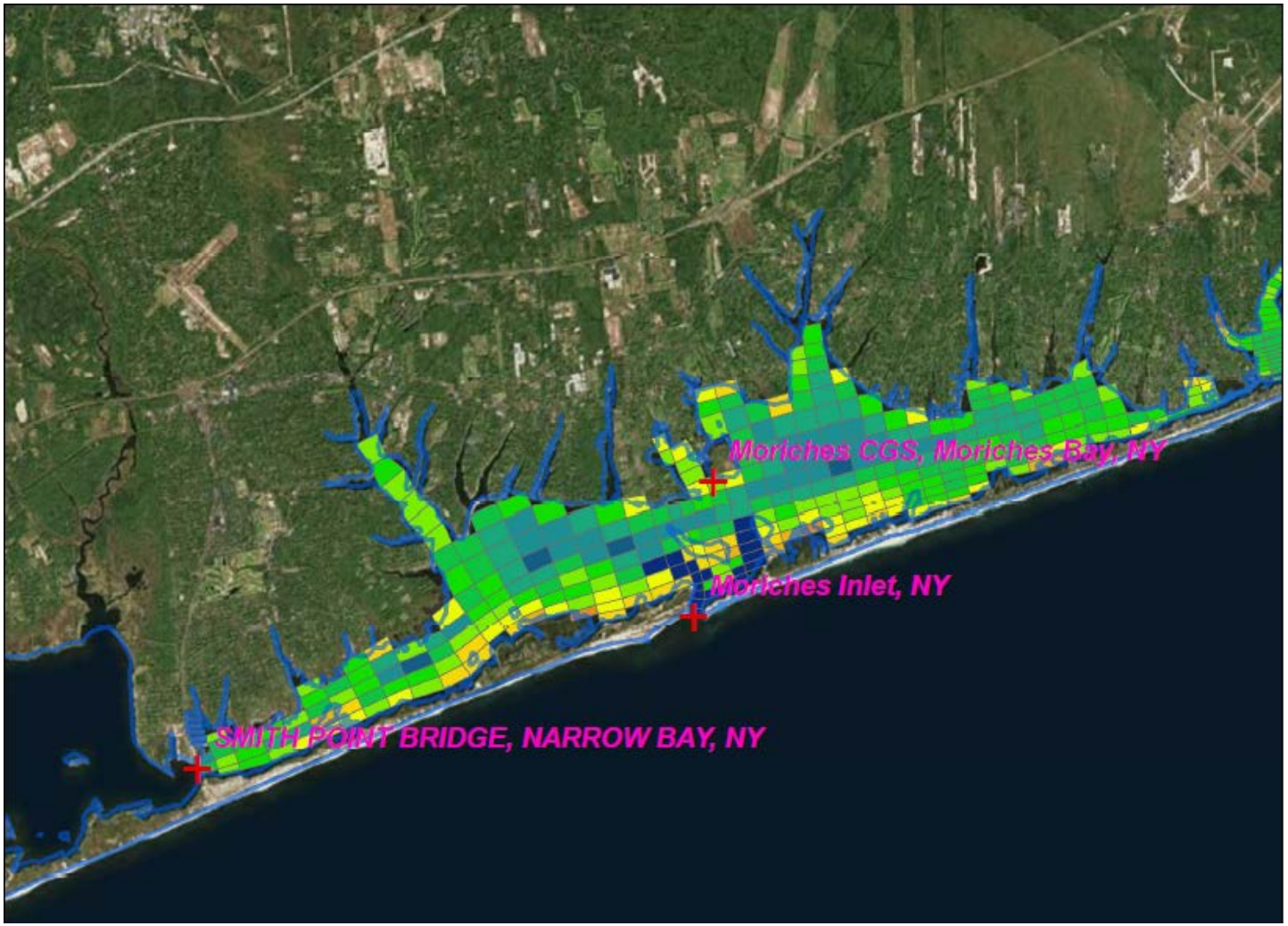
About 80 cells, average size in E-W dir. = 240 m, average size in N-S dir. = 90 m

Model Grid – Shinnecock Bay



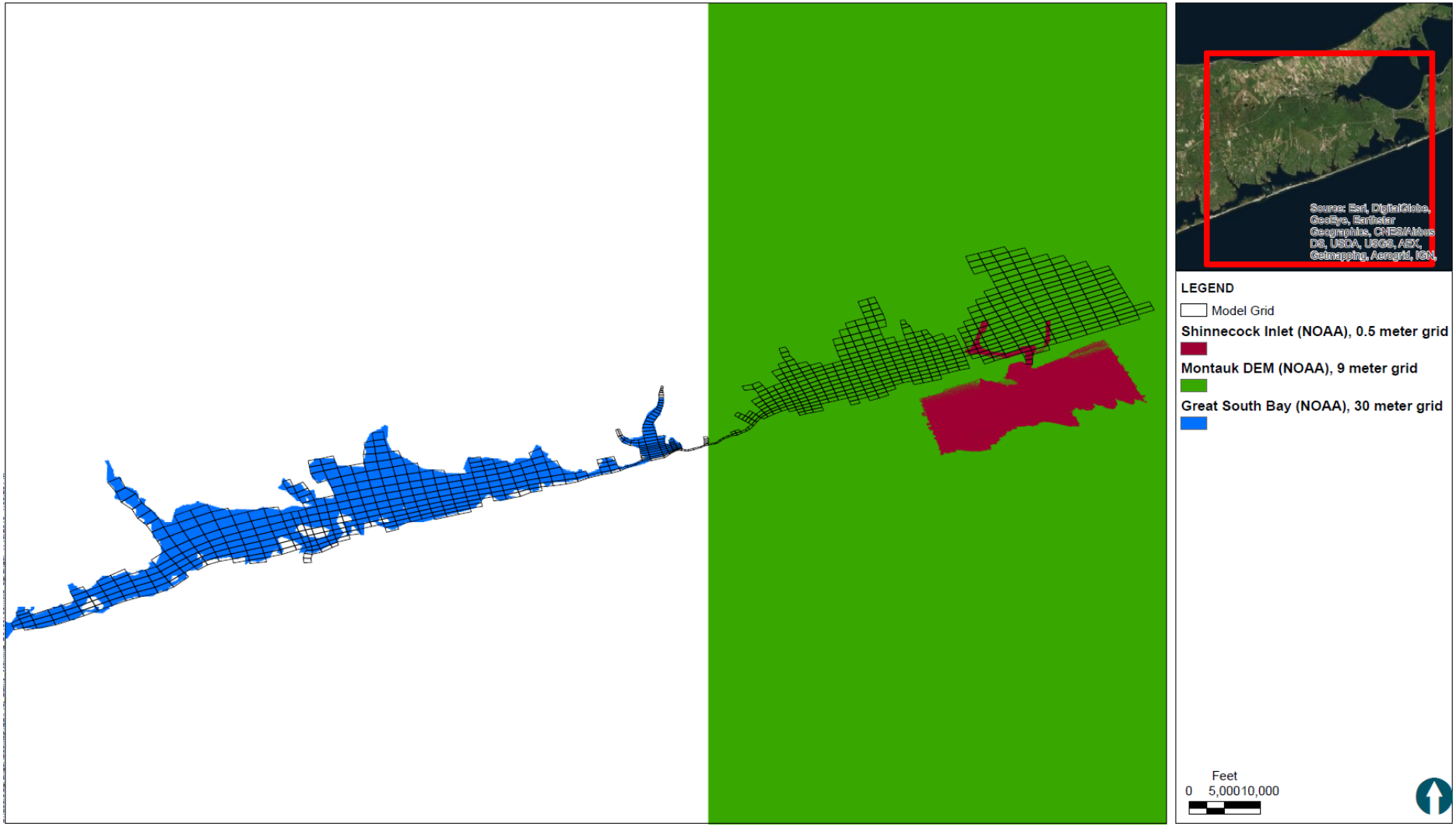
About 470 cells, average size in E-W dir. = 370 m, average size in N-S dir. = 190 m

Model Grid – Moriches Bay



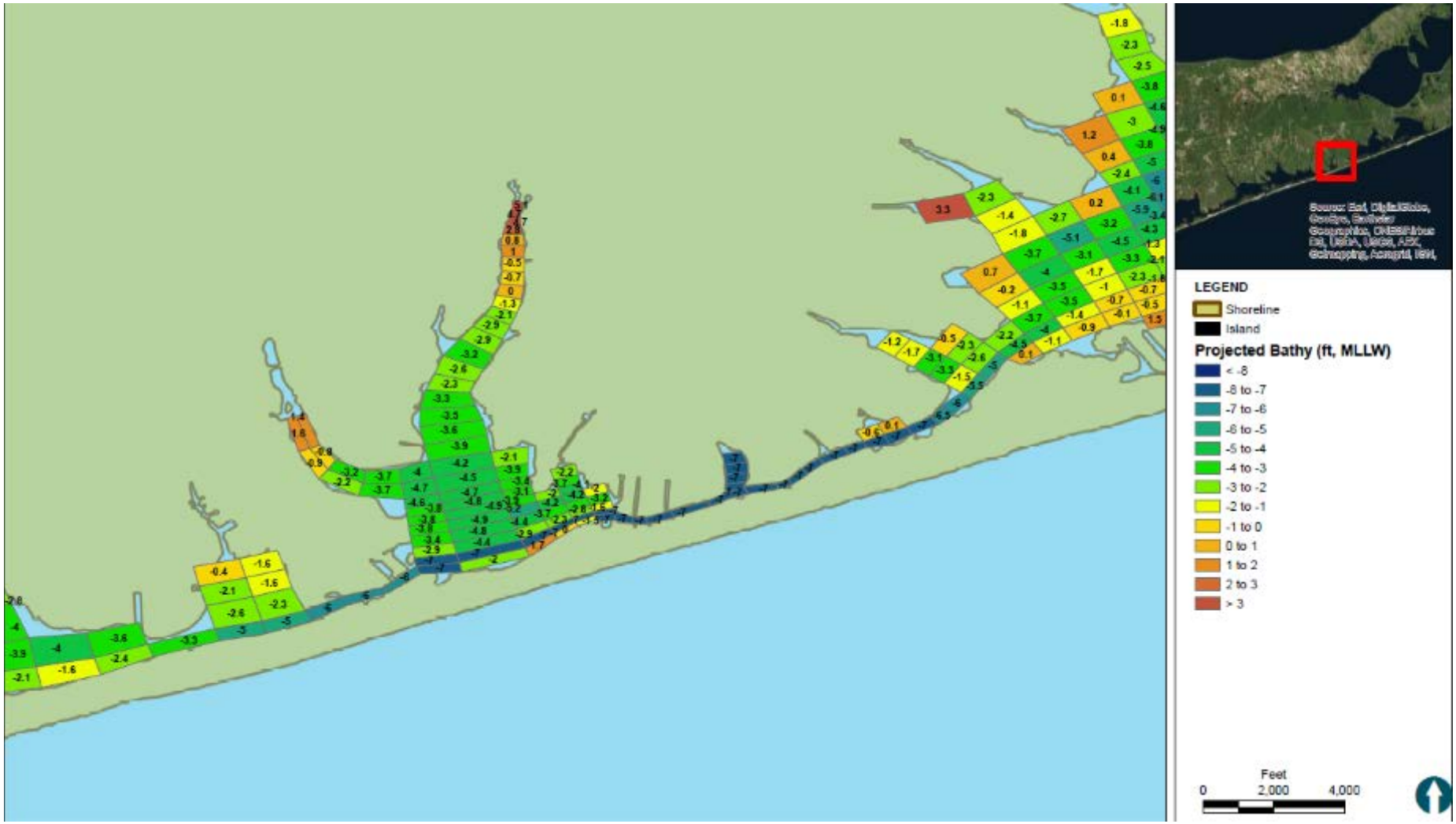
About 320 cells, average size in E-W dir. = 430 m, average size in N-S dir. = 260 m

Bathymetry Data Sources

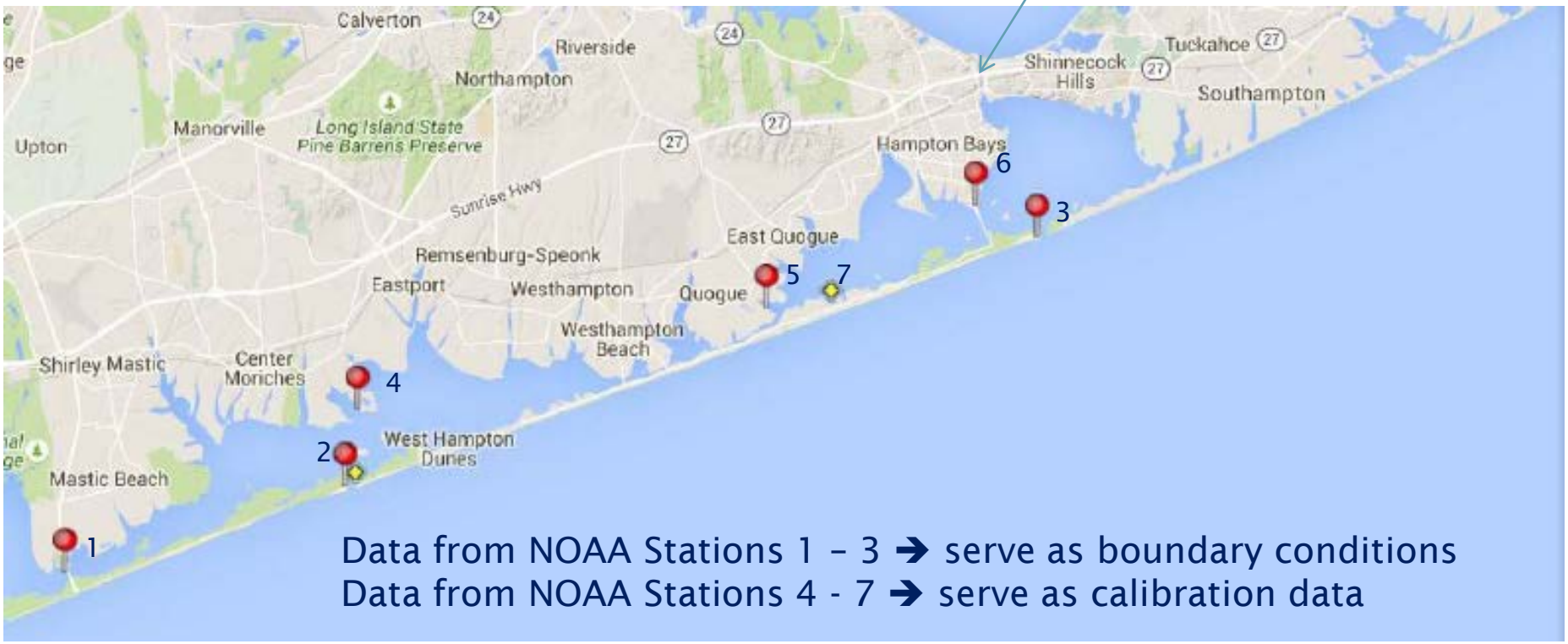


Visually cross-check with NOAA nautical chart 12352

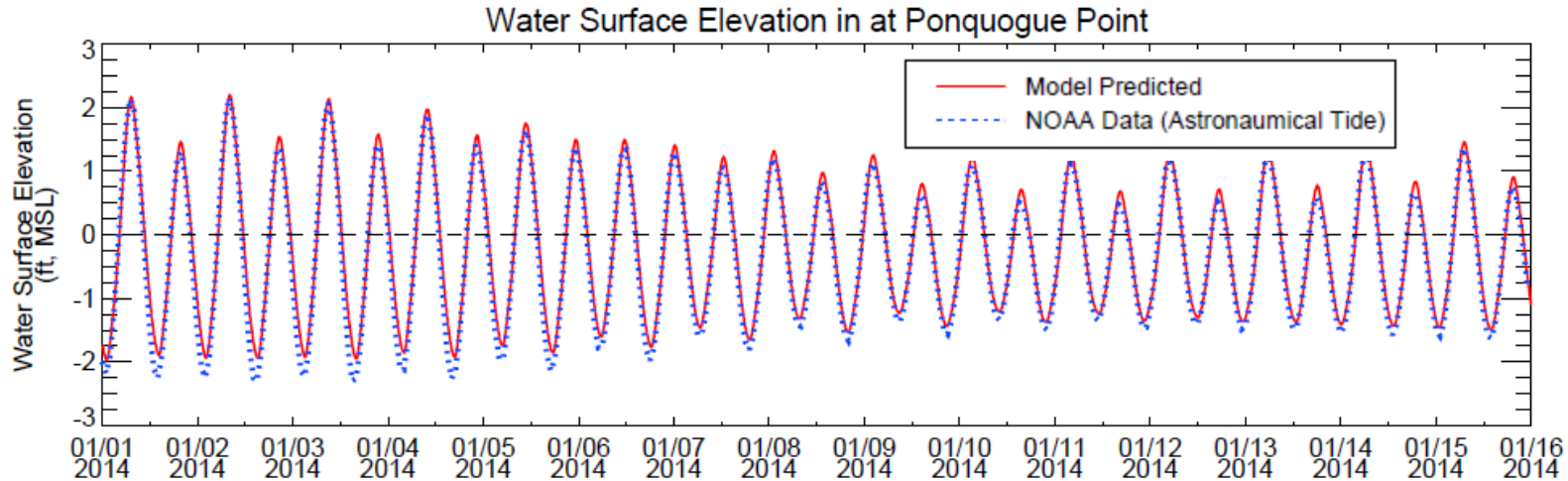
Projected Bathymetry

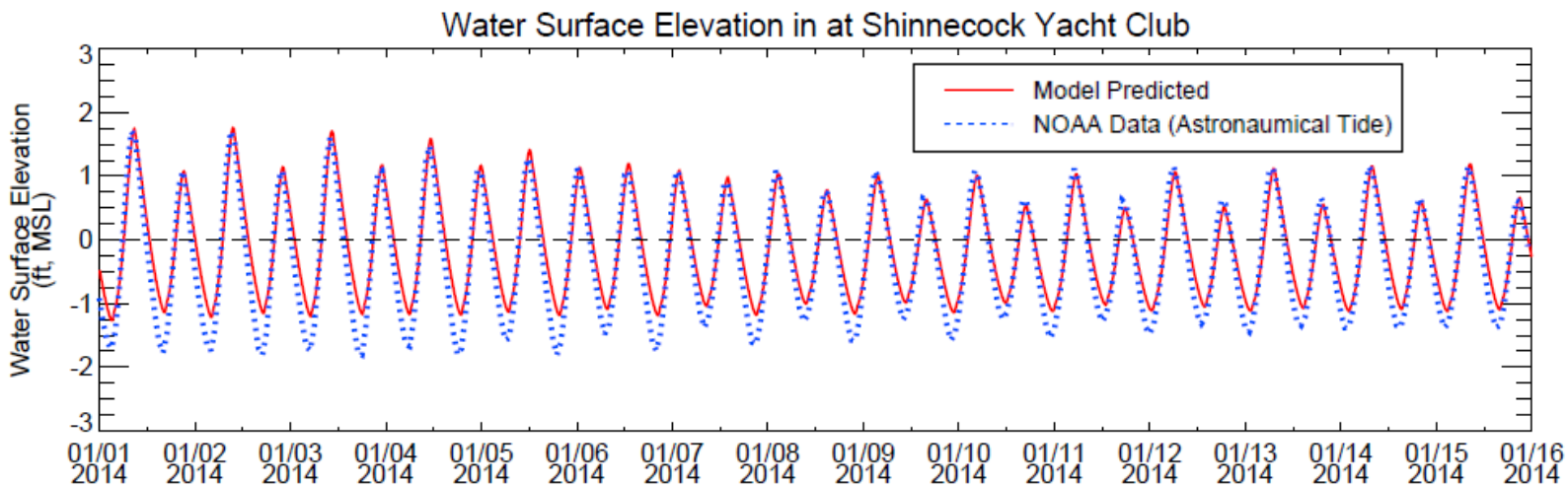


Boundary Data Sources



Calibration to Water Surface Elevation





Preliminary Results

- Animation of current velocity and water depth
- Animation of an instantaneous tracer released along Quantuck Bay shoreline

Next Steps

- Refine calibration
  - Fill bathymetry data gaps
  - Possibly salinity
- Estimate flushing time prediction using conservative tracer
  - Previous estimate 26.3 days (Isabelle Stinnette 2014)
- Compile nitrogen loading estimates
- Analyze nitrogen concentration data
- Calibrate nitrogen cycling model

Water Quality Model Development

- AQ-EUTRO
  - In-house water quality and eutrophication model developed by Anchor QEA
  - Linked to hydrodynamic model
  - Capable of simulating nutrient, phytoplankton and zooplankton (NPZ) dynamics in the system
  - Iterated for differing characteristics of different algal species
  - Level of complexity can be scaled up or down based on study-specific parameters
  - Applied at various sites
- Linked to AQ-EFDC

Modeling algal blooms

Temperature dependence:

$$f(T) = -0.000513\,T^3 + 0.0160T^2 - 0.0867T + 0.382 \quad T \geqslant 5\,^\circ\mathrm{C}$$

Salinity dependence:

$$g(S) = 0.0000882S^3 - 0.00808S^2 + 0.220S - 0.872$$

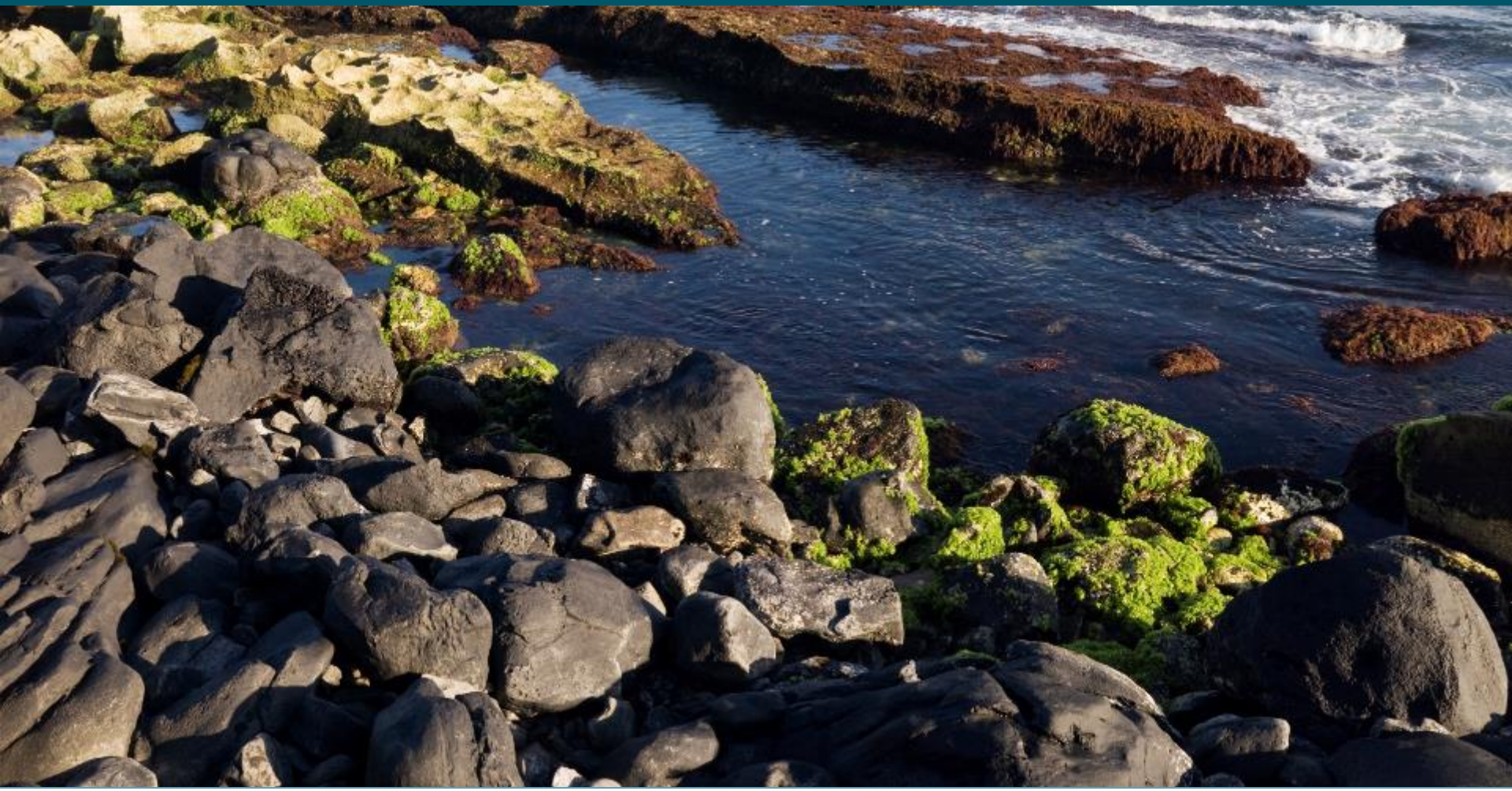
Temperature and salinity :

$$\mu_{\max}(T, S) = \mu_{\max}(T_{\mathrm{opt}}, S_{\mathrm{opt}}) \times f(T) \times g(S)$$

Nitrogen dependence

$$\mu(\mathrm{DIN}, T, S) = \mu(T, S) \times \frac{[\mathrm{DIN}]}{K_N + [\mathrm{DIN}]}$$

Schedule, Milestones & End Product

- Physical model will be refined and ground-truthed through the summer
- AQ-EUTRO model will be concurrently developed for the system.
- Draft runs of link models constructed and used for hindcasting in the fall.
- Final report and presentations to be made in 2016.

Questions/Discussion