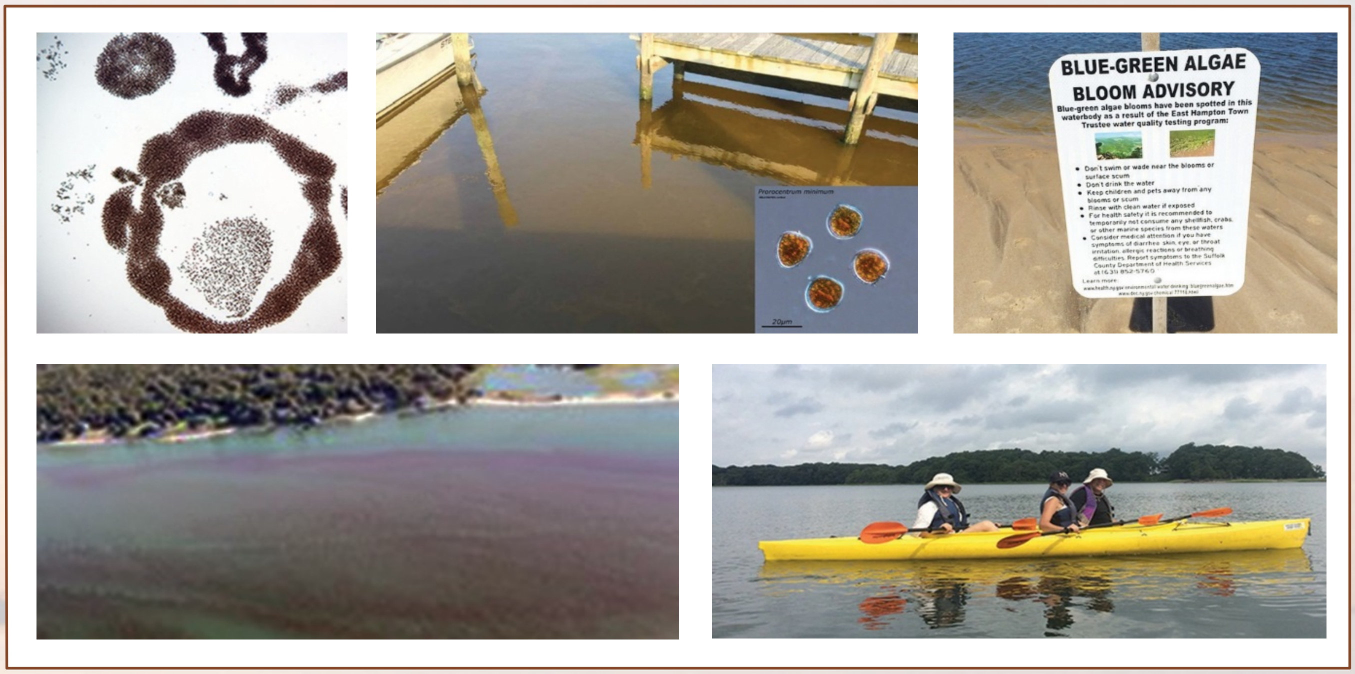
Suffolk County Harmful Algal Bloom Action Plan



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SUFFOLK COUNTY HARMFUL ALGAL BLOOM ACTION PLAN

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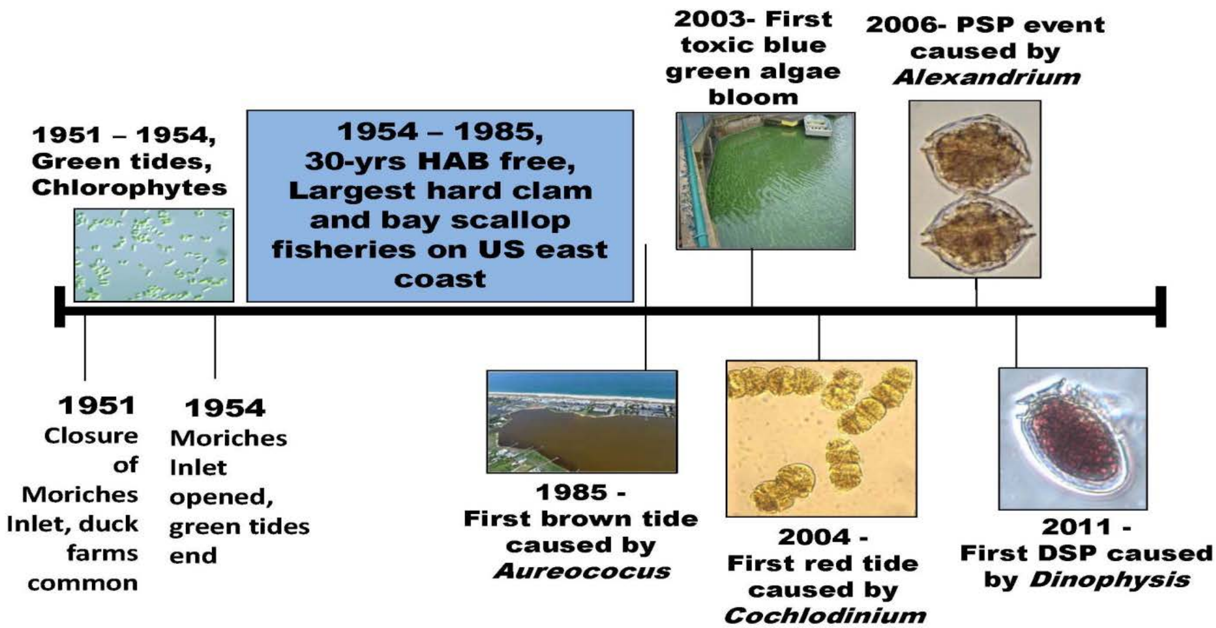
History of Harmful Algae on Long Island



- ***Aureococcus anophagefferens* (Brown Tide):** Not harmful to humans. In high concentrations it turns water murky brown and reduces water transparency. Has a severe negative impact to natural resources such as shellfish and eelgrass. Eelgrass beds are an extremely important component of marine ecosystems, because they provide spawning and nursery grounds for fish and shellfish and play a critical role in estuarine food webs.
- **Cyanobacteria (Blue Green Algae):** Some can produce toxins and can cause negative human health effects when exposed. Although naturally present in lakes and streams, it can become abundant in warm, shallow, undisturbed, nutrient-rich surface waters that receive a lot of sunlight. When blooms occur, it can discolor the water, or produce floating mats or scums on the water's surface.
- ***Cochlodinium polykrikoides* (Rust Tide):** Not harmful to humans. It causes intense and widespread reddish-brown blooms. It has found to be lethal to multiple species and life stages of fish and shellfish.
- ***Alexandrium* (Red Tide*):** Can cause Paralytic Shellfish Poisoning (PSP), an illness caused by eating shellfish contaminated with a powerful biotoxin that *Alexandrium* produces (saxitoxin). Symptoms can progress from tingling of the lips and tongue, to numbness of the face, neck and limbs, loss of muscular control, followed by difficulty breathing.
- ***Dinophysis* (Red Tide*):** Can cause diarrhetic shellfish poisoning (DSP), an illness caused by eating shellfish contaminated with okadaic acid that *Dinophysis* produces.

Other HABs plaguing Suffolk County waters (see Appendix A):
Prorocentrum minimum (Mahogany Tide), *Gymnodinium instriatum*, *Heterocapsa rotundata*, *Peridinium quinquecorne*, *Akashiwo sanguinea*, the raphidophyte, *Heterosigma akashiwo*, and the Euglenophyte group, *Eutreptiella* spp.

*Note: The absence of on an observable bloom does not mean that a harmful bloom is not present.

Executive Summary

Suffolk County's surface waters are a huge economic and lifestyle driver for Long Island and contribute immensely to tourism, commerce, fishing, recreation, and other activities. Harmful Algal Blooms (HABs) pose an increasing threat to the healthy ecological functioning of County surface waters and can reduce the type and level of ecological services County residents and communities derive from these systems. Moreover, some HABs pose a direct threat to public health and safety; they produce toxins that are harmful to humans and pets. HABs are not new to Suffolk County's waters, but they are increasing in frequency and variety. The HAB Synthesis Report (Appendix A) is a comprehensive review of the history of HABs in Suffolk County. The Synthesis Report, prepared by Dr. Chris Gobler and Dr. Theresa Hattenrath-Lehmann, details what is known about the specific causes of HABs, their impacts and what management actions have been taken in response to these HAB events.

There has not been an updated Suffolk County-specific HAB strategy since the 2002 Brown Tide Module of the Peconic Estuary Program Comprehensive Conservation and Management Plan, which is now obsolete. This project was funded by the Suffolk County Water Quality Protection and Restoration Program (WQPRP). The goal of the project is to establish a HAB action plan and framework for moving forward. The project started with a public symposium in May of 2016 at Timber Point Country Club, followed by a full-day workshop of invited HAB experts at SUNY Stony Brook and culminating with this plan. The WQPRP provides funding for projects throughout Suffolk County that protect and restore water resources (both surface and ground water).

Suffolk County and New York Sea Grant (NYSG) have teamed together and, in consultation with Stony Brook University's School of Marine and Atmospheric Sciences (SoMAS) and a wide variety of partner organizations, prepared this HAB Action Plan and strategies to deal with the growing threat posed by HABs. The Action Plan documents the history of HABs in Suffolk County, when and where different harmful species bloomed, the most likely cause(s) of each bloom, their environmental and economic effects and what, if any, management response to the bloom were undertaken. The plan describes the current state of knowledge regarding factors responsible for initiating and sustaining HABs in County waters, along with on-going environmental monitoring efforts and programs. While several factors contribute to the appearance of HABs in County waters, the Action Plan identifies anthropogenic nutrient inputs to surface waters through several sources as the most important and likely controllable factor. These nutrients, primarily nitrogen but, in some cases nitrogen and phosphorus, or just phosphorus, are the fuel that feeds HABs. Although there are multiple sources of nitrogen (e.g. sediment nutrient flux, fertilizer, atmospheric deposition), conventional septic systems and cesspools have been clearly identified as the most significant source of anthropogenic nitrogen inputs causing the degradation of water quality for the majority of the County's surface water resources. The County, State of New York, and multiple other local governments are taking a multi-pronged approach to control and limit nutrient inputs to groundwater and surface waters by transitioning to the use of innovative and alternative onsite wastewater treatment systems (I/A OWTS) which remove significantly more nitrogen than conventional systems. This Action Plan contains recommendations for limiting the inputs of anthropogenic nutrients to groundwater and surface waters to reduce the frequency and severity of future HABs in County waters. Additional recommendations cover important management, monitoring, public health, outreach and research needs as well as for the improved communication and management of HABs among the agencies and organizations involved in the issue. This coordinated strategy for research, monitoring, and management is essential to counter the HAB threat. It is an important component of Suffolk County's broader initiative to protect water quality.

Essential Study Findings

- HABs are a recurring significant problem in Suffolk County waters that warrants an **increased** and **proactive** management response
- HABs have been present in Suffolk County waters at least since the mid-1930's; their **frequency and diversity in the County appear to be increasing** and may have **reached a level unprecedented elsewhere in the United States**
- Suffolk County is not alone in facing a greater threat from HABs; **this is a national, indeed a global phenomenon and problem**
- Suffolk County should **act now** to forestall future HAB problems
- **Reducing nutrient inputs to surface waters**, especially via groundwater inputs, are the highest priority actions that will have **a significant effect** on HABs in Suffolk County
- **Climate variability** is likely to accelerate and exacerbate the HAB issue in Suffolk County and elsewhere
- To combat HABs, Suffolk County can and should **draw on the experience of others** around the United States and internationally
- In combatting HABs, Suffolk County should **continue and extend its cooperative approach with municipal (including Towns, Villages and Trustees) and State governments as well as university scientists, researchers**, non-government organizations (NGOs) and other stakeholders. To complement and leverage resources, HAB efforts should be coordinated with the Long Island Nitrogen Action Plan (LINAP), Subwatersheds Wastewater Plan (SWP) and estuary programs
- Suffolk County's HAB Action Plan should be **tiered**: "Act Now" components for immediate implementation (1st tier) based on current knowledge/experience supported by 2nd and 3rd tier actions/interventions reflecting knowledge gained and derived from monitoring/research programs
- A HAB **monitoring/research program** is a necessary foundation for the County's **adaptive and evolving HAB Action Plan**
- **Continued and extensive water quality (and/or other ecosystem parameter) monitoring** is essential to detect conditions in County surface waters that might help predict blooms
- Suffolk County's HAB Action Plan will need **strong public support**
- Complete control and prevention of HABs is likely not achievable; **significant reduction in the frequency scope, and extent of ecosystem/human health impacts of future HABs in Suffolk County is achievable**

Priority Action Plan Recommendations

Management Recommendations

Top strategic priority:

Reduce nitrogen and phosphorous loading to ground watersheds, surface watersheds and direct inputs to surface waters, particularly by upgrading septic systems, both residential and nonresidential.

- Reduction goals will be quantified in SWP. However, it's clear that critical priority areas will require the order of magnitude of septic nitrogen reduction (50-70%) offered by Innovative/Alternative Onsite Wastewater Treatment Systems (I/A OWTSs) or sewering. South Shore Estuary Reserve (SSER) nitrogen loads are estimated to be 70% septic; Peconic Estuary Program (PEP) has set a 50% nitrogen reduction target in Total Maximum Daily Load (TMDL) areas. A TMDL is the maximum amount of a pollutant that can occur in waterbody and still meet water quality standards.
- Suffolk County should continue to lead with Reclaim Our Water Initiative/SWP along with the LINAP.

- **Actively endorse/promote subwatershed pilot projects like the Georgica Pond pilot project that will feature interception and treatment of nutrients in domestic wastewater from homes around the Pond, more frequent opening of a cut between the Pond and the ocean, and the real-time monitoring of groundwater and Pond waters to gauge the effect of these actions on ambient nutrient levels.**
    - A cooperative approach should be taken and acknowledgement of the multi-jurisdictional roles between state & local governments as well as Trustees.
    - Lake Ronkonkoma should be considered a prime potential pilot subwatershed.
- **Establish ongoing HAB Management Workgroup to coordinate implementation of this HAB Action Plan and to serve as an on-going forum for HAB management in Suffolk County.** The Workgroup would have representation from governmental agencies at various levels, university scientists, local National Estuary Program offices and others entities involved in HABs. Under the aegis of the HAB Management Workgroup, convene an annual workshop of collaborating agencies to achieve inter-governmental cooperation and consistency in HAB and nutrient management policies/practices.
    - The workgroup should collaborate and participate in existing nitrogen reduction program workgroups including the LINAP, Long Island Sound Study (LISS), PEP, and South Shore Estuary Reserve (SSER).
    - The County and the State Department of Environmental Conservation should jointly implement this recommendation and lead the HAB Management Workgroup,

drawing on the assistance of New York Sea Grant and Stony Brook University's School of Marine and Atmospheric Sciences as necessary.

    - The Workgroup should track and report on key outputs and outcomes.
        - Consider developing a template of key performance indicators (KPIs), environmental indicators, and /or a report card.
    - The National Oceanic and Atmospheric Administration (NOAA) ECOHAB Grant is likely to provide funding for Year 1 of workshop (spring 2018).

- **Actively endorse/promote resource restoration efforts such as, but not limited to, shellfish (scallop, clam and oyster) restoration and submerged aquatic vegetation (SAV); these should be based on metrics and criteria (not simply geography) and be aligned with results of ecological endpoint monitoring. Future restoration efforts should follow consistent specific monitoring protocols so they can be accurately and consistently compared across geographies.**
    - Convene a workgroup to create criteria for choosing restoration sites and monitoring methods.
    - Certain restoration efforts in specific areas may have to wait until N reduction targets are achieved.
- **Adopt additional management measures to regulate the amount and composition of nitrogenous fertilizers used in Suffolk County.**
    - Cooperatively work with farmers to implement the Suffolk County Agricultural Stewardship Plan to reduce the leaching of nutrients into groundwater from agricultural practices.
    - Assess effectiveness of existing residential fertilizer regulations and consider modifications as necessary.
- **Actively endorse/promote green infrastructure projects that limit the discharge of nitrogen to surface waters via stormwater runoff.**
    - A notable example is the construction of a sizable rain garden at Centerport Beach where ~80% of the stormwater is captured, thereby increasing infiltration and degradation by soil bacteria.
    - Green infrastructure pilot projects should be incorporated into subwatershed pilot areas (E.g. Georgica Pond, Lake Ronkonkoma).
- **The county should prioritize permeable reactive barriers (PRBs) in key locations to address the legacy nitrogen in river, ponds and embayments.**

Monitoring Recommendations

- **Suffolk County and the New York State Department of Environmental Conservation (NYSDEC) should institute routine monitoring for the presence of the Diarrhetic Shellfish Poison (DSP) toxin.** Advanced monitoring technologies such as Passive Solid-Phase Adsorption

Toxin Tracking (SPATT, water column) and the Abraxis Protein Phosphate Inhibition Assay (PP2A, shellfish meats) may be used by collaborating laboratories as an early warning sign to State and County agencies. The NYSDEC-Shellfish Unit can only use testing methods that are approved by the National Shellfish Sanitation Program (NSSP). Refer to Appendix C- List of NSSP Approved Methods

  - SoMAS in collaboration with DEC (as lead regulatory agency).
  - Estimated cost: $20,000 for ten monitoring locations. Funding source TBD.

- **Deploy a sensor buoy in Lake Ronkonkoma for real time monitoring of cyanobacteria and the physiochemical parameters that are important in cyanobacterial blooms**
  - Managed by United States Geological Survey (USGS).
  - Estimated cost: $50,000 startup, $10,000/year for maintenance. Funding source to be determined (TBD).
- **Evaluate use of the cutting edge remote sensing technologies** such as**:**
  - Imaging FlowCytobot (IFCB) which continuously captures high resolution images of algal cells; the optical and image data are then transmitted to shore in real time.
    - SoMAS and/or Suffolk County Dept. of Health Services (SCDHS) lead. Estimated cost: $135,000 startup; $10,000/year for maintenance. Funding source TBD.
  - Unmanned aerial vehicles (drones) have become more commercially feasible and should be considered for documenting HAB events.
    - SoMAS and/or SCDHS lead. Estimated cost: $5,000. Funding source TBD.

Public Health and Outreach Recommendations

- **In addition to the webpages that DEC maintains (freshwater HABs and marine biotoxins), establish/maintain a mechanism (HAB Website) by which the public can access current information on <u>all</u> HABs in Suffolk County (fresh water and marine) and report unusual environmental conditions that might be associated with an emergent HAB. This shall include the goal of developing an app that provides water quality information/status at your particular location (HABs, shellfish bed, etc).**
  - Website and app to be maintained by SCDHS and populated with information by SCDHS, SUNY Stony Brook and NYSDEC.
  - Estimated cost: $75,000. Funding source TBD.
  - Note: DEC also maintains recorded phone message regarding temporary shellfish closures (631-444-0480).
- **Implement a HAB public outreach/education program to disseminate information about HABs, their origins and effects on aquatic systems in Suffolk County and the risks they can pose to public health.**

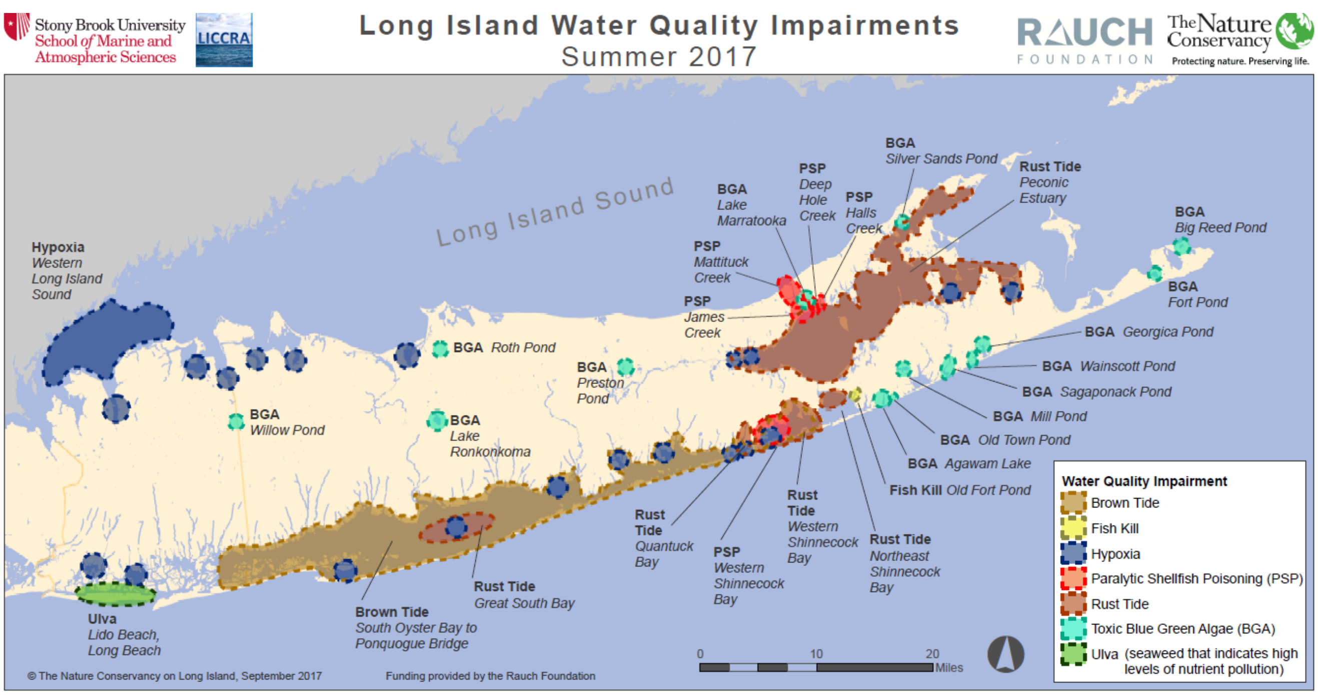
Research/Investigation Recommendations

- **Secure and allocate funding for priority research needs in Suffolk County, similar to the Brown Tide Research Initiative model in the 1990s, which led to several breakthroughs in understanding and managing the Brown Tide. Such HAB research would require at least 1 million dollars a year, over the next 5 years.**
- **Coordinate with project partners/workgroups to evaluate and identify surface water quality data gaps and provide recommendations for revisions to surface water monitoring programs in support of overall HAB monitoring, HAB predictive modeling, and HAB mitigation measures.**
- **Coordinate with project partners/workgroups to develop HAB-specific predictive water quality modeling for the establishment of refined nutrient load reduction goals.**
- **Continue to refine the most appropriate metric to use to measure the risk to public and animal health from cyanoHAB's in the lakes and ponds in the County.** Note: New York State Dept. of Health (NYSDOH) currently recommends using the US Environmental Protection Administration (EPA) draft ambient water quality criterion (4 µg/l) for microcystins for reopening bathing beaches affected by cyanobacteria blooms.
- **Continue to assess the role of legacy sediments and nutrients (phosphorus/nitrogen) in Suffolk County HAB formation and sustenance**
    - Reducing groundwater loads will have the added benefit of reducing sediment flux
    - Site-specific evaluations can be conducted on additional sediment removal or remediation (e.g. Meetinghouse Creek Feasibility Study).
- **Conduct an assessment of the potential utility of using seaweed farms and/or suspension-feeding shellfish aquaculture facilities (collectively referred to as bio-extraction) as a way to reduce nutrient levels in County waters and/or to forestall or mitigate the development of HABs.**
    - Suffolk County is currently funding a seaweed aquaculture feasibility study which includes deployment of 5 kelp dropper lines with kelp seed strings to be monitored during the growing season. The kelp tissue shall be chemically analyzed to assess bio-extraction (N, C) potential. The project will include an assessment of seaweed culture as a commercial enterprise and its potential to improve water quality via bio-extraction.
    - Sea Grant is sponsoring shellfish restoration.
    - Suffolk County should collaborate with the recently funded DEC bio-extraction coordinator to assess the viability and challenges of bio-extraction of nutrients from surface waters.
- **Suffolk County along with collaborating agencies (NYSDEC as lead) should assess the utility and practicality of treating HAB-prone freshwater lakes and ponds with various control methods as a means to limit cyanobacteria growth and/or the availability of nutrients (N**

and/or P) to potentially prevent the development of toxic blooms. The methods to be assessed should include, but not be limited to, various algaecides (e.g. hydrogen peroxide), flocculants (e.g. aluminum sulfate, native clays, Phoslock), circulation systems, ultra-sonic blasters and antialgal biologically derived substances (BDSs).

*Many, if not all, of the recommendations are interrelated. It is important to continue collaboration among the various agencies and stakeholders while proceeding with a cooperative approach to achieve the overarching **goal to fund, implement, and oversee a Comprehensive HAB Monitoring Strategy.**

Note: further detail on some of these recommendations is provided in the Action Plan Recommendations section, p. 51



Introduction

Harmful Algal Blooms (HABs) are a significant threat to the health of Suffolk County residents, to the quality and ecological functioning of the County's valuable fresh and marine surface waters and to the County economy, which depends heavily on the enjoyment and use these waters. This Suffolk County Harmful Algal Bloom Action Plan documents the negative environmental, economic and social consequences of harmful algal blooms (HABs) in the surface waters of Suffolk County. The Plan describes the history of HABs in County waters and their primary cause(s). The report identifies and assesses the options for pre-emptive steps that could be taken to control the most important factors contributing to HABs, based on information and experience in Suffolk County and in other localities around the Nation, and to ameliorate and/or mitigate their effects in Suffolk County's marine and freshwaters. Specific recommendations are made to the County for the control and mitigation of HABs. Finally, the plan provides recommendations for monitoring activities to assess the effectiveness of any Suffolk County actions to control/mitigate HABs, as well as identifying shortcomings in the understanding of HABs that can serve as the basis for directed research conducted or funded by the County to improve its ability to predict and reduce the frequency and severity of HABs in its surface waters.

The natural environment changes continually and so too does human society. The next several decades will see a dramatic rate of change, driven by a changing climate, the ramifications of climate variability on the rest of the biosphere and the attempts by society to affect and/or accommodate these changes in the natural environment. Locally, the need to deal with HABs in Suffolk County is likely to remain an issue of concern for some time. As conditions change in Suffolk County, there will be a need to adjust some aspects of this Action Plan. The plan includes a recommendation that it be revisited periodically to determine and implement these course corrections.

Why Is This Important?

Harmful Algal Blooms are a growing world-wide problem and have been recorded on Long Island and in Suffolk County waters since the mid-1930's. HABs have had clear and demonstrable negative impacts on Long Island's coastal waters and have interfered with the ecological functioning of those systems. Local marine waters provide County residents with a variety of economically and socially important ecosystem services, including food, recreation and aesthetic values. In particular, the repeated and apparently expanding occurrence of HAB's has disrupted coastal food webs in the County's marine waters in ways detrimental to many important resource species, especially molluscan shellfish. These clams, oysters, mussels and scallops, feed by filtering from the water phytoplankton and other organic matter. HABs alter the planktonic community on which these animals depend. Over time, these changes in the production and composition of the phytoplankton community have helped fuel declines in such important fishery species as Atlantic bay scallop (*Argopecten irradians*) and hard clam (*Mercenaria mercenaria*). These fishery declines have a direct, negative impact on the economy and lifestyle of Suffolk County, which have always been tightly bound to its coastal environment.

HABs are not just a threat to the functioning of marine and freshwater ecosystem. Some HABs involve the production of algal toxins that can pose health risks to humans and/or pets, and there are many documented instances of human or pet poisonings around the U.S. and the globe associated with HABs; some of these have involved fatalities. The health and well-being of County residents and visitors is an over-riding concern of County government. A HAB can also impair the designated use of a waterbody, which is established by the State through its water quality standards regulations. As required under the federal Clean Water Act, New York State lists impaired waterbodies that do not support appropriate uses and that may require development of a Total Maximum Daily Load (TMDL) - the maximum amount of a pollutant that can occur in waterbody and still meet water quality standards. Within the TMDL, this loading capacity is allocated among the various point sources and non-point sources. TMDLs only affect permits issued to point sources and have no regulatory effect on non-point sources. Both Federal (US Environmental Protection Agency) and State (NYS Department of Environmental Conservation) permitting of discharges to waters of the United States must ensure attainment of water quality standards, including consistency with any established TMDLs. The New York State Department of Environmental Conservation (NYSDEC) is also required to monitor and close shellfish harvest areas impacted by HABs as a precautionary measure or that have been determined to pose a public health threat due to presence of biotoxins in shellfish at levels at or above action levels required for closure.

But beyond their ecological and environmental impacts, both well-documented in Suffolk County, and their potential threat to public health and safety, HAB's convey more broadly to County residents a sense that something has gone seriously awry in our coastal and fresh waters. While these ecosystems are dynamic and have always experienced some degree of change and disruption, HABs are taken by many people to indicate that we have pushed these systems too far and they have now fundamentally changed, perhaps irrevocably. Some changes are irreversible and we cannot remake the condition of Suffolk County's lakes, ponds, streams and coastal waters into what it was in 1800. But, the literature on habitat restoration gives abundant evidence that much can be accomplished to improve the condition of degraded aquatic systems and to restore their ability to provide the valued ecosystem services they provide.

The impacts of climate variability are in evidence in the County's marine and inland waters. It is generally believed that climate variability, especially warming waters, will favor the intensification of HABs in relation to environmental degradation and eutrophication and perhaps lead to an expansion of the geographic range of warm water-adapted toxic microalgae. Thus, the threat posed by HABs to the integrity of our coastal and freshwater surface waters, the ecosystem services they provide, and the public's health and well-being may increase in future decades. The current and potential future risks of water quality impairment caused by HABs warrants intervention. There is now a body of knowledge, understanding and experience about HABs, their causes and how to control them that the County can use to undertake a series of management actions and interventions that will lessen the HAB problem. This plan is premised on the conviction that it is now time to take such actions.

Previous Work by Suffolk County and Others on HABs

Suffolk County has been engaged in HAB research and management from the initial appearance of brown tide in 1985 in the Peconic Bays and Great South Bay.

Brown Tide Comprehensive Assessment and Management Plan

As part of Suffolk County's ongoing response to the "brown tide" problem, the Brown Tide Comprehensive Assessment and Management Program (BTCAMP) was initiated in 1988. The program's objectives were not only to research the causes and impacts of the brown tide, but to investigate more conventional water quality problems affecting local embayments so that corrective actions to minimize them could be identified and evaluated. The BTCAMP study concentrated on the Peconic Estuary System, although other marine waters where the brown tide had occurred, including Shinnecock Bay, Moriches Bay, and Great South Bay, were also occasionally examined.

The final management plan was supported by a comprehensive series of tasks including monitoring of the bays, assessment of the sources of pollutant loading to the bays (e.g., stormwater runoff, sewage treatment plants, groundwater inflow), analysis of land use in the area surrounding the bays, and computer modeling of water movement and quality in the bays.

BTCAMP found that although all algal growth requires nitrogen and phosphorus macronutrients, the brown tide is apparently not triggered specifically by them. The study suggested that the brown tide may have been caused by other factors including meteorological patterns and specific chemicals (organic nutrients, chelators, and certain metals), and recommended further laboratory and field research in these areas in addition to investigating factors related to brown tide subsidence (viruses, zooplankton grazing) and brown tide impacts on shellfish

Brown Tide Summit (1995)

After its initial and widespread appearance in the waters of eastern Long Island in 1985 and 1986, the brown tide occurred only sporadically in County waters for nearly a decade. However, in 1995 the bloom returned to Long Island with an intensity dwarfing that of recent years and approximating the conditions of the mid-1980's. In the intervening years, as blooms became less frequent and more localized, many hoped that the brown tide would not be a recurrent problem on Long Island. The 1995 resurgence dimmed these hopes and galvanized elected officials, resource managers, scientists, fishermen and environmental groups to search more deeply for the cause(s) of brown tide and for steps to prevent its future occurrence or to ameliorate/mitigate its effects.

The Brown Tide Summit on October 20-21 1995, sponsored by NYSG, was held to give direction to future research on the bloom. Specifically, its objectives were to summarize, then present, knowledge of the brown tide and to identify the research that would be necessary to answer the principal outstanding questions regarding the causes of brown tide and its environmental effects.

Brown Tide Work Plan and Brown Tide Research Initiative (1998)

At the Brown Tide Summit, commitments for Brown Tide research funding were made. The NOAA Coastal Ocean Program announced that $1.5 million, over three years, would be used for Brown Tide funding. Brookhaven National Lab (BNL) and the Suffolk County Executive announced the establishment of the Brown Tide Monitoring Network (discussed below), with $100,000 in Suffolk County funding and at least that much in matching funds from BNL.

As a result of the Summit, the Brown Tide Research Initiative ("BTRI") Committee was formed to prepare a Request for Proposals (RFP), review research proposals and assist in managing the NOAA Coastal Ocean Program funding. That Committee included representatives from NOAA, NYSG Grant, NYS Dept. of Environmental Conservation, the Suffolk County Executive, the U.S. Environmental Protection Agency (EPA)/PEP, a local government representative, a citizen representative and a South Shore Estuary Reserve (SSER) representative.

The BTRI Committee developed a detailed Brown Tide Work Plan based on the research recommendations identified at the Brown Tide Summit. The first three-year $1.5 million BTRI program (1996-1999) was developed to increase knowledge concerning brown tide by identifying the factors and understanding the processes that stimulate and sustain brown tide blooms.

Continued funding for BTRI in 1999-2001, as a $1.5 million three-year effort, came once again from NOAA's COP. NYSG produced a series of BTRI Newsletters detailing progress and findings from the various research projects funded under the program.

Peconic Estuary Program CCMP (2001)

In 2001, the Peconic Estuary Program, administered by Suffolk County and funded through EPA's National Estuary Program (NEP), adopted a blueprint to restore and protect the waters of the Peconic Bays in 2001 - the PEP's Comprehensive Conservation and Management Plan (CCMP). Brown tide and brown tide management are among the priority topics contained in the CCMP, which focuses on continued research to better understand the causes(s) of brown tide as well as the assessment of management options to control or minimize future brown tide blooms. The PEP CCMP will be revised for the first time in 2017-2018. In the 15 years since the plan's initial adoption, the HAB phenomenon has taken on a more complex aspect, with several additional HAB types other than brown tide afflicting the PEP waterbodies every year. It is anticipated that the revised CCMP will retain HABs as a priority issue looking forward, with focus shifting to other species, such as "rust tide" causing *Cochlodinium polykrikoides* and "red tide" causing *Alexandrium fundyense*, which have been more problematic over the last decade.

How Was This Plan Prepared?

The Suffolk County Department of Health Services (SCDHS) contracted with New York Sea Grant (NYSG) to prepare the document through a process of interaction and consultation with a number of groups: 1) a team of four HAB experts drawn from academic and governmental institutions from around the country ("Experts Working Group") who would ensure that the plan would be founded on the most current and complete understandings of the origins, processes and ecological impacts of HABs; 2) a project Advisory Group comprised of agency staff, NGOs and others knowledgeable about HABs and general marine and freshwater ecosystems on Long Island, including management options to conserve/restore ecosystem health and function and 3) a wider audience who participated in the initial HAB Symposium and then reviewed/commented on the final draft prepared by Sea Grant with the assistance of the Expert Working Group and the project Advisory Committee and 4) a small Steering Committee comprised of County (SCDHS and SCDED &P) staff provided NYSG with immediate project oversight as the work went along. Appendix B lists each of these groups.

The project kicked off with a public meeting organized by Suffolk County on 17 May 2016 at the Timber Point Country Club in Great River, New York followed by a daylong working session of the expert working group and invited attendees at Stony Brook University's School of Marine and Atmospheric Sciences. Attendees and agendas of these meetings are found in Appendix C.

As part of the contract, NYSG subcontracted with Drs. Christopher Gobler and Theresa Hattenrath-Lehmann of Stony Brook University's School of Marine and Atmospheric Sciences to prepare a Harmful Algal Bloom Synthesis Report, a historical summary of the HABs that have affected Suffolk County waters since the mid-20th century, the species involved, the ecological and socio-economic impacts of the bloom (if documented) and a description of the management efforts and response, if any. This report, found as Appendix A to this HAB Action Plan, builds upon an earlier draft

Harmful Algal Blooms (HABs)

What Is a HAB?

Microscopic floating algae or phytoplankton (unicellular plant-like organisms) constitute an important component of the biota of virtually all aquatic ecosystems, marine or freshwater. These organisms contain chlorophyll and most require sunlight to live and grow (Figure 1). Most phytoplankton are buoyant and are found in the upper layers of marine and freshwater systems, where sunlight penetrates the water. To grow, phytoplankton require key nutrients such as nitrogen, phosphorus, and silicate which they incorporate from the surrounding water. Phytoplankton provide food for a wide range of aquatic animals including fish, mollusks and jellyfish. In most aquatic ecosystems, phytoplankton form the base of the food chain, capturing the sun's energy, using it with water and nutrients to grow and proliferate, and then passing that energy up the food chain as they are consumed by higher trophic organisms.

Figure 1. Phytoplankton form the base of the food web in Long Island's many bays.

In normal circumstances, the phytoplankton community contains a mixed assemblage comprised of several or dozens of species. However, changes to an aquatic system may favor the growth and excessive proliferation of a single or only a very few species of microalgae. When such a bloom persists over large areas or for extended periods of times and/or reaches very high cell densities, the aquatic ecosystem can be significantly disturbed, with far-reaching consequences for other organisms linked directly or indirectly with the phytoplankton. Such a bloom is called a harmful algal bloom.

The most probable cause of this preferential growth involving one or a few closely-allied species is a change in the amount and/or chemical form of nutrients in the water. In most marine systems, the nutrient nitrogen (N) is suspected as a primary factor in triggering HABs. Different species of phytoplankton have unique preferences or abilities to use nitrogen in various amounts and in different chemical forms. In many instances, it is not simply a change in the nitrogen regime that triggers or kills a bloom. In most fresh water ecosystem, the element phosphorus is generally viewed as the limiting nutrient. However, as will be shown, there are exceptions to these general rules. Beyond the availability of nitrogen or phosphorus, other factors such as availability of other nutrients and trace metals, salinity, water temperature and ambient light levels also affect the growth and toxicity of phytoplankton species.

For the purposes of this plan, the definition of a Harmful Algal Bloom that is adopted by most HAB scientists and government agencies, and codified in the Harmful Algal Bloom and hypoxia Research and Control Amendments of 2004 (P.L. 113-124) is: *a small subset of algal species – including diatom, dinoflagellate and cyanobacterial blooms – that produce toxins or grow excessively, harming humans, other animals and the environment*. Under this definition, the simple presence of toxin-producing phytoplankton in a water body does not constitute a HAB. There must be a bloom (many/widespread cells) and the bloom must have a demonstrable effect on either the host aquatic system and/or humans. Detection of a toxin-producing algal species need not, in and of itself, trigger a management response. Such species may naturally inhabit Suffolk County surface waters but at low levels of abundance that pose little risk to the ecosystem or to humans, and may provide important information to collect and to have, but not necessarily to immediately act upon. Additionally, chemical toxins are not the only substances produced by phytoplankton that can produce human health effects. Some phytoplankton produce lipopolysaccharides that can have toxin-like effects on humans. This non-toxin related exposure is a driving force for the State Department of Health (DOH) bathing beach monitoring protocol focusing on visual assessments rather than toxin data. This protocol is consistent with DOH and DEC messaging to avoid exposure to anything that fits the visual description of a HAB, even if toxin levels are shown to be low.

Not all phytoplankton blooms are harmful. Phytoplankton communities typically go through an annual cycle of growth and senescence that, especially in temperate zones, is tied to seasonal variations in sunlight, water temperature and nutrient cycling/availability. This is a natural part of the functioning of these ecosystems. In contrast, HABs represent a departure from this normal community-wide cycling with clear negative consequences.

The above HAB definition refers solely to microscopic algae, “microalgae” and cyanobacteria. However, the excessive growth of larger types of algae (macroalgae or seaweed) can also cause ecosystem impacts and constitute a public nuisance because of aesthetic or odor-related problems. This has occurred on Long Island, in both western Suffolk and, especially, Nassau Counties. Waters experiencing macroalgae blooms typically have elevated nutrient loadings. On Long Island, persistent blooms of the green macroalga, *Ulva lactuca* (sea lettuce), have occurred in South Shore bays. When large amounts of sea lettuce are washed ashore and decompose in large windrows, the stench can propagate well away from the shoreline and become a public nuisance and aesthetic distraction. Ironically, macroalgae, when cultivated and subject to periodic controlled harvest can help reduce nutrient levels in coastal bays and to perhaps ameliorate or even forestall true microalgae-based HABs. For these reasons, the ambit of this HAB Action Plan encompasses the phenomenon of macroalgal blooms.

Why/How are HABs Harmful?

HABs can impact an aquatic system in a variety of negative ways.

Extremely dense algal blooms can dramatically reduce the penetration of light into surface waters, potentially compromising the health of other aquatic plants, especially rooted plants such as eelgrass (*Zostera marina*) inhabiting the bottom of local bays and estuaries, which serve as an important refuge from predators and nursery grounds for a wide variety of aquatic organisms. In some outbreaks of the brown tide (*Aureococcus anophagefferens*) in Suffolk County waters, light penetration was reduced to less than 0.3 meters. The reduction of ambient light levels in some bay waters is associated with the decline in eelgrass abundance in these areas. This rooted aquatic plant received insufficient light to maintain itself.

Many types of aquatic organisms feed on phytoplankton. Such organisms may find their feeding impaired during a HAB. Most filter feeding organisms (bivalve mollusks, planktivorous fish) have prey size preferences at which they are able to filter their food most efficiently. If, during a HAB event, the dominant phytoplankton is either smaller or larger than a predator's preferred size range, its feeding may be compromised. A HAB may be nutritionally inadequate and, thus, not support the growth of higher trophic levels. The brown tide organism appears to be a case in point. A HAB (such as *Cochlodinium*) may produce toxins that cause feeding to cease or outright kill filter feeders. If this persists over a sufficient period of time, the higher trophic levels may suffer. Additionally, some HAB organisms can also impact predators through direct physical damage to the gills and/or other tissues.

HABs can also interfere with attempts to restore depleted species to an ecosystem. For a number of years, The Nature Conservancy (TNC) attempted to "jump start" the recovery of the depleted hard clam population of Great South Bay through the establishment of several spawner sanctuaries stocked with adult clams on underwater lands it owns. While TNC achieved successful spawning and subsequent setting of juvenile clams, occasional HAB events (Brown Tide) in the Bay produced very high mortalities among the recently-set clams and no recovery of the population was achieved. While it still plants spawner clams in the Bay (roughly 250,000 annually), The Nature Conservancy has modified its restoration approach to focus on addressing the root causes of HAB's, in particular nitrogen pollution, while targeting in-water restoration efforts in areas of the Bay least affected by HAB's. One such area is in far eastern Great South Bay, the area apparently most affected by the breach/inlet created by Superstorm Sandy. Increased flushing of this area with ocean water caused by the breach has led to improved water quality and conditions (e.g. higher dissolved oxygen, salinity and clarity, lower temperatures) more favorable to the growth, reproduction and survival of hard clams and other molluscan shellfish.

HABs frequently produce a tremendous amount of dead and decaying algal biomass that sinks to the bottom waters. The respiration of microbes that degrade this organic material may be sufficient to materially reduce the concentration of dissolved oxygen in bottom waters to the point that it becomes insufficient to meet the requirements of fish and shellfish in the area. This is particular problem in the lower reaches of some of the tributaries to South Shore bays.

As mentioned, certain microalgae naturally produce harmful chemicals that are toxic to humans, wildlife and aquatic life. During HABs involving these species, these toxins can become widespread at harmful or potentially lethal concentrations and the toxins are often passed on to, or eventually bio-accumulated, in higher trophic levels. A relevant local example might be the wellpublicized death of a large number of diamondback terrapins in East End waters in mid-May 2015. The NYS Department of Environmental Conservation had recently closed shellfish harvesting in waters near where the dead turtles were found in Flanders Bay because of high levels of saxitoxin in shellfish meats. Diamondback terrapins eat mussels and mussels feed on phytoplankton. Subsequent analysis confirmed the presence of saxitoxin in the flesh of the dead turtles. The most frequently documented vector of human sickness/mortality associated with HABs is shellfish. Certain shell fishing areas on Long Island, for example Huntington/Northport Bay, have been subject to shell fishing closures because of the presence of toxins contained in shellfish sampled from that area.

HAB's also have a negative impact by prompting bathing beach closures, degrading coastal and aquatic aesthetics, and lowering property values.

What is the history of HABs in Suffolk County?

HABs have been documented on Long Island since the 1930's. It is entirely possible that they occurred well before this, but substantiated records of such occurrences are not available. **Appendix A** to this plan (*Historical Occurrence and Current Status of Harmful Algal Blooms in Suffolk County, NY,* USA) presents a comprehensive and detailed account of the history of HABs in Suffolk County/Long Island, including the timing and geographic extent of the bloom, the microalgal species involved, whatever is known about the causes of the bloom and what, if any, remedial or management response was taken to deal with the event and its possible consequences. Following the definition of a HAB described above, only those events involving a documented bloom with widely-noted, demonstrable impacts are included in this account.

Several classes of HABs have been present in Suffolk County surface waters over the years, but the trend appears to be one of an increasing species diversity and frequency (Figure 2). Prior to 2003, HABs were present only in the "small form" blooms and Brown Tide in the South Shore bays and the Brown Tide in the Peconic-Gardiners Bay Complex. Since 2003, a number of other HAB types have been occurred in County waters. In the brief account of Suffolk County HABs that follows, those HABs that present risks to public health are denoted with the following symbol - ☠. Note that HABs presenting a potential public health threat may also produce serious and damaging ecosystem impacts.

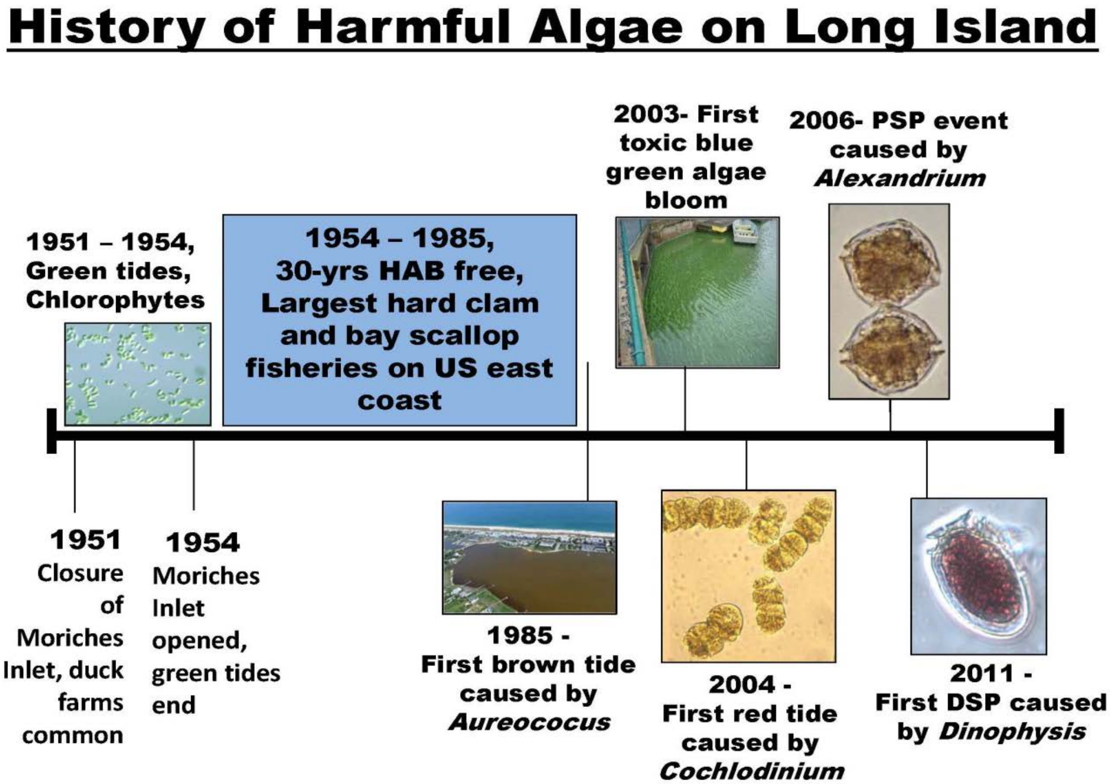


Figure 2. HAB Timeline

"Small Forms" Blooms

In 1930, oyster production in Great South Bay was in a precipitous decline from the industry's peak a decade earlier. Records maintained by the two principal oyster growers on the Bay, Bluepoints Company and Van Der Borgh & Sons, documented that the poor growth of seed oysters (usually imported from seed beds in Connecticut, although some seed came from Bellport Bay) was associated with the presence in Bay waters of dense blooms of small, green microalgae. From the early 1930's through the early 1950's, the waters of Great South Bay and, particularly, Moriches Bay and its tributaries, continued to periodically experience extremely high densities (5-10 million cells/ml) of these very small green algae (chlorophytes), primarily the genus *Nannochloris,* and a marine cyanobacterium, genus *Stichococcus* (Ryther, 1954). Termed "small forms", these blooms were often unusually persistent, developing in the spring and continuing through the following mid-winter. Relatively small algae, in fact, predominate in the normal phytoplankton community of many Long Island coastal bays, but a variety of types of algae are present in succession through the growing season.

Nannochloris and *Stichococcus* were too small (≈2 microns) to be effectively filtered by oysters and hard clams, the backbone of Long Island's shellfish industry. The meat quantity and quality of these shellfish deteriorated and they became unmarketable during "small forms" blooms. Commercial catches (landings) of clams and oysters declined. Clams and oysters grew poorly when faced with “small forms”; their mortality rates rose and their abundance declined. Through such events, the “small forms” blooms devastated the shellfish industry and shellfish populations along Long Island’s South Shore.

In the early 1950’s, researchers identified several likely causes from the proliferation of “small forms” blooms along Long island’s South Shore. The principal culprit appeared to be waste from the many duck farms that lined the tributaries of Moriches Bay and eastern Great South Bay. In the first half of the 20th Century, Long Island was a major producer of Pekin ducks, primarily for the restaurant trade. The Forge River, which drains into Moriches Bay, was the center of Long Island’s duck industry. Long Island ducks were routinely kept in large pens that extended into the shallow tributaries of the South Shore coastal bays (Figure 3). The bacterial degradation of duck wastes produced nitrogen, largely in the form of urea. Research showed that *Nannochloris* and *Stichococcus* were able to utilize urea nitrogen more readily than other phytoplankton. Additionally, in the 1940’s and early 1950’s, eastern Great South Bay and Moriches Bay were very poorly flushed, allowing very high levels of nitrogen to persist in shallow areas for prolonged periods. In 1951, Moriches Inlet actually closed, exacerbating the flushing problem. Moreover, these “small form” species were relatively euryhaline, able to grow well across a wide range of salinities, such as are often present over the course of a year in Long Island’s shallow South Shore embayments. Scientists studying the “small forms” blooms noted that the phenomenon was related not just to the quantitative loadings of nitrogenous wastes into local receiving waters, but also to concentration of these loadings to certain times of year. It was believed at the time that taking steps to distribute these loadings more evenly throughout the year would reduce the extent and severity of the “small forms” blooms.

Figure 3. Long Island duck farm (longislandgenealogy.com)

The small forms blooms proved to be a relatively transitory phenomenon. By the late 1950’s, environmental regulations were beginning to alter duck raising practices so that less waste entered local waters. The increased production costs that the growers incurred in complying with these regulations and changes in the global market for ducks led to fewer duck farms in Suffolk County and relatively fewer ducks on each farm. Lastly, Moriches Inlet was re-opened and stabilized at its present location in 1953 allowing for significant tidal exchange between the ocean and Moriches Bay and greatly increasing the flushing of the Bay.

Brown Tide

The brown tide is likely the HAB that is the most widely recognized by Suffolk County's general public (Figure 4). Brown tide first appeared on Long Island in May 1985, affecting Great South Bay, Moriches Bay, Shinnecock Bay and the Peconic Bays system. It dissipated by early fall. Severe blooms recurred in these same areas in 1986. Since the mid-1980's, brown tide blooms have been recorded periodically and, for the most part unpredictably, mainly in Great South Bay, the Peconic Bays (where the most recent incident was in 1995) and in Quantuck Bay, between Moriches and Shinnecock Bays. A severe brown tide occurred in eastern Moriches Bay, Quantuck Bay and Shinnecock Bay as recently as July 2016.

Figure 4. Brown Tide in eastern Moriches Bay, 2008. (Courtesy of Newsday)

The small pelagophyte *Aureococcus anophagefferens* causes brown tide in Long Island waters and along the US East Coast. A similar organism, *Aureoumbra lagunensis*, has caused extensive blooms off the Texas coast in the Gulf of Mexico and in the Indian River Lagoon in Florida. The geographic range of the brown tide organisms in North America is now known to extend from Texas coastal waters to at least as far north as the coast of New Hampshire and, over the past 30 years brown tide blooms have occurred in many areas along the U.S. East Coast, and as far afield as South African waters and off the coast of China.

When cell densities of brown tide reach 250,000 cells/ml, affected waters typically turn a murky brown. Brown tide has several documented ecosystem impacts. Research shows that cell densities of 35,000 cells/ml begin to impact the feeding and survival of shellfish, especially hard clams and bay scallops, with lesser impacts to oysters, mussels, and razor clams. The intense brown tides of 1985 and 1986 on Long Island effectively eliminated the economically important bay scallop as a fishery resource on the East End. Attempts to restore bay scallop populations through seeding have helped to recover some of this loss but the species remains far less abundant now than prior to the appearance of brown tide's appearance. A brown tide presents no known public health or safety risk.

During a major brown tide, light penetration into coastal waters is substantially reduced and bay bottoms are shaded, interfering with photosynthesis by rooted Submerged Aquatic Vegetation (SAV), on Long Island, mainly eelgrass, *Zostera marina (Figure 5)*. Eelgrass beds are a critical habitat for many marine species and the progressive loss of eelgrass beds from Long Island embayments presents a major ecosystem protection/restoration challenge.

Figure 5. Eelgrass beds on Long Island's east end. (Courtesy of Chris Pickerell, Cornell Cooperative Extension of Suffolk County)

There is some evidence that the turbid water typical of a brown tide may interfere with feeding of finfish that are sight feeders, especially as juveniles. Adult finfish appear to avoid brown tide-affected waters when possible.

In addition to the eventual economic consequences of these brown tide ecosystem impacts, the appearance of the water in a severe brown tide is enough to deter most forms of water-based recreation, such as boating and swimming, and other socio-economic sectors that depend on water and water quality, such as tourism and real estate markets.

Much research and monitoring on brown tide has been undertaken since it first appeared in 1985. Suffolk County has funded some of this research and, on Long island, virtually all of the monitoring activities. Notwithstanding these efforts, the cause(s) of brown tide remain somewhat uncertain. *Aureococcus anophagefferens* has been present in southern New England waters at least since 1982, and perhaps well before that (late 19^{th} century). But blooms sufficiently severe and widespread to attract public notice and attention began only in the mid-1980's. This suggests that something changed in the coastal ecosystem in the early 1980's that triggered the onset of brown tide.

Laboratory research suggests that inputs of conventional inorganic forms of nitrogen and phosphorus as nutrients do not directly trigger a brown tide. Rather, field studies suggest that the assimilation of nitrate and inorganic nutrients by other algae that is subsequently released into the water as organic nitrogen seems to stimulate brown tides because of the ability of *Aureococcus* to utilize organic nutrients for growth. Hence, the loading of inorganic nitrogen can be viewed as a key but *indirect* stimulant of brown tides. The availability of organic nitrogen compounds and/or the relative amounts of dissolved inorganic and organic nitrogen may play an important role. Other possible causes or contributing factors of Brown Tide include:

- The failure of potential grazers (zooplankton and/or molluscan shellfish) to keep brown tide in check
- Meteorological and climatological factors, e.g. reduced flushing due to a change in wind-induced subtidal sea level oscillation resulting in greater retention of land-derived nutrients
- Physio-chemical limits – salinities greater than 26 parts per thousand and temperatures between 20-25^{o} C appear associated with major blooms
- At low light levels (typical of coastal embayments, especially during a bloom) *Aureococcus* can use organic compounds for growth more effectively than competing phytoplankton species

The origin, duration and senescence of any particular brown tide bloom is likely driven by a combination of these factors.

Red Tide (Alexandrium fundyense Blooms)

Alexandrium fundyense is a dinoflagellate which produces a suite of potent neurotoxins called saxitoxins, the causative agent of Paralytic Shellfish Poisoning (PSP). PSP can move through the marine food web as herbivores graze *Alexandrium*, take up the toxin and pass it along to consumer organisms. They are acutely toxic to humans who ingest saxitoxin-contaminated shellfish. Shellfish can become toxic in the absence of a visible bloom of *Alexandrium*. Blooms of *Alexandrium* can lend the water a reddish tint giving rise to the colloquial name “red tide” for these blooms. However, this discoloration does not always occur and levels of toxins in shellfish consuming *Alexandrium* can rise to dangerous levels with no signs of a phytoplankton bloom being present.

While primarily of interest and concern because of its toxicity, *A. fundyense* has historically been an ecosystem disruptor along the east coast of North America mainly in the Canadian Maritime Provinces and the waters of New England. This species has recently been identified as also blooming on the US West Coast. *Alexandrium* in the form of resting cysts and actively growing cells has been found in numerous places on Long Island since the early 1980’s, mainly on the South Shore (it may have been present earlier but gone undetected). Over the period 2006-2015, however, frequency and distribution of *Alexandrium fundyense* blooms in Suffolk County appears to have increased, prompting the closures of many shellfishing areas in these years. One particular hotspot in this more recent era has been the Huntington Bay-Northport Harbor complex, where PSP-related shellfish closures occurred nearly every year from 2006 to 2012 (Figure 6). In 2008, bloom concentrations reach 1 million cells/L in Northport. After improvements were made in the amount of nitrogen removed from the effluent of the local sewage treatment plant whose outflow pipe debauched into the very southerly end of Northport Harbor, this area, which typically witnessed the most frequent high cell counts of *Alexandrium*, displayed much lower cell numbers (see below).

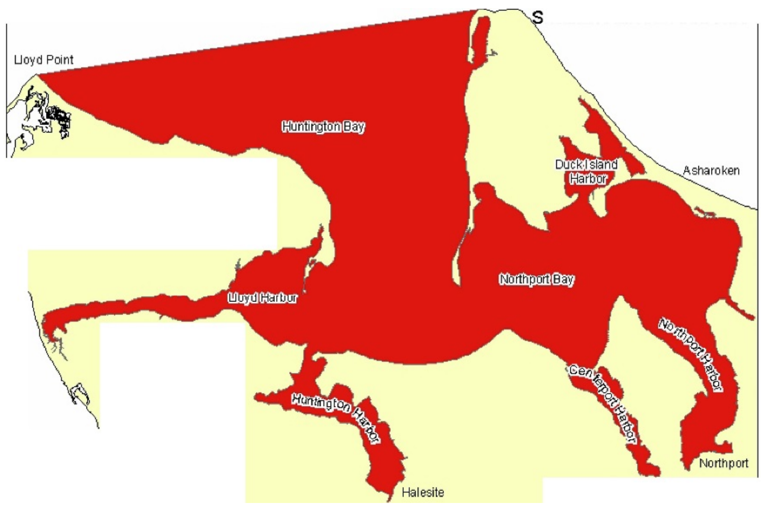


Figure 6. Areas of the Huntington/ Northport Bay complex shellfish bed closures: 2006,2008,2009,2011 (NYSDEC)

The toxic *Alexandrium tamarense* was detected in Reeves Bay and tributary creeks in 1986 and 1989, but it is possible that this was, in fact, *A. fundyense.* The taxonomy of this genera has evolved in the past several decades. The species was originally named *Gonyaulax tamarensis*, then *A. tamarensis*, and most recently *A. fundyense*.

Rust Tide (Cochlodinium polykrikoides Blooms)

Like *Alexandrium, Cochlodinium polykrikoides* is a photosynthetic dinoflagellate that produces a toxin that has been shown to be capable of causing major disruptions in coastal food webs. Species of the genus *Cochlodinium* have been shown to cause HABs in many areas of the globe (Asia, South America, North America, and Europe). Unlike *Alexandrium*, however, *Cochlodinium* is not a threat to human health. While its chemical structure is at present uncertain, this toxin is lethal to a wide variety of marine taxa, including other phytoplankton, zooplankton, and juvenile fish. This is a cosmopolitan species that is widespread in warm temperate and tropical waters. First identified in the Caribbean Sea, *C. polykrikoides* and the closely-related species *C. fulvescens* have been reported in a number of areas along the U.S. East and West Coasts and in Japan and Korea, where extensive blooms of this species have resulted in fishery losses worth many millions of dollars.

C. polykrikoides was first isolated from Long Island waters in 2002, during blooms in West Neck Bay on Shelter Island. Rust tide reappeared in the Peconic Bays system and eastern Shinnecock Bay in 2004 and 2005. The reddish brown tint of waters experiencing blooms of this species has led to its local moniker, "rust tide" (Figure 7). The Peconic Bays system and Shinnecock Bay have experienced rust tides of varying intensity and duration every year since its initial appearance. In 2011, rust tide appeared in Great South Bay for the first time and in 2016 its presence was confirmed in a number of North Shore bays, including Port Jefferson Harbor (Hattenrath-Lehmann, personal communication). *C. polykrikoides* tends to bloom from late summer though early fall

Experimental work performed by Dr. Chris Gobler and colleagues at SoMAS have demonstrated how highly toxic rust tides can be to other local marine organisms. Widespread mortalities of fish in pound nets and wild shellfish resources have been associated with some *C. polykrikoides* blooms in the Peconic estuary and in Shinnecock Bay.

The environmental causes of rust tides are not yet completely clear. Gobler and associates have found *C. polykrikoides* to be capable of assimilating a variety of nitrogen-containing compounds, which may confer a preferential advantage to this species in the early stages of bloom initiation. Once a bloom has developed, the suppressant effect of *C. polykrikoides* toxin on both competing phytoplankton and on potential grazing organisms is presumably a key factor in fueling and sustaining its dominance. The species is capable of forming resting cysts. These cysts may provide a mechanism by which the organism can over-winter in Suffolk County waters and to bloom in recurrent years in the same areas. Resting cysts may be transported from one area to another around Long Island's coast and serve as a vehicle for the further distribution of the species in local waters.

Figure 7. A 2016 toxic 'rust tide' in the Peconic Estuary. (photo courtesy of US Coast Guard Auxiliary)

Cyanobacteria (Blue-Green Algae) Blooms ☠

Cyanobacteria are photosynthetic bacteria. They are among the oldest organisms on Earth and have played a very significant role in the history of life on the planet, being largely responsible for the introduction of the oxygenated atmosphere, the formation of petroleum deposits and the evolution of plants. Often termed blue-green algae because of their color, cyanobacteria are not algae.

Cyanobacteria are found throughout the ocean and in freshwaters. During blooms in eutrophic waters, some species can produce cyanotoxins that can cause illness and death to animals, including humans. Exposure mechanisms for animals (pets, livestock, and wildlife) and humans include direct contact (swimming), ingestion (swallowing water) or inhalation of airborne droplets. Even non-toxin-producing cyanobacteria are capable of causing health effects, although the exact agent/mechanism remains poorly understood. Cyanotoxins can make municipal drinking water supplies suspect, such as occurred in Toledo, Ohio in 2014 when the southwestern end of Lake Erie experienced an unusually heavy "cyano-bloom" and public officials issued a "do not drink" advisory for the City's Lake-based public water supply. Cyanotoxins were detected in the treated drinking water drawn from Owasco Lake in New York's Finger Lakes region in 2016.

Intense cyanobacterial blooms often result in brightly discolored surface waters, paint-like swirls on the water surface and/or the appearance of floating and stranded scum lines (Figure 8). This is usually enough to ward off most humans, although there have been several documented instances in upstate New York of recreational contact irritation attributable to cyanotoxins. Among the HABs affecting Suffolk County, only cyanobacteria blooms involve potential human health risks arising from mere physical contact or water ingestion.

Animal pets and livestock are indifferent to visual cues that a cyano-bloom may be in progress and, sadly, there are many documented instances of pet/livestock deaths from contact with waters experiencing a cyanobacterial bloom.

Figure 8. Cyanobacteria blooms can negatively impact water quality and harm pets (photo SUNY ESF)

First documented in Lake Agawam in the Town of Southampton in 2003, Suffolk County cyanoHABs have been exclusively a fresh water phenomenon, with a number of small lakes and ponds being affected, including Lake Ronkonkoma, Agawam Lake, Mill Pond and Georgica Pond in the Town of Southampton, Maratooka Lake and Fort Pond in Montauk. For the past few years, SCDHS has been following an established a protocol when encountering cyanobacteria blooms (Figure 9). The liver toxin, microcystin, is the most commonly-occurring cyanobacterial toxin isolated from Suffolk County waters. Since 2012, cyanoHABs have been documented in 31 lakes and ponds in Suffolk County through a partnership between Stony Brook University, the Suffolk County Department of Health, and the NYS Department of Environmental Conservation. While in most instances measured toxin levels have been below the public health threshold for human recreational contact, there have been occurrences where this threshold has been exceeded. Over the period 2013-2016, cyanoHABs were reported to a State-maintained database in more lakes in Suffolk County, and more frequently, than in any other county in New York State.

Many species of cyanobacteria appear to thrive at elevated water temperatures. This may increase the frequency and/or severity of these cyanobacterial blooms in Suffolk County waters as water temperatures rise through global warming.

Dinophysis Blooms ☠

Another dinoflagellate genus identified with HABs is *Dinophysis*, an exclusively coastal and marine group. Several *Dinophysis* species, including the species found most frequently on Long Island, *Dinophysis acuminata,* produce the toxin okadaic acid and several toxic congeners. Ingested by humans, primarily through consumption of contaminated molluscan shellfish that have been feeding on the dinoflagellate (some finfish also ingest okadaic acid), okadaic acid causes Diarrhetic Shellfish Poisoning (DSP) with symptoms of severe diarrhea, abdominal cramps and nausea. *Dinophysis sp.* have been responsible for shellfish closures in many areas, including Europe, the West Coast of North America, Texas and eastern Pacific waters (Washington State). Recently, *D. acuminata* has been found in bloom concentrations on Long Island, primarily in Northport Harbor. Earlier work in the 1970's had found that the species then comprised a significant fraction of the phytoplankton in Block Island Sound and Tobaccolot, Napeague and Fort Pond Bays on Long Island's South Fork.

From 2008-2011, Dr. Theresa Hattenrath-Lehmann and colleagues at SoMAS documented annual blooms of *D. acuminata* in the Huntington-Northport Bay & Harbor complex on the North Shore of Long Island. The sampling was most frequent and spatially intense in the inmost reaches of *Northport Harbor. Bloom densities typically averaged 10^4-10^6cells/L; densities greater than a million cells/L were seen in 2011, the year of the most severe bloom. Coincident with the blooming of *D. acuminata* over this period in this area were seasonal blooms of *Alexandrium sp.* (see above). These *Alexandrium* blooms resulted in shellfish and carnivorous gastropod harvest closures maintained until sampling indicated that the bloom had terminated. Assays of shellfish tissues from bloom-affected areas revealed DSP toxin concentrations nearly 10x higher than the U.S. Food & Drug Administration's action level, the first such occurrence on the U.S. East Coast.

**Note: Northport Harbor is closed to the harvest of shellfish year-round due to fecal coliform levels and the presence of the Northport Village's wastewater treatment plant.*

Dinophysis acuminata is an obligate mixotrophic species requiring the consumption of its prey

Mesodinium rubrum from which it steals and utilizes plastids (organelles within algal cells that produce and store food). This complicates deciphering the likely cause(s) of the *D. acuminata* blooms in Northport. The interplay of nutrients, trophic interactions and perhaps water movement and hydrodynamic forces needs to be explicated before the ultimate drivers are delineated.

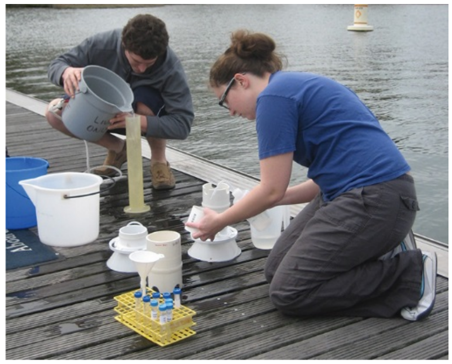
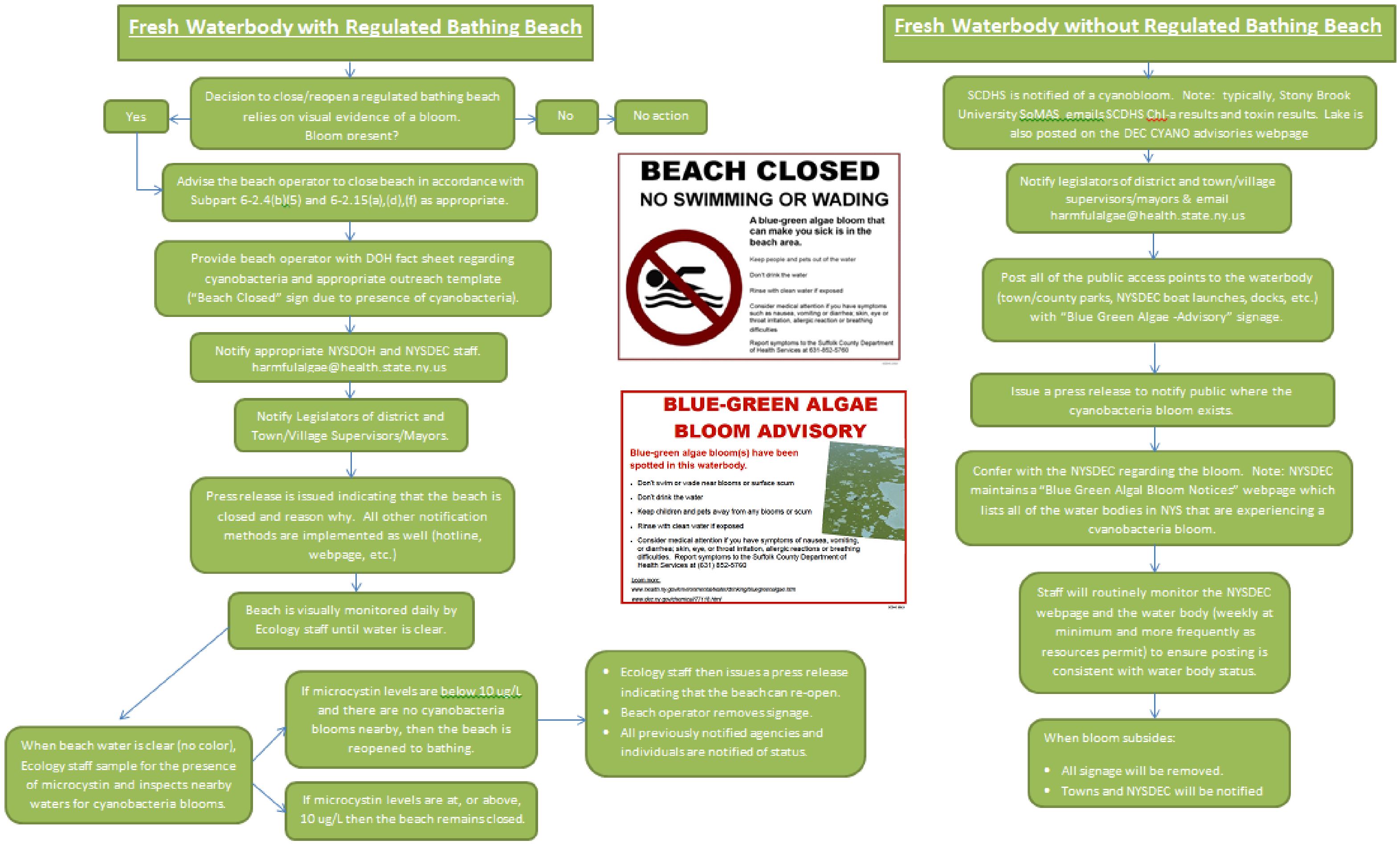


Figure 10. Dr. Theresa Hattenrath-Lehmann and grad student Ryan Wallace of SoMAS processing water samples for the presence of toxin-producing HABs in Northport Harbor (Photo courtesy of T. Hattenrath-Lehmann*)*

SCDHS Public Health Protocols when encountering Cyanobacteria Blooms *

(The following guidance was developed in coordination with NYSDOH-Bureau of Community Environmental Health and Food Protection (BCEHFP)



* Cyanobacteria monitored by SCDHS (visual and Abraxis test kit for microcystin) at bathing beach and by Stony Brook University SoMAS under contract with NYDEC for other areas.

Figure 9. SCDHS Protocol When Encountering Cyanobacteria Blooms in Suffolk County

Mahogany Tide (Prorocentrum minimum Bloom)

The toxic dinoflagellate *Prorocentrum minimum* was first detected in Long Island waters in the 1970's, although not in bloom-level concentrations. *P. minimum* is a dinoflagellate that is toxic to marine organisms but not, apparently, to humans. Intense blooms of this, or any, phytoplankton species can have ecosystem effects apart from any toxic metabolites they might produce. Very intense blooms can result in very low nighttime dissolved oxygen levels caused by the respiration of billions of individual algal cells. In areas where the waters are warm and/or circulation is sluggish, the levels can fall to near zero and trigger massive fish kills. This apparently occurred in 2015 in the Peconic River. Blooms featuring this species are locally known as "mahogany tides" from the distinctive hue taken on by the water during these events.

Historically, mahogany tide has commonly been observed in tributaries across Long Island's south shore during spring months. A widespread mahogany tide occurred in Suffolk County waters in late May – early June 2016 (Figure 10). Affected waters included Great South Bay, western Shinnecock Bay, Georgica Pond in East Hampton, and the Peconic River.

Researchers at the University of Maryland have concluded from a review of the literature on *P. minimum* that, "…this harmful algal bloom species is associated with regions of high dissolved inorganic nitrogen (DIN) and phosphorus (DIP) exports that are strongly influenced by anthropogenic (man-made) sources…". This observation is consistent with the known high nitrogen loading rates from household cesspools to the south shore bays of Long Island recently documented by Suffolk County, Stony Brook University, and other scientists.

Figure 11. A mahogany tide in May 2016 affected South Shore bay waters from Babylon to East Hampton. Insert: the cause of mahogany tide, the dinoflagellate, Prorocentrum minimum.

Macroalgae (Seaweed) Blooms

Seaweeds species such as *Ulva latuca* (sea lettuce) and *Cladophora* are widespread and abundant in Suffolk County, especially in the South Shore bays. In shallow and well-flushed high-light, high-nutrient environments, these species can grow very abundantly and can shade out or smother seagrass (*Zostera marina*) and other valuable benthic habitats. Recent research indicates that excessive macroalgal growth can harm calcifying molluscan shellfish and some crustaceans. When large windrows of decaying macroalgal biomass was ashore, its decomposition is both unsightly and odorous, which can interfere with coastal recreational activities.

While microalgae can itself be a HAB, research has shown that some seaweed species produce a chemical metabolite or exudate that can interfere with the ability of microalgal HABs to bloom. Work by Gobler and others at SoMAS has shown that at least some macroalgae native to Suffolk County can have this effect on microalgal HAB species that are also present in County waters. Additionally, when cultured en masse, many macroalgal species have the ability to extract a substantial amount nitrogen from the water column, potentially limiting some of the fuel necessary for a microalgal HAB species to bloom.

Other HABs

The above descriptions highlight the phytoplankton blooms in Suffolk County since the late 1940's that have met the generally accepted threshold to qualify as Harmful Algal Blooms: 1) reasonably widespread and/or persistent with 2) demonstrable impacts either to the ecosystem or to human interests (e.g., recreation closures, shellfish closures, incidence of disease/mortality, etc.), and 3) documented in the published scientific literature. Over this same period, however, there have been other more transitory or isolated events where blooms have occurred and/or toxin-producing phytoplankton have been identified from Suffolk County waters that have not risen to this standard. Some examples include:

- The toxic dinoflagellate *Gyrodinium aureolum* isolated from the Carmans River in 1981
- *Mesodinium rubrum*, a red tide-causing ciliate, resulted in closure of a stretch of Robert Moses State Park in 1999; *M. rubrum* is the only known food source for the obligate mixotrophic dinoflagellate *Dinophysis*
- *Heterosigma akashiwo*, a red tide-forming raphidophyte found in the Grand Canal off the Connetquot River in 2004

Additional documented occurrences of potential HAB's have occurred in the last 15 years in the Peconic River and tributaries and in Old Fort Pond off Shinnecock Bay.

The occurrence of both the major bloom events and these ephemeral, more isolated instances where potential bloom-forming and/or toxin-producing phytoplankton have been detected on Long Island reinforces the concept that the phytoplankton community of Suffolk County waters is not fixed and unchanging. Species can come and go from the area based on the movement of water masses, or can be present chronically but below bloom-forming concentrations.

Environmental conditions in the County's bays and embayments changes over time, favoring one species or group of species over another based on a range of requirements or preferences. Moreover, some HAB species can form resting spores or cysts that can remain resident but dormant in bottom sediments until favorable environmental conditions prompt them to excyst, transform to a vegetative state, and bloom. Some species are capable of a period of dormancy lasting many decades. Ongoing monitoring of the phytoplankton community is required if incipient changes in this community that might herald negative ecosystem impacts or pose threats to human health and/or impacts to human use of coastal waters are to be detected and appropriate management responses taken.

An Emerging HAB and Potential Public Health Threat – Pseudo-nitzschia?

It is possible for HAB species to be transported considerable distances as a result a result of water mass movement and mixing processes. This requires that County and State officials be cognizant of HABs occurring in neighboring states. In late September 2016, the Interstate Shellfish Sanitation Conference (ISSC) advised member states of a shellfish recall implemented by Maine' shellfish regulatory agency due to the presence of a marine biotoxin (domoic acid) in clams and mussels. Domoic acid is a potent neurotoxin that can cause amnesiac shellfish poisoning (ASP) in shellfish consumers. It is produced by the marine diatom *Pseudo-nitzschia*, a cosmopolitan genus which Maine's Department of Marine Resources (DMR) had detected at very high levels in their near-shore waters. In early October, Maine closed large stretches of their coastal waters to the harvest of shellfish to protect public health.

During the next few weeks in October and November, the shellfish regulatory agencies in Rhode Island and Massachusetts also observed high levels of *Pseudo-nitzschia* in their coastal waters and detected elevated levels of domoic acid in shellfish. On October 7, Rhode Island closed all of Narragansett Bay to shellfishing. On October 11, Massachusetts closed all their areas south of Cape Cod to shellfishing. ISSC sent out additional email notifications to advise other states about the closures.

After receiving the notifications from ISSC, NYSDEC-Bureau of Shellfisheries staff communicated regularly with staff in the shellfish programs in Massachusetts, Rhode Island and Connecticut through October. Connecticut's shellfish program staff agreed to collect plankton samples at Fishers Island, New York on October 11. Their shellfish laboratory screened the samples for the presence of *Pseudo-nitzschia,* which they found at low levels. DEC-Bureau of Shellfisheries staff also notified the commercial oyster grower on Fishers Island to advise them of the situation and provided them with regular updates about the situation in Rhode Island and Massachusetts.
On October 17, DEC-Shellfisheries staff also collected three (3) plankton samples along the north shore of Fishers Island and one (1) sample of oysters provided by the commercial oyster grower to test for the presence of domoic acid. DEC's microbiology lab did observe *Pseudo-nitzschia* in the plankton samples, but the levels were much lower than was being reported by Rhode Island and Massachusetts. The oysters tested negative for the presence of domoic acid. No shellfish closures were implemented in New York.

Maine, Massachusetts and Rhode Island lifted their shellfish closures during the last week of

October. All three states said that the levels of *Pseudo-nitzschia* in September and October were higher than they had previously observed in their waters.

Most recently, NYSDEC was advised on Friday, September 15, 2017 that Maine's DMR had initiated a recall of mussels harvested in several areas due to Pseudo-nitzschia in the water.

Although this HAB has not been reported in Suffolk County waters, it may be an emerging issue that will require monitoring and appropriate coordinated actions by Suffolk County and DEC to protect the public health of shellfish consumers. Do the recent events in southern New England suggest an incipient problem with *Pseudo-nitzschia* in New York waters? Not necessarily, but they do strongly reinforce the notion that a comprehensive HAB management approach for County waters must incorporate a regional awareness.

Nutrients and HABs: Too Much of a Good Thing

The diversity, frequency and severity of HABs in Suffolk County's waters appear to be increasing, mirroring a nationwide and global trend. There are likely several forces at work that would produce this trend, **but excess inputs of nitrogen, phosphorous, or in some instances both, and/or an alteration in the chemical species of nutrient most available for phytoplankton growth is recognized as the single most important factor.**

When humans extensively develop and modify the watershed of an aquatic system, that system not surprisingly changes. One of the most common consequences of watershed development is a dramatic increase in the amount of nitrogen entering the system. Nitrogen plays a pivotal role in the functioning of aquatic systems and is especially important in marine/estuarine waters. However, excessive anthropogenic nitrogen inputs produce negative consequences. In aquatic ecosystems, nitrogen (and phosphorus) act as fertilizers leading to eutrophication, an increase in the rate of supply of organic matter/plant biomass in an ecosystem. This eutrophication includes increased noxious aquatic plant growth and harmful algal blooms.

Harmful algal blooms in U.S. coastal waters result in a negative economic impact estimated at $82 million annually, with the majority of impacts in the public health, tourism and commercial fisheries sectors. Eutrophication can also lead to hypoxia, or low dissolved oxygen concentrations, leading to fish kills and decreasing biodiversity. Adverse impacts from nitrogen and phosphorus pollution occur in 65% of the nation's major estuaries and there are 166 coastal hypoxic dead zones in the U.S. Additional consequences of nutrient-induced eutrophication include the degradation and inhibition of ecologically valuable marsh areas and seagrass beds. At present, the waters of all three major estuarine areas of Suffolk County - - Long Island Sound, the Peconic-Gardiners Bays Complex and the South Shore Estuary Reserve - - have significant water quality and/or human use impairments attributable to anthropogenic nutrient-derived eutrophication.

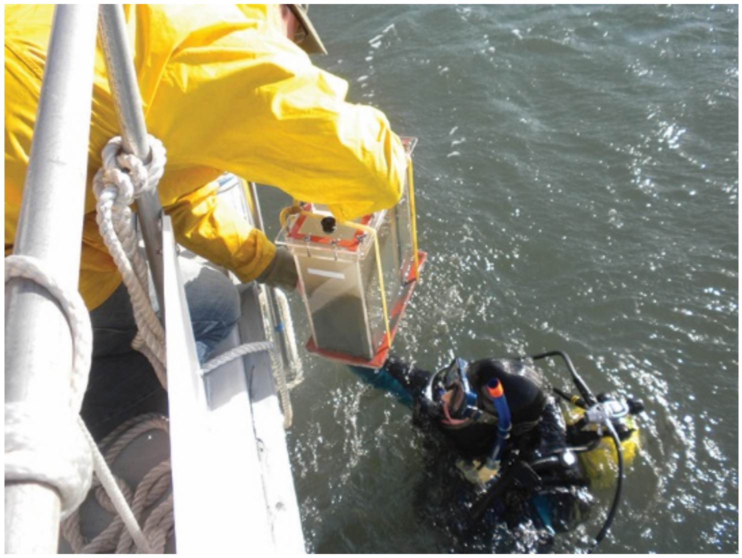


Figure 12. Graduate student Stuart Waugh hands up a box corer during a study of nutrient cycling in Peconic Bay.

In the case of HABs, a general consensus exists that the most effective single action that can be taken to reduce the frequency and severity of HABs in most areas is to limit/reduce excess (human-derived) nitrogen inputs or loadings. This is particularly true for blooms of marine species. This is not to suggest that the only or even the principal, causative factor in all instances is the absolute mass of N loadings into an estuarine system. Other factors do play a role in the global rise in HABs - - changes in nutrient regimes (the composition and relative availability of nutrient pools), alteration of food webs by overfishing, introduction of nonindigenous species, interruptions in grazing on phytoplankton by zooplankton and other organisms and modifications to water flow and flushing regimes can also lead to more frequent and/or severe HABs. The point is that the ability of environmental management to intervene with strategies specifically targeted at some of these other, more nuanced, causes is more limited than is the ability to reduce anthropogenic N loadings. A pre-emptive approach to marine HAB management should have N loadings management at its core. To the extent that local circumstances, knowledge and capabilities allow, additional elements to the plan may be designed and implemented.

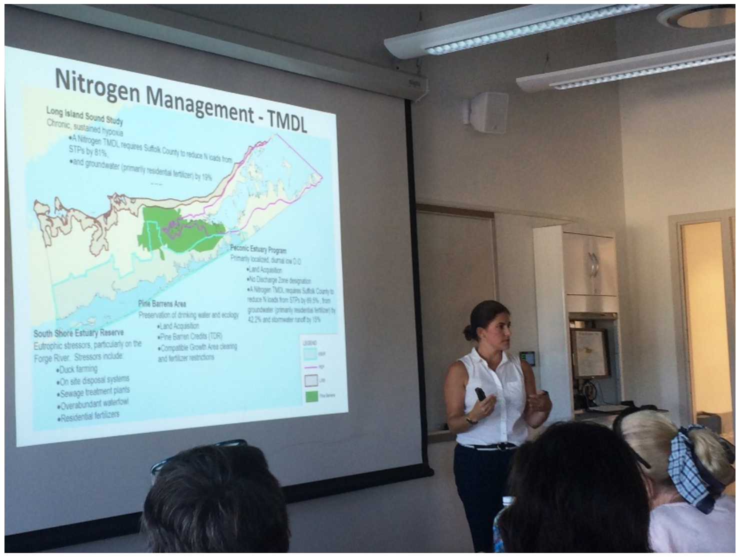


Figure 13. Dr. Alison Branco, Director of the Peconic Estuary Program, explains nitrogen management for several Suffolk County watersheds before a group of concerned citizens, August 2016.

It is important to note that climate variability will affect important parameters and processes that influence HABs—temperature, degree of water column stratification, upwelling and ocean circulation patterns, precipitation patterns and the volume and pattern of nutrient inputs. While the precise impacts of climate variability-related effects on the severity and frequency of HABs in Long Island's surface waters is difficult to predict, most experts feel that the overall effect will make the problem worse. While the impact of climate variability on Suffolk County's surface waters and aquatic ecosystems is largely beyond the County's control, the volume and distribution of nutrient loads to surface waters can be directly affected by County actions. The County needs to take such actions based on the strongest possible scientific linkages between nutrient inputs and what is known about how these predispose or actually trigger HAB's in these waters.

In most coastal waters, the cycling of phosphorus is rapid and it is generally not viewed as the nutrient limiting phytoplankton growth. That limit is typically the amount and relative proportions of different forms of nitrogen. Phosphorus is typically viewed as the primary limiting nutrient in freshwater systems. However, these are general rules that do not always apply. In Long Island marine waters experiencing very high nitrogen levels, research suggests that phosphorus levels could also limit the occurrence of brown tides in certain situations. Similarly, cyanobacteria productivity in certain freshwater ponds in the County appears to be nitrogen-limited. Any nutrient limitation and management program undertaken by the County to counter HAB's should target nitrogen and phosphorus.

Nutrient control or limitation will not forestall future HABs entirely and it may have a relatively greater impact on some HABs than others. However, no other management measure is likely to have as broad a positive impact on the frequency and severity of HABs in Suffolk County waters.
It is important for elected officials and the citizens of Suffolk County to understand that improvements to surface water quality, including a reduced likelihood of a HAB, will not be

achieved immediately with decreasing the nitrogen input to groundwater. The horizontal movement of groundwater to the County's fresh and coastal surface waters is a relatively slow, though it varies spatially. The most immediate benefits will accrue from nitrogen input reductions to groundwater in locations close to the shoreline. For example, reducing groundwater nitrogen loadings at a site four miles from a bay may not produce reduced nitrogen inputs to that waterbody for 20-30 years. Obviously, reductions in nitrogen discharges directly into surface waters, as from an effluent pipe, are capable of producing much quicker responses.

Sources of Anthropogenic Nitrogen to Suffolk County Waters

Anthropogenic nutrients (for coastal waters, nitrogen) are defined as those nutrients arising from human development of and activities in the watershed. For many coastal waters around the U.S., inputs of anthropogenic nutrients equal or well exceed the natural input that were characteristic of the pre-development watershed. For example, anthropogenic nutrients entering Long Island Sound in the 1990's were estimated to approximately equal the natural inputs.

Each sizable waterbody will have a distinctive mix of anthropogenic nitrogen sources. For example, the estimated mix for the Great South Bay / Peconic Estuary watersheds is the following:

- septic and cesspools: 69% / 43%
- atmospheric deposition: 21% / 24%
- residential lawns/fertilizers: 7% / 6%
- agricultural runoff : 1% / 17%
- sewage treatment plants: 1% / 6%
- golf courses: 1% / 4%

Although groundwater travel times vary from subwatershed to subwatershed, it is generally very slow. Therefore, only a portion of the freshwater currently flowing into Great South Bay is "young" enough to have been affected by present land uses and their associated nitrogen sources. Nonetheless, this suggests that these (and past) anthropogenic sources may play a disproportionate role in nitrogen-related impairments within the Bay. Further, it indicates that the portion of inflow affected by anthropogenic nitrogen will increase in the future, lacking some intervention to control nitrogen sources.

The overwhelming importance of **individual on-site septic systems and cesspools** as a source of additional and harmful nitrogen to Great South Bay is clear. The Peconic Estuary has a different mix of nitrogen sources but a similarly slow rate of groundwater inflow. The relative importance of individual septic systems and cesspools is also large in that system; it is the largest single source of nitrogen in 25 out of 43 subwatersheds examined.

These apportionments do not include a potentially large reservoir of nitrogenous organic materials that entered the County's coastal waters in past years and have become sequestered in the bottom sediments of bay tributaries. The amount, significance and potential mobility/availability of these so-called, "legacy" materials are unknown. The short lengths and very low relief characteristic of Long Island's coastal streams would seem to minimize the risk of physical resuspension and transport bayward of these sediments. However, a number of the HABs that have occurred in County waters appear to be usually confined to the very nearshore areas of the bays and, especially, the streams and creeks tributary to these bays. These areas are often characterized by long water residence times and low rates of flushing, giving nutrients a greater opportunity to affect phytoplankton assemblages. The role of these legacy sediment nutrients in bloom dynamics in these areas should be investigated.

Controlling Nitrogen in Suffolk County

There is broad recognition throughout the United States that anthropogenic nitrogen inputs to coastal waters needs to be controlled. Many of the National Estuary Programs have this as one of their principal management objectives, if not the principal one, including the Peconic Estuary Program and the Long Island Sound Study and it commands the attention of virtually every federal agency involved in water quality and natural resources management. On Long Island, leadership on the issue has come from Suffolk County, New York State and the federal NEPs, with the active promotion and involvement of a wide variety of citizens and environmental groups and non-governmental organizations (NGOs) such as The Nature Conservancy.

SCDHS Comprehensive Water Resources Management Plan

The current version of Suffolk County's Water Resources Management Plan (2015) highlights two pressing concerns about nitrogen. First and foremost is the public health concern raised by the increase in nitrogen levels in the subsurface aquifers, which provide County residents with their drinking water. Suffolk County relies exclusively on groundwater for its drinking water. High nitrate levels in drinking water can interfere with the ability of hemoglobin in human blood to carry oxygen throughout the body. This effect is especially significant in infants and is the source of "blue baby syndrome/disease". In addition to nitrogen, the Plan highlights volatile organic chemicals, pesticides and personal care/pharmaceutical products that are increasingly found in drinking water supplies. Beyond the concerns about nitrogen and other contaminants in drinking water, the report recognizes that excess nitrogen entering the County's surface waters is having a clear and negative impact on coastal ecosystems and preventive, proactive measures are required to protect against further degradation and begin to recover the quality of resources that have been impaired.

Under Suffolk County Executive Steven Bellone's Reclaim Our Water Initiative and the Long Island Nitrogen Action Plan (LINAP), SCDHS is preparing a SWP that will set nitrogen load reduction goals based upon the need to achieve water quality and ecological improvements within the County's priority water resources.

Initial efforts will concentrate on the establishment of a uniform and consistent set of subwatershed boundaries for approximately 189 surface water bodies and >800 public supply wells, development of surface water residence times and the generation of nitrogen loading rates through groundwater land use based nitrogen fate and transport modeling. The modeling results will be keyed to baseline water quality for each receiving body and public and supply well and will be used to establish tiered priority areas for wastewater management upgrades.

Following the establishment of tiered priority areas, preliminary load reduction goals will be developed using empirical data relationships, existing regulatory target guidelines, and other readily available data sources from related studies. Initial recommendations for wastewater management upgrades will be provided for each priority tier based upon the ability to meet nitrogen load reduction goals. Other nitrogen loads will be considered, along with reduction goal assumptions, but the focus will be on nitrogen load reductions from individual onsite septic systems and cesspools. LINAP will further consider these loads and reductions, and will expand on alternate available management measures such as permeable reactive barriers and in-water aquaculture.

The SWP is considered an early action/initial step of the overall long-term LINAP program. In addition to being a guide for establishing County wastewater policy, the primary objective of the SWP will be to provide critical information regarding data gaps, areas requiring further detailed study, and ultimately to provide data that can support long-term LINAP scope refinement and focus and other related initiatives ongoing throughout Suffolk County (e.g., LISS, PEP, SSER, and related Town/Village initiatives). In alignment with these objectives, the SWP will be executed on an accelerated timetable and will not include the generation of new, sophisticated models that are typically used for Total Maximum Daily Load (TMDL) studies.

A draft concept priority area map prepared by SCDHS for the first SWP public stakeholder meeting is provided below (Figure 14). The map also depicts HAB "hotspots", areas where different HAB types have shown a propensity to bloom, superimposed on coastal areas with escalating degrees of priority for individual septic system upgrades.

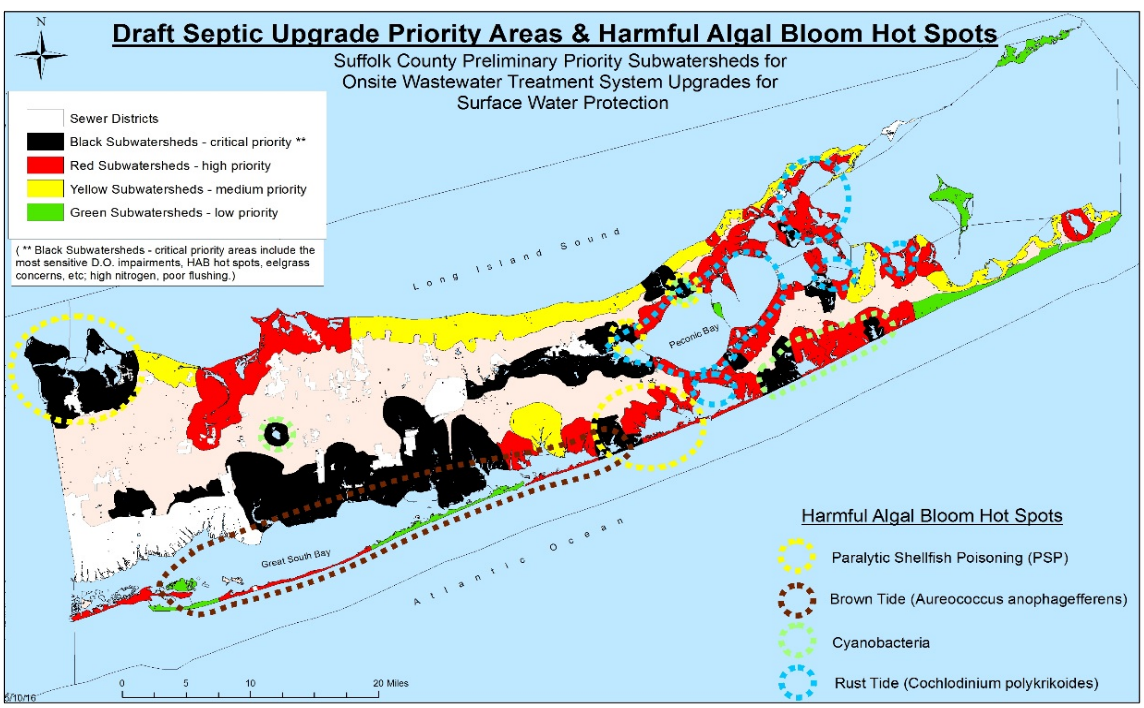


Figure 14. HAB "hotspots" and septic system upgrade areas (courtesy SCDHS)

In addition to the planning efforts of the SCDHS, the SSER and its governing council, the Long Island Sound Study and the PEP have identified nitrogen management as a key management objective for Long Island's South Shore Bays, the Long Island Sound North Shore embayments and the Peconic-Gardiners Bay Complex.

Long Island Nitrogen Action Plan

In 2015, New York State appropriated $5 million to develop LINAP (Figure 15), a NYSDEC and Long Island Regional Planning Council (LIRPC) initiative partnered and in consultation with the Indian Nations, numerous local governments, and interested organizations on Long Island. The objective of the LINAP is to determine nitrogen load reduction targets, as well as alternatives and strategies to meet those targets, for the restoration and protection of Long Island's invaluable water resources.

LINAP will be completed in two general project timeframes. Early Action LINAP will be developed to address common issues and near term management strategies that would be appropriate for implementation and can reasonably expected to be completed over the next 12 to 18 months. This will include, but may not be limited to, assembling available studies and data, sub-watershed delineation, development of nitrogen loading estimates, characterization of waterbody residence times, identification of tiered priority areas, estimation of preliminary load reductions for surface waters, evaluation of and development of load reduction goals for public water supply wells, review of wastewater alternatives and preparation of a draft wastewater plan. Additional considerations for Early Action LINAP include, where feasible, development of wastewater reuse regulations, fertilizer control recommendations, a nitrogen smart communities program, map based planning tools and display tools, countywide wastewater management district analysis, wastewater treatment plant potential analysis, existing wastewater treatment plant performance assessment, agricultural best management practices recommendations, simple/broad land use planning recommendations, simple/broad wetland restoration recommendations, simple/broad green infrastructure recommendations, and simple hydro-modifications.

Full Term LINAP will be used to address those issues not completed under Early Action LINAP. Full Term LINAP will include prioritization of sub-watersheds within each study area, for sub-watershed plans including more rigorous waterbody assessment and modeling, refined load reduction targets, and refined alternatives for load reduction. Additional considerations for Full Term LINAP include full development of financing options, a long term ambient monitoring program, updates to the Long Island 208 plan, ecosystem based management recommendations, and recommendations for more involved hydro-modifications based on hydrodynamic modeling.

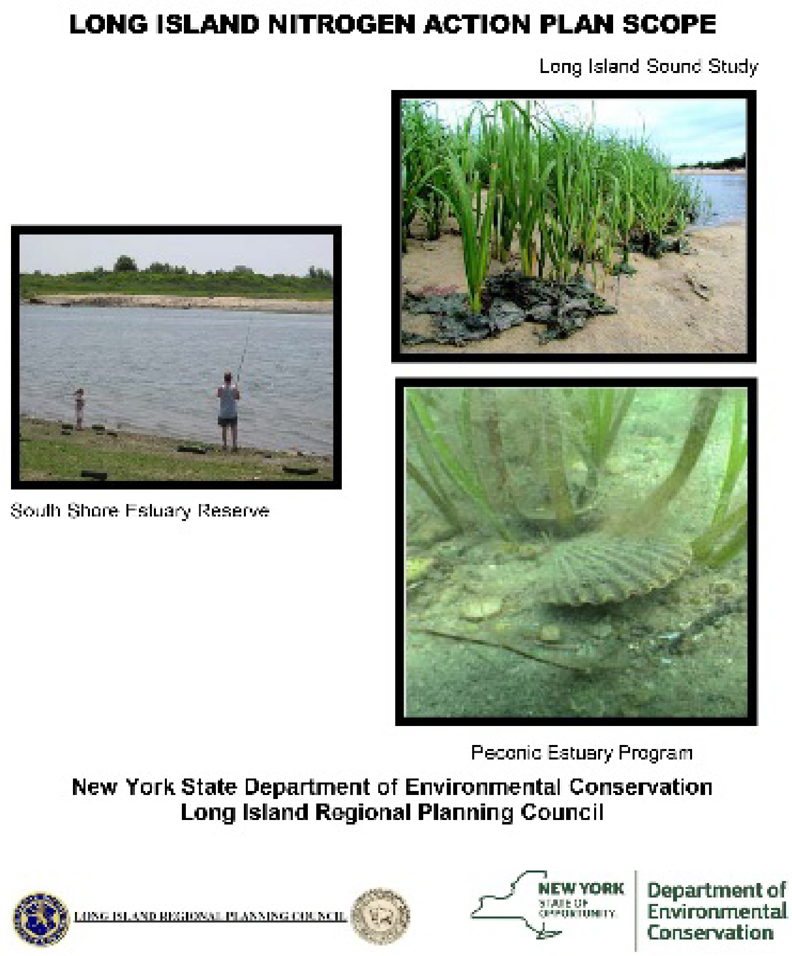


Figure 15. The Long Island Nitrogen Action Plan will assess groundwater quality/quantity, and surface water quality, and develop nitrogen load reduction targets and strategies to meet those targets.

EPA Long Island Sound Study Nitrogen Reduction Strategy

In 2000, the States of Connecticut and New York adopted the LIS Total Maximum Daily Load (TMDL) which allocated a 58.5% reduction to sources of anthropogenic nitrogen, with the bulk (90%) of the TMDL directed at point sources of nitrogen. Substantial N reductions have subsequently been achieved, but modeling and monitoring indicate that current measures will not fully implement the TMDL and water quality standard in Long Island Sound will not be met without further reductions. In part as a result, EPA and the states are moving to establish N concentration or loadings rate thresholds and applying these to the embayments that ring the main stem of Long Island Sound. Nitrogen inputs to these embayments would be source-apportioned and allocations would be apportioned to watershed sources as needed to remain within the threshold. One ecosystem endpoint associated with this initiative is the restoration of eelgrass (*Zostera marina*) beds that were once found in some of these embayments. Watersheds that once held eelgrass and in which point sources are present which, if abated, might lead to eelgrass recovery would be priority targets.

Management Actions Can Successfully Reduce Nutrient Inputs

Management interventions and actions to reduce nutrient inputs and restore ecosystem health and function do work. Below are examples from Long Island and elsewhere.

<u>Example 1: Long Island Sound Study and Hypoxia</u>

As noted, by the mid-1980's, annual nutrient inputs to Long Island Sound were estimated to be roughly twice the pre-development level. The Sound was showing clear signs of eutrophication. The waters of the western Sound were annually experiencing severe and widespread summertime hypoxia and, in some places, anoxia. These conditions were producing substantial fishery resource losses and physical dislocations as animals moved out of hypoxic areas into less affected more eastern parts of the Sound.

In an effort to restore the health of the Sound, EPA, New York and Connecticut formed the Long Island Sound Study in 1985, a bi-state partnership consisting of federal and state agencies, user groups, concerned organizations, and individuals dedicated to restoring and protecting the Sound. A principal goal was to reduce the incidence and severity of summertime hypoxia in the Sound, primarily through a program of establishing anthropogenic nitrogen reduction targets, largely point source reductions from New York City Waste Water Treatment Plants (WWTPs), and then taking steps to meet them. Now, nearly 20 years later, the anthropogenic nitrogen load to Long Island Sound has been reduced by roughly 40 million pounds each year (a 50% reduction and 95% of the TMDL waste-load allocation) and there has been a moderation in the severity of hypoxia (Figure 16). While there remains considerable inter-annual variability and it is possible that an important component of the reduction in hypoxic area has been brought on by meteorological forcing, the area-days index of hypoxia is now well below that when the N reduction targets were first formulated.

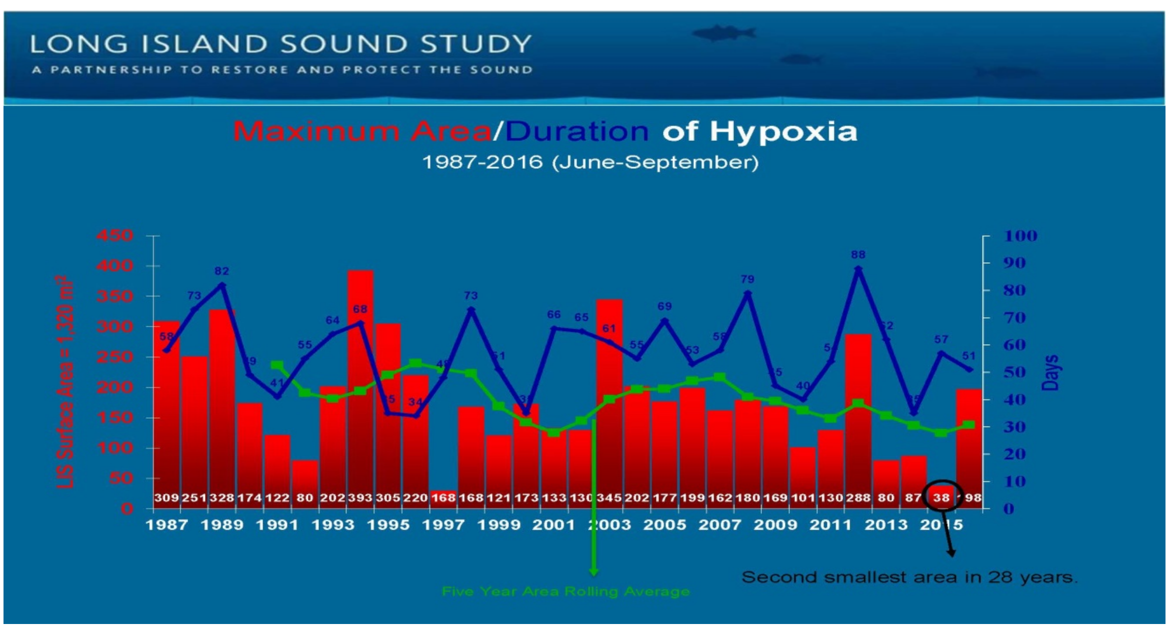


Figure 16. Moderation in the severity of hypoxia in Long Island Sound (courtesy EPA LIS Office)

Example 2: Mumford Cove, CT

Mumford Cove is a small coastal embayment in southeastern Connecticut. In the mid-1940's, a waste treatment facility serving local U.S. Navy housing began discharging into Fort Hill Brook, which drains to Mumford Cove. By 1974, the sewage treatment plant (STP) was expanded in size and effluent discharge. In 1976, the town storm drain system was expanded (Benoit 1975). These improvements resulted in a steady increase in the volume of the discharge to 3.5 mgd.

As the volume of STP and storm water effluent entering Mumford Cove grew, the natural eelgrass (*Zostera marina*) meadows native to the waterbody began to give way to an explosive growth of sea lettuce (the macroalgae *Ulva*). In time, residents of the area began to pressure state and local agencies to amend the impairment of Mumford Cove created by the local discharge. After a prolonged legal struggle, the discharge into Mumford Cove was relocated to the Thames River in 1987. By this time, *Z. marina* had been completely eliminated from Mumford Cove, replaced by the ubiquitous *Ulva*.

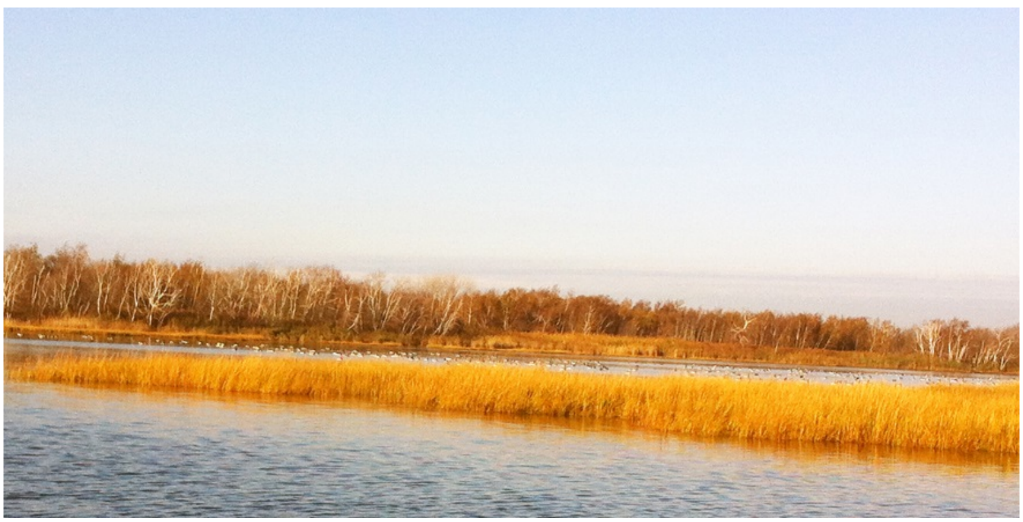


Figure 17. Migrating brant descend to feed on Ulva which proliferates in the nitrogen-rich waters near a Long Island waste treatment plant similar to that of Mumford Cove (Photo by Barbara Branca)

While wastewater outflow was entering Mumford Cove in 1987, water column concentrations of dissolved inorganic nitrogen and dissolved inorganic phosphorous averaged 2.1 mg/L and 2.6 mg/L, respectively. Within several months after relocation of the STP discharge, these nutrient concentrations in Mumford Cove averaged 0.015 mg/L and 0.03 mg/L, respectively. Interestingly, Mumford Cove is the only marine waterbody in CT that has been closed due to PSP-causing algae (although not in recent years).

A year after the STP effluent was eliminated from Mumford Cove, the percentage of the bottom that was covered with sea lettuce declined from 74% to 9%. Concurrently, the Cove was recolonized by the more ecologically desirable seagrass species. The fraction of the bottom covered with seagrass (either *Zostera or* widgeon grass, *Ruppia maritima*) increased from 0% in 1987 to a long-term average of approximately 50% in 2000.

Re-direction of STP effluent away from Mumford Cove affected not only the suitability of the waterbody for desirable Submerged Aquatic Vegetation (SAV) species. In the early 1980's, the Cove was regularly closed to shellfishing because of high levels of Paralytic Shellfish Poison toxin in shellfish meats, one of the few places in Connecticut where such closures have occurred. Once the STP discharge was relocated, PSP toxin levels in the Cove decreased and the shellfish closures ceased and have not recurred.

Example 3: Northport Harbor Sewage Treatment Plant Upgrade and Alexandrium and Dinophysis Blooms

Research conducted by Drs. Chris Gobler and Theresa Hattenrath-Lehmann in Northport Harbor and adjacent parts of the Huntington-Northport Bays complex documented the persistent presence of HAB-related toxins in both the water column and in shellfish over the period 2006 – 2016. Their work drew a strong connection between the abundance of these HAB species in the area and the discharge from the Northport Sewage Treatment Plant and poor flushing, especially within the innermost reaches of Northport Harbor, where the treatment plant outfall is located. High levels of toxins in shellfish samples resulted in the closure of more than 7,000 shellfishing acres in this complex every year from 2006 to 2011, with the exception of 2007.

In 2013, the Village of Northport commenced a multi-million dollar project to upgrade the treatment capabilities of the Northport STP. The project consisted of a denitrification filter, a new pH control building, and an improved effluent strainer to remove inorganic solids. The principal reason for this multi-million dollar construction project was to lower the amount of nitrogen the facility discharges into the harbor to comply with the new state limit on such discharges (10 lbs/day), derived from the Long Island Sound Nitrogen TMDL. Prior to the upgrade, the plant was discharging an estimated 19.4 lbs of nitrogen per day. The post-upgrade loading is 7.5 lbs/day. Since the Northport STP upgrade was completed in June 2013, no significant red tides have been recorded in the Huntington-Northport Harbor complex and no shellfishing closures have been implemented.

Marine Biotoxin Monitoring

The Suffolk County Department of Health Services was the first agency to monitor the presence of biotoxins in Long Island shellfish when it began to examine shellfish for the presence of the saxitoxin responsible for Paralytic Shellfish Poisoning [PSP]) in the 1980's. In general, these monitoring efforts and related research on the presence of biotoxins in County waters conducted by scientists at the then Marine Sciences Research Center of Stony Brook University did not detect actionable levels of these dangerous compounds. In 2006, saxitoxin was detected in shellfish sampled by New York State DEC from the Huntington Bay-Northport Harbor complex and this triggered the first biotoxin-related shellfish harvesting closure on Long Island. In subsequent years, saxitoxin was detected in blue mussels deployed by NYSDEC from this area, Mattituck Creek and several nearshore areas of the Peconics-Gardiners Bay Complex and western Shinnecock Bay. The New York State Department of Environmental Conservation (DEC) accordingly instituted both a contingency plan for the control of marine biotoxins in shellfish intended for human consumption and a routine monitoring program (using the blue mussel, *Mytilus* edulis) at several sites in Suffolk County during the spring of the year. In addition to examining mussel meats, the DEC examines phytoplankton samples for the presence of toxin-forming species.

DEC has established an early warning network involving Suffolk County and municipal governments, instructing their employees in recognizing the signs of a potential biotoxin incident and clarifying notification procedures. Protocols have been established between DEC and shellfish management/public health agencies in neighboring states to mutually report the finding of elevated levels of toxin in shellfish. DEC staff were trained in the microscopic identification of phytoplankton species as early as 2002. However, the microscopic discrimination of potential toxic from benign phytoplankton species is challenging and DEC relies primarily on a bio-assay laboratory method using shellfish tissues to determine whether a biotoxin event might be underway that poses a threat to shellfish consumers.

Random assays of samples collected by DEC Food Inspectors and other staff began in 2004 using the Jellett Rapid Test Kit. In 2007, the program began to use a mouse bioassay and other protocols sanctioned by the National Shellfish Sanitation Program. This program exposes adult blue mussels held in mesh bags suspended in various locations around Long Island. After a minimum of two weeks' exposure sampling begins. Most sites are sampled a minimum of six times between late March and the end of June, but the frequency of sampling is adjusted (increased) if results suggest a biotoxin event is underway. Shellfish samples are typically collected weekly or biweekly depending on the current and historical occurrence of PSP at the monitoring locations. If testing reveals a level of toxin in shellfish meats approaching or exceeding a precautionary threshold of 50 ug toxin/100 g of tissue, DEC implements an emergency closure of the affected area(s) to shellfish harvesting. Although the PSP shellfish closure threshold for saxitoxin in shellfish meats is 80µg/100grams under the National Shellfish Sanitation Program - Model Ordinance, DEC uses a precautionary approach to protect public health due to the frequency of sampling and the potential for saxitoxin levels to exceed this required threshold for shellfish closures before the next scheduled sampling. The area will remain closed until assay results reveal toxins levels well below the threshold of 80µg/100g and trending downward for three consecutive sampling events over a period of at least two weeks. Starting in 2011, DEC implemented biotoxin closures for shellfish lands that also included restrictions on the harvest of carnivorous gastropods (e.g., whelks and moon snails).

From 2006 through 2012, DEC implemented biotoxin closures after it got positive signals for the presence of saxitoxin using a rapid test method for detecting saxitoxin in shellfish (mussels). This rapid test gives a positive signal when saxitoxin levels are > 40 ug/100 g tissue. Beginning in 2013, DEC has not implemented biotoxin-related closures until it has received quantitative mouse bioassay test results showing a saxitoxin level of > 56 ug/100 g tissue in homogenate from mussel samples that had tested positive with the rapid test method the prior day. This two-step approach had reduced the number of areas that have been closed since 2013. Some areas that were closed in the 2006-2012 period might not have been closed if DEC had been able to secure mouse bioassay test results within 24 hours of receiving a positive signal from the rapid test method.

In the event of a biotoxin-related harvest closure, the DEC follows a comprehensive public, shellfish industry and interagency notification protocol to alert others to the problem. The marine biotoxin closures are posted on DEC’s website and typically a Press Release is issued to alert the public to the shellfish closure.

Suffolk County has also conducted monitoring for marine biotoxins in areas of the Peconic Bays and north shore embayments to expand on the biotoxin monitoring locations conducted by DEC (Figure 18). DEC, Suffolk County and researchers at SoMAS have collaborated on marine biotoxin monitoring in Suffolk County to increase the spatial coverage and detection of HABs that pose a public health threat.

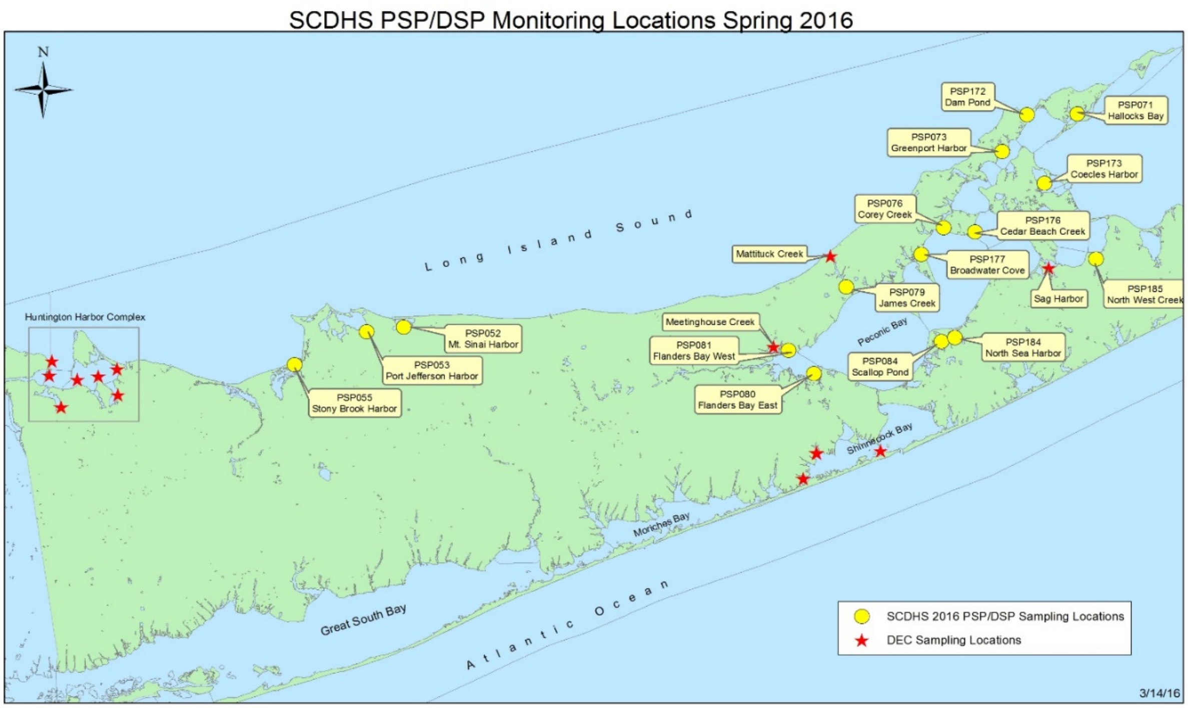


Figure 18. 2016 PSP/DSP Monitoring Locations conducted by Suffolk County and DEC

Long Island Marine Water Quality Monitoring Network

For the past decade, Dr. Chris Gobler on Stony Brook University’s School of Marine and Atmospheric Sciences, along with fellow scientists and graduate/undergraduate students, have regularly (weekly) monitored a set of six water quality parameters - dissolved oxygen, water clarity, temperature, chlorophyll, fecal bacteria, and HABs - in more than 25 water bodies in and around Long Island, including many in Suffolk County (Figure 19). Each week, each water body is given a composite score from one to three (1 = poor, 2 = fair, 3 = good).

The local television station, News 12 Long Island, broadcasts the index results on Thursdays and Fridays during the summer and posts a map and index results on the website (see Figure 19 below). The data obtained and posted from this survey are not presented as an official record of water quality and do not supersede official government water and shellfish quality monitoring, reporting, and warnings. The effort is undertaken to keep residents apprised of trends in general water quality around Long Island.

Figure 19. The Long Island Water Quality Index is communicated using an interactive Google Map format. (courtesy, C. Gobler, Stony Brook University)

Working at the Sub-watershed Level; Georgica Pond

To be fully effective, attempts at HAB prevention, minimization and management may require a quite targeted approach to specific sub-watersheds that accounts for system's unique natural characteristics and the nature/intensity of development of the sub-watershed. Recent examinations into water quality and HAB-related problems in Georgica Pond are a case in point.

Georgica Pond, a 300-acre coastal salt pond in the Town of East Hampton, has experienced a dramatic decline in water quality in recent years. Wastewater from septic systems and cesspools have been identified as the primary source of nitrogen pollution that has caused macro and blue-green microalgae blooms, low oxygen levels and fish kills. In many cases, the blue-green algal blooms produce toxins, which are harmful and potentially fatal to pets and have resulted in closing the pond to crabbing, fishing and swimming.

To document the cause of the above threats and provide a scientific analysis and a sustainable plan for remediation of these environmental and human health risks, the Friends of Georgica Pond Foundation [FGPF] engaged Dr. Christopher Gobler of Stony Brook University's School of Marine and Atmospheric Sciences (SoMAS) to conduct a two-year study. Dr. Gobler placed a telemetry device in the Pond to provide continuous water monitoring of such factors as oxygen levels, salinity and temperature.

Figure 20. Algal mats in Georgica Pond (Photo courtesy of Suffolk County)

A report published twenty years ago on water quality conditions in Georgica Pond cautioned that, "….without repeated openings, concern exists for increasing concentrations of N (nitrogen), P (phosphorus) and fecal coliform." The "openings" mentioned in this report refer to the artificial opening of a "cut" or inlet between the Pond and the Atlantic Ocean that is undertaken twice annually by the Town of East Hampton. This cut, which eventually closes due the natural littoral transport of sand along the ocean beach, increase water exchange the Pond and the ocean with salutary effects on water quality and water levels in Georgica Pond. Dr. Gobler recommended that, in addition to the traditional flushing via opening up the cut to the Atlantic, additional 'letting' might occur whenever salinity levels in the Pond get too low (i.e., creating a cut would result raise salinity levels in the Pond.

In the course of the Gobler study, in 2016, a mechanical aquatic weed harvester was deployed to collect 55,740 lbs of macroalgae (seaweed) and aquatic plants from Georgica Pond. While the amount of nitrogen and phosphorus thus removed from the Pond is only a small fraction of the estimated total annual loads of these nutrient to the Pond, these removals represent roughly 13% of the Pond's N and 23% of its phosphorus load in the summertime months, when Harmful Algae Blooms are most likely.

Dr. Gobler's recommendations, contained in a report presented to the community, include advocating for and installing state-of-the-art wastewater treatment in the watershed of Georgica Pond, as wastewater is the largest single source of nitrogen pollution to the Pond. Priority #1 for FGPF would be the 74 houses situated around the water body.   Based on the findings and recommendations of this work, FGPF has proposed the installation of a permeable reactive barrier to intercept N near the Pond's shoreline.

Figure 21. Floating mats of Cladophora covering the surface of Georgica Pond (Photo courtesy of Suffolk County).

As the new N intercept systems are installed, and using water quality data generated and compiled by the SoMAS Gobler Lab as a baseline for existing degraded conditions, the cumulative impact of all variables related to conditions in the subwatershed would, ostensibly, be thoroughly measured and evaluated by the County's Division of Environmental Quality (DEQ). DEQ will install groundwater monitoring wells in conjunction with groundwater flow measurement devices, like geoprobes and trident probes. The groundwater modelling protocol that results from this project can be applied to other areas of the County and the resulting case study could be of national significance.

The Georgica Pond pilot project will be the first of its kind designed to document, in real time, water quality improvements in a water body that result from reductions in nutrient inputs related to the replacement of non-performing wastewater systems which are not designed to treat for nitrogen with state-of-the-art systems which are proven to reduce nitrogen in wastewater by up to 70%. A Water Body Remediation Invitational Summit that brought together experts from around the country and was hosted by the Chapman Perelman Foundation suggested that clustered septic systems also be evaluated, and affirmed that opening of the inlet to the ocean continue with, perhaps, greater frequency than twice a year.

Action Plan Recommendations

The following recommendations are made to Suffolk County regarding managing HABs in County waters more effectively. **Bold-faced** recommendations are a priority and should be implemented *now*.

Management Recommendations

- **Reduce nitrogen and phosphorous loading to ground watersheds, surface watersheds and direct inputs to surface waters, particularly by upgrading septic systems, both residential and nonresidential.**

    - Reduction goals will be quantified in SWP. However, it's clear that critical priority areas will require the order of magnitude of septic nitrogen reduction (50-70%) offered by Innovative/Alternative Onsite Wastewater Treatment Systems (I/A OWTSs) or sewering. South Shore Estuary Reserve (SSER) nitrogen loads are estimated to be 70% septic; Peconic Estuary Program (PEP) has set a 50% nitrogen reduction target in Total Maximum Daily Load (TMDL) areas. A TMDL is the maximum amount of a pollutant that can occur in waterbody and still meet water quality standards.

    - Onsite residential and non-residential wastewater is the principal source of nitrogen in many Suffolk County waters. This recommendation accords with and complements existing County plans to improve wastewater treatment in the un-sewered areas of Suffolk County that are in close proximity to coastal waters. Of these areas, initially targeting those that are adjacent to poorly flushed coastal waters will do the most to retard HABs in the near future.

    - The County has made a start in identifying HAB-prone/vulnerable surface waters, developing a preliminary map (see Figure 15) depicting the location of HAB "hot spots," based on historical bloom occurrences, and their juxtaposition with areas of varying priority for on-site wastewater treatment system upgrades. Hot spots for different HABs are as follows:
        - Rust Tide: Noyac Bay; eastern Shinnecock Bay; Flanders Bay; Great/Little Peconic Bays; Three-mile Harbor
        - Brown Tide: Great South Bay; Moriches Bay
        - Cyanobacteria: Lake Ronkonkoma; Georgica Pond; others
        - Red Tide: Huntington-Northport Bays Complex; Flanders Bay; western Shinnecock Bay

- While reducing nitrogen loadings to surface waters will likely have the most widespread effect in ameliorating/forestalling future HABs of any management action presently available to the County, the effect of nitrogen reductions may vary across the different HAB species. Microalgal species have unique nutrient requirements; their ability to use different forms of nitrogen can vary widely between species and may vary within a species based on environmental conditions. Any more HAB-specific control measures than the general nitrogen loading reductions called for in the above recommendation will require a more thorough understanding of the linkages between nitrogen and each HAB species. Based on experimental work and some field observations, an initial classification of HABs prevalent in Suffolk County based on their respective general sensitivity to nitrogen reductions might be as follows:

  More sensitive to N reduction: Red and Brown Tides; Dinophysis; macroalgae
  Less sensitive to N reduction: Rust Tide
  Sensitive to P (and perhaps N) reduction: Cyanobacteria and brown tide
- This generalized initial categorization can only be improved upon through additional work on the nutrient requirements and processing abilities of the different HAB species.

- **Actively endorse /promote subwatershed pilot projects like the Georgica Pond pilot project that will feature interception/treatment of nutrients in domestic wastewater from homes around the Pond, more frequent opening of a cut between the Pond and the ocean, and the real-time monitoring of groundwater and Pond waters to gauge the effect of these actions on ambient nutrient levels.**

  - A cooperative approach should be taken and acknowledge the multi-jurisdictional roles between state & local governments as well as Trustees.
  - Lake Ronkonkoma should be considered a prime potential subwatershed pilot area.
  - Such projects shall include the use of permeable reactive barriers (PRBs) to intercept and treat legacy nitrogen pollution from contaminated groundwater. The county should evaluate and prioritize the use of PRBs in key locations. For example, the Watershed Characterization Report for the Forge River Management Plan identifies 5 subwatersheds (Mid Forge West, Poospatuck Creek, Wills Creek, West Mill Pond and Ely Creek) that contribute over 50% of the total nitrogen load to the Forge River.

- **Establish ongoing HAB Management Workgroup to coordinate implementation of this HAB Action Plan and to serve as an on-going forum for HAB management in Suffolk County. The Workgroup would have representation from governmental agencies at various levels, university scientists, local National Estuary Program offices and others entities involved in**

HABs. Under the aegis of the HAB Management Workgroup, convene an annual workshop of collaborating agencies to achieve inter-governmental cooperation and consistency in HAB and nutrient management policies/practices.

- The workgroup should collaborate and participate in existing nitrogen reduction program workgroups including the LINAP, Long Island Sound Study (LISS), and PEP.
- Initial participants: SCDHS; SC Dept. of Economic Development and Planning; NYSDEC; NYSDOH; NYSDOS; LISS; PEP; SSER; SoMAS. The group would meet annually for interagency coordinative purposes.
- The County and the State Department of Environmental Conservation should jointly implement this recommendation and lead the HAB Management Workgroup, drawing on the assistance of New York Sea Grant and Stony Brook University's School of Marine and Atmospheric Sciences as necessary.
- Biannually, the HAB Management Group should hold a public forum to present information to the general public on HAB's in County waters, their recent history and anticipated future outbreaks
- The Workgroup should track and report on key outputs and outcomes.
  - Consider developing a template of key performance indicators (KPIs) and /or report card.

- **Adopt additional management measures to regulate the amount and composition of nitrogenous fertilizers used in Suffolk County.**
  - Cooperatively work with farmers to implement the Suffolk County Agricultural Stewardship Plan to reduce the leaching of nutrients into groundwater from agricultural practices.
  - Assess effectiveness of existing residential fertilizer regulations and consider modifications as necessary.
    - For example, in 2014, it was estimated that N inputs from agricultural, residential and recreational (golf course) fertilizers accounted for more 26.4% of total N inputs to the Peconic Bays System.

- **Actively endorse/promote green infrastructure projects that limit the discharge of nitrogen to surface waters via stormwater runoff.**
  - A notable example is the construction of a sizable rain garden at Centerport Beach where ~80% of the stormwater is captured, thereby increasing infiltration and degradation by soil bacteria.
  - Green infrastructure pilot projects should be incorporated into subwatershed pilot areas (E.g. Georgica Pond, Lake Ronkonkoma).

- **The county should prioritize permeable reactive barriers (PRBs) in key locations to address the legacy nitrogen in river, ponds and embayments.**

- **Actively endorse/promote resource restoration efforts such as, but not limited to, shellfish (scallop, clam and oyster) restoration and submerged aquatic vegetation (SAV); these should be based on metrics and criteria (not simply geography) and be aligned with results of ecological endpoint monitoring. Future restoration efforts should follow consistent specific monitoring protocols so they can be accurately and consistently compared across geographies.**
    - Convene a workgroup to create criteria for choosing restoration sites and monitoring methods.
    - Certain restoration efforts in specific areas may have to wait until N reduction targets are achieved.

- Establish ecosystem endpoints for HAB reduction/mitigation for each type of HAB.
    - As knowledge and information allow, the County should set surface water N concentration limits for specific types of HABs. This is presently an arena confounded by imperfect knowledge, but a start should be made and then an adaptive approach used. An initial limit could be set using the best available existing data (e.g., evaluate statistical relationships of N load to HAB endpoints) and/or the use of existing or newly developed linked hydrodynamic/water quality models. Monitoring activities would gauge the response of the ecosystem and/or HAB/specific indicator species. Depending on the response, adjustments would be made in the degree of N limitation through updates to statistical relationships and/or refinement of the developed model(s).

- Adopt an adaptive HAB action/management approach.
    - As noted earlier in this plan, ecosystems affected by HABs are not static and an area that is presently unlikely to suffer a HAB may in the future become more susceptible to their development. Climate variability and the dynamic movement of water within and among coastal systems will require that a HAB management plan featuring N reduction/limitation will need to be constantly informed by timely monitoring data on conditions in these coastal systems as well as increases in understanding on HAB species physiology and interactions with its biophysical environment. The Suffolk County HAB Action Plan and those who implement it will need to be alert to these changing conditions or improved understandings and to adjust the Action Plan as appropriate.

    - For adaptive management to work, information needs to be collected and shared concerning N loads from watersheds, how that translates to delivery to waterbodies because of a time lag and how the waterbody responds in terms of physio-chemical parameters, HAB and/or indicator species being monitored.

- **Achieve inter-governmental cooperation and consistency in HAB and nutrient management policies/practices.**
    - Natural systems are rarely under the management aegis of a single agency. This is true even for the interior freshwater lakes and ponds of Suffolk County, and even more so the County's coastal waters. The County's HAB Action Plan must be designed and implemented in close communication and coordination with the HAB-related, nutrient reduction and other environmental management programs of towns, municipalities and New York State.
    - Fortunately, in large measure, Suffolk County's activities and programs targeting nutrient pollution generally and the HAB phenomenon specifically are generally conducted in close communication with State agencies (primarily the Departments of Environmental Conservation, State and Health), municipal governments and with waterbody-specific quasi-governmental programs such as the Peconic Estuary Program, the South Shore Estuary Reserve Program and the Long Island Sound Study.

Monitoring Recommendations

- **Suffolk County and the State Department of Environmental Conservation should institute routine monitoring for the presence of the Diarrhetic Shellfish Poison (DSP) toxin. Advanced monitoring technologies such as Passive Solid-Phase Adsorption Toxin Tracking (SPATT, water column) and the Abraxis Protein Phosphate Inhibition Assay (PP2A, shellfish meats) may be used by collaborating laboratories as an early warning sign to State and County agencies. DEC-Shellfisheries can only use testing methods that are approved by the National Shellfish Sanitation Program (NSSP) resulting in regulatory action. Refer to Appendix C- List of NSSP list of approved methods.**
    - Trials have shown that these two methods are effective, reliable and sampling processing time is much quicker than with more traditional assay methods.

- **Deploy a sensor buoy in Lake Ronkonkoma for real time monitoring of cyanobacteria and the physiochemical parameters that are important in cyanobacterial blooms.**
    - Among the freshwater surface waters in Suffolk County, Lake Ronkonkoma, with its propensity for cyano-blooms and its several beaches, probably presents the greatest public health concern.

- **Evaluate use of cutting edge remote monitoring, modeling, buoys, and other *in situ* monitoring tools and technologies to detect the presence/abundance of toxic algal species in local waters.**

- One such tool being used in several coastal areas around the US is the Imaging FlowCytobot, developed at the Woods Hole Oceanographic Institution and now marketed by McLane Research Technologies of East Falmouth, Massachusetts (IFCB). IFCB continuously captures high resolution images of algal cells; the optical and image data are then transmitted to shore in real time. Algal images are processed using automated image classification software, which is able to classify down to the species level with accuracy comparable to that of human experts. *In situ* deployments of up to six months have been achieved with the IFCB.
- Unmanned aerial vehicles (a.k.a. drones) which most recently have become more commercially feasible and should be considered for documenting HAB events.

- Develop an integrated HAB monitoring program.
    - Consider use of state-of-the-art imaging recognition technologies at sentinel sites, as is being done in HAB monitoring programs in in Texas, California and Massachusetts.
    - Explore the possibility of citizen science which has been done for Long Island Sound but not for HABs. Citizen monitoring for HABs is done at the national (Phytoplankton Monitoring Network), state (ME, CA, FL), and regional (Puget Sound) levels. It will be necessary to provide training and put a standard operating procedure in place. Citizen monitoring can be used to achieve greater spatial and temporal sampling coverage than monitoring agencies may be able to support.
        - For example, the BloomWatch program is a nationwide effort to coordinate citizen monitoring of cyanobacterial blooms (see: http://cyanos.org/cyanoscope/)

Public Health and Outreach Recommendations

- **In addition to the webpages that DEC maintains (freshwater HABs and marine biotoxins), establish/maintain a mechanism (HAB Website) by which the public can access current information on all HABs in Suffolk County (fresh water and marine) and report unusual environmental conditions that might be associated with an emergent HAB. This shall include the goal of developing an app that provides water quality information/status at your particular location (HABs, shellfish bed, etc).**
    - Suffolk County and other agencies involved in HABs and HAB management should consider establishing a web site, app and/or a hotline to provide county residents with the most current information about HAB's in County waters and provide an opportunity for citizens to report abnormal environmental phenomena, such as discolored water, fish kills, etc. that might indicate an incipient or active HAB. Any such initiative should incorporate some sort of feedback mechanism so that

someone using it can be assured that his/her message was received and some specific response was forthcoming. The most appropriate entity/agency to host such a portal should be determined by the joint agreement of the agencies involved.

- Such a HAB portal must allow the public access to the most up-to-date information available regarding HABs in Suffolk County surface waters. This requires that the agencies and organizations involved in HAB research and management develop and maintain open and active communication about their work on HABs and its data, results and findings. Protocols for sharing this information between these agencies and organizations should be developed and followed.
- Note: DEC also maintains recorded phone message regarding temporary shellfish closures (631-444-0480).

- **Implement a HAB public outreach/education program to disseminate information about HABs, their origins and effects on aquatic systems in Suffolk County and the risks they can pose to public health.**
    - The HAB outreach/education program would be an adjunct to County efforts to inform and educate the public on the general problem of nutrient pollution of surface waters and the benefits of nutrient limitation/control.
    - HABs have direct impacts on the economy of Suffolk County and, with effort, quantified estimates of these impacts can be developed; programs to monitor and manage HAB's will consume public funds and some management measures to control HABs, such as some nutrient limitation measures, will impose costs on County residents and businesses. Without strong public support, the County's HAB Management Program will likely fail to achieve its objectives.
    - A strong and vigorous education/outreach program that conveys the realistic benefits to County residents/businesses of HAB control can help produce the public support necessary to sustain an effective HAB Management Program. This outreach program will have many audiences, though perhaps none so important as homeowners groups and associations, business groups and citizen associations.
    - The HAB public outreach/education program might have the following components:
        - Fact sheet and video series
        - Public signage at HAB "hotspots"
        - Public lecture series
        - On-line, Interactive "ask the expert" sessions
    - The County should consult with New York Sea Grant on ways to develop the HAB public outreach/education program
    - HAB information (signage, websites, other materials, etc.) should be produced in multiple languages.
    - **Extra efforts should be directed at the most at risk populations that may be relying on the resources extracted.**

- Document health effects from exposure to HABs in Suffolk County

Research/Investigation Recommendations

- **Secure and allocate funding for priority research needs in Suffolk County, similar to the Brown Tide Research Initiative model in the 1990s, which led to several breakthroughs in understanding and managing the Brown Tide. Such HAB research would require at least 1 million dollars a year, over the next 5 years.**

- **Coordinate with project partners/workgroups to evaluate and identify surface water quality data gaps and provide recommendations for revisions to surface water monitoring programs in support of overall HAB monitoring, HAB predictive modeling, and HAB mitigation measures.**

- **Coordinate with project partners/workgroups to develop HAB-specific predictive water quality modeling capable of establishing refined nutrient load reduction goals and forecasting the possible occurrence of a future HAB in a specific waterbody based on monitored environmental conditions and climate variability.**

    - Such a model would also be capable of predicting the likely effect of specific nutrient load reductions on the probability of future blooms in specific waterbodies. This would contribute directly to the determination of HAB-directed nutrient reductions for those areas.

    - Predictive models are a much-used tool in many aspects of environmental and natural resource management, from fisheries management to weather prediction to the management of hypoxia. On the West Coast, the Integrated Ocean Observing System (IOOS) has developed the C-HARM model that couples water circulation models with satellite-sensed data on surface ocean chlorophyll concentrations, routine monitoring of oceanic conditions and biostatistical models to predict the location and timing of blooms of the toxic diatom *Pseudo-nitzschia* along the California coast.

    - To accurately model the complexities of the interconnections between HAB species with their dynamic and variable biological, chemical and physical environments is a daunting task. The initial manifestation of the proposed predictive model would be crude. Understanding advances gained through continued research and improved monitoring of HABs would provide the means for the model's refinement over time.

- **Continue to refine the most appropriate metric to use to measure the risk to public and animal health from cyanoHAB's in the lakes and ponds in the County.**
    - NYSDOH currently recommends using EPA's draft ambient water quality criterion (4 µg/l) for microcystins for reopening bathing beaches. However, continued refinement of cyanobacteria cell concentrations in recreational water that pose human health risks should continue to be examined.

- Continue to assess the role of legacy sediments and nutrients (phosphorus/nitrogen) in Suffolk County HAB formation and sustenance
    - Reducing groundwater loads will have the added benefit of reducing sediment flux
    - Site-specific evaluations can be conducted on additional sediment removal or remediation (e.g. Meetinghouse Creek Feasibility Study).

- **Conduct an assessment of the potential utility of using seaweed farms and/or suspension-feeding shellfish aquaculture facilities as a way to reduce nutrient levels in County waters and/or to forestall or mitigate the development of HABs.** This effect might be amplified by the well-demonstrated inhibitory effect of macroalgal metabolites and exudates on HAB species.

    - Suffolk County should collaborate with the recently funded DEC bio-extraction coordinator to assess the viability and challenges of bio-extraction of nutrients from surface waters.
    - Use of bio-extraction approaches may prove beneficial in certain confined waters that are heavily impacted by nutrient loadings in increasing the effective assimilation capacity of these areas for nutrients and ultimately lowering ambient concentrations.
    - Bio-extraction, while potentially effective in helping to modulate nutrient levels in HAB-prone waters, is not without potential negative environmental and marine space-use concerns, especially when scaled-up to a size where its nutrient extraction effect is likely to become significant.
    - This assessment should, *inter alia*, examine the relative cost-effectiveness of employing bio-extraction approaches at the scale necessary to achieve significant nutrient removals from the target waterbody.

    Macroalgae Culture

    - The County has funded a small-scale demonstration project through the Marine Program of Cornell Cooperative Extension on the feasibility of field culturing a local kelp species in the waters of Peconic Bay, where HABs are a frequent occurrence

- New York ECL §13-0302.10, adopted 9/9/16 pursuant to L. 2016, authorized Suffolk County to allow the underwater lands in Gardiners and Peconic Bays to be used for implementation of a pilot program to conduct an assessment of the feasibility of seaweed cultivation. The pilot program is limited to lessees holding a shellfish cultivation lease from Suffolk County. Per Res. No. 98-2017, Chapter 475 of the Suffolk County Code was amended by the addition of a new Article III that established the Suffolk County Seaweed Cultivation Pilot Program. The Department of Economic Development and Planning, Division of Planning and Environment is responsible for developing/implementing the program; and will also conduct a separate evaluation of commercial seaweed cultivation in these bays given their unique use pattern and spatial context.
- Nutrient bio-extraction programs can complement efforts to control the sources of nutrient to waterbodies experiencing HABs. They are the only feasible way of removing nitrogen and other nutrients once they have been introduced to a waterbody
- Preliminary estimates developed by the Gobler lab at SoMAS suggests that intensive culture with regular harvest of *Ulva* and *Gracilaria* in Shinnecock Bay might extract as much as 3000 lbs of nitrogen per week from the Bay.
- Bio-extraction methods may be especially appropriate in reducing ambient nutrient levels in waterbodies where non-point sources of nitrogen and other nutrients are the predominant sources. This is the case in most of the County's surface waters.
- Preliminary pilot projects have suggested that bio-extraction cultivation of two indigenous seaweeds (sugar kelp [*Saccharina sp.*] and red seaweed [*Graciliaria* tikvahiae] may be feasible and efficacious in Long Island Sound.
- Harvesting and removal of accumulated, naturally-occurring macroalgae from Georgica Pond in 2016 "extracted" approximately 10% of the nitrogen and 20% of the phosphorus summertime load of the nutrient to the Pond. Concurrently, levels of cyanobacteria in Georgica Pond, which were the highest in the County in previous years, were among the lowest in 2016.
- There are ready markets for chemicals and extracts from seaweeds in the food, pharmaceutical, soil amendment and biofuel industries

Suspension-feeding Bivalve Culture

- Experimental research has indicated that sufficient filtering by suspension-feeding bivalve mollusks can forestall the blooming of Brown Tide
- In selected "hot spot" waters, artificial maintenance of sufficient numbers of shellfish, in combination with adequate surveillance to deter poaching, may suffice to avoid incipient Brown Tides that, once initiated, could spread to other areas
- Nitrogen removal rates by wild or cultivated shellfish populations have been calculated in a number of coastal waters around the US and are often equal or

exceed the efficacy of other processes such as denitrification (the sequential reduction of nitrate nitrogen through microbial mediation to inert nitrogen gas) and burial in the sediments.

- The County should actively endorse and promote piloting more extensive wetland restoration in an area (perhaps combined with bio-extraction) and monitor its effect on nutrient cycling, water quality and HAB occurrence.

    - Excess nitrogen inputs can lead to degradation and loss of wetland and seagrass habitats. Drawing on the broad experience of many, the County should develop and implement a plan for the restoration of selected degraded wetlands.

- In certain areas, it may be possible and beneficial to artificially modify hydrologic conditions to make certain waterbodies less prone to HAB development. An example is Georgica Pond, described earlier in the report, where artificially enlarging a connection between the Pond and the Atlantic Ocean increases water exchange and improves water quality in the Pond. Using the assessments on hydrologic conditions, flushing times, etc. contained in its Subwatershed Plan, the County should identify priority sub-watersheds where this type of modification would likely produce beneficial results
    - Monitoring activity has clearly demonstrated the beneficial effects of the barrier island breach near Old Inlet on water quality and ecosystem health in eastern Great South Bay, Bellport Bay and Narrow Bay. The increased exchange of bay and ocean waters and altered water circulation patterns has led to the following in these areas: cooler bay water temperatures; lower nutrient levels; increased water clarity; increased species diversity; altered phytoplankton regime; increased eelgrass abundance and increased abundance and diversity of finfish.
    - Changing the hydrological characteristics may have predictable negative ecosystem consequences and decisions to move forward with this approach need to be made on a case-by-case basis and with the strongest possible scientific understand of the system under examination

- **Suffolk County along with collaborating agencies (NYSDEC as lead) should assess the utility and practicality of treating HAB-prone freshwater lakes and ponds with various control methods as a means to limit cyanobacteria growth and/or the availability of nutrients (N and/or P) and potentially forestall the development of toxic blooms. The methods to be assessed should include, but not limited to, various algaecides (e.g. hydrogen peroxide), flocculants (e.g. aluminum sulfate, native clays, Phoslock), circulation systems, ultra-sonic blasters and antialgal biologically derived substances (BDSs).**

- Evaluate impacts to property values, tourism, and recreational uses from HABs-affected waterbodies

Ideally, management of HABs should be founded on a closely coupled knowledge of how the factors and processes that fuel blooms (nutrient and light availability, optimal temperatures and salinity, water column stability) interact with processes that might serve to deter bloom formation (grazing, disease, vertical migration, horizontal advection/transport and the physical factors of water mass mixing, flushing and dilution). If the former predominate over the latter, algal growth will be accelerated, standing biomass will increase and a bloom may develop. Moreover, for those HAB species that are toxic, the amount of toxin and its relative potency are under both environmental and genetic controls. This is a complex interweaving of factors, relations and responses that is very difficult to understand.

The following priorities were identified for Suffolk County HABs. At this time, the relative priority of this research is not ranked.

- Establish the relative importance of nitrogen and phosphorus in fueling each individual HAB within different systems.

- Much more needs to be understood about the dynamics, toxins, and health threats of cyanohabs in Suffolk County.

- Quantification of *Alexandrium* and *Cochlodinium* cysts in bloom prone regions may be needed to model their populations and understand the origin of these blooms.

- Determine the relative role of multiple drivers in bloom initiation and impacts of multiple stressors on Suffolk County fishery species. In particular, better understanding is needed of how warming waters and other climate variability factors will affect HAB's. These effects will likely be HAB-specific and even location-specific. Models could help address some of this, whereas experimental work will help in other cases. What is required is a state-of-the-science assessment of how climate variability may be expected to alter the occurrence of HABs in Suffolk County and to provide quantitative assessments of how the climate variability expected in the coming decades may alter the growth, toxicity, and intensity of HABs in Suffolk County.

- Determine, if possible, how much nitrogen is enough to sustain a "healthy" ecosystem. This will likely be unique to specific waterbodies based on their current N-loading, flushing/residence time and other ecosystem characteristics.

- Project long term trends in nitrogen loading based on groundwater travel times

- What can be learned about bloom timing and initiation from examining previous blooms?

- What is the role of legacy sediments and nutrients (phosphorus/nitrogen) in Suffolk County HAB formation and sustenance?

- Determine the impact of recurring HAB’s on sensitive habitats such as tidal marshes and seagrass meadows

- Shellfish interactions. Studies are needed to assess the ability of HABs to threaten bivalve populations and aquaculture as well as the potential for bivalve populations and aquaculture to control or intensify HABs.

Substantial progress on these and other questions wherein current knowledge is often quite incomplete will position Suffolk County and other agencies to better manage HABs in their jurisdictions. However, there is sufficient existing knowledge about the interaction between anthropogenic loadings to the County’s surface waters, especially of nutrients, and the occurrence of HABs in these waters to take action now.

Appendix A. ***Historical Occurrence and Current Status of Harmful Algal Blooms in Suffolk County, NY, USA.*** **Theresa K. Hattenrath and Christopher J. Gobler, School of Marine and Atmospheric Sciences, Stony Brook University** (*see document, attached*)

Appendix B. Experts, Advisory Group and Steering Committee, HAB Action Plan Project
Suffolk County HAB Action Plan Experts Working Group

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Dr. Raphael M. Kudela, Professor, Ocean Sciences Department, University of California, Santa Cruz, Ph.D., University of Southern California, Los Angeles, CA
Dr. Margaret Mulholland, Professor, Ocean, Earth & Atmospheric Sciences, Old Dominion University, Ph. D., University of Maryland
Dr. Chris Gobler, School of Marine and Atmospheric Sciences, Stony Brook University
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Robert Nyman, US Environmental Protection Agency
Chris Schubert, US Geological Survey
Mark Tedesco, EPA Long Island Sound Office
Eric Wiegert, NYS Department of Health

Suffolk County HAB Action Plan Steering Committee
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Walter Dawydiak, Suffolk County Department of Health Services
Christopher Gobler, School of Marine and Atmospheric Sciences, Stony Brook University
Michael Jensen, Suffolk County Department of Health Services
Chris Lubicich, Suffolk County Department of Health Services
Nancy Pierson, Suffolk County Department of Health Services
DeWitt Davies, Suffolk County Department of Economic Development/Planning
Susan Filipowich, Suffolk County Department of Economic Development/Planning

Appendix C. Project Findings From Symposium and Workshop

Public Symposium General Findings

In May 2016, NYSG and SCDHS convened a public symposium, held at Timber Point Country Club on the Great South Bay, to inform stakeholders and stakeholder groups in the County about the HAB Action Plan project and to solicit public input on what that plan should cover. However, this symposium also provided a venue for the HAB Expert Working Group to present information about HABs in other areas of the country, what research has revealed about the general causes of these phenomena, what is necessary if management actions are to succeed in controlling or mitigating them, and to discuss these considerations in light of the HAB experience on Long Island. There was a lively exchange of observations and ideas between the invited HAB Experts, local resource managers and scientists and NGO staff that produced a number of fundamental insights, see below, that have guided the development of this HAB Action Plan and Strategy.

• Those areas with relatively high nutrient loads and low flushing rates are most at risk of HAB development; for these areas, reducing nutrient loads is the single most effectual measure to lower the risk of future HABs.

• Robust monitoring and assessment is critical if HAB management is to be successful; the County's surface waters at risk of HABs, especially estuarine waters, are dynamic environments where conditions can change rapidly over fairly short temporal and spatial scales. Shifts in nutrient or pollutants loads, changes in physiochemical factors and various ecological processes can alter these systems sufficiently to render previous management measures and approaches ineffective. Monitoring is required to track these changes and to provide feedback for possible management adjustments.

• Related to the need for continuous monitoring, HAB management must itself be adaptable to changing threats and conditions.

• The past decade suggests that local waters are becoming more susceptible to a greater variety of HABs; each HAB type may have relatively unique causal factors and impacts on affected ecosystems; HAB management must recognize these differences and accommodate them; a "one-size-fits-all" approach will probably have limited success.

• Use of remote sensing and other automated, advanced technologies provides greater ability for HAB managers to detect, understand and react effectively to the dynamic HAB phenomenon; in situ sensors in particular, although in some cases a significant initial capital investment, can provide capabilities that are difficult to achieve with more traditional labor-intensive monitoring programs.

• HAB-directed monitoring programs need to be robustly funded and sustained over time. Reduced incidences of target HABs for a few years should not result in a reduction in the level of monitoring effort. Aquatic environments are inherently dynamic and can respond in unpredictable ways to longer-term influences like climate variability. Declaring success after a few years of HAB management may be premature. This was the case in Lake Erie, where management actions to control cyanobacteria and an ensuing reduction in HAB occurrence led to a reduction in the level of monitoring effort. Subsequently, the blooms recurred but the response of management agencies was delayed.

• To be effective, HAB management needs to incorporate the full range of governmental jurisdictions necessary to capture the problem; in some cases, this may require coordination and cooperation between states; in Suffolk County, the County must work with State and municipal government to address the HAB problem. This appears to be recognized by the County and the various agencies and the prospects for full cooperation in the development and implementation of a HAB Action Plan and Strategy appear good at present.

• Any HAB Action Plan and Strategy will need to have the support of Suffolk County's citizens, communities and businesses. There will be costs associated with actively combating HABs in County waters and the public will be the ultimate arbiter of whether the benefits associated with HAB management is worth the cost. The County should establish an effective means of communicating with the public about the goals and objectives of the HAB Action Plan and Strategy, the costs to the County of not taking action against HABs and other information that will allow County residents to make informed decisions regarding moving forward with the program.

• Managing the County's freshwater lakes and ponds to reduce the incidence and severity of cyanobacteria blooms will likely involve limiting loadings to these waters not just of phosphorus but also nitrogen.

What Do We Know About HABs in Suffolk County?

The day following the public symposium, Sea Grant and SCDHS organized a one-day workshop involving several invited HAB scientific experts from across the U.S. and a small number of individuals from within the County with strong technical and scientific knowledge of HABs within Suffolk County. The purpose of the workshop was to produce a summary of what is known and relatively unknown about HABs in County waters, and elsewhere, and to make a first cut at management recommendations that would help to minimize the frequency/severity of future HABs and/or to offset their impacts on local aquatic systems. Additional recommendations were forthcoming on research and monitoring needs to improve the County's ability to take actions that would reduce the occurrence of HABs in County waters.
Considerable insight was gained from the initial public symposium. Below is listed the basic findings of the second day Invited Experts Workshop.

Knowledge is relatively good on the following:

- Severity, frequency, variety, toxicity and geographic distribution of Suffolk County HABs
- Trends in the HAB-related shellfishing closures
- Link between nitrogen (N) enrichment and HABs. However, more knowledge is necessary.

    PSP and DSP have the strongest link, followed by cyanohabs
    Brown tide and rust tide have weaker links to N, although they are both directly related

- Proximity of surface waters to sources of Nutrients
- Residence time / flushing of different County waters

    LINAP/SWP will develop better estimates for specific water bodies

- Ratio of organic to inorganic N forms; this can and does change spatially and temporally from initial inputs/loadings as the forms of nitrogen are taken up and altered in the estuarine food web
- Role of different N forms in fostering bloom growth and/or toxicity
- Ecological interactions of HABs i.e. with shellfish
- Depth of the water body
- Atmospheric N deposition (EPA estimates)
- Ratio of nitrogen to phosphorus, and shifts therein
- Phosphorus cycling (except for legacy deposition); *phosphorus levels are key to the cyanohabs and, perhaps, brown tide; N and P produce cyanohabs*

Other than excess nitrogen, these factors are known to affect Suffolk County HABs:

- Areas with poor flushing are HAB-prone.
- Loss of top-down biological controls, such as grazing pressure on phytoplankton exerted by molluscan shellfish, zooplankton, and planktiverous fish can contribute to HAB development.
- Increasing temperatures will likely exacerbate several HAB-related threats to County waters, although some blooms, such as Red Tide (*Alexandrium*) may be reduced.
- Changes in the timing/severity/frequency of rain events may favor HAB formation.

    Future climate projections suggest an increase in extreme weather events for Suffolk County/Long Island. For example, the incidence of intense storms causing rainfall to occur in more concentrated bursts followed by long dry periods of drought may increase. Extreme rainfall could increase the transport of nutrients from land into water bodies via runoff. If followed by drought conditions as is projected, water bodies may retain those nutrients for longer periods of time, which increases the potential for HAB development.

- Elevated carbon dioxide levels and increasing ocean acidity associated with climate variability or eutrophication may heighten the effects of HABs, especially on shellfish.
- In some species, cyst beds provide a reservoir for potential repeated re-occurrence of HABs in specific systems.
- CyanoHABs and brown tides can, at times, be controlled by phosphorus

Need more or better information on these topics:

- Ecosystem impacts of rust tide
- The anticipated relationship between HABs and future changes in nutrient loading, temperature, bivalve densities, changes in flushing rates.
- Temperature as a controlling factor in timing of blooms (may be HAB species specific)
- The role of tides and winds as transporters of HAB organisms
- Effect of meteorological events such as rainfall and runoff on HABs
- Inter-annual variability and relationship to climate variability
- Geographic location, characteristics and HAB susceptibility
- HAB mitigation strategies
- Identification of appropriate species to use in HAB monitoring and modeling efforts
- Role of local vs. larger scale nutrient inputs
- Persistence of HAB toxins

Appendix D. National Shellfish Sanitation Program List of Approved Methods

National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish: 2015 Revision

2. Approved Methods for Marine Biotoxin Testing

	Biotoxin Type: Amnesic Shellfish Poisoning (ASP)	Biotoxin Type: Neurotoxic Shellfish Poisoning (NSP)	Biotoxin Type Paralytic Shellfish Poisoning (PSP)	Application: Growing Area Survey & Classification Sample Type: Shellfish	Application: Dockside Testing Program Sample Type: Shellfish	Application: Controlled Relaying Sample Type: Shellfish
APHA Mouse Bioassay[1]		X	X	X	X	X
Receptor Binding Assay (RBA)[2]			X	X		X
PCOX[3]			X	X		X

Footnotes:

[1]Paralytic Shellfish Poisoning (PSP) and Neurotoxic Shellfish Poisoning (NSP) Methods
American Public Health Association. 1970. *Recommended Procedures for the Examination of Sea Water and Shellfish*, 4th Edition, APHA, New York, N.Y.
[2] Receptor Binding Assay (RBA) for Paralytic Shellfish Poisoning (PSP) Toxicity Determination. Dr. Fran Van Dolah. Alternative Method to Mouse Bioassay for PSP in Mussels. ISSC 2013 Summary of Actions Proposal 13-114.
[3]Rourke et al. 2008. Rapid Postcolumn Methodology for Determination of Paralytic Shellfish Toxins in Shellfish Tissue. Journal of AOAC International. Vol.91, No 3: 589-597.

3. Approved Limited Use Methods for Microbiological Testing

	Indicator: MSC	Application: Growing Area Survey and Classification Sample Type: Seawater	Application: Growing Area Survey and Classification Sample Type: Shellfish	Application: Controlled Relaying Sample Type: Seawater	Application: Controlled Relaying Sample Type: Shellfish	Application: Wet Storage Sample Type: Untreated Seawater	Application: Wet Storage Sample Type: Shellfish	Application: Controlled Purification Sample Type: Untreated Seawater	Application: Controlled Purification Sample Type: Shellfish	Application: Market Shellfish Sample Type: In Shell
Modified Double Agar Overlay Method[1]	X		X							

Footnotes:

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National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish: 2015 Revision

4. Approved Limited Use Methods for Marine Biotoxin Testing

	Biotoxin Type: Amnesic Shellfish Poisoning (ASP)	Biotoxin Type: Paralytic Shellfish Poisoning (PSP)	Application: Growing Area Survey & Classification Sample Type: Shellfish	Application: Dockside Testing Program Sample Type: Shellfish	Application: Controlled Relaying Sample Type: Shellfish
Abraxis Shipboard ELISA[3]		X		X	
JRT[2]		X	X	X	X
HPLC[1]	X		X		X
Reveal 2.0 ASP[4]	X		X	X	X
RBA[5]		X	X	X	X

Footnotes:

[1]M.A. Quilliam, M.Xie and W.R. Hardstaff. 1991. Rapid Extraction and Cleanup Procedure for the Determination of Domoic Acid in Tissue Samples. NRC Institute for Marine Biosciences, Technical Report #64, National Research Council Canada #33001. This method may also be used direct without cleanup.
[2]Jellett Rapid Test for PSP, Jellett Rapid Testing Ltd.

a. Method can be used to determine when to perform a mouse bioassay in a previously closed area.
b. A negative result can be substituted for a mouse bioassay to maintain an area in the open status.
c. A positive result shall be used for a precautionary closure.

[3]Saxitoxin (PSP) ELISA Kit. Method can be used in conjunction with rapid extraction method using 70% isopropanol (rubbing alcohol): 5% acetic acid (white vinegar) 2.5:1. ISSC Summary of Actions, Proposal 05-111 (page 15) and 09-107 (page 140).
[4]Reveal 2.0 ASP. Neogen Corporation. Screening Method for Qualitative Determination of Domoic Acid Shellfish. ISSC 2013 Summary of Actions Proposal 13-112.
[5]Receptor Binding Assay (RBA) for Paralytic Shellfish Poisoning (PSP) Toxicity Determination. Dr. Fran Van Dolah. Method for Clams and Scallops for the Purpose of Screening and Precautionary Closure for PSP. ISSC 2013 Summary of Actions Proposal 13-114

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Appendix E. HAB Action Plan Project Symposium Agenda and Attendees

Symposium Agenda
17 May 2016, Timber Point Country Club

12:30	Welcome & Introductions	B. Wise, NYSG
12:45	Suffolk County and Surface Water Quality	P. Scully, Suff. County
1:00	EPA Perspective	EPA rep.
1:10	LI Nitrogen Action Plan/Other Initiatives	S. Kishbaugh, NYSDEC
1:20	Suffolk Co. Comp Water Plan/SCDHS role in HABs	W. Dawydiak, SCDHS
1:30	HAB Action Plan Project	B. Wise, NYSG
1:45	History of HAB's on LI	R. Nuzzi, RNEnviron.
2:00	Causes of HAB's on LI/Research	C. Gobler, SOMAS
2:30	Comments from WG Experts	WG Experts
3:30	Moderated Audience Comments on Project	B. Wise, NYSG
4:15	Closing Remarks	B. Wise, NYSG

Attendees

Registered

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x	Madigan	Michael	imagehunterphoto@mac.com
x	Ruckdeschel	August	august.rudkdeschel@suffolkcounty.ny.gov

Appendix E. Experts Working Group/Advisory Group Workshop Agenda and Attendees

Agenda

18 May 2016, School of Marine & Atmospheric Sciences, Stony Brook University

8:30	Breakfast	
9:00	Welcome, Charge to the Work Group	B. Wise, NYSG, W. Dawydiak, SCDHS
9:10	Current N Mitigation in Suffolk County	W. Dawydiak, SCDHS
9:30	DEC/County Water Quality Monitoring	M. Jensen, SCDHS
10:15	Reaction/Comments from WG Experts	WG Experts
12:00	Lunch (catered)	
12:30	The Known/Unknown re LI HAB's	Group
1:30	Likely Causes; BMP's to Limit LI HAB's	Group
2:30	Break	
2:45	Recommendations for a Preliminary Plan Nitrogen reduction strategies Other management (mitigating impacts, resource restoration) Monitoring (including indicators and predictive models) Research Public Health Protection	Group
3:45	Next steps	B. Wise, NYSG
4:00	End	

Appendix F. HAB Experts Working Group/Advisory Group Workshop, Attendees

The Nature Conservancy
Marci Bortman, Carl LoBue
NYS Department of Health
Eric Wiegert
NYS Department of Environmental Conservation
Bill Hastback
NYS Department of State
Nancy Rucks, Myra Fedyniak
USEPA
Katrina Heinemann, Bob Nyman, Jim Ammerman
School of Marine & Atmospheric Sciences
Chris Gobler, Theresa Hattenrath-Lehmann
New York Sea Grant
Bill Wise, Saundra Ranford, Lane Smith, Barbara Branca
Suffolk County Dept. Health Services
Mike Jensen, Nancy Pierson, Walter Dawydiak
Suffolk County Dept. of Economic Development/Planning
DeWitt Davies, Susan Filipowich
US Geological Survey
Chris Schubert
HAB Experts
Quay Dortch, Rafael Kudela, Margaret Mulholland, Tim Davis